DETERMINATION OF SULFUR DIOXIDE 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 meet the minimum sulfur dioxide (SO_2) service life test requirements set forth in 42 CFR Part 84 Subpart I, Sections 84.110 and 84.126, Subpart K, Section 84.175(b), and Subpart L, Section 84.207.

2. GENERAL

This standard testing procedure (STP) describes the determination of sulfur dioxide service life test for APR or PAPR with cartridge(s) or canister(s) in sufficient detail that a person knowledgeable in the appropriate technical field can select equipment with the necessary accuracy and resolution, conduct the test, and determine whether or not the product passes the test.

3. EQUIPMENT/MATERIAL

3.1. The list of necessary test equipment and materials follows:

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

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

3.1.3. Challenge sulfur dioxide detector: Interscan Corporation, model RM-24-0, or equivalent. Detector range: 0 – 1999 parts per million (ppm), resolution: 1 ppm.

3.1.4. Breakthrough sulfur dioxide detector: Interscan Corporation, model RM-24-2, or equivalent. Detector range: 0 – 19.99 ppm, resolution: 0.01 ppm.

3.1.5. Dilution system: Interscan Corporation, model DS-20/50, or equivalent.

3.1.6. 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 percent (%) set point or ± 0.18% full scale, whichever is greater.

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

3.1.8. Sulfur dioxide gas cylinders, 5 ppm and 500 ppm, balance nitrogen. Primary standard, or better. NOTE: For APR or PAPR with cartridge(s) only.

3.1.9. Sulfur dioxide gas cylinders, 5 ppm and 5,000 ppm, balance nitrogen. Primary standard, or better. NOTE: For chin style or escape APR with canister(s), or PAPR with canister(s) only.

3.1.10. Sulfur dioxide gas cylinders, 5 ppm and 20,000 ppm, balance nitrogen. Primary standard, or better. NOTE: For front or back mounted APR with canister(s) only.

3.1.11. Sulfur dioxide gas cylinder, 99% purity, or better.

3.1.12. Electronic balance with a readability of 0.01 grams (g) and capacity of 1000 g, or better.

3.1.13. Thermocouple: Type J or better.

3.1.14. 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 EDPM 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.

3.1.15. 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. Prior to beginning any testing, all measuring equipment to be used must have been calibrated in accordance with the testing laboratory's calibration procedure and schedule.

All measuring equipment utilized for this testing must 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. The cylinder of 99% sulfur dioxide, as well as the calibration gas cylinders, are used inside the laboratory fume hood. If there is a release of 99% sulfur dioxide outside the hood, sound an alarm, and any personnel in the laboratory should immediately exit from the building. Sulfur dioxide is nonflammable.

4.4. SULFUR DIOXIDE 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 SO2 and may also include only other acid gases or vapors.

4.4.4.3. A respirator cartridge or canister For More Than One Type provides respiratory protection against SO2, may also include other acid gases or vapors, and must also include 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	500	5	30	15
2	Equilibrated 25 %RH	25	25	25	25	32	50	500	5	30	15
2	Equilibrated 85 %RH	25	25	85	25	32	50	500	5	30	15

Table 2: Test Conditions and Pass/Fail 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	500	5	30	15
2	Equilibrated 25 %RH	25	115	170	25	25	115	170	50	500	5	15	7.5
2	Equilibrated 85 %RH	25	115	170	85	25	115	170	50	500	5	15	7.5

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
115 LPM[2]	± 1.0 LPM
170 LPM[2]	± 1.0 LPM
25% RH	± 3 %RH
50% RH	± 3 %RH
85% RH[3]	+0/-5 %RH
500 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 on accuracy of airflow rates exceed specification on 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 will be stored in containers same as or similar to the original packaging prior to testing.

4.4.6. All equilibrated cartridges or canisters will 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

NOTE: Reference Section 3 for equipment, model numbers and manufacturers. Equipment should be operated and calibrated in accordance with the manufacturer's operation and maintenance manual(s), or the laboratory's quality management system.

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

5.2. For equilibration of samples prior to testing against SO_2, follow sections 5.5 through 5.9, 5.12 through 5.16, and 5.19 below. Repeat as necessary for additional samples.

5.3. For testing against SO_2, follow sections 5.4 through 5.14, and 5.17 through 5.19 below. Repeat as necessary for additional samples.

5.4. Calibrate the challenge and breakthrough SO_2 detectors.

5.4.1. For all respirators, calibrate the breakthrough SO_2 detector using the gas cylinder containing 5 ppm SO_2.

5.4.2. For APR and PAPR cartridges, calibrate the challenge SO_2 detector using the gas cylinder containing 500 ppm SO_2.

5.4.3. For APR chin style canisters, calibrate the challenge SO_2 detector using the gas cylinder containing 5,000 ppm SO_2.

5.4.4. For APR front or back mounted canisters, calibrate the challenge SO_2 detector using the gas cylinder containing 20,000 ppm SO_2.

5.4.5. For PAPR canisters, calibrate the challenge SO_2 detector using the gas cylinder containing 5,000 ppm SO_2.

NOTE: For challenge concentrations greater than 1,999 ppm, a gas dilution system must be used. The challenge SO_2 detector will be damaged at concentrations greater than 1,999 ppm. Adjust the dilution system to an appropriate dilution ratio such that the detector will receive an adequate gas flow (typically greater than 500 milliliters per minute (mL/min)) and will not be damaged. The true challenge concentration is determined by multiplying the displayed SO_2 concentration by the dilution ratio. Example: If the dilution ratio is 10:1 and the displayed concentration is 500 ppm, the true challenge concentration is 5,000 ppm.

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 or gas detector, and do not expose the dry test meter to SO_2.

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. Ensure there is adequate flow to the challenge and breakthrough detectors. Typically, 500 mL is required for proper detector operation. NOTE: Over- or under-pressurization of the detector will result in inaccurate concentration measurement.

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

5.11.1. Set the challenge agent mass flow controller to the necessary flow rate setting to achieve the challenge concentration in the air stream. Theoretical flow rates of pure SO_2 are shown in Table 6.

Table 6: Theoretical Flow Rate of Pure Sulfur Dioxide to Achieve Challenge Concentration

Filter Type	Flow Rate for Test	Challenge Concentration	Pure SO_2 Flow Rate
	LPM	ppm	mL/min
APR Cartridge	32	500	16
APR Cartridge	64	500	32
APR Canister (Chin Style & Escape)	32	5,000	160
APR Canister (Chin Style & Escape)	64	5,000	320
APR Canister (Front & Back Mounted)	32	20,000	640
APR Canister (Front & Back Mounted)	64	20,000	1,280
PAPR Canister	115	5,000	575
PAPR Cartridge	115	500	57.5
PAPR Cartridge	170	500	85

5.11.2. Open the 99% SO_2 cylinder to begin challenge agent flow.

5.11.3. Adjust the challenge agent mass flow controller as necessary to achieve the required challenge concentration of SO_2.

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

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

5.14. 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.

5.15. Equilibration is complete when six hours has elapsed.

5.16. 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.

5.17. 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.

5.18. When testing is complete, divert airflow away from the test chamber and close the SO_2 gas cylinder. Remove the cartridge(s) or canister(s) from the test chamber. Measure the final weight, airflow, and resistance to airflow as described above.

5.19. 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 gas detectors show 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, Sections 84.110 and 84.126, Subpart K, Section 84.175(b), 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 shall be reported as shown in Attachment B: Sample Test Data Sheet for Sulfur Dioxide Service Life Test.

8. LIST OF ABBREVIATIONS AND ACRONYMS

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

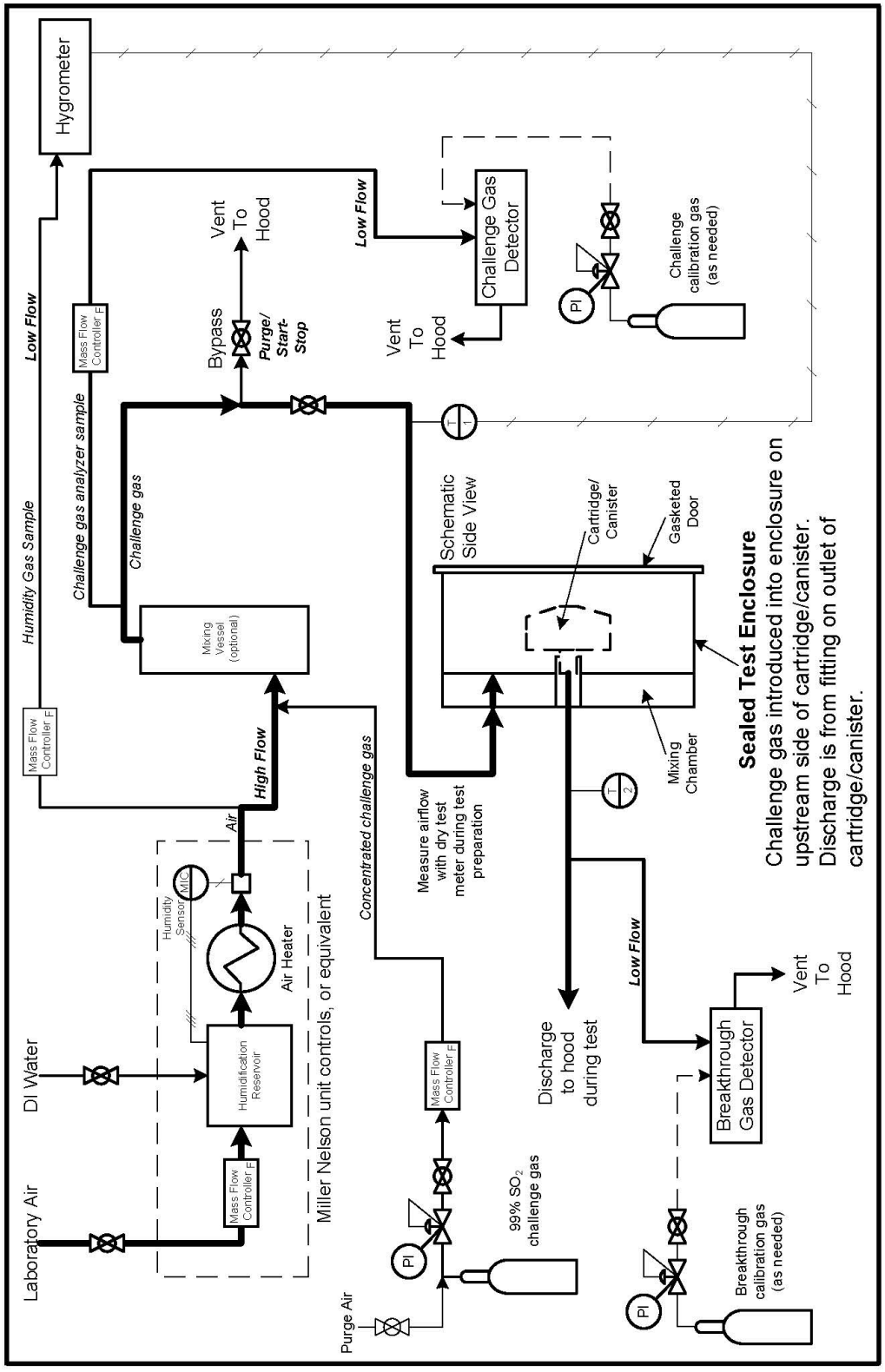
Abbreviation or Acronym	Definition
°C	degrees Celsius
APR	air-purifying respirator
CFR	Code of Federal Regulations
g	gram(s)
in.	inch
LPM	liters per minute
min	minute(s)
mL/min	milliliters per minute
mm	millimeter
MNR	Miller Nelson Research Flow-Temperature-Humidity control system
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standard and Technology
NPPTL	National Personal Protective Technology Laboratory
PAPR	powered air-purifying respirator
ppm	parts per million
RH	relative humidity
SDS	safety data sheet
SO_2	sulfur dioxide
STP	standard testing procedure

9. ATTACHMENTS

9.1. Attachment A: Test Schematic

9.2. Attachment B: Sample Test Data Sheet for Sulfur Dioxide Service Life Test

Attachment A: Test Schematic



Attachment B: Sample Test Data Sheet for Sulfur Dioxide 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:

Test	WEIGHTS (gm.) 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.)	Result
1	As Received						
2	As Received						
3	As Received						
4	25% Preconditioned						
5	25% Preconditioned						
6	85% Preconditioned						
7	85% Preconditioned						

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	1 December 2008	Significant rewrite of RCT-APR-STP-0048. Changes affect form and provide clarification of technical content.
3.0	22 September 2023	Significant rewrite to combine TEB-APR-STP-0048A, -0048B, -0048C, and -0048D. 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.