CARBON MONOXIDE SERVICE LIFE TEST
STANDARD TESTING PROCEDURE (STP)

1. PURPOSE

This test establishes the standard procedure for ensuring that gas mask respirators submitted for Approval, Extension of Approval, or examined during Approval Product audits meet the certification requirements set forth in 42 CFR Part 84. Specifically for this test, the service life for gas mask canisters and escape gas masks from atmospheres containing carbon monoxide (CO) meet the minimum requirements as stated in 42 CFR 84.126 respectively.

2. GENERAL

This STP describes the Carbon Monoxide Service Life Test in sufficient detail that a person knowledgeable in the appropriate technical field can select equipment with the necessary 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. Miller Nelson Research Model 401 Flow-Temperature-Humidity Control System or equivalent.

3.1.2. Interscan Corporation Model 1144 Carbon monoxide detector or equivalent.

3.1.3. Carbon monoxide (CO) cylinder, 99% purity.

3.1.4. "The Gilibrator", Primary Standard Airflow Calibrator or equivalent.

3.1.5. Brooks Rotameters R 215-D for cartridges and R 215-B for canisters or equivalent, capable of delivering 1 to 39 cc per minute.

3.1.6. Gilian Gil-Air-3 Sampling Pump, or equivalent.

3.1.7. Vaisala model HMI 31 temperature/humidity indicator.

3.1.8. Certified gas cylinder, 500 ppm carbon monoxide, balance gas Nitrogen.

3.1.9. Houston Instruments, Model 451BE, strip chart recorder or equivalent.

3.1.10. Electronic balance with accuracy of 0.001 grams (g).

3.1.11. Copper or stainless tubing, ½" diameter, coiled to 18-24 inches in length.

3.1.12. Rock salt for low temperature testing.

3.1.13. Breathing machine, 40 lpm cyclic air flow (for inspired air temperature test only).

3.1.14. Type K thermocouple wire (for inspired air temperature test only).

3.1.15. Foxboro Miran Infrared Analyzer 1A with model 071-5707 closed loop system (for inspired air temperature test only).

3.1.16. Certified gas cylinder, 10 ppm carbon monoxide, balance gas Nitrogen (for inspired air temperature test only).

3.1.17. Tylan flow meter and controller to deliver 77 cc/minute flow (for inspired air temperature test only).

3.2. Ice bath set-up consisting of a large tub (30 gallon trash can with lid) for testing at 0^0C. The upstream air is passed through the ½" copper coil immersed in an ice and water bath. Rock salt is also added to the ice/water bath. The humidity and temperature of the airstream exiting the copper coil is monitored via a probed plastic container mounted inline. The container must be in an upright position to prevent the humidity sensor from being immersed in the excess water produced by the high humidity. Adjustments in temperature and humidity are made to the Miller Nelson system to achieve the desired readings of 95 $\pm$3 percent relative humidity and 0 $\pm$ 2.5°C temperature.

3.3. Test fixture for mounting escape gas masks or canisters. The test fixture used is specific to each manufacturer depending on how the canister is mounted to the facepiece or the design of the escape gas mask respirator. Canisters are tested on their respirator connection that is glued into the ground glass joint. In the case of the escape gas mask (i.e. filter self rescuer) the entire unit is mounted to a test fixture.

3.4. The test chamber consisting of a 12" x 11.5" x 7" air tight box, made of ½" plexiglass with 2 hinge type locks on the door opening lined with gasket material. A ½" hole is located on the backside of the test chamber for the introduction of the test concentration and a 1.5" hole on the top for the exit of the test fixture and to detect the breakthrough concentration. This fixture is not commercially available.

3.5. Large test chamber consisting of a 24" x 24" x 16" air tight box, made of ½" plexiglass with 2 hinge type locks on the door opening lined with gasket material. A ½" hole is located on the backside of the test chamber for the introduction of the test concentration, a 1.5" hole on the side for the exit of the headform test fixture, and a 2.0" hole on the top to allow the excess CO test gas to escape. This chamber is used for the inspired air temperature test. This fixture is not commercially available.

3.6. Resistance tester consisting of a vacuum source capable of delivering 85 Liters per minute (Lpm), a 6-inch slant manometer, and a 29/42 female ground glass joint. The resistance testers currently being used are located on the silica dust chamber.

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 manufacturer's calibration procedure and within the schedule guidelines established by NIOSH. In addition, all equipment utilized for this testing must have been calibrated within the preceding 12 months and traceable to the National Institute of Standards and Technology (NIST).

4.2. Normal laboratory safety practices must be observed:

4.2.1. Safety glasses, lab coats, and hard-toe shoes must be worn at all times.

4.2.2. Work benches must be maintained free of clutter and non-essential test equipment.

4.2.3. When handling any glass laboratory equipment, lab technicians and personnel must wear special gloves which protect against lacerations or punctures.

4.2.4. Laboratory personnel must be provided and wear a radiation badge at all times when performing any testing, research, or analysis in laboratory facilities where necessary.

4.3. CARBON MONOXIDE BENCH TESTS FOR FRONT AND BACK- MOUNTED, AND CHIN STYLE CANISTERS.

4.3.1. Resistance to air flow will be taken before and after each test (84.122).

4.3.2. Two "as received" canisters will be tested at 64 Lpm continuous air flow at 95 $\pm$3 percent relative humidity, 25^{o}C $\pm$ 2.5^{o}C, and containing 20,000 ppm CO.

4.3.3. Three "as received" canisters will be tested at 32 Lpm continuous air flow at 95 $\pm$3 percent relative humidity, 0 $\pm$ 2.5^{o}C, and containing 5000 ppm CO.

4.3.4. Three "as received" canisters will be tested at 32 Lpm continuous air flow at 95 $\pm$3 percent relative humidity, 25^{o}C $\pm$ 2.5^{o}C, and containing 3000 ppm CO.

4.4. CARBON MONOXIDE BENCH TESTS FOR ESCAPE GAS MASK

CANISTERS.

4.4.1. Resistance to air flow will be taken before and after each test (84.122).

4.4.2. Two "as received" canisters will be tested at 32 Lpm, continuous air flow at 95 $\pm$ 3 percent relative humidity, 25 $\pm$ 2.5^{o}C, and containing 10,000 ppm CO.

4.4.3. Three "as received" canisters will be tested at 32 Lpm continuous air flow at 95 $\pm$ 3 percent relative humidity, 0 $\pm$ 2.5^{o}C, and containing 5000 ppm CO.

4.4.4. Three "as received" canisters will be tested at 32 Lpm continuous flow at 95 $\pm$ 3 percent relative humidity, 25 $\pm$ 2.5^{o}C, and containing 3000 ppm CO.

4.5. INSPIRED AIR TEMPERATURE CARBON MONOXIDE BENCH TESTS FOR GAS MASK CANISTERS. (This additional testing is required for those devices reaching 100^{o}C during constant flow preconditioning or testing.) Policy statement for inspired air temperatures dated November 20, 1996.

4.5.1. Resistance to air flow will be taken before and after each test (84.122).

4.5.2. Three complete respirators with "as received" canisters mounted to a head form and connected to a breathing machine cycling at 24 rpm (40 lpm cyclic flow) will be tested in an atmosphere of 1200 ppm IDLH, 95 $\pm$3 percent relative humidity, and 25^{o}C $\pm$ 2.5^{o}C. A temperature probe will be mounted inside the facepiece at the breathing zone and the temperature will be monitored for inspired air during the service life of the canister or a change in the end of service life indicator (ESLI).

4.6 **Please refer to Material Safety Data Sheets and the NIOSH Health and Safety Manual for the proper protection and care in handling, storing, and disposing of the chemicals and gases used in this procedure.**

5. <u>PROCEDURE</u>

5.1. Follow individual instruction manuals for set up and maintenance of equipment used in this procedure prior to beginning testing. Malfunctioning equipment must be repaired or replaced and properly set up and calibrated before starting all tests.

5.2. Attach recorder leads to analyzer output to record CO breakthrough for the service life of the respirator.

5.3. After the manufacturer's specified warmup period, calibrate the CO analyzer using the carbon monoxide certified gas cylinder containing the 500 ppm standard as follows:

5.3.1. With a tee in line on the gas cylinder, insert the intake tubing from the analyzer into the tee.

5.3.2. Turn on the 500 ppm certified carbon monoxide cylinder.

5.3.3. Wait till the reading stabilizes, and adjust the span control to read the certified analysis of the cylinder.

5.4. Set up test equipment as shown in Figure 1 for testing at 20,000, 10,000, and 3,000, ppm or Figure 2 for testing at 5,000 ppm.

5.5. Turn on:

5.5.1. Miller Nelson Unit.

5.5.2. Air and water supplies.

5.5.3. CO cylinder.

5.5.4. CO analyzer.

5.6. Establish the test concentration for the type of respirator being tested.

5.7. From Table 1, determine the flow rate in ml/min of the carbon monoxide needed to deliver the required concentration This flow rate is an approximate point of reference only and may have to be adjusted to deliver the required concentration.

5.8. Determine the challenge test concentration via a dilution factor method by drawing off 1 Lpm test concentration and diluting with a known volume of clean air. By adjusting the rotameter and noting the deflection on the calibrated analyzer, the test concentration can be determined. The volume of clean air required to dilute the 1 Lpm of challenge concentration to produce 5000 ppm is calculated as follows:

5.8.1. $C_1V_1 = C_2V_2$ Where C = concentration and V = volume

$5000 \text{ ppm} \times 1 \text{ Lpm} = 500 \text{ ppm} \times V_2$

$$V_2 = \frac{5000}{500}$$

$$V_2 = 10$$

Therefore: $V_2 - V_1 =$ volume of clean air

5.9. Draw off 1 Lpm of the carbon monoxide in air test concentration and dilute it with the calculated volume of clean air for the required concentration.

5.10. Insert the intake tubing from the analyzer into the dilution air/gas stream. Adjust the rotameter till the analyzer reads 500 ppm. Note the position of the rotameter float for the concentration being determined.

5.10.1. As an example: A reading of 500 ppm for the dilution of 9 Lpm/1 Lpm carbon monoxide test concentration results in a factor of 10. By using the following formula the total CO test concentration can be determined.

Dilution factor x 500 ppm reading = Total CO test concentration.

5.11. Once the CO concentration has been established, testing may begin.

5.12. Weigh the canister or escape gas mask respirator and record the weight.

5.13. Take inhalation and exhalation resistances of the canister mounted on the facepiece or the escape gas mask respirator at 85 Lpm. See Sections 84.122, Title 42, Code of Federal Regulations, Part 84 for breathing resistance requirements.

5.14. Mount escape gas mask respirator or canister onto test fixture and place in test chamber.

5.15. Direct challenge concentration airflow into test chamber. Start timer and recorder. Mount small piece of tygon tubing onto the outlet of the test fixture. Insert intake tubing of detector into a slit cut into the side wall of the tubing to allow the detector to sample at the flow rate of the detector without interference from airflow back pressure. Monitor and record upstream and downstream temperatures throughout testing. Record breakthrough values and times.

5.16. Run test until minimum service life of 60 minutes is surpassed. The maximum allowable CO penetration will be 385 cm^3 during the minimum life. The penetration of CO shall not exceed 500 ppm during this time. Refer to Table 2 for calculation of CO penetration during the minimum service life.

5.17. Dismount the canister or escape gas mask respirator, weigh and record final weight, and take final inhalation and exhalation resistances.

5.18. Shut off the carbon monoxide cylinder.

5.19. Disconnect carbon monoxide tubing from rotameter to prevent contamination of humidity sensor.

5.20. Allow clean air to purge through system for 10 - 15 minutes.

5.21. Turn off air and water supply to Miller Nelson system.

5.22. Turn off Miller Nelson system and analyzer.

6. PASS/FAIL CRITERIA

6.1. The criterion for passing this test is that the maximum allowable CO penetration shall not exceed 385 cm^3 during the minimum life of 60 minutes for gas mask canister respirator assemblies and escape gas mask respirators. The penetration of CO shall not exceed 500 ppm during this time. If the penetration does not exceed these requirements, the units pass the test. If the penetration does exceed these requirements, the units fail the test. The units will be run until the minimum service life is surpassed.

6.2. For inspired air temperature carbon monoxide bench tests for gas mask canisters (section 4.5) the pass/fail criteria is as follows: The inspired air temperature measured at the facepiece must always be less than or equal to 46°C (dry bulb) and less than or equal to 10 ppm CO for the entire test if the inspired air humidity is less than or equal to 50%. The inspired air temperature must be less than or equal to 41°C (dry bulb) and less than or equal to 10 ppm CO for the entire test if the inspired air relative humidity is greater than 50%.

7. <u>RECORDS/TEST SHEETS</u>

7.1. All test data collected will be recorded on the Gas and Vapor Service Life Data Sheet. Any additional comments that the technician running the test wants to enter into the test record will be recorded on the second page of the Gas and Vapor Test Data Sheet.

7.2. If a strip chart recorder is used to record the penetration, the strip chart record of the service life must be attached to the data sheet.

7.3. All videotapes and photographs of the actual test being performed, or of the tested equipment shall be maintained in the task file as part of the permanent record.

7.4. All equipment failing any portion of this test will be handled as follows:

7.4.1. If the failure occurs on new certification application hardware, send a test report to the Team Leader and prepare the hardware for return to the manufacturer.

7.4.2. If the failure occurs on hardware examined under an or off-the-shelf audit; the hardware will be examined by a technician and the Team Leader for cause. All equipment failing any portion of this test may be returned to the manufacturer applicant for examination. However, the hardware tested shall be held at the testing laboratory until authorized for release by the Team Leader, or his designee, following the standard operating procedures outlined in Procedure for Scheduling, and Processing Post-Certification Product Audits, RB-SOP-0005-00.

8. ATTACHMENTS

8.1. Table 1- CO flow rate calculation.

8.2. Table 2- Analysis of data for total CO penetration during minimum service life.

8.3. Set-up and additional notes for inspired air temperature test.

8.4 Figure 1- Bench Top Set-Up.

8.5. Figure 2- Ice Bath Bench Top Set-Up.

8.6. Data Sheet.

TABLE 1

CONCENTRATION CALCULATIONS FOR SYRINGE PUMP INJECTION RATES
At 25°C and 1 atm.

FOR GASES:

$$C = \frac{RK10^3}{Q}$$

$$R = \frac{CQ}{K\ 10^3}$$

where:

R= rate of advance (mm/min) C= concentration (ppm)
K= syringe constant (ml/mm) Q= airflow rate (lpm)

Syringe capacity (ml)	Length (mm)	Syringe constant (K=ml/mm)
20.0	66.5	0.301

Sample calculation: Determine the flow rate of CO required to produce a concentration of 20000 ppm in 64 lpm of air, using a 20 ml syringe constant. The syringe constant is used only for calculation purposes.

$$R = \frac{(20000\ \text{ppm})\ (64\ \text{Lpm})}{(0.301\text{ml/mm})\ 10^3}$$

R = 4252.4 mm/min.

To obtain ml/minute, multiply rate of advance R by syringe constant.

ml/minute = 4252 x 0.301

ml/minute = 1280 ml/minute.

The flow rate of the rotameter for a carbon monoxide concentration of 20,000 ppm should be approximately 1280 ml/min.

TABLE 2

ANALYSIS OF CO DATA COLLECTED

The maximum allowable CO penetration for each canister or escape gas mask respirator is 385 cc during the minimum service life of 60 minutes. Each canister or escape gas mask passes or fails on this basis. The analyzer reads directly in parts per million (ppm) as the recorder is charting. From the area under the curve the total ppm leakage of the canister can be determined. From the total ppm the cc leakage of CO can be calculated using the formula:

$$CO_{cc} = 1000\ (cc/l) \times F_t\ (l/min) \times C_t\ (ppm\ min) \times 10^{-6}\ \frac{\text{Liter CO}}{\text{1 Tppm}}$$

Where:

CO_{cc} = Penetration of CO in cubic centimeters
F_t = flowrate of test atmosphere
C_t = total number of ppm CO in 60 minutes

*Note: the equation $10^{-6}\ \frac{\text{Liter CO}}{\text{1 Tppm}}$ is a factor.

* For every ppm of CO there is a 10^{-6} liter of CO per liter of test atmosphere.

Sample calculation: Respirator unit I at a flow rate of 32 lpm has a 150 ppm CO leakage during the whole 60 minute service life. Determine the penetration of CO in cubic centimeters.

C_t (ppm min) = 60 x 150

C_t (ppm min) = 9000

$$CO_{cc} = 1000\ cc/l \times 32\ lpm \times 9000\ ppm/min \times 10^{-6}\ \frac{\text{Liter CO}}{\text{1 Tppm}}$$

CO_{cc} = 288.0

The maximum allowable CO penetration for Respirator I during the minimum service life of 60 minutes is 288 cm^3. The unit passes the test.

SET-UP AND ADDITIONAL NOTES FOR INSPIRED AIR TEMPERATURE TEST

8.3.1. Calibrate analyzer as in Section 5.3 using 500 ppm cylinder and mark deflection on recorder.

8.3.2. Using the formula in Table 1, calculate the flow rate of the carbon monoxide in 64 lpm air. The challenge concentration flowrate must be in excess of the amount pulled by the breathing machine.

8.3.3. From Section 5.8 and using the dilution method pull off 1Lpm and dilute with clean air. Insert the analyzer tubing into the airstream and note the deflection on the analyzer till it reads 500 ppm. From section 5.10.1 calculate the total CO concentration. Set up infrared analyzer for carbon monoxide sampling and connect to recorder. Sample the test concentration and note deflection on the IR and recorder for the 1200 ppm concentration. The IR is used to detect the CO concentration during the actual testing of the respirator. Insert the sample line of the IR into the test gas airstream during testing.

8.3.4. Zero and span type K thermocouple at 0^{o}C and 100^{o}C and mark point on recorder. Allow the thermocouple to come to room temperature between spans.

8.3.5. Calibrate the breathing machine to pull 40 Lpm cyclic air flow.

8.3.6. Calibrate analyzer using 10 ppm CO cylinder and mark on recorder.

8.3.7. Position and seal the thermocouple inside the facepiece at the breathing zone and mount and seal the complete respirator assembly onto a headform. Place the respirator assembly into the large test box with the ground glass joint exiting the box and connected to the breathing machine.

8.3.8. Sample breakthrough leakage as breathing machine is pulling through the respirator assembly. Run performance tests as per test conditions for inspired air temperature testing, Section 4.5.

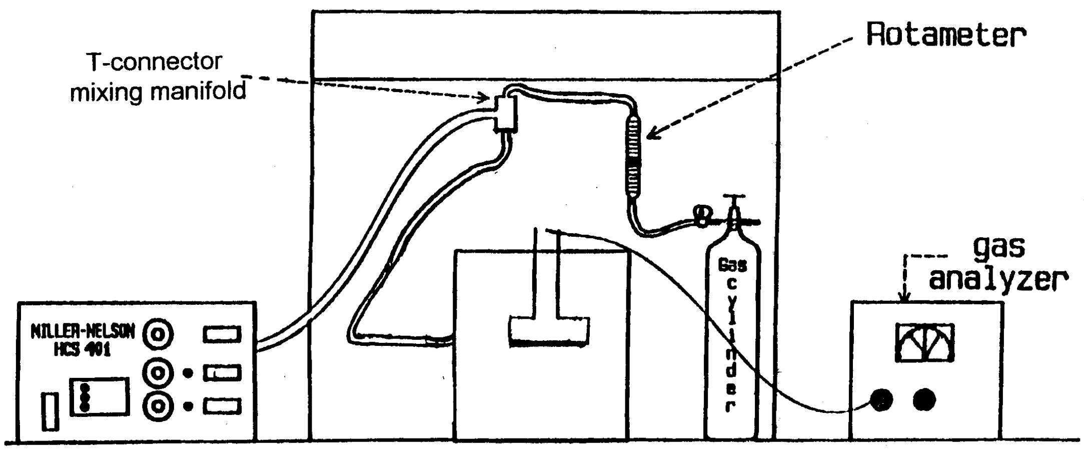

Figure 1- Canister Bench Test Set-Up

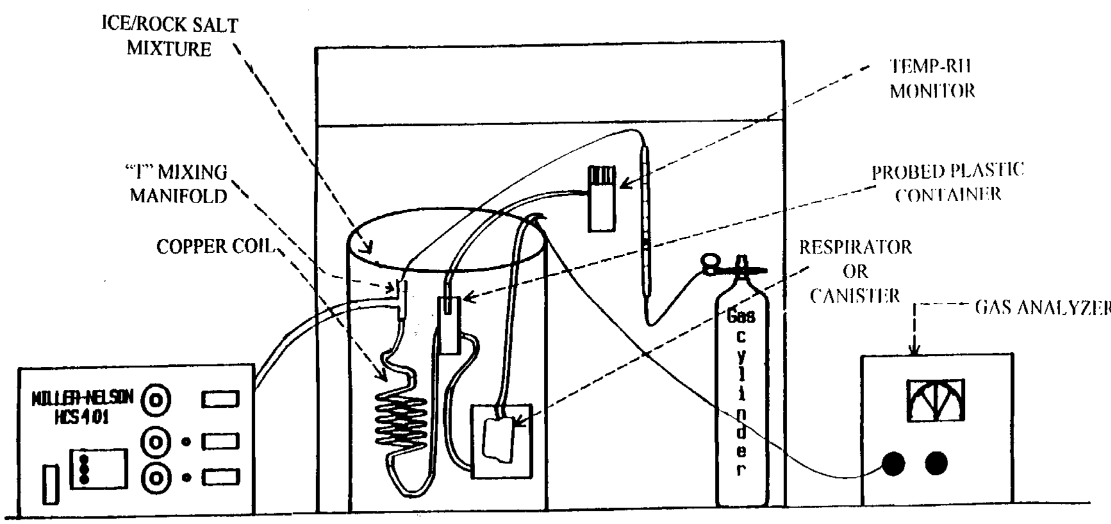

Figure 2- Ice Bath Set-Up

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GAS & VAPOR RESPIRATOR TEST DATA SHEET (Ref.33-48,50,62) **STP No.: [_______]**

Task Number: TN-_____________ Gas Name:

Manufacturer: ________________ Item Tested:

RESISTANCE	Maximum Allowable Resistance (mm of H_2O)				Actual Resistance (mm of H_2O)				Result
Test	Inhalation		Exhalation		Inhalation		Exhalation		
			Initial		Initial	Final	Initial	Final	
1									
2									
3									
4									
5									
6									
7									

Overall Results: Pass ___ Fail ___ Comment:

WEIGHTS AND AIRFLOWS	**WEIGHTS (gm)**					**AIRFLOW (Lpm)**			
						Test Rate		**(PAPR Only)**	
Test		**Con'd**			**Conc. (ppm)**	RH%	Lpm	Initial	Final
1									
2									
3									
4									
5									
6									
7									

Overall Results: Pass ___ Fail ___ Comment:

DATA TABLE	**Test Cond.**	**Final Time (min)**	**Leakage (ppm)**	**Temperature (°C)**		**Corrected Time (min)**
Test				**Dnstream**	**Upstream**	
1						
2						
3						
4						
5						
6						
7						

Overall Results: Pass ___ Fail ___ Comment:

Was all testing equipment in calibration throughout all testing: Yes ___ No

Signature: ____________________ Date:

RB - RESPIRATOR CERTIFICATION TEAM ***Page 2***

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GAS & VAPOR RESPIRATOR TEST DATA SHEET (Ref.33-48,50,62) **STP No.: [____________________]**

Task Number: TN-________________________ **Gas Name:**

Manufacturer: ________________________ **Item Tested:**

Additional Comments:

Signature: ____ **Date:**

Revision History

Revision	Date	Reason for Revision
1.0	10 June 2001	Historic document
1.1	6 June 2005	Update header and format to reflect lab move from Morgantown, WV No changes to method