DETERMINATION OF ORGANIC VAPOR (CARBON TETRACHLORIDE) SERVICE LIFE TEST, AIR-PURIFYING RESPIRATORS AND POWERED AIR-PURIFYING RESPIRATORS WITH CARTRIDGE(S) OR CANISTER(S) STANDARD TESTING PROCEDURE

1. PURPOSE

This document establishes the procedure for ensuring that the level of protection provided by air-purifying respirators (APR) with cartridge(s) or canister(s) and powered air-purifying respirators (PAPR) with cartridge(s) or canister(s) submitted for Approval, Extension of Approval, or examined during Certified Product Audits meets the minimum organic vapor (OV) service life test requirements as allowed for in 42 CFR Part 84 Subpart I, Sections 84.110 and 84.126, and Subpart L, Sections 84.190 and 84.207.

2. GENERAL

This standard testing procedure (STP) describes the named procedure in sufficient detail that a person knowledgeable in the appropriate technical field can select equipment with the necessary resolution, conduct the test, determine whether or not the product passes the test, and create a record of those results, reporting the measurements obtained in a preestablished, standard format.

3. EQUIPMENT/MATERIALS

3.1. Flow-Temperature-Humidity control system: Miller Nelson Research (MNR), model HCS-501-250, or equivalent.

3.2. Chilled mirror hygrometer: Edgetech Instruments, DewMaster, or equivalent. Accuracy is ± 0.2 degrees Celsius (°C) for temperature and dew point.

3.3. Breakthrough OV detector: Foxboro, model MIRAN 1A, with closed loop system, or equivalent.

3.4. High precision pump: Strata, model DCP50, or equivalent. Flow range is 0.01-500 milliliters per hour (ml/hr). Resolution is 0.01 ml/hr from 0.00-50.00 ml/hr, and 1 ml/hr from 50-500 ml/hr. Accuracy is ± 1.5 percent (%) of setting or ± 0.5 ml/hr, whichever is greater.

3.5. Solvent vapor generator: Miller Nelson Research, model SV-2000, or equivalent.

3.6. Syringe: Hamilton, model 7000.5, or equivalent. Injection range of 0-0.5 microliters (µL).

3.7. Mass flow controller: Brooks Instrument, model SLA5850S, or equivalent. With read out and control electronics: Brooks Instrument, model 0254, or equivalent. Accuracy is ± 0.9% set point or ± 0.18% full scale, whichever is greater.

3.8. Dry test meter: American Meter Co., Model DTM-325, or equivalent. Accuracy is ± 1% of reading.

3.9. OV challenge agent: Carbon tetrachloride, liquid. ACS grade, 99.9% purity, or better.

3.10. Electronic balance: Resolution of 0.01 grams (g) and capacity of 1,000 g, or better.

3.11. Thermocouple: Type J, or better.

3.12. Test chamber: The test chamber has interior dimensions of approximately 8 inches (in.) x 21 in. x 21 in. and is constructed of PVC. Within the chamber, there are four evenly spaced canister ports with 40 millimeter (mm) female threads and EPDM rubber gaskets. The chamber front panel is clear acrylic, attaches with eight ½ in. bolts and wing nuts, and seals air-tight with a rubber gasket. The gas enters through a 1-½ in. PVC pipe, mixes in a rear chamber of approximately 3 in. x 21 in. x 21 in. with baffles and enters the main test chamber. The gas is pushed through the respirator cartridge(s) or canister(s) and exits the chamber via a 1-½ in. PVC pipe. Sampling ports are ¼ in. female pipe thread and are located on the inlet and outlet pipes. This fixture is not commercially available.

3.13. Test fixture for mounting cartridge(s) or canister(s): The test fixture used is specific to each manufacturer and respirator model. When possible, respirators using a 40 mm male thread design are directly connected to a 40 mm port in the test chamber. When necessary, a custom test fixture is constructed. The canister or cartridge interface is removed from the respirator, while keeping the sealing surface and locking interface intact. The interface is affixed by hot melt glue to a PVC pipe fitting of appropriate size, sealed with beeswax, and adapted to a 40 mm male thread fitting with standard pipe fittings. For respirators using a multiple cartridge or canister configuration, the canisters or cartridges are tested as a set and a test fixture is constructed using a PVC tee. Respirators with canister(s) and breathing tube shall include the breathing tube as part of the test fixture. When possible, PAPR systems with cartridge(s) or canister(s) shall use the respirator body and breathing tube as the test fixture, with a 40 mm male thread adapter affixed to the breathing tube by hot melt glue and sealed with beeswax.

4. TESTING REQUIREMENTS AND CONDITIONS

4.1. Equipment shall be operated and calibrated in accordance with the testing laboratory's operation and calibration procedure(s) or the manufacturer's operation and maintenance manual(s). All measuring equipment utilized for this testing should have been calibrated using a method traceable to the National Institute of Standards and Technology (NIST), when available.

4.2. Normal laboratory safety practices must be observed. Refer to Safety Data Sheets (SDS) for the proper protection and care in handling, storing, and disposing of the chemicals and gases used in this procedure. All applicable local, state, and federal regulations for the safe handling and use of hazardous substances shall be followed.

4.3. Carbon tetrachloride is a suspected human carcinogen. Containers of carbon tetrachloride are typically used inside the laboratory fume hood. Carbon tetrachloride is considered hazardous by the EPA and must be disposed of accordingly.

4.4. ORGANIC VAPOR BENCH TEST FOR CARTRIDGE(S) OR CANISTER(S)

4.4.1. For any APR with cartridge(s) or canister(s):

For the complete APR, exhalation resistance to airflow will be measured before each test, and inhalation resistance to airflow will be measured before and after each test. The STPs are described in TEB-APR-STP-0003 and TEB-APR-STP-0007.

4.4.2. For any PAPR with cartridge(s) or canister(s):

For the complete tight-fitting PAPR, exhalation resistance to airflow will be measured before each test, and airflow and inhalation resistance to airflow will be measured before and after each test. For the complete loose-fitting PAPR, airflow will be measured before and after each test. The STPs are described in TEB-APR-STP-0003, TEB-APR-STP-0007, and TEB-APR-STP-0012.

4.4.3. For respirators designed for a multiple cartridge or canister configuration, the canisters or cartridges are tested as a set. Each set will be tested together on a single test fixture and will be treated as a single sample.

4.4.4. Test conditions as required by 42 CFR 84.110, 84.126, 84.175(b), and 84.207 are described in Tables 1 through 5.

4.4.4.1. The breakthrough concentration is the maximum allowable penetration for the respirator.

4.4.4.2. A respirator cartridge or canister For One Type provides respiratory protection against carbon tetrachloride and may also include protections for only other organic vapors.

4.4.4.3. A respirator cartridge or canister For More Than One Type provides respiratory protection against carbon tetrachloride, may also include protections for other organic vapors, and must also include protection for at least one other gas or vapor of another type.

Table 1: Test Conditions and Minimum Service Life Criteria for Air-Purifying Respirator with Cartridge(s)

Number of Samples	Condition	Equilibration Conditions For 6 hours			Test Conditions			Concentration		Minimum Service Life	
		Temp.	Airflow	RH	Temp.	Airflow	RH	Challenge	Breakthrough	For One Type	For More Than One Type
		°C	LPM	%	°C	LPM	%	ppm	ppm	min	min
3	As received	NA	NA	NA	25	64	50	1,000	5	50	25
2	Equilibrated 25 %RH	25	25	25	25	32	50	1,000	5	50	25
2	Equilibrated 85 %RH	25	25	85	25	32	50	1,000	5	50	25

Table 2: Test Conditions and Minimum Service Life Criteria for Air-Purifying Respirator with Canister(s)

Number of Samples	Condition	Equilibration Conditions For 6 hours			Test Conditions			Concentration			Minimum Service Life			
		Temp.	Airflow	RH	Temp.	Airflow	RH	Challenge		Breakthrough	For One Type		For More Than One Type	
								Front or Back Mounted	Chin Style or Escape		Front or Back Mounted, or Chin Style	Escape	Front or Back Mounted, or Chin Style	Escape
		°C	LPM	%	°C	LPM	%	ppm	ppm	ppm	min	min	min	min
3	As-received	NA	NA	NA	25	64	50	20,000	5,000	5	12	12	6	12
2	Equilibrated 25 %RH	25	64	25	25	32	50	20,000	5,000	5	12	12	6	12
2	Equilibrated 85 %RH	25	64	85	25	32	50	20,000	5,000	5	12	12	6	12

Table 3: Test Conditions and Minimum Service Life Criteria for Tight- or Loose-Fitting Powered Air-Purifying Respirator with Cartridge(s)

Number of Samples	Condition	Equilibration Conditions For 6 hours				Test Conditions				Concentration		Minimum Service Life	
		Temp.	Airflow		RH	Temp.	Airflow		RH	Challenge	Breakthrough	For One Type	For More Than One Type
			Tight-Fitting	Loose-Fitting			Tight-Fitting	Loose-Fitting					
		°C	LPM	LPM	%	°C	LPM	LPM	%	ppm	ppm	min	min
3	As received	NA	NA	NA	NA	25	115	170	50	1,000	5	50	25
2	Equilibrated 25 %RH	25	115	170	25	25	115	170	50	1,000	5	25	12.5
2	Equilibrated 85 %RH	25	115	170	85	25	115	170	50	1,000	5	25	12.5

Table 4: Test Conditions and Minimum Service Life Criteria for Tight-Fitting Powered Air-Purifying Respirator with Canister(s)

Number of Samples	Condition	Equilibration Conditions For 6 hours			Test Conditions			Concentration		Minimum Service Life
		Temp.	Airflow	RH	Temp.	Airflow	RH	Challenge	Breakthrough	For One Type or More Than One Type
		°C	LPM	%	°C	LPM	%	ppm	ppm	min
3	As received	NA	NA	NA	25	115	50	5,000	5	12
2	Equilibrated 25 %RH	25	115	25	25	115	50	5,000	5	6
2	Equilibrated 85 %RH	25	115	85	25	115	50	5,000	5	6

Table 5: Tolerances for Test Conditions

Parameter	Tolerance
25 °C[1]	± 2.5 °C
25 LPM[2]	± 0.25 LPM
32 LPM[2]	± 0.5 LPM
64 LPM[2]	± 1.0 LPM
115 LPM[2]	± 2.0 LPM
170 LPM[2]	± 2.0 LPM
25 %RH	± 3 %RH
50 %RH	± 3 %RH
85 %RH[3]	+0/-5 %RH
1,000 ppm	± 10%
5,000 ppm	± 10%
20,000 ppm	± 10%

[1.] Temperature specification is for upstream temperature only. There is no requirement or specification for downstream temperature.
[2.] Tolerance for airflow rates exceeds specification of the MNR because flow rates are calibrated for every test. This improves the precision of the measurement and allows for the tighter tolerance on short-term drift.
[3.] RH levels greater than 85% are difficult to maintain and may cause rapid degradation of service life.

4.4.5. All as-received cartridges or canisters shall be stored in containers same as or similar to the original packaging prior to testing.

4.4.6. All equilibrated cartridges or canisters shall be stored in sealed containers, kept in a position such that the direction of airflow would be horizontal, and at room temperature, and testing shall begin within 18 hours after equilibration.

5. PROCEDURE

5.1. Set up the test equipment as shown in Attachment A: Test Schematic.

5.2. For equilibration of samples prior to testing against OV, follow sections 5.5 through 5.9, 5.11 through 5.15, and 5.18 below. Repeat as necessary for additional samples.

5.3. For testing against OV, follow sections 5.4 through 5.13, and 5.16 through 5.18 below. Repeat as necessary for additional samples.

5.4. Calibrate the breakthrough OV detector.

5.4.1. For all respirators, calibrate the breakthrough OV detector for 5 ppm carbon tetrachloride.

5.4.2. For the Miran 1A, set the pathlength to 20.25 meters (m) and wavelength to 12.6 micrometers (μm). NOTE: The wavelength should be the point of maximum detector response, and may be adjusted, if necessary. All other settings of the Miran 1A should be adjusted per the manufacturer's instructions to achieve an appropriate detector response.

5.4.3. While flushing the Miran 1A with clean, dry air, the system should read 0.00 ppm. Adjust the detector zero, if necessary. If using data acquisition software, ensure the software and breakthrough OV detector correlate, and adjust the software, if necessary.

5.4.4. The Miran 1A is accompanied by a closed loop system, which is an accessory provided by the manufacturer. The closed loop system consists of a stainless steel bellows pump, injection septum, and tubing, and has a fixed volume of 5.64 liters (L). The closed loop system is used only during the calibration of the Miran 1A and is disconnected prior to testing.

5.4.5. Using the syringe, inject 0.11 μL of carbon tetrachloride into the closed loop system attached to the Miran 1A. Once stabilized, the system should read 5.00 ppm. Adjust the detector gain, if necessary. If using data acquisition software, ensure the software and breakthrough OV detector correlate, and adjust the software, if necessary. The calculation is described in Attachment B.

5.5. Establish the testing or equilibration conditions to the required values described in section 4.4 above.

5.5.1. Airflow is controlled and adjusted using the MNR and measured at the test chamber using the dry test meter prior to each test. Use caution as to account for any flow losses from the hygrometer, and do not expose the dry test meter to OV.

5.5.2. Relative humidity is controlled and adjusted using the MNR and continuously measured using the chilled mirror hygrometer. A stream of clean air is fed to the hygrometer from near the outlet of the MNR and is controlled to approximately 0.8 LPM using a mass flow controller. The temperature probe is mounted in the inlet pipe of the test chamber.

5.5.3. Temperature is typically determined by the laboratory environmental conditions. It is possible to control and adjust heating of the test system using the MNR, but may result in condensation within the test system if the laboratory temperature is not adequate. Upstream temperature is continuously measured using the chilled mirror hygrometer, with the temperature probe mounted in the inlet pipe of the

test chamber. Downstream temperature is continuously measured using a thermocouple probe mounted in the outlet pipe of the test chamber. NOTE: Temperature differentials in and around the test system may cause condensation and inaccurate test conditions.

5.6. Weight of the cartridge(s) or canister(s) is measured in the initial as-received state, following equilibration, and following test completion.

5.7. Measure airflow and resistance to airflow of the respirator before and after each test as described in section 4.4 above. The measurements before each test are taken prior to equilibration.

5.8. Ensure that the airflow has been diverted and is not entering the test chamber.

5.9. Mount cartridge(s) or canister(s) onto an appropriate test fixture and place in test chamber.

5.10. Establish the challenge concentration to the required values described in section 4.4 above.

5.10.1. Set the high precision pump to the necessary injection rate setting to achieve the challenge concentration in the air stream. Theoretical injection rates of pure OV are shown in Table 6. The calculation is described in Attachment B.

Table 6: Theoretical Injection Rate of Pure Carbon Tetrachloride to Achieve Challenge Concentration

Filter Type	Flow Rate for Test	Challenge Concentration	Pure Carbon Tetrachloride Injection Rate
	LPM	ppm	mL/hr
APR Cartridge	32	1,000	7.59
APR Cartridge	64	1,000	15.18
APR Canister (Chin Style & Escape)	32	5,000	37.95
APR Canister (Chin Style & Escape)	64	5,000	75.90
APR Canister (Front & Back Mounted)	32	20,000	151.80
APR Canister (Front & Back Mounted)	64	20,000	303.61
PAPR Canister	115	5,000	136.39
PAPR Cartridge	115	1,000	27.28
PAPR Cartridge	170	1,000	40.32

5.10.2. The high precision pump withdraws liquid OV from a bottle placed on the electronic balance and delivers OV droplets to the solvent vapor generator. The temperature setting of the solvent vapor generator is variable. Adjust the temperature setting to achieve complete vaporization of the liquid OV, but avoid adding unnecessary heat to the test system.

5.10.3. The challenge concentration is determined by observing the mass of the injected OV over the elapsed time. The calculation is described in Attachment B.

5.11. Testing or equilibration may begin once all parameters have stabilized at the required values.

5.12. Testing or equilibration begins when the airflow is directed into the test chamber.

5.13. Continuously monitor and record the challenge concentration, breakthrough concentration, RH, upstream temperature, and downstream temperature throughout testing or equilibration. Make adjustments as necessary to maintain the required conditions.

5.14. Equilibration is complete when six hours has elapsed.

5.15. When equilibration is complete, divert airflow away from the test chamber. Remove the cartridge(s) or canister(s) from the test chamber. Measure the equilibrated weight as described above. The equilibrated sample is now ready to be used as a test sample.

5.16. A test is complete when the breakthrough concentration limit has been exceeded or the minimum service life has been surpassed by 10%, whichever comes first.

5.17. When testing is complete, divert airflow away from the test chamber and stop OV injection from the high precision pump. Remove the cartridge(s) or canister(s) from the test chamber. Measure the final weight, airflow, and resistance to airflow as described above.

5.18. At the completion of all testing or at the end of a work shift, purge the entire test system with clean, dry air. Prior to powering off equipment, purge the system for a minimum of 30 minutes, or until the breakthrough OV detector shows no measured concentration.

6. PASS/FAIL CRITERIA

6.1. The requirement for passing this test is set forth in 42 CFR Part 84 Subpart I, Section 84.126, and Subpart L, Section 84.207.

6.2. Minimum service life requirements are shown in Tables 1-4 above.

6.3. A failure occurs when the measured test breakthrough concentration exceeds the stated breakthrough concentration limit prior to the test reaching the stated minimum service life time.

6.4. A failure occurs when the airflow or resistance to airflow before or after a test fails to meet the requirements set forth in 42 CFR Part 84 Subpart I, Section 84.122, Subpart K, 84.175(b), and Subpart L, 84.203 and described in TEB-APR-STP-0003, TEB-APR-STP-0007, and TEB-APR-STP-0012.

7. RECORD/TEST SHEETS

7.1. Record the test data in a format that shall be stored and retrievable. Data should be reported similar to Attachment C: Sample Test Data Sheet for Organic Vapor Service Life Test.

8. LIST OF ABBREVIATIONS AND ACRONYMS

Table 7: List of Abbreviations and Acronyms Used Within This Document

Abbreviation or Acronym	Definition
°C	degrees Celsius
%	percent
APR	air-purifying respirator
CFR	Code of Federal Regulations
g	gram(s)
in.	inch
L	liter(s)
LPM	liters per minute
m	meter(s)
min	minute(s)
mL/hr	milliliters per hour
µL	microliter(s)
µm	micrometer(s)
mm	millimeter(s)
MNR	Miller Nelson Research Flow-Temperature-Humidity control system
mol	mole
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standard and Technology
NPPTL	National Personal Protective Technology Laboratory
OV	organic vapor
PAPR	powered air-purifying respirator
ppm	parts per million
RH	relative humidity
SDS	safety data sheet
STP	standard testing procedure

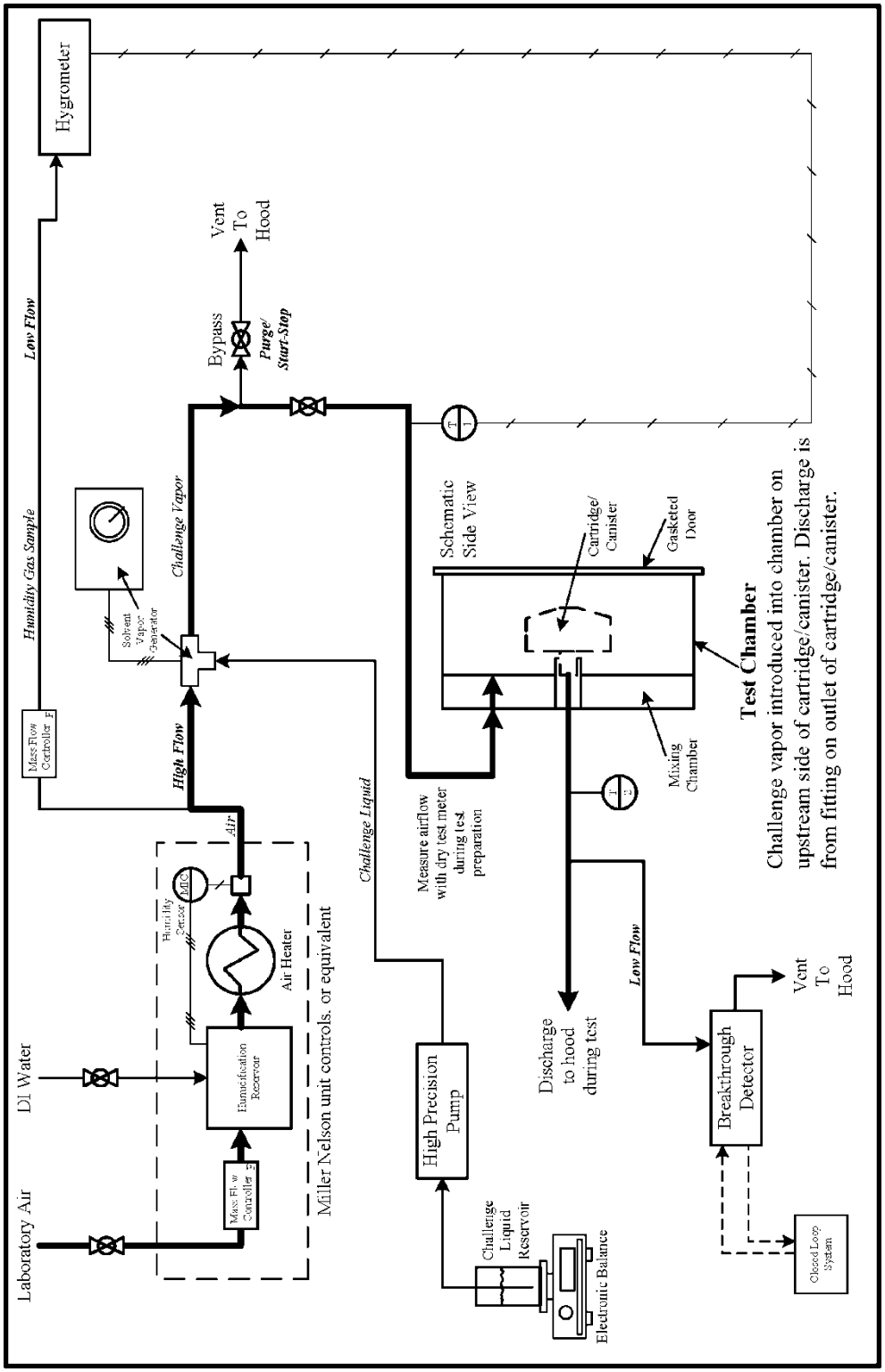
9. ATTACHMENTS

9.1. Attachment A: Test Schematic

9.2. Attachment B: Calculations for Calibration, Injection Rate, and Challenge Concentration

9.3. Attachment C: Sample Test Data Sheet for Organic Vapor Service Life Test

Attachment A: Test Schematic



Attachment B: Calculations for Calibration, Injection Rate, and Challenge Concentration

1. Calibration of Miran 1A detector using closed loop system:

$$injection\ volume = \frac{c \cdot V \cdot M}{V_m \cdot \rho}$$

Where:

- *injection volume* is the volume of OV injected into the Miran 1A closed loop system using the syringe, in units of µL
- c is the desired concentration of OV, in units of ppm
- V is the volume of the closed loop system, in units of L
- M is the molar mass of OV, in units of g/mol
- V_m is the molar volume constant, in units of L/mol
- ρ is the density of OV, in units of g/mL

Example, for 5 ppm of carbon tetrachloride:

$$injection\ volume = \frac{5.00\ ppm \cdot 5.64\ L \cdot 153.81\ g/mol}{24.47\ L/mol \cdot 1.59\ g/mL} \cdot \frac{1 \times 10^6\ \mu L/L}{1 \times 10^3\ mL/L} \cdot \frac{1}{1 \times 10^6\ ppm}$$

$$injection\ volume = 0.11\ \mu L$$

2. Determination of high precision pump injection rate setting:

$$injection\ rate = \frac{c \cdot Q \cdot M}{V_m \cdot \rho}$$

Where:

- *injection rate* is the theoretical injection rate setting of the high precision pump to achieve the desired challenge concentration of OV at a specified airflow, in units of mL/hr
- c is the desired concentration of OV, in units of ppm
- Q is the specified airflow, in units of L/min
- M is the molar mass of OV, in units of g/mol
- V_m is the molar volume constant, in units of L/mol
- ρ is the density of OV, in units of g/mL

Example, for 1,000 ppm of carbon tetrachloride at an airflow of 32 LPM:

$$injection\ rate = \frac{1{,}000\ ppm \cdot 32\ L/min \cdot 153.81\ g/mol}{24.47\ L/mol \cdot 1.59\ g/mL} \cdot \frac{1}{1 \times 10^6\ ppm} \cdot \frac{60\ min}{1\ hr}$$

$$injection\ rate = 7.59\ mL/hr$$

3. Determination of challenge concentration:

$$challenge\ concentration = \frac{m \cdot V_m}{Q \cdot t \cdot M}$$

Where:

- *challenge concentration* is the test challenge concentration of OV at a specified airflow, over the elapsed time, in units of ppm
- m is the mass of injected OV, in units of g
- V_m is the molar volume constant, in units of L/mol
- Q is the specified airflow, in units of L/min
- t is the elapsed time, in units of min
- M is the molar mass of OV, in units of g/mol

Example, for a mass of 10.06 g of carbon tetrachloride at an airflow of 32 LPM for 50 min:

$$challenge\ concentration = \frac{10.06\ g \cdot 24.47\ L/mol}{32\ L/min \cdot 50\ min \cdot 153.81\ g/mol} \cdot \frac{1 \times 10^6\ ppm}{1}$$

$$challenge\ concentration = 1{,}000\ ppm$$

Attachment C: Sample Test Data Sheet for Organic Vapor Service Life Test

National Institute for Occupational Safety and Health

Test Data Sheet

Task Number:
Test:
Manufacturer:
Item Tested:

STP No.:

RESISTANCE

Respirator Type:

Test	Maximum Allowable Resistance (MM of H2O) Inhalation Initial	Inhalation Final	Exhalation Initial	Exhalation Final	Actual Resistance (MM of H2O) Inhalation Initial	Inhalation Final	Exhalation Initial	Exhalation Final	Result
1									
2									
3									
4									
5									
6									
7									

Overall Result: PASS

WEIGHTS (gm.) Test	As Received	Pre-Conditioned	Water Gain	Final Weight	Concentration (ppm)	AIR FLOW (Lpm) RH%	Minimum Allowable	Initial	Final	Result
1										
2										
3										
4										
5										
6										
7										

Overall Result:

DATA TABLE

Test	Test Condition	Breakthrough (ppm)	Temperature (C) Dnstream	Upstream	Minimum Service Life (min.)	Final Time (min.)	Corrected Time (min.)	Result
1								
2								
3								
4								
5								
6								
7								

Overall Result: PASS

Signature:

Date: _____

Test Administrator

Form revision: 1.1 February 8, 2023

Task Number:
Test: **STP No.:**
Manufacturer:
Item Tested:

Comments:

Was all equipment verified to be in calibration throughout all testing?	◯ **Yes**	◯ **No**

Signature: **Date:** _____

Test Administrator

Form revision: 1.1 February 8, 2023

Revision History

Revision	Date	Reason for Revision
1.0	14 March 2002	Historic document
1.1	30 June 2005	Update header and format to reflect lab move from Morgantown, WV No changes to method
2.0	14 March 2008	Significant rewrite of form and clarification of technical content.
3.0	31 October 2025	Significant rewrite to combine TEB-APR-STP-0046A, -0046B, -0046C, and -0046D. Updated document has been renumbered as NPPTL-APR-STP-0046. Changes affect document format and header. Minor revisions to test equipment and method to match current lab practices. Clarification of tolerances for all measured values. For respirators with canisters, the type distinctions have been simplified to “For One Type” and “For More Than One Type.”