



Overview of 2016 through 2018 Testing of Air-Purifying Respirator (APR) Cartridge Performance on Multiple Hanford Tank Headspaces and Exhausters

A Summary of APR Test Results

August 2020

CJ Freeman
J Liu
C Clayton
SK Nune
LA Mahoney

CL Bottenus
TM Brouns
P Humble
MJ Minette

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the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Revision History

Revision Number	Interim Change No.	Effective Date	Description of Change
0	0	September 2017	Initial issue with the title <i>Overview of 2016 Testing of Respirator Cartridge Performance on Multiple Hanford Tank Headspace and Exhausters</i> .
1	0	August 2020	<p>The report was updated to include the additional results from 2017 through 2018 tank and exhauster testing and an updated review of the furan results related to the original 2016 test reports.</p> <p>Details include:</p> <ul style="list-style-type: none"> • Changed of the report title to an <i>Overview of 2016 Through 2018 Testing of Air-Purifying Respirator (APR) Cartridge Performance on Multiple Hanford Tank Headspace and Exhauster</i> • Included the addition of 2017 and 2018 APR cartridge tests on headspace vapors from tanks BY-110, SX-101, and SX-104 as well as exhausters 702-AZ, AP, and AX. Tests on 702-AZ in 2017 were the first cartridge tests conducted during waste-disturbing activities. These results have been added to the text summaries, figures, tables and conclusions throughout the report. • A furan methods review was conducted and is documented in Section 1.1. The result is that now the Carbotrap 300 TDU volatile organic compound tube analytical results are the primary reported values throughout the report for furan, 2,5-dihydrofuran, and 2-methylfuran (this includes the restating of the respective 2016 testing furan results). • Updated the Chemicals of Potential Concerns to 61 (adding dimethyl mercury and 2-propenal) as requested in WRPS-1604188.1 letter.¹ • In comparisons of BY-108 test results to historical data, updated historical data to include 2016 Sitewide Industrial Hygiene Database head space data. • Updated meteorological data in Appendix E to include the 2017 and 2018 tests.

¹ Way, KJ, September 21, 2017 Letter, Tank Operations Contractor – Chemicals of Potential Concern Rev. 1, WRPS-1604188.1. Washington River Protection Solutions, Richland, Washington.

Executive Summary

Between 2016 and 2018, 28 air purifying respirator (APR) cartridge tests were performed on headspace vapors from seven Hanford waste storage tanks (SY-102, A-101, BY-108, AX-101, BY-110, SX-101, and SX-104) and seven waste tank exhausters (AP in 2016, AP in 2018, 702-AZ, AN and AW in 2016, and AX and 702-AZ in 2017). All but two tests were conducted under static conditions absent waste-disturbing activities in the subject tanks or tank farms. The exception was cartridges tested with vapors from 702-AZ in 2017 when samples were taken during waste-disturbing activities. Multipurpose APR cartridges, SCOTT 7422-SD1 (SD1) and 7422-SC1 (SC1), were tested on vapor streams from each of the 14 tanks or exhausters. Out of 61² Chemicals of Potential Concern (COPCs), only ammonia, mercury, N-nitrosodimethylamine (NDMA), 2,5-dimethylfuran, 2,5-dihydrofuran, furan, and 1,3-butadiene exhibited breakthroughs with outlet concentrations that were >10% of their Occupational Exposure Limits (OEL)³.

- Ammonia exhibited breakthrough for 21 of the 28 tank/cartridge tests. Breakthrough was not observed for the two SY-102 tests, the AW SD1 test, the 702-AZ 2016 SC1 cartridge test, the two 2018 AX exhauster tests, and the AP 2018 SC1 cartridge test. The shortest breakthrough times, less than 2 hours, were observed with the BY-108 SC1/SD1, BY-110 SC1, SX-101, and SX-104 tests, which had the highest inlet concentrations—all >780% of the ammonia OEL. Breakthrough times of 2 hours or greater were observed for all of the other tests. Based on measured data, inlet concentration was the only parameter that significantly impacted the breakthrough time. Relative humidity and temperature are still expected to be significant to breakthrough time performance (as represented in manufacturer's breakthrough calculators) but beyond the ranges tested. The breakthrough time observed for BY-110 SC1 was appreciably lower than that expected based on the reported inlet concentration (1.8 hours versus more than 10 hours). However, the reported inlet concentration is highly suspect and the actual value is believed to be nearly 5× higher, which would make the observed breakthrough time correspond with expected values. Finally, in each of the tank/cartridge tests, ammonia breakthrough preceded all other breakthrough observations, indicating that it is a leading candidate for defining the minimum breakthrough times for the cartridges.
- Although neither of the cartridges tested are NIOSH approved for mercury removal, all of the observed mercury breakthrough times⁴ were greater than 16 hours except for the BY-108 SC1 test, which was estimated to be just over 15 hours, and the AX-101 SC1, AP 2018 SC1, and 702-AZ 2017 SD1 tests, which each had measured breakthrough times right at 16 hours. The BY-108 SC1 observation of breakthrough did not appear to correlate with inlet mercury concentration but may be linked to a high total volatile organic compound (VOC) concentration. Therefore, based on the data collected, it appears that mercury inlet concentrations of <80% of the OEL at total VOC levels of less than 6 ppm should correspond to cartridge breakthrough times greater than 15 hours. Because

² In 2017, dimethyl mercury and 2-propenal were added per Way, KJ, September 21, 2017 Letter, Tank Operations Contractor – Chemicals of Potential Concern Rev. 1, WRPS-1604188.1. Washington River Protection Solutions, Richland, Washington.

³ OELs accepted for Hanford tank farm use are based on OELs established by a U.S. governmental agency or national professional organization (e.g., OSHA, National Institute for Occupational Safety and Health, American Conference of Governmental Industrial Hygienists), or if no U.S. OEL exists, standard toxicological practices are applied to develop OELs based on the best available science. The OEL for NDMA was established in 2005 based on the MAK (Maximale Arbeitsplatzkonzentration) Commission standard adopted in Europe.

⁴ Breakthrough times were defined as exceeding 10% of the OEL at the cartridge outlet except for furans and nitrosamines where 50% of the OEL is used.

SCOTT SureLife® Calculator estimations are not available for mercury, the impact of seasonal extremes of temperature and relative humidity on cartridge performance results is not known.⁵

- Three breakthroughs were observed with 1,3-butadiene, including both BY-108 tests and the SX-101 SD1 test. The BY-108 breakthroughs were 3.8 and 5.1 hours for the SD1 and SC1 cartridges, respectively. The BY-108 breakthroughs appeared to be driven by the corresponding higher inlet concentration (>103% of the OEL compared to 2.2%, or less, for all of the other 2016 tests). Higher total VOC levels in BY-108 also are believed to have impacted the observed 1,3-butadiene breakthrough. The SX-101 SD1 “breakthrough” was based on single 8-hour cartridge outlet concentration of 13.9%, where all other outlet concentrations were less than the detection limit⁶ (DL). The corresponding inlet concentrations were also below 5.5%. These data suggest that the single elevated outlet concentration for SX-101 SD1 may be an analytical error rather than a true breakthrough.⁷
- One possible breakthrough was observed for NDMA on the SX-101 SC1 cartridge. Here, the inlet concentration to the cartridge was >4500% of the OEL, which was the highest inlet concentration of any other tank tested. The corresponding outlet concentrations were below the reporting limit (RL), except for the 6-hour and 8-hour measurements, which reached a maximum of 12.4% of the OEL before dropping back to below-RL levels for the remainder of the test. These results could indicate breakthrough behavior at approximately 7 hours but could also be explained by analytical error.
- Another possible breakthrough was observed for 2,5-dimethylfuran during SX-104 SD1 testing. In that case, the maximum inlet concentrations reached 27% of the OEL. The corresponding outlet concentrations were below the DL, except for the measurement at 4 hours, which reached 22% of the OEL, indicating potential breakthrough. However, several 2,5-dimethylfuran measurements from the blank and baseline tubes also reported concentrations greater than the RL, which puts the elevated inlet and outlet measurements for this COPC in question.
- Breakthroughs for both furan and 2,5-dihydrofuran were assessed using a higher cartridge outlet threshold compared to other COPCs—50% of the OEL versus 10% with the Carbotrap 300 TDU tube data. We adopted this approach because of the higher DL/RL values for these two COPCs (i.e., over 40% of the OEL). The specifics on the individual breakthroughs are as follows:
 - For furan, three tests showed evidence of breakthrough above 50% of the OEL—BY-108 (SD1, SC1), and 702-AZ 2017 (SD1). For both BY-108 SD1 and SC1 tests, furan breakthrough above 50% of the OEL occurred after 10 hours. The corresponding maximum inlet concentrations were 819% and 298% of the OEL—two of the highest measured in the data set. Recall that ammonia breakthrough was observed in less than 2 hours for both of the BY-108 tests. The 702-AZ 2017 tests were under waste-disturbing conditions and furan breakthrough above 50% of the OEL occurred after 10 hours for the SCOTT SD1 cartridge (maximum inlet 2995% of the OEL). In comparison, ammonia breakthrough for the SD1 test occurred after 6 hours.
 - For 2,5-dihydrofuran, a single breakthrough above 50% of the OEL was seen in the BY-108 2016 test, occurring between 14 and 16 hours. In that case, outlet concentrations from the

⁵ It is worth noting that the highest measured area sampling concentration for mercury (67% of the OEL) was not much lower than the highest cartridge-inlet concentration (84% of the OEL).

⁶ In this report, DL is used to refer either to an analytical RL or a DL. The use of either an RL or a DL varied among analytical laboratories. An RL (equivalent to a limit of quantification) was used instead of an analytical method DL by several laboratories for specific COPC analyses.

⁷ With inlet concentrations of 5.5% of the OEL, initial outlet concentrations for 1,3-butadiene during the SCOTT 7422-SC1 cartridge were below the DL, but gradually increased reaching a maximum of 7.4 % of the OEL at 14 hours. These results suggest potential breakthrough-like behavior, but at inlet and outlet concentrations below 10% of the OEL.

14- and 16-hour measurements were 42% and 377%, respectively. The corresponding maximum inlet concentration was 278%, which was 5× higher than any other inlet concentration. In comparison, ammonia breakthrough was observed in less than 2 hours.

- Several COPCs showed evidence of early breakthrough behaviors but could not have reached the 10% OEL outlet threshold because the inlet concentrations were too low. Acetaldehyde had inlet concentrations for multiple tests that reached nearly 1.2% of the OEL, and corresponding outlet concentrations for acetaldehyde reached nearly 0.8% OEL. This indicates that a significant amount of the inlet concentration may have made it through the cartridge over the course of the test. Similarly, propanenitrile exhibited inlet concentrations around 0.4% of the OEL, with corresponding outlet concentrations that reached 0.9%. Finally, outlet concentrations of 3-buten-2-one reached 2% of the OEL for the highest inlet concentrations—nearly 12%. These observations suggest that close attention should be paid to these COPCs if inlet concentrations were to increase for tanks in the future.
- From the 2016 testing,⁸ total VOCs, including both COPCs and all non-COPC organic vapors measured in the tests, also were shown to exhibit cartridge breakthrough for the two BY-108 tests. However, because there is no OEL for total VOCs, it is recommended that total VOCs concentration be monitored and used as a potential contributor to other COPC breakthroughs, as described above.

In general, most estimations obtained from the SCOTT SureLife^{®9} Cartridge Calculator were near or below the measured breakthrough values for each of the cartridge tests, thereby validating the use of that tool by Industrial Hygiene in future ammonia service life estimations. However, a number of service life estimations were greater than measured breakthrough times. If an additional 2-hour safety factor were applied to the SureLife[®] estimates, all observed ammonia breakthrough times would be greater than corresponding service life estimations, and ammonia would be a leading candidate for defining the minimum breakthrough times for the cartridges.

A comparison of the respirator cartridge inlet COPC concentrations was made against historical concentrations for each tank/exhauster to assess whether the cartridge testing bounded historic maximum concentrations. Sampling and analysis of 58 of the 61 COPCs was performed in the APR cartridge testing.¹⁰ Out of the 58 COPCs evaluated, only 11 were found to have historical maximum concentrations that were either moderately higher than the cartridge-testing inlet concentrations, defined as 2×–5× the cartridge-inlet value, or significantly higher, defined as greater than 5× the cartridge-inlet value. The COPCs discussed below were identified as having relevant differences between cartridge inlet and maximum historic source concentrations.

Five COPCs—mercury, furan, NDMA, 1-butanol, and acetonitrile—had historic maxima more than 10× higher than maximum inlet concentrations measured in these recent cartridge tests. Two other COPCs—2-heptylfuran and 2-fluoropropene—also were found to have historical maxima that were significantly higher than the maximum cartridge inlets. However, in both cases the historical maxima were from 1994 BY-108 sampling and were either suspect data (2-heptylfuran), or represent a single high data point and COPC detection that has not been replicated in any subsequent sampling. Of these seven COPCs, breakthrough has only been observed for mercury, furan, and NDMA.

⁸ For the 2017 and 2018 tests total VOCs analysis was limited to preliminary investigation of selected tests where there was indication of COPC breakthrough that warranted evaluation of the potential impact of non-COPC VOCs.

⁹ The 3M SCOTT SureLife Calculator was available through technical services at ScottTechSupport@scottsafety.com.

¹⁰ Sampling for three COPCs—nitrous oxide, methanol, and dimethyl mercury—was not performed in the APR tests, with the exception of methanol analysis from SUMMA canister samples used with the 702-AZ (2017) test. The basis for exclusion of these COPCs is provided in Section 1.3.

- Mercury and NDMA historical maxima were approximately 22× and 19× their maximum cartridge-inlet concentrations, respectively. The historical maximum for mercury was from the AN exhauster during a waste-disturbing activity. The highest non-waste-disturbing historical maximum was approximately 3× the highest cartridge inlet. The maximum NDMA historic measurement also came from the AN exhauster but all other NDMA source samples from AN and other tank farms are significantly lower (more than or equal to 10×) than this maximum.
- Historical maxima for furan and 1-butanol both come from 1994 BY-108 headspace measurements, and in both cases, maxima from more recent measurements are substantially lower. The maximum cartridge inlet for furan (2995% of the OEL, 702-AZ (2017)) was higher than any other historic measurement of the tank headspaces or exhausters used in cartridge testing.
- The maximum historic acetonitrile concentration was a recent measurement from BY-108 (94% of the OEL) and was approximately 10× the maximum measured cartridge inlet or outlet concentration during testing. Cartridge inlet and outlet measurements of acetonitrile have been variable, but generally below 10% of the OEL with few exceptions. Historic source and area measurements of acetonitrile have also been highly variable, with no reported measurements exceeding the OEL.

Four COPCs—1,3-butadiene, formaldehyde, 2,3-dihydrofuran, and N-nitrosomorpholine—had historic maxima moderately higher (between 2× and 5×) than their maximum cartridge inlet concentrations. Breakthrough behavior has only been observed for 1,3-butadiene in two BY-108 cartridge tests where other organic compounds also experienced breakthrough and consequently may have contributed to the breakthrough of the 1,3-butadiene. All other COPCs for which breakthrough or breakthrough behavior was observed—ammonia, 2,5-dihydrofuran, and 2,5-dimethylfuran—had cartridge inlet concentrations that were >50% of the historical maxima and were, therefore, not considered either moderately or significantly lower than historical levels.

The revision 0 report with just the first eight tests recommended additional testing or analysis of specific COPCs may be warranted in cases where the cartridge-test conditions may not have achieved an adequate performance¹¹ basis. One option recommended for future testing is to include the ability to artificially elevate the concentrations of COPCs, such as furan, with historically higher concentrations so that respirator cartridge performance can be assessed against concentrations that challenge the cartridge and represent an appropriate bounding condition.

- The recommendation to test tanks during waste-disturbing activities was implemented during 2017 tests. Testing during waste-disturbing conditions in 702-AZ 2017 exhauster did achieve elevated concentrations for some COPCs that helped to more fully assess cartridge performance.¹² With respect to furan compounds, the 702-AZ 2017 exhauster tests during waste-disturbing conditions, along with the re-evaluation of the BY-108 2016 furans and tank headspace sampling from AX-101 and SX-104 did achieve elevated concentrations necessary to better assess cartridge performance for furan, 2,5-dihydrofuran, and 2,5-dimethylfuran.

¹¹ “Adequate performance” refers to being below the breakthrough criterion used in this analysis, which is having a sustained cartridge outlet concentration above 10% of the OEL of a COPC. Ultimately, Industrial Hygiene professionals will use these results along with specific hazard assessments to determine service life, change schedules, and cartridge use that provides the necessary performance.

¹² For 702-AZ 2017 testing, ammonia, N-nitrosodimethylamine, and N-nitrosodiethylamine exceeded their corresponding OELs, and mercury, 2,3-Dihydrofuran, and N-nitrosomethylethylamine had one or more inlet concentration measurements >10% of their OELs.

Acronyms and Abbreviations

APR	air-purifying respirators
BBI	Best Basis Inventory
CAS	Chemical Abstracts Service
COPC	Chemical of Potential Concern
DBBP	dibutyl butylphosphonate
DL	detection limit
DST	double-shell tank
EPA	U.S. Environmental Protection Agency
HMS	Hanford Metrological Station
IH	Industrial Hygiene
GC	gas chromatography
MS	mass spectrometry
NDEA	N-nitrosodiethylamine
NDMA	N-nitrosodimethylamine
NMEA	N-nitrosomethylethylamine
NIOSH	National Institute of Occupational Safety and Health
OEL	Occupational Exposure Limit
OSHA	Occupational Safety and Health Administration
ppmv	parts per million on a volume basis (also shown as ppm in report)
RL	reporting limit
RT	retention time
SureLife [®] Calculator	SCOTT SureLife [®] Cartridge Calculator
SVOA	Semi-Volatile Organic Analysis
SWIHD	Site-Wide Industrial Hygiene Database
TDU	Thermal Desorption Unit
TIC	Tentatively Identified Compounds
TWINS	Tank Waste Information Network System
VOA	volatile organic analyte
VOC	volatile organic compound
WRPS	Washington River Protection Solutions

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1.0 Overview of Respirator Cartridge Testing

Between 2016 and 2018, Washington River Protection Solutions (WRPS) conducted a series of tests using two types of chemical cartridges for air-purifying respirators (APR) at Hanford. The purpose of the testing was to determine the period of time that the cartridges would provide adequate performance¹³ for APRs when exposed to a mixture of Chemicals of Potential Concern (COPCs) from vapors emanating from the headspace of tanks or exiting the exhausters from Hanford waste storage tanks. The Occupational Safety and Health Administration (OSHA) identifies cartridge testing as a valid approach for establishing cartridge service life. Testing is commonly applied in situations where mixtures of COPCs exist, and where other approaches, such as manufacturer recommendations and modeling, are less reliable. The tests were designed and conducted to ensure measurement and/or control of the key variables OSHA identified as important to estimate cartridge service life, including temperature, humidity, COPC concentration, worker breathing rate, and cartridge adsorption capacity. Multipurpose respirator cartridges, SCOTT 7422-SD1 and SCOTT 7422-SC1 (SCOTT Safety, Monroe, North Carolina), were assessed over a 16-hour period on separate days using vapor streams from seven Hanford tank headspaces and seven exhausters in separate tests. Of the exhausters, six were sampled under static (i.e., non-waste-disturbing) conditions and one during waste-disturbing conditions. The source vapors were fed to a respirator cartridge test stand developed by WRPS in collaboration with HiLine Engineering (Richland, Washington).

Table 1 identifies the 28 test conditions and starting times for each of the cartridges tested. Note that the highlighted second half of the tests in Table 1 were incorporated as part of this Revision 1 update.

Table 1. Summary of 2016-2018 APR Cartridge Testing

Tank Farm	Headspace or Exhauster		Cartridge Test Start Date and Time	
	Tank Headspace	Exhauster	SCOTT 7422-SD1	SCOTT 7422-SC1
241-AP		AP Exhauster	6/24/16 11:50 AM	6/25/16 11:41 AM
241-SY	241-SY-102		7/08/16 12:01 PM	7/09/16 10:07 AM
241-BY	241-BY-108		7/15/16 12:02 PM	7/16/16 10:21 AM
241-A	241-A-101		7/22/16 11:35 AM	7/23/16 10:18 AM
241-AY & -AZ		702-AZ Exhauster	8/26/16 11:29 AM	8/27/16 10:15 AM
241-AX	241-AX-101		9/09/16 11:57 AM	9/10/16 10:41 AM
241-AW		AW Exhauster	9/23/16 10:40 AM	9/24/16 10:39 AM
241-AN		AN Exhauster	9/30/16 10:27 AM	10/01/16 10:20 AM
241-AY & -AZ		702-AZ Exhauster during waste-disturbing activities	2/10/17 10:36 AM	2/11/17 12:40 PM
241-SX	241-SX-104		6/16/17 11:25 AM	6/17/17 11:07 AM
241-SX	241-SX-101		6/23/17 10:52 AM	6/24/17 10:17 AM
241-AX		AX Exhauster	8/25/17 11:20 AM	8/26/17 10:09 AM
241-BY	241-BY-110		2/23/18 11:30 AM	2/24/18 10:55 AM
241-AP		AP Exhauster	3/24/18 10:12 AM	03/23/18 12:16 PM

¹³ “Adequate performance” refers to being below the breakthrough criterion used in this analysis, which is having a sustained cartridge outlet concentration above 10% of the OEL of a COPC. Ultimately, Industrial Hygiene professionals will use these results along with specific hazard assessments to determine service life, change schedules, and cartridge use that provides the necessary performance.

Pacific Northwest National Laboratory was tasked with conducting an independent analysis of the analytical results and making recommendations based on the results for respiratory cartridge performance and breakthrough time. Breakthrough times from testing provide input data to Industrial Hygiene professionals to support respirator cartridge service life determinations.

Individual reports for the 28 tests discussed in this report have been prepared and submitted to WRPS. These test reports provide detailed summaries of the test conditions, data analysis, and results for each individual test [1–13]. This report integrates the results from all 2016 through 2018 APR cartridge tests to provide a more comprehensive understanding of APR cartridge performance under the range of test conditions.

Revision 0 of this report was issued in September 2017 and integrated results from the first eight 2016 tests. One significant issue identified was a large difference in cartridge inlet maximum furan and substituted furans concentrations relative to historic measurements. Since then, a technical problem with the primary furan analysis method was identified, and alternate furan measurements have been evaluated. This revision of the report provides the summary results and conclusions from the alternate furan measurements described in Section 1.1, with additional details in Appendix F. In addition, the results of six additional cartridge tests conducted in 2017 and 2018 are included in this report revision.

1.1 Use of Alternate Furan Measurements

Two sorbent tubes currently are used in both vapor source characterization and cartridge testing that support quantitation of the furans class of COPCs, which includes furan (CAS# 110-00-9) and 13 other substituted furans. Prior to 2018, the preferred sorbent tube had been the Tenax TA Thermal Desorption Unit Furans tube, which uses a modified EPA TO-17 method with gas chromatography/mass spectrometry (GC/MS) for quantitation of furan and eight of the 13 substituted furan COPCs. A separate sorbent tube, also used to measure furans, is the Carbotrap 300 Thermal Desorption Unit tube analyzed with a modified EPA TO-17 method with GC/MS for quantitation. Evaluations of furan methods were conducted (see details in Appendix F) that recommended the use of the Carbotrap 300 TDU tube for its three calibrated furan COPCs—furan, 2,5-dihydrofuran, and 2-methylfuran.

The re-evaluation shows significantly higher cartridge inlet concentrations for furan using Carbotrap 300 TDU tube data compared to the original tube analysis results documented in Revision 0 of this report. Furan breakthrough was only observed in two tests during which furan inlet concentrations achieved the highest maximum values of 819% and 3084% of the Occupational Exposure Limit (OEL). In all of the 2016 tests, ammonia breakthrough continues to precede all other breakthrough observations including furan, which indicates that ammonia continues to define the minimum breakthrough times for the cartridges.

1.2 Comparison of Source Concentrations for Cartridge Testing and Historical Analysis

The measurement of the 61 COPCs¹⁴ was the primary focus of the cartridge testing. The 61 COPCs shown in Table 2 represent a set of tank vapor chemicals that have been found in a tank farm source at or

¹⁴ In 2017, dimethylmercury and 2-propenal (acrolein) were added per Way, KJ, September 21, 2017, Letter, Tank Operations Contractor – Chemicals of Potential Concern Rev. 1, WRPS-1604188.1. Washington River Protection Solutions, Richland, Washington.

above 10% of the relevant OEL or are considered “known” or “probable” carcinogens by the International Agency for Research Cancer or other regulatory agencies [14,29].

To fully assess respirator cartridge performance for COPC removal, historical headspace and exhauster data were reviewed to determine if the cartridge inlet concentrations were representative of typical source concentrations. Historical headspace and exhauster data from the Tank Waste Information Network System (TWINS) and the Site-Wide Industrial Hygiene Database (SWIHD) were used for this assessment. Table 2 lists the historical maximum concentrations obtained from SWIHD and/or TWINS for the various headspace and exhauster sources, and the corresponding maximum respirator cartridge inlet concentrations. The 14 tank headspace or tank farm exhauster sources tested are summarized in Table 2 in groups representing tests involving individual tanks (almost all passively ventilated) and their corresponding headspace vapors, and tests involving actively ventilated tank farm exhauster slip stream vapors. Of the seven tank headspace vapor tests, BY-108 and BY-110 are presented separately in Table 2 from the remaining A-101, SY-102, AX-101, SX-101, and SX-104 headspace tests because the BY tanks represent much higher concentrations of many COPCs, and BY-108 was included for testing as a higher bounding case. The remaining columns in Table 2 treat cartridge tests at exhausters separately for tests conducted without and with waste disturbance. Only 702-AZ 2017 exhauster cartridge tests were conducted during waste-disturbing transfer operations and are therefore, separated from other exhauster testing under non-waste-disturbing conditions in Table 2. More detailed historical information and analyses are provided in Appendix C for each of the individual tanks and tank farms.

In general, respirator cartridge inlet concentrations during testing were representative of historical headspace and exhauster concentrations. In some cases, conditions during an individual tank or exhauster tests were not representative of the highest historical concentrations in that specific farm, but another test (often BY-108) provided a bounding test concentration. For many COPCs, concentrations from the tested tanks and exhausters were historically much lower than the 50% of the OEL action level or 10% of the OEL threshold. In these cases, any differences between cartridge tests and historical maxima were not considered significant. All but two of the tests were conducted under non-waste-disturbing tank headspace and tank farm exhauster conditions; therefore, care was taken in analyzing the historical analysis results to consider whether the tanks were sampled under similar conditions. For several COPCs, including mercury, furan, formaldehyde, several nitrosamines, and nitrous oxide,¹⁵ the maximum historical concentrations recorded were significantly higher than respirator cartridge inlet measurements. However, in most cases, the historical maxima were found to have been obtained during waste-disturbing activities. The highest historical concentrations observed during non-waste-disturbing conditions were found to be much more comparable to tested concentrations (maximum values resulting from waste-disturbing conditions are shown in Table 2 in red numbers, with the highest non-waste-disturbing concentrations reported in brackets ‘[#]’).

¹⁵ Nitrous oxide was not measured during cartridge testing because it is not effectively absorbed by respirator cartridges and requires alternative sampling and analysis methods.

Table 2. Hanford Tank Vapor COPCs with Maximum Concentration Data from Both Historical Sampling and FY 2016–2018 Cartridge Testing

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Headspace Concentration, % of OEL (BY-110, 2016 BY-108)		Headspace Concentrations, % of OEL (SY-102, A-101, AX-101, SX-101, SX-104)		Non-disturbed Tests, Exhauster Concentrations, % of OEL (2016 & 2018 AP, 2016 702-AZ, AW, AN, AX)		Disturbed Test, Exhauster Concentrations, % of OEL (2017 702-AZ)		
			Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	
Inorganic											
1	Ammonia	7664-41-7	25 ppm	2576	1915	1572	1385	676 [476]	279	676	310
2	Nitrous Oxide	10024-97-2	50 ppm	1662 (6)	NM	35	NM	<100 (55) [13]	NM	<100	NM
3	Mercury	7439-97-6	25 µg/m ³	68	52	44	67	1824 [234]	84	468	53
Hydrocarbons											
4	1,3-Butadiene	106-99-0	1 ppm	338	138	51	6	<103* (17) [9]	7	11	<2
5	Benzene	71-43-2	0.5 ppm	<11 (2)	0.9	2	0.8	<8 (0.9)	0.4	<7 (0.9)	2
6	Biphenyl	92-52-4	0.2 ppm	<5	<0.09	<2	<0.3 (0.09)	<4 (2)	<24* (<0.6)	<4	<0.09
Alcohols											
7	1-Butanol	71-36-3	20 ppm	318 (22)	5	0.6	0.7	15 [6]	1	0.5	0.3
8	Methanol	67-56-1	200 ppm	<0.8 (0.01)	NM	0.2	NM	<1 (0.3)	NM	<1 (0.1)	9
Ketones											
9	2-Hexanone	591-78-6	5 ppm	0.9	0.4	0.2	0.4	<0.8 (0.3)	0.02	<0.4 (0.02)	0.1
10	3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
11	4-Methyl-2-hexanone	105-42-0	0.5 ppm	<0.8 (0.4)	0.3	<0.8	0.2	<0.4 (0.3)	<0.06 (0.05)	<0.2	0.09
12	6-Methyl-2-heptanone	928-68-7	8 ppm	NM	0.04	NM	n/a	NM	n/a	NM	0.03
13	3-Buten-2-one	78-94-4	0.2 ppm	<29	24	5	2	<5 (3)	1	<3 (2)	0.1
Aldehydes											
14	Formaldehyde	50-00-0	0.3 ppm	6	9	<26 (8)	14	75 [64]	17	<23 (5)	1
15	Acetaldehyde	75-07-0	25 ppm	11	1	0.9	0.5	<0.9 (0.8)	0.3	<0.7 (0.1)	0.6
16	Butanal	123-72-8	25 ppm	0.5	0.6	0.5	0.03	<0.5 (0.1)	0.02	<0.5 (0.02)	0.01
17	2-Methyl-2-butenal	1115-11-3	0.03 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
18	2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
New ²	2-Propenal	107-02-8	0.1 ppm	<11	<1	<138	<0.9	<173 (8)	<0.9	<146 (8)	<1
Furans and Substituted Furans											
19	Furan	110-00-9	1 ppb	54700 (1840)	819	<706 (175)	169	<14500* (715)	392	<14500* [79]	2995
20	2,3-Dihydrofuran	1191-99-7	1 ppb	309	75	<37	44	<73 (41) (23)	<25	<36 (23)	17
21	2,5-Dihydrofuran	1708-29-8	1 ppb	<5660* (457)	278	<980	<53	<15500* (12)	<105	<15500*	<20
22	2-Methylfuran	534-22-5	1 ppb	<4840*	39	<1800	<20	<3930*	<61 (17)	<3930*	14
23	2,5-Dimethylfuran	625-86-5	1 ppb	<34	<19	<27	27* (14)	<53	<19	<26	<3
24	2-Ethyl-5-methylfuran	1703-52-2	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
25	4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
26	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
27	2-Pentylfuran	3777-69-3	1 ppb	<24	<13	<19	<13	<37	<13	<18	7
28	2-Heptylfuran	3777-71-7	1 ppb	6120* (<20)	<11	<16	<11	<31	<11	<15	<2
29	2-Propylfuran	4229-91-8	1 ppb	<30	<16	<23	<16	<47	<16	<23	<3
30	2-Octylfuran	4179-38-8	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
31	2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
32	2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	NM	n/a	NM	n/a	NM	n/a	NM	n/a
Phthalates											
33	Diethylphthalate	84-66-2	5 mg/m ³	<1.3	<0.04 (0.02)	<0.4	<0.1	0.6	<11* (<0.3)	<0.6 (0.2)	<0.04
Nitriles											
34	Acetonitrile	75-05-8	20 ppm	94	1	26	3	<10 (4)	1	3	0.6
35	Propanenitrile	107-12-0	6 ppm	<0.8 (0.5)	0.4	<0.1 (0.07)	0.2	<0.8 (0.1)	0.04	<0.8 (0.02)	0.03
36	Butanenitrile	109-74-0	8 ppm	<0.7 (0.4)	0.2	0.5	0.08	<0.7 (0.1)	0.03	<0.7 (0.01)	0.02
37	Pentanenitrile	110-59-8	6 ppm	<0.8 (0.2)	0.2	<0.2	0.04	<0.8 (0.08)	0.01	<0.8	0.009
38	Hexanenitrile	628-73-9	6 ppm	<0.7 (0.1)	0.05	<0.2 (0.02)	0.2	<0.4 (0.1)	0.02	<0.4	0.004
39	Heptanenitrile	629-08-3	6 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
40	2-Methylene butanenitrile	1647-11-6	0.3 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
41	2,4-Pentadienenitrile	1615-70-9	0.3 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a

Table 2. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Headspace Concentration, % of OEL (BY-110, 2016 BY-108)		Headspace Concentrations, % of OEL (SY-102, A-101, AX-101, SX-101, SX-104)		Non-disturbed Tests, Exhauster Concentrations, % of OEL (2016 & 2018 AP, 2016 702-AZ, AW, AN, AX)		Disturbed Test, Exhauster Concentrations, % of OEL (2017 702-AZ)		
			Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	Max. Historical ¹	Max. Cartridge Inlet ¹	
Amines											
42	Ethylamine	75-04-7	5 ppm	<0.4	4	<0.7	0.3	17	3	<0.9	0.4
Nitrosamines											
43	N-Nitrosodimethylamine	62-75-9	0.3 ppb	2063	1874	9300	4750	85667	4589	820	1578
44	N-Nitrosodiethylamine	55-18-5	0.1 ppb	<1030 (8)	150	<90 (60)	412	328 (53)	71	<209 (66)	398
45	N-Nitrosomethylethylamine	10595-95-6	0.3 ppb	<413 (8)	252	<35	69	285 (257)	106	<81 (10)	26
46	N-Nitrosomorpholine	59-89-2	0.6 ppb	<153 (8)	18	24	14	151	43	<28 (4)	4
Organophosphates											
47	Tributyl phosphate	126-73-8	0.2 ppm	<3	<0.1	<1	<0.2	<3 (0.05)	<19* (<0.5)	<3	<0.07
48	Dibutyl butylphosphonate	78-46-6	0.007 ppm	<256 (<4)	<1	<29	<5	<55* (<17)	<377* (<10)	<45*	<1
Halogenated Hydrocarbons											
49	Chlorinated Biphenyls	Varies	1 mg/m ³	NM	n/a	NM	n/a	NM	n/a	NM	n/a
50	2-Fluoropropene	1184-60-7	0.1 ppm	530 (n/a)	n/a	<3	n/a	<3	n/a	NM	n/a
Pyridines											
51	Pyridine	110-86-1	1 ppm	<5 (0.3)	0.3	<1 (0.2)	0.2	<266* (2.1) [0.2]	<0.2 (0.05)	<24* (0.09)	0.1
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	<8 (0.8)	0.5	<2	<0.06	<408* (<29) (0.06)	<0.2	<81*	<0.08
Organonitrites											
53	Methyl nitrite	624-91-9	0.1 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
54	Butyl nitrite	544-16-1	0.1 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
Organonitrates											
55	Butyl nitrate	928-45-0	2.5 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	NM	n/a	NM	n/a	NM	n/a	NM	n/a
Isocyanates											
59	Methyl isocyanate	624-83-9	20 ppb	NM	n/a	<35	n/a	<36	n/a	<36	n/a
Organometallics											
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM	NM	NM	NM	14	NM	14	NM

¹	"<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.
²	2-propanol and dimethylmercury were added to the COPC List in September, 2017.
*	Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc.) Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.
#	Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets (#), if present, indicate the maximum concentration measured during conditions where no disturbing activities were identified.
<i>italics</i>	Indicates that the historic concentration data is pre-2006 TWINS headspace results (often 1994-1997 data). Where more recent data are 10% or less of the 1990s maximum, the more recent maximum is included in parentheses without italics, using only the above-report maximum if available.
n/a	Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).
NM	Not measured or not reported (cartridge inlet) or no measurement reported in databases (historic maximum).
	Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, 3) the historic maximum was not bounded by another test inlet concentration, and 4) the historic maximum was measured during undisturbed tank headspace conditions for undisturbed cartridge tests, or measured during any tank conditions for disturbed cartridge tests.
	Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, 3) the historic maximum was not bounded by another test inlet concentration, and 4) the historic maximum was measured during undisturbed tank headspace conditions for undisturbed cartridge tests, or measured during any tank conditions for disturbed cartridge tests.

Out of 61 COPCs evaluated, only 11 were found to have historical maximum concentrations that were either moderately or significantly higher than the cartridge-testing inlet concentrations measured. These COPCs are listed below and the differences are described. Comparisons are made to available area-sampling data for all tank farms between 2008 and 2018.¹⁶

- *Mercury* – The maximum mercury cartridge inlet concentration, which was measured under non-disturbed conditions, was substantially lower than the historical maximum of 1824% of the OEL at the AN exhauster. However, the highest historical concentration measured was obtained during a waste-disturbing activity. The historical maximum from non-disturbed conditions was 234% of the OEL, also at the AN exhauster. This maximum is approximately 3× the highest cartridge inlet concentration of 84% of the OEL. For comparison, the highest mercury concentration measured in more than 1400 area samples was 67% of the OEL.
- *1,3-Butadiene* – The maximum butadiene cartridge inlet concentration, like the maximum historical concentration, was measured in BY-108 under non-disturbed conditions. The maximum historical and cartridge inlet concentrations were respectively 338% and 138% of the OEL, so the historical maximum concentration was less than 3× the highest cartridge inlet concentration. For comparison, the highest butadiene concentration measured in 973 area samples was 12% of the OEL.
- *1-Butanol* – The maximum butanol cartridge inlet concentration, like the maximum historical concentration, was measured in BY-108 under non-disturbed conditions. The historical and cartridge inlet concentrations were respectively 318% and 5% of the OEL, so the historical maximum concentration was more than 60× the highest cartridge inlet concentration. This historical maximum was derived from 1994 data. The maximum of more recent BY-108 data was measured in 2016. It was 22% of the OEL, about 4× the cartridge-inlet maximum. This recent BY-108 maximum is higher than any of the historical maxima for tanks other than BY-108. The highest 1-butanol concentration measured in 914 area samples was 0.1% of the OEL.
- *Formaldehyde* – The maximum formaldehyde cartridge inlet concentration was measured at the AX exhauster as 17% of the OEL, and the historical maximum was 64% of the OEL (AN exhauster). Both were measured under non-disturbed conditions. The historical maximum was 75% of the OEL under waste-disturbing AN exhauster conditions. Overall, the historical maxima for formaldehyde measurements were about 4× the highest inlet concentrations measured during cartridge testing. For comparison, the highest formaldehyde concentration measured in more than 1000 area samples was 15% of the OEL, slightly lower than the maximum cartridge-inlet concentration.
- *Furan* – The maximum cartridge inlet furan concentration was 2995% of the OEL, measured at the 702-AZ exhauster under waste-disturbing conditions. It was significantly lower than the historical maximum concentration of 54,700% of the OEL, measured in BY-108 headspace in the 1990s, but significantly higher than measured in any other tank headspace (175%, A-101) or exhauster (715%, 2018 AP exhauster). The 1990s historical maximum concentration was roughly 20× the highest cartridge inlet concentration. The maximum of more recent BY-108 data was measured in 2016. It was 1840% of the OEL, lower than the cartridge-inlet maximum. Out of 915 furan area samples, all were non-detects, therefore, no comparison to area samples can be made.

¹⁶ Area-sampling data typically represents time weighted average concentrations comparable to source and cartridge testing samples, but may not represent instantaneous or short duration concentrations, if present. In addition, area sampling represents only a portion of the data potentially available. WRPS industrial hygiene performs more extensive analysis on vapor concentrations in the breathing zone using additional data sets.

- *2,3-Dihydrofuran* – The maximum cartridge inlet concentration of 2,3-dihydrofuran was 75% of the OEL, measured in the BY-108 headspace. By comparison the historical maximum concentration was 309% of the OEL, measured in BY-110. The historical maximum concentration was 4× the highest cartridge inlet concentration. Out of 496 2,3-dihydrofuran area samples, all were non-detects, therefore, no comparison to area samples can be made.
- *Acetonitrile* – The maximum acetonitrile cartridge inlet concentration of 3% of the OEL was measured in the AX-101 headspace, while the maximum historical concentration of 94% of the OEL was measured in BY-108. The historical maximum concentration was more than 30× the highest cartridge inlet concentration. For comparison, the highest acetonitrile concentration measured in 1080 area samples was 24% of the OEL, and there were eight measurements that exceeded 3% of the OEL.
- *N-nitrosodimethylamine (NDMA)* – The maximum cartridge inlet NDMA concentration, from SX-101, was 4750% of the OEL. The historical maximum of NDMA concentration measurements came from the AN exhauster and was nearly 86,000% of the OEL, or 19× the cartridge inlet maximum. For comparison, out of nearly 1500 NDMA area samples, the highest three concentrations were between 20% and 23% of the OEL, much lower than the SX-101 cartridge-inlet concentration.
- *N-nitrosomorpholine* – The maximum cartridge inlet N-nitrosomorpholine concentration, from the AX exhauster, was 43% of the OEL. The historical maximum concentration also was measured in the AX exhauster and was 151% of the OEL, >4× the cartridge inlet maximum. Out of about 1500 N-nitrosomorpholine area samples, all were non-detects, therefore no comparison to area samples can be made.
- *Other* – 2-heptylfuran and 2-fluoropropene were also found to have historical maxima significantly higher than cartridge testing inlet concentrations. However, in these cases, the maximum was suspect data, or a single high measurement where all subsequent measurements have been significantly lower or below reporting limits (RL). Further discussion of these COPCs is included in Appendix C.

1.3 Summary of Cartridge-Testing Results

Table 3 includes the maximum inlet (source) and maximum cartridge outlet concentrations of all of the COPCs measured in the respirator cartridge tests. Red and yellow highlights are repeated from Table 2 and indicate those COPCs where the maximum cartridge inlet concentration observed was significantly lower (red) or lower (yellow) than the historical maximum source concentration of any tank/exhauster tested. Because of testing and analytical limitations, measurements of nitrous oxide, dimethylmercury, and methanol were not included in the APR cartridge tests. Nitrous oxide is not susceptible to respirator filtration, and there are no known respirator filtration cartridges approved by the National Institute for Occupational Safety and Health for nitrous oxide. Dimethyl mercury was not measured because it requires special sampling and analysis methods. Methanol was not quantified as part of the COPC data set, because it is used as a standard solvent and calibration standard in the analytical procedure for volatile organic compounds (VOC), and the APR test system could not support a separate methanol-specific sorbent tube. However, an alternate SUMMA canister gas sampling method was used for the 2017 702-AZ APR cartridge test only to obtain methanol data.

Table 3. Hanford Tank Vapor COPCs with Maximum Respirator Cartridge Inlet and Outlet Concentrations (% of the OEL)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Headspace Concentration, % of OEL (BY-110, 2016 BY-108)		Headspace Concentrations, % of OEL (SY-102, A-101, AX-101, SX-101, SX-104)		Non-disturbed Tests, Exhauster Concentrations, % of OEL (2016 & 2018 AP, 2016 702-AZ, AW, AN, AX)		Disturbed Test, Exhauster Concentrations, % of OEL (2017 702-AZ)		
			Max. Cartridge Inlet ¹	Max. Cartridge Outlet ²	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ²	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ²	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ²	
Inorganic											
1	Ammonia	7664-41-7	25 ppm	1915	1912	1385	1187	279	217	310	369
2	Nitrous Oxide	10024-97-2	50 ppm	NM		NM		NM		NM	
3	Mercury	7439-97-6	25 µg/m ³	52	14	67	16* (<7)	84	13	53	28
Hydrocarbons											
4	1,3-Butadiene	106-99-0	1 ppm	138	268	6	14	7	6	<2	<2
5	Benzene	71-43-2	0.5 ppm	0.9	0.1	0.8	0.09	0.4	0.1	2	0.07
6	Biphenyl	92-52-4	0.2 ppm	<0.09	<0.09	<0.3 (0.09)	<0.2 (0.1)	<24* (<0.6)	<0.6	<0.09	<0.1
Alcohols											
7	1-Butanol	71-36-3	20 ppm	5	0.005	0.7	0.2	1	<0.02 (0.007)	0.3	0.008
8	Methanol	67-56-1	200 ppm	NM		NM		NM		9	5
Ketones											
9	2-Hexanone	591-78-6	5 ppm	0.4	<0.003	0.4	0.03	0.02	<0.004	0.1	<0.003
10	3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	n/a		n/a		n/a		n/a	
11	4-Methyl-2-hexanone	105-42-0	0.5 ppm	0.3	<0.03	0.2	<0.04	<0.06 (0.05)	<0.04	0.09	<0.03
12	6-Methyl-2-heptanone	928-68-7	8 ppm	0.04	n/a	n/a		n/a		0.03	n/a
13	3-Buten-2-one	78-94-4	0.2 ppm	24	2	2	0.6	1	0.2	0.1	1
Aldehydes											
14	Formaldehyde	50-00-0	0.3 ppm	9	1	14	2	17	3	1	2
15	Acetaldehyde	75-07-0	25 ppm	1	0.8	0.5	0.3	0.3	0.3	0.6	0.3
16	Butanal	123-72-8	25 ppm	0.6	<0.002 (0.001)	0.03	0.005	0.02	0.005	0.01	<0.001
17	2-Methyl-2-butenal	1115-11-3	0.03 ppm	n/a		n/a		n/a		n/a	
18	2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	n/a		n/a		n/a		n/a	
New ²	2-Propenal	107-02-8	0.1 ppm	<1	<0.9	<0.9	<0.9	<0.9	<1	<1	<0.9
Furans and Substituted Furans											
19	Furan	110-00-9	1 ppb	819	698	169	<28	392	<43	2995	88
20	2,3-Dihydrofuran	1191-99-7	1 ppb	75	<3	44	10* (3)	<25	5	17	1
21	2,5-Dihydrofuran	1708-29-8	1 ppb	278	377	<53	<52	<105	<34	<20	<21
22	2-Methylfuran	534-22-5	1 ppb	39	<19	<20	<21	<61 (17)	<20	14	<10
23	2,5-Dimethylfuran	625-86-5	1 ppb	<19	<3	27* (14)	22* (<7)	<19	<7	<3	<3
24	2-Ethyl-5-methylfuran	1703-52-2	1 ppb	n/a		n/a		n/a		n/a	
25	4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	n/a		n/a		n/a		n/a	
26	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	n/a		n/a		n/a		n/a	
27	2-Pentylfuran	3777-69-3	1 ppb	<13	<3 (2)	<13	7	<13	6	7	<3
28	2-Heptylfuran	3777-71-7	1 ppb	<11	<3 (1)	<11	7	<11	8	<2	<2
29	2-Propylfuran	4229-91-8	1 ppb	<16	<3	<16	5	<16	<4 (3)	<3	<2
30	2-Octylfuran	4179-38-8	1 ppb	n/a		n/a		n/a		n/a	
31	2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	n/a		n/a		n/a		n/a	
32	2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	n/a		n/a		n/a		n/a	
Phthalates											
33	Diethylphthalate	84-66-2	5 mg/m ³	<0.04 (0.02)	<0.04 (0.03)	<0.1	<0.08	<11* (<0.3)	<0.3 (0.02)	<0.04	<0.05
Nitriles											
34	Acetonitrile	75-05-8	20 ppm	1	9	3	21*, 12* (1)	1	6	0.6	3
35	Propanenitrile	107-12-0	6 ppm	0.4	0.9	0.2	0.08	0.04	0.007	0.03	0.005
36	Butanenitrile	109-74-0	8 ppm	0.2	0.006	0.08	0.03	0.03	0.004	0.02	<0.002
37	Pentanenitrile	110-59-8	6 ppm	0.2	0.008	0.04	0.007	0.01	<0.004	0.009	<0.003
38	Hexanenitrile	628-73-9	6 ppm	0.05	<0.003	0.2	0.003	0.02	<0.004	0.004	<0.003
39	Heptanenitrile	629-08-3	6 ppm	n/a		n/a		n/a		n/a	
40	2-Methylene butanenitrile	1647-11-6	0.3 ppm	n/a		n/a		n/a		n/a	
41	2,4-Pentadienenitrile	1615-70-9	0.3 ppm	n/a		n/a		n/a		n/a	

Table 3. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Headspace Concentration, % of OEL (BY-110, 2016 BY-108)		Headspace Concentrations, % of OEL (SY-102, A-101, AX-101, SX-101, SX-104)		Non-disturbed Tests, Exhauster Concentrations, % of OEL (2016 & 2018 AP, 2016 702-AZ, AW, AN, AX)		Disturbed Test, Exhauster Concentrations, % of OEL (2017 702-AZ)		
			Max. Cartridge Inlet ¹	Max. Cartridge Outlet ¹	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ¹	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ¹	Max. Cartridge Inlet ¹	Max. Cartridge Outlet ¹	
Amines											
42	Ethylamine	75-04-7	5 ppm	4	0.6	0.3	0.1	3	<0.1	0.4	0.1
Nitrosamines											
43	N-Nitrosodimethylamine	62-75-9	0.3 ppb	1874	<12 (9)	4750	644* (12)	4589	<13	1578	<9 (6)
44	N-Nitrosodiethylamine	55-18-5	0.1 ppb	150	<24	412	<29	71	<26	398	<19
45	N-Nitrosomethylethylamine	10595-95-6	0.3 ppb	252	<10 (7)	69	<11 (9)	106	<10	26	<8
46	N-Nitrosomorpholine	59-89-2	0.6 ppb	18	<4	14	8	43	<4	4	<3
Organophosphates											
47	Tributyl phosphate	126-73-8	0.2 ppm	<0.1	<0.08	<0.2	<0.1	<19* (<0.5)	<0.5	<0.07	<0.09
48	Dibutyl butylphosphonate	78-46-6	0.007 ppm	<1	<1	<5	<3	<377* (<10)	<10	<1	<2
Halogenated Hydrocarbons											
Chlorinated Biphenyls											
49	Chlorinated Biphenyls	Varies	1 mg/m ³	n/a		n/a		n/a		n/a	
50	2-Fluoropropene	1184-60-7	0.1 ppm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Pyridines											
51	Pyridine	110-86-1	1 ppm	0.3	<0.1	0.2	0.09	<0.2 (0.05)	<0.2	0.1	<0.02
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	0.5	<0.2	<0.06	<0.06	<0.2	<0.3	<0.08	<0.05
Organonitriles											
53	Methyl nitrite	624-91-9	0.1 ppm	n/a		n/a		n/a		n/a	
54	Butyl nitrite	544-16-1	0.1 ppm	n/a		n/a		n/a		n/a	
Organonitrates											
55	Butyl nitrate	928-45-0	2.5 ppm	n/a		n/a		n/a		n/a	
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	n/a		n/a		n/a		n/a	
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	n/a		n/a		n/a		n/a	
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	n/a		n/a		n/a		n/a	
Isocyanates											
59	Methyl isocyanate	624-83-9	20 ppb	n/a		n/a		n/a		n/a	
Organometallics											
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM		NM		NM		NM	

¹ "<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.

² 2-propenal and dimethylmercury were added to the COPC List in September, 2017.

* Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc). Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.

Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets (#), if present, indicate the maximum concentration measured where no disturbing activities were identified.

n/a Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).

NM Not measured or not reported.

Obvious breakthrough above 10% of OEL observed, or suspected breakthrough behavior inferred based on sustained increases in cartridge outlet concentrations.

Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, 3) the historic maximum was not bounded by another test inlet concentration, and 4) the historic maximum was measured during undisturbed tank headspace conditions for undisturbed cartridge tests, or measured during any tank conditions for disturbed cartridge tests.

Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, 3) the historic maximum was not bounded by another test inlet concentration, and 4) the historic maximum was measured during undisturbed tank headspace conditions for undisturbed cartridge tests, or measured during any tank conditions for disturbed cartridge tests.

A total of 14 COPCs were detected in the cartridge inlets above 10% of their OELs and above RLs or detection limits (DL) in any of the tests. Those COPCs that were repeatedly observed in the cartridge inlet at levels above the action level (50% of their OELs), and representing the breakthrough concerns, included furan, nitrosamines (NDMA, N-nitrosomethylethylamine, and N-nitrosodiethylamine), ammonia, and mercury. For the BY-108 headspace testing, 1,3-butadiene, 2,3-dihydrofuran, and 2,5-dihydrofuran also were observed in inlets at concentrations exceeding 100%, 50%, and 100% of their OELs, respectively.

Time to breakthrough for any COPC was defined as the time from the onset of cartridge exposure to the tank vapors to the time at which the outlet cartridge concentration exceeded 10% of the OEL.¹⁷ Sustained increases in cartridge outlet concentrations during testing also provided an indication of breakthrough behavior. Further discussion of the breakthrough criteria are provided in Appendix A. Table 3 identifies those 10 COPCs that exhibited breakthrough behavior with an orange highlight.

Most of the APR cartridge tests indicated breakthrough of ammonia. In addition, mercury, 1,3-butadiene, NDMA, furan, 2,5-dihydrofuran, and 2,5-dimethylfuran outlet concentrations above 10% of their OELs indicated breakthrough on one or more of the APR tests. An additional three COPCs exhibited breakthrough behavior, but at much lower levels, below 2% of their OELs. The most complete analysis and discussion of the breakthrough data is provided in Chapter 2.0.

¹⁷ For COPCs with DL or RL values >10% of the OELs, an alternate breakthrough criteria was applied. For example, furan and several substituted furans required use of 50% of the OEL criteria for breakthrough to distinguish between breakthrough and analytical scatter around the DL.

2.0 Analysis of Respirator Cartridge Breakthrough Data

2.1 COPCs with Cartridge Breakthrough Signatures

Table 3 showed a total of seven COPCs that exhibited breakthrough with outlet concentrations that reached or exceeded 10% of their corresponding OELs. These COPCs were ammonia, mercury, NDMA, 2,5-dimethylfuran, 2,5-dihydrofuran, furan, and 1,3-butadiene, all of which were identified in the earlier reports for each of the individual tank/respirator cartridge analyses. Plots of the cartridge outlet concentrations versus time for these seven COPCs are shown in Figures 1 and 2. Three other COPCs exhibited evidence of breakthrough behavior, but at outlet concentrations that were relatively low—all $\leq 2\%$ of their corresponding OELs. These COPCs were acetaldehyde, propanenitrile, and 3-buten-2-one. Finally, total VOC concentrations at the respirator cartridge outlets also exhibited breakthrough signatures in some cases. Here, total VOC represents a calculated sum of individual VOC measurements, including COPCs and non-COPCs (see Appendix B.1 for calculation details).

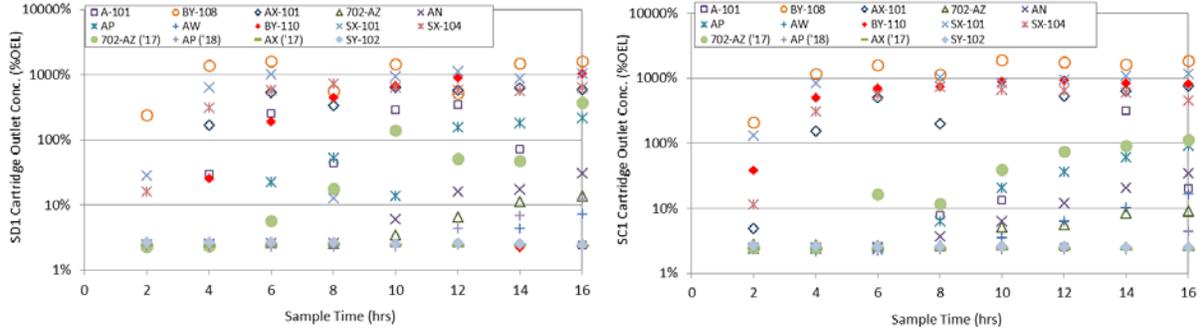
Further discussion of the COPC breakthroughs are provided in the sections below, along with discussion of the total measured VOCs. For these analyses, more precise estimates of the breakthrough times, at 10% of the OELs at cartridge outlets, were calculated by interpolating the data shown in Figure 1. This interpolation procedure is described in Appendix B.2.

2.2 Ammonia

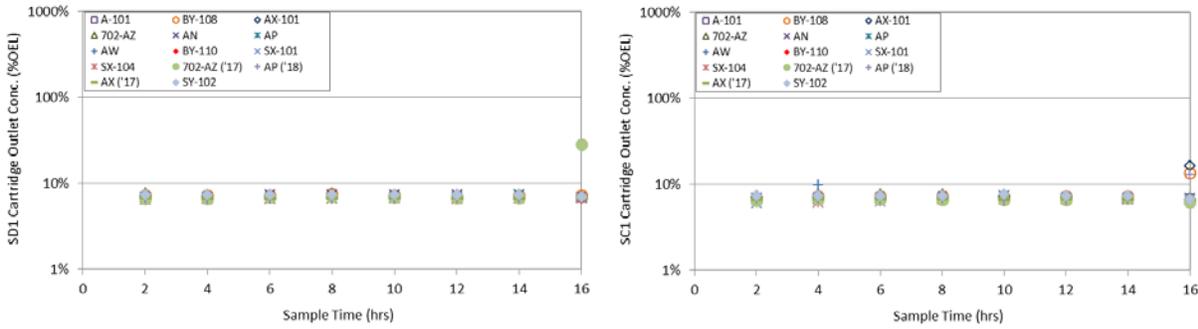
As seen in Figure 1A many of the ammonia cartridge tests exhibited breakthrough above 10% of the OEL at the cartridge outlet within the 16-hour test duration. To establish more exact breakthrough times, interpolation was used on the experimental results to estimate the time within a given 2-hour interval that the outlet concentration crossed 10% of the OEL. Figure 3 shows the interpolated breakthrough times for ammonia for each cartridge test (blue bars). Note that values of 16 hours indicate that no breakthrough above 10% of the OEL occurred during testing. Based on the data in Figure 3, ammonia breakthrough occurred in approximately two-thirds of the cartridge tests.

Also shown in Figure 3 are corresponding service life estimates for each of the cartridge tests (red bars). The service life estimates were made using the SureLife[®] Cartridge Calculator from SCOTT. Because the 7422-SC1 and 7422-SD1 cartridges are the same in terms of carbon type and quantity, the estimated breakthrough time from the SureLife[®] calculator is the same for the two cartridges when the input parameters are the same. The calculator assumes pure ammonia in an inert carrier gas, rather than a mixture of sorbing compounds. The primary inputs to the service life calculator are ammonia inlet concentration, relative humidity and temperature. The averages of these values, up to the point of observed breakthrough, were used for the model inputs, rather than all of the data points in the 16-hour series. Also of note is that any experimental breakthrough times of 16 hours means that there was no breakthrough observed, and 16 hours is represented because it represents the maximum duration of the experiment. Finally, the SureLife[®] calculator limits the ammonia inlet concentration to 300 ppm (1200% of the OEL), so BY-108 concentrations could not be assessed.

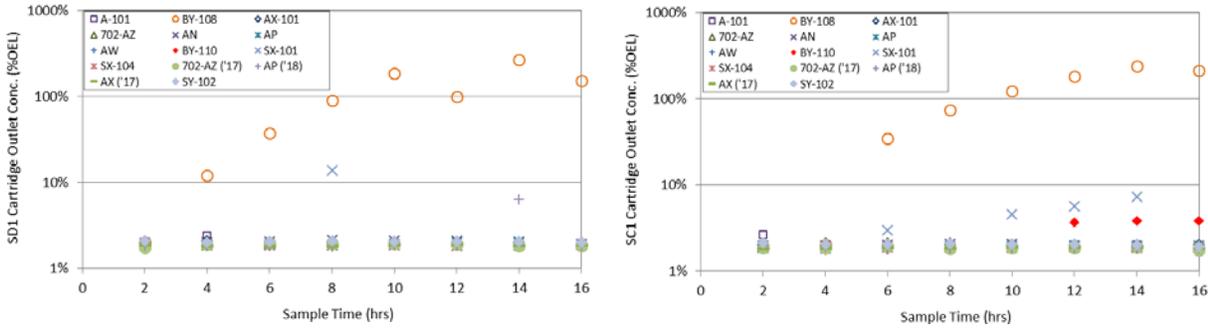
A) Ammonia



B) Mercury



C) 1,3-Butadiene



D) Furan

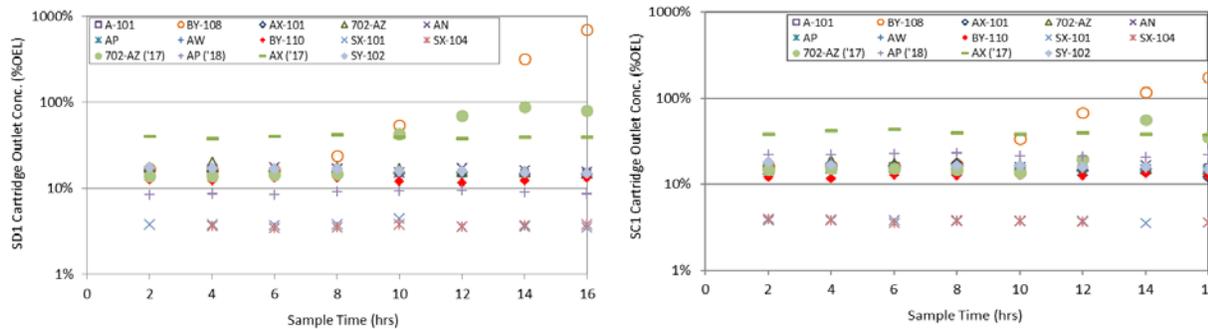
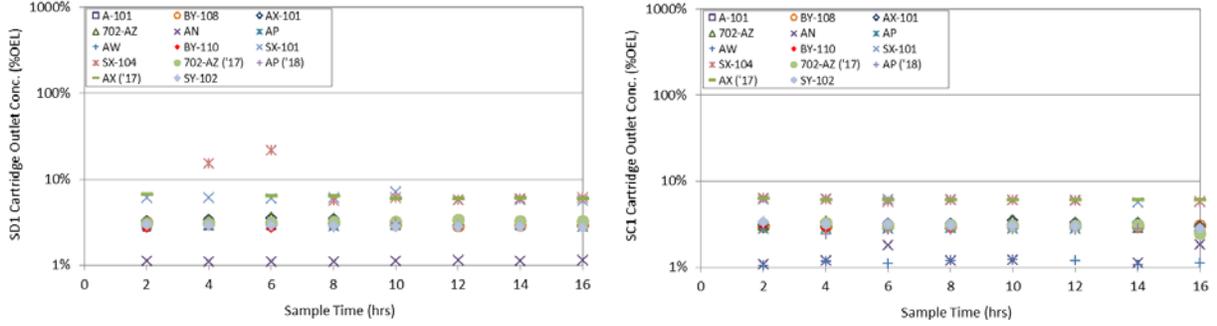
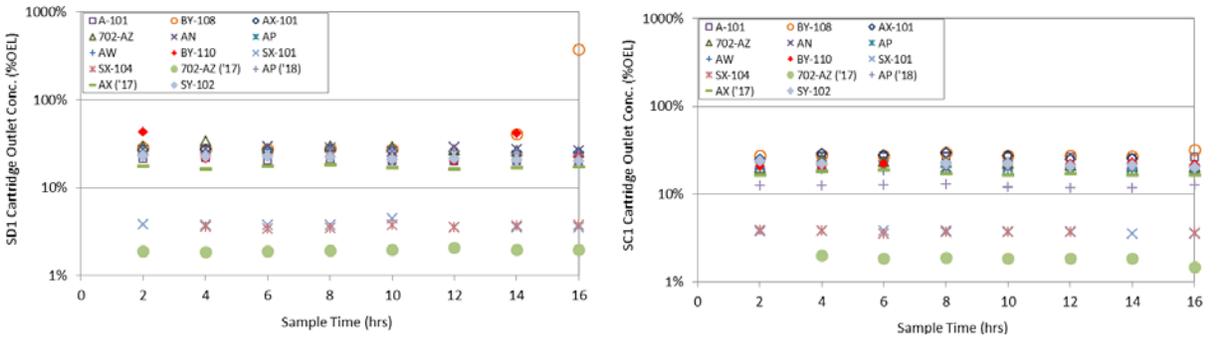


Figure 1. COPCs with Tank Vapor Cartridge Breakthroughs Corresponding to Outlet Concentrations >10% of their OELs. A) Ammonia, B) Mercury, C) 1,3-Butadiene, D) Furan.

E) 2,5-Dimethylfuran



F) 2,5-Dihydrofuran



G) NDMA

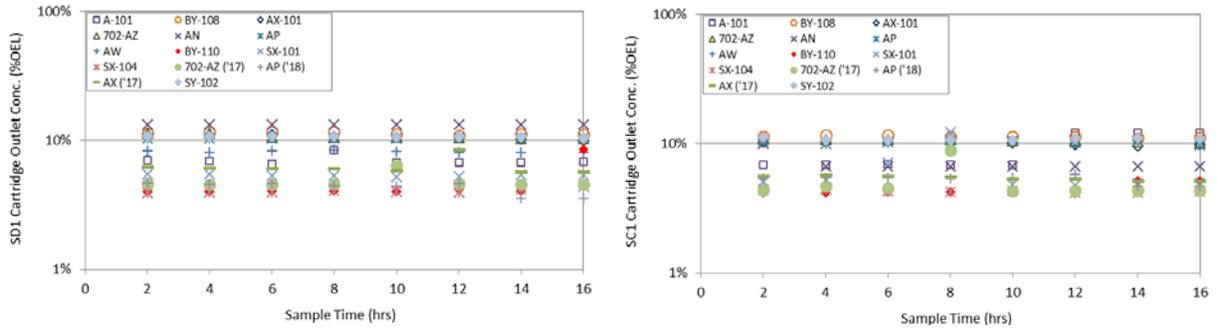


Figure 2. COPCs with Tank Vapor Cartridge Breakthroughs Corresponding to Outlet Concentrations >10% of their OELs. E) 2,5-Dimethylfuran, F) 2,5-Dihydrofuran, G) NDMA.

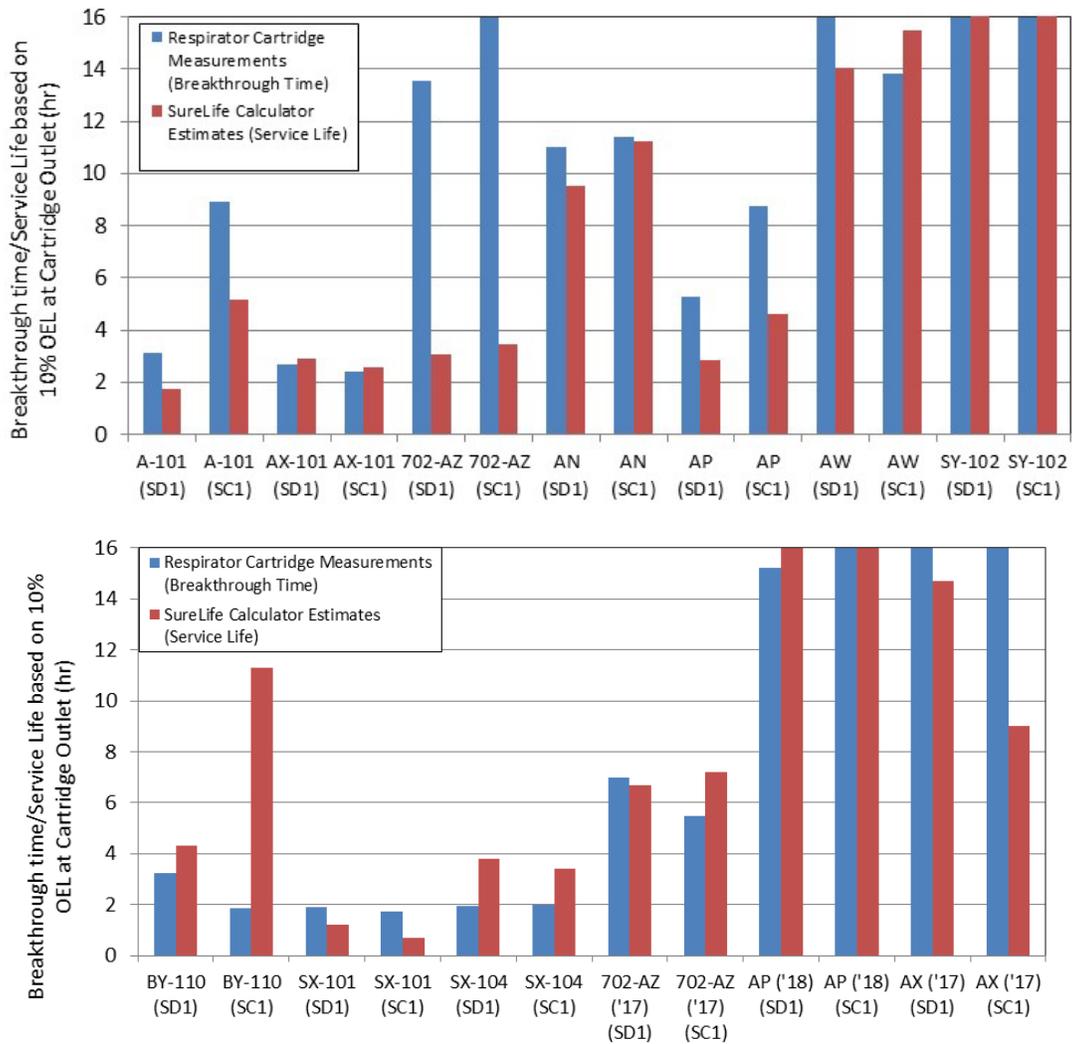


Figure 3. Comparison of Ammonia Breakthrough Time Estimates from Testing and Service Life from SCOTT’s SureLife® Cartridge Calculator (both based on 10% of the OEL at cartridge outlet). A 7422-SC1 cartridge with SCOTT-O-Vista full-face respirator was used in each SureLife® simulation. Upper: tanks tested in 2016¹⁸; lower: tanks tested in 2017–2018.

Most of the SureLife® service life estimations in Figure 3 were near or below the measured breakthrough values for most of the tests, except for SX-104/SD1/SC1, BY-110/SD1/SC1, AP 2018/SD1, AW/SC1, and 702-AZ 2017/SC1. This means that service life estimations were mostly conservative compared to actual observed breakthrough, but not always. To better understand what could be driving discrepancies between the estimated service life and observed breakthrough, a multivariate analysis of the ammonia data from the past cartridge studies was conducted. Based on this analysis, only the inlet concentration of ammonia was determined to be significant (p-value <0.05) to breakthrough during these specific tests. The insignificance of relative humidity and temperature was likely due to the limited ranges in the data set. To visualize the results of the statistical analysis, Figure 4 shows the ammonia breakthrough data plotted against inlet ammonia concentration. Here, the aforementioned relationship between inlet concentration and breakthrough is apparent. Note that Figure 4 shows a “simple fit” of the breakthrough

¹⁸ The BY-108 2016 the inlet concentrations of ammonia were above the Immediately Dangerous to Life or Health value. The SureLife Calculator noted that the concentration not allowed and does not estimate the service life.

data based on the multivariate analysis mentioned above. Because both relative humidity and temperature were not significant in the analysis (likely due to the limited range in the testing), only the inlet concentration is shown.

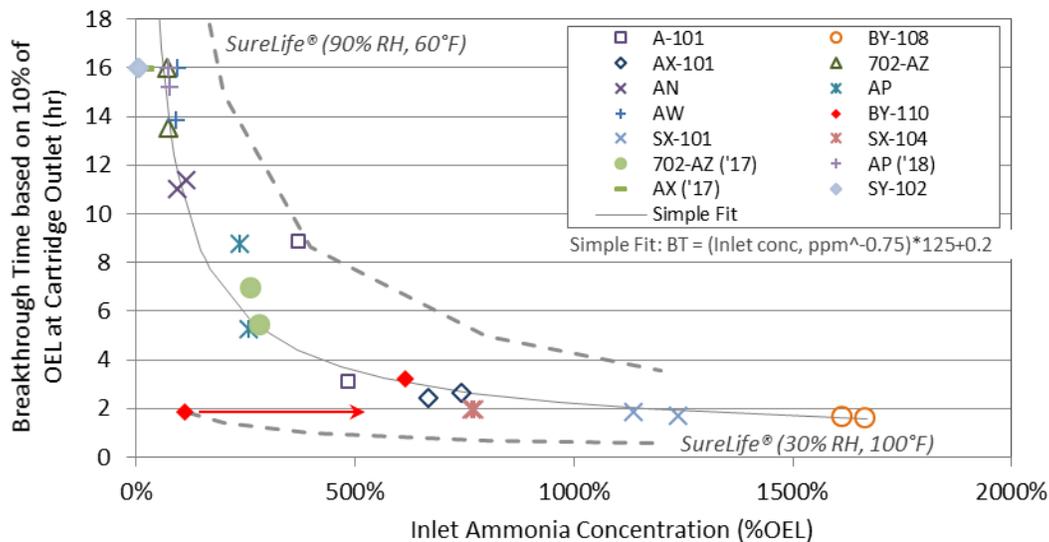


Figure 4. Ammonia Breakthrough Data for Respirator Cartridge Tests, along with SureLife® Service Life Estimations for extreme environmental conditions¹⁹, which refers to the approximate upper (90% relative humidity, 60°F) and lower (30% relative humidity, 100°F) bounds of the analysis (dashed lines). Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours. The SureLife® calculations were performed through technical support at 3M.

Also included in Figure 4 are the ranges of service life from both high and low relative humidity and temperature, as estimated by the SureLife® calculator. These ranges show that all of the measured breakthrough data fall within the stated ranges of SureLife® estimations. However, there is one point that appears to be significantly outside of the general trend of the other data—the BY-110/SC1 point (left-most red diamond), which shows a measured breakthrough time of 1.8 hours for an inlet concentration of 112%. However, after further inspection of those data, the inlet concentration used was primarily weighted by the first (i.e., the 2-hour) measurement, which was approximately 20% of all other data points in the series. If the inlet concentration were within the range of the other inlet concentrations in the series, the breakthrough point would fall within the expected region of in the figure (indicated by the red arrow).

As mentioned above, an important aspect of comparing the breakthrough measurements with SureLife® service life estimations are to confirm that the service life estimations are conservatively lower than measured breakthrough times. Because a number of SureLife® service life estimations were actually higher than the corresponding breakthrough measurements, the data are presented as a parity plot in Figure 5. In this plot, the diagonal line (i.e., the lower dashed line) represents the line where parity between the two data points would exist. Points lower than the parity line can be considered conservative, in that service life estimations were lower than observed breakthrough values.

¹⁹ Extreme environmental conditions refers to the approximate upper (90% RH, 100°F) and lower (30% RH, 60°F) bounds of the analysis.

The comparison in Figure 5 shows the same conclusion as the comparison in Figure 3; that is, there were a number of measurements where the estimated service life was higher than the corresponding measured breakthrough. This means that the service life estimations cannot be deemed conservative in all cases.

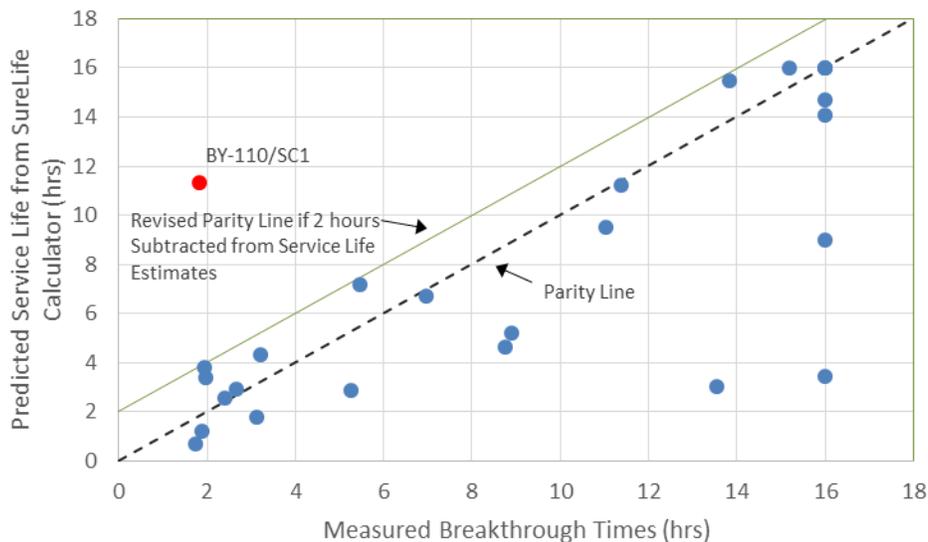


Figure 5. Estimated Service Lives for Ammonia APR Tests Plotted Against Corresponding Measured Breakthrough Times. The diagonal parity line (dashed line) represents parity between the values, and the higher (green) diagonal line represents parity if 2 hours were subtracted from each service life estimation.

This discrepancy is likely due to variability in the service life model inputs (concentration, relative humidity, and temperature). One means of addressing this issue is to consider having an Industrial Hygienist add a safety factor to the service life estimations. Statistical analysis of the service life estimations and measured breakthrough data was performed to determine the success rate for achieving breakthrough times greater than estimated service life minus a safety factor. The 95% lower confidence limit on the success rate was calculated using the Clopper-Pearson method [28]. Figure 5 shows a second diagonal line (upper green line). This corrected parity line represents a comparison of the data if 2 hours were subtracted from each of the service life estimations. With this correction, the service life estimations would be conservatively lower than measured values in all cases. The statistical analysis indicated there is a 95% confidence that 89% of the time measured breakthroughs would be longer than estimated service life minus 2 hours, confirming that with the added safety factor service life estimations would be conservative. Note that the BY-110/SC1 data point is shown as an outlier in Figure 5 (red dot), just as it was in Figure 4. However, if the expected true inlet concentration were used, the estimated service life would fall within the revised parity line.

2.3 Mercury

Figure 6 shows the interpolated breakthrough times from Figure 1B plotted against the corresponding inlet concentrations for each test.

Here, the SD1 and SC1 data are represented by the same markers. Only four tests had observed breakthroughs >10% of the OEL at the cartridge outlet, in less than 16 hours. These were tests of AX-101/SC1, BY-108/SC1, AP 2018/SC1, and 702-AZ 2017/SD1. However, the data point for AX-101/SC1 is suspected to have been swapped with the corresponding inlet values, as reported in

the AX-101 analysis report.[6] This leaves BY-108/SC1, AP 2018/SC1, and 702-AZ 2017/SD1 cartridge data with the only confirmed breakthroughs occurring in less than 16 hours.

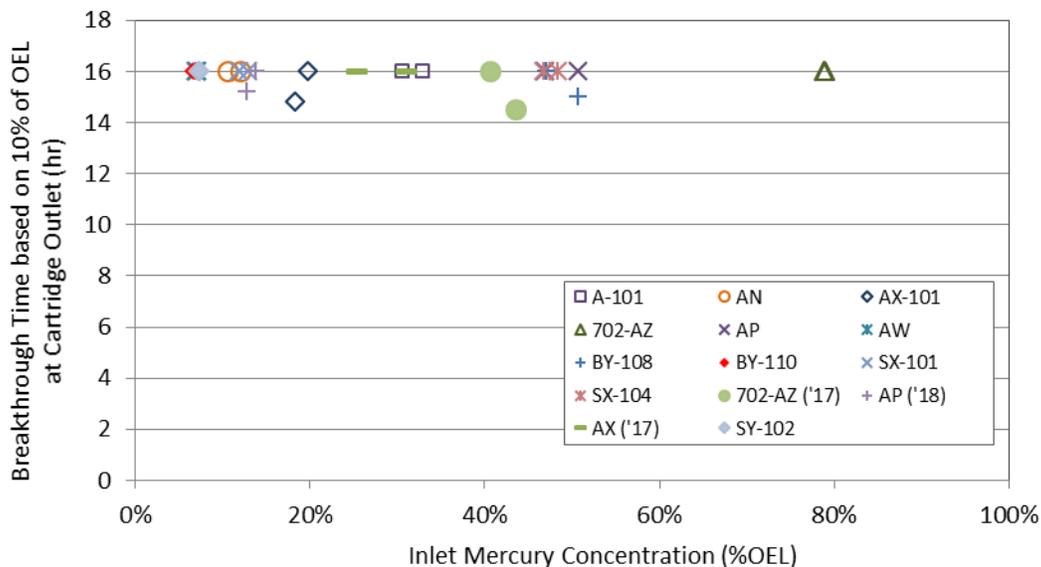


Figure 6. Mercury Breakthrough Data for Respirator Cartridge Tests. Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours.

As seen in Figure 6, the inlet mercury concentration does not appear to be a primary variable impacting the observed breakthroughs because other tests, such as 702-AZ 2016, had higher inlet values. The cumulative VOCs fed to the BY-108/SC1 test were significantly higher than any other test, which is suspected to be a primary contributor to the mercury breakthrough for that cartridge (see Appendix B.1). The SD1 and SC1 cartridges are not NIOSH approved for mercury (therefore, no SureLife® calculator estimations were obtained). Nevertheless, the performance data in Figure 6 show experimental verification of mercury capture in both cartridge types tested with no breakthrough time less than 14 hours.

2.4 1,3-Butadiene

The 1,3-butadiene breakthrough data are plotted in Figure 7. Apparent breakthrough was only observed in the two BY-108 cartridge tests. An elevated outlet value for SX-101/SD1 (13.9%) was measured for the 8-hour segment but all other outlets were less than the DL, and none of the inlet values were >5.0% of the OEL. Therefore, this value was omitted from the figure due to analytical error.²⁰

The BY-108 breakthroughs for SD1 and SC1 occurred at 3.8 and 5.1 hours, respectively. Indeed, BY-108 had the highest inlet concentrations of 1,3-butadiene, which were 138% of the OEL compared to 7% or less for the other tests. The total VOC loading also was higher for the BY-108 tests, with concentrations corresponding to more than 3 ppm. The relative humidity during testing was lower for the SC1 cartridge (52%) compared to the SD1 cartridge (68%), which could have contributed to the slight difference in observed breakthroughs.

²⁰ With inlet concentrations of 5.5% of the OEL, initial outlet concentrations for 1,3-butadiene from the SCOTT 7422-SC1 cartridge were below the DL, but gradually increased reaching a maximum of 7.4% of the OEL at 14 hours. These results suggest potential breakthrough-like behavior but at inlet and outlet concentrations below 10% of the OEL.

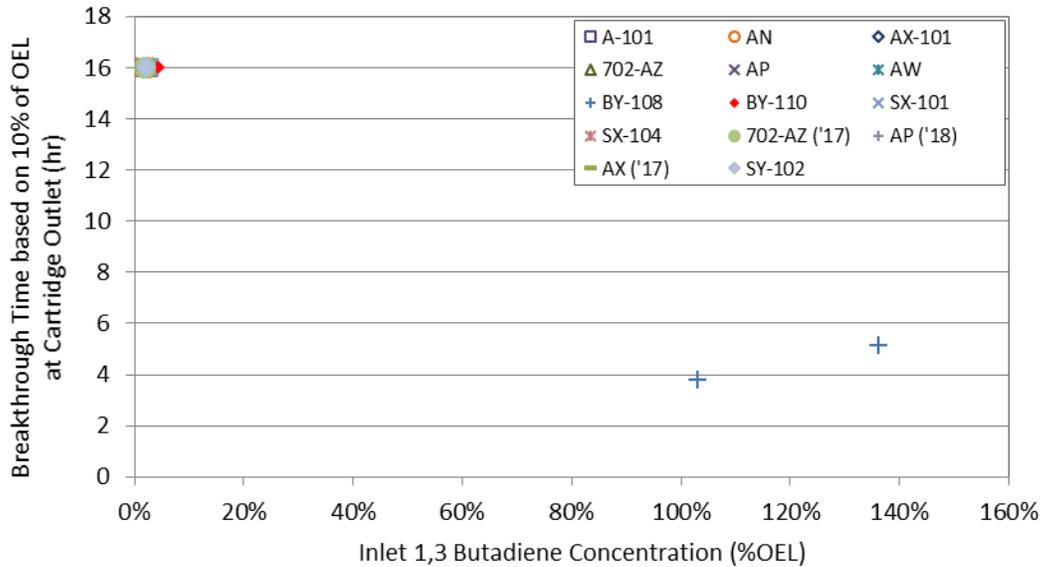


Figure 7. 1,3-Butadiene Breakthrough Data for Respirator Cartridge Tests. Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours.

2.5 Furan

Furan data²¹ in Figure 1D show elevated outlet concentrations for all of the times, cartridges, and tanks tested. This is due to the relatively high DL and RL values for furan, which exceeded 40% and 100% of the OEL, respectively. Therefore, breakthrough at 10% of the OEL could not be calculated for the furan data. As a result, the breakthrough threshold for furan was increased to 50% of the OEL to glean some cartridge performance insight. Figure 8 shows a plot of the resulting breakthrough data for furan. This plot shows four tests in which furan breakthrough appeared to occur—both BY-108 SD1/SC1 tests and both 702-AZ 2017 SD1/SC1 tests.

For the BY-108 SD1 and SC1 tests furan breakthrough, above 50% of the OEL, occurred at 9.8 and 11.1 hours, respectively. The corresponding maximum inlet concentrations were 819% and 298% of the OEL, which were two of the highest concentrations measured. Recall that ammonia breakthrough was observed in less than 2 hours for both of the BY-108 tests.

In the 702-AZ 2017 tests under waste-disturbing conditions, furan breakthrough above 50% of the OEL occurred after 10 hours for the SCOTT SD1 cartridge (maximum inlet 2995% of the OEL), and was indicated for just one measurement at the 14-hour mark for the SCOTT SC1 cartridge (maximum inlet 2533% of the OEL). In comparison, ammonia breakthrough for the SD1 and SC1 tests occurred after 6 hours and 4 hours, respectively.

²¹ This report has been updated to include the Carbotrap 300 TDU data for furan throughout the report.

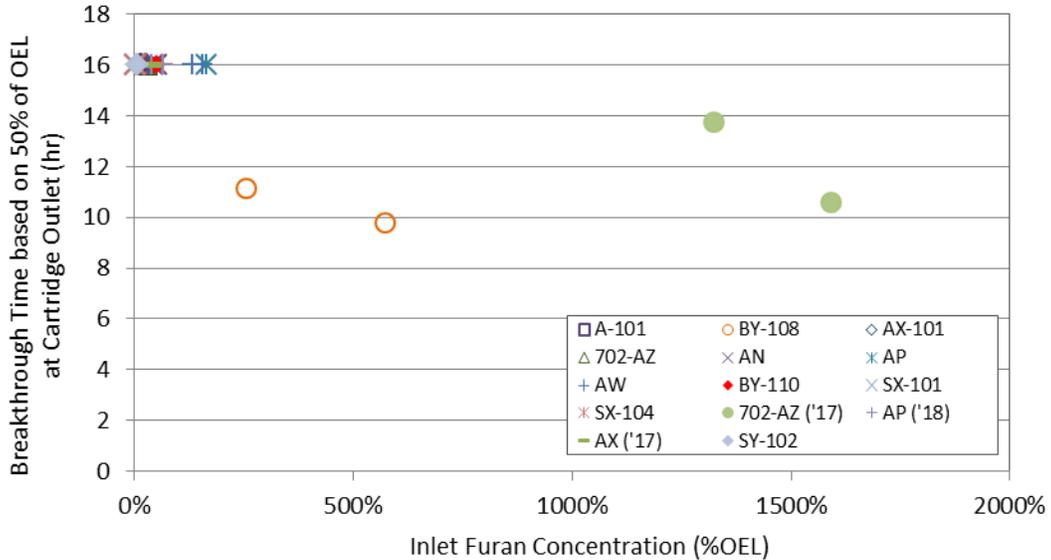


Figure 8. Furan Breakthrough Data for Respirator Cartridge Tests. Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours. Note that the breakthrough threshold was increased from 10% of the OEL to 50% of the OEL due to the high RL value for furan.

2.6 2,5-Dimethylfuran

The 2,5-dimethylfuran breakthrough data are plotted in Figure 9.

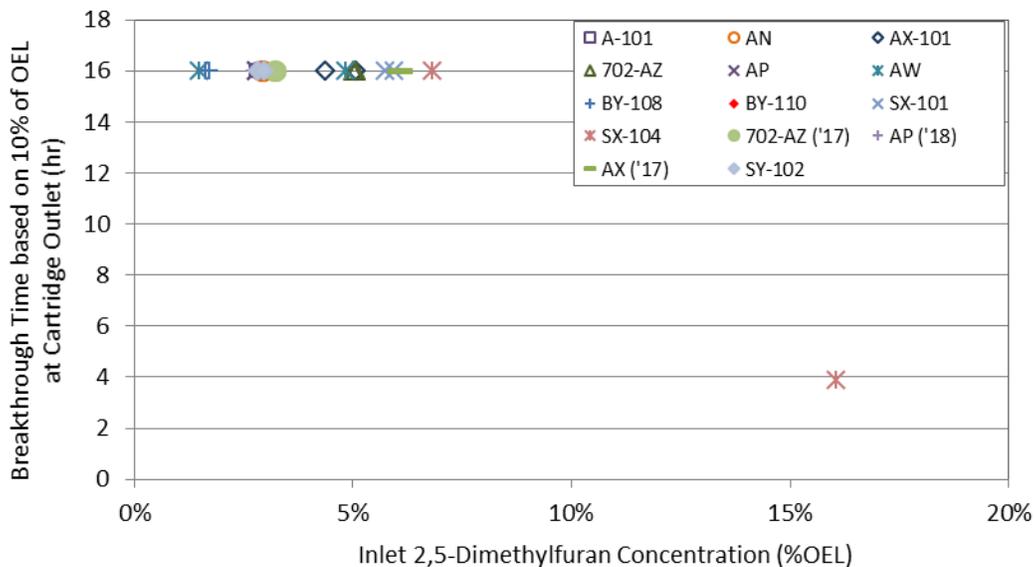


Figure 9. 2,5-Dimethylfuran Breakthrough Data for Respirator Cartridge Tests. Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours.

Only one breakthrough of 2,5-dimethylfuran was observed in the data (i.e., for the SX-104/SD1 test). For this test the maximum inlet concentration was 27% of the OEL and occurred for the initial measurements. The approximate DL and RL for 2,5-dimethylfuran was 6.5% and 17%, respectively. The estimated breakthrough occurred at 3.9 hours. However, several 2,5-dimethylfuran measurements from the blank

and baseline tubes also reported concentrations greater than the RL, which could put the elevated inlet and outlet measurements for SX-104/SD1 in question. Further, the single available historical measurement of the SX-104 headspace was less than the RL (25% of the OEL). Nevertheless, the fact that the one breakthrough observation corresponds to the highest inlet concentration gives weight to the validity of the observation.

2.7 2,5-Dihydrofuran

The 2,5-dihydrofuran breakthrough data²² are plotted in Figure 10. Like furan, 2,5-dihydrofuran had elevated outlet concentrations for all of the times, cartridges, and tanks tested (see Figure 2E). These elevated values are caused by the relatively high DL and RL, which exceeded 50% and 100% of the OEL, respectively. Therefore, like furan, a 50% OEL outlet threshold was applied to the 2,5-dihydrofuran data to clearly distinguish for clear breakthrough behavior. The only cartridge that exceeded this threshold was BY-108 SD1. Here, outlet concentrations from the 14- and 16-hour measurements were 42% and 377%, respectively. The corresponding maximum inlet concentration was 278%, which was 5× higher than any other inlet concentration. Note that the corresponding ammonia breakthrough time for the BY-108/SD1 test was less than 2 hours.

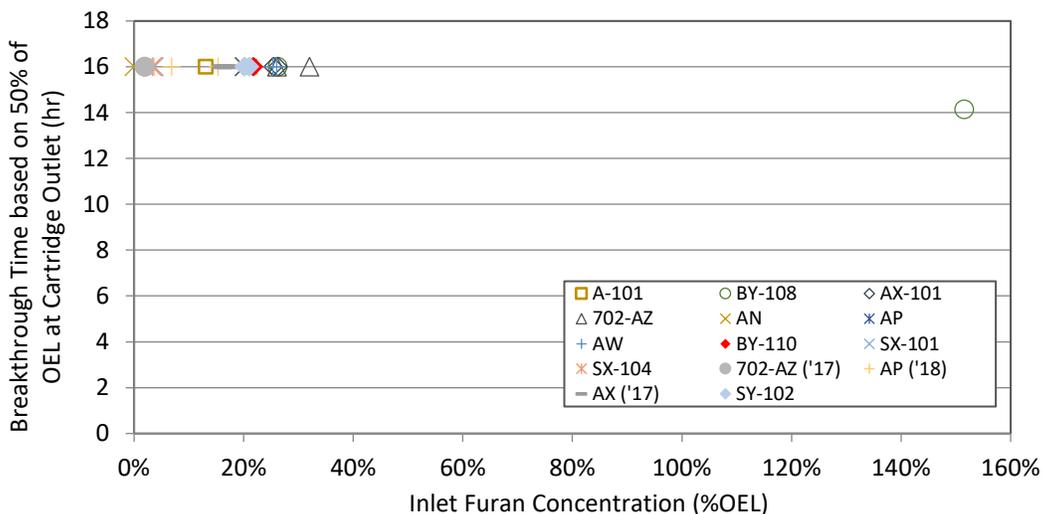


Figure 10. 2,5-Dihydrofuran Breakthrough Data for Respirator Cartridge Tests. Breakthrough times of 16 hours or higher should be interpreted as more than 16 hours. Note that the breakthrough threshold was increased from 10% of the OEL to 50% of the OEL because of the high RL value for 2,5-dihydrofuran.

2.8 NDMA

The NDMA breakthrough data are plotted in Figure 11. Only one valid breakthrough above 10% of the OEL was observed for NDMA. This was for the SX-101/SC1 cartridge. The corresponding maximum inlet concentrations for this test were as high as 4750% of the OEL, which is considerably higher than the available historical measurements, which were less than the RL of 2.3%. The cartridge outlet concentrations for NDMA exceeded the RL for the 6- and 8-hour measurements, reaching a maximum of 12.4% of the OEL, before dropping back to less than RL levels for the remainder of the test. These results

²² This report has been updated to include the Carbotrap 300 TDU data for 2,5-dihydrofuran throughout the report.

highest inlet and outlet values. While it is not clear how likely a breakthrough would be for 3-buten-2-one at higher inlet concentrations, the data suggest that inlet values above 10-20% the OEL should be monitored closely.

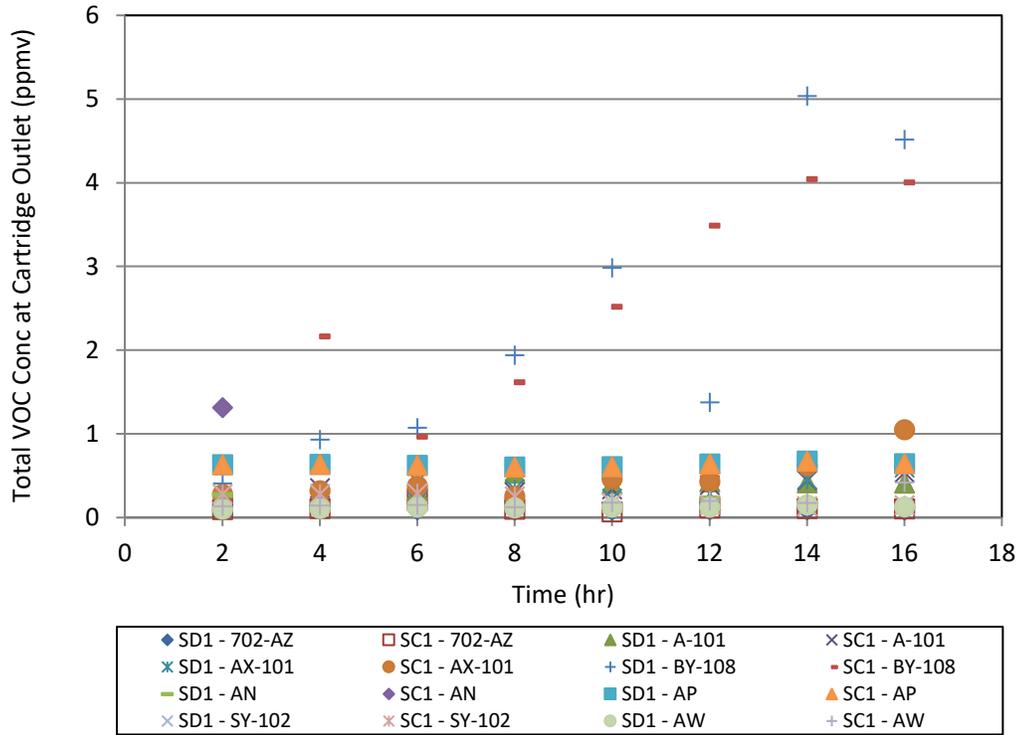


Figure 12. Total VOC Concentrations at Respirator Cartridge Outlets, Calculated on a Volume Basis. Only the results of the 2016 tanks are included here.

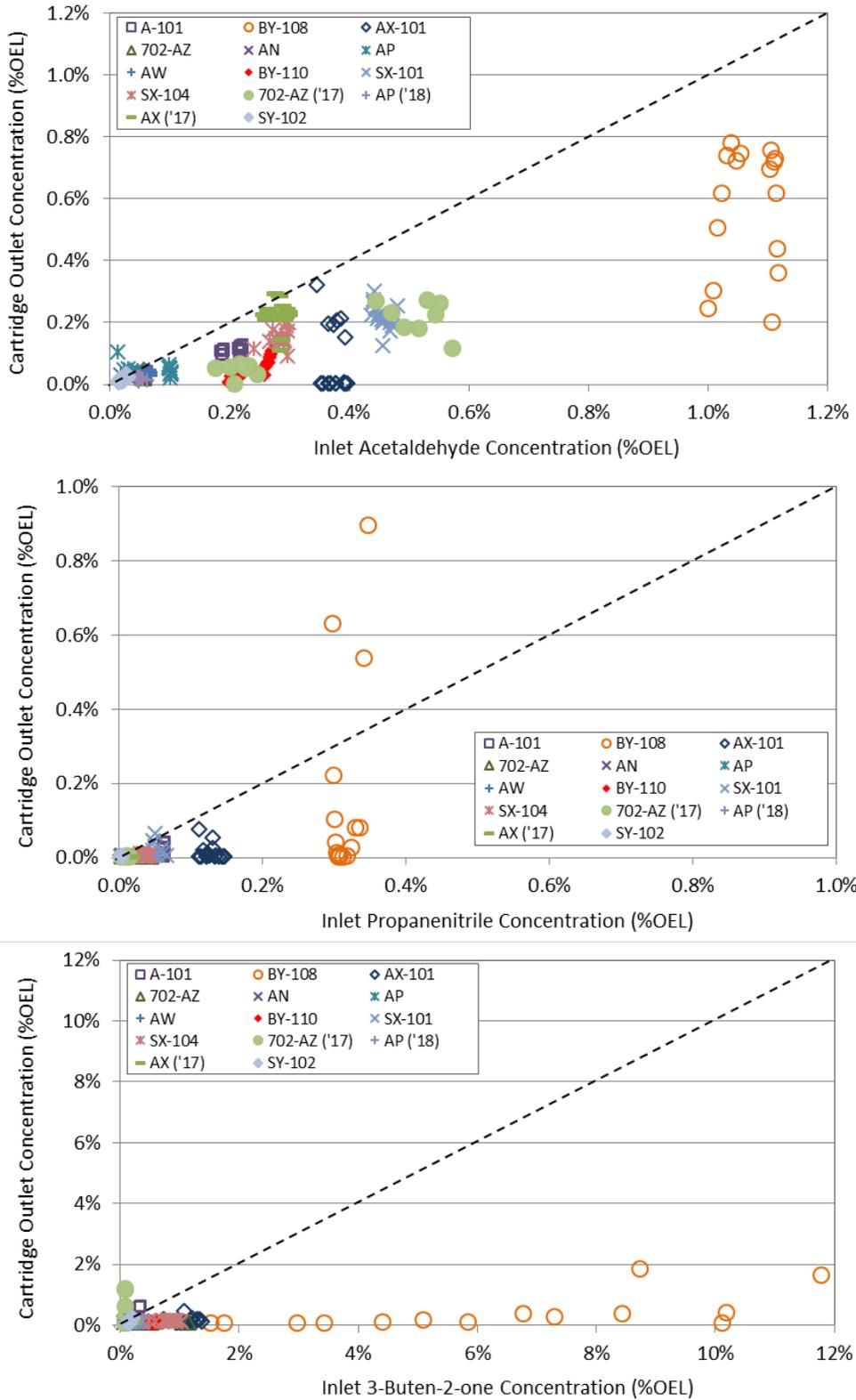


Figure 13. Plots of Outlet Concentrations versus Inlet Concentrations for Acetaldehyde, Propanenitrile, and 3-buten-2-one.

3.0 Cartridge Performance Outside of Tested Ranges

The conditions represented in the multiple tank tests span a range of compositions and environmental conditions. The following sections focus on identifying the important factors for respirator cartridge performance and to what level the testing assessed the known ranges of those factors.

3.1 Factors that Can Impact Cartridge Performance

Mathematical relationships are often used to estimate breakthrough time for adsorption systems [15-18]. These relationships include the Dubinin-Klotz equation [19] and the Wheeler-Jonas equation [19, 20]. The Wheeler-Jonas equation is used by OSHA from the Gerry O. Wood Mathematical Model and many respirator cartridge vendors for respirator cartridge modeling [20]. A typical form of the Wheeler-Jonas equation is as follows:

$$t_b = \frac{W_e W}{C_0 Q} - \frac{W_e \rho_B}{k_v C_0} \ln \left(\frac{C_0 - C}{C} \right) \quad (2)$$

where t_b (minutes) is the breakthrough time; W (g) is the weight of activated carbon; ρ_B (g/cm³) is the packed density in the cartridge; C_0 (g/cm³) is the inlet vapor concentration; C (g/cm³) is the breakthrough concentration; Q (cm³/min) is the flow rate; k_v (minutes⁻¹) is the adsorption rate coefficient; and W_e (g/g carbon) is the adsorption capacity at C_0 . Other factors such as relative humidity, temperature, and competitive adsorption can affect these parameters. Also, this model depends on the Dublin-Radushkevich isotherm equation, which is not thermodynamically consistent in the Henry's law regions; that is, the Dublin-Radushkevich equation does not reduce to Henry's law at low gas concentration when vapor concentrations are very low, such as in sub-parts per billion levels [23]. Therefore, errors can result when using the Wheeler-Jonas equation to estimate breakthrough times in the Henry's law regions.

Note that the Polanyi Adsorption Theory [24] and the Ideal Adsorbed Solution Theory [25] are the two most common equations used to describe multicomponent adsorption, especially binary adsorption. Both of these theories estimate that previously adsorbed vapor molecules will be displaced by more strongly adsorbed vapor molecules. The adsorption rate coefficients also will be affected by competitive adsorption. Wood reported that the correction factors of the adsorption rate coefficient for second eluting vapors averaged 85% and those for third and fourth eluting vapors averaged 56% [26]. The contribution of the adsorption rate coefficient to breakthrough time is usually much smaller compared with the effect of equilibrium adsorption capacity.

Table 4 shows a summary of factors that can impact breakthrough times for respirator cartridges, based on published theoretical and empirical relationships. Here, the factors are grouped into cartridge design factors, which are unique to the respirator cartridge being tested; vapor or gas factors, which are related to the specific compositions of the streams being measured; and environmental factors, which are relevant to the testing conditions, but can change with atmospheric conditions.

Table 4. Factors that Can Impact Breakthrough Time of Chemical Vapor Adsorption on Respirator Cartridges (see Appendix E for details)

Factors	Typical Impact on Breakthrough Time
<i>Cartridge Design Factors</i>	
Micropore volume	Larger micropore volumes will typically lead to higher adsorption capacity and longer breakthrough times.
Packed density	Larger packed density will typically increase the breakthrough time for a fixed volume.
Granule size	Smaller particles will typically increase adsorption rate and increase breakthrough time when pressure drop is acceptable.
Flowrate of vapor or gas stream through cartridge	Higher flow rates will reduce the breakthrough times.
<i>Vapor or Gas Factors</i>	
Molecular weight of vapor or gas constituent	Heavier molecules tend to have higher affinity adsorption and have longer breakthrough times.
Inlet concentration of vapor or gas constituent	Higher inlet concentrations typically lead to shorter breakthrough times.
Competitive adsorption from other vapor or gas constituents	In mixtures, molecules with lower adsorption affinities will have reduced breakthrough times comparatively.
<i>Environmental Factors^a</i>	
Relative humidity of vapor or gas stream	Higher relative humidity levels will typically increase breakthrough times for hydrophilic molecules (those able to hydrogen bond with water), and decrease breakthrough times for non-polar molecules.
Temperature of vapor or gas stream	Higher temperatures will generally decrease the equilibrium adsorption capacity and reduce the breakthrough time.
Pressure of vapor or gas stream	Pressure drop will lead to underestimation of the concentrations of target chemicals. If not corrected, the calculated breakthrough time will be overestimated.

^a See Appendix E for details on environmental factors.

3.2 Sensitivity Analysis

A sensitivity analysis on cartridge performance was conducted on the factors identified in Table 4. The SureLife[®] calculator [20] was used for this analysis. Because the carbon adsorbent used in both the 7422-SC1 and 7422-SD1 cartridges is the same, only the 7422-SC1 cartridge was selected. Four variables—relative humidity, temperature, inlet concentration, and flow rate—were assessed. Only nine of the tank vapor COPCs were available in the SureLife[®] calculator²³; ammonia, pyridine, formaldehyde, 1,3-butadiene, acetonitrile, benzene, 1-butanol, acetaldehyde, and ethylamine. One chemical is evaluated

²³ Because ammonia breakthrough occurred in all tests before any other COPCs, and the manufacturer's estimation, with additional safety factor considerations was conservative in all cases, there is no impact of limitations on COPCs that can be evaluated.

at a time using the SureLife[®] calculator similar to when the service life was estimated for the 7422-SD1 and 7422-SC1 cartridges on ammonia (Figure 3).

The analysis was performed by calculating relative cartridge service life (relative to a reference point) for ranges of each factor. Cartridge service life means the period of time that a filter or sorbent in a specified respirator or other respiratory equipment provides adequate protection to the wearer. A safety factor, such as changing cartridges at a percentage before the estimated breakthrough, needs to be applied to the breakthrough time to estimate the service life of the cartridge. More about the relationship and difference between cartridge service life and breakthrough time can be found in Appendix A.4. Figure 14 shows plots of the resulting sensitivity analysis for each of the four factors assessed.

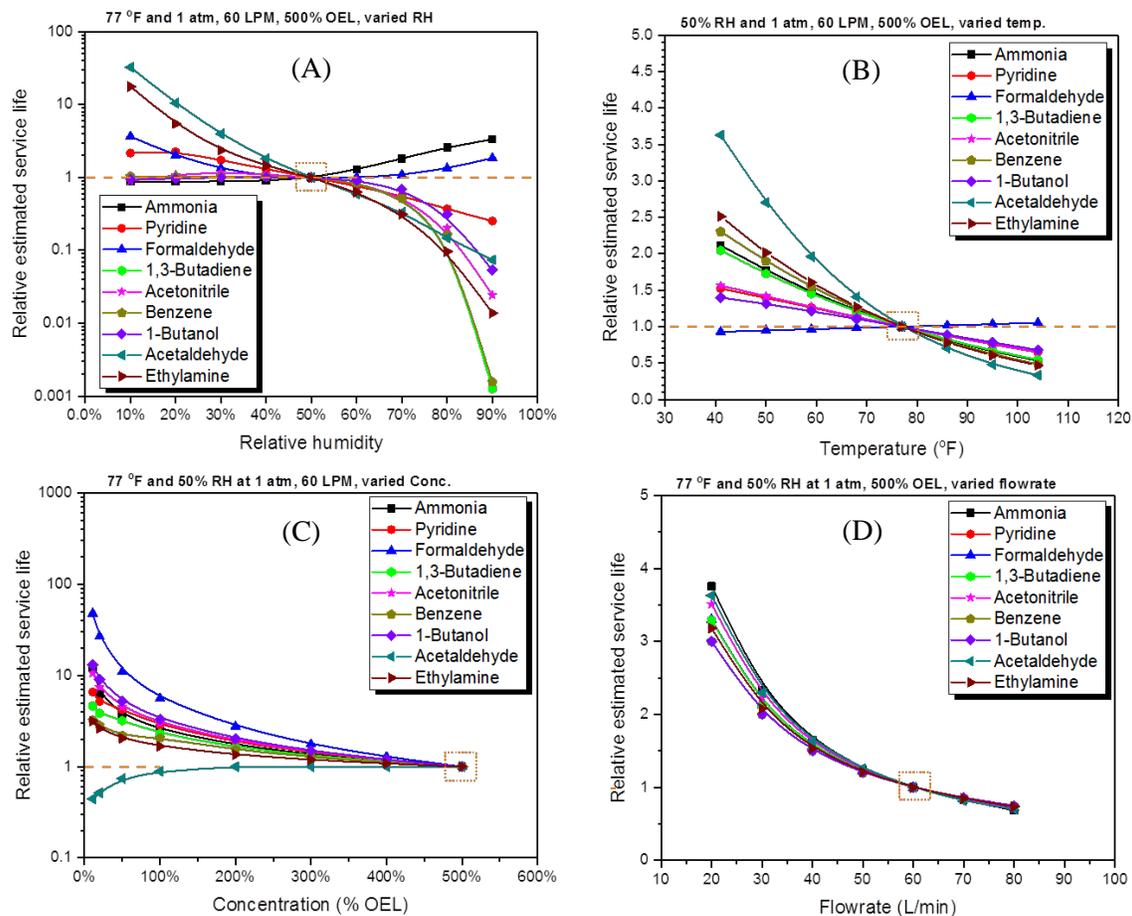


Figure 14. Sensitivity Plots for Variables that Affect Cartridge Performance. Data in these plots were obtained from the SureLife[®] calculator for a 7422-SC1 respirator cartridge.

3.2.1 Impact of Relative Humidity

Figure 14A shows estimated cartridge performance as a function of relative humidity. In general, service life decreases with increasing relative humidity for most constituents, except for polar chemical species, such as ammonia, that have strong interactions with water.

The relative humidity data recorded for the cartridge tests ranged between 33 and 86%. Unlike the strong correlations between meteorological temperatures and testing temperatures, the analysis provided in Appendix E showed only a weak relationship between atmospheric humidity data and the cartridge testing

humidity measurements. This is likely due to the influence of the humidity from the tank itself. However, the meteorological data should more closely represent the humidity conditions on the breathing zones for workers.

The meteorological relative humidity range during cartridge testing was 12 to 84%, and 8 to 100% for the whole year. Based on the breakthrough sensitivities shown in Figure 14A, lower humidity values should result in higher breakthrough times compared to those tested, which should be a conservative effect on the cartridge breakthrough times measured. Although ammonia shows a comparative decrease in breakthrough times at lower humidity levels, the effect is slight compared to other constituents.

There is year-round meteorological data that shows higher relative humidity levels than the ranges tested (see Appendix E). Fortunately, ammonia (and formaldehyde) are both estimated to have a favorable increase in breakthrough times at the higher relative humidity conditions. However, the breakthrough times for the other (non-polar) constituents are estimated to have significant decreases, such that conditions at relative humidity levels greater than 84% should be deemed as uncertain with respect to cartridge performance until further testing can be conducted at the higher humidity levels.

3.2.2 Impact of Temperature

Figure 14B shows a consistent decrease in relative breakthrough times with increasing temperatures, which is consistent with theoretical perspective. The lack of an obvious temperature effect on formaldehyde breakthrough is likely due to a relatively lower heat of adsorption for formaldehyde on activated carbon [21].

Temperatures recorded for the cartridge tests ranged between 66 and 91°F. Appendix E shows meteorological data for 2016, including the points in time when cartridge testing occurred. The 2016 meteorological temperature range during cartridge testing was 21 to 94°F, and -8 to 106°F for the whole year. For several of the constituents in shown in Figure 14(B), the potential impact of reduced breakthrough times with historically higher temperatures (106°F versus 94°F) could be significant, such that cartridge use should not be inferred at temperatures greater than 94°F. Correspondingly, based on the sensitivity data shown in Figure 14B, it is expected that lower temperature conditions should result in higher breakthrough times, meaning that the conditions tested should represent conservative cartridge performance compared to the temperature ranges tested.

3.2.3 Impact of Inlet Concentration

Figure 14C shows a consistent decrease in relative cartridge performance with increasing inlet concentrations. Acetaldehyde shows an opposite effect. Based on the Wheeler-Jonas equation (used by OSHA from the Gerry O. Wood Mathematical Model) shown earlier, it is possible to observe this uncommon opposite effect of inlet concentration when the ratio of the adsorption capacity (W_e) and the inlet concentration (C_o) increases with the increase of the inlet concentration. Based on a conversation with a SCOTT (now 3M) engineer, this phenomenon can be explained by the competitive adsorption from water moisture in air for organic vapors [22]. More importantly, the competition of water loading is more severe when the chemical concentration is low as in the tank vapor field test. Water molecules will replace acetaldehyde molecules easier at lower concentrations than at higher concentration due to the adsorption isotherm trend²⁴ of acetaldehyde on activated carbon [27]. This will lead to a shorter stoichiometric time (when the outlet concentration equals the inlet concentration) that will cause a shorter breakthrough time (when the outlet concentration reaches the permissible concentration) at lower

²⁴ Figure 2 of reference 27.

concentration for acetaldehyde. Because source concentrations were used to challenge the respirator cartridges, this should indicate conservatively low breakthrough times compared to actual tank farm breathing space conditions.²⁵ See Appendix A, Section A.3, for additional discussion of differences in typical tank farm source and area concentrations.

3.2.4 Impact of Gas Flow Rate

Figure 14D shows a consistent estimated decrease in relative cartridge performance with increasing flow rates. Cartridge testing was performed at an equivalent flow rate of 60 L/min (30 L/min for each cartridge), which should represent a conservatively high flow rate in typical use.

²⁵ This is true except for acetaldehyde and some other chemicals where increasing inlet concentration increases the service life.

4.0 Conclusions and Recommendations

Twenty-eight respirator cartridge tests were performed in 2016 through 2018 on headspace vapors from seven tanks (SY-102, A-101, BY-108, AX-101, BY-110, SX-101, and SX-104) and seven exhausters (AP in 2016, AP in 2018, 702-AZ, AN and AW in 2016, and AX and 702-AZ in 2017). All but two of the tests were conducted under static, non-waste-disturbing conditions. In 2017, the 702-AZ exhauster was tested during waste-disturbing activities. Multipurpose respirator cartridges, SCOTT 7422-SD1 (SD1) and Scott 7422-SC1 (SC1), were tested on slip streams from each of the 14 tanks or exhausters. Out of 61 COPCs, only ammonia, mercury, NDMA, 2,5-dimethylfuran, 2,5-dihydrofuran, furan, and 1,3-butadiene exhibited breakthroughs with outlet concentrations that were >10% of their OELs. Further details and recommendations based on each of these breakthrough signatures are provided below:

- Ammonia exhibited breakthrough for 21 of the 28 tank/cartridge tests. Breakthrough was not observed for the two SY-102 tests, the AW/SD1 test, the 702-AZ 2016/SC1 cartridge test, the two AX 2017 exhauster tests, and the AP 2018/SC1 cartridge test. The shortest breakthrough times, less than or equal to 2 hours, were observed with the BY-108 SC1/SD1, BY-110/SC1, SX-101, and SX-104 tests, which had the highest inlet concentrations—all >780% of the ammonia OEL. Breakthrough times of 2 hours or greater were observed for all of the other tests. Based on measured data, inlet concentration was the only parameter that significantly impacted the breakthrough time. Relative humidity and temperature are still expected to significantly affect breakthrough time performance (as represented in manufacturer’s breakthrough calculators) but beyond the ranges tested. The breakthrough time observed for BY-110/SC1 was appreciably lower than that expected based on the reported inlet concentration (1.8 hours versus more than 10 hours). However, the reported inlet concentration is highly suspect and the actual value is believed to be nearly 4× higher, which would make the observed breakthrough time correspond with expected values. Finally, in each of the tank/cartridge tests, ammonia breakthrough preceded all other breakthrough observations, indicating that it is a leading candidate for defining the minimum breakthrough times for the cartridges.
- Although neither of the cartridges tested are NIOSH approved for mercury removal, all of the observed mercury breakthrough times²⁶ were greater than 16 hours except for the BY-108 SC1 test, which was estimated to be just over 14 hours, and the AX-101/SC1, AP 2018/SC1, and 702-AZ 2017 SD1 tests, which each had measured breakthrough times between 14 1/2 and 16 hours. The BY-108/SC1 observation of breakthrough did not appear to correlate with inlet mercury concentration but may be linked to a high total volatile organic compound (VOC) concentration. Therefore, based on the data collected, it appears that mercury inlet concentrations of <80% of the OEL at total VOC levels of less than 6 ppm should correspond to cartridge breakthrough times greater than 15 hours. Because SCOTT SureLife[®] Calculator estimations are not available for mercury, the impact of seasonal extremes of temperature and relative humidity on cartridge performance results is not known.²⁷
- Three breakthroughs were observed with 1,3-butadiene, including both BY-108 tests and the SX-101/SD1 test. The BY-108 breakthroughs were 3.8 and 5.1 hours for the SD1 and SC1 cartridges, respectively. The BY-108 breakthroughs appeared to be driven by the corresponding higher inlet concentration (>103% of the OEL compared to 2.2%, or less, for all of the other 2016 tests). Higher total VOC levels in BY-108 also are believed to have impacted the observed 1,3-butadiene breakthrough. The SX-101/SD1 “breakthrough” was based on single 8-hour

²⁶ Breakthrough times were defined as exceeding 10% of the OEL at the cartridge outlet.

²⁷ It is worth noting that the highest measured area sampling concentration for mercury (67% of the OEL) was not much lower than the highest cartridge-inlet concentration (84% of the OEL).

cartridge outlet concentration of 13.9%, where all other outlet concentrations were less than the DL. The corresponding inlet concentrations were also below 5.5%. These data suggest that the single elevated outlet concentration for SX-101/SD1 may be an analytical error rather than a true breakthrough.²⁸

- One possible breakthrough was observed for NDMA on the SX-101/SC1 cartridge. Here, the inlet concentration to the cartridge was >4500% of the OEL, which was the highest inlet concentration of any other tank tested. The corresponding outlet concentrations were below the RL, except for the 6-hour and 8-hour measurements, which reached a maximum of 12.4% of the OEL before dropping back to below-RL levels for the remainder of the test. These results could indicate breakthrough behavior at approximately 7 hours but could also be explained by analytical error.
- Another possible breakthrough was observed for 2,5-dimethylfuran during SX-104/SD1 testing. In that case, the maximum inlet concentrations reached 27% of the OEL. The corresponding outlet concentrations were below the DL, except for the measurement at 4 hours, which reached 22% of the OEL, indicating potential breakthrough. However, several 2,5-dimethylfuran measurements from the blank and baseline tubes also reported concentrations greater than the RL, which puts the elevated inlet and outlet measurements for this COPC in question.
- Breakthroughs for both furan and 2,5 dihydrofuran were assessed using a higher cartridge outlet threshold compared to other COPCs—50% of the OEL versus 10% with the Carbotrap 300 TDU tube data. This was due to the higher DL/RL values—ranging over 40% of the OEL. The specifics on the individual breakthroughs are as follows:
 - For furan, three tests showed evidence of breakthrough above 50% of the OEL—BY-108 (SD1, SC1), and 702-AZ 2017/SD1. For both BY-108/SD1 and SC1 tests, furan breakthrough above 50% of the OEL occurred after 10 hours. The corresponding maximum inlet concentrations were 819% and 298% of the OEL—two of the highest measured in the data set. Recall that ammonia breakthrough was observed in less than 2 hours for both of the BY-108 tests. The 702-AZ 2017 tests were conducted under waste-disturbing conditions and furan breakthrough above 50% of the OEL occurred after 10 hours for the SCOTT SD1 cartridge (maximum inlet 2995% of the OEL). In comparison, ammonia breakthrough for the SD1 test occurred after 6 hours.
 - In the BY-108 2016 test for 2,5-dihydrofuran, a single breakthrough above 50% of the OEL was occurred between 14 and 16 hours. In that case, outlet concentrations from the 14- and 16-hour measurements were 42% and 377%, respectively. The corresponding maximum inlet concentration was 278%, which was 5× higher than any other inlet concentration. In comparison, ammonia breakthrough was observed in less than 2 hours.
- Several COPCs showed evidence of early breakthrough behaviors but could not have reached the 10% of OEL outlet threshold because their inlet concentrations were too low. Acetaldehyde had inlet concentrations for multiple tests that reached nearly 1.2% of its OEL, and corresponding outlet concentrations for acetaldehyde reached nearly 0.8% of the OEL. This indicates that a significant amount of the inlet concentration may have made it through the cartridge over the course of the test. Similarly, propanenitrile exhibited had inlet concentrations around 0.4% of the OEL, with corresponding outlet concentrations that reached 0.9%. Finally, 3-buten-2-one had outlet concentrations that reached 2% of the OEL for the highest inlet concentrations—nearly 12%. These observations suggest that close attention should be paid to these COPCs if inlet concentrations were to increase for tanks in the future.

²⁸ With inlet concentrations of 5.5% of the OEL, initial outlet concentrations for 1,3-butadiene during the SCOTT 7422-SC1 cartridge were below the DL, but gradually increased reaching a maximum of 7.4% of the OEL at 14 hours. These results suggest potential breakthrough-like behavior but at inlet and outlet concentrations <10% of the OEL.

- From the 2016 testing [30], total VOCs, including both COPCs and non-COPC organic vapors measured in the tests, also were shown to exhibit cartridge breakthrough for the two BY-108 tests. However, because there is no OEL for total VOCs, it is recommended that total VOCs concentration be monitored and used as a potential contributor to other COPC breakthroughs, as described above.

In general, most estimations obtained from the SCOTT SureLife^{®29} Cartridge Calculator were near or below the measured breakthrough values for each of the cartridge tests, thereby corroborate the use of that tool by Industrial Hygiene in future ammonia service life estimations. However, a number of service life estimations were greater than measured breakthrough times. If an additional 2-hour safety factor were applied to the SureLife[®] estimates, all observed ammonia breakthrough times tested through 2018 would be greater than corresponding service life estimations, and ammonia would be a leading candidate for defining the minimum breakthrough times for the cartridges. Statistical analysis indicated there is a 95% confidence that 89% of the time measured breakthroughs would be longer than estimated service life minus 2 hours.

A comparison of the respirator cartridge inlet COPC concentrations was made against historical concentrations for each tank/exhauster to assess whether the cartridge testing bounded historic maximum concentrations. Sampling and analysis of 58 of the 61 COPCs was performed in the APR cartridge testing.³⁰ Out of the 58 COPCs evaluated, only 11 were found to have historical maximum concentrations that were either moderately higher than the cartridge-testing inlet concentrations, defined as 2×–5× the cartridge inlet value, or significantly higher, defined as greater than 5× the cartridge inlet value. The following COPCs were identified as having relevant differences between cartridge inlet and maximum historic source concentrations.

- Five COPCs—mercury, furan, NDMA, 1-butanol, and acetonitrile—had historic maxima more than 10× higher than maximum inlet concentrations measured in these recent cartridge tests. Two other COPCs—2-heptylfuran and 2-fluoropropene—also were found to have historical maxima that were significantly higher than the maximum cartridge inlets. However, in both cases the historical maxima were from 1994 BY-108 sampling and were either suspect data (2-heptylfuran) or represent a single high data point and COPC detection that has not been replicated in any subsequent sampling. Of these seven COPCs, breakthrough has only been observed for mercury, furan, and NDMA.
- Mercury and NDMA historical maxima were approximately 22× and 19× their maximum cartridge inlet concentrations, respectively. The historical maximum for mercury was from the AN exhauster during a waste-disturbing activity. The highest non-waste-disturbing historical maximum was approximately 3× the highest cartridge inlet. The maximum NDMA historic measurement also came from the AN exhauster but all other NDMA source samples from AN and other tank farms are significantly lower ($\geq 10\times$) than this maximum.
- Historical maxima for furan and 1-butanol both come from 1994 BY-108 headspace measurements, and in both cases, maxima from more recent measurements are substantially lower. The maximum cartridge inlet for furan (2995% of the OEL, 702-AZ in 2017) was higher than any other historic measurement of the tank headspaces or exhausters used in cartridge testing.

²⁹ The 3M SCOTT SureLife Calculator was available through technical services at ScottTechSupport@scottsafety.com.

³⁰ Sampling for three COPCs—nitrous oxide, methanol, and dimethyl mercury—was not performed in the APR tests, with the exception of methanol analysis from SUMMA canister samples used with the 702-AZ (2017) test. The basis for exclusion of these COPCs is provided in Section 1.3.

- The maximum historic acetonitrile concentration was a recent measurement from BY-108 (94% of the OEL) and was approximately 10× the maximum measured cartridge inlet or outlet concentration during testing. Cartridge inlet and outlet measurements of acetonitrile have been variable, but generally below 10% of the OEL with few exceptions. Historic source and area measurements of acetonitrile have also been highly variable, with no reported measurements exceeding the OEL.

Four COPCs—1,3-butadiene, formaldehyde, 2,3-dihydrofuran, and N-nitrosomorpholine—had historic maxima moderately higher (2×–5×) than their maximum cartridge inlet concentrations. For 1,3-butadiene breakthrough behavior was only observed in two BY-108 cartridge tests where other organic compounds also experienced breakthrough and consequently may have contributed to the breakthrough of the 1,3-butadiene. All other COPCs for which breakthrough or breakthrough behavior was observed—ammonia, 2,5-dihydrofuran, and 2,5-dimethylfuran—had cartridge inlet concentrations that were >50% of the historical maxima and were, therefore, not considered either moderately or significantly lower than historical levels.

The revision 0 report with just the first eight tests recommended additional testing or analysis of specific COPCs may be warranted in cases where the cartridge-test conditions may not have achieved an adequate performance³¹ basis. One option recommended for future testing is to include the ability to artificially elevate the concentrations of COPCs, such as furan, with historically higher concentrations so that respirator cartridge performance can be assessed against concentrations that challenge the cartridge and represent an appropriate bounding condition.

- The recommendation to test tanks during waste-disturbing activities was implemented during 2017 tests. Testing during waste-disturbing conditions in 702-AZ 2017 exhauster did achieve elevated concentrations for some COPCs that helped to more fully assess cartridge performance.³² With respect to furan compounds, the 702-AZ 2017 exhauster tests during waste-disturbing conditions, along with the re-evaluation of the BY-108 2016 furans and tank headspace sampling from AX-101 and SX-104 did achieve elevated concentrations necessary to better assess cartridge performance for furan, 2,5-dihydrofuran, and 2,5-dimethylfuran.

³¹ “Adequate performance” refers to being below the breakthrough criterion used in this analysis, which is having a sustained cartridge outlet concentration above 10% of the OEL of a COPC. Ultimately, Industrial Hygiene professionals will use these results along with specific hazard assessments to determine service life, change schedules, and cartridge use that provides the necessary performance.

³² For 702-AZ 2017 testing, ammonia, N-nitrosodimethylamine, and N-nitrosodiethylamine exceeded their corresponding OELs, and mercury, 2,3-Dihydrofuran, and N-nitrosomethylethylamine had one or more inlet concentration measurements >10% of their OELs.

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Appendix A

Testing Assumptions and Approach

Appendix A

Testing Assumptions and Approach

A.1 Testing Program

Based on Occupational Safety and Health Administration (OSHA) guidance (Section 2; [8]), a sample testing approach was pursued for quantifying respirator cartridge effectiveness for Hanford tank vapors. Washington River Protection Solutions (WRPS) developed a sampling approach outlined in TFC-PLN-168, “Industrial Hygiene Sampling and Analysis Plan for Respirator Cartridge Testing,” and “Air Purifying Respirator Cartridge Test Apparatus, RPP-STE-59226.”[21,22]

The APR cartridge-testing setup was developed by WRPS and used for measurements of vapors from the AP tank farm exhauster.[21,22,16] The test system and methodology were developed in consultation with recognized subject matter experts to follow the example of tank farm headspace field sampling for the purposes of cartridge testing.

The Sampling and Analysis Plan was developed under the direction and oversight of Industrial Hygienists in conjunction with the Tank Farms Operations Contractor for Retrieval and Closure, and Tank Farms Project and/or Production Operations Project Management Team, as applicable. Trained Industrial Hygiene Technicians under the direction of a qualified Industrial Hygienist collected chemical vapor samples from the influent and effluent sides of the cartridge-test apparatus. Before the test stand was transported to the tank farms, WRPS Sampling Equipment Operators, Industrial Hygiene Technicians, and Field Work Supervisors underwent training at HiLine Engineering (Richland, Washington).

The APR cartridge test was designed and constructed to operate without negative effects on performance to the following environmental conditions:

- Temperature: 32 to 115°F
- Relative Humidity: 5 to 100%
- Precipitation: Up to 4 inches in 6 hours
- Wind: Up to 20 mph with blowing dust.

To better evaluate the performance of the cartridges,³³ WRPS developed a testing program with the following conservative conditions to support robust cartridge service life estimates:

- The flow rate through each APR cartridge was set at 30 L/min (equivalent to 60 L/min for a pair of cartridges), which corresponds to more than twice the normal breathing rate of a worker and is slightly higher than the OSHA recommended testing flow rate of 53.3 L/min.[23,24]
- Tank farm vapors source sampling was performed on headspace vapors rather than from Hanford Tank farm atmospheric concentrations (i.e., source sampling versus the breathing zone).
- A threshold concentration of 10% of the OEL for each COPC was chosen.

³³ The SCOTT cartridges are multipurpose APR respirator cartridges for use on Xcel Half-Mask and all SCOTT full face pieces. The cartridge is part of a system that must be evaluated for the activity being planned by the Industrial Hygiene staff.

- Using the cartridge-testing rig, separate tests were performed on two National Institute of Occupational Safety and Health (NIOSH)-approved respiratory protection cartridges: SCOTT 7422-SD1 and SCOTT 7422-SC1 for using the APR test rig.[25]³⁴

Vapor concentrations upstream and downstream of the cartridges were monitored with an array of sorbent tubes (see Table A.1). During the 2016 testing, influent (upstream) concentrations were measured at the beginning and end of each 16-hour verification survey. Later testing sampled the influent stream every two hours. The effluent (downstream) sorbent tubes were changed out every 2 hours until the experiment was finished. A measured quantity of sample air was drawn in through the sorbent tube (see Table A.1).[21,22] Compounds from the sorbent tubes were extracted and analyzed using analytical methods referenced in Table A.1.

Table A.1. Information on Sorbent Media used to Capture Contaminants, Flow Rates Used, Methods to used Extract Analyte from Sorbent Media, and Methods used to Quantify or Estimate the Concentrations of Hazardous Contaminant

Analyte Category	Media	Flow Rate (mL/min)	Analytical Method ^a	Instrument Used ^b	Analysis Location ^c
Acetonitrile	Charcoal Tube, SKC-226-09	100	NIOSH 1606	GC-FID	ALS
Acetonitrile	Carbotrap 300 TDU Tube	33	EPA TO-17 Modified	GC/MS	WRPS
Furans	TDU Tenax TA	50	EPA TO-17 Modified	GC/MS	WRPS
Semi-Volatile Organic Compounds	Carbotrap 150 TDU Tube	33	EPA TO-17 Modified	GC/MS	WRPS
Volatile Organic Compounds	Carbotrap 300 TDU tube	33	EPA TO-17 Modified	GC/MS	WRPS
Mercury	Anasorb C300, SKC-226-17-1A	250	NIOSH-6009	CVAA	WHL
Ammonia	Anasorb 747 (sulfuric acid), SKC-226-29	200	OSHA-ID-188	IC	WHL
1,3-butadiene	Charcoal, SKC-226-37, (Parts A and B)	200	NIOSH-1024	GC-FID	ALS
Aldehyde	DNPH Treated Silica Gel, SKC-226-119	200	EPA TO-11A	HPLC	ALS
Pyridine	Coconut Shell Charcoal, SKC-226-01	1000	NIOSH-1613	GC-FID	ALS

³⁴ SCOTT part numbers 7422-SC1 and 7422-SD1 are multipurpose APR respirator cartridges for use on Xcel Half-Mask and all SCOTT full face pieces with NIOSH approval for OV/AM/MA/CL/HC/SD/CD/HF/FM/HS application. The -SD1 cartridge has the same multipurpose features as the -SC1, but also includes a P100 particulate filter. <https://www.3m-scott.com/download/742-series-cartridges-user-instructions-english/>

Analyte Category	Media	Flow Rate (mL/min)	Analytical Method ^a	Instrument Used ^b	Analysis Location ^c
Nitrosamines	Thermosorb/N	2000	NIOSH-2522 Modified	GC-TEA	CBAL
Ethylamine	XAD-7 (NBD) Chloride), SKC 226-96	100	OSHA-ID-34, 36, 40, and 41	HPLC-UV	ALS

^a Analytical Method

NIOSH: National Institute of Occupation Safety and Health
EPA: U.S. Environmental Protection Agency
OSHA: Occupational Safety and Health Administration

^b Instrument Used

GC-FID: Gas Chromatography-Flame Ionization Detector
GC/MS: Gas Chromatography-Mass Spectrometry
CVAA: Cold Vapor Atomic Absorption
IC: Ion Chromatography
HPLC: High Performance Liquid Chromatography
GC-TEA: Gas Chromatography-Thermal Energy Analyzer
HPLC-UV: High Performance Liquid Chromatography-Ultraviolet Detector

^c Analysis Location

ALS: ALS Environmental Salt Lake City
WRPS-222S: WRPS, Organic Studies Group
WHL-222S: Wastren Hanford Laboratory
CBAL: Columbia Basin Analytical Laboratory, part of the RJ Lee Group

The measurement of 61 COPCs was the primary focus of the testing. The 61 COPCs represent a set of tank vapor chemicals found in a tank farm source >10% of the OEL, or are considered “known” or “probable” carcinogens by the International Agency for Research Cancer or other regulatory agencies.[31,32] A full listing of these COPCs is provided in Section 1.3.

A.2 Cartridge Selection

SCOTT Safety offers a range of respiratory protection products. Their 742 Series cartridges are approved by the NIOSH and can be used for different types of air-purifying masks. Two multipurpose cartridges types, 7422-SD1 and 7422-SC1, were used to assess Hanford tanks exhauster and headspace vapor streams. These cartridges were chosen because they are suitable for capturing organic vapors, acid gases, ammonia/ methylamine, and formaldehyde. The same activated carbon type and carbon volume (120 mL) are used in both the SD1 and the SC1 cartridges. The activated carbon used in the SD1 and SC1 cartridges were supplied by a third party. Both SD1 and SC1 cartridges have same carbon types (irregular shaped, and volume (120 mL); however, the cartridge configurations are different. The SD1 cartridge combines a particulate filter with the activated carbon cartridge. This configuration is advantageous in that it removes particulate aerosols at a 99.97% efficiency level while also removing Chemicals of Potential Concern (COPC). Because of the volume needed for the particulate filter medium and the need to provide equivalent COPC removal, the corresponding carbon packing density for the SD1 cartridge is slightly higher than in the SC1 cartridge. Other than these differences, the SC1 and SD1 cartridges are similar in nature and in expected performance.

A.3 Testing Source and Setup

Sources for the respirator cartridge testing were selected to ensure that the mixture of COPCs challenging the cartridges represented actual tank farm mixtures. Direct tank vapor sources including tank headspace and tank farm exhauster slip streams were chosen to ensure conservatively high concentrations relative to the area concentrations of expected respirator use.

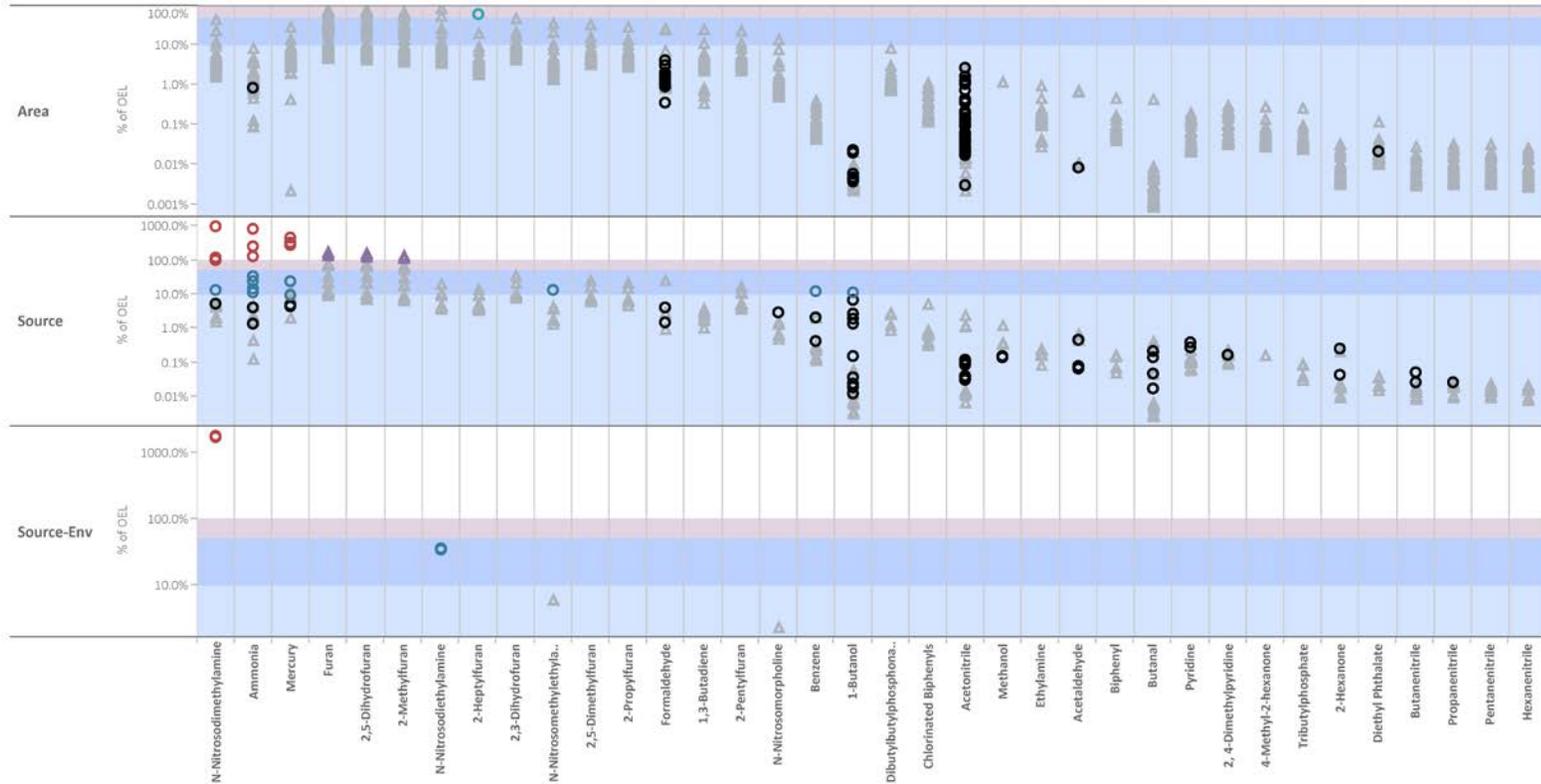
Figure A.1 provides a summary of the 241-AZ tank farm historical area and source monitoring from January 2009 through September 2016, as an example of typical differences between headspace or exhauster source measurements and monitoring of the potential breathing zone or “area” of workers in and around the tank farm. Area concentrations shown for the AZ tank farm indicate just one compound detected COPCs above 10% of Occupational Exposure Limits (OEL) within the tank farm. Most samples from area air sampling are non-detects less than the reported DL. In contrast, the source data from stack or headspace sampling indicates several COPCs detected above 10% of their OELs, and in this specific farm, ammonia, mercury, and N-nitrosodimethylamine are identified with detected levels above 100% of their OELs. None of these three COPCs were detected at elevated source concentrations during area sampling. Only ammonia was detected at a concentration near 1% of its OEL. Only one COPC, 2-heptylfuran, is identified in Figure A.1 as being detected near 100% of its OEL during area sampling, whereas source measurements for that compound were all non-detects with an RL at or below 10% of the OEL. In general, area concentrations for COPCs are substantially lower (e.g., 10× or more) than source concentrations. However, there are exceptions, such as 2-heptylfuran. Several other COPCs—specifically formaldehyde, acetonitrile, and acetaldehyde—are shown as detects in area sampling at levels comparable to or higher than source concentrations. But all of these COPCs are at concentrations well below 10% of their OELs. Tank farm area sampling also may result in detection of COPCs that did not originate from the sources in that farm. They could be from other nearby farms or from non-tank farm sources entirely including ambient background concentrations.

The primary COPCs present at source concentrations of key concern to respirator cartridge performance testing (e.g., ammonia, mercury, nitrosamines) have historically been detected and quantified at much higher concentrations in tank farm sources than in ambient area samples, making testing with actual tank farm source concentrations an appropriately conservative approach for evaluating cartridge performance.

The respirator cartridge-testing system was developed by WRPS and HiLine Engineering (Richland, Washington) as a means to comprehensively test respirator cartridge performance with actual Hanford tank headspace or exhauster slip stream gases. Tank headspace or exhauster slip stream vapors are pulled direct from the source through a flexible hose connecting the tank or exhauster sampling port within the tank farm/exhauster fence line to the respirator cartridge-testing system outside the farm [1-8]. Multiple in-line particulate filters are installed in the line between the tank/exhauster and test system to remove potential radioactive particulates. Each filter unit contains a hydrophobic polytetrafluoroethylene filter (Fluoropore,TM Millipore Sigma, Billerica, Massachusetts) that is required pursuant to the radiological work permit. This polytetrafluoroethylene filter medium is the same material used for routine tank vapor area monitoring as well as sampling and analysis of sources (headspace and exhausters) and was selected because of its broad chemical compatibility that minimizes sorption of, or reactions with, chemical compounds. The filter medium is not expected to adversely impact the test objectives because all tank farm vapor sampling uses this type of filter medium.

AZ Farm Air Sampling Results Relative to OEL - Chemicals of Potential Concern

1/20/2009 to 12/13/2016 (Data Reviewed as of July 2017)



Footnotes:

- 1) Analytical air sampling data is presented; samples (e.g. sorbent tubes) were collected in the field and analyzed by laboratory instrumentation.
- 2) % of OEL = Chemical Concentration (or Reported Detection Limit for non-detections) + Chemical OEL
- 3) Data sourced from Site Wide Industrial Hygiene Database (SWIHD); results were compared to Occupational Exposure Limits (OELs) for chemicals identified as chemicals of potential concern (COPCs)
- 4) Open triangles represent sample results that are less than the laboratory instrumentation detection limits, and results are reported as their appropriate Reported Detection Limit (RDL). RDL is the minimum concentration a laboratory instrument can detect, and it varies depending on instrument performance, calibration, and sensitivity. Additionally, insufficient sample volume and dilution during sample preparation can increase reported detection limits. When a less than detect sample result is received, it is known to be less than the reported detection value, and appropriate measures are taken as necessary for worker protection.
- 5) Analytes with no markers in a given category (e.g., headspace) were not analyzed for.

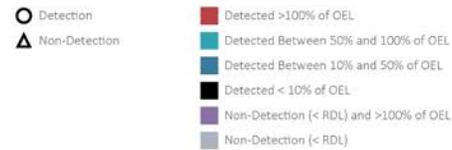


Figure A.1. Comparison of Source and Area Air Sampling in the AZ Farm³⁵

³⁵ The figure is adapted from hanfordvapors.com (https://hanfordvapors.com/wp-content/uploads/2017/05/percent_oel_nonpersonal_az_farm-1.pdf). Additional data and sampling results from other tank farms and time periods also are available.

The hose was wrapped in heat tape to maintain in-tank vapor temperatures as near as possible as vapors were transferred to the testing system. Other benefits of trying to maintain the vapor temperature during transfer was reducing the condensation of water, which can act as a sink for chemicals, and preventing potential condensation of other chemicals, including COPCs. There were two connection hoses:

1. The hose from the riser to the inlet of the respirator-cartridge testing system was a Centurion Process, LLC 1-in. RFRTTP polytetrafluoroethylene Teflon-lined hose with an ethylene propylene diene monomer rubber cover with 1-in. 316 stainless steel male national pipe thread ends.
2. The return hose was a Centurion Process, LLC 1-in. RT smoothbore fluorinated ethylene propylene-lined hose with an ethylene propylene diene monomer cover with 1-in. 316 stainless steel male national pipe thread ends.

The test equipment allows for sampling the vapor stream both before and after the cartridge, so that performance for a given COPC can be quantified. Sorbent media tubes were used to capture the COPCs and other hazardous contaminants. After a given test segment, the sorbent tubes were removed and analyzed. Sampling of the exhaust gas was performed every 2 hours, but this timing can be modified as necessary.

Figure A.2 provides a general schematic diagram for the respirator cartridge test apparatus, and Figure A.3 shows photographs of the actual equipment.

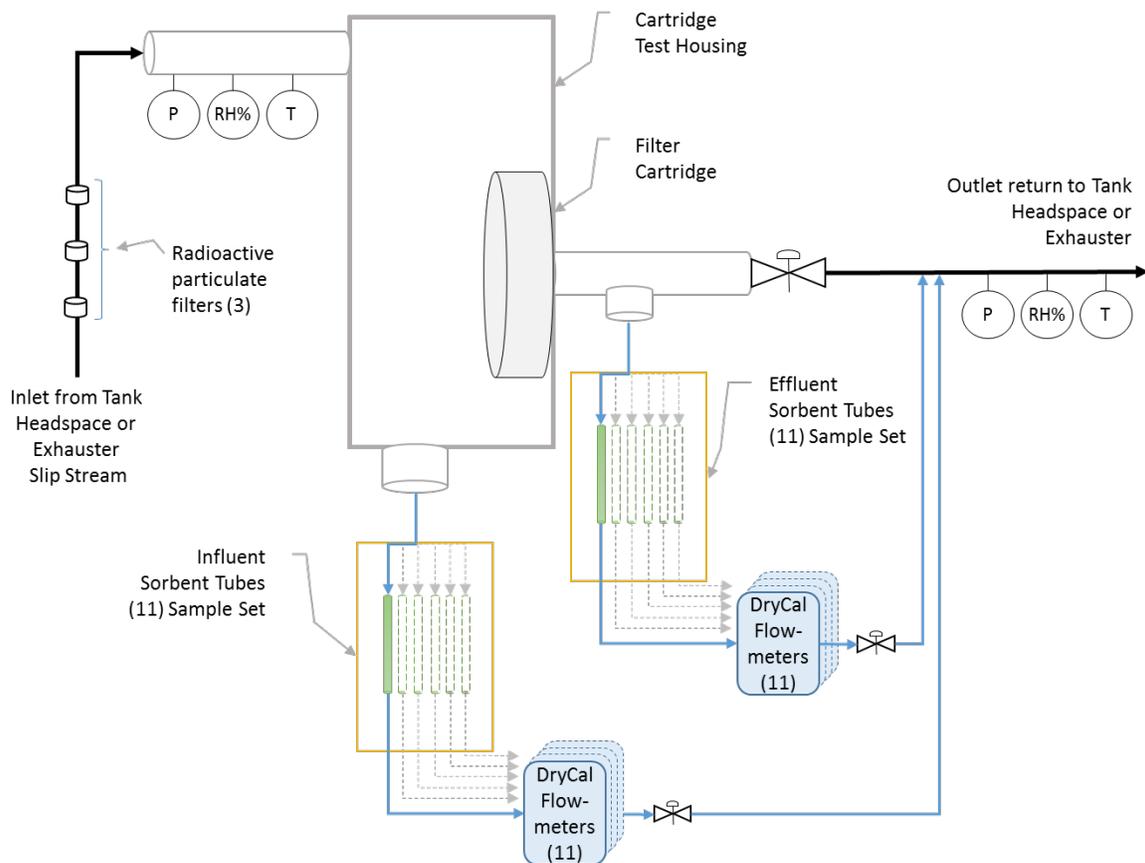


Figure A.2. General Schematic of Respirator Cartridge Test Apparatus

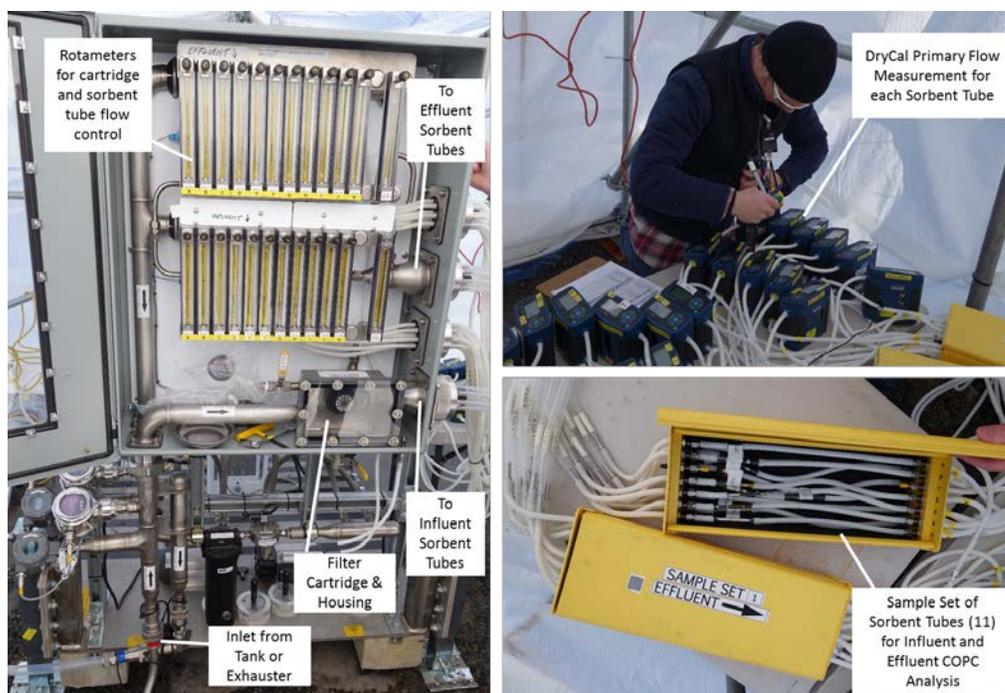


Figure A.3. Photographs of the Respirator Cartridge Test Equipment

The test system operates using vacuum to draw tank gases/vapors into the unit so that the potential for leakage to atmosphere is minimized until the gases/vapors are under positive pressure downstream of the vacuum pumps. By the time gases reach the vacuum pump, COPCs are essentially captured or removed by either the sorbent tubes or the respirator cartridge [1-8, 26].

Flows through the respirator cartridge and through each sorbent tube are set and controlled/maintained using manual flow control valves on the outlet of each rotameter, and rotameters were calibrated against DryCal primary flow calibrators before and after testing. DryCal flow meters also were used downstream of the sorbent tubes to measure the flow through each sorbent tube. All equipment connections were leak tested prior to initiation of the test. Temperature, relative humidity, and pressure of the inlet gas/vapor stream are monitored by calibrated instrumentation.

Using Industrial Hygiene-approved materials, cartridge-test equipment was constructed so that it would not influence/interfere with vapor analysis. Stainless steel or Teflon™ tubing and fittings are used where possible because of their relatively inert nature to the vapors being analyzed. Limited portions of the assembly used acrylic, Viton™, glass, and Masterflex C-flex tubing, which are commonly used for various vapor-sampling applications.

A.4 Breakthrough Criteria

A general definition of breakthrough time is the time at which the effluent concentration reaches its maximum permissible level [9]. Within the adsorption research community, researchers use different definitions of breakthrough time based on their specific needs. Some researchers choose the time when the first detectable concentration is captured as the breakthrough time [10], some choose a time when the effluent concentration reaches a percentage of the influent concentration [11], and others choose a time when the effluent concentration matches the influent concentration to assess the equilibrium breakthrough capacity and to compare with adsorption isotherm results [12].

There is a difference between cartridge service life and breakthrough time. According to OSHA, service life means the period of time that a respirator, filter or sorbent, or other respiratory equipment provides adequate protection to the wearer [13]. To prevent any contamination, cartridges should ideally be changed before expected breakthrough. Therefore, a safety factor, such as changing cartridges before 90% of the estimated breakthrough, needs to be applied to the breakthrough time to estimate the service life of the cartridge. To estimate the cartridge service life, the most common practice is to use the time when the effluent concentration reaches a percentage of either the OEL or influent concentration for a specific chemical. OSHA suggests the software package “MultiVapor” based on Gerry Wood’s model (provided by NIOSH) to estimate the service life of cartridge. Here, the time at which the effluent concentration reaches 10% of the influent concentration was chosen as the breakthrough time [14,15]. In a field method developed to determine the service lives of respirator cartridges, the time when the effluent concentration reached about 10% of the influent concentration was used as the breakthrough time [16]. Respirator vendors such as Honeywell (North Safety) used similar breakthrough criteria [17]. However, some other respirator vendors such as 3M and MSA use the time when the effluent concentration reaches a certain percentage of an OEL to determine the breakthrough time and to estimate the cartridge service life [18,19]. Some literature on service life indicator deemed that this 50% of the OEL is actually a common breakthrough time determination criterion to estimate cartridge service life [20].

There is no universal standard for determining breakthrough time or service life. The service life calculator from vendors such as the SureLife Calculator from SCOTT Safety (now 3M Company) allows the user to define the breakthrough criteria either based on percentage of inlet concentration or a fixed concentration. Therefore, for the cartridge performance tests, we defined breakthrough as the time when the effluent concentration reaches 10% of the OEL³⁶. When the influent concentration of the chemical is higher than its OEL, the 10% of the OEL criterion is more conservative than 10% of the influent concentration. This works particularly well for ammonia and nitrosamine compounds. When the influent concentration is lower than the OEL, the 10% of the OEL criterion is not as conservative as 10% of the inlet concentration. However, when the influent concentration is less than the OEL, 10% of the OEL is still conservative because the effluent concentration is substantially less than the limit of the acceptable concentration of a hazardous substance in the workplace.

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Appendix B
Data Analysis

Appendix B

Data Analysis

B.1 Calculation of Total Volatile Organic Compounds

Volatile organic compounds (VOC) refer to organic compounds with low boiling points. VOCs typically exhibit adsorption behavior on carbon-based sorbents. In addition, there is the potential for VOCs to competitively adsorb on the active carbon sites. Therefore, a rollup of the total VOCs was made to better assess their cumulative impact on cartridge performance. Data from the following analytical tube sources were used in the total VOC rollup:

- TDU VOA: Calibrated Volatile Organic Analysis (VOA)
- TDU SVOA: Calibrated Semi-Volatile Organic Analysis
- TDU VOA: Non-calibrated Volatile Organic Analysis–Tentatively Identified Compounds (VOATIC)
- TDU SVOA: Non-calibrated Semi-Volatile Organic Analysis – Tentatively Identified Compounds (SVOATIC)
- EPA TO-11A: Aldehyde Screen
- NIOSH 1613: Pyridine Screen
- Furans in Vapor Samples by Secondary Ion Mass Spectrometry
- VOA Aliphatic VAA: Organic Amines.

The analytical amounts in each sample tube were reported as mass per tube. The mass of a given compound that the respirator cartridge was exposed to was calculated by adjusting the amount of material found in the sample tube by the ratio of sample air forced through the tube to air flow (standard conditions) through the respirator (target 3600 L). The equation below shows the calculation used for this adjustment; m represents mass while V represents the volume of gas exposed to either the respirator or the sample tube over the course of the experiment.

$$m_{respirator} = m_{tube} \frac{V_{respirator}}{V_{tube}} \quad \text{equation B.1}$$

Attempts were made to measure a large number of compounds, especially downstream of the cartridge, but in many cases none were detected. Instead of setting those values to zero, their amounts were set at their respective detection/reporting limits, which was approximately 12% higher in some cases. To convert the mass-based concentrations to a volume-based concentration (ppmv) the individual VOC mass measurements were divided by their corresponding molecular weight values. The moles of each VOC compound were then converted to volumes at standard conditions using the molar density for an ideal gas (24.45 moles per liter). The individual VOC compound volumes were then summed up into a Total VOC volume for each time period and divided by the standardized volume of gas passed through the respirator for that given time period. This process yielded eight inlet and eight outlet measurements for each tank/cartridge test. However, for the data sets of AP, SY-102, A-101, and BY-108, there were only two inlet data points—the initial value and the final value. Tables B.1 and B.2 show the results of the aforementioned analysis.

Table B.1. Total VOC (non-Chemicals of Potential Concern and COPCs) for the AP, A-101, SY-102 and BY-108 Data Sets

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
AP/SD1	2	70.5	742	5.4	4.8	5.4	0.82	0.63
AP/SD1	4	70.5	742		5.2	11.1		0.63
AP/SD1	6	70.5	742		4.9	17.1		0.62
AP/SD1	8	70.5	742		4.6	23.2		0.60
AP/SD1	10	70.5	742		4.4	29.7		0.61
AP/SD1	12	70.5	742		4.5	36.4		0.64
AP/SD1	14	70.5	742		5.0	43.3		0.67
AP/SD1	16	70.5	742	7.2	4.1	50.5	0.93	0.64
AP/SC1	2	75.7	744	2.5	5.1	2.5	0.82	0.63
AP/SC1	4	75.7	744		3.2	5.3		0.63
AP/SC1	6	75.7	744		3.3	8.4		0.62
AP/SC1	8	75.7	744		4.9	11.8		0.60
AP/SC1	10	75.7	744		2.8	15.5		0.61
AP/SC1	12	75.7	744		2.1	19.5		0.64
AP/SC1	14	75.7	744		2.1	23.8		0.67
AP/SC1	16	75.7	744	4.6	3.1	28.5	0.93	0.64

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
SY-102/SD1	2	81.6	710	6.8	6.4	6.8	0.40	0.28
SY-102/SD1	4	84.0	713		5.4	13.0		0.28
SY-102/SD1	6	86.9	712		5.9	18.6		0.29
SY-102/SD1	8	85.0	712		9.0	23.8		0.25
SY-102/SD1	10	75.6	713		2.5	28.3		0.17
SY-102/SD1	12	70.7	714		2.1	32.3		0.15
SY-102/SD1	14	77.2	715		2.3	35.8		0.13
SY-102/SD1	16	66.9	725	2.9	2.1	38.6	0.22	0.15
SY-102/SC1	2	77.1	716	8.6	5.1	8.6	0.40	0.28
SY-102/SC1	4	82.0	718		4.5	16.4		0.28
SY-102/SC1	6	83.8	717		1.9	23.5		0.29
SY-102/SC1	8	85.9	717		3.4	29.9		0.25
SY-102/SC1	10	83.1	717		4.0	35.5		0.17
SY-102/SC1	12	75.2	718		2.1	40.4		0.15
SY-102/SC1	14	72.8	718		2.9	44.5		0.13
SY-102/SC1	16	68.4	716	3.4	2.0	47.9	0.22	0.15

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
A-101/SD1	2	81.9	734	10.6	3.0	10.6	1.40	0.19
A-101/SD1	4	87.1	735		3.8	20.6		0.27
A-101/SD1	6	85.2	735		4.2	30.1		0.32
A-101/SD1	8	84.3	736		4.5	39.1		0.53
A-101/SD1	10	74.0	736		4.5	47.5		0.40
A-101/SD1	12	69.1	738		4.3	55.4		0.43
A-101/SD1	14	68.6	737		4.1	62.8		0.41
A-101/SD1	16	68.6	736	6.8	3.9	69.6	0.70	0.41
A-101/SC1	2	83.6	736	2.6	1.5	2.6	0.25	0.13
A-101/SC1	4	85.4	736		4.6	5.8		0.35
A-101/SC1	6	88.2	735		5.6	9.5		0.43
A-101/SC1	8	87.4	734		4.4	13.8		0.30
A-101/SC1	10	84.4	733		3.8	18.6		0.33
A-101/SC1	12	77.2	734		3.9	23.9		0.39
A-101/SC1	14	73.9	735		4.1	29.8		0.44
A-101/SC1	16	70.1	734	6.4	5.4	36.2	0.64	0.54

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
BY-108/SD1	2	83.7	720	63.4	6.8	63.4	6.36	0.40
BY-108/SD1	4	87.0	721		8.8	124.2		0.93
BY-108/SD1	6	88.2	722		10.3	182.5		1.07
BY-108/SD1	8	87.4	722		16.6	238.2		1.94
BY-108/SD1	10	76.6	720		24.9	291.3		2.98
BY-108/SD1	12	70.9	734		11.5	341.9		1.37
BY-108/SD1	14	71.0	724		42.8	389.8		5.04
BY-108/SD1	16	65.5	721	45.4	43.3	435.3	4.81	4.51
BY-108/SC1	2	83.1	719	55.7	2.9	55.7	5.49	0.23
BY-108/SC1	4	87.8	726		15.1	109.8		2.16
BY-108/SC1	6	89.2	720		8.5	162.6		0.96
BY-108/SC1	8	90.7	720		13.2	213.8		1.61
BY-108/SC1	10	83.9	718		20.2	263.7		2.52
BY-108/SC1	12	80.3	719		27.6	312.0		3.48
BY-108/SC1	14	74.6	720		33.7	358.9		4.04
BY-108/SC1	16	72.9	718	45.4	33.2	404.3	4.75	4.00

Table B.2. Total VOC (non-COPCs and COPCs) for AX-101, 702-AZ, AN and AW Data Sets

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
AX-101/SD1	2	73.6	739	17.5	2.2	17.5	1.85	0.14
AX-101/SD1	4	79.0	738	14.8	3.0	32.3	1.76	0.24
AX-101/SD1	6	81.6	737	15.0	1.9	47.3	1.80	0.19
AX-101/SD1	8	77.4	736	9.8	2.5	57.1	1.18	0.34
AX-101/SD1	10	69.4	737	8.1	1.8	65.2	0.97	0.23
AX-101/SD1	12	65.6	736	9.1	2.3	74.3	1.11	0.28
AX-101/SD1	14	61.8	735	8.3	4.4	82.6	1.02	0.45
AX-101/SD1	16	57.1	736	11.0	4.8	93.6	1.29	0.60
AX-101/SC1	2	71.5	732	12.8	2.8	12.8	1.46	0.27
AX-101/SC1	4	85.6	731	14.6	3.7	27.4	1.77	0.32
AX-101/SC1	6	91.0	729	16.4	3.7	43.9	1.99	0.37
AX-101/SC1	8	93.3	727	15.3	3.0	59.2	1.86	0.25
AX-101/SC1	10	85.8	727	14.3	3.8	73.4	1.76	0.46
AX-101/SC1	12	74.8	729	9.6	3.3	83.1	1.20	0.43
AX-101/SC1	14	70.5	730	10.7	6.0	93.8	1.43	0.62
AX-101/SC1	16	69.0	729	7.0	8.8	100.8	0.94	1.05

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
AN/SD1	2	65.4	724	3.0	2.6	3.0	0.27	0.27
AN/SD1	4	72.8	722	2.3	2.0	5.3	0.37	0.12
AN/SD1	6	77.1	721	3.5	2.1	8.8	0.37	0.13
AN/SD1	8	78.9	720	4.6	1.8	13.4	0.37	0.12
AN/SD1	10	72.1	722	3.2	1.9	16.7	0.37	0.13
AN/SD1	12	70.4	721	3.4	2.6	20.0	0.37	0.23
AN/SD1	14	68.2	730	1.2	3.2	21.2	0.37	0.17
AN/SD1	16	65.1	741	3.9	1.7	25.1	0.48	0.13
AN/SC1	2	67.4	726	2.9	8.9	2.9	0.35	1.31
AN/SC1	4	71.3	725	3.7	1.9	6.5	0.60	0.13
AN/SC1	6	72.6	726	3.9	1.6	10.4	0.64	0.12
AN/SC1	8	71.2	726	5.0	1.3	15.4	0.84	0.11
AN/SC1	10	66.3	727	4.1	1.4	19.5	0.69	0.12
AN/SC1	12	62.6	727	2.8	1.6	22.3	0.44	0.13
AN/SC1	14	59.0	728	2.9	1.8	25.2	0.47	0.14
AN/SC1	16	56.6	726	3.0	1.4	28.2	0.41	0.12

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
702-AZ/SD1	2	93.2	732	8.2	1.0	8.2	0.61	0.09
702-AZ/SD1	4	101.4	731	2.9	1.1	11.1	0.41	0.10
702-AZ/SD1	6	97.3	729	2.6	1.0	13.7	0.41	0.09
702-AZ/SD1	8	94.6	728	2.8	0.9	16.5	0.41	0.09
702-AZ/SD1	10	89.0	728	2.7	0.9	19.2	0.41	0.09
702-AZ/SD1	12	82.2	728	2.3	0.9	21.5	0.41	0.09
702-AZ/SD1	14	78.8	728	2.2	0.9	23.7	0.41	0.09
702-AZ/SD1	16	75.8	727	2.2	0.8	25.9	0.21	0.09
702-AZ/SC1	2	92.7	727	2.5	0.9	2.5	0.24	0.09
702-AZ/SC1	4	104.4	726	2.5	1.1	5.0	0.23	0.11
702-AZ/SC1	6	95.8	726	2.6	1.8	7.6	0.25	0.23
702-AZ/SC1	8	93.4	726	2.4	1.0	10.0	0.22	0.10
702-AZ/SC1	10	86.5	727	2.2	0.7	12.2	0.20	0.06
702-AZ/SC1	12	78.3	728	16.6	1.0	28.8	0.77	0.11
702-AZ/SC1	14	72.3	730	2.1	1.0	30.9	0.20	0.11
702-AZ/SC1	16	71.6	731	2.5	0.9	33.4	0.25	0.10

Tank/ Cartridge	Time Period End (hr)	Temp (F)	Press (Torr)	Inlet Conc (mg per period)	Outlet Conc (mg per period)	Cumulative Mass Fed (mg)	Inlet Conc (ppmv)	Outlet Conc (ppmv)
AW/SD1	2	64.0	733	5.4	1.4	5.4	0.47	0.10
AW/SD1	4	70.2	733	4.1	1.5	9.5	0.46	0.10
AW/SD1	6	71.2	733	4.4	1.7	13.9	0.46	0.12
AW/SD1	8	72.9	733	4.3	1.6	18.2	0.46	0.11
AW/SD1	10	69.8	734	4.3	1.8	22.5	0.46	0.12
AW/SD1	12	61.4	735	4.1	1.6	26.6	0.46	0.12
AW/SD1	14	59.5	736	4.2	2.3	30.8	0.46	0.15
AW/SD1	16	58.2	737	5.0	1.5	35.7	0.46	0.13
AW/SC1	2	70.1	739	3.8	1.5	3.8	0.36	0.13
AW/SC1	4	74.4	739	3.9	1.6	7.6	0.44	0.14
AW/SC1	6	76.2	738	3.9	1.8	11.5	0.45	0.15
AW/SC1	8	73.3	736	3.8	1.4	15.3	0.44	0.12
AW/SC1	10	65.8	736	3.5	1.7	18.8	0.40	0.18
AW/SC1	12	63.0	738	3.4	1.9	22.2	0.39	0.20
AW/SC1	14	60.7	736	3.2	2.2	25.4	0.35	0.17
AW/SC1	16	56.6	736	4.4	3.4	29.8	0.47	0.42

B.2 Calculation of Breakthrough Times

Each COPC with observed breakthrough signatures was further assessed to infer when the point of breakthrough occurred at a higher resolution than the 2-hour collection times. An interpolation was used to determine the time when 10% of the OEL concentration at the outlet would have occurred. Based on theoretical adsorption information, the log of outlet concentrations was used for the interpolation. Once the interpolated breakthrough time was determined, the average inlet concentrations and measured gas stream properties were determined up until that point for use in subsequent analyses. The results of the interpolation procedures are shown in Tables B.3 (ammonia), B.4 (mercury), B.5 (1,3-butadiene), B.6 (furan), B.7 (2,5-dihydrofuran), B.8 (2,5-dimethylfuran), and B.9 (NDMA). For furan and 2,5-dihydrofuran, which have relatively high DL and RL values, a breakthrough threshold of 50% of the OEL was used to calculate breakthrough times.

Note that the data sources are from the Appendix D and Appendix C data given in each of the prior tank analysis reports.

Table B.3. Calculation of Breakthrough Times for Ammonia

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet - interpolated (hour)	Breakthrough Time at 10% of OEL Concentration in Outlet - estimated (hour)	Averages for Period Up to Calculated Breakthrough					
				Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	3.1	1.8	121	484%	84.5	735	56.0	20.6
A-101	SC1	8.9	5.2	93	371%	85.8	735	81.1	18.6
AX-101	SD1	2.7	2.9	186	744%	76.3	738	75.3	32.3
AX-101	SC1	2.4	2.6	167	668%	78.6	736	70.6	27.4
702-AZ	SD1	13.5	3.1	18	74%	90.9	729	33.3	23.7
702-AZ	SC1	> 16	3.5	18	72%	86.9	728	36.8	33.4
AN	SD1	11.0	9.5	24	96%	72.8	722	70.3	20.0
AN	SC1	11.4	11.2	29	115%	68.6	726	71.9	22.3
AP	SD1	5.3	2.9	64	257%	70.5	742	46.9	17.1
AP	SC1	8.8	4.6	59	237%	75.7	743	66.0	15.5
AW	SD1	> 16	14.1	23	94%	65.9	734	75.0	35.7
AW	SC1	13.8	15.5	23	93%	69.1	737	74.0	25.4
BY-108	SD1	1.7		416	1663%	83.7	720	86.0	63.4
BY-108	SC1	1.7		403	1611%	83.1	722	59.5	55.7
SY-102	SD1	> 16	>16	1.1	4.3%	78.5	714	64.7	38.6
SY-102	SC1	> 16	>16	2.0	7.8%	78.5	716	53.8	47.9
BY-110	SD1	3.2	4.3	154	615%	48.1	740	69.4	Not calculated
BY-110	SC1	1.8	11.3	28	112%	53.6	720	64.0	Not calculated
SX-101	SD1	1.9	1.2	284	1137%	94.6	717	67.7	Not calculated
SX-101	SC1	1.7	0.7	310	1238%	100.1	717	58.1	Not calculated
SX-104	SD1	1.9	3.8	193	773%	74.0	708	84.6	Not calculated
SX-104	SC1	2.0	3.4	192	768%	83.7	711	84.9	Not calculated
702-AZ ('17)	SD1	7.0	6.7	65	261%	58.2	741	68.4	Not calculated
702-AZ ('17)	SC1	5.5	7.2	71	283%	54.9	725	70.6	Not calculated
AP ('18)	SD1	15.2	>16	19	78%	56.0	727	76.3	Not calculated
AP ('18)	SC1	> 16	>16	18	73%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	14.7	3.9	16%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	9.0	3.3	13%	86.8	718	45.4	Not calculated

Table B.4. Calculation of Breakthrough Times for Mercury

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	> 16	9.31E-04	30.6%	77.4	736	74.5	69.6
A-101	SC1	> 16	1.00E-03	32.9%	81.3	735	81.6	36.2
AX-101	SD1	> 16	6.00E-04	19.7%	70.7	737	73.0	93.6
AX-101	SC1	14.8	5.57E-04	18.3%	80.2	733	63.3	101
702-AZ	SD1	> 16	2.40E-03	78.9%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	2.40E-03	78.8%	86.9	728	36.8	33.4
AN	SD1	> 16	3.23E-04	10.6%	71.3	725	72.8	25.1
AN	SC1	> 16	3.67E-04	12.0%	65.9	726	71.8	28.2
AP	SD1	> 16	1.54E-03	50.7%	70.5	742	46.9	50.5
AP	SC1	> 16	1.43E-03	46.8%	75.7	743	66.0	28.5
AW	SD1	> 16	2.15E-04	7.0%	65.9	734	75.0	35.7
AW	SC1	> 16	2.12E-04	7.0%	67.5	737	75.9	29.8
BY-108	SD1	> 16	2.23E-04	7.3%	78.5	714	64.7	38.6
BY-108	SC1	> 16	2.18E-04	7.2%	78.5	716	53.8	47.9
SY-102	SD1	> 16	1.43E-03	47.0%	78.8	723	65.7	435
SY-102	SC1	15	1.54E-03	50.7%	82.8	722	56.8	404
BY-110	SD1	> 16	2.04E-04	6.7%	41.3	735	72.3	Not calculated
BY-110	SC1	> 16	2.12E-04	7.0%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	3.62E-04	11.9%	85.4	718	63.4	Not calculated
SX-101	SC1	> 16	3.93E-04	12.9%	91.0	719	59.1	Not calculated
SX-104	SD1	> 16	1.47E-03	48.3%	67.6	710	82.6	Not calculated
SX-104	SC1	> 16	1.43E-03	46.8%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	14.5	1.33E-03	43.6%	51.0	742	79.2	Not calculated
702-AZ ('17)	SC1	> 16	1.24E-03	40.6%	49.6	729	79.6	Not calculated
AP ('18)	SD1	> 16	4.19E-04	13.8%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	3.88E-04	12.7%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	9.43E-04	30.9%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	7.69E-04	25.2%	86.8	718	45.4	Not calculated

Table B.5. Calculation of Breakthrough Times for 1,3-Butadiene

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					Cumulative Mass of VOC Fed (mg)
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	
A-101	SD1	> 16	0.0196	2.0%	77.4	736	74.5	69.6
A-101	SC1	> 16	0.0221	2.2%	81.3	735	81.6	36.2
AX-101	SD1	> 16	0.0195	2.0%	70.7	737	73.0	93.6
AX-101	SC1	> 16	0.0196	2.0%	80.2	733	63.3	101
702-AZ	SD1	> 16	0.0206	2.1%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	0.0222	2.2%	86.9	728	36.8	33.4
AN	SD1	> 16	0.0204	2.0%	71.3	725	72.8	25.1
AN	SC1	> 16	0.0198	2.0%	65.9	726	71.8	28.2
AP	SD1	> 16	0.0191	1.9%	70.5	742	46.9	50.5
AP	SC1	> 16	0.0192	1.9%	75.7	743	66.0	28.5
AW	SD1	> 16	0.0191	1.9%	65.9	734	75.0	35.7
AW	SC1	> 16	0.0194	1.9%	67.5	737	75.9	29.8
BY-108	SD1	> 16	0.0207	2.1%	78.5	714	64.7	38.6
BY-108	SC1	> 16	0.0204	2.0%	78.5	716	53.8	47.9
SY-102	SD1	3.8	1.0291	102.9%	85.4	720	67.9	124
SY-102	SC1	5.1	1.3601	136.0%	86.7	723	52.2	163
BY-110	SD1	> 16	0.0385	3.8%	53.6	720	64.0	Not calculated
BY-110	SC1	> 16	0.0380	3.8%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	0.0271	2.7%	85.4	718	63.4	Not calculated
SX-101	SC1	> 16	0.0237	2.4%	91.0	719	59.1	Not calculated
SX-104	SD1	> 16	0.0186	1.9%	67.6	710	82.6	Not calculated
SX-104	SC1	> 16	0.0189	1.9%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	> 16	0.0188	1.9%	51.0	742	79.2	Not calculated
702-AZ ('17)	SC1	> 16	0.0187	1.9%	49.6	729	79.6	Not calculated
AP ('18)	SD1	> 16	0.0244	2.4%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	0.0186	1.9%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	0.0192	1.9%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	0.0190	1.9%	86.8	718	45.4	Not calculated

Table B.6. Calculation of Breakthrough Times for Furan

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	> 16	3.12E-04	31%	77.4	736	74.5	69.6
A-101	SC1	> 16	1.57E-04	16%	81.3	735	81.6	36.2
AX-101	SD1	> 16	1.70E-04	17%	70.7	737	73.0	93.6
AX-101	SC1	> 16	1.55E-04	15%	80.2	733	63.3	100.8
702-AZ	SD1	> 16	2.50E-04	25%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	2.87E-04	29%	86.9	728	36.8	33.4
AN	SD1	9.8	5.73E-03	573%	84.6	721	59.1	291.3
AN	SC1	11.1	2.57E-03	257%	85.8	722	52.5	312.0
AP	SD1	> 16	4.42E-04	44%	71.3	725	72.8	25.1
AP	SC1	> 16	5.14E-04	51%	65.9	726	71.8	28.2
AW	SD1				70.5	742	46.9	43.3
AW	SC1	> 16	1.67E-03	167%	75.7	743	66.0	28.5
BY-108	SD1	> 16	1.51E-04	15%	78.5	714	64.7	38.6
BY-108	SC1	> 16	1.57E-04	16%	78.5	716	53.8	47.9
SY-102	SD1	> 16	1.58E-03	158%	65.9	734	75.0	35.7
SY-102	SC1	> 16	1.34E-03	134%	67.5	737	75.9	29.8
BY-110	SD1	> 16	1.26E-04	13%	41.3	735	72.3	Not calculated
BY-110	SC1	> 16	5.12E-04	51%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	3.57E-05	4%	85.4	718	63.4	Not calculated
SX-101	SC1	> 16	3.69E-05	4%	91.0	719	59.1	Not calculated
SX-104	SD1	> 16	3.22E-05	3%	67.6	710	82.6	Not calculated
SX-104	SC1	> 16	3.61E-05	4%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	10.6	1.59E-02	1591%	53.8	742	74.8	Not calculated
702-AZ ('17)	SC1	13.8	1.32E-02	1323%	50.5	727	78.2	Not calculated
AP ('18)	SD1	> 16	6.60E-04	66%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	4.16E-04	42%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	3.88E-04	39%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	3.73E-04	37%	86.8	718	45.4	Not calculated

Table B.7. Calculation of Breakthrough Times for 2,5-Dihydrofuran

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	> 16	2.11E-04	21.1%	77.4	736	74.5	69.6
A-101	SC1	> 16	1.31E-04	13.1%	81.3	735	81.6	36.2
AX-101	SD1	> 16	2.54E-04	25.4%	70.7	737	73.0	93.6
AX-101	SC1	> 16	2.63E-04	26.3%	80.2	733	63.3	100.8
702-AZ	SD1	> 16	3.20E-04	32.0%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	2.61E-04	26.1%	86.9	728	36.8	33.4
AN	SD1	14.1	1.52E-03	151.5%	78.8	723	65.7	435.3
AN	SC1	> 16	2.62E-04	26.2%	82.8	722	56.8	404.3
AP	SD1				70.5	742	46.9	50.5
AP	SC1	> 16	2.00E-04	20.0%	75.7	743	66.0	28.5
AW	SD1	> 16	2.53E-04	25.3%	65.9	734	75.0	35.7
AW	SC1	> 16	2.02E-04	20.2%	67.5	737	75.9	29.8
BY-108	SD1	> 16	2.01E-04	20.1%	78.5	714	64.7	38.6
BY-108	SC1	> 16	2.10E-04	21.0%	78.5	716	53.8	47.9
SY-102	SD1	> 16	2.60E-04	26.0%	71.3	725	72.8	25.1
SY-102	SC1	> 16	2.53E-04	25.3%	65.9	726	71.8	28.2
BY-110	SD1	> 16	2.19E-04	21.9%	41.3	735	72.3	Not calculated
BY-110	SC1	> 16	2.19E-04	21.9%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	3.55E-05	3.6%	85.4	718	63.4	Not calculated
SX-101	SC1	> 16	3.67E-05	3.7%	91.0	719	59.1	Not calculated
SX-104	SD1	> 16	3.28E-05	3.3%	67.6	710	82.6	Not calculated
SX-104	SC1	> 16	3.59E-05	3.6%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	> 16	1.95E-05	2.0%	51.0	742	79.2	Not calculated
702-AZ ('17)	SC1	> 16	1.92E-05	1.9%	49.6	729	79.6	Not calculated
AP ('18)	SD1	> 16	1.53E-04	15.3%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	6.84E-05	6.8%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	1.68E-04	16.8%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	1.62E-04	16.2%	86.8	718	45.4	Not calculated

Table B.8. Calculation of Breakthrough Times for 2,5-Dimethylfuran

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	> 16	2.81E-05	2.8%	77.4	736	74.5	69.6
A-101	SC1	> 16	2.79E-05	2.8%	81.3	735	81.6	36.2
AX-101	SD1	> 16	5.06E-05	5.1%	70.7	737	73.0	93.6
AX-101	SC1	> 16	4.37E-05	4.4%	80.2	733	63.3	100.8
702-AZ	SD1	> 16	5.06E-05	5.1%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	5.00E-05	5.0%	86.9	728	36.8	33.4
AN	SD1	> 16	2.93E-05	2.9%	78.8	723	65.7	435.3
AN	SC1	> 16	2.90E-05	2.9%	82.8	722	56.8	404.3
AP	SD1	> 16	2.79E-05	2.8%	70.5	742	46.9	50.5
AP	SC1	> 16	2.80E-05	2.8%	75.7	743	66.0	28.5
AW	SD1	> 16	4.83E-05	4.8%	65.9	734	75.0	35.7
AW	SC1	> 16	1.48E-05	1.5%	67.5	737	75.9	29.8
BY-108	SD1	> 16	2.83E-05	2.8%	78.5	714	64.7	38.6
BY-108	SC1	> 16	2.97E-05	3.0%	78.5	716	53.8	47.9
SY-102	SD1	> 16	1.72E-05	1.7%	71.3	725	72.8	25.1
SY-102	SC1	> 16	1.62E-05	1.6%	65.9	726	71.8	28.2
BY-110	SD1	> 16	2.84E-05	2.8%	41.3	735	72.3	Not calculated
BY-110	SC1	> 16	2.91E-05	2.9%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	5.74E-05	5.7%	85.4	718	63.4	Not calculated
SX-101	SC1	> 16	5.93E-05	5.9%	91.0	719	59.1	Not calculated
SX-104	SD1	3.9	1.61E-04	16.1%	75.9	708	82.6	Not calculated
SX-104	SC1	> 16	6.80E-05	6.8%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	> 16	3.23E-05	3.2%	51.0	742	79.2	Not calculated
702-AZ ('17)	SC1	> 16	3.18E-05	3.2%	49.6	729	79.6	Not calculated
AP ('18)	SD1	> 16	2.77E-05	2.8%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	2.78E-05	2.8%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	6.12E-05	6.1%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	6.01E-05	6.0%	86.8	718	45.4	Not calculated

Table B.9. Calculation of Breakthrough Times for NDMA

Tank	Cartridge	Breakthrough Time at 10% of OEL Concentration in Outlet – interpolated (hour)	Averages for Period Up to Calculated Breakthrough					
			Cartridge Inlet Concentration (ppm)	Cartridge Inlet Concentration (% of OEL)	Stream Temperature (F)	Inlet Pressure (Torr)	Relative Humidity (%)	Cumulative Mass of VOC Fed (mg)
A-101	SD1	> 16	5.95E-04	198%	77.4	736	74.5	69.6
A-101	SC1	> 16	3.45E-04	115%	81.3	735	81.6	36.2
AX-101	SD1	> 16	1.94E-03	647%	70.7	737	73.0	93.6
AX-101	SC1	> 16	2.15E-03	716%	80.2	733	63.3	100.8
702-AZ	SD1	> 16	2.14E-03	714%	89.0	729	34.6	25.9
702-AZ	SC1	> 16	1.92E-03	641%	86.9	728	36.8	33.4
AN	SD1	> 16	2.45E-04	82%	78.8	723	65.7	435.3
AN	SC1	> 16	2.32E-04	77%	82.8	722	56.8	404.3
AP	SD1	> 16	9.15E-03	3049%	70.5	742	46.9	50.5
AP	SC1	> 16	5.67E-03	1889%	75.7	743	66.0	28.5
AW	SD1	> 16	4.46E-03	1488%	65.9	734	75.0	35.7
AW	SC1	> 16	3.93E-03	1310%	67.5	737	75.9	29.8
BY-108	SD1	> 16	1.94E-04	65%	78.5	714	64.7	38.6
BY-108	SC1	> 16	4.07E-04	136%	78.5	716	53.8	47.9
SY-102	SD1	> 16	1.06E-02	3518%	71.3	725	72.8	25.1
SY-102	SC1	> 16	9.54E-03	3181%	65.9	726	71.8	28.2
BY-110	SD1	> 16	2.69E-03	897%	41.3	735	72.3	Not calculated
BY-110	SC1	> 16	2.68E-03	893%	52.7	721	71.9	Not calculated
SX-101	SD1	> 16	1.10E-02	3677%	85.4	718	63.4	Not calculated
SX-101	SC1	7.2	8.48E-03	2826%	101.2	717	51.2	Not calculated
SX-104	SD1	> 16	4.82E-03	1607%	67.6	710	82.6	Not calculated
SX-104	SC1	> 16	3.90E-03	1300%	77.0	712	85.9	Not calculated
702-AZ ('17)	SD1	> 16	3.76E-03	1255%	51.0	742	79.2	Not calculated
702-AZ ('17)	SC1	> 16	3.92E-03	1306%	49.6	729	79.6	Not calculated
AP ('18)	SD1	> 16	4.15E-03	1382%	57.2	692	71.7	Not calculated
AP ('18)	SC1	> 16	6.42E-03	2141%	52.6	724	78.2	Not calculated
AX ('17)	SD1	> 16	1.25E-04	42%	80.4	716	57.7	Not calculated
AX ('17)	SC1	> 16	1.45E-04	48%	86.8	718	45.4	Not calculated

Appendix C

Historical COPC Data Comparisons to Respirator Testing Conditions

Appendix C

Historical Data Comparisons to Respirator Cartridge-Testing Conditions

The historical headspace-characterization data and Industrial Hygiene (IH) data—referred to in this report as “TWINS HS” and “TWINS IH”—were obtained from the Tank Characterization Database via the Tank Waste Information Network System (TWINS). Pre-2006 vapor analysis results, stored in TWINS HS,⁽³⁷⁾ were obtained via a TWINS query on June 20, 2016, for all the tanks and exhaust systems in this report. The TWINS IH data were downloaded on the following dates as cartridge-test reporting progressed:

- October 7, 2016, for A-101 and SY-102 headspaces,
- December 21, 2016, for AX-101 headspace, 702-AZ stack tests in 2016 (no waste disturbance) and 2017 (waste disturbance), AW exhauster tests, and AN exhauster,
- March 8, 2017, for AP exhauster (as updated in 2017 revision of the report for the 2016 tests), and headspaces of SX-101 and SX-104,
- December 7, 2017, for AX exhauster data from the Site-Wide Industrial Hygiene Database (SWIHD) Source database, and
- May 9, 2018, for headspaces of BY-108 (2016 tests) and BY-110 (2018 tests), and AP exhauster (2018 tests).

Post-2014 headspace vapor data were obtained from the SWIHD by a query, producing a set referred to as “SWIHD HS.” There were several different download dates for these data as well, which are the same as for the TWINS IH data downloads.

Although surveys conducted after those in the listed downloads might provide higher historical maxima, the double-shell tank (DST) exhauster data in the downloads that were used cover a period back to 2005 and include a variety of DST activities. These data are expected to provide a sufficiently complete basis for comparison to cartridge data. In the case of single-shell tank headspaces, activities and surveys have been infrequent or nonexistent since the download dates, and again, the data in the downloads is expected to be sufficiently complete.

For the TWINS IH and SWIHD HS data sets, each line of data in the set represents a measurement made on the contents of a single sorbent tube (or other collector). In many cases, a single sample air stream passed through a series of two or more collectors, which meant the actual sample concentration was the sum of the contributions from all the collectors in the series. The intent of this sample collection method was to have most or all of the vapor deposited in the first collector, with a relatively small amount of breakthrough into the second collector.

The TWINS IH and SWIHD HS data sets currently do not contain explicit information to denote which data came from collectors in series or to identify which collectors belong in a set. This absence causes some difficulty in identifying which data should be summed to obtain the true concentration for the sample stream. For the purpose of providing a historical data set for comparison to cartridge data, use of

³⁷ No data have been added to TWINS HS since April 2005, so the June 2016 download does not require updating.

the uncombined raw data was considered to be adequate. Therefore, uncombined data were used for most of the data analyses.³⁸ As a result, some historical concentration maxima and averages will be underestimated in those analyses; the underestimates are expected to be within a factor of 2 of the true (summed) concentration value, because in almost all cases, there are no more than two collectors in series. Preliminary examination of the data suggested that when data combination is not performed, it is rare to underestimate concentrations of Chemicals of Potential Concern (COPC) by 40% or more.

Some historical concentration data were removed from consideration because they were flagged as having certain measurement quality issues. TWINS HS data were eliminated from consideration if they were:

- Quality Assurance samples (blanks, laboratory control samples, or spikes)
- Marked as suspect (Data Qualifier Flag S)
- Associated with a contaminant in a blank, trip blank, or field blank (Data Qualifier Flags B, T, or F)
- Marked with a laboratory-defined flag whose meaning was not generically defined and might indicate a serious data-quality issue (Data Qualifier Flag Y).

TWINS IH and SWIHD HS data were eliminated from consideration if they:

- Were associated with a contaminant in a blank (Data Qualifier Flag b or B), a laboratory control sample that was out of range (Data Qualifier flag a), a low-level standard with percent recovery outside the specified range (Data Qualifier flag L)³⁹
- Had an excessive relative percent difference between duplicates (Data Qualifier Flag c)
- Were marked with a laboratory-defined flag whose meaning was not generically defined and might indicate a serious data-quality issue (Data Qualifier Flag Y).

TWINS HS results associated with chemicals that were ambiguously identified (e.g., “alkane,” “unknown,” “C6 ketone”) were deleted unless the molecular weight of one of the chemicals could be unambiguously specified (e.g., “octanenitrile and others” was kept). In these mixture cases, where the Chemical ID consisted of a Chemical Abstracts Service (CAS) number followed by M, the molecular weight of the identified chemical was added to the data record, the CAS number was used for the Chemical ID, and the concentration expressed in parts per million (absent from the downloaded database) was calculated from the concentration in milligrams per cubic meter at 25°C and the molecular weight.

A number of chemicals in the TWINS IH data set had “needs conversion” notes in the concentration (mg/m³ and ppm) columns, rather than numbers, and required calculations to supply these concentrations. The calculations made use of values already in the database: the molecular weight, the Reported Value and its units, and the Sample Volume and its units. Here, a temperature of 25°C and a pressure of 1 atm were assumed.

³⁸ A method for combining collector concentrations for SWIHD HS data, though not for SWIHD Source or TWINS IH data, was developed partway through the cartridge testing project. Consequently, the impact of series collectors is accounted for (SWIHD HS collector concentrations were combined) only for the SX-101, SX-104, and BY-110 headspaces. The 2017 tank vapor COPC report describes the approach.

³⁹ Data with the flag “q” were not excluded, although this flag was temporarily used by the 222-S Laboratory to signify the same thing that the flag “L” currently signifies. There were relatively few data for which “q” was present. Such data were few enough and low enough in concentration that they would have had no effect on historical maxima and little effect on historical averages if they had been excluded.

The method described above was consistent with that used in the 2016 tank vapor COPC report [1] except that measurements that were non-reports—less than the reporting limit (RL) for the analyte—were excluded from the 2016 COPC analysis but were not excluded in this study. In addition, Data Quality Flags for TWINS IH and SWIHD HS data have been updated since the 2016 COPC report.[40]

Databases were further examined to make sure that for each cartridge-testing source, the concentration data subsets used in analyses were consistent with the location where the cartridge-testing sample was taken.

- *AP Stack, 2016 and 2018 Tests* – The TWINS HS database contained data identified as having the location “AP Ventilation.” These data were included as part of this analysis. The SWIHD HS database contained no data for the AP stack. AP Farm data whose survey titles indicated sampling from valve pits, motor housings, or other non-stack sources were excluded from this analysis. All of the TWINS IH data that were used in analysis were listed in the database as having the location “Primary Exhauster.” Data where the location was an individual tank name, “CAM Cabinet,” or “Inside Farm” were not used. They may have been relevant to in-stack concentrations, but their apparent location made that unclear. Almost all data that were used had “stack” or “exhauster” somewhere in the survey title. TWINS HS and TWINS IH data from before September 8, 2016, the date when the AP exhauster upgrade was completed, were used for comparison to FY16 cartridge data. TWINS IH data from after that date were used for comparison to FY18 cartridge data.
- *SY-102 Headspace* – The TWINS HS database contained only headspace data for the specific location given by the database as SY-102 and required no special selection. The SWIHD HS database contained no data for SY-102 or any other DST. The TWINS IH database required sorting so that only headspace data were used. All SY-related data in the TWINS IH database were given a Primary Location of “Primary Exhauster” or “Inside Farm.” Of these, most measurements had survey titles that included phrases such as “transfer...baseline,” “transfer...stack,” “S-complex... SUMMA sampling,” “stack sampling,” etc. These measurements were deemed not to qualify as SY-102 headspace samples because it was not clear whether they included SY-101 contributions at the shared SY stack. However, one set of samples with Primary Location listed as “Primary Exhauster” had a survey title of “SY-102 Riser #14 Headspace SUMMA.” These were deemed to be headspace samples, in spite of the exhauster label in the location, and were included in the analysis.
- *BY-108 Headspace, 2016 Tests* – The TWINS HS and SWIHD HS data for BY-108 were used without special selection. The SWIHD HS data for BY-108 were from three dates in October 2016. All BY Farm data in the TWINS IH database were attributed to individual tank locations; that is, there were no location designations such as “Inside Farm,” “Outside Farm,” etc. Of the data that had BY-108 as a Location, all had survey titles that included phrases such as “BY-108 BF COPC Sampling,” “BY-108 COPC Sampling,” or “BY-108 BF COPC Make-up.” Because the location was specified as BY-108, and many of the surveys contained BF (i.e., “Breather Filter”) in the title, all of the TWINS IH BY-108 data were considered appropriate for comparison to cartridge-testing samples from the tank headspace.
- *A-101 Headspace* – Data from the TWINS HS and SWIHD HS databases for A-101 were used without special selection. Almost all A Farm data in the TWINS IH database were attributed to individual tank locations, although three rows had location notations of “Inside Farm.” Only data that had A-101 as a location were used. All of these had survey titles that included phrases such as “Breather Filter Sampling,” or “Headspace.” Because the location was specified as A-101 and Survey Titles all referred to headspace or breather filter sampling, all TWINS IH data for A-101 were used in the analysis.

⁴⁰ The current Data Qualifier Flags are defined in the 222-S Laboratory Guidance Document, ATS-GD-1048, Rev. A-7, effective November 16, 2016.

- *AX-101 Headspace* – Data from the TWINS HS and SWIHD HS databases for AX-101 were used without special selection. AX Farm data in the TWINS IH database that had AX101 listed as a location and a survey title of “AX Breather Filters” were used for the analysis. Because the location was specified as AX-101 and the survey titles referred to breather filters, these TWINS IH AX-101 data were considered appropriate for comparison to cartridge-testing samples from the tank headspace. Other AX Farm data, which were not used in analysis, had a location designation of “Outside Farm.” These unused data had survey titles that included phrases such as “Characterizing sources around AX BF” or “Characterizing potential sources around AX.”
- *702-AZ Stack (AY/AZ exhaust), 2016 and 2017 Tests* – The TWINS HS database contained data identified as having the location “AY/AZ Vent Sys,” which were included as part of this analysis. The SWIHD HS database contained no data for the 702-AZ exhaust. The 702-AZ Farm data in the TWINS IH database had 702-AZ for the farm and listed several different locations: “Stack,” “Primary Stack,” “Ventilation System,” and “Building.” Of these, data from the first three locations were used in the analysis, but data with a “Building” location were not used. The unused data were from survey 13-01781, which was titled “AY Recirc Stack Baseline.”
- *AN Stack* – The TWINS HS database contained data identified as having the location “AN Ventilation,” which were included as part of this analysis. The SWIHD HS database contained no data for the AN stack. Of the AN Farm data in the TWINS IH database, data used in analysis all had the location “Primary Exhauster” listed. Data where the location was an individual tank name, “CAM Cabinet” or “Inside Farm” were not used. Survey titles for the “Inside Farm” location included descriptors such as “COPC” or “stack.” They may have been relevant to in-stack concentrations, but their apparent location made that unclear. All data with the location “Primary Exhauster” were used except for data with survey titles that included some form of the phrase “fan motor housing.” Almost all data that had “stack” or “train” somewhere in the survey title were used.
- *AW Stack* – Data from the TWINS HS database identified as having the location “AW Ventilation” were included as part of this analysis. No data for the AW stack was found in the SWIHD HS database. Data in the AW Farm data in the TWINS IH database that had the location “Primary Exhauster” listed were used in the analysis. Data with the location listed as an individual tank name, “CAM Cabinet,” or “Inside Farm” were not used. Survey Titles for the “Inside Farm” location included descriptors such as “evaporator pot dump,” “motor housing,” or “inlet filter AWxxx” were not considered relevant to analysis of in-stack concentrations. Data with locations identified as “Primary Exhauster” were used except when the survey title included “fan motor housing sampling.” Almost all the data that had “stack” somewhere in the survey title were used.
- *AX Exhauster* – The only data available for the AX exhauster were two Industrial Hygiene surveys that were carried out at the POR127 stack in October 2017. No headspace or other data for the AX Farm were used because that data predated the addition of the AX exhauster.
- *SX-101 and SX-104 Headspace* – The TWINS HS database contained headspace data for SX-101 and SX-104 measurements. All of the TWINS HS data for organic compounds and ammonia in these two SX tanks were from measurements made in 1999 or before. However, these data were taken while a sludge cooler (active ventilation) was in place. Active ventilation ended in 2003,⁴¹ and only data later than 2003 are relevant to the current passively ventilated conditions. The SWIHD HS database contained no headspace data for SX-101 and therefore, was not used in the SX-101 analysis. However, SWIHD HS data for SX-104, based on measurements taken in July 2015, were present. All of the TWINS IH data that had “SX101” or “SX104” noted in the “Location” field of the database were used. These data had survey titles that alluded to “BF” (breather filter) and “S-complex COPC summa sampling,” and were taken in 2006.

⁴¹ Email from JE Meacham to LA Mahoney, “RE: Exhauster system changes,” December 21, 2017, 3:11:18 PM.

- *BY-110 Headspace* – The TWINS HS database contained BY-110 headspace data, all of which were from measurements made in 1997 or before. Since that time, there have been no operational changes in ventilation or waste inventory; therefore, the TWINS HS data are considered applicable. The SWIHD HS database also contained BY-110 data (July 28, 2015). All of the TWINS IH data that had “BY110” noted in the “Location” field of the database were used. These data were taken in 2008-2009 and had survey titles that alluded to “BF” (breather filter) or “COPC sampling.”

Maximum and average⁴² exhaust concentrations were found for each analyte for the combined TWINS IH and SWIHD HS⁴³ databases, as were counts of the number of measurements⁴⁴. These maxima are given in Table C.1 through Table C.4⁴⁵, together with Occupational Exposure Limits (OEL). Average concentrations were routinely affected by a number of non-reports and were deemed to be less valuable than historical maxima for comparison to cartridge inlet concentrations. Therefore, they are not presented in the tables, but only in the individual cartridge-testing reports [3-15]. Maximum cartridge inlet concentrations are presented as the first value in each cell, and maximum historical concentrations are presented following a “/”.

Because the TWINS HS data were older, and in many cases did not represent the current source from which cartridge-test samples were taken, they were considered to be not as representative of the vapors present during cartridge testing, and the default decision was to omit them from calculations. However, in some cases, the maximum and average concentrations for an analyte were considerably different if they were determined from a combination of all three databases. When this was the case, the results for the three-database combination are tabulated in individual cartridge-testing reports along with those for the default two-database combination. That is, Table F.1 in each of the individual cartridge-testing reports contains two rows for such a chemical instead of one, with the upper row (the default two-database combination) in normal font and the lower row (the two-database combination) in italics. The two criteria for tabulating this extra information were 1) that at least one concentration for the chemical exceeded the OEL and 2) that there was a significant difference between the value obtained from the two-database combination and that from the three-database combination. The significant difference could be either that there were data for the three-database set but no data for the two-database set (i.e., data only in TWINS HS), or that there was a difference of a factor of 3 or more, in either direction, between the value obtained from the two-database combination and that from the three-database combination. In Table C.1 through Table C.4, TWINS HS data (maximum measurements are indicated by italics) were used only when more recent data were not available, and when it was judged that the waste generating the vapor had not permanently changed so that early measurements were not applicable.

⁴² Arithmetic average.

⁴³ This evaluation used concentration data in SWIHD HS and converted them to %OEL rather than directly using the %OEL data in SWIHD HS. Although this approach was consistent with the methods used on the other two data sets, there are cases where it gave a %OEL value smaller than that found in the SWIHD database. This difference occurs because concentrations in SWIHD HS may be truncated to one or two significant figures, while the %OEL values in SWIHD HS are calculated from concentrations before truncation. The difference between %OEL based on truncated and non-truncated concentrations is small enough to have no effect on conclusions about whether cartridge maxima are consistent with historical maxima.

⁴⁴ Because the SWIHD HS database contained no stack data, the TWINS IH data were the only concentrations present in the two-database combination for the AP stack, AN stack, AW stack, and 702-AZ cases.

⁴⁵ All %OEL values were calculated from concentration data that had been rounded to a minimum of three significant figures.

Because the RLs on concentrations in the historical database were generally higher than the RLs or detection limits (DL) in the cartridge tests, it was necessary to analyze data in a way that would let the effect of less than RL historical data be recognized. To do this, it was assumed that all of the non-reports in the databases had concentrations equal to the measurements' RLs. If a maximum value was a non-report, it was marked with "<" in Table C.1 through Table C.4.

To better understand the historical maxima, the historical data sets were reviewed to determine which data were taken during planned tank operations that caused waste disturbance or were taken during or just after ventilation system outages. Such maxima are not relevant to the majority of cartridge tests that were performed during periods when no disturbances occurred. However, they could have relevance to the 2017 tests at 702-AZ, which were carried out during waste-disturbing activity (i.e., transfer).

Note that procedures already in place prevent air-purifying respirators from being used in downwind areas during certain types of planned operations; for example, waste transfers, other waste-disturbing activities, and ventilation restarts after outages. Tank farm personnel would use more protective equipment such as self-contained breathing apparatus or supplied air. Thus, maxima that come from data taken during these operations need to be recognized as such because they may be less pertinent to the intended purpose of cartridge testing.

Waste transfers, waste recirculation, and addition of water from evaporators are considered to be waste-disturbing activities in the discussion in this appendix. Raw water additions also are discussed when present; however, for dates when they are present without waste transfers, they are not taken as waste-disturbing events.

Only TWINS IH data were checked for disturbance conditions. Headspace data (TWINS and SWIHD) were not so reviewed because it was expected to be rare for headspace sampling to be conducted during planned operations that caused waste disturbances.

Table C.1. Comparison of Maximum Cartridge Inlet Concentrations in 2016 to Historical Tank Headspace

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Headspace Concentration (% of OEL / % of OEL) ¹			
			SY-102	2016 BY-108	A-101	AX-101
			Maximum	Maximum	Maximum	Maximum
Inorganic						
1 Ammonia	7664-41-7	25 ppm	8/13	1915/2576	484/592	801/376
2 Nitrous Oxide	10024-97-2	50 ppm	NM/NM	NM/1662 (4)	NM/4	NM/3
3 Mercury	7439-97-6	25 µg/m ³	<7/<12	52/68	34/44	24/24
Hydrocarbons						
4 1,3-Butadiene	106-99-0	1 ppm	<2/<2	138/338	<3/51	<2/<2
5 Benzene	71-43-2	0.5 ppm	0.1/<1.2	0.9/<11 (2)	0.1/2	0.2/<0.6
6 Biphenyl	92-52-4	0.2 ppm	<0.05/<2	<0.09/<5	<0.3/<2	<0.1/<0.5
Alcohols						
7 1-Butanol	71-36-3	20 ppm	0.3/0.06	5/318 (22)	0.1/0.2	0.3/0.2
8 Methanol	67-56-1	200 ppm	NM/0.09	NM/0.8 (0.01)	NM/0.2	NM/NM
Ketones						
9 2-Hexanone	591-78-6	5 ppm	0.008/<0.1	0.4/0.9	0.02/<0.2 (0.04)	0.06/<0.2 (0.02)
10 3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
11 4-Methyl-2-hexanone	105-42-0	0.5 ppm	<0.03/<0.8	0.3/<0.8 (0.4)	<0.03/<0.8	0.02/<0.2
12 6-Methyl-2-heptanone	928-68-7	8 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
13 3-Buten-2-one	78-94-4	0.2 ppm	0.2/<4	24/<29	0.4/<4 (1)	2/3
Aldehydes						
14 Formaldehyde	50-00-0	0.3 ppm	4/1	9/6	5/8	14/<26 (3)
15 Acetaldehyde	75-07-0	25 ppm	0.1/0.1	1/11	0.2/0.6	0.4/<0.7
16 Butanal	123-72-8	25 ppm	0.02/<0.03	0.1/0.5	0.008/0.06	0.02/<0.4 (0.03)
17 2-Methyl-2-butenal	1115-11-3	0.03 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
18 2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
New ² 2-Propenal	107-02-8	0.1 ppm	NM/6	NM/11	NM/6	NM/138
Furans and Substituted Furans						
19 Furan	110-00-9	1 ppb	<16/<704	819/54700 (1840)	45/<706 (175)	24/<387
20 2,3-Dihydrofuran	1191-99-7	1 ppb	<25/<37	75/<47	<25/<36	44/<37
21 2,5-Dihydrofuran	1708-29-8	1 ppb	<21/<684	278/<5660*	<26/<686	<28/<141
22 2-Methylfuran	534-22-5	1 ppb	<11/<584	39/<4840*	<15/<586	<16/<224
23 2,5-Dimethylfuran	625-86-5	1 ppb	<19/<27	<19/<34	<19/<26	<19/<27
24 2-Ethyl-5-methylfuran	1703-52-2	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
25 4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
26 3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
27 2-Pentylfuran	3777-69-3	1 ppb	<13/<19	<13/<24	<13/<18	<13/<19
28 2-Heptylfuran	3777-71-7	1 ppb	<11/<16	<11/6120* (<20)	<11/<15	<11/<16
29 2-Propylfuran	4229-91-8	1 ppb	<16/<23	<16/<30	<16/<23	<16/<23
30 2-Octylfuran	4179-38-8	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
31 2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
32 2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Phthalates						
33 Diethylphthalate	84-66-2	5 mg/m ³	<0.02/<0.4	<0.04/<1.3	<0.1/<0.3	<0.04/<0.2
Nitriles						
34 Acetonitrile	75-05-8	20 ppm	1/7	0.8/94	1/26	3/<2 (0.1)
35 Propanenitrile	107-12-0	6 ppm	<0.004/<0.1	0.4/<0.8 (0.5)	0.1/<0.1 (0.07)	0.2/0.07
36 Butanenitrile	109-74-0	8 ppm	<0.003/<0.09	0.2/<0.7 (0.4)	0.04/0.5	0.06/0.05
37 Pentanenitrile	110-59-8	6 ppm	0.005/<0.1	0.2/<0.8 (0.2)	0.02/<0.1	0.02/<0.08
38 Hexanenitrile	628-73-9	6 ppm	<0.003/<0.08	0.05/<0.7 (0.1)	<0.003/<0.2	0.2/<0.1
39 Heptanenitrile	629-08-3	6 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
40 2-Methylene butanenitrile	1647-11-6	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
41 2,4-Pentadienenitrile	1615-70-9	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Amines						
42 Ethylamine	75-04-7	5 ppm	<0.1/<0.4	4/<0.4	0.3/<0.5	<0.1/<0.4
Nitrosamines						
43 N-Nitrosodimethylamine	62-75-9	0.3 ppb	151/145	134/2063	224/417	932/533
44 N-Nitrosodiethylamine	55-18-5	0.1 ppb	<24/<90	35/<1030 (8)	74/<84 (60)	<23/<60
45 N-Nitrosomethylethylamine	10595-95-6	0.3 ppb	<9/<35	132/<413 (8)	<11/<33	16/<23
46 N-Nitrosomorpholine	59-89-2	0.6 ppb	<3/<13	18/<153 (8)	8/24	14/<9
Organophosphates						
47 Tributyl phosphate	126-73-8	0.2 ppm	<0.1/<1	<0.1/<3	<0.2/<1	<0.08/<0.6
48 Dibutyl butylphosphonate	78-46-6	0.007 ppm	<1/<29	<1/<91	<5/<29	<2/<17
Halogenated Hydrocarbons						
49 Chlorinated Biphenyls	Varies	1 mg/m ³	n/a/NM	n/a/NM	n/a/NM	n/a/NM
50 2-Fluoropropene	1184-60-7	0.1 ppm	n/a/NM	n/a/530 (n/a)	n/a/2	n/a/1

Table C.1. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Headspace Concentration (% of OEL / % of OEL) ¹				
			SY-102	2016 BY-108	A-101	AX-101	
			Maximum	Maximum	Maximum	Maximum	
Pyridines							
51	Pyridine	110-86-1	1 ppm	<0.2/<0.6	0.3/<5 (0.3)	0.2/<1 (0.2)	0.2/<0.5
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	<0.06/<1	0.5/<8 (0.8)	<0.06/<2	<0.05/<0.6
Organonitriles							
53	Methyl nitrite	624-91-9	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
54	Butyl nitrite	544-16-1	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Organonitrates							
55	Butyl nitrate	928-45-0	2.5 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Isocyanates							
59	Methyl isocyanate	624-83-9	20 ppb	n/a/NM	n/a/NM	n/a/<35	n/a/NM
Organometallics							
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM/NM	NM/NM	NM/NM	NM/NM

¹	"<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.
²	2-propenal and dimethylmercury were added to the COPC List in September, 2017.
*	Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc) Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.
##	Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets [#], if present, indicate the maximum concentration measured during conditions where no disturbing activities were identified.
<i>italics</i>	Indicates that the historic concentration data is pre-2006 TWINS headspace results (often 1994-1997 data). Where more recent data are 10% or less of the 1990s maximum, the more recent maximum is included in parentheses without italics, using only the above-report maximum if available.
n/a	Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).
NM	Not measured or not reported (cartridge inlet) or no measurement reported in databases (historic maximum).
	Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Heavy-line cell border indicates the bounding cartridge-inlet maximum concentration over all tests; border is applied only if there was at least one test in which measurement was performed for the COPC (not nitrous oxide, for example), and an above-report concentration (historic or cartridge) was more than 50% of the OEL in any of the tests.

Table C.2. Comparison of 2016 Cartridge Inlet Concentrations to Historical Tank Farm Exhauster Maximum Concentrations

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Exhauster Concentration (% of OEL / % of OEL) ¹				
			2016 AP Exhauster (Old Exhauster)	2016 702-AZ Exhauster (Undisturbed Test)	AW Exhauster	AN Exhauster	
			Maximum	Maximum	Maximum	Maximum	
Inorganic							
1	Ammonia	7664-41-7	25 ppm	279/476	76/676 [275]	106/644 [192]	130/536 [336]
2	Nitrous Oxide	10024-97-2	50 ppm	NM/50 [13]	NM/<100	NM/23 [9]	NM/55
3	Mercury	7439-97-6	25 µg/m ³	56/468 [84]	84/468 [102]	7/1184 [13]	16/1824 [234]
Hydrocarbons							
4	1,3-Butadiene	106-99-0	1 ppm	<2/<15	<4/11	<2/<103* (17) [9]	<2/<15
5	Benzene	71-43-2	0.5 ppm	0.1/<8 (0.18)	0.4/<7 (0.9)	0.04/<3 (0.1)	0.06/<4
6	Biphenyl	92-52-4	0.2 ppm	<0.04/<3	<24* (<0.1)/<4	<0.1/<0.6	<0.6/2
Alcohols							
7	1-Butanol	71-36-3	20 ppm	0.3/0.6	0.3/0.5	1/6	0.2/15 [3]
8	Methanol	67-56-1	200 ppm	NM/<0.6 (0.3)	NM/<1 (0.1)	NM/<0.8	NM/<0.6
Ketones							
9	2-Hexanone	591-78-6	5 ppm	0.008/<0.8 (0.1)	0.02/<0.4 (0.02)	0.01/<0.3 (0.3)	0.004/<0.4 (0.2)
10	3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
11	4-Methyl-2-hexanone	105-42-0	0.5 ppm	<0.03/0.3	<0.06/<0.2	<0.03/<0.1	0.05/<0.4
12	6-Methyl-2-heptanone	928-68-7	8 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
13	3-Buten-2-one	78-94-4	0.2 ppm	0.3/<2 (1)	1/<3 (2)	0.3/<3 (2)	0.5/<3 (3)
Aldehydes							
14	Formaldehyde	50-00-0	0.3 ppm	6/33 [26]	3/<23 (5)	3/<32 (19) [3]	4/75 [64]
15	Acetaldehyde	75-07-0	25 ppm	0.1/0.7	0.06/<0.7 (0.1)	0.07/<0.9 (0.1)	0.06/0.8
16	Butanal	123-72-8	25 ppm	0.02/<0.2 (0.03)	0.02/<0.5 (0.02)	0.009/<0.5 (0.09)	0.002/<0.5 (0.1)
17	2-Methyl-2-butenal	1115-11-3	0.03 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
18	2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
New ²	2-Propenal	107-02-8	0.1 ppm	NM/<108	NM/<146 (8)	NM/<173	NM/<144
Furans and Substituted Furans							
19	Furan	110-00-9	1 ppb	392/<5230* (280) [250]	<62 (58)/<14500* [79]	204/<1500 (181)	85/<3170* (678) [120]
20	2,3-Dihydrofuran	1191-99-7	1 ppb	<25/<36	<25/<36 (23)	<25/<12	<25/41
21	2,5-Dihydrofuran	1708-29-8	1 ppb	<21/<5620*	<105/<15500*	<27/<182 (12)	<28/<2750*
22	2-Methylfuran	534-22-5	1 ppb	<10/<1420*	<61 (17)/<3930*	<16/<116	<16/<2100*
23	2,5-Dimethylfuran	625-86-5	1 ppb	<19/<26	<19/<26	<19/<8	<19/<26
24	2-Ethyl-5-methylfuran	1703-52-2	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
25	4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
26	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
27	2-Pentylfuran	3777-69-3	1 ppb	<13/<18	<13/<18	<13/<6	<13/<18
28	2-Heptylfuran	3777-71-7	1 ppb	<11/<15	<11/<15	<11/<5	<11/<15
29	2-Propylfuran	4229-91-8	1 ppb	<16/<23	<16/<23	<16/<7	<16/<23
30	2-Octylfuran	4179-38-8	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
31	2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
32	2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Phthalates							
33	Diethylphthalate	84-66-2	5 mg/m ³	<0.02/0.3	<11* (<0.04)/<0.6 (0.2)	<0.06/0.4	<0.3/0.6
Nitriles							
34	Acetonitrile	75-05-8	20 ppm	0.04/4	0.2/3	0.5/2	1/<10 (1.7)
35	Propanenitrile	107-12-0	6 ppm	0.008/<0.7 (0.01)	0.04/<0.8 (0.02)	0.006/<0.3 (0.1)	0.005/<0.4 (0.05)
36	Butanenitrile	109-74-0	8 ppm	0.005/<0.5 (0.02)	0.03/<0.7 (0.01)	0.003/<0.2 (0.08)	0.002/<0.3 (0.1)
37	Pentanenitrile	110-59-8	6 ppm	<0.003/<0.3 (0.02)	0.01/<0.8	<0.004/0.08	0.007/<0.2 (0.03)
38	Hexanenitrile	628-73-9	6 ppm	<0.003/<0.1 (0.02)	0.02/<0.4	0.002/0.1	<0.003/<0.3 (0.04)
39	Heptanenitrile	629-08-3	6 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
40	2-Methylene butanenitrile	1647-11-6	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
41	2,4-Pentadienenitrile	1615-70-9	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Amines							
42	Ethylamine	75-04-7	5 ppm	0.5/17	<0.1/<0.9	<0.1/12	3/12
Nitrosamines							
43	N-Nitrosodimethylamine	62-75-9	0.3 ppb	3629/6333	760/820	1638/2163	4589/85667
44	N-Nitrosodiethylamine	55-18-5	0.1 ppb	<23/328 [53]	31/<209 [66]	<24/<194 (11)	71/<179
45	N-Nitrosomethylethylamine	10595-95-6	0.3 ppb	45/111	<10/<81 (10) [7]	14/<72 (8)	106/285 [257]
46	N-Nitrosomorpholine	59-89-2	0.6 ppb	23/52 [32]	<4/<28 (4)	6/<27 (6)	33/68
Organophosphates							
47	Tributyl phosphate	126-73-8	0.2 ppm	<0.07/<2	<19* (<0.08)/<3	<0.1/<0.4	<0.5/<1 (0.05)
48	Dibutyl butylphosphonate	78-46-6	0.007 ppm	<1/<55* (<1)	<377* (<2)/<45*	<2/<11	<10/<17
Halogenated Hydrocarbons							
49	Chlorinated Biphenyls	Varies	1 mg/m ³	n/a/NM	n/a/NM	n/a/NM	n/a/NM
50	2-Fluoropropene	1184-60-7	0.1 ppm	n/a/<2	n/a/NM	n/a/NM	n/a/<3

Table C.2. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Exhauster Concentration (% of OEL / % of OEL) ¹				
			2016 AP Exhauster (Old Exhauster)	2016 702-AZ Exhauster (Undisturbed Test)	AW Exhauster	AN Exhauster	
			Maximum	Maximum	Maximum	Maximum	
Pyridines							
51	Pyridine	110-86-1	1 ppm	<0.05/<13 (0.1)	<0.2/<24* (0.09)	<0.04/<13 (2.1)	0.05/<266* (0.2)
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	<0.08/<29	<0.2/<81*	<0.05/<20 (0.06)	<0.05/<408*
Organonitrites							
53	Methyl nitrite	624-91-9	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
54	Butyl nitrite	544-16-1	0.1 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Organonitrates							
55	Butyl nitrate	928-45-0	2.5 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	n/a/NM	n/a/NM	n/a/NM	n/a/NM
Isocyanates							
59	Methyl isocyanate	624-83-9	20 ppb	n/a/<36	n/a/<36	n/a/<35	n/a/<35
Organometallics							
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM/5	NM/14	NM/0.1	NM/NM

¹ "<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.

² 2-propenal and dimethylmercury were added to the COPC List in September, 2017.

* Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc) Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.

Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets (#), if present, indicate the maximum concentration measured during conditions where no disturbing activities were identified.

Italics Indicates that the historic concentration data is pre-2006 TWINS headspace results (often 1994-1997 data). Where more recent data are 10% or less of the 1990s maximum, the more recent maximum is included in parentheses without italics, using only the above-report maximum if available.

n/a Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).

NM Not measured or not reported (cartridge inlet) or no measurement reported in databases (historic maximum).

Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.

Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.

Heavy-line cell border indicates the bounding cartridge-inlet maximum concentration over all tests; border is applied only if there was at least one test in which measurement was performed for the COPC (not nitrous oxide, for example), and an above-report concentration (historic or cartridge) was more than 50% of the OEL in any of the tests.

Table C.3. Comparison of Maximum Cartridge Inlet Concentrations in 2018 to Historical Tank Headspace Maximum Concentrations

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Headspace Concentration (% of OEL / % of OEL) ¹			
			SX-101	SX-104	BY-110	
			Maximum	Maximum	Maximum	
Inorganic						
1	Ammonia	7664-41-7	25 ppm	1385/25	828/1572	943/1704 (4)
2	Nitrous Oxide	10024-97-2	50 ppm	NM/4	NM/35	NM/250 (6)
3	Mercury	7439-97-6	25 µg/m ³	14/<0.2	67/32	<8/<12
Hydrocarbons						
4	1,3-Butadiene	106-99-0	1 ppm	6/<0.2	<2/29	<4/258
5	Benzene	71-43-2	0.5 ppm	0.8/<0.6	0.4/0.8	0.3/2
6	Biphenyl	92-52-4	0.2 ppm	<0.2/<0.1	0.09/<0.09	<0.03/<0.3
Alcohols						
7	1-Butanol	71-36-3	20 ppm	0.7/0.05	0.1/0.6	2/0.4
8	Methanol	67-56-1	200 ppm	NM/NM	NM/NM	NM/<0.8
Ketones						
9	2-Hexanone	591-78-6	5 ppm	0.2/<0.08	0.4/0.2	0.1/0.8
10	3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	n/a/NM	n/a/NM	n/a/NM
11	4-Methyl-2-hexanone	105-42-0	0.5 ppm	0.08/NM	0.2/NM	0.1/1
12	6-Methyl-2-heptanone	928-68-7	8 ppm	n/a/NM	n/a/NM	0.04/NM
13	3-Buten-2-one	78-94-4	0.2 ppm	0.6/<3	1/5	3/<1
Aldehydes						
14	Formaldehyde	50-00-0	0.3 ppm	9/5	5/5	2/6
15	Acetaldehyde	75-07-0	25 ppm	0.5/NM	0.3/0.9	0.4/1
16	Butanal	123-72-8	25 ppm	0.03/0.04	0.02/0.5	0.6/0.3
17	2-Methyl-2-butenal	1115-11-3	0.03 ppm	n/a/NM	n/a/NM	n/a/NM
18	2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
New ²	2-Propenal	107-02-8	0.1 ppm	<0.9/NM	<0.9/<0.9	<1/<0.9
Furans and Substituted Furans						
19	Furan	110-00-9	1 ppb	169/<230	<29/<310 (143)	168/295
20	2,3-Dihydrofuran	1191-99-7	1 ppb	<3/NM	10/<34	<3/309
21	2,5-Dihydrofuran	1708-29-8	1 ppb	<53/<730	<53/<980	<23/457
22	2-Methylfuran	534-22-5	1 ppb	<13/<1300	<20/<1800	11/<206
23	2,5-Dimethylfuran	625-86-5	1 ppb	<6/NM	27* (14)/<25	<3/<26
24	2-Ethyl-5-methylfuran	1703-52-2	1 ppb	n/a/NM	n/a/NM	n/a/NM
25	4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	n/a/NM	n/a/NM	n/a/NM
26	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	n/a/NM	n/a/NM	n/a/NM
27	2-Pentylfuran	3777-69-3	1 ppb	<5/NM	<5/<17	<3/<18
28	2-Heptylfuran	3777-71-7	1 ppb	<4/NM	<4/<14	<3/<15
29	2-Propylfuran	4229-91-8	1 ppb	<4/NM	<4/<21	<2/<23
30	2-Octylfuran	4179-38-8	1 ppb	n/a/NM	n/a/NM	n/a/NM
31	2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	n/a/NM	n/a/NM	n/a/NM
32	2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	n/a/NM	n/a/NM	n/a/NM
Phthalates						
33	Diethylphthalate	84-66-2	5 mg/m ³	<0.1/<0.02	<0.04/<0.01	0.02/<0.06
Nitriles						
34	Acetonitrile	75-05-8	20 ppm	1/<0.02	2/14	1/27
35	Propanenitrile	107-12-0	6 ppm	0.09/<0.06	0.05/<0.08 (0.05)	0.05/0.2
36	Butanenitrile	109-74-0	8 ppm	0.08/<0.2	0.05/<0.3 (0.08)	0.1/0.2
37	Pentanenitrile	110-59-8	6 ppm	0.03/<0.2	0.04/<0.2	0.03/<0.04
38	Hexanenitrile	628-73-9	6 ppm	0.02/<0.09	0.03/<0.1 (0.02)	0.02/0.07
39	Heptanenitrile	629-08-3	6 ppm	n/a/NM	n/a/NM	n/a/NM
40	2-Methylene butanenitrile	1647-11-6	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
41	2,4-Pentadienenitrile	1615-70-9	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
Amines						
42	Ethylamine	75-04-7	5 ppm	<0.3/NM	<0.09/<0.7	0.9/<0.4
Nitrosamines						
43	N-Nitrosodimethylamine	62-75-9	0.3 ppb	4750/<2	2119/9300	1874/<18
44	N-Nitrosodiethylamine	55-18-5	0.1 ppb	57/<5	412/<37	150/<39
45	N-Nitrosomethylethylamine	10595-95-6	0.3 ppb	69/<2	32/<14	252/<15
46	N-Nitrosomorpholine	59-89-2	0.6 ppb	9/<0.8	11/<6	<2/<6
Organophosphates						
47	Tributyl phosphate	126-73-8	0.2 ppm	<0.2/<0.06	<0.07/<0.06	<0.03/<0.15
48	Dibutyl butylphosphonate	78-46-6	0.007 ppm	<4/<1	<1/<1	<0.4/<256 (<4)
Halogenated Hydrocarbons						
49	Chlorinated Biphenyls	Varies	1 mg/m ³	n/a/NM	n/a/NM	n/a/NM
50	2-Fluoropropene	1184-60-7	0.1 ppm	n/a/<2	n/a/<3	n/a/NM

Table C.3. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Headspace Concentration (% of OEL / % of OEL) ¹			
			SX-101	SX-104	BY-110	
			Maximum	Maximum	Maximum	
Pyridines						
51	Pyridine	110-86-1	1 ppm	0.07/<0.1	0.05/0.2	0.1/<0.7 (0.3)
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	<0.04/<0.4	<0.04/<0.4	0.03/<1
Organonitrites						
53	Methyl nitrite	624-91-9	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
54	Butyl nitrite	544-16-1	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
Organonitrates						
55	Butyl nitrate	928-45-0	2.5 ppm	n/a/NM	n/a/NM	n/a/NM
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	n/a/NM	n/a/NM	n/a/NM
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	n/a/NM	n/a/NM	n/a/NM
Isocyanates						
59	Methyl isocyanate	624-83-9	20 ppb	n/a/NM	n/a/NM	n/a/NM
Organometallics						
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM/NM	NM/NM	NM/NM

¹	"<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.
²	2-propenal and dimethylmercury were added to the COPC List in September, 2017.
*	Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc) Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.
##	Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets (#), if present, indicate the maximum concentration measured during conditions where no disturbing activities were identified.
<i>italics</i>	Indicates that the historic concentration data is pre-2006 TWINS headspace results (often 1994-1997 data). Where more recent data are 10% or less of the 1990s maximum, the more recent maximum is included in parentheses without italics, using only the above-report maximum if available.
n/a	Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).
NM	Not measured or not reported (cartridge inlet) or no measurement reported in databases (historic maximum).
	Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Heavy-line cell border indicates the bounding cartridge-inlet maximum concentration over all tests; border is applied only if there was at least one test in which measurement was performed for the COPC (not nitrous oxide, for example), and an above-report concentration (historic or cartridge) was more than 50% of the OEL in any of the tests.

Table C.4. Comparison of Maximum Cartridge Inlet Concentrations in 2017–2018 to Historical Tank Farm Exhauster Maximum Concentrations

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Exhauster Concentration (% of OEL / % of OEL) ¹			
			2017 702-AZ Exhauster (Waste Disturbance)	AX Exhauster	2018 AP Exhauster (New Exhauster)	
			Maximum	Maximum	Maximum	
Inorganic						
1	Ammonia	7664-41-7	25 ppm	310/676	24/13	95/412
2	Nitrous Oxide	10024-97-2	50 ppm	NM/<100	NM/NM	NM/NM
3	Mercury	7439-97-6	25 µg/m ³	53/468	33/20	16/<50 (32)
Hydrocarbons						
4	1,3-Butadiene	106-99-0	1 ppm	<2/11	<2/NM	7/<1
5	Benzene	71-43-2	0.5 ppm	2/<7 (0.9)	0.06/NM	0.06/<2
6	Biphenyl	92-52-4	0.2 ppm	<0.09/<4	0.05/NM	<0.05/<0.6
Alcohols						
7	1-Butanol	71-36-3	20 ppm	0.3/0.5	0.02/NM	0.06/0.2
8	Methanol	67-56-1	200 ppm	9/<1 (0.1)	NM/NM	NM/NM
Ketones						
9	2-Hexanone	591-78-6	5 ppm	0.1/<0.4 (0.02)	0.005/NM	0.005/<0.2
10	3-Methyl-3-butene-2-one	814-78-8	0.02 ppm	n/a/NM	n/a/NM	n/a/NM
11	4-Methyl-2-hexanone	105-42-0	0.5 ppm	0.09/<0.2	<0.02/NM	<0.02/<0.4
12	6-Methyl-2-heptanone	928-68-7	8 ppm	0.03/NM	n/a/NM	n/a/NM
13	3-Buten-2-one	78-94-4	0.2 ppm	0.1/<3 (2)	0.2/NM	0.4/<5 (2)
Aldehydes						
14	Formaldehyde	50-00-0	0.3 ppm	1/<23 (5)	17/11	1/2
15	Acetaldehyde	75-07-0	25 ppm	0.6/<0.7 (0.1)	0.3/0.5	0.06/0.09
16	Butanal	123-72-8	25 ppm	0.01/<0.5 (0.02)	0.004/0.01	0.003/<0.04 (0.008)
17	2-Methyl-2-butenal	1115-11-3	0.03 ppm	n/a/NM	n/a/NM	n/a/NM
18	2-Ethyl-hex-2-enal	645-62-5	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
New ²	2-Propenal	107-02-8	0.1 ppm	<1/<146 (8)	<0.9/<1	<0.9/<12
Furans and Substituted Furans						
19	Furan	110-00-9	1 ppb	2995/<14500* (79)	<40/<6	104/715
20	2,3-Dihydrofuran	1191-99-7	1 ppb	17/<36 (23)	<3/<6	<3/<73
21	2,5-Dihydrofuran	1708-29-8	1 ppb	<20/<15500*	<18/<6	<25/<290
22	2-Methylfuran	534-22-5	1 ppb	14/<3930*	<10/<5	<10/<247
23	2,5-Dimethylfuran	625-86-5	1 ppb	<3/<26	<6/<4	<3/<53
24	2-Ethyl-5-methylfuran	1703-52-2	1 ppb	n/a/NM	n/a/NM	n/a/NM
25	4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9	1 ppb	n/a/NM	n/a/NM	n/a/NM
26	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4	1 ppb	n/a/NM	n/a/NM	n/a/NM
27	2-Pentylfuran	3777-69-3	1 ppb	7/<18	<5/<3	<3/<37
28	2-Heptylfuran	3777-71-7	1 ppb	<2/<15	7/<3	<3/<31
29	2-Propylfuran	4229-91-8	1 ppb	<3/<23	<4/<4	<2/<47
30	2-Octylfuran	4179-38-8	1 ppb	n/a/NM	n/a/NM	n/a/NM
31	2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5	1 ppb	n/a/NM	n/a/NM	n/a/NM
32	2-(2-Methyl-6-oxoheptyl)furan	51595-87-0	1 ppb	n/a/NM	n/a/NM	n/a/NM
Phthalates						
33	Diethylphthalate	84-66-2	5 mg/m ³	<0.04/<0.6 (0.2)	<0.02/NM	<0.02/<0.1
Nitriles						
34	Acetonitrile	75-05-8	20 ppm	0.6/3	0.08/NM	0.05/<5 (0.3)
35	Propanenitrile	107-12-0	6 ppm	0.03/<0.8 (0.02)	0.02/NM	0.005/<0.04
36	Butanenitrile	109-74-0	8 ppm	0.02/<0.7 (0.01)	0.01/NM	0.002/<0.04
37	Pentanenitrile	110-59-8	6 ppm	0.009/<0.8	0.004/NM	<0.003/<0.04
38	Hexanenitrile	628-73-9	6 ppm	0.004/<0.4	0.001/NM	<0.002/<0.03
39	Heptanenitrile	629-08-3	6 ppm	n/a/NM	n/a/NM	n/a/NM
40	2-Methylene butanenitrile	1647-11-6	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
41	2,4-Pentadienenitrile	1615-70-9	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
Amines						
42	Ethylamine	75-04-7	5 ppm	0.4/<0.9	<0.1/NM	0.09/<0.3 (0.2)
Nitrosamines						
43	N-Nitrosodimethylamine	62-75-9	0.3 ppb	1578/820	73/46	2681*/5267
44	N-Nitrosodiethylamine	55-18-5	0.1 ppb	398/<209 (66)	18/<3	<11/<48 (17)
45	N-Nitrosomethylamine	10595-95-6	0.3 ppb	26/<81 (10)	6/2	21/49
46	N-Nitrosomorpholine	59-89-2	0.6 ppb	4/<28 (4)	43/151	3/16
Organophosphates						
47	Tributyl phosphate	126-73-8	0.2 ppm	<0.07/<3	<0.06/NM	<0.06/<0.3
48	Dibutyl butylphosphonate	78-46-6	0.007 ppm	<1/<45*	<0.7/NM	<0.6/<10
Halogenated Hydrocarbons						
49	Chlorinated Biphenyls	Varies	1 mg/m ³	n/a/NM	n/a/NM	n/a/NM
50	2-Fluoropropene	1184-60-7	0.1 ppm	n/a/NM	n/a/NM	n/a/NM

Table C.4. (continued)

COPC Number & Name	CAS Number	Occupational Exposure Limit (OEL)	Cartridge Inlet / Historic Exhauster Concentration (% of OEL / % of OEL) ¹			
			2017 702-AZ Exhauster (Waste Disturbance)	AX Exhauster	2018 AP Exhauster (New Exhauster)	
			Maximum	Maximum	Maximum	
Pyridines						
51	Pyridine	110-86-1	1 ppm	0.1/<24* (0.09)	0.01/NM	<0.04/<0.3
52	2,4-Dimethylpyridine	108-47-4	0.5 ppm	<0.08/<81*	<0.04/NM	<0.05/<0.4
Organonitrites						
53	Methyl nitrite	624-91-9	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
54	Butyl nitrite	544-16-1	0.1 ppm	n/a/NM	n/a/NM	n/a/NM
Organonitrates						
55	Butyl nitrate	928-45-0	2.5 ppm	n/a/NM	n/a/NM	n/a/NM
56	1,4-Butanediol, dinitrate	3457-91-8	0.05 ppm	n/a/NM	n/a/NM	n/a/NM
57	2-Nitro-2-methylpropane	594-70-7	0.3 ppm	n/a/NM	n/a/NM	n/a/NM
58	1,2,3-Propanetriol, 1,3-dinitrate	623-87-0	0.05 ppm	n/a/NM	n/a/NM	n/a/NM
Isocyanates						
59	Methyl Isocyanate	624-83-9	20 ppb	n/a/<36	NM/NM	n/a/NM
Organometallics						
New ²	Dimethylmercury	593-74-8	0.010 mg/m ³ (as Hg)	NM/14	NM/NM	NM/3

¹	"<" indicates the maximum is from a nonreport (<RL) analysis result, and reported (>RL) values for the COPC were not obtained or are less than 0.01% of the OEL. Value in parenthesis, if present, indicates the maximum reported (detected) value >RL.
²	2-propenal and dimethylmercury were added to the COPC List in September, 2017.
*	Suspect data due to sample quality issue discussed in Appendix C (e.g., low sample volume, more than one significant data quality flag, etc) Value in parenthesis, (#), if present, indicates the maximum reported (detected) value >RL, or best estimate of true value.
##	Maximum concentrations that were obtained during waste-disturbing or ventilation-disturbing activities are noted in red font. Values in brackets (#), if present, indicate the maximum concentration measured during conditions where no disturbing activities were identified.
<i>italics</i>	Indicates that the historic concentration data is pre-2006 TWINS headspace results (often 1994-1997 data). Where more recent data are 10% or less of the 1990s maximum, the more recent maximum is included in parentheses without italics, using only the above-report maximum if available.
n/a	Indicates that sampling and analysis have been performed but the analyte has not been detected above thresholds for reporting of tentatively identified compounds (TICs).
NM	Not measured or not reported (cartridge inlet) or no measurement reported in databases (historic maximum).
	Values highlighted in red indicate cartridge inlet concentrations that were significantly lower than the applicable historical maximum (<20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Values highlighted in yellow indicate cartridge inlet concentrations that were lower than the applicable historical maximum (<50% but >20% of historical). Values are highlighted only if 1) the historic maximum represented an above-report or above detect value, 2) either the cartridge or historical maximum was higher than tank farm action level of 50% of OEL, and 3) the historic maximum was one measured during undisturbed headspace conditions, for undisturbed cartridge tests, or any conditions, for tests during disturbance.
	Heavy-line cell border indicates the bounding cartridge-inlet maximum concentration over all tests; border is applied only if there was at least one test in which measurement was performed for the COPC (not nitrous oxide, for example), and an above-report concentration (historic or cartridge) was more than 50% of the OEL in any of the tests.

The first type of information used to identify waste-disturbing or ventilation-disturbing activities was the title of the Industrial Hygiene survey in the TWINS IH database. Surveys were considered to reflect waste-disturbing operations if their titles included a reference to “retrieval”, “transfer”, “tank Y to tank Z”, “Z% complete” (referring to a retrieval), ALC (air-lift circulator), recirculation, portable exhausters on single-shell tanks, or the 242-A evaporator (implying an ongoing evaporation campaign). However, if the title also included the words “baseline”, “re”, or “start”, the survey was considered to precede transfer operations and to not include the effects of waste disturbance. Ventilation-disturbing activities were identified by survey titles that included a reference to “outage”, “restart of exhauster”, “exhauster startup”, or just “startup” if there was no additional reference to a transfer or retrieval.

The information in the survey title was tested and supplemented by consulting the TWINS databases of tank transfers (pre-2001 and post-2000).⁴⁶ These databases are related to Best Basis Inventory (BBI)⁴⁷ determinations and focus on activities that change the waste inventories in tanks. They do not include any information about ventilation disturbances, and only include information on in-tank recirculation if it indirectly changed the inventory (e.g., by inducing a gas release).

The cartridge inlet concentrations discussed in the following sections include (as appropriate) above-report concentrations, below-report concentrations (in which case RLs were used for comparison), and below-detects (in which case DLs were used for comparison). The use of below-detect versus below-report depends on the type of sample analysis. For more background, see Appendix D, which discusses the difference between DLs and RLs for furans.

The larger discrepancies, or apparent discrepancies, between historical data and cartridge inlet concentrations are discussed below. Discrepancies are discussed if the maximum historical concentration of a compound was >10% of the OEL and the maximum cartridge inlet concentration was <50% of the historical value. However, discrepancies are considered significant only if the maximum historical concentration was >10% of the OEL and the maximum cartridge inlet concentration is <20% of the historical value. In some cases other COPCs (even if not discrepant by the above definition) are also discussed. When the cartridge inlet maximum is greater than or equal to the historical, there is usually no discussion.

In cases where the cartridge inlet concentration (maximum or average) was below the RL or the DL, the RL or DL is used as a basis for comparison. The same approach is taken for historical concentrations that were below the RL (“below-report” or “<RL”).

C.1 AP Exhauster (2016 Tests): Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where there were differences the historical data were examined for explanations in the type or circumstances of sampling.

Generally speaking, AP Farm tanks with headspaces upstream of the AP stack have been active over the whole period of record. A number of waste transfers, exchanges, or receipts from the 242-A evaporator have occurred between 2000 (when TWINS headspace data were taken) and the initiation of 2016 cartridge testing (June 24, 2016). These changes in waste contents have included receipts from SY-102, BY tanks, and numerous interchanges within the A tank complex. The most recent activities, before cartridge testing, were in April 2016. So, on the one hand, the waste present in the AP tanks during cartridge testing could be different from that present during earlier stack sampling. On the other hand, activities in tanks affecting the AP stack will continue, and there is no way to be sure that historical data could not apply to future stack concentrations. Therefore, in the case of the AP stack, the age of historical data will not be taken as a reason to consider the historical data irrelevant.

⁴⁶ See the “Tank Transfers” menu item under <https://twins.labworks.org/twinsdata/Forms/About.aspx>. Note that many entries in these databases refer to inventory changes caused not by a waste-affecting operation but by re-baselining, changes in inventory calculation assumptions, changes in level instrumentation, etc. Some (not all) spontaneous gas releases also are included.

⁴⁷ The Best-Basis Inventory (BBI) establishes the inventory of the underground waste storage tanks at Hanford by using sample data, process knowledge, surveillance data, and waste stream composition information from the Hanford Defined Waste (HDW) computer model (Agnew SF, J. Boyer, RA Corbin, TB Duran, JR FitzPatrick, KA Jurgensen, TP Ortiz, and BL Young. 1997. *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4*. LA-UR-96-3860, Los Alamos National Laboratory, Los Alamos, New Mexico.).

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.1.1 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. The highest nitrous oxide concentration found in the TWINS IH database was 25 ppm (50% of the OEL). This concentration was measured on September 6, 2006, during a 242-A evaporator campaign. Two of the three above-reports were measured on May 9, 2006, during an SY-101 to AP-107 waste transfer (as recorded in the BBI activity database). The remaining above-report was measured on June 23, 2005, more than a month after the end of the last preceding waste transfer on May 18, 2005. This June 23, 2005, measurement of 6.73 ppm (13% of the OEL) is the only one considered to have occurred during non-disturbance conditions.

C.1.2 Mercury

The maximum cartridge inlet concentration of 56% of the OEL is low compared to the historical maximum concentration of 0.117 mg/m³ (468% of the OEL), although the average concentrations are similar for historical data and cartridge data. The maximum found in the historical data was measured on December 17, 2014, during a waste-disturbing activity, a tank-to-tank transfer from AP-104 to AW-102 (December 15-19, 2014, according to the BBI tank activity database). Other high historical concentrations, listed in order of decreasing concentration, were:

- 0.110 mg/m³, August 22, 2012, survey title “AP 104 Recirc Stack Sampling” – The BBI database confirms that AP-104 waste was being recirculated during August 20–23, 2012, which includes the survey date, with enough effect to release 3 kgal of gas.
- 0.0269 mg/m³, July 16, 2015, survey title indicates an evaporator campaign – The BBI database states that a transfer occurred from 242-A to AP-103 during July 12–22, 2015, which includes the survey date.

The highest of the remaining above-report concentrations is 0.0209 mg/m³ (84% of the OEL). This and all lower concentrations, whether measured during waste disturbance or not, are low enough that the cartridge inlet maximum is >20% of those historical data. The cartridge maximum is consistent with the non-disturbed historical concentrations.

C.1.3 1,3-Butadiene

The maximum cartridge inlet concentration of <2% of the OEL, which is below the DL, is low compared to the historical maximum concentration, a below-report datum that had an RL of 0.145 ppm (<15% of the OEL), although the average concentrations are similar for historical and cartridge data. Most of the historical RLs are 0.05 ppm (5% of the OEL) or less. There are no above-report historical measurements. Because the cartridge-test concentration was below its DL and there are no above-report historical data, it is unclear whether the inlet concentration was <20% of the historical maximum.

C.1.4 Formaldehyde

The maximum cartridge inlet concentration of 6% of the OEL is low compared to the historical maximum concentration of 0.0985 ppm (33% of the OEL). This maximum was measured on May 13, 2014, during a transfer. Other high historical concentrations, listed in order of decreasing concentration, were:

- 0.081 ppm, August 29, 2012, survey title indicates a transfer – The BBI database indicates a transfer from AP-104 to 241-AW-106 occurred during August 27–31, 2012, which includes the survey date.

- 0.078 ppm, April 30, 2012, survey title indicates a transfer baseline – The BBI database shows no AP Farm transfer on or near this date, which confirms the baseline.

The maximum above-report concentration for non-disturbed conditions was 0.078 ppm (26% of the OEL). The cartridge inlet maximum inlet concentration was about 20% of this non-disturbance historical maximum concentration and is considered to be significantly lower than historical data.

C.1.5 Furan

The maximum cartridge inlet concentration of 392% of the OEL (measured by the Carbotrap 300 TDU method) is very low compared to the historical maximum concentration, a below-report datum that had an RL of 52.3 ppb (<5230% of the OEL). That maximum historical measurement came from a Carbotrap 300 TDU sample taken on January 11, 2007. At 0.97 L, the sample volume was small compared to most of the AP samples in which furan was measured; this explains the high RL. The second highest RL was 8.4 ppb (<840% of the OEL), and all other RLs were less than 1 ppb (<100% of the OEL). The highest above-report historical concentrations, listed in order of decreasing concentration, were:

- 2.8 ppb, December 17, 2014, survey title indicates a transfer – The BBI database indicates a transfer from AP-104 to AW-102 during December 15-19, 2014, which includes the survey date.
- 2.5 ppb, September 21, 2012, survey title indicates a transfer baseline – The BBI database shows the last preceding AP Farm transfer ended on September 4, 2012, which confirms the baseline.

The maximum above-report concentration for non-disturbed conditions was 2.5 ppb (250% of the OEL). Three other above-report measurements that are titled as transfer baselines are also above 1 ppb (100% of the OEL). The cartridge inlet maximum inlet concentration is higher than 20% of the maximum historical above-report concentration under non-disturbed conditions and is considered to be consistent.

C.1.6 2,3-Dihydrofuran

The maximum cartridge inlet concentration of 2.5% of the OEL (a below-report for which the RL was 25% of the OEL) is low compared to the historical maximum concentration, a below-report datum from April 27, 2016, that had an RL of 0.356 ppb (<36% of the OEL). However, there are no above-report historical concentrations, so no firm conclusion can be drawn about where the cartridge inlet concentration for this chemical lies with respect to historical data.

C.1.7 2,5-Dihydrofuran, 2-Methylfuran

As for furan, the maximum and average historical concentrations are controlled by the RL from a 0.97 L Carbotrap 300 TDU sample. Because these two furan chemicals have no above-report historical data, no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.1.8 2,5-Dimethylfuran, 2-Pentylfuran, 2-Heptylfuran, 2-Propylfuran

The maximum and average cartridge inlet concentrations appear to be low compared to the historical maximum concentrations, which in all cases are below-report data. There are no above-report historical data for these chemicals, so no firm conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.1.9 Ethylamine

The maximum cartridge inlet concentration of 0.5% of the OEL is low compared to the historical maximum concentration of 0.829 ppm (17% of the OEL). The historical data maximum, from an above-report data subset of eight values, was measured on November 11, 2005, with no indication either in the survey title or the BBI activity database that a disturbance had occurred. The cartridge inlet maximum concentration is much <20% of the maximum historical above-report concentration under non-disturbed conditions.

C.1.10 N-nitrosodiethylamine

The maximum cartridge inlet concentration of <23% of the OEL, which is below the DL, is low compared to the historical maximum concentration of 0.328 ppb (328% of the OEL). This measurement was taken on August 16, 2012, during a tank-to-tank transfer from AW-106 to AP-101. There were six above-report concentrations in the data set. Other high above-report historical concentrations, listed in order of decreasing concentration, were:

- 0.088 ppb, August 22, 2012, during AP-104 recirculation (as was discussed for mercury data).
- 0.053 ppb, April 30, 2012, survey title indicates a transfer baseline – The BBI database shows no AP Farm transfer on or near this date, which confirms the baseline.

Of the six above-report concentrations in historical data, the highest for which there was no indication of disturbance was 0.053 ppm (53% of the OEL). Because the cartridge-test concentration was below its DL, it is unclear whether it was <20% of the non-disturbance historical maximum.

C.1.11 N-nitrosomethylethylamine

The maximum cartridge inlet concentration of 45% of the OEL is lower than the historical maximum concentration of 0.334 ppb (111% of the OEL). This measurement was taken on October 31, 2013, and was titled as a baseline for a tank-to-tank transfer from AN-101 to AP-104. According to the BBI tank activity database, the last AP Farm transfer had ended on September 25, 2013, which confirms the baseline. The maximum cartridge inlet concentration was <50% but >20% of the non-disturbance historical maximum, and therefore, not substantially lower than the historical concentration.

C.1.12 N-nitrosomorpholine

The maximum cartridge inlet concentration of 23% of the OEL is lower than the historical maximum concentration of 0.309 ppb (52% of the OEL). This measurement was taken on October 23, 2011 and was titled as a tank-to-tank transfer from AN-106 to AP-104. According to the BBI tank activity database, a transfer did occur on that date. There were 21 above-report concentrations in the data set. Other high above-report historical concentrations, listed in order of decreasing concentration, were:

- 0.26 ppb, August 6, 2012, survey title indicates an AP-101 to AP-105 transfer – The BBI database shows a transfer on this date.
- 0.20 ppb, August 22, 2012, during AP-104 recirculation (as was discussed for mercury data).
- 0.19 ppb, August 10, 2012, survey title indicates an AN-106 to AP-104 transfer – The BBI database shows a transfer from AP-105 to AP-101 on the preceding day, August 9, 2012. Headspace vapors could still have been elevated from a transfer that took place this soon before sampling.

Most of the remaining above-report data, whether measured during disturbance or not, are in the range from 0.11 ppb to 0.18 ppb (18 to 30% of the OEL). The maximum cartridge inlet concentration was <50% but >20% of the non-disturbance historical maxima, and therefore, was not substantially lower than undisturbed historical concentrations.

C.1.13 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <1% of the OEL, which is below the DL, is low compared to the historical maximum concentration, a below-report datum with an RL of 0.00387 ppm (55% of the OEL). The maximum historical measurement came from an April 26, 2005, SVOA sample with a volume of 0.25 L, which is a small volume compared to most of the AP samples in which DBBP was measured; this explains the high RL. All other historical RLs were ~1.3% of the OEL. The unusually high less than RL maximum accounts for the high average concentration as well. There are no above-report historical data for this chemical, so no firm conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.1.14 Pyridine

The maximum cartridge inlet concentration of <0.05% of the OEL is low compared to the historical maximum concentration, a below-report datum that had an RL of 0.127 ppm (<13% of the OEL). The historical measurement came from a July 24, 2013, 24.3 L pyridines sample. It is not clear why a sample with a volume this high had such a high RL. The second highest RL was 0.086 ppm (8.6% of the OEL) for a 0.97 L sample taken on January 11, 2007, and all other RLs were less than 0.01 ppm (1% of the OEL). The unusually high less than RL maximum accounts for the high average pyridine concentration as well.

There were three above-report concentrations in historical data. According to both the survey title and the BBI tank activity database, the highest concentration was 0.0012 ppm (0.12% of the OEL), which was measured on July 16, 2015, during a 242-A campaign. The highest for which no disturbance was indicated in the survey title was taken on July 31, 2014 and was 0.00053 ppm (0.05% of the OEL). The most recent AP Farm transfer had ended on May 28, 2014. The cartridge test inlet concentrations are considered to be similar to the non-disturbance historical data.

C.1.15 2,4-Dimethylpyridine

The maximum and average historical concentrations are controlled by the RL from the same 0.97 L Carbotrap 300 TDU sample that was mentioned as producing the second-high RL for pyridine. Because this substituted pyridine has no above-report historical data, no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.1.16 Methyl Isocyanate

This chemical was a tentatively identified compound at the inlet in cartridge testing. There is only one historical concentration, a below-report datum that had an RL of 0.00729 ppm (<36% of the OEL). Given the scarcity of data, no conclusion can be drawn about where this chemical's cartridge inlet concentration lies with respect to historical data.

C.1.17 Summary of Historical Data for the AP Exhauster (2016 Tests)

In summary, cartridge inlet concentrations for the AP exhauster that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance for the historical maximum: mercury.
- Differences arose from using the RLs of below-report data for the historical maximum: pyridine.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 1,3-butadiene, 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, 2-propylfuran, N-nitrosodiethylamine, dibutyl butylphosphonate, 2,4-dimethylpyridine, and methyl isocyanate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: formaldehyde and ethylamine.

C.2 SY-102 Headspace: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found the historical data were examined for explanations in the type or circumstances of sampling.

Tank SY-102 is an actively ventilated DST, as are the other tanks in the SY Farm. Ventilation is configured such that vapors do not cascade between SY tanks. Between 1999 and 2007, the SY-102 tank received waste from SY-101, S Farm, SX Farm, and U Farm. Sodium hydroxide was added in 2012 for corrosion control. Vapor data taken from the headspace during and after 2008 best represent the waste that was present at the date of the July 2016 cartridge test and is the most plausible basis for comparison to cartridge inlet concentrations. Post-2007 data are considered to have been taken under conditions of non-disturbance in SY-102, although there have been several small transfers from the 222-S laboratory into SY-101 since 2007, and these could conceivably have affected concentrations in the SY-102 headspace. Data taken earlier than 2008 do not appear in Table C.1, although they do appear in the SY-102 individual test report.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.2.1 Furan

The maximum cartridge inlet concentration of 16.1% of the OEL (a below-report measured by the Carbotrap 300 TDU, for which the RL was 16.1% of the OEL) is very low compared to the historical maximum concentration, which was a below-report SWIHD HS datum that had an RL of 7.04 ppb (<704% of the OEL). This was not an unusually high furan RL for Carbotrap 300 TDU samples in the SWIHD HS database. The furan RL for furan analysis samples was lower, 0.38 ppb (38% of the OEL) or less. All of the SY-102 SWIHD HS data were taken during June 14–21, 2016. There were no above-report historical headspace data in SWIHD HS or TWINS IH. The only above-report concentration was found in the TWINS HS database; it was measured in 2000, and therefore, came from an inventory that does not correspond to the one present during cartridge testing. Therefore, no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.2.2 2,3-Dihydrofuran, 2,5-Dihydrofuran, 2-Methylfuran, 2-Pentylfuran, 2-Heptylfuran

The situation for all these furan compounds is similar to that for furan. The historical maxima came from RLs for either the Carbotrap 300 TDU or the furans analysis method, and there were no above-report historical data from SWIHD HS or TWINS IH. As for furan, the high RLs for 2,5-dihydrofuran and 2-methylfuran come from SWIHD HS and are not unusually high for Carbotrap 300 TDU analyses. No conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.2.3 N-nitrosomethylethylamine

The maximum cartridge inlet concentration of <9% of the OEL, which is less than the DL, is low compared to the historical maximum concentration, a below-report with an RL of 0.104 ppb (<35% of the OEL). This historical RL was not unusually high for samples in the SWIHD HS database. There were no above-report concentrations in the historical data. No conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.2.4 N-nitrosomorpholine

The situation is similar to that for N-nitrosomethylethylamine. There were no above-report historical data, and the historical RL was not unusually high for samples in the SWIHD HS database. No conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.2.5 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <1.1% of the OEL, which is below its DL, is low compared to the historical maximum concentration, a below-report datum with RL of 0.002 ppm (<29% of the OEL). This historical RL was not unusually high for samples in the SWIHD HS database. There were no above-report concentrations in historical data. No conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.2.6 Summary of Historical Data for the SY-102 Headspace

In summary, cartridge inlet concentrations for the SY-102 headspace that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance for the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: furan, 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2-pentylfuran, 2-heptylfuran, N-nitrosomethylethylamine, N-nitrosomorpholine, and dibutyl butylphosphonate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: none.

C.3 BY-108 Headspace (2016 Tests): Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where there were differences the historical data were examined for explanations in the type or circumstances of sampling.

Tank BY-108 has been inactive throughout the period of record for which historical vapor concentration data have been collected. Regarding waste disturbances, it must be noted that BY Farm tanks are arranged in six-tank cascades that tie three tanks in BX Farm to three tanks in BY Farm. Tanks BX-107, BX-108, BX-109, BY-107, BY-108, and BY-109 are connected with each other by overflow lines through which vapors may move from one tank headspace to another [16]. Thus, it would have been physically possible for waste disturbances in any of five other tanks to have affected vapor concentrations in BY-108. However, there were no such waste-disturbing operations in any of the tanks of the BY-108-related cascades in the period during which vapor data were recorded. Hence none of the available data for BY-108 were taken during waste-disturbing conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.3.1 Ammonia

The maximum cartridge inlet concentration was 1915% of the OEL, compared to the historical maximum concentration of 644 ppm (2576% of the OEL). This historical data point comes from the TWINS IH database, which contains only one ammonia datum, and was a breather-filter measurement made on July 14, 2009. For comparison, five October 2016 samples in SWIHD HS were lower, containing 367 to 441 ppm ammonia. The maximum cartridge-inlet concentration was comparable to the historical maximum and more recent headspace data.

C.3.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. The maximum historical concentration found in the TWINS HS database was 831 ppm (1662% of the OEL). This concentration was measured on September 10, 1996. Forty measurements in TWINS HS are all above-report, ranging from 440 ppm to 831 ppm, and all were taken between 1994 and 1997. Only one recent measurement, made on July 15, 2009, was found in TWINS IH. However, this concentration of 1.8 ppm (3.6% of the OEL) was measured via a nitrous oxide badge, which probably did not describe the nitrous oxide concentration in the tank headspace.

C.3.3 Mercury

The maximum cartridge inlet concentration was 52.0% of the OEL. The value is comparable to the historical maximum, 0.0170 mg/m³ (concentration 68.0% of the OEL). This measurement came from SWIHD HS and was taken on October 6, 2016. The cartridge inlet maximum concentration is not significantly below the historical concentration.

C.3.4 1,3-Butadiene

The maximum cartridge inlet concentration of 138% of the OEL is low compared to the historical maximum concentration, the sole above-report datum from TWINS IH, which was taken on April 8, 2008. It had a concentration of 3.38 ppm (338% of the OEL). The 10 above-reports in TWINS HS were taken between 1994 and 1997 and ranged from 0.043 ppm to 0.174 ppm (4 to 17% of the OEL). For comparison, six October 2016 samples in SWIHD HS contained 1.79 to 2.64 ppm of butadiene. The maximum cartridge inlet concentration was <50% but >20% of the maximum historical measurement, and therefore, was not substantially lower than the historical record.

C.3.5 Benzene

The maximum cartridge inlet concentration of 0.86% of the OEL is low compared to the historical maximum concentration, a below-report datum that had an RL of 0.0529 ppm (<11% of the OEL). This RL was for a September 17, 2009, sample with a small volume of 0.15 L, producing an unusually high RL. The maximum relatively recent above-report concentration, excluding TWINS HS data, was 0.0100 ppm (2.00% of the OEL), found in the SWIHD HS database and measured in October 2016. There were no above-report historical data in TWINS IH. The numerous above-report historical data in TWINS HS, which were collected between 1994 and 1997, ranged from 0.016 ppm to 0.19 ppm (3 to 38% of the OEL).⁴⁸ The cartridge inlet concentration is <20% of the historical maximum and is considered significantly less than the maximum historical measurement, with the caveat that recent SWIHD HS headspace concentrations were close to the cartridge inlet maximum.

C.3.6 1-Butanol

The maximum cartridge inlet concentration of 5.0% of the OEL is slightly more than 20% of the TWINS IH maximum found from 2009 breather-filter data but is much lower than the 63.5 ppm (318% of the OEL) measured in the headspace on October 27, 1994. The above-report TWINS HS headspace data collected on other dates between 1994 and 1997 were between 4 and 22 ppm (20 to 110% of the OEL). The maximum headspace concentration in SWIHD HS was 4.17 ppm (20.9% of the OEL), measured on October 6, 2016, and there is also a slightly higher concentration of 4.32 ppm (21.6% of the OEL) in the TWINS IH database measured at 2009 at a breather filter. The cartridge inlet concentration is <20% of the historical maximum from TWINS HS and is about 25% of the more recent maximum from SWIHD HS. It is concluded that the cartridge inlet concentration was significantly lower than the historical maximum.

C.3.7 Acetaldehyde

The maximum cartridge inlet concentration of 1.1% of the OEL is lower than the maximum of 2.8 ppm (11.3% of the OEL) that was measured on April 8, 2008. This was the only measurement in TWINS IH. No data were found in TWINS HS, and the October 2016 SWIHD HS maximum was 0.302 ppm (1.21% of the OEL). The cartridge inlet concentration is <20% of the historical maximum and is considered significantly less than the historical maximum, with the caveat that several recent headspace concentrations were close to the cartridge inlet maximum.

⁴⁸ The TWINS HS maximum of 38% of the OEL does not appear in the tables because it does not fully meet the criteria for use of TWINS HS data in analysis: it is greater than 3× the maximum in more recent historical data, but it does not exceed the OEL.

C.3.8 Furan

The maximum cartridge inlet concentration of 819% of the OEL (as measured by the Carbotrap 300 TDU method) is much lower than the maximum in the TWINS IH database, which is a below-report with an RL of 58.3 ppb (<5830% of the OEL), a high RL that came from a 0.15-L sample taken on September 17, 2009. The cartridge inlet concentration also was much lower than the only above-report concentration in the TWINS HS database, 547 ppb (54700% of the OEL), which was measured in the headspace in 1994. The only above-report concentration in the TWINS IH database was 10.3 ppb (1030% of the OEL), which was measured in a 1-L sample taken at a breather filter on September 17, 2009. In the SWIHD HS database, the maximum concentration was 18.4 ppb (1840% of the OEL) in October 2016. The cartridge inlet concentration is <20% of the historical maximum and is considered significantly less than historical, with the caveat that recent SWIHD HS headspace concentrations were close to the cartridge inlet maximum.

C.3.9 2,3-Dihydrofuran, 2,5-Dimethylfuran, 2-Pentylfuran, 2-Propylfuran

The cartridge inlet maxima were 74.5% of the OEL for 2,3-dihydrofuran, less than a DL of ~3% of the OEL for 2,5-dimethylfuran (where the RL was 19% of the OEL), 3.57% of the OEL for 2-pentylfuran (below the RL of 13% of the OEL), and 11.1% of the OEL for 2-propylfuran (less than the RL of 16% of the OEL). All of the cartridge concentrations were measured by the furans method. All of the historical maxima were below-reports with RLs in the range of ~20 to 50% of the OEL.

The cartridge-inlet maximum concentration of 2,3-dihydrofuran was high enough to make it consistent with the historical maxima, even at the highest historical RL. For the other furans, the cartridge-inlet concentrations were low and there were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.3.10 2,5-Dihydrofuran, 2-Methylfuran

The maximum cartridge inlet concentration, measured by the Carbotrap 300 TDU method, was 278% of the OEL for 2,5-dihydrofuran and 39.2% of the OEL for 2-methylfuran, both concentrations much less than the below-report historical maxima that had RLs of ~5000% of the OEL for these two furans. These high RLs came from the same 0.15-L TWINS IH sample discussed for furan. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.3.11 2-Heptylfuran

The maximum cartridge inlet concentration of 4.5% of the OEL (a below-report for which the RL was 11% of the OEL) is within the range of the historical maximum from recent data, a SWIHD HS below-report with an RL of 0.196 ppb (<19.6% of the OEL). In addition, the cartridge inlet maximum is much lower than the TWINS HS maximum of 61.2 ppb (6120% of the OEL) measured in the headspace in 1994. The cartridge inlet concentration is <20% of the maximum (TWINS HS) historical data. However, it is worth noting that both of the BY-108 2-heptylfuran measurements that are present in TWINS HS were considered to be misidentifications [17].

C.3.12 Acetonitrile

The maximum cartridge inlet concentration of 0.77% of the OEL, measured by the Carbotrap 300 TDU method, is much lower than the historical maximum of 18.8 ppm (94.0% of the OEL) that was measured in October 2016. This historical maximum comes from SWIHD HS and was made using the acetonitrile method. Other measurements made in the same period, by the same method, ranged from 2.23 ppm to 9.76 ppm. The cartridge inlet concentration is <20% of the historical maximum and is considered significantly less than historical.

C.3.13 N-nitrosodimethylamine (NDMA)

The maximum cartridge inlet concentration was 134% of the OEL, much lower than the historical maximum of 6.19 ppb (2063% of the OEL). The historical maximum came from the SWIHD HS database, a headspace measurement made in October 2016. There are no TWINS HS data for nitrosamines in this tank. The cartridge inlet maximum falls below 20% of the historical maximum and therefore, is considered significantly below historical.

C.3.14 N-nitrosodiethylamine (NDEA), N-nitrosomethylethylamine (NMEA), and N-nitrosomorpholine

For these three nitrosamines, the cartridge inlet maxima were 34.5% of the OEL for NDEA, 132% of the OEL for NMEA, and 18.3% OEL for N-nitrosomorpholine. The historical maxima were October 2016 SWIHD HS below-reports that had RLs of 1030% of the OEL for NDEA, 413% for NMEA, and 153% for N-nitrosomorpholine. The only above-report data come from a single breather-filter sample in TWINS IH, taken on July 15, 2009. The concentrations were 0.00809 ppb NDEA (8.09% of the OEL), 0.0239 ppb NMEA (7.97% of the OEL), and 0.0482 ppb N-nitrosomorpholine (8.03% of the OEL). There are no TWINS HS data for nitrosamines in this tank. The cartridge inlet maxima are higher than the above-report historical maxima for all three nitrosamines.

C.3.15 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <1% of the OEL, which is below its DL, is low compared to the historical maximum concentration, a below-report datum with an RL of 0.00636 ppm (<91% of the OEL). This RL was for a September 17, 2009, sample in TWINS IH that had a small volume, of 0.15 L. All the historical data in TWINS HS, dating from 1994, were also below-reports. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.3.16 2-Fluoropropene

2-Fluoropropene is a Tentatively Identified Compound (TIC) and was not positively identified as being present in the cartridge inlet—while the historical maximum concentration was 0.53 ppm (530% of the OEL). The historical data were present only in the TWINS HS database, a single data point taken in 1994. The cartridge inlet concentration is probably <20% of historical data, but because it is a TIC, no conclusion can be drawn.

C.3.17 Summary of Historical Data for the BY-108 Headspace (2016 Tests)

In summary, cartridge inlet concentration maxima for the BY-108 headspace that were substantially lower than historical maxima can be described as follows:

- Differences arose from using historical data taken during disturbance for the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-propylfuran, dibutyl butylphosphonate, and 2-fluoropropene.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: benzene, 1-butanol, acetaldehyde, furan, 2-heptylfuran, acetonitrile, and N-nitrosodimethylamine.

C.4 702-AZ (2016 and 2017 Tests): Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling. Two sets of cartridge tests were carried out. In 2016 tests were performed during a period when the waste was not being disturbed and had not been disturbed recently, and in 2017, the cartridge tests were performed during a waste transfer. There was no substantial change in the exhaustor system between the two series of tests.

Generally speaking, the AY and AZ Farm tanks with headspaces upstream of the 702-AZ stack have been active over the whole period of record. A number of waste transfers or exchanges have occurred between 2000, when TWINS HS data were taken, and August 26, 2016, when the 2016 cartridge testing began. These changes in waste contents have included receipts from SY-101, C-106, AN-106, and numerous interchanges within the A complex. The waste-disturbing activities that most closely preceded 2016 cartridge testing were in April and June 2016. Further waste transfers employing the AY and AZ Farms were carried out in the period between August 2016 and February 10, 2017, when the 2017 cartridge tests began. Nearly 397,000 gallons of tank waste from 241-AP-103 were pumped into 241-AY-101, beginning on the evening of February 9, 2017, approximately 13 hours before SCOTT 7422-SD1 cartridge testing was initiated on February 10, 2017. The transfer ended on the evening of February 11, 2017, approximately 11 hours before the SCOTT 7422-SC1 cartridge testing was completed on the morning of February 12, 2017.

Therefore, waste present in the AY and AZ tanks during cartridge testing could be different from the waste present during earlier stack sampling. However, activities in tanks affecting the 702-AZ stack will continue, and there is no way to say that historical data could not apply to future stack concentrations. Therefore, in the case of the 702-AZ stack, the age of historical data will not be taken as a reason to consider the historical data irrelevant.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections. When possible, the 2016 cartridge-inlet maxima are compared only to historical maxima taken when there was no disturbance, while the 2017 cartridge-inlet maxima are compared to the historical maxima over all the data.

C.4.1 Ammonia

The maximum cartridge inlet concentration of 76% of the OEL, in 2016, and 310% of the OEL, in 2017, are low compared to the historical maximum concentration of 169 ppm (676% of the OEL), although the average concentrations are similar for historical data and 2016 cartridge data. The overall maximum in historical data was measured on January 6, 2011, during a disturbance (an exhauster restart).

The highest historical concentration measured during non-disturbance conditions was 69 ppm (275% of the OEL). This was a transfer baseline sample taken on March 3, 2011; the BBI tank activity database confirms that this was an actual baseline (i.e., no waste transfer occurred in the AY/AZ farms at that time) and that there had been no waste transfers for months before. The 2016 cartridge maximum is low by comparison but is >20% of this non-disturbance historical maximum and, therefore, is not considered significantly different. The 2017 cartridge-inlet maximum is nearly 50% of the overall historical maximum (with disturbance) and is not considered significantly different.

C.4.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. There were two measurements in historical data on August 14, 2000, both below-reports with an RL of 50 ppm (<100% of the OEL), found in the TWINS HS database. One more below-report concentration (found in TWINS IH) was measured on June 16, 2005. This measurement had an RL of 1 ppm (2% of the OEL). The last preceding waste transfer had been on May 22, 2005, so the sample is considered to have been taken during non-disturbance conditions.

C.4.3 Mercury

The maximum cartridge inlet concentration of 84% of the OEL, in 2016, and 52.9%, in 2017, are low compared to the historical maximum concentration of 0.117 mg/m³ (468% of the OEL), although the average concentrations are similar for historical data and 2016 cartridge data.

This maximum in historical data, 468% of the OEL, was measured on August 14, 2013, during a waste-disturbing AY-101 recirculation activity. The BBI database shows no tank-to-tank transfer at or near this date. This overall historical maximum is the appropriate one for comparison to 2017 cartridge results. The 2017 cartridge-inlet maximum of 52.9% of the OEL is <20% of the historical maximum and is considered significantly different.

Other high concentrations, excluding those from surveys identified in their titles as being carried out for exhauster restarts, were:

- 0.0359 mg/m³, March 15, 2016, survey title includes “AP-103 to AY-101 Transfer” – The BBI database indicates raw water added to AY-102 during March 7–27, 2016, which includes the survey date.
- 0.0354 mg/m³, March 17, 2011, survey title includes “AN101 to AY101 Transfer” – The BBI database indicates raw water added to AY-101 during March 11–17, 2011, which includes the survey date, and a waste transfer from AN-101 to AY-101 during March 16–17, 2011, which includes the survey date.
- 0.0254 mg/m³, March 16, 2011, survey title includes “AN101 to AY101 Transfer” – The BBI database indicates raw water was added to AY-101 during March 11-17, 2011, which includes the survey date, and a waste transfer from AN-101 to AY-101 occurred during March 16–17, 2011, which includes the survey date. If this survey was carried out before the transfer started on the same day, it is a baseline measurement.

The highest concentration measured during non-disturbance conditions was either 0.0359 mg/m³ (144% of the OEL), if raw water additions are not considered waste-disturbing, or 0.0254 mg/m³ (102% of the OEL), if the survey is assumed to have been carried out before transfer started. The 2016 cartridge maximum is >50% of these non-disturbance historical maxima and, therefore, is not considered one of the larger discrepancies, nor is it significant.

C.4.4 1,3-Butadiene

The maximum 2016 and 2017 cartridge inlet concentrations were both below the sample RLs. The 2016 cartridge maximum was <3.6% of the OEL, and the 2017 cartridge maximum was <1.95% of the OEL. Both are low compared to the historical maximum concentration of 0.109 ppm (11% of the OEL), although the average concentrations are similar for historical data and 2016 cartridge data. The maximum in historical data was measured on September 8, 2015. The survey title did not indicate a disturbance; however, the BBI activity database shows the survey was made during a waste transfer from AZ-102 to AW-102 during September 4–9, 2015. The only other two above-report measurements were taken during an exhauster restart (as shown by the survey title).

Because none of the above-report historical data were from undisturbed conditions, it is unclear whether the 2016 cartridge maximum was <20% of an undisturbed historical maximum. The 2017 cartridge-inlet maximum (<1.95% of the OEL) is compared to the known maximum over all the historical data, 11%. Its RL, the upper bound of the concentration, is barely >20% of the historical maximum. The 2017 cartridge-inlet maximum is considered significantly lower than the historical data.

C.4.5 Formaldehyde

The maximum cartridge inlet concentrations of 3.0% of the OEL, for 2016, and 1.44% of the OEL, for 2017, are low compared to the historical maximum concentration, a below-report datum that had an RL of 0.069 ppm (<23% of the OEL). The maximum above-report concentration in historical data was 0.015 ppm (4.9% of the OEL). It was measured on December 17, 2006, with no disturbance indicated in the survey title. However, the BBI activity database shows the survey was made during a waste transfer from AY-102 to AN-106 on December 16-19, 2006.

The 2016 cartridge maximum is lower than the maximum above-report historical concentration. However, because it is >20% of a maximum that occurred during waste disturbance, which would be expected to cause an increased concentration, it is considered not to be significantly discrepant for conditions. The 2017 cartridge maximum is also >20% of the above-report historical maximum and is not considered to be significantly low.

C.4.6 Furan

The maximum above-report cartridge inlet concentrations measured by the Carbotrap 300 TDU method were 58.0% of the OEL in 2016 (undisturbed conditions) and 2995% of the OEL in 2017. These were low or very low compared to the historical maximum concentration, a below-report datum that had an RL of 145 ppb (<14,500% of the OEL). This historical measurement came from a December 17, 2006, Carbotrap 300 TDU sample in TWINS IH that had a volume of 0.35 L, which is a small volume compared to other 702-AZ samples in which furan was measured; this explains the high RL. The second highest RL was 10 ppb (<1000% of the OEL), and all other RLs were <4.3 ppb (<430% of the OEL), with many being less than 1 ppb (<100% of the OEL). The unusually high less than RL maximum accounts for the high average furan concentration as well.

There was only one above-report furan concentration in the historical data, 0.79 ppb (79% of the OEL). It was measured on June 18, 2015, with a survey title that did not indicate disturbance. The BBI tank activity database shows no waste transfer or other waste disturbance in the AY/AZ farms for months before the sample was taken. The 2016 cartridge inlet maximum inlet concentration is not significantly less than the single historical undisturbed above-report concentration.

The 2017 cartridge-inlet maximum of 2995% of the OEL is about 20% of the unusually high RL that provided the overall historical maximum, is higher than most RLs found in the data, and is much higher than the single above-report historical value. The 2017 cartridge maximum is not considered to be significantly low.

C.4.7 2,3-Dihydrofuran

The maximum cartridge inlet concentrations were 6.2% of the OEL in 2016 (a below-report for which the RL was 25% of the OEL) and 16.8% of the OEL in 2017. The historical maximum concentration was a below-report datum that had an RL of 0.356 ppb (<36% of the OEL). There was a single maximum above-report concentration of 0.228 ppb (23% of the OEL), which was measured on June 19, 2014, during an exhauster restart.

Because there are no above-report historical data except one measurement taken during ventilation disturbance (as stated in the survey title), no firm conclusion can be drawn about where this chemical's 2016 cartridge inlet concentration lies with respect to non-disturbance historical data. However, cartridge inlet data taken during non-disturbed conditions would be expected to be lower than those taken during a disturbance, so the 2016 cartridge inlet concentrations were probably consistent with historical data. The 2017 cartridge-inlet maximum, 16.8% of the OEL, was >50% of the historical above-report maximum and was not significantly different.

C.4.8 2,5-Dihydrofuran, 2-Methylfuran

The maximum historical concentration comes from a below-report measurement made from the same 0.35 L Carbotrap 300 TDU sample (taken on December 17, 2006) that dominated the historical furan concentration. There are no above-report historical data for these chemicals, so no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.4.9 2,5-Dimethylfuran, 2-Pentylfuran, 2-Heptylfuran, 2-Propylfuran

The maximum and average cartridge inlet concentrations appear to be low compared to the historical maximum concentrations, which in all cases are below-report data. There are no above-report historical data for these chemicals, so no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.4.10 N-nitrosodiethylamine

The maximum cartridge inlet concentrations were 31% of the OEL, in 2016 with no disturbance, and 398% of the OEL, in 2017 during waste disturbance. The historical maximum concentration was a below-report datum that had an RL of 0.209 ppb (<209% of the OEL). This value came from the TWINS IH database, in which it is not unusually high, although many other historical below-reports in TWINS IH had RLs of 0.1 ppb (<100% of the OEL) or less. There was a single above-report concentration in historical data, 0.066 ppm (66% of the OEL), which was measured on June 19, 2014, during an exhauster restart.

Because there are no above-report historical data except one measurement taken during a ventilation disturbance (as stated in the survey title), no firm conclusion can be drawn about where this chemical's 2016 cartridge inlet concentration lies with respect to non-disturbance historical data. However, historical data taken during non-disturbed conditions would be expected to be lower than those taken during a disturbance, so the 2016 cartridge inlet concentrations were probably consistent with historical data. The 2017 cartridge-inlet maximum was greater than the historical above-report maximum and was not significantly lower.

C.4.11 N-nitrosomethylethylamine

The maximum cartridge inlet concentrations were <9.6% of the OEL, which was the RL, in 2016, and 26.1% of the OEL in 2017 during waste disturbance. The historical maximum concentration was a below-report datum that had an RL of 0.242 ppb (<81% of the OEL). This historical RL was not unusually high in the TWINS IH database. There were six above-report concentrations in historical data, ranging from 0.020 to 0.031 ppb (7-10% of the OEL). Of these, the three highest were measured on June 19, 2014, (two measurements) and January 6, 2011, during exhauster restarts. The three lower values were all about 0.02 ppb (7% of the OEL); at least one of these was both labeled baseline in the survey title and was free of waste disturbance in the BBI tank activity database.

The 2016 cartridge inlet measurements are reasonably comparable to the non-disturbed historical data. The 2017 cartridge inlet maximum exceeds the above-report historical maximum and therefore, is not considered significantly different.

C.4.12 N-nitrosomorpholine

The maximum cartridge inlet concentrations were <3.67% of the OEL, which was the RL, in 2016, and 3.74% of the OEL (above the RL) in 2017. Both of these cartridge maxima are low compared to the historical maximum concentration, a below-report datum that had an RL of 0.167 ppb (<28% of the OEL). This historical RL was not unusually high in TWINS IH. There was a single above-report concentration in historical data, 0.025 ppm (4% of the OEL), which was measured on June 19, 2014, during an exhauster restart.

Because there are no above-report historical data except one measurement taken during a ventilation disturbance, no firm conclusion can be drawn about where the 2016 cartridge inlet maximum for this chemical lies with respect to non-disturbed historical data. However, cartridge inlet data taken during non-disturbed conditions would be expected to be lower than those taken during a disturbance, so the 2016 cartridge inlet concentrations were probably consistent with historical data. The 2017 cartridge maximum is about equal to the single above-report historical concentration, so there is no evidence of a significant different in concentration.

C.4.13 Dibutyl butylphosphonate (DBBP)

The maximum historical concentration comes from a below-report measurement made on the same 0.35 L Carbotrap 300 TDU sample (taken on December 17, 2006) that dominated the furan concentration. There are no above-report historical data for this chemical, so no conclusion can be drawn about where its cartridge inlet concentrations lie with respect to historical data.

C.4.14 Pyridine

The maximum cartridge inlet concentrations were <0.15% of the OEL, which was the RL, in 2016, and 0.14% of the OEL (an above-report datum) in 2017. Both concentrations are low compared to the historical maximum concentration, a below-report datum that had an RL of 0.238 ppm (<24% of the OEL). The historical measurement came from a December 17, 2006, Carbotrap 300 TDU sample with a volume of 0.35 L, which is a small volume compared to other 702-AZ samples in which pyridine was measured; this explains the high RL. The second highest RL was 0.00625 ppm (<0.6% of the OEL). The unusually high less than RL maximum accounts for the high average pyridine concentration as well. There were two above-report concentrations in historical data, 0.00050 ppm and 0.00088 ppm (0.05% and 0.09% of the OEL, respectively). Both were measured during exhauster restarts that occurred on June 19, 2014.

Given that cartridge inlet data taken during non-disturbed conditions would be expected to be lower than those taken during a disturbance, the 2016 cartridge inlet concentrations were probably consistent with historical data. The 2017 cartridge-inlet maximum is also consistent.

C.4.15 2,4-Dimethylpyridine

As for pyridine, the maximum and average historical concentrations are controlled by the RL from the 0.35 L Carbotrap 300 TDU sample. Because this substituted pyridine has no above-report historical data, no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.4.16 Methyl isocyanate

This chemical was a TIC at the inlet in both series of cartridge testing. There is only one historical concentration, a below-report datum that had an RL of 0.00714 ppm (<36% of the OEL). Given the scarcity of data, no conclusion can be drawn about where this chemical's cartridge inlet concentration lies with respect to historical data.

C.4.17 Summary of Historical Data for 702-AZ (2016 Tests Without Disturbance)

In summary, cartridge inlet maxima for the 2016 702-AZ tests that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during ventilation or waste disturbance for the historical maximum and were resolved by using non-disturbance historical data: ammonia, mercury, 2,3-dihydrofuran, N-nitrosodiethylamine, N-nitrosomethylethylamine, N-nitrosomorpholine, and pyridine.
- Differences arose from using the RLs of below-report data for the historical maximum: formaldehyde.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 1,3-butadiene, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, 2-propylfuran, dibutyl butylphosphonate, 2,4-dimethylpyridine, and methyl isocyanate.

- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: none.

C.4.18 Summary of Historical Data for 702-AZ (2017 tests with disturbance)

In summary, the cartridge inlet maxima for the 2017 702-AZ tests that were substantially lower than historical data can be described as follows:

- Differences arose from using the RLs of below-report data for the historical maximum: formaldehyde.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of above-report data: 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, 2-propylfuran, dibutyl butylphosphonate, 2,4-dimethylpyridine, and methyl isocyanate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: mercury and 1,3-butadiene.

C.5 AW Exhauster: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling. Cartridge tests were carried out in 2016 tests, during a period when the waste was not being disturbed and had not been disturbed recently.

Generally speaking, with the exception of AW-101, the AW Farm tanks with headspaces upstream of the AW stack have been active over the whole period of record. A number of waste transfers, exchanges, or receipts from the 242-A evaporator occurred between 2000, when TWINS HS data were taken, and September 23, 2016, when the 2016 cartridge testing began. These changes in waste contents have included receipts from SY-101 and numerous interchanges within the A complex. The waste-disturbing activities that most closely preceded 2016 cartridge testing were in June 2016.

Therefore, the waste present in the AW tanks during cartridge testing could be different from that present during earlier stack sampling. However, activities in tanks affecting the AW stack will continue, and there is no way to say that historical data could not apply to future stack concentrations. So, in the case of the AW stack, the age of historical data will not be taken as a reason to consider the historical data irrelevant.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections. When possible, the cartridge-inlet maxima are compared only to historical maxima taken when there was no disturbance.

C.5.1 Ammonia

The maximum cartridge inlet concentration of 106% of the OEL is low compared to the historical maximum concentration of 161 ppm (644% of the OEL), although the average concentrations are similar for historical and cartridge data. The highest above-report historical data consist of the following, in decreasing order of concentration:

- 161 ppm, April 4, 2006, survey title is “Sampling Strategy for the 242-A Evaporator” – The BBI tank activity database indicates evaporator water transferred to AW-102 during April 1-30, 2006, which includes the survey date.
- 123 ppm, December 2, 2006, survey title includes “AW to AN Xfer” – The BBI database indicates waste transfer from AN-106 to AW-102 during December 1-8, 2006, which includes the survey date.
- 91 ppm, August 27, 2006, survey title includes “AW-evaporator circ.” – The BBI database indicates raw water added to AW-102 during August 10-18, 2006, (9 days before the survey date) and a waste transfer from AW-102 to the 242-A evaporator on August 31, 2006, (4 days after the survey date). It is not clear whether some kind of waste circulation between AW-102 and 242-A was occurring during the survey. The BBI database might not list recirculation operations that did not change the tank inventory.
- 48 ppm, July 6, 2005, survey title says nothing about activity – The BBI database indicates that the last preceding transfer was in March 2005, which was several months before the survey.

The highest historical concentration measured without disturbance being indicated was 48 ppm (192% of the OEL). This measurement was made in 2005. The cartridge maximum is low by comparison to this non-disturbance historical maximum but is within a factor of 2, which is considered an acceptable match.

C.5.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. There were two measurements in TWINS HS historical data on June 14, 2000, both below-reports with an RL of 50 ppm (<100% of the OEL). Two above-report concentrations (found in TWINS IH) were measured on April 4, 2006, (11.3 ppm) and July 19, 2005 (4.7 ppm). The first of these was measured during addition of 242-A evaporator water to AW-102, and the second during a time when AW Farm activity had not occurred for a few months. The July 19, 2005, concentration of 4.7 ppm (9.4% of the OEL) is considered to be during non-disturbance conditions.

C.5.3 Mercury

The maximum cartridge inlet concentration of 7% of the OEL is very low compared to the historical maximum concentration of 0.296 mg/m³ (1184% of the OEL), and the average inlet concentration also is much lower than the historical average.

The highest above-report historical data consist of the following, in decreasing order of concentration from the maximum down:

- 0.296 mg/m³, December 17, 2014, survey title says nothing about activity – The BBI database indicates a waste transfer from AP-104 to AW-102 during December 15-19, 2014, which includes the survey date.
- 0.274 mg/m³, August 29, 2012, survey title says nothing about activity – The BBI database indicates a waste transfer from AP-104 to AW-106 during August 27-31, 2012, which includes the survey date.
- 0.0317 mg/m³, December 2, 2006, survey title indicates a transfer – The BBI database indicates a waste transfer from AN-106 to AW-102 during December 1-8, 2006, which includes the survey date.
- 0.0255 mg/m³, June 24, 2015, survey title says nothing about activity – The BBI database indicates a waste transfer from AZ-102 to AW-102 during June 22–28, 2015, which includes the survey date.

- 0.0206 mg/m³, May 11, 2015, survey title includes “242-A campaign” – The BBI database indicates a waste transfer from AW-102 to the 242-A evaporator during May 5–11, 2015, which includes the survey date.
- 0.00934 mg/m³, June 21, 2015, survey title says nothing about activity – The BBI database indicates raw water added to AW-102 during June 10-29, 2015, which includes the survey date, and a waste transfer from AW-102 to 242-A during June 12–19, 2015, (ending 2 days before the survey), possibly too soon for the headspace to be cleared of vapor from the waste disturbance.
- 0.00651 mg/m³, July 16, 2015, survey title indicates a 242-A campaign – The BBI database indicates waste was transferred from AW-102 to 242-A during July 10–21, 2015, which includes the survey date.
- 0.00503 mg/m³, July 31, 2014, survey title says nothing about activity – The BBI database indicates evaporator water was transferred to AW-102 during July 24–31, 2014, which includes the survey date.
- 0.00444 mg/m³, September 16, 2014, survey title says nothing about activity – The BBI database indicates waste was transferred from AW-102 to 242-A during September 4–30, 2014, which includes the survey date.
- 0.00412 mg/m³, September 15, 2015, survey title refers to a 242-A campaign – The BBI database indicates waste was transferred from AW-102 to 242-A during September 14–23, 2015, which includes the survey date.
- 0.00370 mg/m³, July 24, 2013, survey title refers to a transfer – The BBI database indicates waste was transferred from AP-107 to AW-102 during July 22–25, 2013, which includes the survey date.
- 0.00316 mg/m³, March 17, 2015, survey title indicates a 242-A campaign; however, the BBI database does not show any AW Farm waste transfer between the end of 2014 and the end of March 2015.

The highest non-disturbance concentration in historical data was 0.00316 mg/m³ (13% of the OEL). The cartridge inlet maximum (7% of the OEL) is more than 20% of the non-disturbance historical maximum and is considered acceptably close.

C.5.4 1,3-Butadiene

The maximum cartridge inlet concentration of <2.0% of the OEL, which is below the DL, is low compared to the historical maximum concentration, a below-report datum that had an RL of 1.03 ppm (<103% of the OEL), although the average concentrations are acceptably close for historical and cartridge data. The maximum historical measurement came from a butadiene sample with a volume of 0.88 L, which is a small volume compared to most of the AW samples in which butadiene was measured; this explains the high RL. Most of the historical RLs are 0.05 ppm (5% of the OEL) or less. There are two above-report historical measurements:

- 0.164 ppm, September 8, 2015, survey title says nothing about activity – The BBI database indicates evaporator water was transferred from AZ-102 to AW-102 during September 4–9, 2015, which includes the survey date.
- 0.085 ppm, August 14, 2012, survey title indicates a baseline – The BBI database indicates raw water was added to AW-106 during August 14–31, 2012, (began on the survey date) and a waste

transfer from AW-106 to AP-101 during August 14–17, 2012, (began on survey date). It is not explicitly stated that the baseline was taken before activities began on August 14, 2012, although it seems likely.

The higher of the two measurements was taken during a waste transfer. The measurement taken as a baseline and assumed to be before the start of transfer the same day, was 0.085 ppm (9% of the OEL). The cartridge-test concentration was below its DL, which was >20% of the non-disturbance historical maximum.

C.5.5 Formaldehyde

The maximum cartridge inlet concentration of 2.6% of the OEL is low compared to the historical maximum concentration, a below-report with an RL of 0.0968 ppm (32% of the OEL). The maximum above-report concentration was 0.057 ppm (19% of the OEL), measured on August 29, 2012, during a waste transfer from AP-104 to AW-106 during August 27–31, 2012. All other historical concentrations, whether measured during a disturbance or not, were 0.01 ppm (3.3% of the OEL) or less. The cartridge inlet maximum inlet concentration was comparable to those lower historical concentrations.

C.5.6 2-Propenal (Acrolein)

Because there were no above-report concentrations available for either the historical AW data set or the cartridge-test data, the data did not support an evaluation of whether the cartridge-inlet concentrations were significantly lower than the historical data

C.5.7 Furan

The maximum cartridge inlet concentration of 204% of the OEL (measured by Carbotrap 300 TDU) is very low compared to the historical maximum concentration, a below-report datum that had an RL of 15 ppb (<1500% of the OEL). This RL, based on a SUMMA canister measurement from July 6, 2005, was unusually high. The second highest RL was 1.4 ppb (<140% of the OEL). The unusually high less than RL maximum accounts for the high average furan concentration as well. There was only one above-report historical concentration, 1.8 ppb (181% of the OEL). The survey title for this sample, which was taken on December 17, 2014, gave no indication of disturbance. However, the BBI database indicates waste was transferred from AP-104 to AW-102 during December 15–19, 2014, which includes the survey date. The maximum cartridge-inlet concentration during undisturbed conditions is slightly higher than the single above-report historical concentration that was measured during disturbed conditions, where higher concentrations might be expected. Although these is only one above-report historical datum, the fact that it is about the same as the maximum cartridge-inlet concentration (even though the latter involved waste disturbance) suggests a conclusion that the cartridge-inlet concentrations were not inconsistent with historical data.

C.5.8 2,5-Dihydrofuran

The maximum cartridge inlet concentration of <27% of the OEL (the RL), is very low compared to the historical maximum concentration, a below-report datum with an RL of 1.82 ppb (<182% of the OEL). This was not an unusually high historical less than RL in TWINS IH. A set of RLs almost as high as this accounts for much of the historical average. There was only one above-report historical concentration, 0.12 ppb (12% of the OEL), for which there was no indication of disturbance. The survey title for this sample, which was taken on September 16, 2014, gave no indication of disturbance. However, the BBI

database indicates waste was transferred from AW-102 to the 242-A evaporator during September 4–30, 2014, which includes the survey date. There are no historical concentrations taken during non-disturbed conditions, so no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.5.9 2,3-Dihydrofuran, 2-Methylfuran

Because these two furan chemicals have no above-report historical data, no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.5.10 2-Heptylfuran

Because there were no above-report concentrations for either the historical AW data set or the cartridge-test data, the data did not support an evaluation of whether the cartridge-inlet concentrations were significantly lower than the historical data.

C.5.11 Ethylamine

The maximum 2016 cartridge inlet concentration of <0.099% of the OEL, which is below the RL, is low compared to the historical maximum concentration of 0.609 ppm (12% of the OEL). The maximum in historical data, for which four values were above-report, was measured on November 7, 2005, with no indication either in the survey title or the BBI database that a disturbance was occurring. The cartridge inlet maximum concentration is much <20% of the maximum historical above-report concentration.

C.5.12 N-nitrosodiethylamine

The maximum cartridge inlet concentration of <24% of the OEL, which is below the RL, is low compared to the historical maximum concentration, a below-report with an RL of 0.194 ppb (<194% of the OEL). This historical RL was not unusually high: a number of RLs were above 0.15 ppb (150% of the OEL). There is only one above-report concentration in the historical data, 0.0105 ppm (11% of the OEL), which was measured on August 16, 2012, during a waste transfer from AW-106 to AP-101. The sole historical above-report datum was measured during a transfer. It was less than the RL given for the cartridge test. Since the disturbance was likely to give a relatively high historical concentration, but the cartridge-test RL exceeded this historical datum, the cartridge-test data are not considered out of line with historical data.

C.5.13 N-nitrosomethylethylamine

The maximum cartridge inlet concentration of 14% of the OEL is low compared to the historical maximum concentration, a below-report with an RL of 0.216 ppb (<72% of the OEL). This historical RL was not unusually high; a number of RLs were above 0.17 ppb (57% of the OEL). There were four above-report concentrations in historical data. The highest concentration, which the survey title described as a baseline for a transfer, was 0.025 ppb (8% of the OEL) measured on August 14, 2012. However, the BBI tank activity database shows a waste transfer from AW-106 to AP-101 during August 14–17, 2012. There was no statement that the survey was taken before transfer started, although it seems likely. In either case, because the historical above-report maximum was less than the cartridge-test maximum, the cartridge-test data are not considered out of line with historical data.

C.5.14 N-nitrosomorpholine

The maximum cartridge inlet concentration of 6.22% of the OEL is low compared to the historical maximum concentration, a below-report concentration with an RL of 0.164 ppb (<27.3% of the OEL). The highest of the four above-report concentrations was 0.0339 ppb (5.65% of the OEL). Because the historical above-report maximum was less than the cartridge-test maximum, the cartridge-test data are not considered out of line with historical data.

C.5.15 Dibutyl Butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <2% of the OEL, which is below the DL, is low compared to the historical maximum concentration, a below-report datum with an RL of 0.000775 ppm (11% of the OEL).

The maximum historical measurement came from a July 6, 2005, SVOA sample with a volume of 1.26 L, which is a small volume compared to most of the TWINS IH samples in which DBBP was measured; this explains the high RL. All other historical RLs were less than or equal to 0.00016 ppm (2.3% of the OEL). The unusually high less than RL maximum accounts for the high average concentration as well. There are no above-report historical data for this chemical, so no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.5.16 Pyridine

The maximum cartridge inlet concentration of <0.035% of the OEL, which is its RL, is low compared to the historical maximum concentration, a below-report datum that had an RL of 0.129 ppm (<13% of the OEL). The historical maximum came from a July 18, 2013, pyridines sample with a volume of 24.0 L. It is not clear why a sample with this high volume had such a high RL. The second highest RL was about the same, and all other RLs were less than 0.03 ppm (3% of the OEL). The unusually high less than RL maximum accounts for the high average pyridine concentration as well.

The three above-report historical data consist of the following, in decreasing order of concentration from the maximum down:

- 0.021 ppm, April 4, 2006, survey title refers to the 242-A evaporator strategy – The BBI database indicates an evaporator water transfer to AW-102 during April 2006, which includes the survey date.
- 0.00054 ppm, July 16, 2015, survey title refers to a 242-A campaign – The BBI database indicates waste transferred from AW-102 to 242-A during July 10–21, 2015, which includes the survey date.
- 0.00038 ppm, December 17, 2014, survey title says nothing about activity – The BBI database indicates a waste transfer from AP-104 to AW-102 during December 15–19, 2014, which includes the survey date.

None of the historical data were for non-disturbed conditions. The lowest of them is 0.00038 ppm (0.038% of the OEL). Because this measurement under disturbed conditions is in the range of the cartridge inlet maximum, the cartridge-test inlet concentrations are considered to be similar to the non-disturbance historical data.

C.5.17 2,4-Dimethylpyridine

The maximum and average historical concentrations are controlled by the RL from the same 2013 pyridines sample that produced the maximum RL for pyridine. There is one above-report historical measurement, 0.00029 ppm (0.06% of the OEL), which was taken on July 16, 2015, during an evaporator campaign. The sole historical above-report datum was measured during a transfer. It was about the same as the RL given for the cartridge test (0.05% of the OEL). Because the disturbance was likely to give a relatively high historical concentration but the cartridge-test RL exceeded this historical datum, the cartridge-test data are not considered out of line with historical data.

C.5.18 Methyl isocyanate

This chemical was a TIC at the inlet in cartridge testing. There is only one historical concentration, a below-report datum that had an RL of 0.00707 ppm (<35% of the OEL). Given the scarcity of data, no conclusion can be drawn about where this chemical's cartridge inlet concentration lies with respect to historical data.

C.5.19 Summary of Historical Data for the AW Exhauster

In summary, cartridge inlet maxima for the AW exhauster that were substantially lower than historical maxima can be described as follows:

- Differences arose from using historical data taken during waste disturbance for the historical maximum and were resolved by using non-disturbance historical data: ammonia, mercury, 1,3-butadiene, and formaldehyde.
- Differences arose from using the RLs of below-report data for the historical maximum: N-nitrosodiethylamine, N-nitrosomethylethylamine, N-nitrosomorpholine, pyridine, and 2,4-dimethylpyridine.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, dibutyl butylphosphonate, and methyl isocyanate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: ethylamine.

C.6 AN Exhauster: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

Two of seven AN Farm tanks with headspaces upstream of the AN stack—AN-101 and AN-106—have been active over the whole period of record. A number of waste transfers or exchanges took place between 2000 (when TWINS HS data were taken) and September 30, 2016, when cartridge testing began. These changes in waste contents have included receipts from C-100 and C-200 tanks and numerous interchanges within the A complex. The most recent activities, before cartridge testing, were in March

2016. Therefore, some of the waste present in the AN tanks during cartridge testing could be different from that present during earlier stack sampling. However, activities in tanks affecting the AN stack will continue, and there is no way to say that historical data could not apply to future stack concentrations. So, in the case of the AN stack, the fact that historical vapor concentrations came from different wastes will not be taken as a reason to consider the historical data irrelevant. However, it should also be noted that the AN exhauster was changed to a higher flow system in August/September 2008,⁴⁹ so concentrations measured before that time would be expected to be higher than would be produced by the same waste if it were present after that time.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.6.1 Ammonia

The maximum cartridge inlet concentration of 130% of the OEL is low compared to the historical maximum concentration of 134 ppm (536% of the OEL). The highest above-report historical data consist of the following, in decreasing order of concentration:

- 134 ppm, March 27, 2006, survey title says nothing about disturbance – The BBI tank activity database indicates raw water was added to AN-106 during March 26–28, 2006, which includes the survey date.
- 116 ppm, October 18, 2006, survey title says nothing about disturbance – The BBI database indicates waste was transferred from C-204 to AN-106 during October 17-31, 2006, which includes the survey date.
- 104 ppm, July 21, 2005, survey title says nothing about disturbance – The BBI database indicates a waste transfer from C-202 to AN-106 during July 11–28, 2005, which includes the survey date.
- 84 ppm, August 24, 2012, survey title says nothing about disturbance – The BBI database indicates raw water was added to AN-106 during August 6–24, 2012, which includes the survey date. The most recent waste transfer had been from C-104 to AN-101 and had ended on August 17, 2012, which was 7 days before the survey.

The 2012 sample is the historical non-disturbance maximum, at 84 ppm (336% of the OEL). The cartridge inlet maximum is between 20% and 50% of the non-disturbance historical maximum and is not considered significant.

C.6.2 Nitrous Oxide

Nitrous oxide was not measured during cartridge testing. The historical data consist of the following four measurements, all above-reports, in decreasing order of concentration:

- 27.6 ppm and 26.1 ppm, August 23, 2006, survey title says nothing about disturbance – The BBI tank activity database indicates a waste transfer from C-103 to AN-106 on the survey date.
- 14.0 ppm, July 22, 2005, survey title says nothing about disturbance – The BBI database indicates a waste transfer from C-202 to AN-106 during July 11–28, 2005, which includes the survey date.

⁴⁹ Email from RS Nicholson to JE Meacham, July 25, 2017; subject: “When the new AN Farm primary exhaust system came on line.”

- 11.1 ppm, October 18, 2006, survey title refers to a transfer – The BBI database indicates a waste transfer from C-204 to AN-106 during October 17–31, 2006, which includes the survey date.

None of the surveys occurred during non-disturbed conditions. In addition, all of these concentrations were measured for the old lower flow AN exhauster system, and so may be high relative to current exhauster conditions.

C.6.3 Mercury

The maximum cartridge inlet concentration of 16% of the OEL is low compared to the historical maximum concentration of 0.456 mg/m³ (1824% of the OEL), and the average inlet concentration also is lower than historical data. The highest above-report historical data consist of the following, in decreasing order of concentration:

- 0.456 mg/m³, August 11, 2012, survey title includes “AN-106 to AP-104 Transfer” – The BBI tank activity database indicates raw water added to AN-106 during August 6–24, 2012, which includes the survey date, and a waste transfer from AN-106 to AP-104 on August 11, 2012, which also includes the survey date.
- 0.319 mg/m³, September 26, 2012, survey title includes “AN-106 to AP-104 Transfer” – The BBI database indicates waste was transferred from AN-106 to AP-104 during September 26–27, 2012, which includes the survey date.
- 0.116 mg/m³, September 13, 2013, survey title includes “baseline for AN-101 to AP-104” – The BBI database indicates waste was transferred between C-110 and AN-106 during September 10–26, 2013, which includes the survey date, and a waste transfer from AN-101 to C-101 during September 11–12, 2013, (1 day before the survey). In this case the survey was a baseline for a subsequent transfer to AP-104, but was taken during a concurrent operation involving AN-106.
- 0.113 mg/m³, December 10, 2012, survey title includes “C-101 retrieval” – The BBI database indicates a waste transfer from C-101 to AN-101 during December 10–28, 2012, which includes the survey date.
- 0.0778 mg/m³, June 13, 2014, survey title includes “C-105 post-transfer” – The BBI database indicates raw water was added to AN-106 during June 11–14, 2014, which includes the survey date, and waste was transferred from C-105 to AN-106 on June 11, 2014, (2 days before the survey, possibly not enough time for vapor generated by waste disturbance to clear from the headspace).
- 0.0586 mg/m³, August 10, 2012, survey title includes “baseline for AN-106 to AP-104” – The BBI database indicates raw water was added to AN-106 during August 6–24, 2012, which includes the survey date. The last previous waste transfer (AN-106 to C-107) ended on August 6, 2012, which was 4 days before the survey.

Extensive historical data, including one titled as baseline, were taken during waste transfers. The highest concentration for a sample with no evidence of concurrent or recent waste transfer was 0.0586 mg/m³ (234% of the OEL). The cartridge inlet maximum is <20% of the non-disturbance historical maximum and is considered significant.

C.6.4 1,3-Butadiene

The maximum cartridge inlet concentration of <2.1% of the OEL, which is below the DL, is low compared to the historical maximum concentration, an October 12, 2011, below-report datum that had

an RL of 0.146 ppm (<15% of the OEL), although the average concentrations are acceptably close for historical and cartridge data. The maximum historical measurement came from a butadiene sample whose sample volume was not unusual. Most of the historical RLs are 0.05 ppm (5% of the OEL) or less. There are no above-report historical measurements. Because this chemical has no above-report historical data, no conclusion can be drawn about where its cartridge inlet concentrations lies with respect to historical data.

C.6.5 1-Butanol

The maximum cartridge inlet concentration of 0.19% of the OEL is low compared to the historical maximum concentration, which is 3.04 ppm (15% of the OEL). The historical maximum comes from one of three samples taken on August 23, 2006. The survey titles give no indication of disturbance; however, tank activity data in the BBI database show a waste transfer from C-103 to AN-106 on the survey date. In addition, this concentration was measured for the old lower flow AN exhauster system, and so it may be high relative to current exhauster conditions. Other historical above-report measurements, whether from disturbed conditions or not, are below 0.6 ppm (3% of the OEL). The cartridge maximum is consistent with the lower historical data.

C.6.6 Formaldehyde

The maximum cartridge inlet concentration of 4.4% of the OEL is low compared to the historical maximum concentration, which is 0.224 ppm (75% of the OEL). The highest above-report historical data consist of the following, in decreasing order of concentration:

- 0.224 ppm, December 10, 2012, survey title includes “C-101 retrieval” – The BBI database indicates a waste transfer from C-101 to AN-101 during December 10–28, 2012, which includes the survey date.
- 0.191 ppm, April 30, 2012, survey title includes “baseline” – The BBI database indicates raw water was added to AN-106 during April 2-22, 2012, which was 8 days before the survey date, and waste transferred from C-112 to AN-101 during April 2–18, 2012, which was 12 days before the survey date.

The non-disturbance historical maximum is 0.191 ppm (64% of the OEL). The cartridge inlet maximum inlet concentration was <20% of the non-disturbance historical maximum concentration.

C.6.7 Furan

The maximum cartridge inlet concentration of 84.7% of the OEL (measured by the Carbotrap 300 TDU method), is very low compared to the historical maximum concentration, an October 23, 2006 below-report datum that had an RL of 31.7 ppb (<3170% of the OEL). The sample volume for the below-report was 0.19 L, which is unusually low. The second highest RL was 12 ppb (<1200% of the OEL) from a sample with 0.32 L volume taken on March 27, 2006. These unusually high less than RL measurements account for the high average historical concentration as well.

There were eight above-report historical concentrations, the highest of which were the following, in decreasing order of concentration:

- 6.78 ppb, October 12, 2011, survey title includes “Transfer AN-101 to AP-104” – The BBI database indicates a waste transfer from C-107 to AN-106 during October 10–28, 2011, which includes the

survey date, and a waste transfer from AN-101 to AP-104 during October 10–28, 2011, which also includes the survey date.

- 2.67 ppb, September 26, 2012, survey title includes “AN-106 to AP-104 Transfer” – The BBI database indicates a waste transfer from AN-106 to AP-104 during September 26–27, 2012, which includes the survey date.
- 1.20 ppb, October 31, 2013, survey title includes “baseline” – The BBI database indicates the last previous waste transfer was from C-110 to AN-106 during October 1–16, 2013 (ending 15 days before the survey date).

Of the eight above-report concentrations, 1.2 ppb (120% of the OEL) was the highest measurement for which there was no evidence of disturbance. The cartridge inlet maximum inlet concentration is not significantly less than the non-disturbance historical above-report maximum concentration.

C.6.8 2,3-Dihydrofuran

The maximum cartridge inlet concentration of <3.1% of the OEL, which is below both the DL and the RL (25% OEL), is low compared to the historical maximum concentration of 0.405 ppb (41% of the OEL). This was the only above-report concentration, and it was measured on December 10, 2012 during a retrieval from C-101 to AN-101. There are no above-report historical measurements from non-disturbed conditions, so no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.6.9 2,5-Dihydrofuran, 2-Methylfuran

The below-report historical maxima for these two chemicals come from the same 0.19 L sample that gave the maximum furan concentration. As in that case, the high less than RL values contribute much of the historical average. Because these two chemicals have no above-report historical data, no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.6.10 2,5-Dimethylfuran, 2-Pentylfuran, 2-Heptylfuran, 2-Propylfuran

The below-report historical maxima for these two chemicals do not include any unusually high RLs. Because these chemicals have no above-report historical data, no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.6.11 N-nitrosodimethylamine

The maximum cartridge inlet concentration of 4589% of the OEL is low compared to the historical maximum concentration of 257 ppb (85,667% of the OEL). This historical maximum was titled as a baseline measurement on September 23, 2011. The BBI activity database indicates that the last preceding activity, a waste transfer from AN-106 to AP-104, ended on August 31, 2011 (23 days before the survey). Therefore, this maximum is considered to reflect a non-disturbance condition. The cartridge-test maximum is <20% of the historical maximum.

C.6.12 N-nitrosodiethylamine

The maximum cartridge inlet concentration of 71% of the OEL is low compared to the historical maximum concentration, a below-report with an RL of 0.179 ppb (<179% of the OEL). The sample volume was not unusually small, and there were four other samples with similar RLs. There are no above-report measurements. Because this chemical has no above-report historical data, no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.6.13 N-nitrosomethylethylamine

The maximum cartridge inlet concentration of 106% of the OEL is low compared to the historical maximum concentration, 0.856 ppb (285% of the OEL). There were a number of above-report historical concentrations, the highest of which were the following, in decreasing order of concentration:

- 0.856 ppb, December 29, 2011, survey title is “241-C-112 to AN-101 Post Start AN Farm COPC” – The BBI database indicates a waste transfer from AN-101 to C-112 during December 28–30, 2011, which includes the survey date.
- 0.770 ppb, August 29, 2011, survey title refers to a transfer baseline – The BBI database indicates a waste transfer from AN-106 to AP-104 during August 29–31, 2011. The transfer started on the survey date; although it is not stated that the baseline was taken before the transfer began, it seems likely.

The highest measurement for which there was no definite evidence of disturbance was 0.77 ppb (257% of the OEL). The cartridge inlet maximum inlet concentration is between 20% and 50% of the historical above-report maximum concentration and is not considered a significant discrepancy.

C.6.14 N-nitrosomorpholine

The maximum cartridge inlet concentration of 33% of the OEL is low compared to the historical maximum concentration, 0.407 ppb (68% of the OEL). The sample was taken on August 11, 2012, and its survey title includes “baseline for AN-106 to AP-104.” However, the BBI database indicates raw water was added to AN-106 during August 6–24, 2012, which includes the survey date, and there was a waste transfer from AN-106 to AP-104 on August 11, 2012, the day of the survey. Although it is not stated that the baseline was taken before the transfer began, it seems likely. Hence this measurement is considered to be from non-disturbed conditions. The cartridge inlet maximum inlet concentration is between 20% and 50% of the historical above-report maximum concentration under non-disturbed conditions and is not considered a significant discrepancy.

C.6.15 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <2% of the OEL, which is below the RL (10% of the OEL), is low compared to the historical maximum concentration, a below-report datum with an RL of 0.00121 ppm (17% of the OEL). Two samples, one from July 21, 2005, and the other from October 23, 2006, both had high RLs of about 0.0012 ppm. Their sample volumes were 1.2 L for the 2005 sample and 0.18 L for the 2006 sample. There are no above-report historical data for this chemical, so no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.6.16 Pyridine

The maximum cartridge inlet concentration of <0.036% of the OEL, which is its RL, is low compared to the historical maximum concentration, a below-report datum that had an RL of 2.66 ppm (<266% of the OEL). The historical maximum came from a 2011 pyridines sample with a volume of 0.058 L, which is a very low volume that explains the high RL. The second highest RL was 0.0186 ppm (<19% the OEL), and all other RLs were less than 0.007 ppm (<0.7% of the OEL). The unusually high less than RL maximum accounts for the high average concentration as well. There were eight above-report concentrations in historical data, of which the highest was 0.015 ppm (0.15% of the OEL). Whether conditions did or did not include waste disturbance, the above-report historical concentrations are so low that there is no significant discrepancy. The cartridge-test inlet concentrations are considered to be similar to the historical data.

C.6.17 2,4-Dimethylpyridine

The maximum and average historical concentrations are controlled by the RL from the same low-volume 2011 pyridines sample that produced the maximum RL for pyridine. Because this chemical has no above-report historical data, no conclusion can be drawn about where its cartridge inlet concentration lies with respect to historical data.

C.6.18 Methyl Isocyanate

This chemical was a TIC at the inlet in cartridge testing. There is only one historical concentration, a below-report datum that had an RL of 0.007 ppm (<35% of the OEL). Given the scarcity of data, no conclusion can be drawn about where this chemical's cartridge inlet concentration lies with respect to historical data.

C.6.19 Summary of Historical Data for the AN Exhauster

In summary, cartridge inlet concentrations for the AN exhauster that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during waste disturbance for the historical maximum: ammonia, and 1-butanol.
- Differences arose from using the RLs of below-report data for the historical maximum: pyridine.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 1,3-butadiene, 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, 2-propylfuran, N-nitrosodiethylamine, 2,4-dimethylpyridine, and methyl isocyanate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: mercury, formaldehyde, and N-nitrosodimethylamine.

C.7 A-101 Headspace: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

Much of the waste in A-101 was transferred out over the May 2000–July 2003 period. Hence, all data predating July 2003 are considered inappropriate for comparison to the July 2016 cartridge-test data. This includes all data from the TWINS HS database, in which the latest A-101 data were taken in September 2002. Earlier data do not appear in Table C.1, although they do appear in the A-101 individual test report.

The headspaces of all six tanks in the A Farm are connected by overflow cascade lines and a ventilation header [16]. Therefore, waste disturbances in any A Farm tank could propagate changes in vapor concentration to the A-101 headspace. However, there have been no such waste disturbances in the post-2003 period. All post-2003 A-101 vapor data were taken under non-disturbance conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.7.1 Ammonia

The maximum cartridge inlet concentration of 484% of the OEL is low compared to the historical maximum concentration in TWINS HS, 800 ppm (3200% of the OEL). However, this measurement was made in 1995 and is not pertinent to the waste that was present during cartridge testing in 2016. The maximum historical concentration measured in data sets other than TWINS HS was 148 ppm (592% of the OEL), measured on July 17, 2015 (SWIHD HS). The cartridge-testing inlet concentration is close to and consistent with the historical maximum for more current conditions.

C.7.2 Nitrous Oxide

Nitrous oxide was not measured during cartridge testing. A number of measurements were found in the TWINS HS database, but all were taken in 1998 or earlier and are not a good match for the waste presently in the tank. Only one recent measurement was found in TWINS IH. This was a below-report with an RL of 1.9 ppm (<3.8% of the OEL), which was measured on July 28, 2005, at a breather filter.

C.7.3 1,3-Butadiene

The maximum cartridge inlet concentration was less than the RL (2.6% of the OEL) and was <20% of the historical maximum of 0.512 ppm (51% of the OEL), measured on July 17, 2015 (SWIHD HS). There were no other post-2003 above-report data for the chemical; all other measurements were below the RL of 0.019 ppm (1.9% of the OEL). The cartridge inlet concentration is considered to be <20% of historical data.

C.7.4 Furan

The maximum cartridge inlet concentration of 45% of the OEL (measured by the Carbotrap 300 TDU method) is much lower than the historical maximum, a June 1, 2016, below-report with an RL of 7.06 ppb (<706% of the OEL) that was found in the SWIHD HS database. It was also lower than the only above-report concentration in SWIHD HS, 1.75 ppb (175% of the OEL), which was measured in the headspace on July 17, 2015. There were no above-report concentrations in the TWINS IH database, and the only measurement in the TWINS HS database was a below-report from a sample taken in 2002, before the waste transfer out of A-101 was complete. The cartridge inlet maximum concentration is between 20% and 50% of the historical above-report maximum and therefore, is not considered significantly lower.

C.7.5 2,5-Dihydrofuran, 2-Methylfuran

For both these chemicals, the cartridge inlet concentration was below the DL, 26% of the OEL for 2,5-dihydrofuran and 15% OEL for 2-methylfuran. The concentrations were less than the below-report historical maxima that came from RLs that were 686% and 586% of the OEL for 2,5-dihydrofuran and 2-methylfuran, respectively. The high RLs for 2,5-dihydrofuran and 2-methylfuran come from SWIHD HS and are not unusually high for Carbotrap 300 TDU analyses. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.7.6 2,3-Dihydrofuran, 2,5-Dimethylfuran, 2-Pentylfuran, 2-Heptylfuran, 2-Propylfuran

For all these chemicals, the cartridge inlet concentration (or its DL, for <DL cases) is 5% of the OEL or less. The concentrations were less than the below-report historical maxima that came from RLs that were 11–25% of the OEL. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.7.7 Acetonitrile

The maximum cartridge inlet concentration of 0.69% of the OEL is less than the SWIHD HS historical maximum, 5.16 ppm (26% of the OEL) measured in 2015. There are a number of other historical measurements in SWIHD HS, all taken during 2015–2016 that are greater than 5× the maximum cartridge inlet concentration. The cartridge inlet concentration is <20% of historical data.

C.7.8 N-nitrosomorpholine

The maximum cartridge inlet concentration of 8% of the OEL was less than the historical maximum concentration of 0.143 ppb (24% of the OEL). This measurement was in SWIHD HS. It was the only above-report in the databases and was taken on May 24, 2016. The maximum cartridge inlet concentration was <50% but >20% of the single above-report historical concentration, and therefore, was not substantially lower than available historical data.

C.7.9 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <4.5% of the OEL, which is below its DL, is low compared to the historical maximum concentration, a below-report datum with RL of 0.002 ppm (<29% of the OEL). This was not an unusually high RL value in the 2015–2016 SWIHD HS database. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.7.10 Methyl nitrite

The cartridge inlet concentration was a non-detect—a tentatively identified compound—while the historical maximum concentration was 0.43 ppm (430% of the OEL). Historical data were present only in the TWINS HS database, three measurements taken in 1995. These are inapplicable because the measurements were taken before waste removal in 2000–2003. There were no above-report historical data after 2003, so no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.7.11 Methyl isocyanate

This chemical was a TIC at the inlet in cartridge testing. There were only two historical concentrations, both below-report. The maximum had an RL of 0.00702 ppm (<35% of the OEL). Given the scarcity of data, no conclusion can be drawn about where the cartridge inlet concentration for this chemical lies with respect to historical data.

C.7.12 Summary of Historical Data for the A-101 Headspace

In summary, cartridge inlet concentrations for the A-101 headspace that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance for the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: ammonia.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-heptylfuran, 2-pentylfuran, 2-propylfuran, dibutyl butylphosphonate, methyl nitrite, and methyl isocyanate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: 1,3-butadiene and acetonitrile.

C.8 AX-101 Headspace: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

Much of the waste in tank AX-101 was transferred out over the March 2001–April 2003 period. Hence, all data predating April 2003 are considered inappropriate for comparison to the July 2016 cartridge-test data. This includes all data from the TWINS HS database, in which the latest AX-101 data were taken in September 2002. Earlier data do not appear in Table C.1, although they do appear in the AX-101 individual test report.

The headspaces of all four tanks in the AX Farm are connected by overflow cascade lines and a ventilation header [16]. Therefore, waste disturbances in any AX Farm tank could propagate changes in vapor concentration to the AX-101 headspace. However, there have been no such waste disturbances in the post-2003 period. All post-2003 AX-101 vapor data were taken under passive-ventilation, non-disturbance conditions, as were the July 2016 cartridge-test data. (Subsequently an exhauster was connected to the AX ventilation header, providing active ventilation. See Section C.11 for measurements made under those conditions.)

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.8.1 Nitrous Oxide

Nitrous oxide was not measured during cartridge testing. Only one historical measurement was found in TWINS IH. This was a below-report with an RL of 1.6 ppm (<3.2% of the OEL), which was measured on August 4, 2005, at a breather filter.

C.8.2 Furan

The maximum cartridge inlet concentration of 23.7% of the OEL is much lower than the historical maximum, a 2005 below-report with an RL of 3.87 ppb (<387% of the OEL) that was found in the TWINS IH database. The sample volume was 1.2 L. This volume cannot be determined to have been unusually low for TWINS IH, because there were only two furan measurements in the database, both 1.2 L. There were no historical above-report concentrations in any of the databases, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.8.3 2,5-Dihydrofuran, 2-Methylfuran

For both these chemicals, the cartridge inlet concentration is less than the RLs of 16 to 28% of the OEL, less than the RLs of the below-report historical maxima. The maximum RL for 2,5-dihydrofuran (141% of the OEL) came from SWIHD HS and was at least 4× the next highest RL. The maximum RL for 2-methylfuran came from TWINS IH (224% of RL) and was approximately 2× the next highest RL. The RLs for 2,5-dihydrofuran and 2-methylfuran are high relative to the OELs, but come from the same sample as for the furan maximum, and cannot be determined to have been unusually low volume. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.8.4 2,5-Dimethylfuran, 2-Heptylfuran, 2-Propylfuran

For all these chemicals, the cartridge inlet concentration is less than a DL of ~3 to 5% of the OELs, and for comparison, the RLs are 11–19% of the OEL. These cartridge inlet concentrations are much less than the below-report historical maxima that had RLs of 16 to 27% of the OELs. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.8.5 2-Pentylfuran

The maximum cartridge inlet concentration of 6.3% of the OEL is less than the cartridge RL of 13% but is more than 20% of the below-report historical maximum, an RL of 0.186 ppb (<19% of the OEL) measured on November 26, 2014 and found in SWIHD HS. Although the maximum cartridge inlet concentration is much less than that given by the TWINS HS database (274% of the OEL), the latter measurement was made in 1995, before retrieval, and is not applicable. The cartridge inlet concentration is consistent with the applicable historical data.

C.8.6 Dibutyl butylphosphonate (DBBP)

The maximum cartridge inlet concentration of <1.5% of the OEL, which is below its DL, is low compared to the historical maximum concentration, a below-report datum with RL of 0.00116 ppm (<17% of the OEL) from a TWINS IH sample taken on August 4, 2005, with a 1.2 L sample volume. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentration lies with respect to historical data.

C.8.7 Summary of Historical Data for the AX-101 Headspace

In summary, cartridge inlet concentrations for the AX-101 headspace that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance for the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: 2-pentylfuran.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: furan, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-heptylfuran, 2-propylfuran, and dibutyl butylphosphonate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: none.

C.9 SX-104 Headspace: Comparison with Historical Data

The SX-104 tank underwent salt well pumping in 1997–1999; this substantially reduced its waste volume, from 587 kgal to 466 kgal. This pumping is considered to have changed the waste sufficiently to make pre-2000 data irrelevant, which excludes TWINS HS data that were measured in 1995. Furthermore, pre-2004 data are irrelevant because of the change from active to passive ventilation in 2003.

Because SX Farm tanks are arranged in three-tank cascades, tanks SX-104, SX-105, and SX-106 are connected with each other by overflow lines through which vapors may move from one tank headspace to another [16]. It is physically possible for waste disturbances in SX-105 and SX-106 to have affected vapor concentrations in SX-104. There was no activity in SX-104 after 1999. The other tanks in its cascade—SX-105 and SX-106—had no waste-disturbing operations in 1995, 2006, or 2015, the only years for which SX-104 headspace data are available. Hence, none of the available data for SX-104 were taken during waste-disturbing conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.9.1 Ammonia

The maximum cartridge inlet concentration of 828% of the OEL is within a factor of two of the historical maximum concentration of 393 ppm (1572% of the OEL). This data point came from the SWIHD HS database and was measured on July 10, 2015. By contrast, the single ammonia measurement in the TWINS IH database, made in 2006 at the breather filter, was 47 ppm. The more recent historical data are considered to be comparable with the cartridge-testing inlet concentrations.

C.9.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing, and there are no nitrous oxide data in the SWIHD HS database. There is one historical concentration in TWINS IH, 17.3 ppm (35% of the OEL), measured in 2006.

C.9.3 Mercury

The maximum cartridge inlet concentration was 66.7% of the OEL. The sole historical measurement was 0.008 mg/m³ (32% of the OEL). This data point came from the SWIHD HS database and was measured on July 10, 2015. The single mercury measurement in the TWINS IH database, made in 2006 at the breather filter, was 0.002 mg/m³. The 2015 historical datum for mercury is in the range of 20 to 50% of the cartridge inlet maximum. The cartridge inlet maximum is considered comparable to the available historical datum.

C.9.4 1,3-Butadiene

The maximum cartridge inlet concentration was less than the RL, which was 1.93% of the OEL. This is low compared to the historical maximum concentration of 0.293 ppm (29% of the OEL). This data point came from the SWIHD HS database and was measured on July 10, 2015. By contrast, the single measurement in the TWINS IH database, made in 2006, was less than the RL of 0.0028 ppm (<0.28% of the OEL). The cartridge-testing inlet concentration was <20% of the historical maximum and is considered significantly different.

C.9.5 Furan

The cartridge inlet maximum was below the DL for furan, <28.6% of the OEL (Carbotrap 300 TDU method). The historical maximum was a 2006 below-report with an RL of 3.1 ppb (concentration <310% of the OEL). The highest above-report historical concentration was in the SWIHD HS database, measured on July 10, 2015. This concentration was 1.43 ppb (143% of the OEL, measured by the Carbotrap 300 TDU tube). The cartridge-testing inlet concentrations were consistently <20% of the historical maximum and therefore, are not considered comparable.

C.9.6 Substituted Furans

Substituted furans that were measured by the furans method were 2,3-dihydrofuran (9.77% of the OEL), 2,5-dimethylfuran (26.6% of the OEL), 2-pentylfuran (less than the DL; 5.36% of the OEL), 2-heptylfuran (less than the DL; 4.05% of the OEL), and 2-propylfuran (3.77% of the OEL). The substituted furans measured by the Carbotrap 300 TDU method were below their DLs, with concentrations of <52.8% of the OEL for 2,5-dihydrofuran and <20.0% of the OEL for 2-methylfuran.

The TWINS IH and SWIHD HS databases contained only below-report data for all the substituted furans. The below-report maxima have RLs of <34% of the OEL for 2,3-dihydrofuran (2015 SWIHD HS), <980% of the OEL for 2,5-dihydrofuran (2006 TWINS IH), <1800% of the OEL for 2-methylfuran (2006 TWINS IH), <25% of the OEL for 2,5-dimethylfuran (2015 SWIHD HS), <21% of the OEL for 2-propylfuran (2015 SWIHD HS), <17% of the OEL for 2-pentylfuran (2015 SWIHD HS), and <14% of the OEL for 2-heptylfuran (2015 SWIHD HS).

The cartridge inlet maximum for 2,5-dimethylfuran, which was 26.6% of the OEL, was higher than the RL of the below-report historical maximum (<25% of the OEL), suggesting higher concentration during the cartridge test. However, there are no above-report historical data for these chemicals, so no firm conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data. In addition, the cartridge-inlet maximum comes from the SD1 cartridge, for which the cartridge-inlet baseline and blank concentrations were equal to or greater than the inlet maximum, rendering it suspect. The SC1 inlet maximum was 14.0%.

C.9.7 Acetonitrile

The maximum cartridge inlet concentration was 1.59% of the OEL, measured by the Carbotrap 300 TDU method. These values are low compared to the historical maximum concentration of 2.82 ppm (14% of the OEL, acetonitrile method), or 0.803 ppm (4.02% of the OEL, Carbotrap 300 TDU method). These two historical measurements were from the same sampling event but used different analysis methods. They came from the SWIHD HS database and were measured on July 10, 2015. The single measurement in the TWINS IH database, made in 2006 at the breather filter, was less than the RL of 0.0028 ppm (<0.014% of the OEL). Although the difference in measurement methods might account for some of the difference between cartridge-inlet and historical maxima, the maximum cartridge testing inlet concentration was <20% of the recent historical maximum and is considered significantly different.

C.9.8 N-nitrosodimethylamine (NDMA)

The maximum cartridge inlet concentration was 2119% of the OEL. The historical maximum concentration was 27.9 ppb (9300% of the OEL). The historical value came from the SWIHD HS database; it was measured on July 10, 2015. The cartridge-testing inlet maximum was >20% of the historical maximum and therefore, is considered comparable.

C.9.9 N-nitrosodiethylamine (NDEA), N-nitrosomethylethylamine (NMEA), N-nitrosomorpholine

The cartridge inlet maxima were above their DLs for NDEA, NMEA, and N-nitrosomorpholine, at values of 412%, 32.3%, and 11.2% of the OEL respectively. The TWINS IH and SWIHD HS databases contained only below-report data for these three nitrosamines. The maximum historical RLs, which were all from 2015 SWIHD HS data, were <37% of the OEL for NDEA, <14% of the OEL for NMEA, and <5.7% of the OEL for N-nitrosomorpholine. Although all the historical maxima are below-report, their RLs are so much lower than the concentrations measured during cartridge testing that it is clear the cartridge-testing concentrations were higher and therefore, not significantly different.

C.9.10 Summary of Historical Data Comparisons

Some cartridge inlet maxima for the chemicals of interest in the SX-104 headspace were substantially higher than the historical maxima. These included NDEA, NMEA, and N-nitrosomorpholine. Other chemicals—ammonia and NDMA—had cartridge inlet maxima that were within a factor of two of historical maxima and were considered comparable.

The cartridge inlet concentrations that were lower than historical data can be described as follows:

- Differences could not be resolved because of the scarcity of above-report data: 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-propylfuran, 2-pentylfuran, and 2-heptylfuran.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: 1,3-butadiene, furan, and acetonitrile.
- In the case of acetonitrile, one possible reason for the difference between the cartridge-inlet maxima and the historical maxima was that the former was measured by the Carbotrap 300 TDU tube and the latter by the acetonitrile method.

C.10 SX-101 Headspace: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

SX-101 has been almost inactive since 2003. A small volume addition of raw water was made in 2005. The sludge-cooler ventilation was not shut down until 2003. Because of the change in ventilation, pre-2004 headspace and activity data are considered irrelevant.

With respect to waste disturbance, it must be noted that SX Farm tanks are arranged in three-tank cascades. Tanks SX-101, SX-102, and SX-103 are connected with each other by overflow lines through which vapors may move from one tank headspace to another [16]. It is physically possible for waste disturbances in SX-102 and SX-103 to have affected vapor concentrations in SX-101. However, there were no waste-disturbing operations in any of the tanks of the SX-101 cascade in 2006, the only year for which post-2003 SX-101 headspace data are available. Hence none of the available data for SX-101 were taken during waste-disturbing conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.10.1 Ammonia

The maximum cartridge inlet concentration was 1385% of the OEL. This cartridge inlet maximum is high compared to the historical maximum concentration of 6.22 ppm (25% of the OEL). This data point comes from the TWINS IH database and was a breather-filter measurement made on August 7, 2006. The historical data apparently do not provide good guidance for the presence of high concentrations under current headspace conditions.

C.10.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. There is one historical concentration in TWINS IH, 2.1 ppm (4.2% of the OEL). The maximum above-report concentration in the TWINS HS database was measured in 1997 and is not relevant.

C.10.3 Mercury

The maximum cartridge inlet concentration was 13.8% of the OEL. This cartridge inlet maximum is high compared to the sole historical measurement, a below-report with a RL of 0.000051 mg/m³ (concentration <0.204% of the OEL). This measurement came from TWINS IH; it was a breather-filter measurement made on August 7, 2006. For this chemical, the historical data apparently do not provide good guidance for the presence of high concentrations under current headspace conditions.

C.10.4 Furan and Substituted Furans

For the APR cartridges, the above-detection-limit cartridge inlet maxima for furan was 169% of the OEL by the Carbotrap 300 TDU method. All the inlet concentrations of substituted furans were below their DLs for both the species measured by the Carbotrap 300 TDU method (2,5-dihydrofuran and 2-methylfuran) and those measured by the furans method (all others).

None of the furan chemicals had historical concentration data given in the TWINS HS database. The TWINS IH database contained data for only three of these chemicals: furan, 2,5-dihydrofuran, and 2-methylfuran. All three of these were measured only in 2006 and had only two measurements each, all below-reports. These below-report maxima, measured by the Carbotrap 300 TDU method, had RLs of <230% of the OEL for furan, <730% for 2,5-dihydrofuran, and <1300% for 2-methylfuran. There are no above-report historical data for these chemicals, so no conclusion can be drawn about where their cartridge inlet concentrations lie with respect to historical data.

C.10.5 N-nitrosodimethylamine (NDMA)

The maximum cartridge inlet concentration was 4750% of the OEL, which is very high compared to the sole historical concentration, a below-report datum that had an RL of 0.0070 ppb (<2.3% of the OEL). This value came from the TWINS IH database; it was a breather-filter measurement made on August 7, 2006. There are no TWINS HS data for nitrosamines in this tank. For this chemical, the historical data apparently do not provide good guidance for the presence of high concentrations under current headspace conditions.

C.10.6 N-nitrosodiethylamine (NDEA), N-nitrosomethylethylamine (NMEA), N-nitrosomorpholine

The comparison between the cartridge inlet maxima and the historical maxima gives the same type of results for these nitrosamines as for NDMA. The cartridge inlet maxima were 56.5% of the OEL for NDEA, 68.5% of the OEL for NMEA, and 8.59% of the OEL for N-nitrosomorpholine.

The historical maxima were below-reports that had RLs of <5.09% of the OEL for NDEA, <1.97% for NMEA, and <0.75% for N-nitrosomorpholine. These values were from the sole historical sample, which was in the TWINS IH database; it was a breather-filter measurement made on August 7, 2006. There are no TWINS HS data for nitrosamines in this tank. For these chemicals, the historical data apparently do not provide good guidance for the presence of high concentrations under current headspace conditions.

C.10.7 Summary of Historical Data Comparisons

In summary, most cartridge inlet maxima for the chemicals of interest in the SX-101 headspace were substantially higher than the historical maxima. These included ammonia, mercury, NDMA, NDEA, NMEA, and N-nitrosomorpholine.

The cartridge inlet concentrations that were substantially lower than historical data can be described as follows:

- Differences could not be resolved because of the scarcity of above-report historical data: furan, 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, and 2-propylfuran.

C.11 AX Exhauster: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

The AX Farm exhauster was installed in late February 2017. There were no activities in the AX Farm during 2017, except for an addition of less than 1 kgal of raw water during the July 18–19, 2017 timeframe. This low-volume activity is unlikely to have had any effect by the time of October 2017 when vapor data were measured. Hence, none of the available data for the AX Farm, after exhauster installation, were taken during waste-disturbing conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections. The comparison is limited because the two AX exhauster surveys covered only ammonia, mercury, aldehydes (analyzed by the aldehyde method), furans (analyzed by the furans method), and nitrosamines.

C.11.1 Ammonia

The maximum cartridge inlet concentration was 23.9% of the OEL. The historical maximum was 3.22 ppm (12.9% of the OEL). The cartridge-inlet maximum is comparable to the historical maximum.⁵⁰

C.11.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing or in the relevant historical data.

⁵⁰ When cartridge data were first reported [12], ammonia data from the AX exhauster surveys were not yet available either in SWIHD source or in TWINS IH. The data have since been added to TWINS IH and are presented here.

C.11.3 Mercury

The maximum cartridge inlet concentration was 32.7% of the OEL, which was high compared to the historical maximum of 0.005 mg/m³ (20.0% of the OEL). For this chemical, the cartridge-test data and the historical data are in agreement in that there is no sign that the cartridge testing missed capturing high concentrations.

C.11.4 Formaldehyde

The maximum cartridge inlet concentration was 17.2% of the OEL, which was higher than the historical maximum concentration of 11.3% of the OEL. For this chemical, the cartridge-test data and historical data are in agreement.

C.11.5 N-nitrosodimethylamine (NDMA)

The maximum cartridge inlet concentrations was 73.0% of the OEL, which was higher than the historical maximum concentration of 45.7% of the OEL. For this chemical, the cartridge-test data and historical data are in agreement.

C.11.6 N-nitrosodiethylamine (NDEA)

The maximum cartridge inlet concentration was 17.6% of the OEL, which was higher than the historical concentrations, below-reports with a maximum RL of 3.00% of the OEL. This chemical had a cartridge-test maximum concentration that exceeded the historical maximum concentration by more than a factor of 5; thus, there is no indication that the cartridge-testing missed capturing high concentrations.

C.11.7 N-nitrosomethylethylamine (NMEA)

The maximum cartridge inlet concentration was 6.18% of the OEL, which was higher than the historical maximum of 1.67% of the OEL. The cartridge-test maximum concentration for NMEA exceeded historical maximum concentrations. Thus, there is no indication that the cartridge-testing missed capturing high concentrations.

C.11.8 N-nitrosomorpholine

The maximum cartridge inlet concentration was 42.9% of the OEL, which was lower than the historical maximum of 151% of the OEL. For this chemical, the cartridge test and historical data are considered not to be significantly different because the cartridge-test maximum concentration, although lower than the historical measurement, is within a factor of 5.

C.11.9 Summary of Historical Data Comparisons

A number of cartridge inlet maximum concentrations for COPCs in the AX exhauster were higher than historical maximum concentrations. These COPCs included ammonia, mercury, formaldehyde, NDMA, NDEA, and NMEA.

The cartridge inlet concentrations that were substantially lower than historical data can be described as follows:

- Differences could not be resolved, and cartridge inlet data were between 20% and 50% of historical maximum: N-nitrosomorpholine.

C.12 BY-110 Headspace: Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

BY-110 has been inactive throughout the period of record for which historical vapor concentration data have been collected. With regard to waste disturbance, it must be noted that BY Farm tanks are arranged in six-tank cascades that tie three tanks in BX Farm to three tanks in BY Farm. Tanks BX-110, BX-111, BX-112, BY-110, BY-111, and BY-112 are connected with each other by overflow lines through which vapors may move from one tank headspace to another [16]. Thus, it would have been physically possible for waste disturbances in any of five other tanks to have affected vapor concentrations in BY-110. However, there were no waste-disturbing operations in any of the tanks of the BY-110-related cascades in the period during which vapor data were recorded. Hence none of the available data for BY-110 were taken during waste-disturbing conditions.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.12.1 Ammonia

The maximum cartridge inlet concentration was 943% of the OEL. This cartridge inlet maximum is lower than the historical maximum concentration of 426 ppm (1704% of the OEL). This historical data point comes from the TWINS HS database and was measured on November 11, 1994. The only BY-110 ammonia measurement in the SWIHD HS database is 438 ppm, but this 2015 datum is suspect because of a “Y” Data Quality Flag. The only other measurement is in TWINS IH, a 1.11 ppm concentration (4% of the OEL) measured on April 8, 2008 at a breather filter. The cartridge inlet maximum is >50% of the historical maximum, and therefore, is not considered a discrepancy.

C.12.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing. The relatively recent historical maximum in TWINS IH, 2.88 ppm (5.76% of the OEL) was measured at the breather filter in 2009. The maximum above-report concentration in the TWINS HS database was 125 ppm (250% of the OEL); it was measured in November 1994.

C.12.3 Mercury

The maximum cartridge inlet concentration was below the RL of 8.09% of the OEL. The historical measurements were both below-reports, with the maximum RL being 0.0030 mg/m³ (concentration <12.0% of the OEL). This measurement came from SWIHD HS and was taken in July 2015. The cartridge inlet maximum may be consistent with the historical maximum, but this is uncertain because there are no above-report historical data.

C.12.4 1,3-Butadiene

The maximum cartridge inlet concentration was a below-report with a RL of 3.87% of the OEL. This is low compared to the historical maximum concentration, which comes from SWIHD HS and was taken in July 2015. It had a concentration of 2.58 ppm (258% of the OEL). The maximum cartridge inlet concentration was much <20% of the maximum historical measurement, and therefore, was significantly below the historical record.

C.12.5 Furan

The maximum cartridge inlet concentration of 168% of the OEL is less than the maximum in the SWIHD HS database, which is 2.95 ppb (295% of the OEL). This datum came from a sample taken on July 28, 2015. The Carbotrap 300 TDU method was used to measure both the cartridge-inlet and historical maxima. The cartridge inlet maximum is >50% of the historical maximum, and therefore, is not considered a discrepancy.

C.12.6 2,3-Dihydrofuran, 2,5-Dihydrofuran

For both 2,3-dihydrofuran (measured by the furans method) and 2,5-dihydrofuran (measured by the Carbotrap 300 TDU method), the cartridge inlet concentration were below the DL of 3.34% OEL and 23.4% of the OEL, respectively. These are much less than the above-report historical maxima, 3.09 ppb (309% of the OEL) and 4.57 ppb (457% of the OEL), respectively. These historical maxima were 2015 SWIHD HS data, with concentrations measured by the furans method. The maximum cartridge inlet concentrations were much <20% of the maximum historical measurements and, therefore, were significantly below the historical record.

C.12.7 2-Methylfuran, 2,5-Dimethylfuran, 2-Pentylfuran, 2-Heptylfuran, 2-Propylfuran

The cartridge inlet maximum was 10.6% of the OEL for 2-methylfuran (Carbotrap 300 TDU method), while the cartridge inlet maxima for 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, and 2-propylfuran (all furans method), were less than the DL of ~3% of the OEL (or 1.88% of the OEL, for 2-propylfuran). All of the historical maxima were below-reports with RLs in the range of ~15 to 26% of the OEL, except that the 2-methylfuran RL was 206% of the OEL.

There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.12.8 Acetonitrile

The maximum cartridge inlet concentration of 1.12% of the OEL, measured by the Carbotrap 300 TDU method, is much lower than the historical maximum of 5.37 ppm (26.9% of the OEL) that was measured in July 2015. This historical maximum comes from SWIHD HS and was made using the acetonitrile method. The maximum APR cartridge inlet concentration, which was measured by the Carbotrap 300 TDU method, is <20% of the historical maximum concentration and is considered significantly less than the historical concentration.

C.12.9 N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosomethylethylamine (NMEA), N-nitrosomorpholine

The cartridge inlet concentration maxima were 1874% of the OEL for NDMA, 150% of the OEL for NDEA, 252% OEL for NMEA, and a below-report with a RL of 1.66% of the OEL for N-nitrosomorpholine. The historical maxima, all of which were below-reports, had RLs ranging from ~15 to 39% OEL for NDMA, NDEA, and NMEA, and an RL of 6% for N-nitrosomorpholine. These maxima came from the SWIHD HS database, for a headspace sample taken in July 2015. The cartridge inlet maxima are much higher than the historical maxima for NDMA, NDEA, and NMEA. For N-nitrosomorpholine, the historical and cartridge-inlet data were consistent to the extent that both were below the RL, with similar values of RL; there is no evidence of discrepancy.

Most of the NDMA inlet concentrations for both APR cartridges had multiple Data Quality Flags, “BL” for all eight measurements from cartridge SC1, and “DL” or “DEL” for the seven highest concentrations from cartridge SD1. The maximum APR cartridge inlet concentration had the “DEL” flags, indicating that the sample had been diluted to bring it within the calibration but the concentration remained above calibration range; in addition, the calibration at the low end of the range was outside specifications.

C.12.10 Dibutyl Butylphosphonate (DBBP)

The maximum cartridge inlet concentration is below its DL of 0.38% of the OEL. The historical maximum concentration was a SWIHD HS below-report datum with an RL of 0.0003 ppm (<4.29% of the OEL). There were also below-report historical data in TWINS HS, dating from 1994. The highest of the RLs in TWINS HS was 0.0179 ppm (256% of the OEL), while others measured using the same method had RLs a factor of ~5 less, making the maximum RL in TWINS HS questionable. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.12.11 Summary of Historical Data Comparisons

In summary, the cartridge inlet concentrations for the BY-110 headspace that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance as the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: mercury, 2-methylfuran, 2,5-dimethylfuran, 2-heptylfuran, 2-propylfuran, 2-pentylfuran, and dibutyl butylphosphonate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: 1,3-butadiene, 2,3-dihydrofuran, 2,5-dihydrofuran, and acetonitrile.

C.13 AP Exhauster (2018 Tests After Exhauster Upgrade): Comparison with Historical Data

The maximum and average COPC concentrations measured during cartridge testing were compared to the maximum and average historical concentrations, and where differences were found, the historical data were examined for explanations in the type or circumstances of sampling.

The AP Farm contains six actively ventilated DSTs, all of which are exhausted through the AP stack. Waste transfers involving these tanks are frequent, potentially leading to changes in the concentrations of COPCs in the wastes in the tanks and in the exhaust from the headspaces. However, there were no waste transfers or water additions in any AP tank during March 23–25, 2018, the date of the FY18 cartridge-testing campaign.⁵¹

As of September 8, 2016, after the AP cartridge-testing campaign that had been conducted on June 24–26, 2016, the AP exhauster was upgraded, changing the active ventilation rate. Consequently, it was necessary to compare the FY18 cartridge-testing inlet concentrations to data taken after the exhauster upgrade, omitting earlier stack samples. In addition, because of the exhauster change it is not appropriate to compare the FY18 AP cartridge-inlet concentrations to those measured during the FY16 cartridge-testing campaign.

The larger discrepancies, or apparent discrepancies, between cartridge inlet and historical concentrations are discussed in the following sections.

C.13.1 Ammonia

The maximum cartridge inlet concentration was 94.9% of the OEL. The cartridge inlet maximum is low compared to the historical maximum concentration of 103 ppm (412% of the OEL). This historical measurement was made on January 26, 2017, about a month after the last preceding transfer of 6 kgal from AP-102 to AY-102 on December 31, 2016. The cartridge-inlet maximum falls between 20% and 50% of the historical maximum, but not below the 20% level that is considered to be significantly below historical.

C.13.2 Nitrous Oxide

Nitrous oxide was not measured in cartridge testing, nor was it measured at the AP exhauster after September 8, 2016.

C.13.3 Mercury

The maximum cartridge inlet concentration was 16.2% of the OEL. The historical maximum was a below-report TWINS IH measurement with a RL of 0.0125 mg/m³ (50.0% of the OEL). The highest historical above-report measurement was 0.00791 mg/m³ (31.6% of the OEL). The cartridge-inlet maximum was about 50% of the historical maximum and is not considered a discrepancy.

⁵¹ Although there were no waste-disturbing operations during cartridge-test sampling, the previous week there had been a transfer of 17 kgal of supernatant liquid from AP-103 to AN-101 (March 17–18, 2018). Some residual elevation in headspace concentration might have remained; on the other hand, the transfer was relatively small.

C.13.4 Furan

The maximum cartridge inlet concentration of 104% OEL, which was measured by the Carbotrap 300 TDU method, is much lower than the maximum in the TWINS IH database, which is 7.15 ppb (715% of the OEL). This above-report concentration was measured on March 22, 2017, more than a month after the last preceding tank activity. The cartridge inlet maximum concentration is <20% of the more recent historical maximum. The cartridge inlet concentration is considered significantly less than historical.

C.13.5 2,3-Dihydrofuran, 2,5-Dihydrofuran, 2-Methylfuran, 2,5-Dimethylfuran, 2-Pentylfuran, 2-Propylfuran, 2-Heptylfuran

For all of the substituted furans, the cartridge-inlet maxima were below DLs and the historical maxima were below the DLs, with details as follow:

- 2,3-dihydrofuran: < 3.28%, historical < 73.2% (furans method),
- 2,5-dihydrofuran: < 25.0%, historical < 290% (Carbotrap 300 TDU method),
- 2-methylfuran: < 10.3%, historical < 247% (Carbotrap 300 TDU method),
- 2,5-dimethylfuran: < 3.09%, historical < 53.4% (furans method),
- 2-pentylfuran: < 3.11%, historical < 37.1% (furans method),
- 2-heptylfuran: < 2.93%, historical < 30.9% (furans method), and
- 2-propylfuran: < 1.85%, historical < 46.6% (furans method).

The methods listed are for the historical data. There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet concentrations lie with respect to historical data.

C.13.6 N-nitrosodimethylamine (NDMA)

The maximum cartridge inlet concentration of NDMA was 2681% of the OEL. The historical maximum was 15.8 ppb (5267% of the OEL). It was measured on August 8, 2017, less than a month after a transfer of 273 kgal from the 242-A evaporator to AP-104 (July 1–13, 2017). This historical maximum might have included residual elevated headspace concentration in AP-104 because of the large transfer. However, the second-highest historical NDMA concentration was almost the same, 15.7 ppb, and there had been no activity for about 5 months preceding that datum. The cartridge-inlet maxima are above 50% of the historical maximum and are not considered significantly below historical.

The NDMA inlet concentrations for the SC1 cartridge all have “DLa” flags except for one “Da”, and the NDMA inlet concentrations SD1 cartridge all have “D” flags. The maximum cartridge inlet concentration, 2681% of the OEL, came from the SC1 data set. The maximum inlet concentration for the SD1 cartridge data alone was 1733% of the OEL.

The cartridge maxima are suspect because of multiple data-quality flags in the SC1 cartridge inlet data. However, the SD1 maximum, like the overall maxima, are >20% of the historical maximum. The NDMA cartridge maximum can be considered consistent with the historical maximum.

C.13.7 N-nitrosodiethylamine (NDEA)

All cartridge-inlet concentrations of NDEA were less than the DL, which was 9-11% OEL. The historical maximum was a below-report with an RL of 0.0478 ppb (47.8% of the OEL). The maximum of the above-report measurements was 0.0169 ppb (16.9% of the OEL), measured on December 13, 2016, with no tank activity during sampling or in the preceding seven months. It is possible that the cartridge-inlet maximum is consistent with the historical above-report maximum, since the cartridge-inlet DL is close to the historical datum. However, in the absence of above-report cartridge-inlet data for NDEA, no conclusion about consistency can be drawn.

C.13.8 N-nitrosomethylethylamine (NMEA)

The maximum cartridge inlet concentration of NMEA was 20.7% of the OEL. The historical maximum was 0.148 ppb (49.3% OEL). It was measured on August 8, 2017, less than a month after a large transfer of 273 kgal from the 242-A evaporator to AP-104 (July 1–13, 2017). This historical maximum might have included residual elevated headspace concentration because of the large transfer. However, the second-highest historical NMEA concentration was almost the same, 0.137 ppb, and there had been no activity in the five months preceding that datum. The cartridge-inlet maximum is between 20% and 50% of the historical maximum, and therefore, is not considered significantly discrepant from historical.

All the NMEA inlet concentrations for the SC1 APR cartridge had the single flag “a”, denoting spike recovery outside its specified range. The maximum cartridge inlet concentrations came from the SC1 data set. There were low recoveries of nitrosamines for the SC1 samples because of a change in extraction procedure, but the 222-S Laboratory considers the data usable.⁵²

The NMEA cartridge maximum can be considered consistent with the historical maximum.

C.13.9 N-nitrosomorpholine

The maximum cartridge inlet concentrations of N-nitrosomorpholine was 3.28% of the OEL. The historical maximum was 0.0944 ppb (15.7% OEL). It was measured on August 22, 2017, more than a month after the last preceding transfer. The cartridge-inlet maximum is a little more than 20% of the historical maximum. The range from 20% to 50% is not considered significantly discrepant from historical, although this nitrosamine is on the borderline of discrepancy.

All the N-nitrosomorpholine inlet concentrations for the SC1 cartridge had the single flag “a”, and the maximum cartridge inlet concentration came from the SC1 data set. There were low recoveries of nitrosamines for the SC1 samples because of a change in extraction procedure, but the 222-S Laboratory considers the data usable.⁵² The presence of low recoveries suggests that the actual cartridge-inlet concentrations for SC1 may have been higher than measured.

The N-nitrosomorpholine cartridge maximum can be considered consistent with the historical maxima.

⁵² Email from DR Hansen (222-S Laboratory) to LA Mahoney, “RE: Two residual questions (both AP),” March 27, 2019 12:39 PM.

C.13.10 Dibutyl Butylphosphonate (DBBP)

The maximum cartridge inlet concentrations of DBBP are below their DL of 0.64% OEL. The historical maximum concentration was a below-report datum with an RL of 0.0007 ppm (<10.2% of the OEL). There were no above-report historical data, so no conclusion can be drawn about where the cartridge inlet DBBP concentrations lie with respect to historical data.

C.13.11 Summary of Historical Data Comparisons

In summary, for the AP exhauster, after its September 8, 2016, upgrade, the maximum cartridge inlet concentrations that were substantially lower than historical data can be described as follows:

- Differences arose from using historical data taken during disturbance as the historical maximum: none.
- Differences arose from using the RLs of below-report data for the historical maximum: none.
- Differences arose from using data for vapor produced by a no-longer-existing inventory for the historical maximum: none.
- Differences could not be resolved because of the scarcity of non-disturbance above-report data: 2,3-dihydrofuran, 2,5-dihydrofuran, 2-methylfuran, 2,5-dimethylfuran, 2-pentylfuran, 2-heptylfuran, 2-propylfuran, N-nitrosodiethylamine, and dibutyl butylphosphonate.
- Cartridge inlet concentrations were determined to be significantly lower than above-report historical concentrations: furan.

C.14 COPCs Near Historical Area-Sample Concentrations

There are three COPCs where the available area-sampling data for all tank farms between 2008 and 2018⁵³ showed maximum concentrations that were nearly the same as or higher than those measured in APR cartridge inlet samples during testing. These COPCs were

- Mercury that has shown breakthrough and an area-sampling maximum nearly equal to the cartridge-inlet maximum
- Acetonitrile that has not shown breakthrough and an area-sampling maximum exceeding the cartridge-inlet maximum
- Formaldehyde that has not shown breakthrough and an area-sampling maximum nearly equal to the cartridge-inlet maximum.

⁵³ Area-sampling data typically represents time weighted average concentrations comparable to source and cartridge testing samples, but may not represent instantaneous or short duration concentrations, if present. In addition, area sampling represents only a portion of the data potentially available. WRPS industrial hygiene performs more extensive analysis on vapor concentrations in the breathing zone using additional data sets.

C.15 References

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Appendix D

Detection Limits Versus Reporting Limits for Furans

Appendix D

Detection Limits Versus Reporting Limits for Furans

A total of 14 furan or substituted furans are on the current list of Chemicals of Potential Concern (COPC). Six of these furans are Tentatively Identified Compounds that were not detected in any respirator cartridge test samples. Eight remaining furans were quantified in respirator cartridge testing: 1) furan, 2) 2,3-dihydrofuran, 3) 2,5-dihydrofuran, 4) 2-methylfuran, 5) 2,5-dimethylfuran, 6) 2-pentylfuran, 7) 2-heptylfuran, and 8) 2-propylfuran. The Occupational Exposure Limit (OEL) for each of these furans is 1 ppb, which is among the lowest OELs of all COPCs. As discussed Appendix E, three of these furans, furan, 2,5-dimethylfuran, and 2-methylfuran, were measured using the Carbotrap 300 TDU method because the furans-specific sampling method (Tenax tubes) had been found not to retain these chemicals and therefore, underestimated their concentrations. The remaining five were measured using the furans-specific method.

COPC analysis results for tank farm vapors are typically reported in relation to a reporting limit (RL), which represents a quantitation limit referring to the minimum mass of an analyte that can be measured within specified limits of precision and accuracy. RL is a measured value representing the low point of the calibration curve. The analytical method or instrument detection limit (DL) represents a minimum mass of an analyte that can be measured above the instrument background noise. DL is a statistically calculated value. When an RL is used for reporting, it generally means that the analyte is not present in a sufficient amount to be reliably quantified below the RL value. The DL is always lower than the RL. When a DL is used for reporting, it generally means that the analyte is not present at or above the DL value. Historical tank vapor source data reported in the Tank Waste Information Network System (TWINS) and Site-Wide Industrial Hygiene Database (SWIHD) data sets have been primarily quantified and reported as RLs. Depending on the sample volume collected for analysis, a RL reported on a concentration basis may vary widely. For furans, historical RL concentrations have ranged from as low as 0.1 ppb to more than 50 ppb, depending on the specific COPC, sampling method (Carbotrap 300 TDU versus furans), and sample volume collected. On a percentage of the OEL basis, this equates to a range of 10% to more than 5000% of the OEL.

For cartridge testing, the furan samples were collected over 2 hours with an approximate volume target of 4 L or more. The analytical laboratory was requested to report to a DL rather than an RL to ensure that the COPCs could be detected down to 10% of the OEL or less. In practice, analytical DLs for the furans in cartridge testing were typically 5% of the OEL or lower by the furans method, but in the vicinity of 20% by the Carbotrap 300 TDU method. While use of the DL provides the opportunity for a lower level reported concentrations, it also introduces lower confidence in precision or accuracy of the analyte's quantitation. During review of cartridge-testing data from the furan analysis in the individual tank/exhauster test reports, concerns were raised because the cartridge inlet and outlet values were very close, and in some cases, the outlet values above detection were suspected of exhibiting potential "bleed through" in the cartridge. There was a greater level of variability than seen, for example, with nitrosamine analysis results that reported to an RL.

For these reasons, further assessments of furan analytical results, including comparison to baseline samples (i.e., background) and blank samples (i.e., pre-test sorbent tubes) were conducted. Table D.1 shows the respirator cartridge maximum furan data over combined inlet and effluent that were reported in the eight prior tank/cartridge reports in the upper third of the table (labeled "Measured"). The two other sections of the table show the analytical results for the "Baseline" and "Blank" samples, also for inlet and effluent combined.

Table D.1. Maximum Measured Respirator Concentrations (inlet and effluent) for the 15 Furan COPCs. Baseline and blank values also are included for comparison.

	COPC Number and Name	OEL	2016 AP Exhauste r Max. % OEL	SY-102 Max. % OEL	A-101 Max. % OEL	2016 BY- 108 Max. % OEL	2016 702- AZ Exhauster Max. %	AX-101 Max. % OEL	AN Exhauster Max. % OEL	2016 AW Exhauster Max % OEL	BY-110 Max. % OEL	SX-101 Max. % OEL	SX-104 Max. % OEL	702- AZ_2017 Max. % OEL	AP_2018 Max. % OEL	AX_2017 Max. %OEL	Approximate Reporting limit (%OEL)*
Measured	19 Furan	1 ppb	391.8%	18.1%	45.5%	818.5%	58.0%	23.7%	84.7%	203.9%	167.8%	168.9%	28.6%	2994.5%	103.8%	43.3%	114.1%
	20 2,3-Dihydrofuran	1 ppb	5.0%	2.0%	4.2%	74.5%	6.2%	43.6%	3.1%	2.5%	3.3%	3.8%	9.8%	16.8%	3.3%	3.5%	23.8%
	21 2,5-Dihydrofuran	1 ppb	20.9%	24.1%	27.1%	376.8%	104.9%	29.6%	29.9%	29.0%	43.8%	53.0%	52.8%	20.6%	25.8%	19.0%	110.8%
	22 2-Methylfuran	1 ppb	10.6%	12.2%	15.7%	39.2%	16.6%	17.2%	17.3%	16.8%	10.6%	12.7%	20.9%	13.8%	10.3%	10.3%	94.6%
	23 2,5-Dimethylfuran	1 ppb	3.1%	3.4%	3.1%	3.2%	5.3%	5.2%	1.8%	5.0%	3.1%	7.2%	26.6%	3.5%	3.1%	6.7%	17.3%
	27 2-Pentylfuran	1 ppb	5.6%	7.2%	2.7%	3.6%	5.5%	6.3%	3.1%	4.2%	3.2%	5.9%	5.4%	6.8%	3.1%	5.5%	12.1%
	28 2-Heptylfuran	1 ppb	1.6%	2.5%	1.8%	4.5%	2.6%	2.7%	1.5%	3.3%	3.0%	4.5%	7.1%	2.3%	2.9%	7.9%	10.0%
	29 2-Propylfuran	1 ppb	3.0%	6.4%	3.3%	11.0%	3.8%	3.7%	1.3%	3.6%	1.9%	4.4%	3.8%	2.5%	1.8%	4.1%	15.1%
	Baseline	19 Furan	1 ppb	15.7%	16.4%	14.7%	14.8%	15.7%	16.2%	15.8%	15.9%	12.4%	6.1%	26.6%	636.6%	20.7%	41.8%
20 2,3-Dihydrofuran		1 ppb	2.8%	1.7%	1.6%	1.7%	1.6%	1.5%	2.1%	2.1%	3.1%	3.3%	3.3%	1.4%	3.2%	3.6%	23.8%
21 2,5-Dihydrofuran		1 ppb	21.0%	21.8%	24.1%	25.2%	25.9%	27.5%	26.8%	26.9%	21.5%	48.2%	49.1%	20.3%	11.7%	18.4%	110.8%
22 2-Methylfuran		1 ppb	10.6%	11.0%	14.0%	14.6%	26.9%	15.9%	15.5%	15.6%	8.1%	11.5%	11.8%	10.2%	9.3%	9.9%	94.6%
23 2,5-Dimethylfuran		1 ppb	2.9%	3.0%	2.8%	2.9%	3.9%	3.5%	1.2%	3.3%	2.9%	6.2%	30.5%	3.3%	3.0%	6.4%	17.3%
27 2-Pentylfuran		1 ppb	3.9%	7.6%	1.7%	9.6%	1.7%	2.9%	1.0%	2.7%	2.9%	5.1%	5.1%	4.9%	3.0%	5.2%	12.1%
28 2-Heptylfuran		1 ppb	2.1%	1.1%	1.0%	1.7%	2.6%	2.3%	1.0%	2.2%	2.7%	3.9%	3.8%	2.2%	2.8%	11.7%	10.0%
29 2-Propylfuran		1 ppb	2.6%	5.7%	2.7%	2.6%	2.8%	2.5%	0.9%	2.4%	1.7%	3.8%	3.8%	2.4%	1.8%	3.9%	15.1%
Blank derived		19 Furan	1 ppb	15.7%	16.4%	14.7%	14.8%	15.7%	16.2%	15.8%	5.9%	12.4%	26.1%	26.6%	15.2%	20.7%	41.8%
	20 2,3-Dihydrofuran	1 ppb	1.7%	1.7%	1.6%	1.7%	1.3%	1.5%	2.1%	2.1%	3.1%	3.3%	3.3%	1.4%	3.2%	3.4%	23.8%
	21 2,5-Dihydrofuran	1 ppb	21.0%	21.8%	24.1%	25.2%	25.9%	27.5%	26.8%	21.2%	21.5%	48.2%	49.1%	20.3%	11.7%	18.4%	110.8%
	22 2-Methylfuran	1 ppb	10.6%	11.0%	14.0%	14.6%	15.0%	15.9%	15.5%	10.7%	8.1%	11.5%	11.8%	10.2%	9.3%	9.9%	94.6%
	23 2,5-Dimethylfuran	1 ppb	2.9%	3.0%	2.8%	2.9%	2.3%	3.5%	1.2%	1.2%	2.9%	6.2%	26.1%	3.3%	3.0%	6.4%	17.3%
	27 2-Pentylfuran	1 ppb	1.5%	1.7%	1.6%	1.6%	2.2%	2.9%	1.0%	0.9%	2.9%	5.1%	5.1%	2.8%	3.0%	5.2%	12.1%
	28 2-Heptylfuran	1 ppb	1.0%	1.1%	1.0%	1.1%	0.8%	2.3%	1.0%	1.0%	2.7%	3.9%	3.8%	2.2%	2.8%	4.0%	10.0%
	29 2-Propylfuran	1 ppb	2.6%	2.6%	2.5%	2.6%	2.1%	2.5%	0.9%	0.9%	1.7%	3.8%	3.8%	2.4%	1.8%	3.9%	15.1%

Notes:

- Two analytical methods were used for furans. Furan, 2,5-dihydrofuran, and 2-methylfuran were analyzed using the Carbotrap 300 TDU method while the other furans were analyzed using Tenax method.
- Measurements less than DLs are shown in red. Values larger than DLs have qualifier "J" except for the values in green boxes. Qualifier "J" means that the values were estimated because they are between DLs and RLs.
- The values in the yellow boxes are highlighted because they are larger than the maximum measured results or higher than RLs, which indicate an incomplete media regeneration for blank samples or local air or system contamination.

* The approximate RL values were calculated based on a reference mass (3.1 NGS for Tenax and 12 NGS for Carbotrap 300 TDU) and overall average volume for all APR tanks.

The “Baseline” and “Blank” data in Table D.1 clearly show a number of furan measurements that are significantly above the analytical DL, when there should have been no measurable furan on those samples. Measurable values on blanks could be residue from prior analysis because the analytical tubes are regenerated and reused.⁵⁴ Regardless, the background and blank level of furans above the DL complicate interpretation of variations in outlet concentrations at low levels. For this reason, the RL for the furans was adopted in this report to better assess the overall furan results and provide a more consistent comparison to historical furan data that was also quantified to an RL. The RL provided by the analytical laboratory for the furan measurements, corresponds to 3.1 ng per tube. This value was used to calculate an equivalent average percent of the OEL RL for each of the furans, which are shown in the right-most column of Table D.1. None of the “Baseline” or “Blank” values are above the RL values. Because of the identified variation between the “Baseline” and “Blank” values, the use of RLs versus analytical DLs is recommended for furans going forward. It also is important to note that none of the respirator cartridge outlet measurement for any of the furans were greater than the corresponding RLs. There is still a need to improve the RL and DL for furans so that analysis results can reliably attain low percentage of the OEL values (e.g., 10% of the OEL or less).

⁵⁴ One tube of each batch of 20 tubes that are regenerated is analyzed to certify cleanliness of the batch, which should minimize the opportunity for contamination of future samples.

Appendix E

Meteorological Data Comparisons to Respirator Testing Conditions

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Meteorological Data Comparisons to Respirator Testing Conditions

Meteorological data from the Hanford Meteorological Station (HMS or Station 21) was accessed for comparisons to the respirator cartridge-testing data. The HMS is located between the 200-East and 200-West areas at Hanford. Two other meteorological stations were also evaluated, Station 6 located in the 200-East area, and Station 19 located in the 200-West area. All three towers are in relatively close proximity, so the values were similar. Data from the HMS were used because it was available on an hourly basis. A full set of 2016, 2017, and 2018 data was extracted for the cartridge testing comparisons. Figure E.1 shows plots of the hourly relative humidity and temperature data for 2016 through 2018.

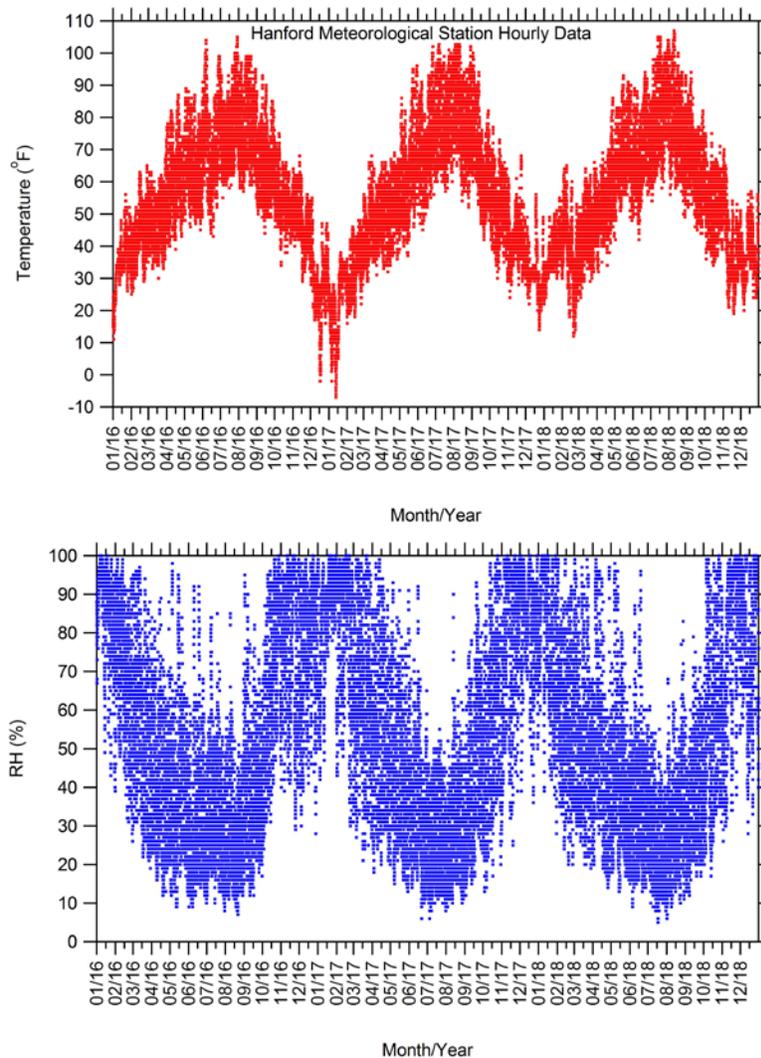


Figure E.1. Hourly Temperature (upper panel – red markers) and Relative Humidity (lower panel – blue markers) Measurements for January 1, 2016, through December 31, 2018, as Recorded at the HMS.

Figure E.2 shows a comparison plot of the same relative humidity and temperature data as in Figure E.1. Here, additional points from testing after revision 0 were included from January 1, 2017, through January 2019. HMS data are represented as black markers in the figure. The colored markers represent when cartridge testing was being performed, with each color representing a unique tank or exhauster test. Figure E.2 helps to represent and highlight the maximum relative humidity and temperature conditions that occur in the Hanford 200 area throughout the year. Based on the cluster of the colored markers it can be interpreted that the cartridge tests were performed in the middle to upper range of the annual outside temperatures, spanning approximately 30 to 90°F, and approximately 10 to 97% relative humidity. Correspondingly, the cartridge testing did not occur during the lowest and highest annual outside temperature ranges.

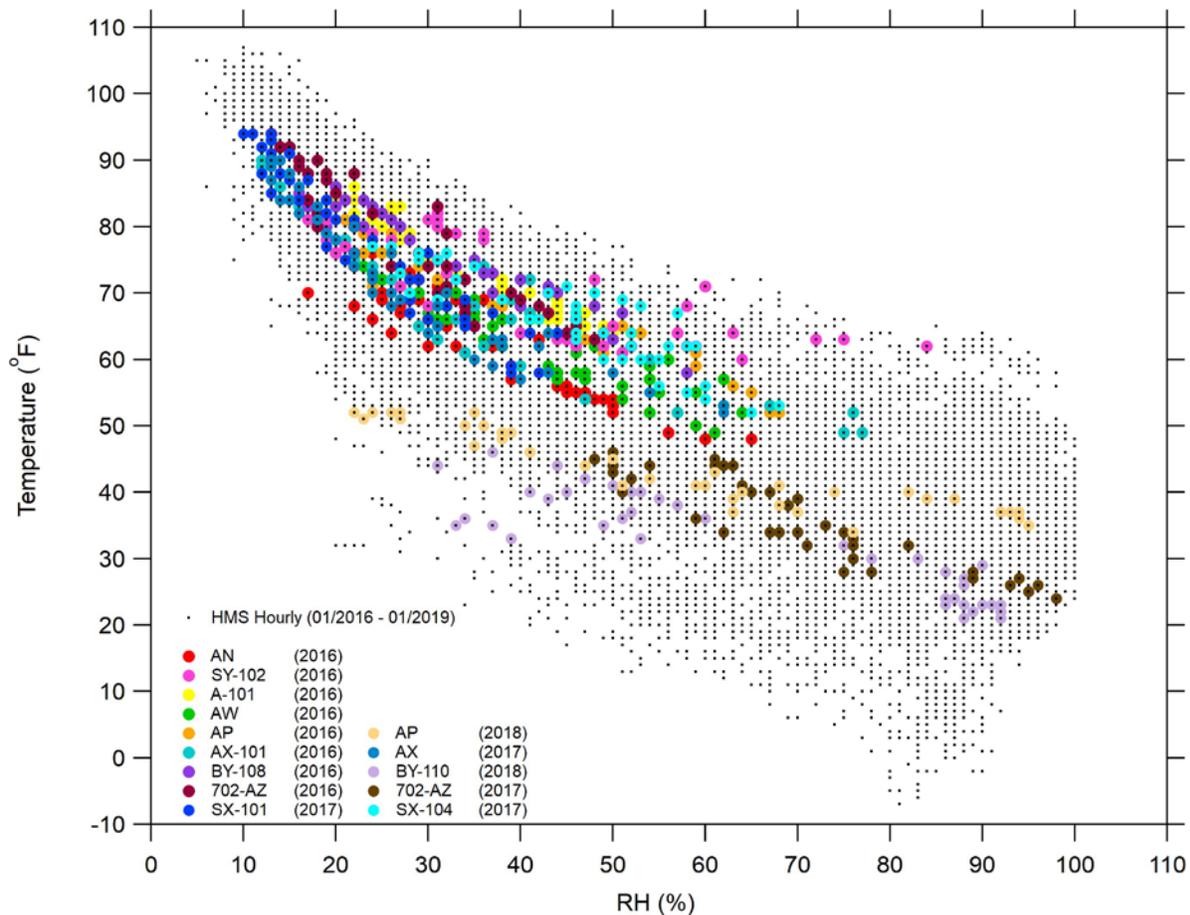


Figure E.2. Scatter Plot of the Ambient Temperature versus Relative Humidity Ambient Data Measured at HMS between January 1, 2016, and January 2019. Colored markers indicate corresponding to specific tank or exhauster cartridge-testing activities.

Next, the meteorological relative humidity and temperature data were compared to the corresponding relative humidity and temperature data taken during the 2016 cartridge testing for the four exhauster tests (AP, 702-AZ, AW, and AN) and the four tank headspace tests (SY-102, BY-108, A-101, and AX-101). These comparisons are shown in Figure E.3a. The 2017 through 2018 cartridge testing included the three exhauster tests (702-AZ 2017, AX 2017, and AP 2018) and the three tank headspace tests (SX-104, SX-101, and BY-110) that are shown in Figure E.3b.

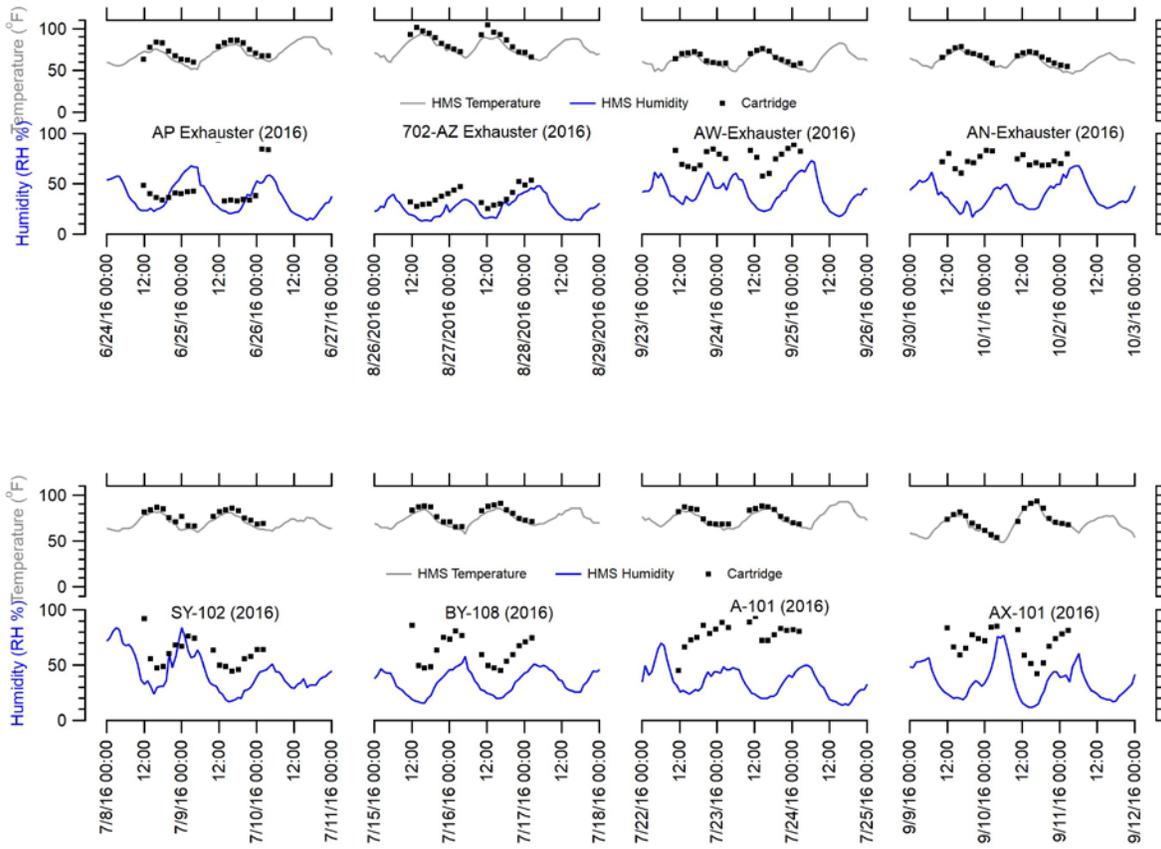


Figure E.3a. Overlay of 2016 Testing Cartridge Relative Humidity and Temperature Measurements Collected at 2-Hour Intervals during Cartridge Testing with 200 Area Meteorological Data from HMS. The upper panel summarizes the data for the four exhausters tested (AP, 702-AZ, AW, and AN) and the lower panel summarizes the data for the four tanks tested (SY-102, BY-108, A-101, and AX-101).

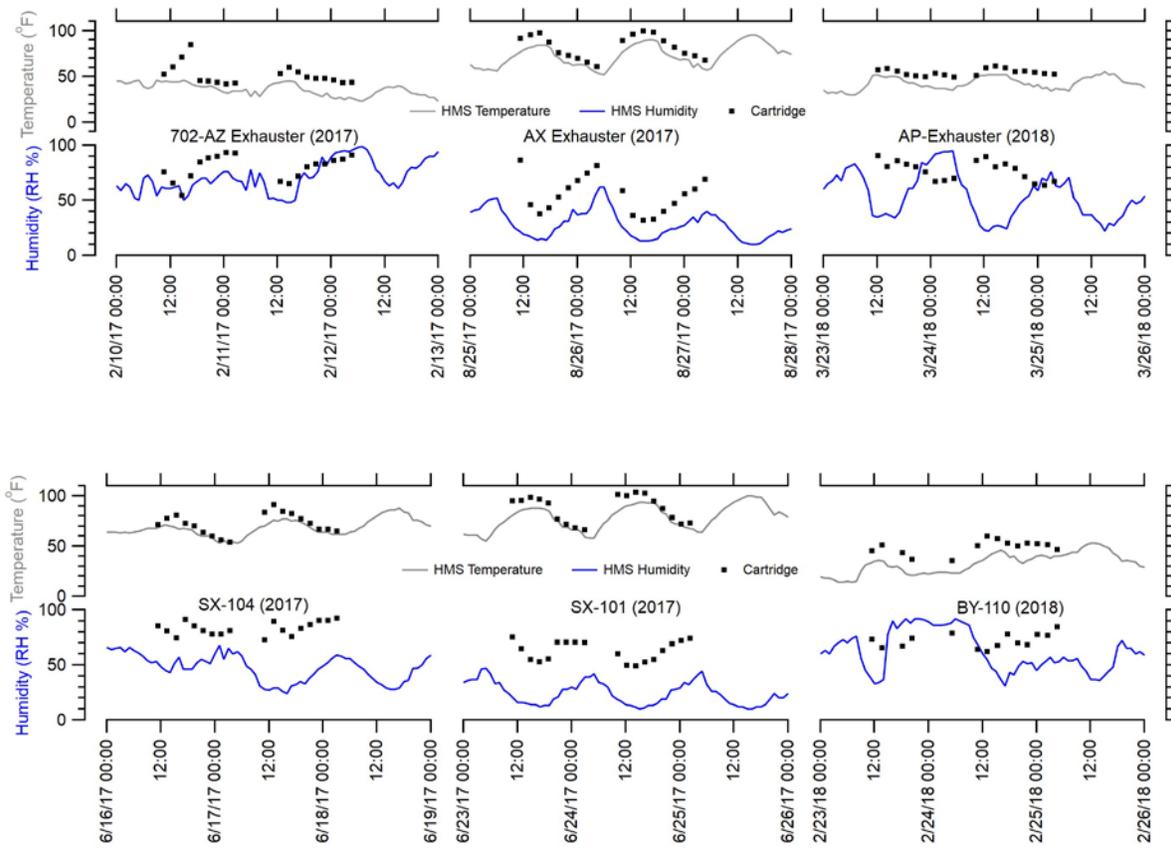


Figure E.3b. Overlay of 2017 and 2018 Testing Cartridge Relative Humidity and Temperature Measurements Collected at 2-Hour Intervals during Cartridge Testing with 200 Area Meteorological Data from HMS. The upper panel summarizes the data for the four exhausters tested (702-AZ 2017, AX 2017, and AP 2018) and the lower panel summarizes the data for the four tanks tested (SX-104, SX-101, and BY-110).

The data in Figures E.3a and E.3b show a strong relationship between the meteorological and cartridge temperature data for all the tank testing periods. This relationship pertains to both exhausters and tank headspaces. However, the comparison of relative humidity levels was much more inconsistent. For the majority of tests (exhauster and tank headspaces), the cartridge testing relative humidity levels were significantly higher than meteorological relative humidity levels. The likely reason is that humidity from tank-based water was being generated.

Appendix F

Assessment of the Use of Alternate Furan Measurements for Respirator Cartridge Performance Determinations

Appendix F

Assessment of the Use of Alternate Furan Measurements for Respirator Cartridge Performance Determinations

From Letter Report 69802-01 May 8, 2018. It is important to note that the letter report used a 10% of the Occupational Exposure Limit (OEL) threshold for breakthrough determination while this report uses a 50% of the OEL thresholds for furan and 2,5-dihydrofuran.

F.1 Overview

Two sorbent tubes are currently used in both vapor source characterization and cartridge testing that support quantitation of the furans class of Chemicals of Potential Concern (COPC), which includes furan (CAS# 110-00-9) and 13 other substituted furans. Prior to this letter report, the preferred sorbent tube had been the Tenax TA TDU “furans” tube, which uses a modified EPA TO-17 method with gas chromatography/mass spectroscopy (GC/MS) for quantitation. This furans tube addresses 8 of the 14 furan COPCs. A separate sorbent tube, also used to measure furans, is the Carbotrap 300 TDU tube. This tube also is analyzed with a modified EPA TO-17 method with GC/MS for quantitation. The Carbotrap 300 TDU tube is calibrated for three of the furan COPCs—furan; 2,5-dihydrofuran; and 2-methylfuran—all of which also are quantified with the furans tube. Six other furans COPCs are Tentatively Identified Compounds (TIC) measured using the Carbotrap 300 TDU tube without calibration standards. Table F.1 provides a summary of the 14 furans COPCs and current analytical methods.

Table F.1. Furans COPCs and Corresponding Analytical Methods.

Furans COPCs Name	CAS Number	Sorbent Tube Analysis Methods ^{a,b}	
		‘Furan’ Tube (TENAX TA)	Carbotrap 300 Tube
Furan	110-00-9	X	X
2,3-Dihydrofuran	1191-99-7	X	
2,5-Dihydrofuran	1708-29-8	X	X
2-Methylfuran	534-22-5	X	X
2,5-Dimethylfuran	625-86-5	X	
2-Ethyl-5-methylfuran	1703-52-2		TIC
4-(1-Methylpropyl)-2,3-dihydrofuran	34379-54-9		TIC
3-(1,1-Dimethylethyl)-2,3-dihydrofuran	34314-82-4		TIC
2-Pentylfuran	3777-69-3	X	
2-Heptylfuran	3777-71-7	X	
2-Propylfuran	4229-91-8	X	
2-Octylfuran	4179-38-8		TIC
2-(3-Oxo-3-phenylprop-1-enyl)furan	717-21-5		TIC
2-(2-Methyl-6-oxoheptyl)furan	51595-87-0		TIC

^a Both sorbent tubes are thermally desorbed and analyzed with GC/MS using a modified EPA TO-17 method at the 222S Laboratory. The target sample collection flow rate is the same for both sorbent tubes (i.e. approximately 33 mL/min during respirator cartridge testing).

^b “X” indicates method is calibrated for the COPC. The “TIC” notation indicates that a reference standard is not available to accurately quantify, assign an analytical DL or RL, or definitively confirm the identity of the TIC.

For the 2016 cartridge testing, PNNL was instructed by the 222S Laboratory management to use the furans tube data in lieu of Carbotrap 300 TDU tube data because it provided a lower level of quantitation. The Carbotrap 300 TDU tube furan results were only to be used to determine whether furan TICs were detected.

In comparing furan measurements from the Site-Wide Industrial Hygiene database (SWIHD) headspace and exhauster data, a discrepancy was noted between data from the furans and Carbotrap 300 TDU sorbent tubes for samples taken at the same location and time. Figure F.1 shows SWIHD source concentrations of furans quantified from the Carbotrap 300 TDU sorbent tube had consistently higher concentrations than those obtained at the same time with the furans sorbent tube.

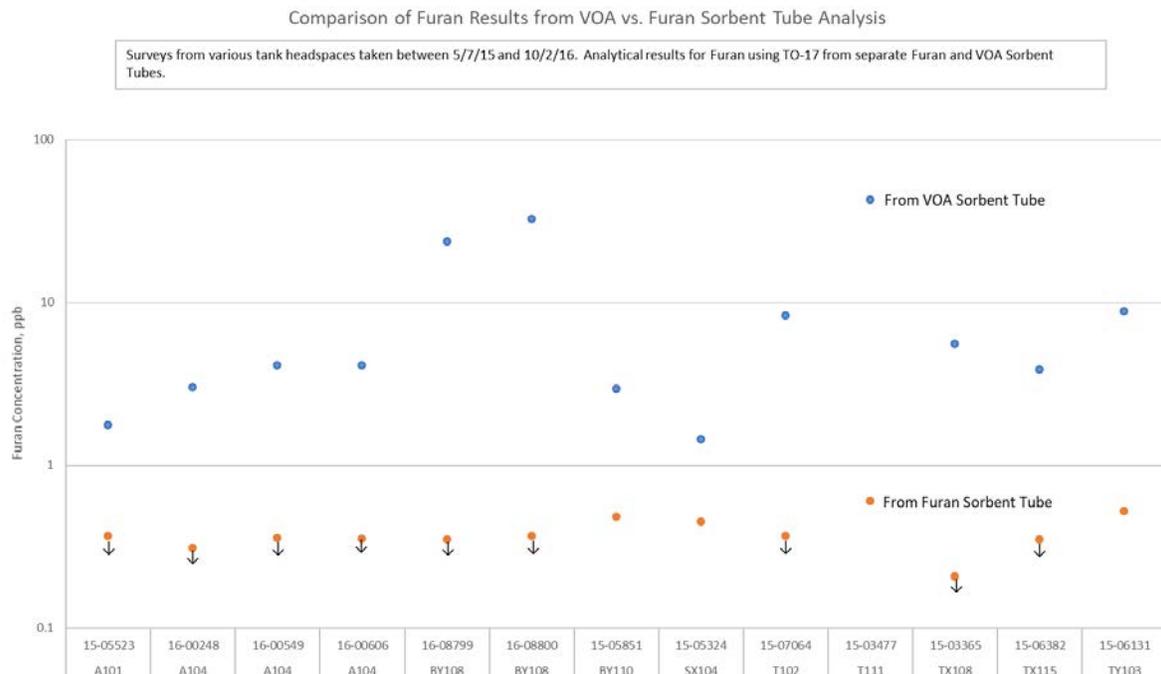


Figure F.1. Comparison of Selected SWIHD Furan Analysis Results from Two Sorbent Tubes. Data Points noted with ↓ indicates measurements less than the detection limit. Note: the VOA Sorbent Tube is the Carbotrap 300 TDU tube.

The quantitative difference varies from survey-to-survey, but in all cases the Carbotrap 300 TDU tube provides significantly higher results. Further review of SWIHD headspace data confirmed that historical maxima reported for furan from each tank farm resulted from Carbotrap 300 TDU tube quantitation versus furans tube quantitation. Similarly, all historical maxima from samples collected since 2006 for the other two calibrated substituted furans from the Carbotrap 300 TDU tube—2,5-dihydrofuran and 2-methylfuran—resulted from the Carbotrap 300 TDU tube quantitation rather than the furans tube.

F.2 Potential Impact and Path Forward

Although both sorbent tubes are calibrated for selected furan compounds, it is apparent that one of the two methods is providing a false reading for the calibrated furan compounds. The 222S Laboratory team and Industrial Hygiene evaluated the data and methods. Results indicate that the Carbotrap 300 TDU tube is providing a more accurate measurement, while the furans tube results represent a false negative for furan. Specifically, it appears that several of the lower boiling point and molecular weight furan COPCs have the propensity to be released from the furans tube prior to quantitation. This observation is based on a

volume challenge test conducted at the 222S Laboratory on both tubes. The 222S Laboratory team also addressed a question about the potential interference of other compounds on the furan peaks measured from the Carbotrap 300 TDU tube, and the potential for those interferences to drive elevated readings. Their response cited a calibration protocol that assured them of minimal interferences with the furan measurements.

Based on the current interrogation results and recommendations from the 222S Laboratory and Industrial Hygiene, PNNL reprocessed all prior cartridge-test results to provided quantitative furans data using the Carbotrap 300 TDU tube analysis results. Results indicate significantly higher cartridge inlet concentrations for furan using the Carbotrap 300 TDU tube data compared to the original furans tube analysis results documented in previous cartridge reports.[1–10]

A summary of analysis results for furan, 2,5-dihydrofuran, and 2-methyl furan from the Carbotrap 300 TDU sorbent tubes are shown in Table F.2 for those tests where inlet concentrations exceeded DL.

Table F.2. Summary of Furans Inlet and Outlet Concentrations for Cartridge Tests using Carbotrap 300 TDU Sorbent Tube and Furans Sorbent Tube Analysis Results.⁵⁵

Test – Tank Headspace or Exhauster Slip Stream	COPC	Furans Tube		Carbotrap 300 TDU Tube		Carbotrap 300 TDU Tube Comments
		Inlet Max Avg. (% OEL)	Outlet Max (% OEL)	Inlet Max Avg. (% OEL)	Outlet Max (% OEL)	
AP Exhauster (SD1/SC1)	Furan	2 2	1	392 355	<DL (16)	
A-101 (SD1/SC1)	Furan	5 3	1	42 26	<DL (16)	
BY-108 (SD1/SC1)	Furan	5 2	1	819 456	698	Breakthrough after 6 hours (SD1) and 8 hours (SC1)
	2,5- Dihydrofuran	21 13	3	278 89	377	Breakthrough after 10–12 hours (SD1)
	2- Methylfuran	12 11	4	39 30	<DL (19)	
AX-101 (SD1/SC1)	Furan	15 5	6	24 <DL (17)	<DL (17)	
702-AZ Exhauster (non-waste- disturbing) (SD1/SC1)	Furan ¹	9 <DL (6)	<DL (6)	62 27	<DL (20)	
702-AZ Exhauster (waste-disturbing) (SD1/SC1)	Furan ¹	5 3	<DL (2)	3084 1392	87	Breakthrough after 8 hours (SD1) and 10 hours (SC1)
AW Exhauster (SD1/SC1)	Furan	<DL <DL (6)	<DL (6)	204 146	<DL (17)	
AN Exhauster (SD1/SC1)	Furan	<DL <DL (6)	<DL (6)	85 48	<DL (18)	
SX-101 (SD1/SC1)	Furan	<DL <DL (4)	<DL (4)	169 75	<DL (29)	
SX-104 (TL/FR57) ²	Furan	<DL <DL (3)	<DL (3)	100 39	<DL (28)	

¹ 2-Methylfuran had at least one measurement slightly greater than DL, but all measurements were less than the RL.

² Multipurpose high-efficiency PAPR cartridges, MSA-TL (TL1) (MSA Safety Inc., Pittsburgh, Pennsylvania) and 3M FR-57 (TL2) (3M Company, Maplewood, Minnesota).

Furan inlet concentrations were >10% of the OEL in 10 of the 11 tanks or exhausters tested, and inlet concentrations were >100% of the OEL in six of the tests. The highest inlet concentrations observed were during 702-AZ exhauster tests under waste-disturbing conditions, where inlet concentrations were >1000% of the OEL for most of the test.

For cartridge tests in which maximum inlet furan concentrations ranged from 24 to 392% of the OEL (0.24 to 3.9 ppb), all outlet concentrations were less than the DL, indicating no evidence of breakthrough. A plot from the AW exhauster testing (Figure F.2) is representative of the eight tanks or exhausters tested with maximum inlet concentrations at or below 392% of the OEL.

⁵⁵ In the final quality approved spreadsheet *AY-AZ (2017) Master Calculations 16JUL2018.xlsx*, 7/16/18 3:30 PM, the maximum OEL values changed to 2995% of the OEL for the inlet on the SD1 cartridge and 2533% of the OEL for the inlet on the SC1 cartridge. Additionally, in the 702-AZ 2017 SCOTT SD1 cartridge test, the Carbotrap 300 TDU tube measured 2-methylfuran inlet concentrations at 13.8% of the OEL. In the 702-AZ 2017 SCOTT SC1 cartridge test, the Carbotrap 300 TDU tube measured 2-methylfuran inlet concentrations of 11.5% of the OEL.

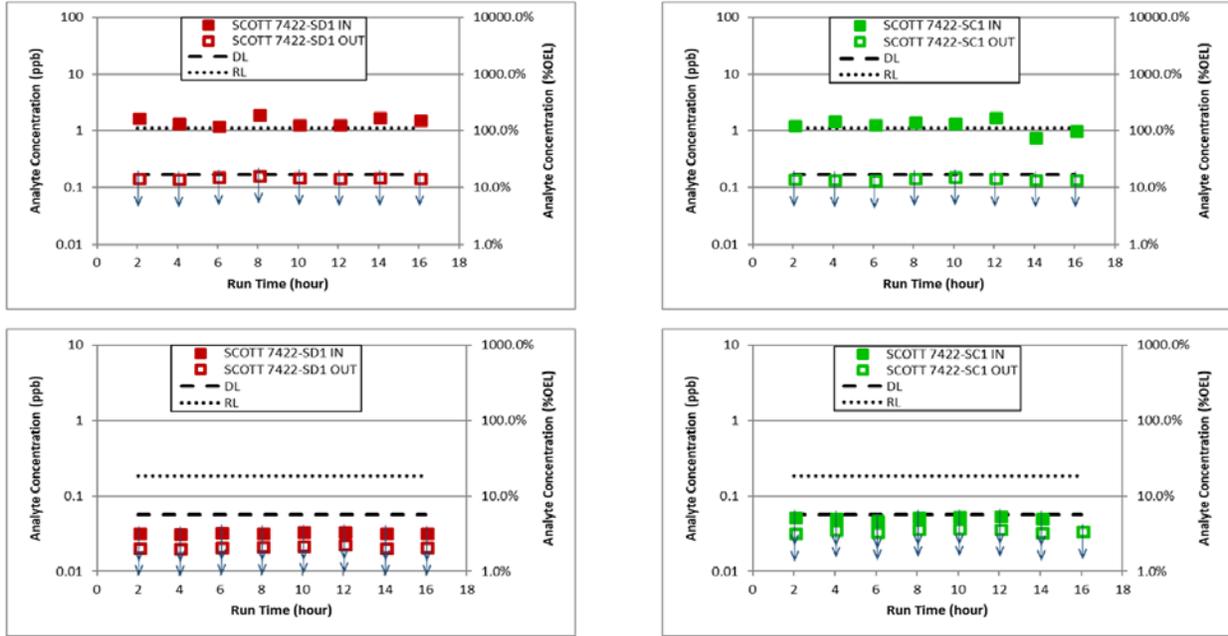


Figure F.2. Plots of Measured Furan Concentrations before the Inlets and after the Outlets of the Two Respirator Cartridges Tested on an AW Exhauster Slipstream. Top panels represent Carbotrap 300 TDU sorbent tube results; bottom panels represent furans sorbent tube⁵⁶ results.

For the BY-108 cartridge testing, the inlet furan concentrations ranged from 233% to 819% of the OEL (see Figure F.3). Here, furan breakthrough times corresponding to outlet concentrations above the DL (~17% of the OEL) ranged from just after 6 hours for the SCOTT SD1 cartridge (maximum inlet 819% of the OEL), to after 8 hours for the SCOTT SC1 cartridge (maximum inlet 298% of the OEL). For comparison, ammonia breakthrough for BY-108 SD1 and SC1 tests occurred within 2 hours [4], and total VOC breakthrough was evident after 6 hours.[10] Furan breakthrough in the BY-108 tests appears to correlate with the onset of total VOC breakthrough. Breakthrough of 2,5-dihydrofuran also was observed after 10–12 hours, but only in the BY-108 SD1 test.

⁵⁶ Tenax TA Tube

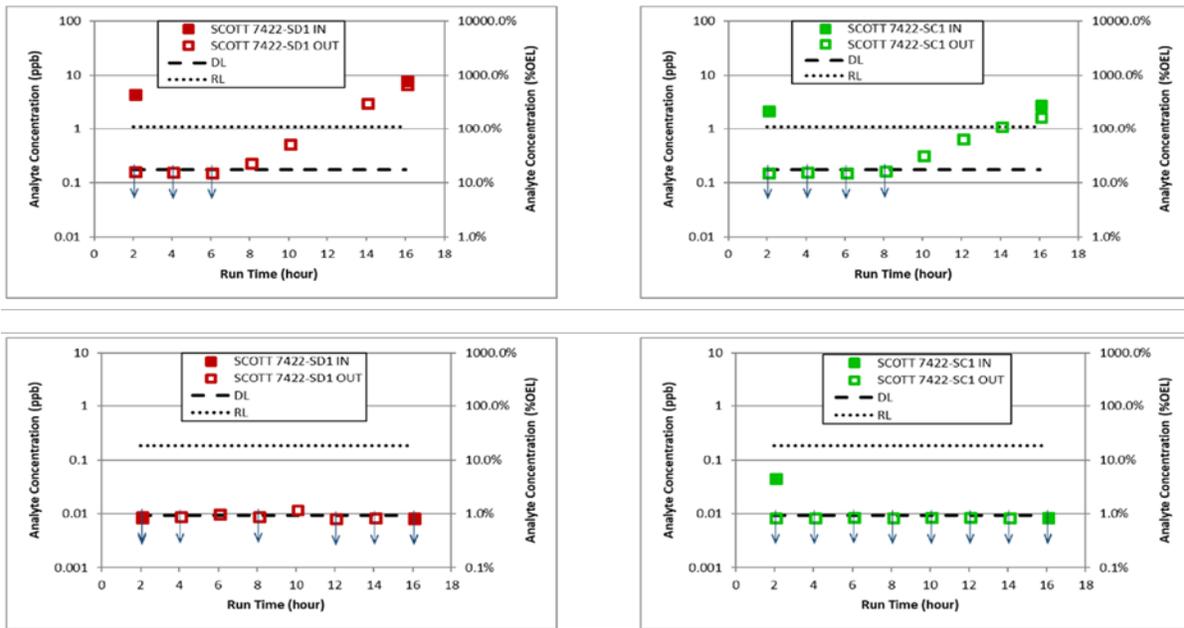


Figure F.3. Plots of Measured Furan Concentrations before the Inlets and after the Outlets of the Two Respirator Cartridges Tested on BY-108 Headspace Vapors. Top panels represent Carbotrap 300 TDU sorbent tube results; bottom panels represent furans sorbent tube results.

For the cartridge testing on the 702-AZ waste-disturbing event, inlet furan concentrations ranged from 440% to 3084% of the OEL (see Figure F.4).

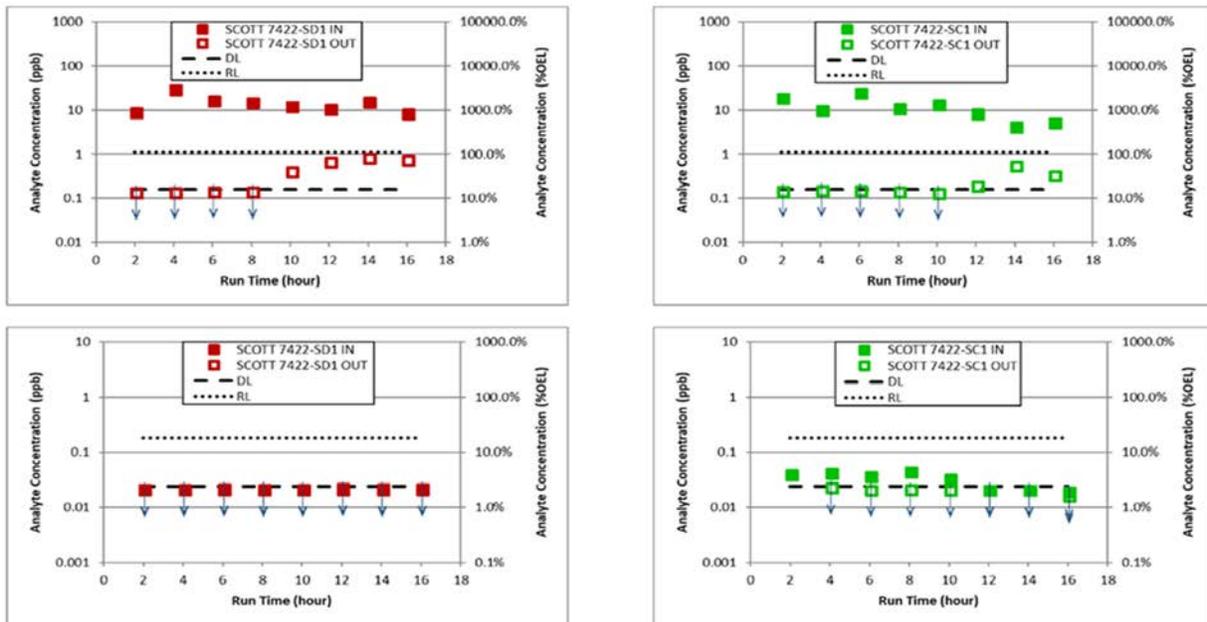


Figure F.4. Plots of Measured Furan Concentrations before the Inlets and after the Outlets of the Two Respirator Cartridges Tested on the 702-AZ Exhauster Slipstream under Waste-Disturbing Conditions in 2017. Top panels represent Carbotrap 300 TDU sorbent tube results; bottom panels represent furans (Tenax TA) sorbent tube results.

Here, furan breakthrough times ranged from after 8 hours for the SCOTT SD1 cartridge (maximum inlet 3084% of the OEL) to after 10 hours for the SCOTT SC1 cartridge (maximum inlet 2610% of the OEL). For comparison, ammonia breakthrough for 702-AZ SD1 and SC1 tests occurred after 6 hours and 4 hours, respectively.[9] Total VOC analysis has not been conducted for the 702-AZ exhauster waste-disturbing test. Ammonia breakthrough continued to precede all other breakthrough observations, including furan.

F.3 Conclusions

Using analytical results from Carbotrap 300 TDU tubes for three calibrated furan compounds—furan, 2,5-dihydrofuran, and 2-methylfuran—respirator cartridge breakthrough analyses were re-assessed for the 11 tank headspace and tank farm exhauster cartridge tests conducted in FY 2016 and FY 2017. This re-assessment was driven by observed differences between historical headspace and exhauster sample analysis using different sorbent tubes. An assessment from the 222S Laboratory and Industrial Hygiene management also indicated that the baseline furans sorbent tube appears to provide false-negative concentrations for these furan compounds, and that the Carbotrap 300 TDU tubes provide better quantitative results.

Re-assessment results using data from the Carbotrap 300 TDU sorbent tube indicate that the SCOTT 7422-SD1 and -SC1 air-purifying respirator (APR) cartridges were effective in removal of furan. Inlet concentrations of furan up to 392% of the OEL resulted in outlet concentrations less than the DL for the entire testing period (up to 16 hours of testing).

Furan breakthrough was only observed in two tests, where furan inlet concentrations achieved the highest maximum values of 819% and 3084% of the OEL.

- In the BY-108 tests, furan breakthrough occurred after 6 hours for the SCOTT SD1 cartridge (maximum inlet 819% of the OEL), and after 8 hours for the SCOTT SC1 cartridge (maximum inlet 298% of the OEL). In comparison, ammonia breakthrough was observed in less than 2 hours. Furan breakthrough appeared to correlate with total VOC breakthrough.
- In the 702-AZ tests under waste-disturbing conditions, furan breakthrough occurred after 8 hours for the SCOTT SD1 cartridge (maximum inlet 3084% of the OEL), and after 10 hours for the SCOTT SC1 cartridge (maximum inlet 2610% of the OEL).⁵⁷ In comparison, ammonia breakthrough for the SD1 and SC1 tests occurred after 6 hours and 4 hours, respectively. Total VOC concentrations are not available at this time, so they could not be compared.

In all tests, ammonia breakthrough continues to precede all other breakthrough observations, including furan, indicating that ammonia continues to define the minimum breakthrough times for the cartridges.

The analytical results for Furan, 2,5-dihydrofuran, and 2-methylfuran using the Carbotrap 300 TDU sorbent tube alternative methodology are summarized in Tables F.3–F.11 for the APR cartridge testing. These results are extracted from the original data in Appendix D of each individual APR report. Red highlighted values reflect measurements that were >10% of the respective OEL values. Green and orange highlighted values reflect measurements in the 2 to 10% of the OEL range. The three elements of position (the fourth column) include the survey (001 for SD1 and 002 for SC1), inlet (IN), or outlet (EF) and the time sequence (A through H indicate 2-hour intervals corresponding to 2 through 16 hours similar to the third column).

⁵⁷ In the final quality approved spreadsheet *AY-AZ (2017) Master Calculations 16JUL2018.xlsx*, 7/16/18 3:30 PM the maximum OEL values changed to 2995% of the OEL for the inlet on the SD1 cartridge and 2533% of the OEL for the inlet on the SC1 cartridge. Additionally, in the 702-AZ 2017 SCOTT SD1 cartridge test, the Carbotrap 300 TDU tube measured 2-methylfuran inlet concentrations of 13.8% of the OEL. In the 702-AZ 2017 SCOTT SC1 cartridge test, the Carbotrap 300 TDU tube measured 2-methylfuran inlet concentrations of 11.5% of the OEL.

F.4 References

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4. Nune SK, CK Clayton, J Liu, CJ Freeman, TM Brouns, and LA Mahoney. 2020. *Analysis of Respirator Cartridge Performance Testing on Hanford Tank BY-108*. PNNL-26180, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.
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Supplemental Data to the Letter Report 69802-01

Table F.3. A-101 (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	4.5E-04	0.001	45.5%		J	17.0%
19	Furan	16	001-IN-H	1.7E-04	0.001	17.0%	YES		17.0%
19	Furan	2	001-EF-A	1.6E-04	0.001	16.2%	YES		17.0%
19	Furan	4	001-EF-B	1.6E-04	0.001	16.4%	YES		17.0%
19	Furan	6	001-EF-C	1.5E-04	0.001	15.0%	YES		17.0%
19	Furan	8	001-EF-D	1.6E-04	0.001	15.7%	YES		17.0%
19	Furan	10	001-EF-E	1.5E-04	0.001	15.3%	YES		17.0%
19	Furan	12	001-EF-F	1.5E-04	0.001	15.1%	YES		17.0%
19	Furan	14	001-EF-G	1.5E-04	0.001	15.1%	YES		17.0%
19	Furan	16	001-EF-H	1.5E-04	0.001	15.3%	YES		17.0%
19	Furan	2	002-IN-A		0.001				17.0%
19	Furan	16	002-IN-H	2.0E-04	0.001	20.2%		JY	17.0%
19	Furan	2	002-EF-A		0.001				17.0%
19	Furan	4	002-EF-B	1.6E-04	0.001	15.9%	YES	UY	17.0%
19	Furan	6	002-EF-C	1.6E-04	0.001	15.8%	YES	UY	17.0%
19	Furan	8	002-EF-D	1.6E-04	0.001	15.9%	YES	UY	17.0%
19	Furan	10	002-EF-E	1.6E-04	0.001	15.7%	YES	UY	17.0%
19	Furan	12	002-EF-F	1.6E-04	0.001	15.5%	YES	QUY	17.0%
19	Furan	14	002-EF-G	1.5E-04	0.001	15.3%	YES	UY	17.0%
19	Furan	16	002-EF-H	1.5E-04	0.001	15.4%	YES	UY	17.0%
21	2,5-Dihydrofuran	2	001-IN-A	1.9E-04	0.001	19.4%	YES		27.1%
21	2,5-Dihydrofuran	16	001-IN-H	2.3E-04	0.001	22.7%	YES		27.1%
21	2,5-Dihydrofuran	2	001-EF-A	2.2E-04	0.001	21.6%	YES		27.1%
21	2,5-Dihydrofuran	4	001-EF-B	2.2E-04	0.001	21.9%	YES		27.1%
21	2,5-Dihydrofuran	6	001-EF-C	2.0E-04	0.001	20.1%	YES		27.1%
21	2,5-Dihydrofuran	8	001-EF-D	2.1E-04	0.001	20.9%	YES		27.1%
21	2,5-Dihydrofuran	10	001-EF-E	2.0E-04	0.001	20.4%	YES		27.1%
21	2,5-Dihydrofuran	12	001-EF-F	2.0E-04	0.001	20.1%	YES		27.1%
21	2,5-Dihydrofuran	14	001-EF-G	2.0E-04	0.001	20.2%	YES		27.1%
21	2,5-Dihydrofuran	16	001-EF-H	2.0E-04	0.001	20.4%	YES		27.1%
21	2,5-Dihydrofuran	2	002-IN-A		0.001				27.1%
21	2,5-Dihydrofuran	16	002-IN-H	2.6E-04	0.001	26.2%	YES	UY	27.1%
21	2,5-Dihydrofuran	2	002-EF-A		0.001				27.1%
21	2,5-Dihydrofuran	4	002-EF-B	2.7E-04	0.001	27.0%	YES	UY	27.1%
21	2,5-Dihydrofuran	6	002-EF-C	2.7E-04	0.001	26.8%	YES	UY	27.1%
21	2,5-Dihydrofuran	8	002-EF-D	2.7E-04	0.001	27.1%	YES	UY	27.1%
21	2,5-Dihydrofuran	10	002-EF-E	2.7E-04	0.001	26.7%	YES	UY	27.1%
21	2,5-Dihydrofuran	12	002-EF-F	2.6E-04	0.001	26.4%	YES	QUY	27.1%
21	2,5-Dihydrofuran	14	002-EF-G	2.6E-04	0.001	26.0%	YES	UY	27.1%
21	2,5-Dihydrofuran	16	002-EF-H	2.6E-04	0.001	26.3%	YES	UY	27.1%
22	2-Methylfuran	2	001-IN-A	9.8E-05	0.001	9.80%	YES		15.7%
22	2-Methylfuran	16	001-IN-H	1.1E-04	0.001	11.5%	YES		15.7%
22	2-Methylfuran	2	001-EF-A	1.1E-04	0.001	10.9%	YES		15.7%
22	2-Methylfuran	4	001-EF-B	1.1E-04	0.001	11.0%	YES		15.7%
22	2-Methylfuran	6	001-EF-C	1.0E-04	0.001	10.1%	YES		15.7%
22	2-Methylfuran	8	001-EF-D	1.1E-04	0.001	10.6%	YES		15.7%
22	2-Methylfuran	10	001-EF-E	1.0E-04	0.001	10.3%	YES		15.7%
22	2-Methylfuran	12	001-EF-F	1.0E-04	0.001	10.1%	YES		15.7%
22	2-Methylfuran	14	001-EF-G	1.0E-04	0.001	10.2%	YES		15.7%
22	2-Methylfuran	16	001-EF-H	1.0E-04	0.001	10.3%	YES		15.7%
22	2-Methylfuran	2	002-IN-A		0.001				15.7%
22	2-Methylfuran	16	002-IN-H	1.5E-04	0.001	15.2%	YES	UY	15.7%
22	2-Methylfuran	2	002-EF-A		0.001				15.7%
22	2-Methylfuran	4	002-EF-B	1.6E-04	0.001	15.6%	YES	UY	15.7%
22	2-Methylfuran	6	002-EF-C	1.6E-04	0.001	15.6%	YES	UY	15.7%
22	2-Methylfuran	8	002-EF-D	1.6E-04	0.001	15.7%	YES	UY	15.7%
22	2-Methylfuran	10	002-EF-E	1.5E-04	0.001	15.5%	YES	UY	15.7%
22	2-Methylfuran	12	002-EF-F	1.5E-04	0.001	15.3%	YES	QUY	15.7%
22	2-Methylfuran	14	002-EF-G	1.5E-04	0.001	15.1%	YES	UY	15.7%
22	2-Methylfuran	16	002-EF-H	1.5E-04	0.001	15.2%	YES	UY	15.7%

Table F.4. AN Exhauster (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	1.4E-04	0.001	14.0%	YES	U	17.6%
19	Furan	4	001-IN-B	4.0E-04	0.001	39.9%		J	17.6%
19	Furan	6	001-IN-C	8.5E-04	0.001	84.7%		J	17.6%
19	Furan	8	001-IN-D	5.0E-04	0.001	50.1%		J	17.6%
19	Furan	10	001-IN-E	7.1E-04	0.001	70.8%		J	17.6%
19	Furan	12	001-IN-F	6.3E-04	0.001	62.8%		J	17.6%
19	Furan	14	001-IN-G	1.6E-04	0.001	15.6%	YES	U	17.6%
19	Furan	16	001-IN-H	1.6E-04	0.001	15.7%	YES	U	17.6%
19	Furan	2	001-EF-A	1.6E-04	0.001	16.0%	YES	U	17.6%
19	Furan	4	001-EF-B	1.6E-04	0.001	16.5%	YES	U	17.6%
19	Furan	6	001-EF-C	1.8E-04	0.001	17.6%	YES	U	17.6%
19	Furan	8	001-EF-D	1.7E-04	0.001	16.9%	YES	U	17.6%
19	Furan	10	001-EF-E	1.5E-04	0.001	15.3%	YES	U	17.6%
19	Furan	12	001-EF-F	1.7E-04	0.001	17.1%	YES	U	17.6%
19	Furan	14	001-EF-G	1.6E-04	0.001	16.2%	YES	U	17.6%
19	Furan	16	001-EF-H	1.6E-04	0.001	15.6%	YES	U	17.6%
19	Furan	2	002-IN-A	5.0E-04	0.001	50.1%		J	17.6%
19	Furan	4	002-IN-B	3.7E-04	0.001	37.0%		JQ	17.6%
19	Furan	6	002-IN-C	7.8E-04	0.001	77.5%		J	17.6%
19	Furan	8	002-IN-D	4.2E-04	0.001	41.6%		J	17.6%
19	Furan	10	002-IN-E	4.1E-04	0.001	41.0%		J	17.6%
19	Furan	12	002-IN-F	5.5E-04	0.001	54.5%		JQ	17.6%
19	Furan	14	002-IN-G	5.4E-04	0.001	54.1%		J	17.6%
19	Furan	16	002-IN-H	5.6E-04	0.001	55.6%		J	17.6%
19	Furan	2	002-EF-A	1.6E-04	0.001	16.3%	YES	U	17.6%
19	Furan	4	002-EF-B	1.6E-04	0.001	15.6%	YES	U	17.6%
19	Furan	6	002-EF-C	1.6E-04	0.001	15.8%	YES	U	17.6%
19	Furan	8	002-EF-D	1.5E-04	0.001	14.8%	YES	U	17.6%
19	Furan	10	002-EF-E	1.6E-04	0.001	15.8%	YES	U	17.6%
19	Furan	12	002-EF-F	1.7E-04	0.001	16.6%	YES	U	17.6%
19	Furan	14	002-EF-G	1.7E-04	0.001	16.6%	YES	U	17.6%
19	Furan	16	002-EF-H	1.4E-04	0.001	13.8%	YES	U	17.6%
21	2,5-Dihydrofuran	2	001-IN-A	2.4E-04	0.001	23.8%	YES	U	29.9%
21	2,5-Dihydrofuran	4	001-IN-B	2.5E-04	0.001	25.2%	YES	U	29.9%
21	2,5-Dihydrofuran	6	001-IN-C	2.5E-04	0.001	24.8%	YES	U	29.9%
21	2,5-Dihydrofuran	8	001-IN-D	2.7E-04	0.001	27.3%	YES	U	29.9%
21	2,5-Dihydrofuran	10	001-IN-E	2.7E-04	0.001	27.5%	YES	U	29.9%
21	2,5-Dihydrofuran	12	001-IN-F	2.7E-04	0.001	26.7%	YES	U	29.9%
21	2,5-Dihydrofuran	14	001-IN-G	2.6E-04	0.001	26.4%	YES	U	29.9%
21	2,5-Dihydrofuran	16	001-IN-H	2.7E-04	0.001	26.7%	YES	U	29.9%
21	2,5-Dihydrofuran	2	001-EF-A	2.7E-04	0.001	27.2%	YES	U	29.9%
21	2,5-Dihydrofuran	4	001-EF-B	2.8E-04	0.001	28.0%	YES	U	29.9%
21	2,5-Dihydrofuran	6	001-EF-C	3.0E-04	0.001	29.9%	YES	U	29.9%
21	2,5-Dihydrofuran	8	001-EF-D	2.9E-04	0.001	28.7%	YES	U	29.9%
21	2,5-Dihydrofuran	10	001-EF-E	2.6E-04	0.001	26.1%	YES	U	29.9%
21	2,5-Dihydrofuran	12	001-EF-F	2.9E-04	0.001	29.0%	YES	U	29.9%
21	2,5-Dihydrofuran	14	001-EF-G	2.8E-04	0.001	27.6%	YES	U	29.9%
21	2,5-Dihydrofuran	16	001-EF-H	2.7E-04	0.001	26.6%	YES	U	29.9%
21	2,5-Dihydrofuran	2	002-IN-A	1.8E-04	0.001	18.1%	YES	U	29.9%
21	2,5-Dihydrofuran	4	002-IN-B	2.5E-04	0.001	25.1%	YES	QU	29.9%
21	2,5-Dihydrofuran	6	002-IN-C	2.8E-04	0.001	28.1%	YES	U	29.9%
21	2,5-Dihydrofuran	8	002-IN-D	2.7E-04	0.001	26.9%	YES	U	29.9%
21	2,5-Dihydrofuran	10	002-IN-E	2.8E-04	0.001	27.9%	YES	U	29.9%
21	2,5-Dihydrofuran	12	002-IN-F	2.7E-04	0.001	27.4%	YES	QU	29.9%
21	2,5-Dihydrofuran	14	002-IN-G	2.8E-04	0.001	28.3%	YES	U	29.9%
21	2,5-Dihydrofuran	16	002-IN-H	2.1E-04	0.001	20.9%	YES	U	29.9%
21	2,5-Dihydrofuran	2	002-EF-A	2.2E-04	0.001	21.7%	YES	U	29.9%
21	2,5-Dihydrofuran	4	002-EF-B	2.1E-04	0.001	20.9%	YES	U	29.9%
21	2,5-Dihydrofuran	6	002-EF-C	2.1E-04	0.001	21.1%	YES	U	29.9%
21	2,5-Dihydrofuran	8	002-EF-D	2.0E-04	0.001	19.7%	YES	U	29.9%
21	2,5-Dihydrofuran	10	002-EF-E	2.1E-04	0.001	21.1%	YES	U	29.9%

Table F.4. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
21	2,5-Dihydrofuran	12	002-EF-F	2.2E-04	0.001	22.2%	YES	U	29.9%
21	2,5-Dihydrofuran	14	002-EF-G	2.2E-04	0.001	22.2%	YES	U	29.9%
21	2,5-Dihydrofuran	16	002-EF-H	1.8E-04	0.001	18.4%	YES	U	29.9%
22	2-Methylfuran	2	001-IN-A	1.4E-04	0.001	13.8%	YES	U	17.3%
22	2-Methylfuran	4	001-IN-B	1.5E-04	0.001	14.6%	YES	U	17.3%
22	2-Methylfuran	6	001-IN-C	1.4E-04	0.001	14.3%	YES	U	17.3%
22	2-Methylfuran	8	001-IN-D	1.6E-04	0.001	15.8%	YES	U	17.3%
22	2-Methylfuran	10	001-IN-E	1.6E-04	0.001	15.9%	YES	U	17.3%
22	2-Methylfuran	12	001-IN-F	1.5E-04	0.001	15.5%	YES	U	17.3%
22	2-Methylfuran	14	001-IN-G	1.5E-04	0.001	15.3%	YES	U	17.3%
22	2-Methylfuran	16	001-IN-H	1.5E-04	0.001	15.4%	YES	U	17.3%
22	2-Methylfuran	2	001-EF-A	1.6E-04	0.001	15.8%	YES	U	17.3%
22	2-Methylfuran	4	001-EF-B	1.6E-04	0.001	16.2%	YES	U	17.3%
22	2-Methylfuran	6	001-EF-C	1.7E-04	0.001	17.3%	YES	U	17.3%
22	2-Methylfuran	8	001-EF-D	1.7E-04	0.001	16.6%	YES	U	17.3%
22	2-Methylfuran	10	001-EF-E	1.5E-04	0.001	15.1%	YES	U	17.3%
22	2-Methylfuran	12	001-EF-F	1.7E-04	0.001	16.8%	YES	U	17.3%
22	2-Methylfuran	14	001-EF-G	1.6E-04	0.001	16.0%	YES	U	17.3%
22	2-Methylfuran	16	001-EF-H	1.5E-04	0.001	15.4%	YES	U	17.3%
22	2-Methylfuran	2	002-IN-A	9.2E-05	0.001	9.16%	YES	U	17.3%
22	2-Methylfuran	4	002-IN-B	1.5E-04	0.001	14.6%	YES	QU	17.3%
22	2-Methylfuran	6	002-IN-C	1.6E-04	0.001	16.3%	YES	U	17.3%
22	2-Methylfuran	8	002-IN-D	1.6E-04	0.001	15.6%	YES	U	17.3%
22	2-Methylfuran	10	002-IN-E	1.6E-04	0.001	16.1%	YES	U	17.3%
22	2-Methylfuran	12	002-IN-F	1.6E-04	0.001	15.9%	YES	QU	17.3%
22	2-Methylfuran	14	002-IN-G	1.6E-04	0.001	16.4%	YES	U	17.3%
22	2-Methylfuran	16	002-IN-H	1.1E-04	0.001	10.5%	YES	U	17.3%
22	2-Methylfuran	2	002-EF-A	1.1E-04	0.001	11.0%	YES	U	17.3%
22	2-Methylfuran	4	002-EF-B	1.1E-04	0.001	10.5%	YES	U	17.3%
22	2-Methylfuran	6	002-EF-C	1.1E-04	0.001	10.6%	YES	U	17.3%
22	2-Methylfuran	8	002-EF-D	1.0E-04	0.001	9.96%	YES	U	17.3%
22	2-Methylfuran	10	002-EF-E	1.1E-04	0.001	10.6%	YES	U	17.3%
22	2-Methylfuran	12	002-EF-F	1.1E-04	0.001	11.2%	YES	U	17.3%
22	2-Methylfuran	14	002-EF-G	1.1E-04	0.001	11.2%	YES	U	17.3%
22	2-Methylfuran	16	002-EF-H	9.3E-05	0.001	9.30%	YES	U	17.3%

Table F.5. AX-101 (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	1.5E-04	0.001	14.8%	YES	U	17.4%
19	Furan	4	001-IN-B	1.6E-04	0.001	16.2%		J	17.4%
19	Furan	6	001-IN-C	1.9E-04	0.001	18.5%		J	17.4%
19	Furan	8	001-IN-D	1.6E-04	0.001	15.6%	YES	U	17.4%
19	Furan	10	001-IN-E	1.8E-04	0.001	18.2%		JQ	17.4%
19	Furan	12	001-IN-F	2.4E-04	0.001	23.7%		J	17.4%
19	Furan	14	001-IN-G	1.4E-04	0.001	14.3%	YES	U	17.4%
19	Furan	16	001-IN-H	1.5E-04	0.001	14.6%	YES	U	17.4%
19	Furan	2	001-EF-A	1.6E-04	0.001	15.8%	YES	U	17.4%
19	Furan	4	001-EF-B	1.6E-04	0.001	16.1%	YES	U	17.4%
19	Furan	6	001-EF-C	1.6E-04	0.001	15.9%	YES	U	17.4%
19	Furan	8	001-EF-D	1.6E-04	0.001	15.7%	YES	U	17.4%
19	Furan	10	001-EF-E	1.5E-04	0.001	15.4%	YES	U	17.4%
19	Furan	12	001-EF-F	1.5E-04	0.001	15.4%	YES	U	17.4%
19	Furan	14	001-EF-G	1.5E-04	0.001	14.8%	YES	U	17.4%
19	Furan	16	001-EF-H	1.5E-04	0.001	14.6%	YES	U	17.4%
19	Furan	2	002-IN-A	1.5E-04	0.001	14.9%	YES	U	17.4%
19	Furan	4	002-IN-B	1.5E-04	0.001	15.1%	YES	U	17.4%
19	Furan	6	002-IN-C	1.5E-04	0.001	14.9%	YES	U	17.4%
19	Furan	8	002-IN-D	1.6E-04	0.001	16.0%	YES	U	17.4%
19	Furan	10	002-IN-E	1.6E-04	0.001	16.4%	YES	U	17.4%
19	Furan	12	002-IN-F	1.5E-04	0.001	15.3%	YES	U	17.4%
19	Furan	14	002-IN-G	1.5E-04	0.001	15.4%	YES	U	17.4%
19	Furan	16	002-IN-H	1.6E-04	0.001	15.6%	YES	U	17.4%
19	Furan	2	002-EF-A	1.5E-04	0.001	14.7%	YES	U	17.4%
19	Furan	4	002-EF-B	1.7E-04	0.001	17.2%	YES	U	17.4%
19	Furan	6	002-EF-C	1.7E-04	0.001	16.5%	YES	U	17.4%
19	Furan	8	002-EF-D	1.7E-04	0.001	17.4%	YES	U	17.4%
19	Furan	10	002-EF-E	1.6E-04	0.001	16.2%	YES	U	17.4%
19	Furan	12	002-EF-F	1.5E-04	0.001	14.6%	YES	U	17.4%
19	Furan	14	002-EF-G	1.5E-04	0.001	15.0%	YES	U	17.4%
19	Furan	16	002-EF-H	1.2E-04	0.001	12.1%	YES	U	17.4%
21	2,5-Dihydrofuran	2	001-IN-A	2.5E-04	0.001	25.2%	YES	U	29.6%
21	2,5-Dihydrofuran	4	001-IN-B	2.4E-04	0.001	24.4%	YES	U	29.6%
21	2,5-Dihydrofuran	6	001-IN-C	2.8E-04	0.001	28.0%	YES	U	29.6%
21	2,5-Dihydrofuran	8	001-IN-D	2.7E-04	0.001	26.6%	YES	U	29.6%
21	2,5-Dihydrofuran	10	001-IN-E	2.5E-04	0.001	24.8%	YES	QU	29.6%
21	2,5-Dihydrofuran	12	001-IN-F	2.5E-04	0.001	24.8%	YES	U	29.6%
21	2,5-Dihydrofuran	14	001-IN-G	2.4E-04	0.001	24.3%	YES	U	29.6%
21	2,5-Dihydrofuran	16	001-IN-H	2.5E-04	0.001	24.9%	YES	U	29.6%
21	2,5-Dihydrofuran	2	001-EF-A	2.7E-04	0.001	26.8%	YES	U	29.6%
21	2,5-Dihydrofuran	4	001-EF-B	2.7E-04	0.001	27.3%	YES	U	29.6%
21	2,5-Dihydrofuran	6	001-EF-C	2.7E-04	0.001	27.0%	YES	U	29.6%
21	2,5-Dihydrofuran	8	001-EF-D	2.7E-04	0.001	26.8%	YES	U	29.6%
21	2,5-Dihydrofuran	10	001-EF-E	2.6E-04	0.001	26.2%	YES	U	29.6%
21	2,5-Dihydrofuran	12	001-EF-F	2.6E-04	0.001	26.2%	YES	U	29.6%
21	2,5-Dihydrofuran	14	001-EF-G	2.5E-04	0.001	25.2%	YES	U	29.6%
21	2,5-Dihydrofuran	16	001-EF-H	2.5E-04	0.001	24.9%	YES	U	29.6%
21	2,5-Dihydrofuran	2	002-IN-A	2.5E-04	0.001	25.4%	YES	U	29.6%
21	2,5-Dihydrofuran	4	002-IN-B	2.6E-04	0.001	25.7%	YES	U	29.6%
21	2,5-Dihydrofuran	6	002-IN-C	2.5E-04	0.001	25.3%	YES	U	29.6%
21	2,5-Dihydrofuran	8	002-IN-D	2.7E-04	0.001	27.3%	YES	U	29.6%
21	2,5-Dihydrofuran	10	002-IN-E	2.8E-04	0.001	27.9%	YES	U	29.6%
21	2,5-Dihydrofuran	12	002-IN-F	2.6E-04	0.001	26.0%	YES	U	29.6%
21	2,5-Dihydrofuran	14	002-IN-G	2.6E-04	0.001	26.1%	YES	U	29.6%
21	2,5-Dihydrofuran	16	002-IN-H	2.7E-04	0.001	26.6%	YES	U	29.6%
21	2,5-Dihydrofuran	2	002-EF-A	2.5E-04	0.001	24.9%	YES	U	29.6%
21	2,5-Dihydrofuran	4	002-EF-B	2.9E-04	0.001	29.3%	YES	U	29.6%
21	2,5-Dihydrofuran	6	002-EF-C	2.8E-04	0.001	28.1%	YES	U	29.6%
21	2,5-Dihydrofuran	8	002-EF-D	3.0E-04	0.001	29.6%	YES	U	29.6%
21	2,5-Dihydrofuran	10	002-EF-E	2.7E-04	0.001	27.5%	YES	U	29.6%

Table F.5. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
21	2,5-Dihydrofuran	12	002-EF-F	2.5E-04	0.001	24.9%	YES	U	29.6%
21	2,5-Dihydrofuran	14	002-EF-G	2.6E-04	0.001	25.5%	YES	U	29.6%
21	2,5-Dihydrofuran	16	002-EF-H	2.1E-04	0.001	20.6%	YES	U	29.6%
22	2-Methylfuran	2	001-IN-A	1.5E-04	0.001	14.6%	YES	U	17.2%
22	2-Methylfuran	4	001-IN-B	1.4E-04	0.001	14.2%	YES	U	17.2%
22	2-Methylfuran	6	001-IN-C	1.6E-04	0.001	16.2%	YES	U	17.2%
22	2-Methylfuran	8	001-IN-D	1.5E-04	0.001	15.4%	YES	U	17.2%
22	2-Methylfuran	10	001-IN-E	1.4E-04	0.001	14.4%	YES	QU	17.2%
22	2-Methylfuran	12	001-IN-F	1.4E-04	0.001	14.4%	YES	U	17.2%
22	2-Methylfuran	14	001-IN-G	1.4E-04	0.001	14.1%	YES	U	17.2%
22	2-Methylfuran	16	001-IN-H	1.4E-04	0.001	14.4%	YES	U	17.2%
22	2-Methylfuran	2	001-EF-A	1.6E-04	0.001	15.5%	YES	U	17.2%
22	2-Methylfuran	4	001-EF-B	1.6E-04	0.001	15.8%	YES	U	17.2%
22	2-Methylfuran	6	001-EF-C	1.6E-04	0.001	15.6%	YES	U	17.2%
22	2-Methylfuran	8	001-EF-D	1.6E-04	0.001	15.5%	YES	Y	17.2%
22	2-Methylfuran	10	001-EF-E	1.5E-04	0.001	15.2%	YES	U	17.2%
22	2-Methylfuran	12	001-EF-F	1.5E-04	0.001	15.2%	YES	U	17.2%
22	2-Methylfuran	14	001-EF-G	1.5E-04	0.001	14.6%	YES	U	17.2%
22	2-Methylfuran	16	001-EF-H	1.4E-04	0.001	14.4%	YES	U	17.2%
22	2-Methylfuran	2	002-IN-A	1.5E-04	0.001	14.7%	YES	U	17.2%
22	2-Methylfuran	4	002-IN-B	1.5E-04	0.001	14.9%	YES	U	17.2%
22	2-Methylfuran	6	002-IN-C	1.5E-04	0.001	14.7%	YES	U	17.2%
22	2-Methylfuran	8	002-IN-D	1.6E-04	0.001	15.8%	YES	U	17.2%
22	2-Methylfuran	10	002-IN-E	1.6E-04	0.001	16.2%	YES	U	17.2%
22	2-Methylfuran	12	002-IN-F	1.5E-04	0.001	15.1%	YES	U	17.2%
22	2-Methylfuran	14	002-IN-G	1.5E-04	0.001	15.1%	YES	U	17.2%
22	2-Methylfuran	16	002-IN-H	1.5E-04	0.001	15.4%	YES	U	17.2%
22	2-Methylfuran	2	002-EF-A	1.4E-04	0.001	14.4%	YES	U	17.2%
22	2-Methylfuran	4	002-EF-B	1.7E-04	0.001	17.0%	YES	U	17.2%
22	2-Methylfuran	6	002-EF-C	1.6E-04	0.001	16.3%	YES	U	17.2%
22	2-Methylfuran	8	002-EF-D	1.7E-04	0.001	17.2%	YES	U	17.2%
22	2-Methylfuran	10	002-EF-E	1.6E-04	0.001	15.9%	YES	U	17.2%
22	2-Methylfuran	12	002-EF-F	1.4E-04	0.001	14.4%	YES	U	17.2%
22	2-Methylfuran	14	002-EF-G	1.5E-04	0.001	14.8%	YES	U	17.2%
22	2-Methylfuran	16	002-EF-H	1.2E-04	0.001	11.9%	YES	U	17.2%

Table F.6. 702 AZ Exhauster (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	6.2E-04	0.001	61.7%	YES	U	61.7%
19	Furan	4	001-IN-B	1.9E-04	0.001	19.0%		J	61.7%
19	Furan	6	001-IN-C	1.6E-04	0.001	15.7%		J	61.7%
19	Furan	8	001-IN-D	2.7E-04	0.001	27.1%		J	61.7%
19	Furan	10	001-IN-E	1.6E-04	0.001	16.1%	YES	U	61.7%
19	Furan	12	001-IN-F	1.8E-04	0.001	17.7%		J	61.7%
19	Furan	14	001-IN-G	2.5E-04	0.001	25.4%		J	61.7%
19	Furan	16	001-IN-H	1.8E-04	0.001	17.7%		J	61.7%
19	Furan	2	001-EF-A	1.8E-04	0.001	17.6%	YES	U	61.7%
19	Furan	4	001-EF-B	2.0E-04	0.001	20.1%	YES	U	61.7%
19	Furan	6	001-EF-C	1.7E-04	0.001	16.6%	YES	U	61.7%
19	Furan	8	001-EF-D	1.8E-04	0.001	17.5%	YES	U	61.7%
19	Furan	10	001-EF-E	1.7E-04	0.001	17.0%	YES	U	61.7%
19	Furan	12	001-EF-F	1.6E-04	0.001	16.0%	YES	U	61.7%
19	Furan	14	001-EF-G	1.6E-04	0.001	15.7%	YES	U	61.7%
19	Furan	16	001-EF-H	1.5E-04	0.001	15.0%	YES	U	61.7%
19	Furan	2	002-IN-A	1.7E-04	0.001	16.8%		J	61.7%
19	Furan	4	002-IN-B	1.7E-04	0.001	17.1%	YES	U	61.7%
19	Furan	6	002-IN-C	1.7E-04	0.001	16.6%	YES	U	61.7%
19	Furan	8	002-IN-D	1.7E-04	0.001	17.2%	YES	U	61.7%
19	Furan	10	002-IN-E	2.0E-04	0.001	20.0%		J	61.7%
19	Furan	12	002-IN-F	2.9E-04	0.001	29.2%		J	61.7%
19	Furan	14	002-IN-G	5.5E-04	0.001	54.6%		J	61.7%
19	Furan	16	002-IN-H	5.8E-04	0.001	58.0%		J	61.7%
19	Furan	2	002-EF-A	1.5E-04	0.001	15.0%	YES	U	61.7%
19	Furan	4	002-EF-B	1.9E-04	0.001	18.8%	YES	U	61.7%
19	Furan	6	002-EF-C	1.7E-04	0.001	17.5%	YES	U	61.7%
19	Furan	8	002-EF-D	1.7E-04	0.001	17.2%	YES	U	61.7%
19	Furan	10	002-EF-E	1.7E-04	0.001	16.8%	YES	U	61.7%
19	Furan	12	002-EF-F	1.6E-04	0.001	16.1%	YES	U	61.7%
19	Furan	14	002-EF-G	1.6E-04	0.001	15.6%	YES	U	61.7%
19	Furan	16	002-EF-H	1.5E-04	0.001	15.3%	YES	U	61.7%
21	2,5-Dihydrofuran	2	001-IN-A	1.0E-03	0.001	105%	YES	U	104.9%
21	2,5-Dihydrofuran	4	001-IN-B	2.1E-04	0.001	21.4%	YES	U	104.9%
21	2,5-Dihydrofuran	6	001-IN-C	2.1E-04	0.001	21.0%	YES	U	104.9%
21	2,5-Dihydrofuran	8	001-IN-D	2.1E-04	0.001	21.5%	YES	U	104.9%
21	2,5-Dihydrofuran	10	001-IN-E	2.1E-04	0.001	21.4%	YES	U	104.9%
21	2,5-Dihydrofuran	12	001-IN-F	2.0E-04	0.001	19.9%	YES	U	104.9%
21	2,5-Dihydrofuran	14	001-IN-G	2.1E-04	0.001	20.8%	YES	U	104.9%
21	2,5-Dihydrofuran	16	001-IN-H	2.5E-04	0.001	25.3%	YES	U	104.9%
21	2,5-Dihydrofuran	2	001-EF-A	3.0E-04	0.001	29.9%	YES	U	104.9%
21	2,5-Dihydrofuran	4	001-EF-B	3.4E-04	0.001	34.2%	YES	U	104.9%
21	2,5-Dihydrofuran	6	001-EF-C	2.8E-04	0.001	28.2%	YES	U	104.9%
21	2,5-Dihydrofuran	8	001-EF-D	3.0E-04	0.001	29.8%	YES	U	104.9%
21	2,5-Dihydrofuran	10	001-EF-E	2.9E-04	0.001	28.9%	YES	U	104.9%
21	2,5-Dihydrofuran	12	001-EF-F	2.7E-04	0.001	27.3%	YES	U	104.9%
21	2,5-Dihydrofuran	14	001-EF-G	2.7E-04	0.001	26.7%	YES	U	104.9%
21	2,5-Dihydrofuran	16	001-EF-H	2.5E-04	0.001	25.4%	YES	U	104.9%
21	2,5-Dihydrofuran	2	002-IN-A	2.1E-04	0.001	21.1%	YES	U	104.9%
21	2,5-Dihydrofuran	4	002-IN-B	2.9E-04	0.001	29.1%	YES	U	104.9%
21	2,5-Dihydrofuran	6	002-IN-C	2.8E-04	0.001	28.1%	YES	U	104.9%
21	2,5-Dihydrofuran	8	002-IN-D	2.9E-04	0.001	29.2%	YES	U	104.9%
21	2,5-Dihydrofuran	10	002-IN-E	2.7E-04	0.001	27.2%	YES	U	104.9%
21	2,5-Dihydrofuran	12	002-IN-F	2.6E-04	0.001	26.4%	YES	U	104.9%
21	2,5-Dihydrofuran	14	002-IN-G	2.6E-04	0.001	26.1%	YES	U	104.9%
21	2,5-Dihydrofuran	16	002-IN-H	2.1E-04	0.001	21.4%	YES	U	104.9%
21	2,5-Dihydrofuran	2	002-EF-A	2.0E-04	0.001	20.0%	YES	U	104.9%
21	2,5-Dihydrofuran	4	002-EF-B	2.5E-04	0.001	25.1%	YES	U	104.9%
21	2,5-Dihydrofuran	6	002-EF-C	2.3E-04	0.001	23.3%	YES	U	104.9%
21	2,5-Dihydrofuran	8	002-EF-D	2.3E-04	0.001	22.9%	YES	U	104.9%
21	2,5-Dihydrofuran	10	002-EF-E	2.2E-04	0.001	22.4%	YES	U	104.9%

Table F.6. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
21	2,5-Dihydrofuran	12	002-EF-F	2.2E-04	0.001	21.5%	YES	U	104.9%
21	2,5-Dihydrofuran	14	002-EF-G	2.1E-04	0.001	20.9%	YES	U	104.9%
21	2,5-Dihydrofuran	16	002-EF-H	2.0E-04	0.001	20.4%	YES	U	104.9%
22	2-Methylfuran	2	001-IN-A	6.1E-04	0.001	60.8%	YES	U	60.8%
22	2-Methylfuran	4	001-IN-B	1.7E-04	0.001	16.6%		J	60.8%
22	2-Methylfuran	6	001-IN-C	1.1E-04	0.001	10.6%	YES	U	60.8%
22	2-Methylfuran	8	001-IN-D	1.1E-04	0.001	10.8%	YES	U	60.8%
22	2-Methylfuran	10	001-IN-E	1.1E-04	0.001	10.8%	YES	U	60.8%
22	2-Methylfuran	12	001-IN-F	1.0E-04	0.001	10.0%	YES	U	60.8%
22	2-Methylfuran	14	001-IN-G	1.1E-04	0.001	10.5%	YES	U	60.8%
22	2-Methylfuran	16	001-IN-H	1.5E-04	0.001	14.7%	YES	U	60.8%
22	2-Methylfuran	2	001-EF-A	1.7E-04	0.001	17.3%	YES	U	60.8%
22	2-Methylfuran	4	001-EF-B	2.0E-04	0.001	19.8%	YES	U	60.8%
22	2-Methylfuran	6	001-EF-C	1.6E-04	0.001	16.4%	YES	U	60.8%
22	2-Methylfuran	8	001-EF-D	1.7E-04	0.001	17.2%	YES	U	60.8%
22	2-Methylfuran	10	001-EF-E	1.7E-04	0.001	16.7%	YES	U	60.8%
22	2-Methylfuran	12	001-EF-F	1.6E-04	0.001	15.8%	YES	U	60.8%
22	2-Methylfuran	14	001-EF-G	1.5E-04	0.001	15.5%	YES	U	60.8%
22	2-Methylfuran	16	001-EF-H	1.5E-04	0.001	14.7%	YES	U	60.8%
22	2-Methylfuran	2	002-IN-A	1.1E-04	0.001	10.6%	YES	U	60.8%
22	2-Methylfuran	4	002-IN-B	1.7E-04	0.001	16.9%	YES	U	60.8%
22	2-Methylfuran	6	002-IN-C	1.6E-04	0.001	16.3%	YES	U	60.8%
22	2-Methylfuran	8	002-IN-D	1.7E-04	0.001	16.9%	YES	U	60.8%
22	2-Methylfuran	10	002-IN-E	1.6E-04	0.001	15.8%	YES	U	60.8%
22	2-Methylfuran	12	002-IN-F	1.5E-04	0.001	15.3%	YES	U	60.8%
22	2-Methylfuran	14	002-IN-G	1.5E-04	0.001	15.1%	YES	U	60.8%
22	2-Methylfuran	16	002-IN-H	1.1E-04	0.001	10.8%	YES	U	60.8%
22	2-Methylfuran	2	002-EF-A	1.0E-04	0.001	10.1%	YES	U	60.8%
22	2-Methylfuran	4	002-EF-B	1.3E-04	0.001	12.6%	YES	U	60.8%
22	2-Methylfuran	6	002-EF-C	1.2E-04	0.001	11.8%	YES	U	60.8%
22	2-Methylfuran	8	002-EF-D	1.2E-04	0.001	11.6%	YES	U	60.8%
22	2-Methylfuran	10	002-EF-E	1.1E-04	0.001	11.3%	YES	U	60.8%
22	2-Methylfuran	12	002-EF-F	1.1E-04	0.001	10.8%	YES	U	60.8%
22	2-Methylfuran	14	002-EF-G	1.1E-04	0.001	10.5%	YES	U	60.8%
22	2-Methylfuran	16	002-EF-H	1.0E-04	0.001	10.3%	YES	U	60.8%

Table F.7. BY-108 (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	4.7E-03	0.001	474%			17.2%
19	Furan	16	001-IN-H	8.2E-03	0.001	819%			17.2%
19	Furan	2	001-EF-A	1.7E-04	0.001	16.8%	YES		17.2%
19	Furan	4	001-EF-B	1.6E-04	0.001	16.3%	YES		17.2%
19	Furan	6	001-EF-C	1.6E-04	0.001	16.3%	YES		17.2%
19	Furan	8	001-EF-D	2.4E-04	0.001	23.9%		J	17.2%
19	Furan	10	001-EF-E	5.5E-04	0.001	54.7%		J	17.2%
19	Furan	12	001-EF-F		0.001				17.2%
19	Furan	14	001-EF-G	3.2E-03	0.001	320%			17.2%
19	Furan	16	001-EF-H	7.0E-03	0.001	698%			17.2%
19	Furan	2	002-IN-A	2.3E-03	0.001	233%			17.2%
19	Furan	16	002-IN-H	3.0E-03	0.001	298%			17.2%
19	Furan	2	002-EF-A	1.6E-04	0.001	16.2%	YES		17.2%
19	Furan	4	002-EF-B	1.7E-04	0.001	16.6%	YES		17.2%
19	Furan	6	002-EF-C	1.6E-04	0.001	16.2%	YES		17.2%
19	Furan	8	002-EF-D	1.7E-04	0.001	17.2%	YES		17.2%
19	Furan	10	002-EF-E	3.4E-04	0.001	33.5%		J	17.2%
19	Furan	12	002-EF-F	6.8E-04	0.001	68.1%		J	17.2%
19	Furan	14	002-EF-G	1.2E-03	0.001	118%			17.2%
19	Furan	16	002-EF-H	1.8E-03	0.001	177%			17.2%
21	2,5-Dihydrofuran	2	001-IN-A	2.5E-04	0.001	25.3%	YES		32.2%
21	2,5-Dihydrofuran	16	001-IN-H	2.8E-03	0.001	278%			32.2%
21	2,5-Dihydrofuran	2	001-EF-A	2.9E-04	0.001	28.6%	YES		32.2%
21	2,5-Dihydrofuran	4	001-EF-B	2.8E-04	0.001	27.8%	YES		32.2%
21	2,5-Dihydrofuran	6	001-EF-C	2.8E-04	0.001	27.7%	YES		32.2%
21	2,5-Dihydrofuran	8	001-EF-D	2.8E-04	0.001	28.3%	YES		32.2%
21	2,5-Dihydrofuran	10	001-EF-E	2.8E-04	0.001	27.6%	YES		32.2%
21	2,5-Dihydrofuran	12	001-EF-F		0.001				32.2%
21	2,5-Dihydrofuran	14	001-EF-G	4.1E-04	0.001	41.5%		J	32.2%
21	2,5-Dihydrofuran	16	001-EF-H	3.8E-03	0.001	377%			32.2%
21	2,5-Dihydrofuran	2	002-IN-A	2.5E-04	0.001	25.4%	YES		32.2%
21	2,5-Dihydrofuran	16	002-IN-H	2.7E-04	0.001	27.0%	YES		32.2%
21	2,5-Dihydrofuran	2	002-EF-A	2.8E-04	0.001	27.5%	YES		32.2%
21	2,5-Dihydrofuran	4	002-EF-B	2.8E-04	0.001	28.2%	YES		32.2%
21	2,5-Dihydrofuran	6	002-EF-C	2.7E-04	0.001	27.5%	YES		32.2%
21	2,5-Dihydrofuran	8	002-EF-D	2.9E-04	0.001	29.3%	YES		32.2%
21	2,5-Dihydrofuran	10	002-EF-E	2.8E-04	0.001	27.6%	YES		32.2%
21	2,5-Dihydrofuran	12	002-EF-F	2.8E-04	0.001	27.6%	YES		32.2%
21	2,5-Dihydrofuran	14	002-EF-G	2.7E-04	0.001	26.8%	YES		32.2%
21	2,5-Dihydrofuran	16	002-EF-H	3.2E-04	0.001	32.2%	YES		32.2%
22	2-Methylfuran	2	001-IN-A	2.4E-04	0.001	23.9%		J	18.6%
22	2-Methylfuran	16	001-IN-H	3.9E-04	0.001	39.2%		J	18.6%
22	2-Methylfuran	2	001-EF-A	1.7E-04	0.001	16.5%	YES		18.6%
22	2-Methylfuran	4	001-EF-B	1.6E-04	0.001	16.1%	YES		18.6%
22	2-Methylfuran	6	001-EF-C	1.6E-04	0.001	16.1%	YES		18.6%
22	2-Methylfuran	8	001-EF-D	1.6E-04	0.001	16.4%	YES		18.6%
22	2-Methylfuran	10	001-EF-E	1.6E-04	0.001	16.0%	YES		18.6%
22	2-Methylfuran	12	001-EF-F		0.001				18.6%
22	2-Methylfuran	14	001-EF-G	1.0E-04	0.001	10.5%	YES		18.6%
22	2-Methylfuran	16	001-EF-H	1.0E-04	0.001	10.5%	YES		18.6%
22	2-Methylfuran	2	002-IN-A	3.4E-04	0.001	34.1%		J	18.6%
22	2-Methylfuran	16	002-IN-H	2.5E-04	0.001	24.7%		J	18.6%
22	2-Methylfuran	2	002-EF-A	1.6E-04	0.001	15.9%	YES		18.6%
22	2-Methylfuran	4	002-EF-B	1.6E-04	0.001	16.3%	YES		18.6%
22	2-Methylfuran	6	002-EF-C	1.6E-04	0.001	15.9%	YES		18.6%
22	2-Methylfuran	8	002-EF-D	1.7E-04	0.001	17.0%	YES		18.6%
22	2-Methylfuran	10	002-EF-E	1.6E-04	0.001	16.0%	YES		18.6%
22	2-Methylfuran	12	002-EF-F	1.6E-04	0.001	16.0%	YES		18.6%
22	2-Methylfuran	14	002-EF-G	1.6E-04	0.001	15.5%	YES		18.6%
22	2-Methylfuran	16	002-EF-H	1.9E-04	0.001	18.6%	YES		18.6%

Table F.8. SY-102 (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	1.5E-04	0.001	14.5%	YES		18.1%
19	Furan	16	001-IN-H	1.6E-04	0.001	15.6%	YES		18.1%
19	Furan	2	001-EF-A	1.7E-04	0.001	17.5%	YES		18.1%
19	Furan	4	001-EF-B	1.7E-04	0.001	17.1%	YES		18.1%
19	Furan	6	001-EF-C	1.7E-04	0.001	16.9%	YES		18.1%
19	Furan	8	001-EF-D	1.7E-04	0.001	16.7%	YES		18.1%
19	Furan	10	001-EF-E	1.6E-04	0.001	15.8%	YES		18.1%
19	Furan	12	001-EF-F	1.6E-04	0.001	16.0%	YES		18.1%
19	Furan	14	001-EF-G	1.5E-04	0.001	15.4%	YES		18.1%
19	Furan	16	001-EF-H	1.5E-04	0.001	15.1%	YES		18.1%
19	Furan	2	002-IN-A	1.6E-04	0.001	16.1%	YES		18.1%
19	Furan	16	002-IN-H	1.5E-04	0.001	15.4%	YES		18.1%
19	Furan	2	002-EF-A	1.8E-04	0.001	18.1%	YES		18.1%
19	Furan	4	002-EF-B	1.7E-04	0.001	16.8%	YES		18.1%
19	Furan	6	002-EF-C		0.001				18.1%
19	Furan	8	002-EF-D	1.7E-04	0.001	16.6%	YES		18.1%
19	Furan	10	002-EF-E	1.7E-04	0.001	16.6%	YES		18.1%
19	Furan	12	002-EF-F	1.6E-04	0.001	15.8%	YES		18.1%
19	Furan	14	002-EF-G	1.6E-04	0.001	16.0%	YES		18.1%
19	Furan	16	002-EF-H	1.5E-04	0.001	15.0%	YES		18.1%
21	2,5-Dihydrofuran	2	001-IN-A	1.9E-04	0.001	19.4%	YES		24.1%
21	2,5-Dihydrofuran	16	001-IN-H	2.1E-04	0.001	20.8%	YES		24.1%
21	2,5-Dihydrofuran	2	001-EF-A	2.3E-04	0.001	23.3%	YES		24.1%
21	2,5-Dihydrofuran	4	001-EF-B	2.3E-04	0.001	22.8%	YES		24.1%
21	2,5-Dihydrofuran	6	001-EF-C	2.3E-04	0.001	22.6%	YES		24.1%
21	2,5-Dihydrofuran	8	001-EF-D	2.2E-04	0.001	22.3%	YES		24.1%
21	2,5-Dihydrofuran	10	001-EF-E	2.1E-04	0.001	21.1%	YES		24.1%
21	2,5-Dihydrofuran	12	001-EF-F	2.1E-04	0.001	21.3%	YES		24.1%
21	2,5-Dihydrofuran	14	001-EF-G	2.1E-04	0.001	20.5%	YES		24.1%
21	2,5-Dihydrofuran	16	001-EF-H	2.0E-04	0.001	20.2%	YES		24.1%
21	2,5-Dihydrofuran	2	002-IN-A	2.1E-04	0.001	21.5%	YES		24.1%
21	2,5-Dihydrofuran	16	002-IN-H	2.1E-04	0.001	20.6%	YES		24.1%
21	2,5-Dihydrofuran	2	002-EF-A	2.4E-04	0.001	24.1%	YES		24.1%
21	2,5-Dihydrofuran	4	002-EF-B	2.2E-04	0.001	22.4%	YES		24.1%
21	2,5-Dihydrofuran	6	002-EF-C		0.001				24.1%
21	2,5-Dihydrofuran	8	002-EF-D	2.2E-04	0.001	22.2%	YES		24.1%
21	2,5-Dihydrofuran	10	002-EF-E	2.2E-04	0.001	22.2%	YES		24.1%
21	2,5-Dihydrofuran	12	002-EF-F	2.1E-04	0.001	21.1%	YES		24.1%
21	2,5-Dihydrofuran	14	002-EF-G	2.1E-04	0.001	21.3%	YES		24.1%
21	2,5-Dihydrofuran	16	002-EF-H	2.0E-04	0.001	20.0%	YES		24.1%
22	2-Methylfuran	2	001-IN-A	9.8E-05	0.001	9.78%	YES		12.2%
22	2-Methylfuran	16	001-IN-H	1.1E-04	0.001	10.5%	YES		12.2%
22	2-Methylfuran	2	001-EF-A	1.2E-04	0.001	11.8%	YES		12.2%
22	2-Methylfuran	4	001-EF-B	1.2E-04	0.001	11.5%	YES		12.2%
22	2-Methylfuran	6	001-EF-C	1.1E-04	0.001	11.4%	YES		12.2%
22	2-Methylfuran	8	001-EF-D	1.1E-04	0.001	11.3%	YES		12.2%
22	2-Methylfuran	10	001-EF-E	1.1E-04	0.001	10.6%	YES		12.2%
22	2-Methylfuran	12	001-EF-F	1.1E-04	0.001	10.7%	YES		12.2%
22	2-Methylfuran	14	001-EF-G	1.0E-04	0.001	10.4%	YES		12.2%
22	2-Methylfuran	16	001-EF-H	1.0E-04	0.001	10.2%	YES		12.2%
22	2-Methylfuran	2	002-IN-A	1.1E-04	0.001	10.8%	YES		12.2%
22	2-Methylfuran	16	002-IN-H	1.0E-04	0.001	10.4%	YES		12.2%
22	2-Methylfuran	2	002-EF-A	1.2E-04	0.001	12.2%	YES		12.2%
22	2-Methylfuran	4	002-EF-B	1.1E-04	0.001	11.3%	YES		12.2%
22	2-Methylfuran	6	002-EF-C		0.001				12.2%
22	2-Methylfuran	8	002-EF-D	1.1E-04	0.001	11.2%	YES		12.2%
22	2-Methylfuran	10	002-EF-E	1.1E-04	0.001	11.2%	YES		12.2%
22	2-Methylfuran	12	002-EF-F	1.1E-04	0.001	10.6%	YES		12.2%
22	2-Methylfuran	14	002-EF-G	1.1E-04	0.001	10.8%	YES		12.2%
22	2-Methylfuran	16	002-EF-H	1.0E-04	0.001	10.1%	YES		12.2%

Table F.9. AP Exhauster (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A		0.001				15.7%
19	Furan	4	001-IN-B		0.001				15.7%
19	Furan	6	001-IN-C		0.001				15.7%
19	Furan	8	001-IN-D		0.001				15.7%
19	Furan	10	001-IN-E		0.001				15.7%
19	Furan	12	001-IN-F		0.001				15.7%
19	Furan	14	001-IN-G		0.001				15.7%
19	Furan	16	001-IN-H		0.001				15.7%
19	Furan	2	001-EF-A		0.001				15.7%
19	Furan	4	001-EF-B		0.001				15.7%
19	Furan	6	001-EF-C		0.001				15.7%
19	Furan	8	001-EF-D		0.001				15.7%
19	Furan	10	001-EF-E		0.001				15.7%
19	Furan	12	001-EF-F		0.001				15.7%
19	Furan	14	001-EF-G		0.001				15.7%
19	Furan	16	001-EF-H		0.001				15.7%
19	Furan	2	002-IN-A	3.9E-03	0.001	392%			15.7%
19	Furan	4	002-IN-B		0.001				15.7%
19	Furan	6	002-IN-C		0.001				15.7%
19	Furan	8	002-IN-D		0.001				15.7%
19	Furan	10	002-IN-E		0.001				15.7%
19	Furan	12	002-IN-F		0.001				15.7%
19	Furan	14	002-IN-G		0.001				15.7%
19	Furan	16	002-IN-H	3.2E-03	0.001	319%			15.7%
19	Furan	2	002-EF-A	1.5E-04	0.001	14.6%	YES		15.7%
19	Furan	4	002-EF-B	1.5E-04	0.001	15.2%	YES		15.7%
19	Furan	6	002-EF-C	1.6E-04	0.001	15.7%	YES		15.7%
19	Furan	8	002-EF-D	1.6E-04	0.001	15.5%	YES		15.7%
19	Furan	10	002-EF-E	1.5E-04	0.001	15.0%	YES		15.7%
19	Furan	12	002-EF-F	1.4E-04	0.001	14.5%	YES		15.7%
19	Furan	14	002-EF-G	1.5E-04	0.001	14.9%	YES		15.7%
19	Furan	16	002-EF-H	1.5E-04	0.001	14.7%	YES		15.7%
21	2,5-Dihydrofuran	2	001-IN-A		0.001				20.9%
21	2,5-Dihydrofuran	4	001-IN-B		0.001				20.9%
21	2,5-Dihydrofuran	6	001-IN-C		0.001				20.9%
21	2,5-Dihydrofuran	8	001-IN-D		0.001				20.9%
21	2,5-Dihydrofuran	10	001-IN-E		0.001				20.9%
21	2,5-Dihydrofuran	12	001-IN-F		0.001				20.9%
21	2,5-Dihydrofuran	14	001-IN-G		0.001				20.9%
21	2,5-Dihydrofuran	16	001-IN-H		0.001				20.9%
21	2,5-Dihydrofuran	2	001-EF-A		0.001				20.9%
21	2,5-Dihydrofuran	4	001-EF-B		0.001				20.9%
21	2,5-Dihydrofuran	6	001-EF-C		0.001				20.9%
21	2,5-Dihydrofuran	8	001-EF-D		0.001				20.9%
21	2,5-Dihydrofuran	10	001-EF-E		0.001				20.9%
21	2,5-Dihydrofuran	12	001-EF-F		0.001				20.9%
21	2,5-Dihydrofuran	14	001-EF-G		0.001				20.9%
21	2,5-Dihydrofuran	16	001-EF-H		0.001				20.9%
21	2,5-Dihydrofuran	2	002-IN-A	2.0E-04	0.001	20.4%	YES		20.9%
21	2,5-Dihydrofuran	4	002-IN-B		0.001				20.9%
21	2,5-Dihydrofuran	6	002-IN-C		0.001				20.9%
21	2,5-Dihydrofuran	8	002-IN-D		0.001				20.9%
21	2,5-Dihydrofuran	10	002-IN-E		0.001				20.9%
21	2,5-Dihydrofuran	12	002-IN-F		0.001				20.9%
21	2,5-Dihydrofuran	14	002-IN-G		0.001				20.9%
21	2,5-Dihydrofuran	16	002-IN-H	2.1E-04	0.001	20.6%	YES		20.9%
21	2,5-Dihydrofuran	2	002-EF-A	1.9E-04	0.001	19.4%	YES		20.9%
21	2,5-Dihydrofuran	4	002-EF-B	2.0E-04	0.001	20.3%	YES		20.9%
21	2,5-Dihydrofuran	6	002-EF-C	2.1E-04	0.001	20.9%	YES		20.9%
21	2,5-Dihydrofuran	8	002-EF-D	2.1E-04	0.001	20.8%	YES		20.9%
21	2,5-Dihydrofuran	10	002-EF-E	2.0E-04	0.001	20.0%	YES		20.9%

Table F.9. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
21	2,5-Dihydrofuran	12	002-EF-F	1.9E-04	0.001	19.4%	YES		20.9%
21	2,5-Dihydrofuran	14	002-EF-G	2.0E-04	0.001	19.9%	YES		20.9%
21	2,5-Dihydrofuran	16	002-EF-H	2.0E-04	0.001	19.6%	YES		20.9%
22	2-Methylfuran	2	001-IN-A		0.001				10.6%
22	2-Methylfuran	4	001-IN-B		0.001				10.6%
22	2-Methylfuran	6	001-IN-C		0.001				10.6%
22	2-Methylfuran	8	001-IN-D		0.001				10.6%
22	2-Methylfuran	10	001-IN-E		0.001				10.6%
22	2-Methylfuran	12	001-IN-F		0.001				10.6%
22	2-Methylfuran	14	001-IN-G		0.001				10.6%
22	2-Methylfuran	16	001-IN-H		0.001				10.6%
22	2-Methylfuran	2	001-EF-A		0.001				10.6%
22	2-Methylfuran	4	001-EF-B		0.001				10.6%
22	2-Methylfuran	6	001-EF-C		0.001				10.6%
22	2-Methylfuran	8	001-EF-D		0.001				10.6%
22	2-Methylfuran	10	001-EF-E		0.001				10.6%
22	2-Methylfuran	12	001-EF-F		0.001				10.6%
22	2-Methylfuran	14	001-EF-G		0.001				10.6%
22	2-Methylfuran	16	001-EF-H		0.001				10.6%
22	2-Methylfuran	2	002-IN-A	1.0E-04	0.001	10.3%	YES		10.6%
22	2-Methylfuran	4	002-IN-B		0.001				10.6%
22	2-Methylfuran	6	002-IN-C		0.001				10.6%
22	2-Methylfuran	8	002-IN-D		0.001				10.6%
22	2-Methylfuran	10	002-IN-E		0.001				10.6%
22	2-Methylfuran	12	002-IN-F		0.001				10.6%
22	2-Methylfuran	14	002-IN-G		0.001				10.6%
22	2-Methylfuran	16	002-IN-H	1.0E-04	0.001	10.4%	YES		10.6%
22	2-Methylfuran	2	002-EF-A	9.8E-05	0.001	9.81%	YES		10.6%
22	2-Methylfuran	4	002-EF-B	1.0E-04	0.001	10.2%	YES		10.6%
22	2-Methylfuran	6	002-EF-C	1.1E-04	0.001	10.6%	YES		10.6%
22	2-Methylfuran	8	002-EF-D	1.0E-04	0.001	10.5%	YES		10.6%
22	2-Methylfuran	10	002-EF-E	1.0E-04	0.001	10.1%	YES		10.6%
22	2-Methylfuran	12	002-EF-F	9.8E-05	0.001	9.77%	YES		10.6%
22	2-Methylfuran	14	002-EF-G	1.0E-04	0.001	10.1%	YES		10.6%
22	2-Methylfuran	16	002-EF-H	9.9E-05	0.001	9.88%	YES		10.6%

Table F.10. AW Exhauster (2016) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
19	Furan	2	001-IN-A	1.8E-03	0.001	176%			17.1%
19	Furan	4	001-IN-B	1.4E-03	0.001	141%			17.1%
19	Furan	6	001-IN-C	1.3E-03	0.001	129%			17.1%
19	Furan	8	001-IN-D	2.0E-03	0.001	204%			17.1%
19	Furan	10	001-IN-E	1.4E-03	0.001	135%			17.1%
19	Furan	12	001-IN-F	1.3E-03	0.001	133%			17.1%
19	Furan	14	001-IN-G	1.8E-03	0.001	180%			17.1%
19	Furan	16	001-IN-H	1.6E-03	0.001	163%			17.1%
19	Furan	2	001-EF-A	1.5E-04	0.001	15.1%	YES		17.1%
19	Furan	4	001-EF-B	1.5E-04	0.001	14.7%	YES		17.1%
19	Furan	6	001-EF-C	1.6E-04	0.001	16.0%	YES		17.1%
19	Furan	8	001-EF-D	1.7E-04	0.001	17.1%	YES		17.1%
19	Furan	10	001-EF-E	1.6E-04	0.001	15.8%	YES		17.1%
19	Furan	12	001-EF-F	1.5E-04	0.001	15.4%	YES		17.1%
19	Furan	14	001-EF-G	1.5E-04	0.001	15.4%	YES		17.1%
19	Furan	16	001-EF-H	1.5E-04	0.001	15.4%	YES		17.1%
19	Furan	2	002-IN-A	1.3E-03	0.001	130%			17.1%
19	Furan	4	002-IN-B	1.6E-03	0.001	157%			17.1%
19	Furan	6	002-IN-C	1.3E-03	0.001	135%			17.1%
19	Furan	8	002-IN-D	1.5E-03	0.001	148%			17.1%
19	Furan	10	002-IN-E	1.4E-03	0.001	140%			17.1%
19	Furan	12	002-IN-F	1.8E-03	0.001	180%			17.1%
19	Furan	14	002-IN-G	8.1E-04	0.001	81.0%			17.1%
19	Furan	16	002-IN-H	1.0E-03	0.001	104%			17.1%
19	Furan	2	002-EF-A	1.5E-04	0.001	14.9%	YES		17.1%
19	Furan	4	002-EF-B	1.5E-04	0.001	14.6%	YES		17.1%
19	Furan	6	002-EF-C	1.4E-04	0.001	14.0%	YES		17.1%
19	Furan	8	002-EF-D	1.5E-04	0.001	15.4%	YES		17.1%
19	Furan	10	002-EF-E	1.6E-04	0.001	15.9%	YES		17.1%
19	Furan	12	002-EF-F	1.5E-04	0.001	15.2%	YES		17.1%
19	Furan	14	002-EF-G	1.5E-04	0.001	14.5%	YES		17.1%
19	Furan	16	002-EF-H	1.5E-04	0.001	14.5%	YES		17.1%
21	2,5-Dihydrofuran	2	001-IN-A	2.4E-04	0.001	23.9%	YES		29.0%
21	2,5-Dihydrofuran	4	001-IN-B	2.4E-04	0.001	24.0%	YES		29.0%
21	2,5-Dihydrofuran	6	001-IN-C	2.7E-04	0.001	26.9%	YES		29.0%
21	2,5-Dihydrofuran	8	001-IN-D	2.6E-04	0.001	26.4%	YES		29.0%
21	2,5-Dihydrofuran	10	001-IN-E	2.6E-04	0.001	26.2%	YES		29.0%
21	2,5-Dihydrofuran	12	001-IN-F	2.6E-04	0.001	25.9%	YES		29.0%
21	2,5-Dihydrofuran	14	001-IN-G	2.5E-04	0.001	24.5%	YES		29.0%
21	2,5-Dihydrofuran	16	001-IN-H	2.5E-04	0.001	24.7%	YES		29.0%
21	2,5-Dihydrofuran	2	001-EF-A	2.6E-04	0.001	25.6%	YES		29.0%
21	2,5-Dihydrofuran	4	001-EF-B	2.5E-04	0.001	25.0%	YES		29.0%
21	2,5-Dihydrofuran	6	001-EF-C	2.7E-04	0.001	27.1%	YES		29.0%
21	2,5-Dihydrofuran	8	001-EF-D	2.9E-04	0.001	29.0%	YES		29.0%
21	2,5-Dihydrofuran	10	001-EF-E	2.7E-04	0.001	26.9%	YES		29.0%
21	2,5-Dihydrofuran	12	001-EF-F	2.6E-04	0.001	26.1%	YES		29.0%
21	2,5-Dihydrofuran	14	001-EF-G	2.6E-04	0.001	26.3%	YES		29.0%
21	2,5-Dihydrofuran	16	001-EF-H	2.6E-04	0.001	26.1%	YES		29.0%
21	2,5-Dihydrofuran	2	002-IN-A	2.1E-04	0.001	21.3%	YES		29.0%
21	2,5-Dihydrofuran	4	002-IN-B	2.0E-04	0.001	19.7%	YES		29.0%
21	2,5-Dihydrofuran	6	002-IN-C	1.9E-04	0.001	19.2%	YES		29.0%
21	2,5-Dihydrofuran	8	002-IN-D	2.1E-04	0.001	21.1%	YES		29.0%
21	2,5-Dihydrofuran	10	002-IN-E	2.0E-04	0.001	20.0%	YES		29.0%
21	2,5-Dihydrofuran	12	002-IN-F	2.0E-04	0.001	20.2%	YES		29.0%
21	2,5-Dihydrofuran	14	002-IN-G	1.9E-04	0.001	19.5%	YES		29.0%
21	2,5-Dihydrofuran	16	002-IN-H	2.0E-04	0.001	20.2%	YES		29.0%
21	2,5-Dihydrofuran	2	002-EF-A	2.0E-04	0.001	20.0%	YES		29.0%
21	2,5-Dihydrofuran	4	002-EF-B	1.9E-04	0.001	19.5%	YES		29.0%
21	2,5-Dihydrofuran	6	002-EF-C	1.9E-04	0.001	18.7%	YES		29.0%
21	2,5-Dihydrofuran	8	002-EF-D	2.1E-04	0.001	20.5%	YES		29.0%
21	2,5-Dihydrofuran	10	002-EF-E	2.1E-04	0.001	21.2%	YES		29.0%

Table F.10. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
21	2,5-Dihydrofuran	12	002-EF-F	2.0E-04	0.001	20.3%	YES		29.0%
21	2,5-Dihydrofuran	14	002-EF-G	1.9E-04	0.001	19.4%	YES		29.0%
21	2,5-Dihydrofuran	16	002-EF-H	1.9E-04	0.001	19.4%	YES		29.0%
22	2-Methylfuran	2	001-IN-A	1.4E-04	0.001	13.9%	YES		16.8%
22	2-Methylfuran	4	001-IN-B	1.4E-04	0.001	13.9%	YES		16.8%
22	2-Methylfuran	6	001-IN-C	1.6E-04	0.001	15.6%	YES		16.8%
22	2-Methylfuran	8	001-IN-D	1.5E-04	0.001	15.3%	YES		16.8%
22	2-Methylfuran	10	001-IN-E	1.5E-04	0.001	15.2%	YES		16.8%
22	2-Methylfuran	12	001-IN-F	1.5E-04	0.001	15.0%	YES		16.8%
22	2-Methylfuran	14	001-IN-G	1.4E-04	0.001	14.2%	YES		16.8%
22	2-Methylfuran	16	001-IN-H	1.4E-04	0.001	14.3%	YES		16.8%
22	2-Methylfuran	2	001-EF-A	1.5E-04	0.001	14.8%	YES		16.8%
22	2-Methylfuran	4	001-EF-B	1.4E-04	0.001	14.5%	YES		16.8%
22	2-Methylfuran	6	001-EF-C	1.6E-04	0.001	15.7%	YES		16.8%
22	2-Methylfuran	8	001-EF-D	1.7E-04	0.001	16.8%	YES		16.8%
22	2-Methylfuran	10	001-EF-E	1.6E-04	0.001	15.6%	YES		16.8%
22	2-Methylfuran	12	001-EF-F	1.5E-04	0.001	15.1%	YES		16.8%
22	2-Methylfuran	14	001-EF-G	1.5E-04	0.001	15.2%	YES		16.8%
22	2-Methylfuran	16	001-EF-H	1.5E-04	0.001	15.1%	YES		16.8%
22	2-Methylfuran	2	002-IN-A	1.1E-04	0.001	10.8%	YES		16.8%
22	2-Methylfuran	4	002-IN-B	1.0E-04	0.001	9.96%	YES		16.8%
22	2-Methylfuran	6	002-IN-C	9.7E-05	0.001	9.67%	YES		16.8%
22	2-Methylfuran	8	002-IN-D	1.1E-04	0.001	10.7%	YES		16.8%
22	2-Methylfuran	10	002-IN-E	1.0E-04	0.001	10.1%	YES		16.8%
22	2-Methylfuran	12	002-IN-F	1.0E-04	0.001	10.2%	YES		16.8%
22	2-Methylfuran	14	002-IN-G	9.8E-05	0.001	9.81%	YES		16.8%
22	2-Methylfuran	16	002-IN-H	1.0E-04	0.001	10.2%	YES		16.8%
22	2-Methylfuran	2	002-EF-A	1.0E-04	0.001	10.1%	YES		16.8%
22	2-Methylfuran	4	002-EF-B	9.8E-05	0.001	9.83%	YES		16.8%
22	2-Methylfuran	6	002-EF-C	9.4E-05	0.001	9.42%	YES		16.8%
22	2-Methylfuran	8	002-EF-D	1.0E-04	0.001	10.4%	YES		16.8%
22	2-Methylfuran	10	002-EF-E	1.1E-04	0.001	10.7%	YES		16.8%
22	2-Methylfuran	12	002-EF-F	1.0E-04	0.001	10.2%	YES		16.8%
22	2-Methylfuran	14	002-EF-G	9.8E-05	0.001	9.77%	YES		16.8%
22	2-Methylfuran	16	002-EF-H	9.8E-05	0.001	9.78%	YES		16.8%

Table F.11. 702 AZ Exhauster (2017) Furan, 2,5-Dihydrofuran, and 2-Methylfuran Analytical Results using the Carbotrap 300 TDU Sorbent Tube Alternative Methodology

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
20	Furan	2	SD1-IN-A	9.2E-03	0.001	919.8%			15.2%
20	Furan	4	SD1-IN-B	3.0E-02	0.001	2994.5%			15.2%
20	Furan	6	SD1-IN-C	1.7E-02	0.001	1689.1%			15.2%
20	Furan	8	SD1-IN-D	1.6E-02	0.001	1571.9%			15.2%
20	Furan	10	SD1-IN-E	1.3E-02	0.001	1270.7%			15.2%
20	Furan	12	SD1-IN-F	1.1E-02	0.001	1098.1%			15.2%
20	Furan	14	SD1-IN-G	1.6E-02	0.001	1634.1%			15.2%
20	Furan	16	SD1-IN-H	9.0E-03	0.001	895.9%			15.2%
20	Furan	2	SD1-EF-A	1.4E-04	0.001	13.9%	YES	U	15.2%
20	Furan	4	SD1-EF-B	1.4E-04	0.001	14.0%	YES	U	15.2%
20	Furan	6	SD1-EF-C	1.4E-04	0.001	14.4%	YES	U	15.2%
20	Furan	8	SD1-EF-D	1.5E-04	0.001	14.7%	YES	U	15.2%
20	Furan	10	SD1-EF-E	4.3E-04	0.001	43.0%		J	15.2%
20	Furan	12	SD1-EF-F	7.1E-04	0.001	70.7%		J	15.2%
20	Furan	14	SD1-EF-G	8.8E-04	0.001	88.1%		J	15.2%
20	Furan	16	SD1-EF-H	8.0E-04	0.001	80.0%		J	15.2%
20	Furan	2	SC1-IN-A	1.9E-02	0.001	1882.8%			15.2%
20	Furan	4	SC1-IN-B	1.0E-02	0.001	1012.8%			15.2%
20	Furan	6	SC1-IN-C	2.5E-02	0.001	2532.9%			15.2%
20	Furan	8	SC1-IN-D	1.1E-02	0.001	1134.6%			15.2%
20	Furan	10	SC1-IN-E	1.4E-02	0.001	1387.0%			15.2%
20	Furan	12	SC1-IN-F	8.7E-03	0.001	871.1%			15.2%
20	Furan	14	SC1-IN-G	4.4E-03	0.001	437.2%			15.2%
20	Furan	16	SC1-IN-H	5.4E-03	0.001	542.2%			15.2%
20	Furan	2	SC1-EF-A	1.5E-04	0.001	14.8%	YES	U	15.2%
20	Furan	4	SC1-EF-B	1.5E-04	0.001	15.2%	YES	U	15.2%
20	Furan	6	SC1-EF-C	1.5E-04	0.001	15.2%	YES	U	15.2%
20	Furan	8	SC1-EF-D	1.5E-04	0.001	14.7%	YES	U	15.2%
20	Furan	10	SC1-EF-E	1.4E-04	0.001	13.7%	YES	U	15.2%
20	Furan	12	SC1-EF-F	2.0E-04	0.001	19.6%		J	15.2%
20	Furan	14	SC1-EF-G	5.7E-04	0.001	56.5%		J	15.2%
20	Furan	16	SC1-EF-H	3.5E-04	0.001	34.8%		J	15.2%
22	2,5-Dihydrofuran	2	SD1-IN-A	2.0E-04	0.001	20.1%	YES	U	20.6%
22	2,5-Dihydrofuran	4	SD1-IN-B	1.9E-04	0.001	19.4%	YES	U	20.6%
22	2,5-Dihydrofuran	6	SD1-IN-C	2.0E-04	0.001	20.1%	YES	U	20.6%
22	2,5-Dihydrofuran	8	SD1-IN-D	2.0E-04	0.001	19.8%	YES	U	20.6%
22	2,5-Dihydrofuran	10	SD1-IN-E	1.9E-04	0.001	19.4%	YES	U	20.6%
22	2,5-Dihydrofuran	12	SD1-IN-F	2.0E-04	0.001	19.6%	YES	U	20.6%
22	2,5-Dihydrofuran	14	SD1-IN-G	1.9E-04	0.001	19.4%	YES	U	20.6%
22	2,5-Dihydrofuran	16	SD1-IN-H	1.9E-04	0.001	19.1%	YES	U	20.6%
22	2,5-Dihydrofuran	2	SD1-EF-A	1.9E-04	0.001	18.6%	YES	U	20.6%
22	2,5-Dihydrofuran	4	SD1-EF-B	1.9E-04	0.001	18.6%	YES	U	20.6%
22	2,5-Dihydrofuran	6	SD1-EF-C	1.9E-04	0.001	19.2%	YES	U	20.6%
22	2,5-Dihydrofuran	8	SD1-EF-D	2.0E-04	0.001	19.6%	YES	U	20.6%
22	2,5-Dihydrofuran	10	SD1-EF-E	2.0E-04	0.001	20.4%	YES	U	20.6%
22	2,5-Dihydrofuran	12	SD1-EF-F	2.0E-04	0.001	19.9%	YES	U	20.6%
22	2,5-Dihydrofuran	14	SD1-EF-G	2.0E-04	0.001	20.5%	YES	U	20.6%
22	2,5-Dihydrofuran	16	SD1-EF-H	2.1E-04	0.001	20.6%	YES	U	20.6%
22	2,5-Dihydrofuran	2	SC1-IN-A	1.9E-04	0.001	19.2%	YES	U	20.6%
22	2,5-Dihydrofuran	4	SC1-IN-B	2.0E-04	0.001	19.7%	YES	U	20.6%
22	2,5-Dihydrofuran	6	SC1-IN-C	2.0E-04	0.001	20.0%	YES	U	20.6%
22	2,5-Dihydrofuran	8	SC1-IN-D	2.0E-04	0.001	20.2%	YES	U	20.6%
22	2,5-Dihydrofuran	10	SC1-IN-E	1.9E-04	0.001	18.5%	YES	U	20.6%
22	2,5-Dihydrofuran	12	SC1-IN-F	1.9E-04	0.001	18.6%	YES	U	20.6%
22	2,5-Dihydrofuran	14	SC1-IN-G	1.9E-04	0.001	18.7%	YES	U	20.6%
22	2,5-Dihydrofuran	16	SC1-IN-H	1.7E-04	0.001	17.3%	YES	U	20.6%
22	2,5-Dihydrofuran	2	SC1-EF-A	2.0E-04	0.001	19.8%	YES	U	20.6%
22	2,5-Dihydrofuran	4	SC1-EF-B	2.0E-04	0.001	20.3%	YES	U	20.6%
22	2,5-Dihydrofuran	6	SC1-EF-C	2.0E-04	0.001	20.3%	YES	U	20.6%
22	2,5-Dihydrofuran	8	SC1-EF-D	2.0E-04	0.001	19.6%	YES	U	20.6%
22	2,5-Dihydrofuran	10	SC1-EF-E	1.8E-04	0.001	18.3%	YES	U	20.6%

Table F.11. (continued)

COPC #	Analyte	End Time (h)	Position	Conc. (ppm)	OEL (ppm)	Fraction of OEL	Measurement < DL RL?	Quality Code	Approx. DL RL (%OEL)
22	2,5-Dihydrofuran	12	SC1-EF-F	1.8E-04	0.001	18.2%	YES	U	20.6%
22	2,5-Dihydrofuran	14	SC1-EF-G	1.8E-04	0.001	18.3%	YES	U	20.6%
22	2,5-Dihydrofuran	16	SC1-EF-H	1.7E-04	0.001	17.3%	YES	U	20.6%
23	2-Methylfuran	2	SD1-IN-A	1.1E-04	0.001	10.9%		J	10.4%
23	2-Methylfuran	4	SD1-IN-B	1.1E-04	0.001	11.3%		J	10.4%
23	2-Methylfuran	6	SD1-IN-C	1.3E-04	0.001	13.2%		J	10.4%
23	2-Methylfuran	8	SD1-IN-D	1.4E-04	0.001	13.8%		J	10.4%
23	2-Methylfuran	10	SD1-IN-E	1.3E-04	0.001	12.8%		J	10.4%
23	2-Methylfuran	12	SD1-IN-F	1.3E-04	0.001	12.9%		J	10.4%
23	2-Methylfuran	14	SD1-IN-G	1.4E-04	0.001	13.5%		J	10.4%
23	2-Methylfuran	16	SD1-IN-H	1.1E-04	0.001	11.1%		J	10.4%
23	2-Methylfuran	2	SD1-EF-A	9.4E-05	0.001	9.38%	YES	U	10.4%
23	2-Methylfuran	4	SD1-EF-B	9.4E-05	0.001	9.40%	YES	U	10.4%
23	2-Methylfuran	6	SD1-EF-C	9.7E-05	0.001	9.67%	YES	U	10.4%
23	2-Methylfuran	8	SD1-EF-D	9.9E-05	0.001	9.88%	YES	U	10.4%
23	2-Methylfuran	10	SD1-EF-E	1.0E-04	0.001	10.3%	YES	U	10.4%
23	2-Methylfuran	12	SD1-EF-F	1.0E-04	0.001	10.0%	YES	U	10.4%
23	2-Methylfuran	14	SD1-EF-G	1.0E-04	0.001	10.3%	YES	U	10.4%
23	2-Methylfuran	16	SD1-EF-H	1.0E-04	0.001	10.4%	YES	U	10.4%
23	2-Methylfuran	2	SC1-IN-A	9.7E-05	0.001	9.66%	YES	U	10.4%
23	2-Methylfuran	4	SC1-IN-B	1.1E-04	0.001	11.5%		J	10.4%
23	2-Methylfuran	6	SC1-IN-C	1.0E-04	0.001	10.1%	YES	U	10.4%
23	2-Methylfuran	8	SC1-IN-D	1.0E-04	0.001	10.2%	YES	U	10.4%
23	2-Methylfuran	10	SC1-IN-E	9.3E-05	0.001	9.34%	YES	U	10.4%
23	2-Methylfuran	12	SC1-IN-F	9.4E-05	0.001	9.39%	YES	U	10.4%
23	2-Methylfuran	14	SC1-IN-G	9.4E-05	0.001	9.42%	YES	U	10.4%
23	2-Methylfuran	16	SC1-IN-H	8.7E-05	0.001	8.72%	YES	U	10.4%
23	2-Methylfuran	2	SC1-EF-A	1.0E-04	0.001	9.99%	YES	U	10.4%
23	2-Methylfuran	4	SC1-EF-B	1.0E-04	0.001	10.2%	YES	U	10.4%
23	2-Methylfuran	6	SC1-EF-C	1.0E-04	0.001	10.2%	YES	U	10.4%
23	2-Methylfuran	8	SC1-EF-D	9.9E-05	0.001	9.88%	YES	U	10.4%
23	2-Methylfuran	10	SC1-EF-E	9.3E-05	0.001	9.25%	YES	U	10.4%
23	2-Methylfuran	12	SC1-EF-F	9.2E-05	0.001	9.17%	YES	U	10.4%
23	2-Methylfuran	14	SC1-EF-G	9.2E-05	0.001	9.23%	YES	U	10.4%
23	2-Methylfuran	16	SC1-EF-H	8.7E-05	0.001	8.73%	YES	U	10.4%



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