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National Personal Protective Technology Laboratory
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NOTE: The Respirator Branch maintains an updated index of current procedures.

DETERMINATION OF OPEN CIRCUIT, SELF-CONTAINED BREATHING APPARATUS (SCBA)
PERFORMANCE DURING DYNAMIC TESTING AGAINST CHEMICAL AGENTS
OF SARIN (GB) VAPOR AND DISTILLED SULFUR MUSTARD (HD)
VAPOR AND LIQUID STANDARD TESTING PROCEDURE (STP)

1. PURPOSE

- 1.1 This test establishes the procedures for ensuring the level of respiratory protection provided under special Chemical, Biological, Radiological, and Nuclear (CBRN) requirements for Open-circuit Self-Contained Breathing Apparatus (SCBA) with Full Facepiece submitted for Approval, Extension of Approval, or examined during Certification Product Audits, meet the minimum certification standards set forth in Title 42 CFR, Part 84, Subpart G, Section 84.63(c).
- 1.2 This procedure is used to test SCBA systems against Sarin GB vapor or Distilled Sulfur Mustard (HD) vapor and/or liquid, while the mask is operated in dynamic mode by means of a breather pump connected to the mouth area of the manikin. The mask is installed on a head/upper torso form known as a Simulant Agent Resistant Test Manikin (SMARTMAN). The SMARTMAN is enclosed in an air-tight exposure chamber. Instrumentation is integrated under one static chamber platform capable of generating and controlling challenge concentrations and detecting precise agent permeation of a tested respirator. Sampling ports, associated detection systems and exhalation engineering controls in the SMARTMAN are used to detect the presence of agent at known sampling areas of the eye and oral/nasal regions.

2. GENERAL

The STP describes a test entitled “Determination of Open Circuit Self-Contained Breathing Apparatus (SCBA) Performance During Dynamic Testing Against Chemical Agents (GB and HD)” 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

3.1. List of necessary test equipment follows:

- 3.1.1. Head/upper torso form, SMARTMAN, or equivalent, (see picture 1). The SMARTMAN is made of cast zinc, hollow shell, and comprises the head, neck,

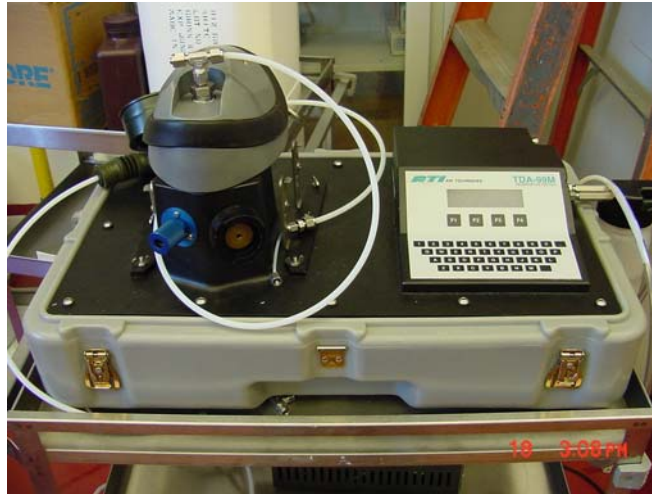
shoulders, and upper chest. The SMARTMAN is manufactured by ILC Dover, Frederica, DE. The head features a medium-size anatomically correct surface consisting of dimensional eyes, nose, ears, mouth orifice, and chin. The facial features are on a movable section of the head to facilitate installing and removing a peripheral 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 1 1/4" diameter, leads from the mouth area to the breather pump. One tube connects to the center of the left eye and is generally 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 can be used to measure differential pressure, while the second one is used to monitor presence of agent. The four tubes are 1/4" 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.



Picture 1: Head/Upper Torso Manikin, SMARTMAN

- 3.1.2. Leak detector Model TDA-99M, or equivalent, (see picture 2). The TDA-99M is manufactured by Air Techniques, Inc. The TDA-99M is one of the primary technician tools for accessing leaks in the mechanical seals of the respirator and fitting the face piece to the SMARTMAN prior to actual introduction of agent. The TDA-99M 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 mineral oil (Brand Name-“Emery 3004”) aerosol that is used to detect leakage into the interior of the respirator. With the respirator properly installed on the

SMARTMAN and the breather pump operating at manufacturer specifications, the TDA-99M generates a liquid particulate aerosol at a concentration of $100\text{mg}/\text{m}^3$. Aerosol is introduced into the agent exposure chamber. The interior of the mounted SMARTMAN mask is monitored for presence of the aerosol. The leak detector compares the concentration of aerosol inside with the concentration outside, and calculates a percent penetration.



Picture 2: Leak detector Model TDA-99M

- 3.13 Miniature Continuous Air Monitoring System, (MINICAMS) (or equivalent)(Picture 3). The MINICAMS, manufactured by OI Analytical, is a gas chromatograph equipped with a hydrogen flame emission detector and a preconcentrator tube. The preconcentrator tube is a small tube containing an adsorbent material to scrub out agent vapor contained in 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 preconcentrating the agent, the detection limit is lowered. The MINICAMS unique software calculates the amount of agent detected over a specified period of time. The Limit of Detection (LOD) is equal to 20% of the TWA. Residual contamination is the amount of challenge agent lingering in the breathing zone of the respirator when a new, clean unit is mounted on the SMARTMAN. Residual contamination is quantified at the beginning of each test / evaluation, the detection instrumentation must remain stable for a period of 30 minutes prior to the initiation of any test / evaluation.



Picture 3: Miniature Continuous Air Monitoring System, (MINICAMS)

- 3.1.4. Syringe pump, Sage Model M365 or equivalent (Picture 4). This multirange, variable rate infusion pump is used to inject liquid agent at a controlled rate into an air stream to generate a vapor challenge. The challenge concentration can be varied over a wide range to accommodate the requirements. The liquid agent is contained in a syringe connected by a flexible cannula (a small tube for insertion into a body cavity or into a duct or vessel) to the dilution airline. The plunger of the syringe is driven at a controlled rate by the pump to deliver a constant flow of agent. The concentration of agent is adjusted by changing the speed setting of the pump. (Rate Flow Range = 20.0 ml /min. – 0.3 ml/hr, Flow Accuracy = +/- 5% Nominal)



Picture 4: Syringe pump, Sage Model M365

- 3.1.5. Flow-Temperature-Humidity Control System or equivalent (see picture 5). This system, referred to as the Miller-Nelson (MN) control system, manufactured by Miller-Nelson Research, Inc., is an automated system to control the airflow, temperature, and humidity of an air supply for an operating system. Laboratory air and distilled water are supplied to the unit; the three sensors and controlling mechanisms are incorporated electronically, and the unit output is air of the required volume/flow (200-50 L/min. +/- 2%), and relative humidity (20-80 +/- 3%) and temperature (20-30 °C +/- 0.3%).



Picture 5: Flow-Temperature-Humidity Control System

- 3.1.6. Exposure Chamber, or equivalent, (Picture 6). The exposure chamber is constructed of clear, chemical resistant sheets (Plexiglas® or Lexan). The floor is thicker than the sides and top in order to support the weight of the SMARTMAN, which weighs approximately 85 pounds. The front panel is removable, and is held in place with clamps on each edge. The dimensions are approximately 2 ft. cubed. There are four Plexiglas legs attached to the bottom to hold the chamber above the floor of the hood and allow room for the tubing and the face adjustment handle. A M12A1 military air purifying collective filter is installed on top of the chamber to filter the air that passes out of the chamber. 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 Exposure Chamber” is a unit used to perform a fit and leak check on a test unit (no agents used in this chamber) before it is installed in the agent exposure chamber.



Picture 6: Exposure Chamber

- 3.1.7. Mixing Chamber, or equivalent, (Picture 7). This chamber is fabricated of PVC pipe, with caps on both ends and three baffles fixed inside to ensure mixing of agent vapor and air. A pressure gauge, mounted on the chamber, indicates internal mixture pressure and serves as a safety pressure indicator. Maximum pressure is indicated per manufacturer pressure gauge instructions and markings.



Picture 7: Mixing chamber

- 3.1.8. Breather Pump, manufactured by Jaeco Fluid Systems, Inc., Model E1R1, or equivalent. (Picture 8). This is the standard United States Army breather pump used to simulate a person's breathing for testing of filters and other items. It is a

double pump, operated by a single electric motor. The original pump was modified by substituting a variable speed motor for the single speed motor, thus allowing the number of strokes per minute to be varied. The pump controls a gearbox with 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.



Picture 8: Breather Pump

- 3.1.9. Mass Flow Controllers (or equivalent). Manufactured by Tylan Electronic or Brooks Instruments are used to control the flow of sample to the MINICAMS and the flow of laboratory air to flush out the exposure chamber when the agent challenge is removed. The mass flow controllers are sized to meet the requirements. Flows are controlled to +/- 2% of set point. A M-18 (military air purifying collective filter) is positioned in-line between the exposure chamber and the breathing pump.
- 3.1.10. Challenge Detector (GB): A MIRAN (or equivalent) will be used as a detector for GB. The MIRAN is an infrared absorption based detector that uses a long path length cell up to 20 meters, into which the air sample is introduced. Standardization is accomplished by injecting several different concentrations of agent and using Lab-View and Excel to calculate the regression.

- 3.1.11. Challenge Detector (HD): A gas chromatograph equipped with a flame ionization detector (FID) or a MINICAMS equipped with FID (or equivalent) will be used to detect Distilled Sulfur Mustard (HD). Standardization is accomplished by injecting several different concentrations of agent and using Lab-View and Excel to calculate the regression.
- 3.1.12. Air Compressor & Cascade System: An air-compressed system capable of maintaining upper limit of 4500psi and a lower limit of 500psi. The system must be capable of simulating the pressure decay curve from full rated tank pressure to the point where the low pressure alarm on the SCBA activates. The SCBA system should be returned to fully rated tank pressure, continuing the process until the test is terminated. The decay cycles may be continuous or stepwise.

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 schedule.
- 4.2. System Test Conditions
- 4.2.1 Breathing Machine
- Airflow = 40 liters per minute
 - Respirations = 36 +/- 2 Strokes per minute
 - Tidal Volume = 1.1 liter
- 4.2.2 High Pressure Compressed Air Supply, Grade D Compressed Air or Grade E Liquefied Air (Source for SCBA Operating System)
- Pressure Decay Profile = Rated SCBA Service Pressure to low pressure alarm
 - Tank capacity = 2400 liters (minimum)
 - Temperature = 25±5 °C
 - Oxygen: 19.5 to 23.5%
 - CO by Volume: Less than 10ppm
 - CO₂ by Volume: Less than 1000ppm
 - Condensed Hydrocarbons by Weight: Less than 5 mg/m³
 - Odor: No Odor Detectable by Olfactory Senses
 - Dew Point: Less than -50 degrees F at 1 atmosphere per OSHA 1910.134 (i) (4) (iii)
- 4.2.3 Miller-Nelson air flow into exposure chamber
- Airflow Rate
 - GB airflow = 50 L/min
 - HD airflow = 50 L/min
 - Relative Humidity = 25±5%
 - Temperature = 25 ± 3°C

- 4.2.4 SMARTMAN Sampling Point
A single Nasal port to supply dual MINICAM detectors.
- 4.2.5 Sarin (GB) Vapor Test
Challenge Concentration = $2000 \pm 10\%$ mg/m³
Equipment Concentration Upper Limit = 15 ng/200mL
Challenge Time (disseminator on) = 30 minutes \pm 10 seconds
Monitor & Hold Time = 5.5 hours
Syringe Injection Rate = as required based upon syringe pump used
Syringe Injected Volume = as required based upon syringe pump used
- 4.2.6 Distilled Sulfur Mustard (HD) Liquid and Vapor Test
- 4.2.6.1 HD Liquid Application
Drop Size = 20 microliters
Total Volume = 0.86 milliliters (43 drops of 20 micro liters)
Facepiece (Appendix A) = 25 drops
Associated Hardware (Appendix B) = 18 drops
Use of an external shroud or hood attached to the facepiece requires contamination droplets to be placed on those areas of the shroud covering the areas of the depicted facepiece diagram. Droplet application on a shroud stresses the same facepiece areas identified for the non-shrouded facepiece but instead of applications being on bare facepiece material they are on the shroud covering that depicted area/seam/joint/interface.
- 4.2.6.2 HD Vapor Challenge
Challenge Concentration = $300 \pm 10\%$ mg/m³
Equipment Concentration Upper Limit = 40 ng/500mL
Challenge Time (pump on) = 30 minutes \pm 10 seconds
Monitor & Hold Time = 5.5 hours
Syringe Injection Rate = as required based upon syringe pump used
Syringe Injected Volume = as required based upon syringe pump used
- 4.2.7. Test Termination Parameters: The test will be terminated to protect the detectors from over-saturation. The termination point should be set at or above the highest calibration point.
- 4.2.8. Compressed air inlet pressure is rated cylinder pressure per manufacturer instructions. Duration of test determines the amount of compressed air required to maintain the SCBA at manufacturer operating compressed air specifications. Compressed air source provides required high pressure air over the entire duration of the test. Maximum air pressure is 4500 psig but may vary depending on SCBA air cylinder rating to 3000 psig or 2216/2200psi. Minimum air pressure required is 500psi. At the minimum air pressure reading in the tested air

cylinder valve area of the SCBA, initiate airflow from second cylinder and isolate first cylinder for recharging. The compressed air cycle continues until the end of the specified test.

- 4.3 Safety: Normal laboratory safety practices must be observed. This includes all safety precautions described in the current Appalachian Laboratory for Occupational Safety & Health (ALOSH) Facility Laboratory Safety Manual, U.S. Army Soldiers and Biological Chemical Command Laboratory Safety Manual, and/or equivalent manuals.
 - 4.3.1. Safety glasses, lab coats, and assigned respirator must be worn at all times.
 - 4.3.2. Work surfaces must be maintained, free of clutter and non-essential test equipment.
 - 4.3.3. When, handling any glass laboratory equipment, lab technicians and personnel must wear gloves, which protect against lacerations or punctures.
 - 4.3.4. Laboratory personnel must be trained in safe operating procedures appropriate for the test.
 - 4.3.5. Surety lab procedures outlined in applicable SOPs are required to be on hand. Annual training classes focus on the familiarization of required occupational safety and health subjects in accordance with specified surety lab procedures.
 - 4.3.6. Please refer to Material Safety Data Sheets and appropriate Health and Safety manuals, or other appropriate documentation for the proper protection and care in handling, storing, and disposing of the chemicals and gases used in this procedure.

4.4. MINICAMS

- 4.4.1 A Laboratory MINICAMS is used as the detector for agent penetration/permeation of the SCBA. It consists of a monitor, PC computer, Stream Selection System, Linear Mass Flowmeter and optional printer or recorder.
- 4.4.2. A small volume of air is drawn through a preconcentrator tube containing an adsorbent material: GB sample volume is approximately 200 ml/min and HD sample volume is approximately 500 ml/min. Agent in the sample is adsorbed on the material. Later in the cycle the tube is heated to desorb the agent, which then flows through a gas chromatograph column to a flame emission detector. Because the total agent in the sample is detected at one time instead of continuously, the detection limit is much lower. The total quantity of agent detected is calculated back to the sample volume and is expressed as ng/L.

- 4.4.3 Operation of the MINICAMS requires the use of compressed air, hydrogen, and nitrogen, of a high purity. The operating manual recommends operating parameters (temperature, timing, pressures, etc.) and cycle times (3, 5, 10 or 15 min.), depending on the application. GB analysis requires a 3 minute cycle and HD requires a 5 minute cycle.
- 4.4.4. The MINICAMS is installed in accordance with the operating manual. The appropriate optical filter for GB or HD must be installed in front of the photomultiplier tube. In principle, when GB or HD burns in a hydrogen flame, a chemical species (phosphorus or sulfur) is formed that emits radiation at a unique wavelength. The optical filter isolates the radiation and allows it to pass into the photomultiplier tube (PMT), whose output voltage is correlated with the quantity of agent burned in the flame.
- 4.4.5. Set up the MINICAMS in accordance with operating manual and the method for the agent that is being used. In order to quantify the agent in the sample, the MINICAMS must be standardized. Standardization is accomplished by injecting a small quantity (1.0 or 2.0 uL) of a standard solution of the agent onto the preconcentrator tube during the INJECT segment of the test cycle. The standard solutions of agent are made in isopropanol or hexane, spectrophotometric grade. At least three injections of each quantity of agent should be injected. By pressing the F2 key on the keyboard, the data is saved and a standard curve is calculated and displayed.
- 4.4.6 Pretest activities for the MINICAMS are as follows:
- Start the MINICAMS
 - Set or verify operational parameters for appropriate agent
 - Perform standardization
 - Record ASCII file name on Data Sheet (Appendix A&B)
 - Standby for start of testing
- 4.5. Agent vapor generator
- 4.5.1. The vapor challenge for SMARTMAN testing is generated by injecting the required quantity of liquid agent into the volume of air that passes through the exposure chamber to give the challenge in mg/m^3 . This is accomplished by a combination of controlled airflow from the Miller- Nelson Air controller and a syringe pump for injecting the agent through a heated tee into the air stream. Determine the volume of air needed to pass through the exposure chamber per minute (flow rate) and the quantity of agent necessary to give the specified challenge concentration for this flow rate. From the pump operating manual select the syringe size and pump rate that will inject the required amount of agent per unit time. Draw up the total amount of agent needed into the syringe, with a small excess, connect one end of the cannula (the small flexible tube that is inserted into the air duct) to the syringe, and the other end to the heated tee in the

air duct. Clamp the barrel of the syringe onto the pump and move the plunger drive until it contacts the end of the plunger. Turn on the power to the pump. The plunger will be activated and agent will be injected into the air stream as a vapor from the heated tee. The mixture passes into the mixing chamber where it is thoroughly mixed, ready to be introduced into the exposure chamber for the test.

4.6. Miller-Nelson (MN) Controller

- 4.6.1. The Miller Nelson unit receives compressed air from the laboratory air supply system. Operate the Miller Nelson according to the manufacturer's instructions. The sensors for relative humidity and temperature must be calibrated, as must be the flow controller, since it is important that the total flow through the test system be known in order to supply the requisite amount of agent from the syringe pump.
- 4.6.2. Set the readout panels on the Miller Nelson to approximately 50 L/min. flow (see 4.2.3) and the 25 +/- 5% relative humidity. The temperature is normally set at room temperature, $25 \pm 3^{\circ}\text{C}$. Allow the air to flow through the mixing chamber and the M18 filter until it is time to start the test.

4.7. Syringe pump.

- 4.7.1. A syringe pump is used to inject liquid agent into the dilution air stream at a controlled rate such that the concentration of agent in air is that required for the challenge specified for the test. The injection rate must remain constant for the entire period. The syringe pump controls allow the pump rate to be changed by using a switch.
- 4.7.2. Select the size syringe that will hold sufficient agent for the challenge period and the total volume of air required. Fill the syringe to the volume determined and attach the syringe to the fitting on the flexible cannula. The cannula is normally made of plastic with Luer locks on each end. One end of the cannula is attached to the heated tee in the dilution airline. Set the syringe in the holder and clamp it in place. Move the drive block until it is firmly against the end of the plunger.
- 4.7.3. Set the switch on the pump to the setting required for the size syringe and the injection rate. Turning on the power switch will start the drive block pushing the plunger of the syringe to begin generating the agent challenge concentration.

4.8. TDA-99M Aerosol Leak Detector

- 4.8.1. The TDA-99M leak detector is used to detect leaks into the SCBA after it has been installed on the SMARTMAN headform. Connect the SCBA to the air supply system using a cylinder valve mounting fixture. See Appendix E for a drawing of the fixture. Because of the length of time, 360 minutes, the SCBA is operated using air supplied to the SCBA from a cylinder system. Ensure that

installation procedures for the SCBA valve follow the manufacturer's installation procedures for torque and that the seal (gasket or O-ring) is a new seal provided by the manufacturer.

- 4.8.2. Turn on the power and let the detector equilibrate, according to the manufacturer's instructions. The SCBA should be operating. Turn on the breather pump to activate the test mask. Connect the detector inlet to a sample line from the SMARTMAN. When aerosol is being generated, direct the wand to various portions of the facepiece and all mechanical seals or joints to detect any leak paths. Any leaks found must be corrected. Insure the SCBA does not go into negative pressure. If negative pressure is observed, terminate test and recheck/trouble shoot compressed air lines and face seal. If no localized leaks are found, replace the front panel of the exposure chamber.
- 4.8.3. Connect the TDA-99M to a port into the exposure chamber and fill the chamber with aerosols. Maintain a constant aerosol concentration of 100 mg/m³ inside the exposure chamber for 30 minutes. Check the display on the TDA-99M for detection of aerosol inside the facepiece. If there is evidence of leakage, attempt to find and eliminate the leak. When the detector indicates a maximum percent penetration of 0.001% or <0.0010 % assume there is no leak in the facepiece and begin the test

4.9. Quality Control Measures

- 4.9.1. SMARTMAN Leak Test: Because the SMARTMAN is made of cast zinc, it is possible for leak paths to form through the metal casting to allow agent vapor to pass through from the headform cavity into the interior of the mask mounted on the headform. Install a 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.
- 4.9.2. Standardization of Instrumentation: Standardize the MINICAMS by using liquid standard solutions of the agents at various concentrations. These solutions are to be made in accordance with CAT IOP #214, Preparing Standard Agent Solutions for Instrumentation, or equivalent laboratory procedures. A stock solution is the primary solution made by weighing a quantity of agent into a volumetric flask and diluting to volume. This solution may be used for two weeks, unless deterioration is noted before that time. The stock solution is diluted further to make a series of standard solutions that are used to standardize the MINICAMS. The standard solutions may be used for one week, unless MINICAMS analyses indicate that the solutions are deteriorating. Class A glassware must be used for all volumetric work. Calibration curves should have a minimum correlation value of $r^2 = 0.999$ for GB and $r^2 = 0.99$ for HD.

- 4.9.3. Determination of Flows: Since flow rates are used in several aspects of this test, it is necessary to use calibrated flow meters to set the flows used in the instruments. Flow meters are calibrated by the Army TM&DE and Metrology Laboratory, or equivalent using instruments traceable to NIST. Flow meters to be checked against calibrated meters are the Miller-Nelson Air Flow Controller, electronic flow meters used for the MINICAMS preconcentrator tube and the breather flow from the breather pump.
- 4.9.4 Leak Testing: SCBA leak testing using the TDA-99M Aerosol Tester is performed on the facepiece after installation on the SMARTMAN and while the breather pump is operating. With the wand, move the aerosol challenge over all parts of the facepiece and test unit. If there is no leak, the display on the TDA-99M should read 0.000 % penetration. Do not start a test until a value \leq 0.0010% is indicated.
- 4.9.5 Detector Response: Check the response of the detector, MINICAMS before and after each test. This is done by injecting an aliquot of standard solution that contains a known concentration of agent near the mid-range of the standard curve. Inject the aliquot into the end of the heated sample line from the oronasal sampling port; it is necessary to disconnect the line from the bottom of the chamber to do this. This is called a “check shot”. Repeat it at the end of the test to assure that the detector has not changed during the test. The response of the detector should fall on the standard curve at the value expected for the amount of agent in the aliquot, or within 10% of that value. Record results of check shot in Laboratory Notebook. If the checkshot does not reproduce a verifiable result, repeat the checkshot. If the second checkshot is not within the 10% parameter, the test is invalid.

5. PROCEDURE (Vapor Challenge GB or Liquid/Vapor- Challenge HD)

- 5.1. Assemble SCBA per manufacturer’s instruction with the exception of the air cylinder and connect the compressed air system capable of supplying high pressure breathing air to the SCBA. Insure air inlet pressure gauge reads the SCBA rated service pressure +/- 50 psig. Insure SCBA air pressure gauge reads in the full range.
- 5.2. Take a digital photograph of assembled unit for use later.
- 5.3. Mount unit on the SMARTMAN in the “clean” exposure chamber. The facepiece should be mounted to the SMARTMAN per the manufacturers’ instructions
- 5.4. The test SCBA must be connected to the compressed air supply system using a cylinder valve mounting fixture. See Appendix E for a drawing of the fixture. Ensure that installation procedures for the valve follow the manufacturer’s installation procedures for torque and that the seal (gasket or O-ring) is a new seal provided by the manufacturer. . Insure inlet pressure gauge does not exceed the SCBA rated service pressure at any time.

- 5.5. Turn on Miller-Nelson and breathing pump. Insure that the SCBA is in the pressure demand mode.
- 5.6. Using the TDA 99M, leak test the SCBA in the operational pressure demand mode. Connect the detector inlet to a sample line from the SMARTMAN. When aerosol is being generated, direct the wand to various portions of the facepiece and all mechanical seals and joints to detect any leaks. The aerosol will be detected inside the facepiece if it finds a leak path. If any leaks are found, they must be corrected. If no localized leaks are found, replace the front panel of the exposure chamber. Connect the TDA-99M to a port into the exposure chamber and fill the chamber with the aerosol challenge. Maintain 100 mg/m³ aerosol challenge inside the chamber for five minutes. Check the display on the TDA-99M for detection of aerosol inside the facepiece. If there is evidence of leakage, attempt to find and eliminate the leak. When the detector indicates a minimum percent penetration of 0.0010, assume there is no leak in the facepiece and begin the test.
- 5.7. Remove SCBA from “clean” chamber and install on SMARTMAN in the appropriate agent exposure chamber.
- 5.8. Mount unit on the SMARTMAN in the “hot” exposure chamber. Repeat steps 5.3 - 5.5, except that once the chamber is sealed and no leaks are confirmed, the aerosol challenge is discontinued.
- 5.9. Use only one of the nasal sampling ports for facepiece sampling.
- 5.10. Background Characterization. A background characterization must be run before every test run/evaluation. The instrumentation should be monitored for a period of 60 minutes prior to the initiation of the test. Confirm that background level is less than the lowest point on the MINICAM calibration curve. The background characterization must be defined prior to placing the test respirator on the SMARTMAN.
- 5.11. Set up standard operational mode of test equipment. Ensure all test equipment is within calibration.
- 5.12. Set Miller-Nelson for air flow into exposure chamber set to deliver required rate
Airflow Rate
GB airflow = 50 L/min
HD airflow = 50 L/min
Relative Humidity = 50±5%
Temperature = 25 ± 3°C
- 5.13. Load liquid agent in syringe and set syringe pump to correct flow rate to achieve the required agent challenge concentration. See items 4.2.5 (GB) or 4.2.6.2 (HD).
- 5.14. Ensure MINICAM is calibrated, perform “check shot” and ready for operating mode.

- 5.15. Ensure that the challenge concentration instrument is calibrated and a check shot has been performed and it is ready for analysis. Monitor chamber concentration during the 60 minute Background Characterization period. Characterization readings should reflect steady state conditions.
- 5.16. Time zero or the start of the test is when the chamber concentration reading is above the lowest calibration point after drops have been applied to the SCBA and/or vapor is introduced into the chamber.
- 5.17. Liquid Application of HD droplets: Liquid drops are delivered to the surface of the SCBA to test permeation. A total of 43 droplets (size of 20 micro liters each) are specified. Placement of the droplets, via syringe on to the system is specified in (Appendix A & B). Mark location of actual droplets on a digital photograph of the equipment being tested. Photographs must be maintained in the Task Folder. The Appendices A& B are schematics for the suggested location of the agent drops. Liquid application of HD occurs before the vapor challenge of HD begins. If an external shroud is mounted on the facepiece, apply droplets per standard diagram but on surfaces of the shroud that mirror the routine faceblank areas.
- 5.18. Introduce agent challenge [Sarin (GB) or Distilled Sulfur Mustard (HD)] to exposure chamber. Turn the valve in the line from by-pass to the mixing chamber to direct flow to the exposure chamber. The total flow to the chamber is approximately 50 L/min from Miller Nelson, which includes enough excess to make up for the clean air exhausted from the mask into the chamber and maintain the constant challenge as required. The concentration of challenge agent is calculated on the basis of the mass balance of quantity of agent injected and total dilution airflow being introduced into the chamber. The syringe flow rate is set to introduce the quantity of agent necessary to generate the challenge concentration required. Record when the MINICAMS begin monitoring the interior of the mask. It may be required to start the MINICAMS before introducing agent into the chamber so that the first sampling period will coincide with the first agent challenge. This will indicate whether there is an initial penetration of agent into the mask that might not be detected if the first sampling occurs a minute or two after introduction of the challenge.
 - 5.18.1. The syringe pump should run for the prescribed challenge period of 30 minutes \pm 10 seconds. At the end of the challenge period, turn off the syringe pump. Record the total volume, elapsed time and air flow rate delivered from the Miller-Nelson. These values will be recorded in the laboratory notebook and test data sheets (Appendix C & D).
 - 5.18.2. The Flame Ionization Detector (FID) with a sample loop connected to a gas chromatograph will be used to monitor the challenge concentration in the exposure chamber, which will be recorded on the computer at a given time.
- 5.19. System Hold or Monitor Time

- 5.19.1. For HD, continue flushing the chamber with the Miller-Nelson, with the breathing machine operating at the same rate for 5.5 hours. MINICAMS should continue to analyze until Equipment Concentration Upper Limit for the detector is reached or the 5.5 hours is elapsed.
- 5.19.2. For GB, continue flushing the chamber with the Miller-Nelson, with the breathing machine operating at the same rate for 5.5 hours.
- 5.20. Test Surveillance
 - 5.20.1. The technician should monitor the test to make sure all components of the system function and collect data as required.
- 5.21. Termination of Test
 - 5.21.1. When the full time for the test has elapsed, terminate the test. Turn off breather pump. Depressurize the SCBA by terminating the compressed air feed, purge the air from the SCBA by opening the purge valve, and allow air to drain while the primary air cylinder valve is open. When gauge reads 0 on SCBA, close purge valve and close air cylinder valve. Disconnect SCBA in accordance with local lab safety procedures Perform a check shot of agent to assure that the detection system is still operating correctly. Take an aliquot of one of the mid-range standard solutions of agent with a microliter syringe and inject it into the nasal sampling port by disconnecting the line from the bottom of the exposure chamber. The MINICAMS response should be that indicated on the standard curve for the amount of agent contained in the aliquot. The response must be within 10% of the correct value for the test to be valid.
 - 5.21.2. Turn off the MINICAMS. Turn off Miller-Nelson airflow through the exposure chamber. Open the chamber front panel. Remove the test item (separate it into components) and double-bag the components. Remove the bagged components to the decontamination hood for temporary storage, decontamination, monitoring, and disposal. Wipe down the interior of the chamber and the SMARTMAN. Dispose of cleaning materials according to local hazardous waste SOP.
 - 5.21.3. Timeline or Sequence of Activities
 - Validate instrumentation and check shot
 - Helium Leak check peripheral seals (if applicable)
 - Install SCBA in clean exposure chamber
 - Challenge SCBA with TDA-99M for 5 minutes
 - Install SCBA in exposure chamber
 - Challenge SCBA with TDA-99M for 5 minutes
 - Start MINICAMS
 - Monitor background behind the mask and chamber concentration
 - Add droplets (HD only)

Close exposure chamber
Start makeup air using Miller-Nelson
Start syringe pump
Record Start Time
Challenge Time (30 minutes)
Stop syringe pump
Hold Time (5.5 hours)
End of Test
Check shoot instrumentation

5.22. Data Analysis

- 5.22.1. Technician is responsible for accurately maintaining a laboratory notebook and all required records. Hardcopies of data should be annotated when pertinent events occur, such as a checkshot or test start time. Supervisor must pre-approve any deviation from standard test method and signoff in technician's notebook. Notebooks should be signed and dated, copies of all hardcopies of data that are generated shall be kept in the assigned task folder with NIOSH Task number.
- 5.22.2. Technician must complete all required Test Data Sheets (Appendix C & D). Originals of all Test Data Sheets must be completed and retained in the task file.
- 5.22.3. Transfer the permeation data from the MINICAMS computer into a computer for analysis by Microsoft Excel. Display the data on a spreadsheet. Because MINICAMS data is formatted on separate pages, there are gaps in the lines of data. These gaps must be deleted so that the data are in one continuous table. Next, the actual sample data must be separated from the blanks into another table. This table will contain data from the nasal area and associated time markers. . The resulting table will each have two columns, time and nanograms. Convert the nanograms into a concentration, ng/L, by multiplying nanograms by a factor obtained by dividing the actual sample volume (typically 200 mL) into 1000 mL/L (the factor in this case is 5/L. Example: $1.73 \text{ ng} \times 5/L = 8.65 \text{ ng/L}$). Using Excel's Chart Wizard feature, a plot of concentration vs. time can be visualized and printed, using all the data in the table.

Transfer the permeation data; the challenge concentration data, the environmental data and the leak check data into a computer for analysis by Microsoft Excel. Display the data on a spreadsheet and store a copy of the computer file in with the test file.

Leak Check data: Plot the leak check data versus time with its associated error bars.

Environmental data: Plot the environmental data versus time with its associated error bars.

Challenge Concentration data: Plot the challenge concentration versus time with its associated error bars. Plot the Ct versus time with its associated error bars.

Permeation data: Plot Permeation concentration data versus time. If MINICAMS is collecting the permeation data the following directions apply.

Because MINICAMS data is formatted on separate pages, there are gaps in the lines of data. These gaps must be deleted so that the data are in one continuous table. Next, the actual sample data must be separated from the blanks into another table. This table will contain data from the nasal area and associated time markers. The resulting table will each have two columns, time and nanograms.

To convert nanograms into a concentration, mg/m^3 , use this calculation:

$$\frac{\text{mg}}{\text{m}^3} = A \times \frac{\text{mg}}{10^6 \text{ ng}} \times B \times \frac{10^3 \text{ mL}}{\text{L}} \times \frac{10^3 \text{ L}}{\text{m}^3} \times E$$

where:

$$A = \text{Mass Recovered (ng)}$$

$$B = \frac{1}{\text{Sample Flow Rate (mL/min)}}$$

$$E = \frac{1}{\text{Sample Time (min)}}$$

6. PASS\FAIL CRITERIA

- 6.1. The criterion for passing this test is set within the regulatory authority of 42 CFR, Part 84, Subpart G, Section 84.63(c); Volume 60, Number 110, June 8, 1995. A compound, two tier pass/fail criterion must be met. The criterion is:

6.1.1. Sarin (GB) Penetration Test:

Challenge: 2000 mg/m^3 for 30 minutes

Test Time: 360 minutes

Dual Pass/Fail Criteria:

a) Maximum agent breakthrough: 2.1 $\text{mg}\cdot\text{min}/\text{m}^3$ (integrated concentration over time or CT)

b) Maximum Peak Excursions: 0.087 mg/m^3 : Three consecutive data points at or exceeding the peak value constitutes a failure.

Note: Overall CT limit of 2.1 $\text{mg}\cdot\text{min}/\text{m}^3$ including peaks cannot be exceeded.

6.1.2. Distilled Sulfur Mustard (HD) Penetration and Permeation Test:

Challenge: 300 mg/m³ for 30 minutes plus 43 maximum 20 µl liquid droplets

Test Period: 360 minutes

Dual Pass/Fail Criteria:

a) Maximum agent breakthrough: 6.0 mg-min/m³ (integrated concentration over time or CT)

b) Maximum Peak Excursions: 0.60 mg/m³ Three consecutive data points at or exceeding the peak value constitutes a failure.

Note: Overall CT limit of 6.0 mg/m³ including all peaks cannot be exceeded.

6.1.3 Precision and accuracy must be determined for each instrument.

6.2. This test establishes the procedures for ensuring the level of respiratory protection provided under special Chemical, Biological, Radiological, and Nuclear (CBRN) requirements for Open-circuit Self-Contained Breathing Apparatus (SCBA) with Full Facepiece submitted for Approval, Extension of Approval, or examined during Certification Product Audits, meet the minimum certification standards set forth in Title 42 CFR, Part 84, Subpart G, Section 84.63(c).

7. RECORDS/TEST SHEETS

7.1. All test data will be recorded on the test data sheets (Appendix C & D). GRADE D Air quality control certificates are required to be on file for the current compressor output air. Grade D air routine maintenance checks and procedures are required to be filed and capable of confirming the quality of used Grade D air in support of SCBA certification.

7.2. All videotapes and photographs of the actual test being performed by SBCCOM/NIOSH personnel, or of the test equipment shall be maintained in the task file as part of the permanent record.

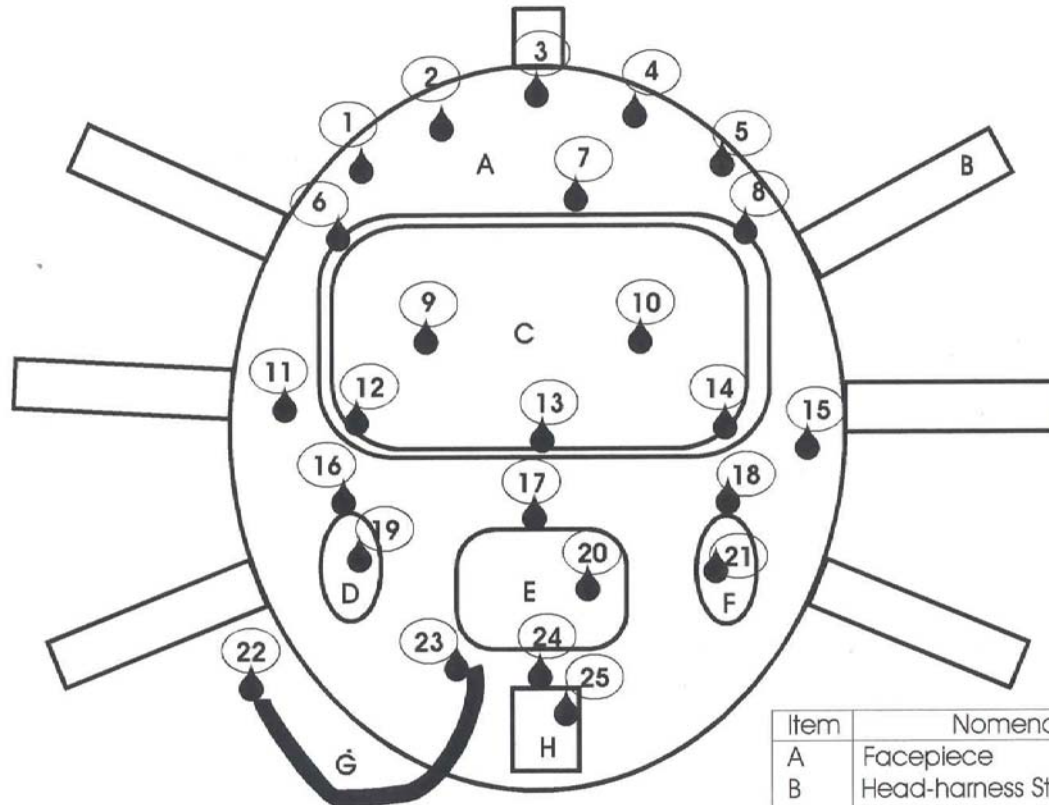
7.3. All equipment failing any portion of this test will be handled as follows;

7.3.1. If a failure occurs on a new certification application, or extension of approval application, SBCCOM will send a test report to the RCT Leader and prepare any uncontaminated hardware for return to the manufacturer.

7.3.2. If a failure occurs on hardware examined under an Off-the-Shelf Audit the hardware will be examined by SBCCOM technician and the SBCCOM Laboratory Manager for cause. All equipment failing or passing any portion of this test will be contaminated with chemical warfare agent and will be disposed of in accordance with SBCCOM chemical surety practices.

Appendix A

Schematic of HD Agent Droplet Placement for SCBA Facepiece



Note:

1. Approximate Placement of Drops.
2. Test Requires 25 Drops on the Facepiece.
3. The Entire SCBA Unit, Including the Facepiece, Requires a Total of 43, Refer to Appendix B for Remaining Drop Placement.

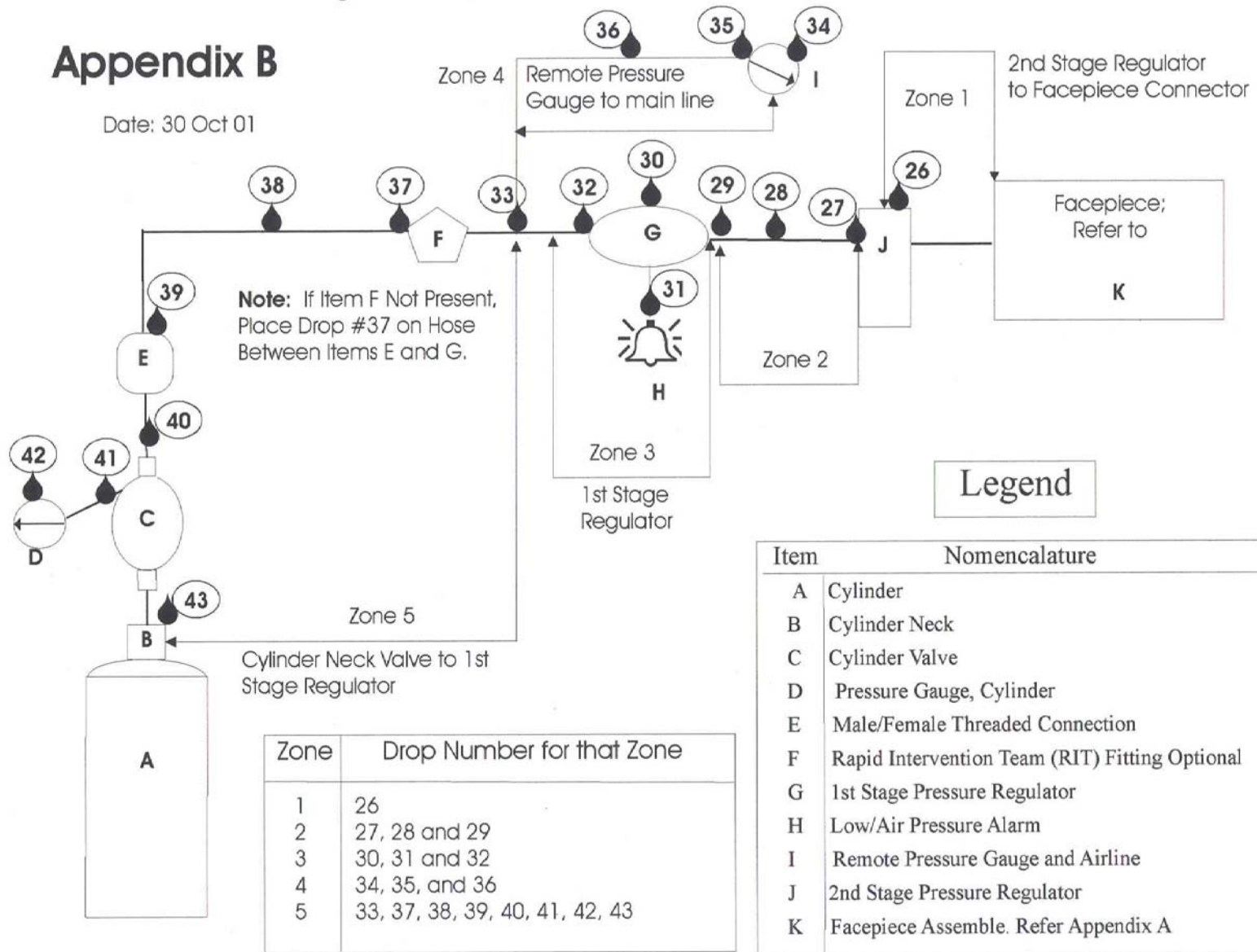
Date: 30 Oct 2001

Item	Nomenclature
A	Facepiece
B	Head-harness Strap
C	Eye Lens (1 or 2 Lenses)
D	Side Voicemitter (If Present)
E	Housing for 2nd Stage Regulator
F	Side Voicemitter (If Present)
G	Drink Tube (If Present)
H	Exhalation Valve

Schematic of HD Agent Droplet Placement From Facepiece to Cylinder Thread

Appendix B

Date: 30 Oct 01



Appendix C

SARIN (GB) VAPOR PERMEATION and PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 1	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #1

Equipment Calibrations Current		Operators Initials	Test Date	
Equipment Calibrations Current	Yes/No		Sarin Challenge Conditions	
Exposure Chamber Conditions			Syringe Pump Rate	
Airflow			Volume of Sarin Used	
Temperature Range			Calculated Conc.	
Relative Humidity Range				

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -SARIN (GB) VAPOR				
Respirator /Class	Requirements		Supervisors Initials	
	Test Time Minimum	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
CRBN-SCBA	360 Minutes	0.087 mg/m3		
		Maximum GB Breakthrough (integrated concentration over time [CT])	Pass	Fail
		2.1 mg-minutes/m3		
		Actual Calculated CT		

Comments/ Deviations from Method:

Technicians Signature:	Supervisors Signature:

Appendix C

SARIN (GB) VAPOR PERMEATION and PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 2	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #2

		Operators Initials	Test Date	
Equipment Calibrations Current	Yes/No			
Exposure Chamber Conditions			Sarin Challenge Conditions	
Airflow			Syringe Pump Rate	
Temperature Range			Volume of Sarin Used	
Relative Humidity Range			Calculated Conc.	

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -SARIN (GB) VAPOR				
	Requirements		Supervisors Initials	
Respirator /Class	Test Time Minimum	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
		0.087 mg/m3		
CRBN-SCBA	360 Minutes	Maximum GB Breakthrough (integrated concentration over time (CT))	Pass	Fail
		2.1 mg-minutes/m3		
		Actual Calculated CT		

Comments/ Deviations from Method:

Technicians Signature:	Supervisors Signature:

Appendix C

SARIN (GB) VAPOR PERMEATION and PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 3	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #3

		Operators Initials	Test Date	
Equipment Calibrations Current	Yes/No			
Exposure Chamber Conditions			Sarin Challenge Conditions	
Airflow			Syringe Pump Rate	
Temperature Range			Volume of Sarin Used	
Relative Humidity Range			Calculated Conc.	

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -SARIN (GB) VAPOR				
Respirator /Class	Requirements		Supervisors Initials	
	Test Time Minimum	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
CRBN-SCBA	360 Minutes	0.087 mg/m3		
		Maximum Breakthrough (integrated concentration over time [CT])	Pass	Fail
		2.1 mg-minutes/m3		
		Actual Calculated CT		

Comments/ Deviations from Method:

Technicians Signature:	Supervisors Signature:

Appendix C

SARIN (GB) VAPOR PERMEATION and PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Summary Data Sheet	
Task #	
Manufacturer's Name	
Model Number/Name	

Requirement:
 Open -circuit positive pressure / pressure demand Self Contained Breathing Apparatus shall demonstrate no permeation or penetration of Sarin (GB) vapor greater than the Maximum Peak Excursion 0.087 mg/m³ (3 consecutive test data points \geq 0.087 mg/m, each constitute a failure where each test value is based on a sample time not exceeding 2 minutes) or the Maximum Breakthrough (integrated concentration over time [CT]) of 2.1 mg-minutes/m³.

APPROVAL - Permeation or Penetration of Sarin (GB) vapor					
Respirator /Class	Maximum Peak Excursion (3 consecutive data points \geq to)	Units Tested	Pass Percentages	Pass	Fail
SCBA – Open-circuit positive pressure/pressure demand	0.087 mg/m ³	3	100%		
	Maximum GB Breakthrough (integrated concentration over time [CT])	Units Tested	Pass Percentages	Pass	Fail
	2.1 mg-minutes/m ³	3	100%		
	Actual Calculated CT	Tested Unit #			
		1			
		2			
		3			

Test Administrator Signature: _____ **Date of Completion:** _____

Appendix D

DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR PERMEATION AND PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 1	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #1

Equipment Calibrations Current		Operators Initials	Test Date	
Yes/No			Distilled Sulfur Mustard (HD) Challenge Conditions	
Exposure Chamber Conditions				
Airflow			# of 20 ul Liquid Droplets(HD)	
Temperature Range			Pump Rate	
Relative Humidity Range			Volume of HD Used	
			Calculated Conc.	

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR				
Respirator /Class	Requirements		Supervisors Initials	
	Test Time	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
CRBN-SCBA	360 Minutes	0.6 mg/m3		
		Maximum Breakthrough (integrated concentration over time [CT])	Pass	Fail
		6.0 mg-minutes/m3		
		Actual Calculated CT		

Comments/ Deviations from Method:

Technicians Signature:	Supervisors Signature:

Appendix D

DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR PERMEATION AND PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 2	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #2

		Operators Initials	Test Date	
Equipment Calibrations Current	Yes/No		Distilled Sulfur Mustard (HD) Challenge Conditions	
Exposure Chamber Conditions			# of 20 ul Liquid Droplets(HD)	
Airflow			Pump Rate	
Temperature Range			Volume of HD Used	
Relative Humidity Range			Calculated Conc.	

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR				
Respirator /Class	Requirements		Supervisors Initials	
	Test Time	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
CRBN-SCBA	360 Minutes	0.6 mg/m3		
		Maximum Breakthrough (integrated concentration over time [CT])	Pass	Fail
		6.0 mg-minutes/m3		
		Actual Calculated CT		

Comments/ Deviations from Method:

Technicians Signature:	Supervisors Signature:

Appendix D

DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR PERMEATION AND PENETRATION TEST FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES Test Data Sheet 3	
Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Test Unit #3

		Operators Initials	Test Date	
Equipment Calibrations Current	Yes/No	Distilled Sulfur Mustard (HD) Challenge Conditions		
Exposure Chamber Conditions				
Airflow		# of 20 ul Liquid Droplets(HD)		
Temperature Range		Pump Rate		
Relative Humidity Range		Volume of HD Used		
		Calculated Conc.		

SCBA SYSTEM PERMEATION & PENETRATION TEST UNIT APPROVAL -DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR				
	Requirements		Supervisors Initials	
Respirator /Class	Test Time	Maximum Peak Excursion (3 consecutive data points >= to)	Pass	Fail
CRBN-SCBA	360 Minutes	0.6 mg/m3		
		Maximum Breakthrough (integrated concentration over time [CT])	Pass	Fail
		6.0 mg-minutes/m3		
		Actual Calculated CT		
Comments/ Deviations from Method:				

Technicians Signature:	Supervisors Signature:

Appendix D

**DISTILLED SULFUR MUSTARD (HD) LIQUID AND VAPOR
PERMEATION AND PENETRATION TEST
FOR SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECES
Test Data Summary Sheet**

Task #	
Manufacturer's Name	
Model Number/Name	
Facepiece Model Number	

Requirement:

Open -circuit positive pressure / pressure demand Self Contained Breathing Apparatus shall demonstrate no permeation or penetration of Distilled Sulfur Mustard (HD) liquid or vapor greater than the Maximum Peak Excursion of 0.6 mg/m3 (3 consecutive test data points \geq 0.6 mg/m3, each constitute a failure where each test value is based on a sample time not exceeding 2 minutes) or the Maximum Breakthrough (integrated concentration over time [CT]) of 6.0 mg-minutes/m3.

APPROVAL - Permeation or Penetration of Distilled Sulfur Mustard (HD) liquid or vapor					
Respirator /Class	Maximum Peak Excursion (3 consecutive data points \geq to)	Units Tested	Pass Percentages	Pass	Fail
SCBA – Open-circuit positive pressure/pressure demand	0.60 mg/m3	3	100%		
	Maximum Breakthrough (integrated concentration over time [CT])	Units Tested	Pass Percentages	Pass	Fail
	6.0 mg-minutes/m3	3	100%		
	Actual Calculated CT	Tested Unit #			
		1			
		2			
		3			

Test Administrator
Signature: _____

Date of Completion: _____

Appendix E

