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DETERMINATION OF CAPACITY OF AS-RECEIVED AND ENVIRONMENTALLY TREATED CLOSED-CIRCUIT ESCAPE RESPIRATORS (CCER)

1. PURPOSE

This procedure establishes the test for ensuring that Closed-Circuit Escape Respirators (CCER) submitted for Approval, Extension of Approval, or examined during Certified Product Audits, meet the certification standards as set forth in Sections 84.303 and 84.304, of Subpart O−Closed Circuit Escape Respirators updated requirements to 42 CFR Part 84.

2. GENERAL

This Standard Testing Procedure (STP) describes the CCER capacity test, and the equipment, instruments, materials, and minimum performance criteria in sufficient detail such 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 respirator passes the test.

3. EQUIPMENT / MATERIALS

3.1 The ABMS instrument and equipment schematic (Figure 1 in the Attachments), includes using a LabVIEW digital display, control, and data recording software.

3.2 The following instruments performing stressor measurements must be capable of breath-by-breath responses and have the following measurement ranges:

3.2.1 Carbon dioxide (CO_2) gas analyzer capable of detecting CO_2 from 0.00 to 15.00 volume %, accurate to within ±0.02% CO_2, with a response time of approximately 100 milliseconds and possessing a digital display readout (resolution) ±0.01% (such as AEI Technologies Carbon Dioxide analyzer Model CD-3A or equivalent)

3.2.2 Oxygen (O_2) gas analyzer capable of detecting O_2 from 0.00 to 100.00 volume %, accurate to within ± 0.01% O_2, with a response time of approximately 100 milliseconds and possessing digital display readout (resolution) ±0.01% (such as AEI Technologies Oxygen analyzer Model S3-A/I or equivalent gas analyzer)

3.2.3 Thermocouple modified to induce evaporative cooling from its tip (thermocouple wire junction point) and capable of measuring a breathing circuit wet bulb temperature ranging from 0 to 100 °C (such as an Omega P/N 5SRTC-TT-T-36-36 Type ‘T’, 0.005-inch outer diameter thermocouple with appropriate junction point covering).

3.2.4 Pressure transducer capable of measuring breathing circuit breathing resistance from -562.5 to +562.5 mm water (such as a Validyne Model P55D-1-N-2-28-S-4-A or equivalent pressure transducer)

3.3 Support/control instruments and equipment include the following:

3.3.1 Thermocouple capable of breath-by-breath response and measuring a breathing circuit dry bulb temperature ranging from 0 to 100°C (such as an Omega P/N 5SRTC-TT-T-36-36 Type 'T', 0.005-inch outer diameter thermocouple, or equivalent)

3.3.2 Gas sample system electronic moisture removal device, electronic gas chiller capable of lowering the automated breathing and metabolic simulator (ABMS) gas sample system dew point to 3.5 °C, (such as the DEEC Instadryer or equivalent)

3.3.3 CO_2 Mass Flow Controller (MFC) capable of measuring 0-5 LPM (such as the Brooks SLA5850S CO_2, or equivalent)

3.3.4 N_2 MFC capable of measuring 0-1.7 LPM (such as a Brooks SLA5850S or equivalent)

3.3.4.1 Activated when N_2 flow rates decrease below 1.6 LPM; deactivated when N_2 flow rates increase above 1.7 LPM.

3.3.5 N_2 MFC capable of measuring 0-20 LPM (such as a Brooks SLA5850S or equivalent)

3.3.5.1 Activated when N_2 flow rates increase above 1.7 LPM; deactivated when N_2 flow rates decrease below 1.6 LPM

3.3.6 Weigh scale with a 0 to 35,000 mg range with 1 mg scale resolution (such as the Ohaus Ranger R71MHD35 weigh scale or equivalent)

3.3.7 Gas spirometer (such as the Collins P-1700-120 Liter scale gas spirometer or equivalent)

3.3.8 Timer (accurate to 0.01 percent)

3.3.9 Physitemp Thermalert Model TH-8 temperature indicator, or equivalent, with 'T' type thermocouple

3.3.10 Electronic barometric pressure transducer (such as the Vaisala PTU300 electronic barometric pressure transmitter or equivalent)

3.4 Materials required include the following:

3.4.1 Nitrogen (N_2) Cylinder – At minimum, High Purity grade containing $\geq$99.99% N_2

3.4.2 Carbon dioxide cylinder – At minimum, Coleman/Instrument grade containing $\geq$99.99% CO_2

3.4.3 Calibration gas traceable to recognized international standards containing 80.0% oxygen, 12.0% nitrogen, and 8.0% carbon dioxide

3.4.4 Phenolphthalein

3.4.5 Deionized water for the ABMS recirculating water system

4. TESTING REQUIREMENTS AND CONDITIONS

4.1. Prior to beginning any testing, confirm that all measuring equipment and instruments employed have been calibrated in accordance with the testing laboratory's calibration procedure and schedule. All measuring equipment and instruments utilized must have been calibrated using a method traceable to recognized international standards when available.

4.2. Tests will be conducted at the following ambient conditions

4.2.1. Ambient temperatures of 23 ºC ± 3 ºC; and

4.2.2. Atmospheric pressures of 735 mmHg ± 15 mmHg

4.3. Prior to beginning the Capacity Test Procedure, the CCER will be inspected using the manufacturer's and NIOSH inspection criteria. The manufacturer's inspection will be specific to their respirator unit and are defined in the User Instructions (UI). NIOSH inspections will include:

4.3.1. Applying a -300mm H_2O vacuum to assess the integrity of the breathing tube and associated parts of the respirator unit.

4.3.2. Using a phenolphthalein swab to detect alkaline chemicals present in the CCER unit user interface.

4.4. Capacity Test Requirements and Conditions

4.4.1. Capacity tests will continuously monitor the stressors listed in Table 1. The stressors will be measured at the interface between the CCER and the ABMS "mouth" by instruments capable of breath-by-breath measurement. Stressor measurements will be evaluated as one-minute averages. The operating (overall) averages of each stressor will be calculated upon the completion of each test as the average of the one-minute measurements of the stressor recorded over the entire test.

4.4.2. Capacity tests will conclude when the stored breathing gas supply has been fully expended, or any one-minute average stressor measurement is outside the acceptable excursion range.

4.4.3. The capacity test is conducted on five units submitted for approval (refer to Table 3), as follows:

4.4.3.1. Three units will be tested in the condition in which they are received from the applicant.

4.4.3.2. Two units will be tested after being subjected to the environmental treatments according to the standard procedure for environmental treatments of CCERs.

4.4.4. Each unit will be tested at a constant work rate which depends on the capacity specified by the manufacturer, according to the requirements in Table 2.

5. PROCEDURE

5.1. Initial Startup

5.1.1. Verify all equipment is on and all test system operating parameters are in the appropriate range for valid testing.

5.1.2. Calibrate the O_2 and CO_2 exhaust flows analyzers.

5.1.3. Perform ABMS gas analyzer calibration for O_2 and CO_2.

5.1.3.1. Confirm the response times for each gas analyzer are within acceptable ranges as established by the manufacturer.

5.1.4. Verify correct waveform for the specific capacity test.

5.1.4.1. For a CAP 1 test, set the VO_2 to 2.50 L/min; see Figure 2.

5.1.4.2. For a CAP 2 test, set the VO_2 to 2.00 L/min; see Figure 3.

5.1.4.3. For a CAP 3 test, set the VO_2 to 1.35 L/min; see Figure 4.

5.1.5. Mount the CCER unit on the ABMS trachea and perform a leak check for the ABMS. Ensure all orifices are properly sealed and that the system is leak tight.

5.2. Perform the capacity test by selecting the appropriate test protocol to set the corresponding VO_2, VCO_2, ventilation rate, and respiratory frequency operating conditions just prior to beginning the simulation.

5.2.1. The manufacturer's recommended start-up procedure for the CCER being tested must be simulated on the ABMS as closely as possible, as described in the manufacturer's UI.

5.2.2. Monitor the values in Table 1 throughout the test.

5.2.3. Determine the completion time as the time elapsed from test start to when the gas supply is fully expended. Expended gas supply is usually indicated when either the breathing bag is empty, or (if present) the O_2 cylinder is empty, and (as a result) peak inhalation pressure begins to spike below -300 mmH_2O. The test is also stopped if the peak breathing resistance exceeds +200 mmH_2O.

5.3. Data Analysis

5.3.1. Calculate the achieved capacity as the product of the completion time (in minutes) and the VO_2 (STPD L/minute) set point used in the test protocol.

5.3.2. Calculate the overall average for each of the stressor measurements using the one-minute average values from the test start to when the breathing gas supply is fully expended.

5.3.3. Identify the maximum inhaled CO_2, minimum inhaled O_2, maximum exhaled and minimum inhaled breathing resistance, and maximum inhaled wet bulb temperature using the one-minute average values from test start to when the breathing gas supply is fully expended.

5.3.4. Record the calculated values and completion time on the test data sheet.

6. PASS/FAIL CRITERIA

6.1. The apparatus fails this test and approval if:

6.1.1. Any average stressor measurement (as the overall average stressor from test start to when the breathing gas supply is fully expended) is outside the acceptable operating average range shown in Table 1 (middle column).

6.1.2. Any one-minute average stressor measurement (minimum to maximum stressor from test start to when the breathing gas supply is fully expended) is outside the acceptable excursion range shown in Table 1 (last column).

Table 1: Monitored Stressors and their Acceptable Ranges

Stressor	**Acceptable Range Operating Average**	**Acceptable Range Excursion**
Average inhaled CO_2	<1.5%	≤4%
Average inhaled O_2	>19.5%	≥15%
Peak Breathing Resistances	$\Delta P \leq 200$ mm H_2O	$-300 \leq \Delta P \leq 200$ mm H_2O
Wet-bulb temperature	<43˚C	≤50˚C

6.2. The apparatus fails certification if the achieved capacity is below the minimum capacity as indicated in Table 2.

Table 2: Capacity Test Requirements (all volumes are given at standard temperature (0°C) and pressure (760 mm Hg), dry)

Capacity Rating	**Capacity (L)**	**VO_2 (L/min)**	**VCO_2 (L/min)**	**Ve (L/min)**	**RF (Breaths/min)**
Cap 1	$20 \leq L \leq 59$	2.50	2.50	55	22
Cap 2	$60 \leq L \leq 79$	2.00	1.80	44	20
Cap 3	$L \geq 80$	1.35	1.15	30	18

VO_2=volume of oxygen consumed/min; VCO_2=volume of carbon dioxide produced/min; Ve = ventilation rate; RF = respiratory frequency

7. RECORDS / TEST SHEETS

7.1. Data shall be recorded and stored as an attached data sheet to include the following information in the TEST DATA SHEET (INCLUDING PRE-TEST CHECK DATA) FOR DETERMINATION OF CCER CAPACITY, STP 0602.

TEST DATA SHEET (INCLUDING PRE-TEST CHECK DATA) FOR DETERMINATION OF CCER CAPACITY, STP 0602

Date	Barometric Pressure (mm Hg)	S/N #	Manufacturer Date	Expiration Date	Phenolphthalein (Pass or Fail)	Oxygen Flow Rate (LPM)	CCER Leak Flow Rate (mL/min)
Case Integrity	Case Seal	Secure Tape or Latch	Oxygen Indicator (psig)	Oxygen Starter	Temperature Indicator	Moisture Indicator	Waveform/Protocol
Oxygen Response (ms)	Carbon Dioxide Response (ms)	Oxygen Criteria Time (ms)	Carbon Dioxide Criteria Time (ms)	ABMS Leak Rate (mL/min)	ABMS Leak Rate with CCER (mL/min)	Technician Initials	Comments

Table 3: Example Test Summary Data for all CCER Units Submitted for NIOSH Approval

Device ID	**Test**	**Test date**	**Completion time**	**Calculated Capacity**	**Indicate Minimum Capacity**	**Comments**
	As-received					
	As-received					
	As-received					
	Environmental treatments					
	Environmental treatments					

8. ATTACHMENTS

8.1 Figure 1: Schematic of the ABMS
8.2 Figure 2: Graph for CAP 1 Test
8.3 Figure 3: Graph for CAP 2 Test
8.4 Figure 4: Graph for CAP 3 Test

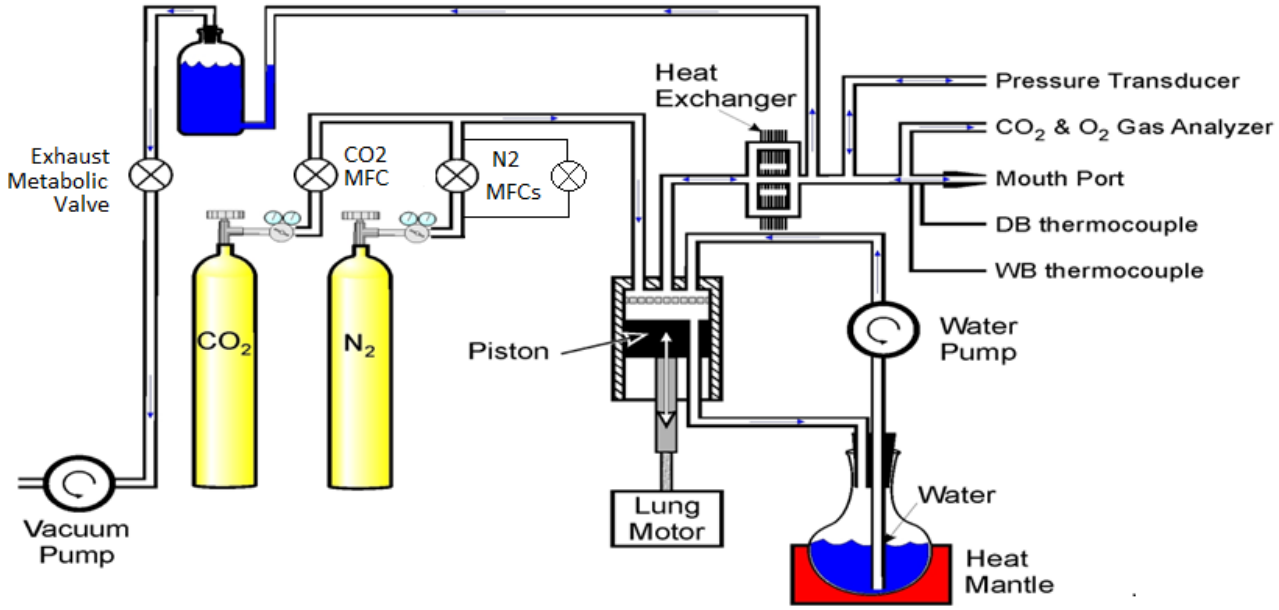

Figure 1: Schematic of the ABMS

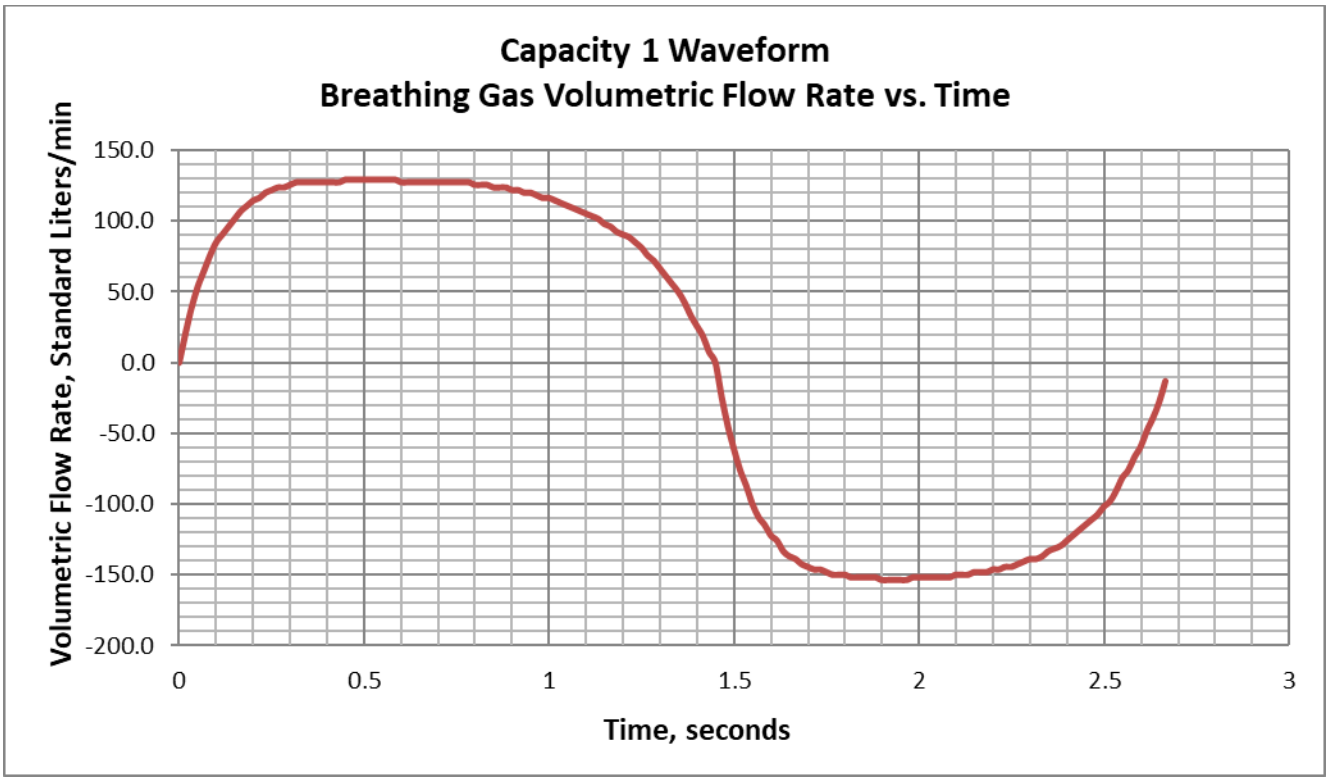

Figure 2: Example graph for CAP 1 Test, showing breathing gas volumetric flow rate (y-axis) vs. time (x-axis).

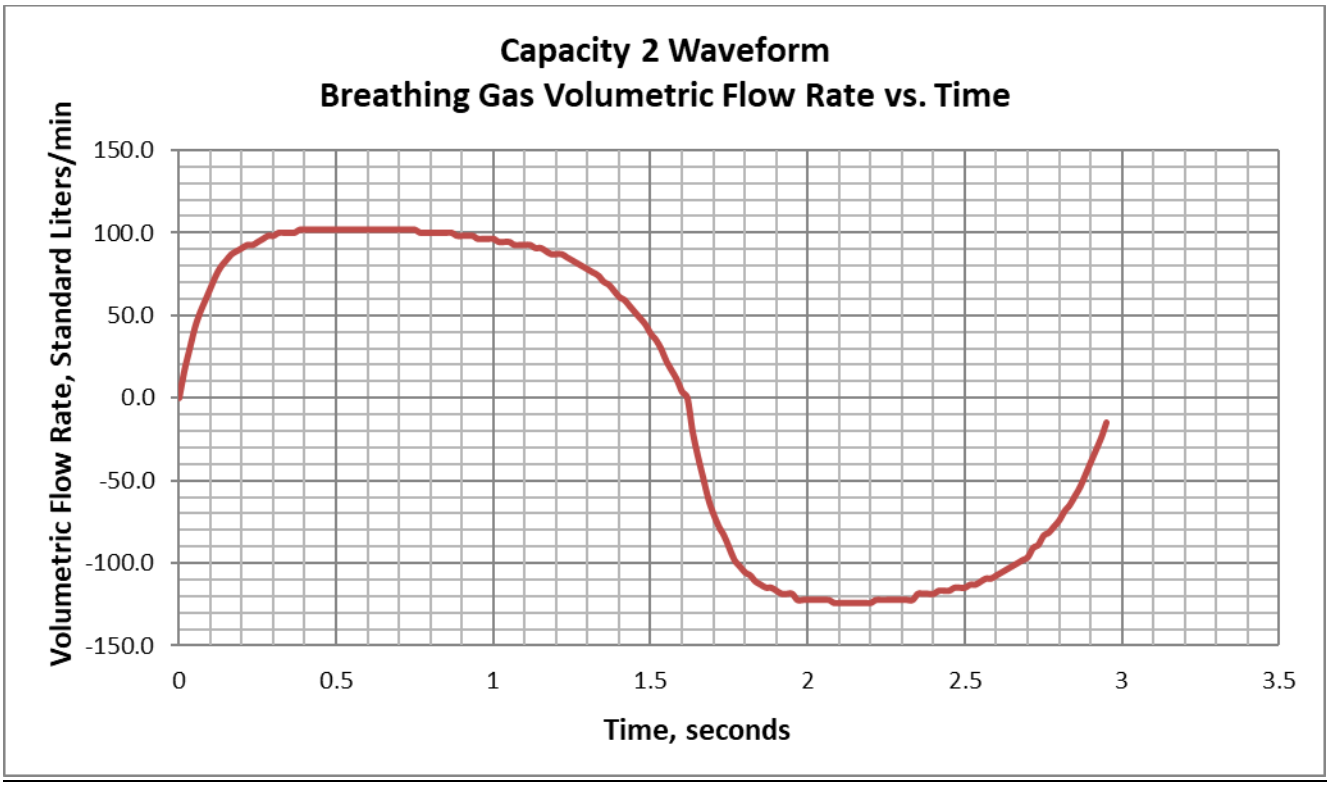

Figure 3: Example graph for CAP 2 Test, showing breathing gas volumetric flow rate (y-axis) vs. time (x-axis).

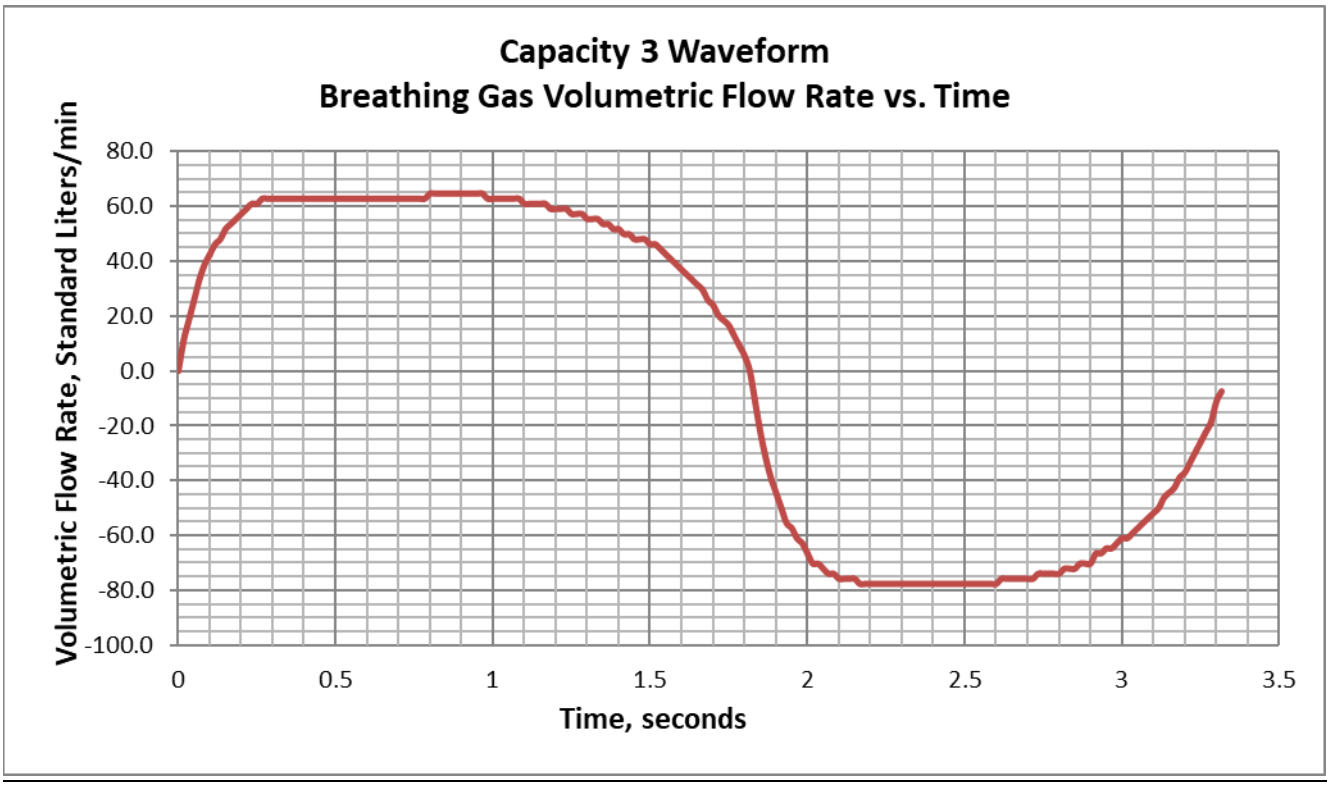

Figure 4: Example graph for CAP 3 Test, showing breathing gas volumetric flow rate (y-axis) vs. time (x-axis).

Revision History

Revision	Date	Reason for Revision
0	10 November 2010	Initial Record
1.0		Final Review
1.0	22 November 2011	Administrative changes – Document number changed
2.0	3 April 2012	Administrative changes were made to include information from the release of the proposed rule and TEB suggested changes.
		Former document number - STP-00001-PSDB-0006
0.0	25 March 2014	New document number (TEB-CCER-STP-0602) to reflect numbering in the approval library, normalization of format. No changes to procedure from historical document.
1.0	05 January 2022	Changes were made to the equipment and materials and the procedure. Examples waveforms were added as figures.