CVB-CBRN-CUR-STP-0802

# DETERMINATION OF COMBINATION UNIT RESPIRATOR (CUR) PERFORMANCE DURING DYNAMIC TESTING AGAINST THE CHEMICAL AGENT SARIN (GB) VAPOR, STANDARD TESTING PROCEDURE (STP)

## 1. PURPOSE

This document establishes the procedure for ensuring that the demonstrated performance of CUR systems against sarin vapor (GB) challenge meets the certification requirements set forth in NFPA 1987 Standard on *Combination Unit Respirator Systems for Tactical and Technical Operations*. This standard testing procedure (STP) was developed in coordination with the NFPA 1987 *Standard on Combination Unit Respirator Systems for Tactical and Technical Operations* subcommittee. To use this STP, refer to CUR Performance Requirements in NFPA 1987 Section 7.1.1.2. and CUR System Requirements in NFPA 1987 Section 8.1.1.

*Disclaimer: Standard Testing Procedures (STPs) 800, 801, 802, 819 and 848 are referenced in the National Fire Protection Association (NFPA) Standard on Combination Unit Respirator Systems for Tactical and Technical Operations, NFPA 1987 (2023). These STPs were developed in concert with the NFPA 1987 standard. These STPs are not presently in effect; NIOSH is not currently using these STPs for the purpose of testing or approving combination unit respirators. Consequently, the STPs are being provided for* ***informational purposes only*** *since each is referenced NFPA 1987.*

## 2. GENERAL

This 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/MATERIAL

3.1. SMARTMAN, Head/upper torso form or equivalent manufactured by ILC Dover, Frederica, DE - The **S**imulant **A**gent **R**esistant **T**est **Man**ikin, SMARTMAN, is a cast zinc, hollow shell and comprised of a head, neck, shoulders and upper chest. The head features an anatomically correct surface consisting of dimensional eyes, nose, ears, mouth orifice, forehead, and chin. The facial features are on a movable section of the head to facilitate installing and removing a peripheral front face seal, which is made of rubber and fits into a channel between the face and the permanent part of the head. The seal is inflated to press against the inside of the facepiece seal area to assure against leakage. The surface of the face of the SMARTMAN is connected in several places to outside sampling ports by means of stainless steel tubing that is located inside the form and passes out the bottom. The largest tube, about 1¼" diameter, leads from the mouth area to the breather pump. One tube connects to the center of the left eye and can be used to monitor the upper, or eye, area of the interior of the mask. One tube connects to the lower middle forehead above the bridge of the nose and can be used to monitor pressure, or differential pressure when connected by means of a manometer to the nose area. There are two metal tubes protruding outward from the oral/nasal region; one is used to measure differential pressure by means of a magnehelic gauge, while the second one is used to monitor presence of agent. The four tubes are ¼" diameter. The SMARTMAN is mounted and sealed to the floor of an exposure

chamber, which is raised by four legs to allow the tubing to exit and connect to the external monitoring devices. A large channel is molded at the bottom of the SMARTMAN to allow the anchoring of respirator system shrouds as they are intended per manufacturer instructions.

3.2. Exposure chamber - The exposure chamber is constructed of clear, chemical resistant material (Plexiglas® or Lexan®) or other equivalent material. The floor must be constructed to support the 85-pound weight of the SMARTMAN. The front panel is removable and includes two glove ports for manipulating test articles without opening the chamber. The internal volume is approximately 12 $ft^3$. The chamber is tightly sealed when closed and all exhaust air passes through a filter before entering the fume hood. There are ports in the sides to accommodate tubing for the challenge concentration and clean purge air. An electric fan is installed near the top front to achieve a well-mixed challenge concentration. A "Clean Chamber" refers to a unit used to perform a fit and leak check on a respirator test unit (no agents used in this chamber) before it is installed in the agent exposure chamber. An "Agent Chamber" is a chamber used to perform testing of the respirator unit, using agent.

3.3. Aerosol leak detector, ATI Model TDA-99B or equivalent - The TDA-99B is manufactured by Air Techniques, Inc. The TDA-99B is used to ensure the correct functioning and fitting of a respirator face piece to the SMARTMAN headform. The TDA-99B is used to confirm the proper facepiece seal and integrity of the respirator after it has been mounted on the SMARTMAN. The device generates a polyalphaolefin (PAO) aerosol that is used to detect leakage into the interior of the respirator. The leak detector compares the concentration of aerosol inside the mask with the concentration outside, and calculates a percent penetration value.

3.4. Effluent concentration detector, Miniature Continuous Air Monitoring System, MINICAMS or equivalent - This instrument(s) is used to analyze the concentration of agent inside the mask. The MINICAMS, manufactured by OI Analytical, is a gas chromatograph equipped with a hydrogen flame photometric detector and a preconcentrator tube (PCT). The PCT is a small tube containing an adsorbent material to collect agent vapor from a sample of air drawn through it for a set time period. The tube is then heated to desorb the agent and introduce it into the column and subsequently the detector. By concentrating the agent in this manner, very low levels of agent can be accurately quantified. Two MINICAMS are required in order to continuously monitor the interior of the respirator, with the operator ensuring that the systems are timed such that one instrument is in the sample cycle, while the other is in the purge cycle.

3.5. Vapor generation system - This system is comprised of a chemical delivery device (i.e. syringe pump), and a vaporization device (i.e. heated 'tee'). The chemical delivery device must be able to accommodate the required injection rates for all challenge concentrations specified in this document. The vaporization device may vary in design but will often involve the use of heat to vaporize liquid agent. Care must be taken to design the system such that the applied heat does not begin to degrade the agent, or push the temperature of the challenge air stream outside of the acceptable parameters.

3.6. Environmental control system - This subsystem may be a single device (i.e., a Miller Nelson system) or comprised of multiple individual components that together deliver an air stream into the agent chamber at the required temperature, humidity, and flow rate.

3.7. Breather pump, Jaeco Fluid Systems Model E1R1 or equivalent - The Jaeco E1R1 is a double pump, operated by a variable speed electric motor. The number of strokes (breaths) per minute can be varied from 1-60. The pump is controlled by a gearbox with planetary gears and a Scotch Yoke that produces the sinusoidal breathing pattern. The sinusoidal pattern starts at zero flow rate, rises to a maximum, or peak, flow of approximately π (3.1416) times the rated flow rate in liters per minute, and drops back to zero. The exhalation stroke of the pump follows the same sinusoidal pattern. The tidal volume (volume per breath) can be adjusted up to 1.5 liters. An equivalent pump would be any device that can deliver a sinusoidal breathing pattern at the breathing rate and volume specified below.

3.8. Challenge concentration detector - This instrument is used to monitor the challenge concentration delivered to the respirator. The detector must be calibrated across the full range of target concentrations specified in this document.

3.9. Breathing air supply and pressure control system – The basic requirement of this system is an air-compressor or a cylinder capable of maintaining upper limit of 7000 psig and a lower limit of 250psig. The system must be capable of simulating a linear pressure decay curve from full rated air cylinder pressure to the lower limit air pressure range (Appendix B).

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. Aerosol Leak Test

4.2.1. The aerosol leak test, using an appropriate leak detector (TDA-99B or equivalent), is used to detect leaks into the respirator after it has been installed on the SMARTMAN headform in two stages. Stage one is conducted on each new specimen in a clean chamber. Upon successful testing in the clean chamber, stage two will be conducted in the agent chamber. No live agent testing shall be started until satisfactory stage two results have been achieved. For successful leakage testing, the detector shall indicate an average penetration of less than 0.0050%.

4.3. Live Agent Test System Conditions

4.3.1. Breathing Parameters

Airflow = 40 ± 4 liters per minute

Respirations = 36 ± 2 strokes per minute

4.3.2. High-Pressure, Compressed-Air Supply, Grade D Compressed Air or Grade E Liquefied Air (Source for CUR, SCBA-mode Operating System)

Pressure Decay Profile: Rated SCBA-mode service pressure upper limit, with linear press decay over expected cylinder time to no less than 290 psi (Appendix B).

Temperature: 25 ± 5 °C

Oxygen: 19.5 to 23.5%

CO by Volume: Less than 10 ppm

$CO_2$ by Volume: Less than 1,000 ppm

Dew Point: 24 ppm of H2O, Less than -65 °F at 1 atmosphere.

Condensed Oil & Particulate: Less than 5 $mg/m^3$.

TVHC: Less than 25 ppm of Total Volatile Hydrocarbon Content.

Odor: None to Slight OV

GRADE D/E Air quality control certificates are required to be on file for the current compressor output air. Grade D/E air routine maintenance checks and procedures are required to be filed and capable of confirming the quality of used Grade D/E air in support of CUR certification.

4.3.3. High-Pressure, Compressed-Air Cycle, Compressed air source shall provide required high-pressure air over the entire duration of the test. Air supply pressure is based upon the CUR, SCBA-mode design requirements, but shall not be less than 290 psig. The pressure decay duration from the starting pressure or 'full cylinder' value to the minimum pressure will be as defined by the manufacturer.

4.3.4. Airflow settings into agent chamber

4.3.4.1. The conditions noted immediately below shall be measured as the air is being delivered to the chamber.

Relative humidity = 50 ± 5%

Temperature = 25 ± 3°C

4.3.4.2. Airflow rate = To be defined by the test laboratory as necessary to meet challenge concentration requirements in the agent chamber. This measurement shall be recorded as part of the test record.

4.3.5. GB Vapor Test Conditions

4.3.5.1. For both the high-concentration, and the low concentration challenges, the laboratory shall determine the appropriate agent injection rates and volume necessary to establish the required vapor concentration as sampled in the breathing zone (refer to 4.5.2.). These values shall be recorded as part of the test record.

4.3.5.2. All agent used in this test shall be Chemical Agent Standard Analytical Reference Material (CASARM). Proper CASARM storage requirements shall be followed.

4.3.5.3. Ramp time ≤ 8 minutes (time from initial start of liquid agent injection to lowest acceptable challenge concentration, 1,800 mg/m$^3$)

4.3.5.4. SCBA-mode vapor challenge concentration = 2,000 mg/m$^3$ ± 200 SCBA-mode vapor challenge time (disseminator on) = 30 minutes +1/-0

4.3.5.5. APR-mode vapor challenge concentration = 210 mg/m$^3$ ± 21 (Starts at minute 40 ± 1)

4.3.5.6. The vapor concentration of GB must have been reduced to 210 mg/m$^3$ ± 21 by the start of the APR-mode challenge phase.

4.3.5.7. APR-mode vapor challenge time (disseminator on) = 45 minutes +1/-0 after vapor challenge concentration achieved.

4.3.6. Vapor exposure test duration shall be six hours.

4.4. Effluent Concentration Measurement

4.4.1. The effluent measurement system shall be capable of continuously monitoring the agent concentration inside the mask. If using MINICAMS, two instruments shall be timed such that the sample stream is continuously monitored (i.e., one instrument in 'sample' mode while other is in 'purge' mode).

4.4.2. Sampling shall be from the nasal region sampling port of the manikin. If the interface design incorporates a separate ocular air management zone, this shall be sampled also. If there are additional air management zones, these shall be sampled. The configuration of the test manikin may need to be adjusted to enable this.

4.4.3. The measurement interval time shall be ≤ 3 min for GB.

4.4.4. The effluent concentration monitoring system shall be calibrated at a minimum over the range 0.0003 mg/m$^3$ – 0.044 mg/m$^3$ for GB, prior to testing and in accordance with manufacturer's instructions if applicable.

4.5. Challenge Concentration Measurement

4.5.1. The challenge concentration shall be monitored using a calibrated detector. If the test system vapor generation system is used to calibrate the challenge monitoring equipment, an independent referee system shall also be used to confirm the concentrations measured.

4.5.2. The challenge concentration shall be measured in the agent chamber, at a location approximately 5" in front of the manikin's nose.

4.5.3. The measurement interval time shall be ≤ 1.5 min for GB.

4.6. Quality Control Measures

4.6.1. Manikin leak test - It is possible for leak paths to form, allowing chemical warfare agent vapor to pass through from the manikin headform directly into the

interior of the respirator mounted on the headform. Install a clean peripheral seal on the headform and inflate it. Flood the interior of the headform with helium. Use the probe of the helium leak detector to check the entire surface and the seal for presence of helium. Any leak found must be eliminated. This test is to be performed on each new or reconditioned SMARTMAN and monthly on the head-forms when they are in use.

4.6.2. Effluent detector response - **Check shots** are used to verify the calibration of the effluent detector, before and after each test. An aliquot of standard solution containing a known concentration of agent is injected directly into the instrument sample port. The aliquot concentration shall be near the mid-range of the standard curve. The detector response must fall within ±15% of the expected value. Repeat it at the end of the test to ensure that the detector response has not changed during the test. If the measurement falls outside the acceptable range, repeat the injection. If the second measurement falls outside the acceptable range, begin corrective actions. If this occurs immediately following a test, the test data may be invalid and requires close review.

4.6.3. Effluent sampling system – **Line Shots** are performed monthly to ensure the effluent sample collection and analysis system is functioning properly. An aliquot of standard solution containing a known concentration of agent is injected directly into the heated sample line at the nasal and ocular sampling port of the manikin. The aliquot concentration shall be near the mid-range of the standard curve. The detector response must fall on the standard curve at ± 20% of the value expected for the aliquot.

5. PROCEDURE

5.1. Assemble CUR per manufacturer's user instructions with the exception of the air pressure vessel or any batteries.

5.1.1. Air pressure vessels are not typically tested according to these standard testing procedures. Using a high-pressure adapter supplied by the applicant, the only components of the pressure vessel assembly to be tested shall be the valve and seals. See Appendix C for a drawing of a typical adapter. Exception shall be made for units that need the pressure vessel as part of the CUR structure. To facilitate disposal when the pressure vessel body is used, the pressure vessel shall not be used to supply air and shall be rendered incapable of maintaining air pressure. In all cases, any special adapters needed to connect the CUR SCBA pneumatic system to the stationary air source shall be provided by the applicant with the test specimens.

5.1.2. All air purifying canisters installed for testing shall have completed environmental conditioning.

5.1.3. If the CUR is so equipped, the PAPR mode shall be operated using the house power supply delivering the correct rated voltage and current by means of an adapter which shall be supplied by the applicant. Batteries shall be removed from the CUR before testing begins. Using the manufacturer's supplied PAPR power adaptor, connect the PAPR and verify operation prior to mounting the respirator on the testing manikin.

5.1.4. If a shroud or other accessory is being tested as part of the respirator system, ensure that tested accessories are mounted properly and serviceable.

5.2. Take at least two digital photographs of the completely assembled unit. One photograph is of the completely assembled unit; the other is a close up of the completely assembled and accessorized facepiece with the regulator and/or breathing hose attached.

5.3. Mount the unit on the SMARTMAN in the clean chamber. The facepiece shall be mounted to the SMARTMAN per the applicant's operating/user instructions. Ensure all parts of the facepiece are mounted/seated correctly on the headform.

5.4. The CUR test specimen shall be connected to the stationary compressed air supply system. Ensure that the correct adapter is being used and has been installed according to the manufacturer specifications. A properly calibrated torque wrench may be necessary to exert the required torque as expressed in foot-pounds. Any needed adapters (pneumatic or power) shall stay with the CUR unit throughout the complete testing process. Ensure that the installation procedures for installing the valve into the pneumatic adaptor follow the applicant's installation procedures covering method and torque, and that the seal (gasket or O-ring) is a new seal provided by the applicant. Once assembled, activate the stationary pneumatic supply system. Ensure the air inlet pressure gauge reads the CUR rated service pressure ±10 psig at start of test and that adequate high-pressure air is available for the duration of the test. Ensure the CUR air pressure gauge reads in the full range.

5.5. Once connected for testing, ensure the inlet pressure gauge from the high-pressure air source does not exceed the CUR rated service pressure at any time.

5.6. Turn on the breathing pump. Ensure that the CUR is maintaining positive pressure in the SCBA operational mode. This shall be confirmed by visually checking the integrated SMARTMAN Magnehelic, or equivalent, pressure gauge. The integrated Magnehelic pressure gauge shall be used only as a qualitative indicator of CUR positive pressure. Lack of positive pressure in the CUR facepiece will result in the Magnehelic gauge reading in the negative pressure range.

5.7. Using the mask leakage detector, leak test the CUR. Connect the leakage detector inlet to the nasal sample line from the SMARTMAN.

5.7.1. The leak detector shall be powered on, allowed to equilibrate, and operated according to the manufacturer's instructions.

5.7.2. The CUR shall be operated in SCBA mode. Allow time to create a stable value on the mask leakage detector. Start the aerosol generation using the wand attachment of the leak detector, if so equipped. While aerosol is being generated, direct the wand to various portions of the facepiece and all mechanical seals and joints to detect any leaks. If any leaks are found, they shall be corrected only by adjusting the fit of the mask, or undertaking assembly or leak correction procedures as defined in the user instructions for the device. If no localized leaks are found, replace the front panel of the chamber. Connect the mask leakage detector aerosol generator to a port into the chamber and fill the chamber with the aerosol challenge. Maintain the aerosol challenge inside the chamber for the remaining portion of the leakage test (minimum of 15 minutes).

5.7.3. The CUR shall be switched through its available operating modes in the following sequence. Each mode shall be sustained for a period of three minutes before switching to the next mode. For CUR offering fewer operational modes, the missing modes shall be skipped.

SCBA mode

PAPR mode (blower on)

APR mode (where APR mode is dedicated)

SCBA mode

APR mode (where APR mode is dedicated)

PAPR mode (blower off)

SCBA mode

5.7.4. If aerosol penetration exceeds the requirement established in section 4.2., stop the test, reanalyze the system and start a new leakage test. Proceed to the next step once the criteria in Section 4.2 have been met.

5.8. Ensure effluent concentration measurement system is calibrated and ready for the operating mode by performing a check shot. Record the check shot times and concentrations. If using MINICAMS, ensure the two instruments are timed appropriately for continuous monitoring.

5.9. Install a clean laboratory control (i.e., not a test sample) CBRN respirator in the agent chamber. Using the effluent concentration measurement system, ensure that the background concentration is less than 0.0002 mg/m$^3$. The SMARTMAN shall be allowed to operate until the steady state background meets this requirement. Any reading at or above this value shall require corrective actions.

5.9.1. It is acceptable for this value to be outside of the calibration curve of the detector because it is not used in a quantifiable manner.

5.10. Remove the CUR from the clean chamber and install on the SMARTMAN in the agent chamber. The pressure vessel valve and the assigned adapter shall stay together and transfer with the CUR under test.

5.11. Mount the CUR under test on the SMARTMAN in the agent chamber. Conduct a mask leakage test by repeating steps 5.4-5.7.

5.12. Turn on the environmental control system and ensure the air entering the SMARTMAN chamber is at the appropriate temperature and humidity conditions.

5.13. Repeat the background characterization described in section 5.9, using the CUR under test. The effluent concentration measurement shall be monitored for a period of 20 minutes prior to the initiation of the agent test. Confirm that the background level is less than the requirement in Section 5.9. If the required background level has not been achieved prior to starting the agent exposure, troubleshoot the SMARTMAN system. Do not start the test until the required background level has been achieved.

5.14. Ensure that the challenge-concentration instrument is calibrated and is ready to analyze the challenge atmosphere. Monitor agent chamber during the 20-minute background characterization period. Characterization reading shall reflect a steady state condition.

5.15. Load the liquid agent into the vapor generation system. Ensure challenge airflow is directed away from the agent chamber (bypass mode). Set and record all vapor generation parameters, then begin agent generation.

5.16. Once steady-state challenge concentration is observed in bypass mode, introduce GB vapor agent challenge to the agent chamber.

5.17. Record the starting time ('time zero') as the time when agent vapor is introduced to the agent chamber.

5.18. Monitor and record the concentration of agent inside the chamber for the entire duration of the test. Adjust agent vapor concentration per the requirements in section 4.3.5.

5.19. At minute 40, begin switching modes of operation in accordance with Appendix A. Follow the operating mode sequence at the stated time point as necessary for the configuration under test.

5.20. At minute 85, stop chemical injection and allow the chamber concentration to decay naturally.

5.21. At the completion of the switching sequence, ensure the respirator system is properly operating in the APR (or PAPR-off) configuration and allow it to continue in this mode until completion of the test.

5.22. At the completion of the test, perform a check shot of agent to ensure that the detection system is still operating correctly. Direct challenge airflow towards the bypass mode, shutdown any externally powered devices in the agent chamber, and begin decontamination procedures.

5.23. If any physical degradation of the CUR is observed at any point during or at the end of the test, detailed photographs shall be captured prior to decontamination procedures. In this event, the test hardware shall be set aside safely in another hood for further inspection by the customer, if necessary.

5.24. Required Data Output & Calculations

5.24.1. The Concentration*Time $Ct_n$ value for sample $n$ and with units mg*min/m$^3$ shall be calculated by multiplying the observed concentration value $C$ (mg/m$^3$) by the sample time $t$ (min) of the detector.

$$Ct_n = C_n \times t$$

5.24.2. Cumulative Concentration*Time $Ct_{cum}$ (mg*min/m3) shall be calculated by summing the values of $Ct_n$ for all points within the test duration.

$$Ct_{cum} = \sum Ct_n$$

5.24.3. In the event two more detectors are required to ensure continuous monitoring of the sample stream, the $Ct_{cum}$ value for each detector will be reported individually as well as added together for a total Concentration*Time value, $Ct_{tot}$.

5.24.4. All data below the value of 0.0003 mg/m$^3$ shall be excluded from *Ct* calculations.

5.24.5. The final report shall include a data plot of the concentration measurement vs time for all analytical equipment, a plot of the $Ct_{cum}$ and $Ct_{tot}$ vs time, and the calculated $Ct_{tot}$ at the completion of the test duration.

6. PASS/FAIL CRITERIA

6.1. The criterion for passing this test is set within NFPA 1987 *Standard on Combination Unit Respirator Systems for Tactical and Technical Operations*. The criterion is:

6.1.1. Total cumulative breakthrough, $Ct_{tot}$: 2.1 mg-min/m$^3$

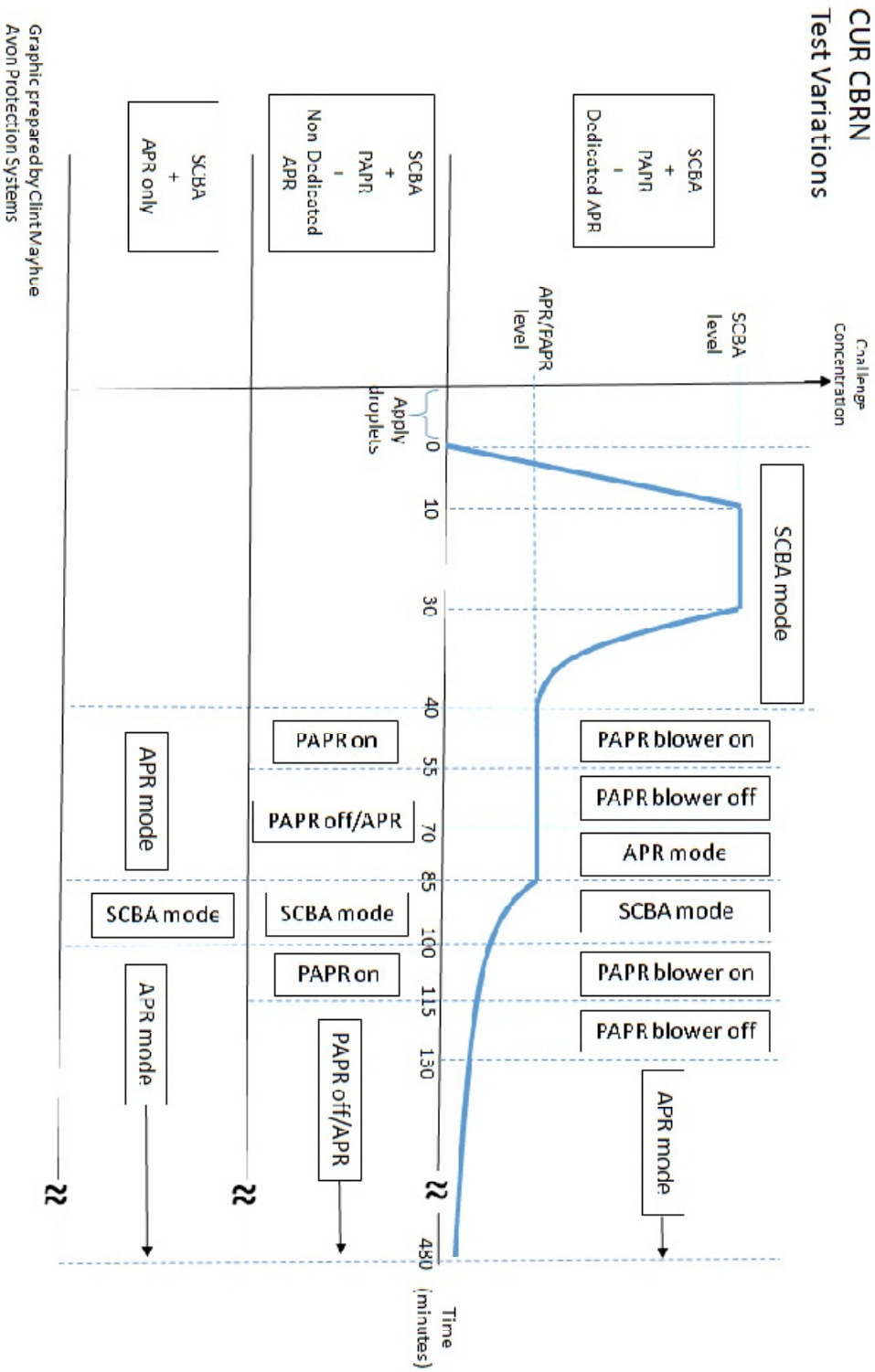
6.1.2. Maximum Peak Excursions: 0.087 mg-min/m$^3$

6.1.3. Three consecutive data points at or exceeding the peak value constitutes a failure. The test may be terminated immediately if this condition is met.

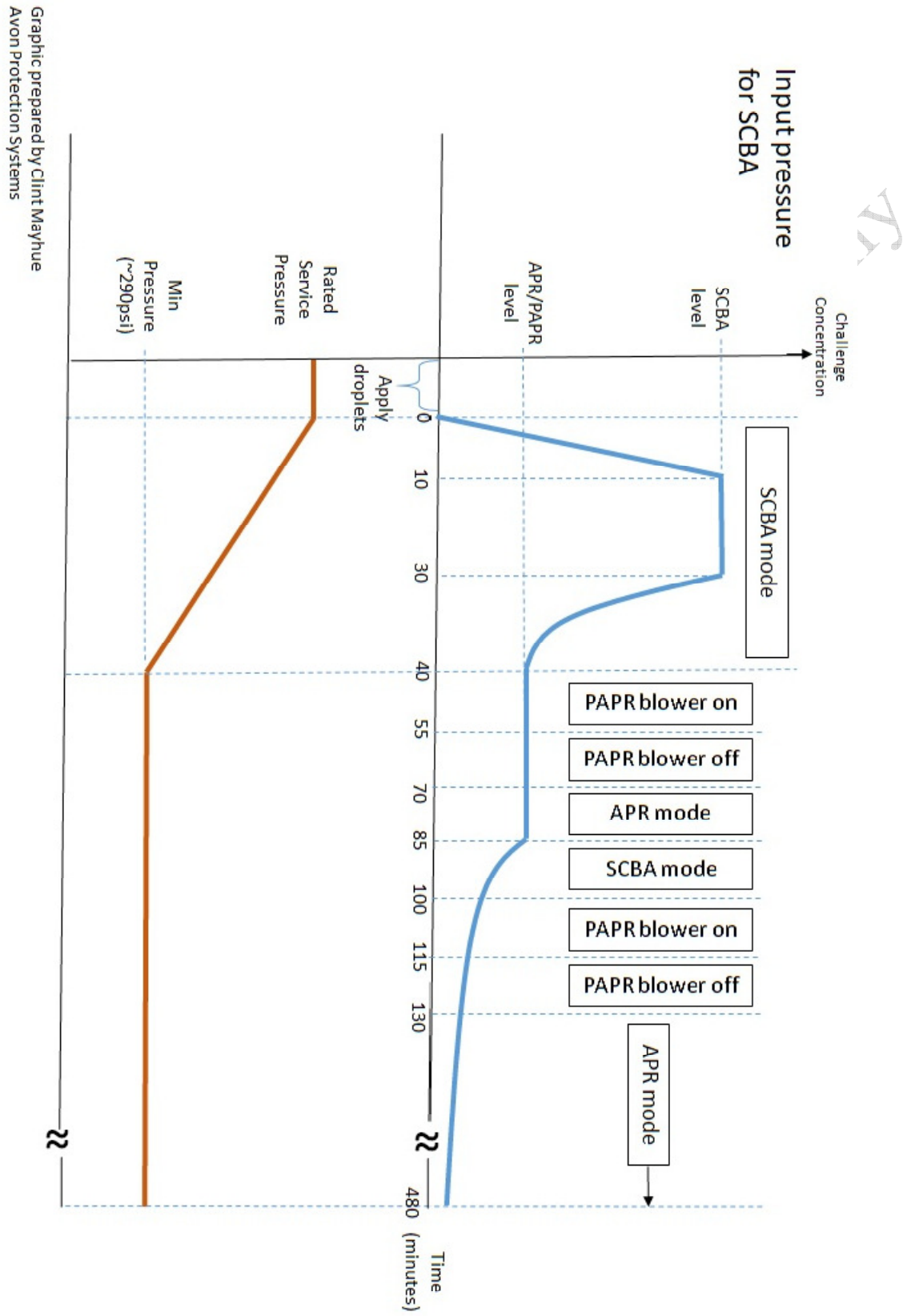
7. RECORDS\TEST SHEETS

7.1. All test data will be recorded in a format which has been documented as being acceptable to NIOSH. All applicable data, graphs and photographs taken/made by laboratory personnel will remain on file at the lab where the test was conducted and will be retrievable within 48-hour notification to the storing lab and be maintained in accordance with local administrative SOPs. Test records shall be kept in accordance with defined record retention policy or a minimum of five years after completion of test, whichever is longer.

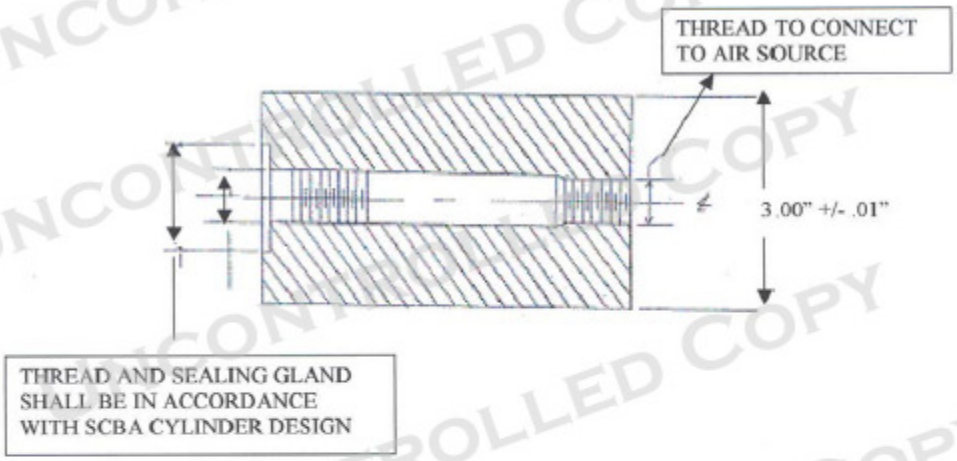
Appendix A: CUR Challenge Profile



Appendix B: CUR Supply Pressure Profile



Appendix C: Cylinder Adapter Diagram




| TORQUE (ft lb) | 4500 / 2216 / 3000 (psi) | DEPTH & DIAMETER (inches) | ADAPTER |
|---|---|---|---|
| 80 ± 10 | 4500 / 2216 / 3000 | 0.102 ± 0.002 / 1.126 ± 0.003 | LABELED "C" |
| 95-115 (average 100) | 4500 | 0.102 ± 0.002 / 1.126 ± 0.003 | LABELED "C" |
| 70-75 | 4500 | 0.107 ± 0.002 / 1.145 ± 0.003 | LABELED "D" |
| 90 ± 10 | 4500 | 0.107 ± 0.002 / 1.145 ± 0.003 | LABELED "D" |
| 75 ± 10 | 2216 / 3000 | 0.107 ± 0.002 / 1.018 ± 0.003 | LABELED "B" |

# Revision History

| Revision | Date | Reason for Revision |
|---|---|---|
| 0.0 | 26 February 2024 | Establishment of the STP. |
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