



National Institute for Occupational Safety and Health
National Personal Protective Technology Laboratory
P.O. Box 18070
Pittsburgh, PA 15236

Procedure No. RCT-CBRN-STP-0200, 0201	Revision: 1.1	Date: 3 June 2005
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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(a)(c)(d).
- 1.2 This procedure is used to test SCBA systems against Sarin (GB) vapor or Distilled Sulfur Mustard (HD) vapor and liquid, while the respirator is operated in dynamic mode by means of a breather pump connected to the mouth area of a manikin headform. Instrumentation is integrated under this static chamber platform for the purpose of generating and controlling challenge concentrations and detecting precise agent permeation of a tested respirator.
- 1.3 Within this procedure, there are two separate tests: RCT-CBRN-STP-0200 for Challenge of Sarin (GB) Vapor and RCT-CBRN-STP-0201 for Challenge of Distilled Mustard (HD) Vapor and Liquid. This procedure is designed to rigorously test the evaluated respirator and generate repeatable independent pass or fail results.

2. GENERAL

The STP describes a test entitled “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” in sufficient detail that a team of persons 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.

Approvals:	<u>1st</u> Level	<u>2nd</u> Level	<u>3rd</u> Level
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3. EQUIPMENT: List of necessary test equipment follows

- 3.1 SMARTMAN, Head/upper torso form or equivalent (see picture 1). Manufactured by ILC Dover, Frederica, DE. The **Simulant Agent Resistant Test Manikin**, 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.



Picture 1: Head/Upper Torso Manikin, SMARTMAN

- 3.2. 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 aerosol leaks in the mechanical seals of the respirator and the correct fitting of a respirator face piece to the SMARTMAN headform. 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 value.



Picture 2: Leak detector Model TDA-99M

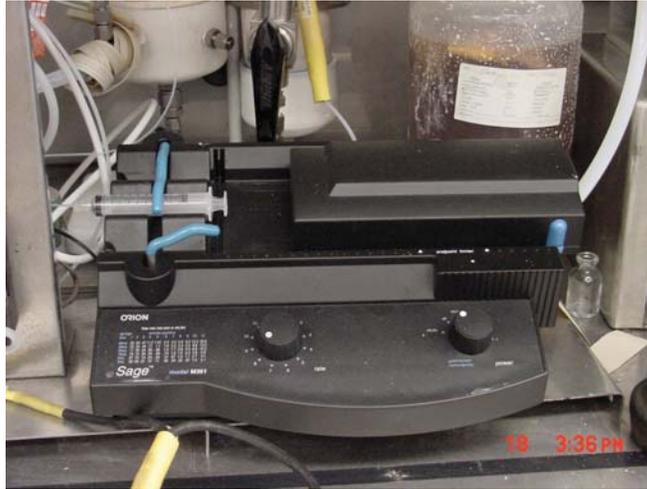
- 3.3. Miniature Continuous Air Monitoring System, MINICAMS or equivalent (see picture 3). The MINICAMS, manufactured by OI Analytical, is a gas chromatograph equipped with a hydrogen flame emission detector and a preconcentrator tube. The preconcentrator tube is a small tube containing an adsorbent 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 8 hr Time Weighted Average for the specific chemical agent being detected. Residual contamination is the amount of challenge agent lingering in the breathing zone of the respirator when a new, clean respirator 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 60 minutes prior to the initiation of any test / evaluation. Two MINICAMS are required in order to continuously monitor the interior of the respirator.



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

- 3.4 Syringe pump, Sage Model M365 or equivalent (see 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. to 0.3 ml/hr, Flow Accuracy = +/- 5% Nominal.



Picture 4: Syringe pump, Sage Model M365

- 3.5 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

- 3.6 Exposure Chamber or equivalent (see picture 6). 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 is held in place with clamps on each edge. The dimensions are approximately 2 ft. cubed. Four Plexiglas legs are 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 respirator test unit (no agents used in this chamber) before it is installed in the agent exposure chamber. An “Agent Exposure Chamber” is a chamber used to perform testing of the respirator unit, using agent.



Picture 6: Exposure Chamber

- 3.7 Mixing Chamber or equivalent (see picture 7). This chamber is fabricated of PVC pipe, with caps on both ends and three baffles fixed inside to ensure mixing of chemical warfare 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. A heating blanket is wrapped around the chamber to facilitate chemical vaporization. This is the primary mixing area that allows the chemical agent syringe pump flow and the regulated air flow from the Miller Nelson controller to mix and generate a specified concentration of chemical warfare agent. When the mixture is not being passed into the exposure chamber for a test, it is passed through a scrubber filter (an M18 filter or equivalent). A M-18 (military air purifying collective filter) is positioned in-line between the exposure chamber and the breathing pump.



Picture 7: Mixing chamber

- 3.8 Breather Pump, Model E1R1 or equivalent (see picture 8). Manufactured by Jaeco Fluid Systems, Inc. This is the standard United States Army breather pump used to simulate breathing for testing of filters and other items. It is a double pump, operated by a single electric motor. The original pump design 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 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.



Picture 8: Breather Pump

- 3.9 Mass Flow Controllers or equivalent. Manufactured by Tylan Electronic or Brooks Instruments. Mass flow controllers 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 flow requirements. Flows are controlled to +/- 2% of set point.
- 3.10 Ambient Air Analyzer, MIRAN model 1A or 205B, or equivalent (see picture 9 and 10). Manufactured by Thermo Environmental Instruments Inc. It is an infrared absorption based detector that uses a long path length cell up to 20 meters, into which the air sample is introduced. This analyzer is used to monitor the challenge concentration of the vapor phase of the chemical warfare agents. Model 1A is used for the Sarin (GB) concentration and model 205B is used for the Distilled Mustard (HD) concentration.



Picture 9: Miran Analyzer, Model 205B

NO PHOTO CURRENTLY AVAILABLE

Picture 10: Miran Analyzer, Model 1A

- 3.11 Air Compressor & Cascade System or equivalent (see picture 11). An air-compressor or a cylinder system capable of maintaining upper limit of 5000 psi and a lower limit of 500psi. The system must be capable of simulating the pressure decay curve from full rated air cylinder pressure to the lower limit air pressure range of 500 psig. At less than 500 psi, the tested SCBA system must be returned to fully rated cylinder pressure (4500, 2216 or 3000 psig, or the specified SCBA system air pressure under test). The cycle must be continued until the test is terminated at the end of six (6) hours. The decay cycles may be continuous or stepwise.

NO PHOTO CURRENTLY AVAILABLE

Picture 11: Air Compressor & Cascade System

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 its' 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 Liquified Air (Source for SCBA Operating System)

Pressure Decay Profile = Rated SCBA service pressure upper limit, with natural human respiratory decay over expected cylinder time and down to less than 500 psi before refreshing back to the upper limit of air pressure.

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

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

Condensed Oil & Particulate: Less than 5 mg/m³.

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 SCBA certification.

4.2.3 Miller-Nelson air flow settings into exposure chamber

Airflow Rate: Determine an appropriate flow based upon obtaining a stable concentration, based upon the volume of the exposure chamber, considering the agent challenge concentration desired, volume of chamber, breather air flow, and dilution air discharged from the SCBA.

Relative Humidity = 50 ±5%

Temperature = 25 ± 3°C

4.2.4 SMARTMAN Sampling Point

A single Nasal port to supply dual MINICAMS detectors.

4.2.5 Sarin (GB) Vapor Test

4.2.5.1 Vapor Challenge Concentration = $2000 \text{ mg/m}^3 \pm 10 \%$

Vapor Challenge Time (disseminator on) = 30 minutes, but no longer than 31 minutes

Monitor & Hold Time = 5.5 hours

Total Test Time = 6 hours

Syringe Injection Rate = as required based upon syringe pump used

Syringe Injected Volume = as required based upon syringe pump used

4.2.5.2 Liquid Sarin (GB) must be Chemical Agent Standard Analytical Reference Material (CASARM). Analysis must be NIST traceable. Proper CASARM storage requirements must be followed.

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 Droplet Diagram (Appendix A) = 25 drops

Associated Hardware Droplet Diagram (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.

Manual Liquid Droplet HD Application starts the total time from when the first droplet is applied while MINICAMSs are actively sampling.

4.2.6.2 HD Vapor Challenge

Vapor Challenge Concentration = $300 \text{ mg/m}^3 \pm 10 \%$

Vapor Challenge Time (disseminator on) = 30 minutes, but no longer than 31 minutes

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

Total Test Time = 6 hours (Manual Liquid Droplet HD Application starts the total time from when the first droplet is applied while MINICAMSs are actively sampling.)

4.2.6.3 Liquid Distilled Mustard (HD) must be Chemical Agent Standard Analytical Reference Material (CASARM). Analysis must be NIST traceable. Proper CASARM storage requirements must be followed.

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 for each one of the MINICAMSs in use.

4.2.8. High Pressure Compressed Air Cycle. 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 cylinder pressure is 4500 psig but may vary depending on SCBA air cylinder ratings of 3000 psig or 2216/2200psi. Minimum air pressure required is 500psi. When the tested respirator unit alarms and reaches its testable low air minimum pressure of 500psig, efficient transfer of manual or processed standby air pressure is required to be initiated from second cylinder or built in house high pressure compressed air and isolate first cylinder for recharging. The compressed air cycle continues until the end of the specified test.

4.3 Safety and Training: 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 Procedures, and/or equivalent manuals.

4.3.1. Safety glasses, lab coats and assigned respirator must be worn as required.

- 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 should protect against lacerations or punctures.
- 4.3.4. Laboratory personnel must be trained in safe operating procedures appropriate for the test.
- 4.3.5. The responsible technician must be knowledgeable about the specific Self Contained Breathing Apparatus (SCBA) being tested and should be able to readily identify all SCBA hardware accessories, components, subcomponents, noted accessories and be able to support accurate trouble shooting of the SCBA to ensure it is operating in the pressure demand mode. The responsible technician must be able to properly align and fit the respirator facepiece on the SMARTMAN headform.
- 4.3.6. All equipment passing these NIOSH test protocols will be treated as hazardous materials in accordance with local laboratory procedures and methods. Disposal of such contaminated SCBA materials is the responsibility of the testing laboratory and respirator manufacturers are released of equipment accountability IAW NIOSH and local testing lab test equipment procedures per local testing lab procedures.
- 4.3.7. 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.
- 4.3.8. 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, 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 and HD sample volume is approximately 200 mL. 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 4-minute cycle and HD requires a 6-minute cycle. The two MINICAMS will be synchronized so that one minicam sampling begins when the other minicam sampling ends.
- 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. MINICAMS are configured in accordance with the operating manual and the specific method for the chemical warfare 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, spectrophotometric grade. At least three injections of each quantity of agent should be injected.
- 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 generation for GB and HD.
 - 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, taking into account the volume of air discharged into the chamber from the SCBA.

Example:

The conditions below are to be used as guidelines. Conditions for each individual system will have to be determined for each laboratory setup to achieve the required ramp up time.

GB Setup (mass balance)

Chamber size = 8 ft^3

Target Challenge Concentration = $2000 \text{ mg}/\text{m}^3 \pm 200$

Ramp Up Time = 4 - 5 minutes (time from initial start of syringe pump to $1800 \text{ mg}/\text{m}^3$ lowest acceptable Challenge Concentration)

Dilution Air from Breather Pump = 40 l/m

Miller-Nelson Challenge Mixing Air = 90 l/m

Syringe Rate for Challenge Injection = 0.34 ml/m

Total GB in 30 minutes = 10.2 ml

HD Setup (mass balance)

Chamber size = 8 ft^3

Target Challenge Concentration = $300 \text{ mg}/\text{m}^3 \pm 30$

Ramp Up Time = 3-5 minutes (time from initial start of syringe pump to $270 \text{ mg}/\text{m}^3$ lowest acceptable Challenge Concentration)

Dilution Air from Breather Pump = 40 l/m

Miller-Nelson Challenge Mixing Air = 50 l/m

Syringe Rate for Challenge Injection = 1 ml/hr

Total HD in 30 minutes = 0.5 ml

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 according to paragraph 4.2.3. Allow the clean 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. Manual setting of the syringe pump controls allows the pump rate to be changed by using a turn knob.

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. Turning off the power switch will stop the drive block from pushing against the plunger and stop the challenge agent concentration flow at the predetermined time.

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. The SCBA is operated using air supplied to the SCBA from a cylinder air storage system. Ensure that 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 leak 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 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 penetration of less than 0.0010 %, continue with the next item in the test procedure.

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, allowing chemical warfare agent vapor to pass through from the headform cavity 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.
- 4.9.2. 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. Agent solutions must be stored at 4°F or lower.

- 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, the breather flow from the breather pump and the syringe 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. Allow the TDA-99M to stabilize in its initial detection procedure. When readings are stable within ± 2 end place digits of 0.0000, the TDA-99M Aerosol Tester is ready to begin detecting potential leak paths. If there is no leak, the display on the TDA-99M should read 0.0000 % penetration.
- 4.9.5 MINICAMS Detector Response: Check the response of the MINICAMS detector, 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 response 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 (0200) or Liquid/Vapor Challenge HD (0201))

5.1. Vapor Challenge GB (0200)

- 5.1.1. Assemble SCBA per manufacturer's instructions with the exception of the air cylinder. Air cylinders are not tested according to these standard testing procedures. Only the air cylinder neck valve and gaskets are tested using the high-pressure adaptor.
- 5.1.2. Take a digital photograph of assembled unit for use later.
- 5.1.3. Mount unit on the SMARTMAN in the clean exposure chamber. The facepiece should be mounted to the SMARTMAN per the manufacturers' operating/user instructions. Ensure all parts of the facepiece are mounted/seated correctly on the headform. If a shroud or other accessory is being tested as part of the respirator system, ensure that they are mounted properly and serviceable. Batteries must be removed from the "PASS" device before testing begins.
- 5.1.4. The test SCBA must be connected to the compressed air supply system using an air cylinder valve-mounting adaptor. See Appendix E for a drawing of the adaptor. Different high-pressure air cylinders and rated SCBA respirators require different cylinder adaptor dimensions. Ensure that the correct adaptor is being used according to the manufacturer specifications. A calibrated torque wrench is used to exert the required foot-pounds of torque pressure. This adaptor will stay with the SCBA unit through out the complete testing process. 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. 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 ± 10 psig. Insure SCBA air pressure gauge reads in the full range. The responsible technician must insure that the inlet air pressure gauge is at maximum rated pressure for the start of test and ample high-pressure air is available for the duration of the test.
- 5.1.5. Insure inlet pressure gauge from high-pressure air source does not exceed the SCBA rated service pressure at any time.
- 5.1.6. Turn on the breathing pump. Insure that the SCBA is in the pressure demand mode. This can be confirmed by visually checking the integrated SMARTMAN magnehelic pressure gauge needle movement. Magnehelic pressure gauge should be used only as a qualitative indicator of SCBA positive pressure. Lack of positive pressure in the SCBA will result in the magnehelic gauge reading in the negative pressure range.

- 5.1.7 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, allow the SCBA to breath and create stable value on the TDA-99M. When the 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 by the authorized laboratory technician or manager only. 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 the aerosol challenge inside the chamber for thirty (30) minutes of continuous TDA-99M operations below 0.0010% penetration. If penetration exceeds 0.0010%, the TDA-99M alarm sounds, and/or the digital readout shows higher values, stop the 30 minute test, reanalyze the system and restart a new 30 minute test period. The SCBA must pass a continuous 30 minute test at ≤ 0.0009 % penetration parameters in separate clean exposure chamber and agent exposure chamber to be considered “qualified” to progress on in the agent testing. If after repeated attempts a successful leakage test cannot be achieved, the laboratory manager may use alternative means to seal the facepiece to the headform, with the concurrence of the applicant. Alternate means of sealing the facepiece must not compromise the normal use of the SCBA.
- 5.1.8 Before the SCBA respirator facepiece can be placed on the SMARTMAN in the agent exposure chamber, the MINICAMS must have shown a steady state background lower than the lowest point on the calibration curves. This is accomplished by installing a M40 respirator on the SMARTMAN. The SMARTMAN should be allowed to breathe until the steady state background is lower than the lowest calibration curve point indicated on the respective MINICAMS.
- 5.1.9 Remove SCBA from clean exposure chamber and install on SMARTMAN in the GB agent exposure chamber. The neck cylinder valve and assigned adaptor must stay together and transfer with the testing SCBA.
- 5.1.10 Mount unit on the SMARTMAN in the agent exposure chamber. Conduct a TDA-99M 30 minute test by repeating steps 5.1.3 – 5.1.7, with the exception that once the agent exposure chamber is sealed and no leaks are confirmed with the TDA-99M. The TDA-99M aerosol challenge is discontinued. Insure that the removal of the TDA-99M test hardware does not disturb the established seal of the SCBA facepiece to the SMARTMAN system.

- 5.1.11 Turn on the Miller Nelson Flow temperature and humidity controller.
- 5.1.12 MINICAMS Background Characterization. A background characterization must be run before every chemical warfare agent test. The MINICAMS should be monitored for a period of 60 minutes prior to the initiation of the chemical agent warfare test. Confirm that background level is less than the lowest point on the MINICAM calibration curve. If the background level is not less than required, trouble shoot the SMARTMAN system, do not start the test, advise laboratory manager and if necessary remove the SCBA facepiece, decon the headform, redon the facepiece and restart the procedure for characterization as necessary. .
- 5.1.13 Set up standard operational mode of test equipment. Ensure all test equipment is within calibration.
- 5.1.14 Set Miller-Nelson for air flow into exposure chamber set to deliver required rates. See paragraph 4.2.3.
- 5.1.15 Load liquid agent in syringe and set syringe pump to correct flow rate to achieve the required agent challenge concentration. See paragraph 4.2.5 (GB)
- 5.1.16 Ensure MINICAM is calibrated, perform “check shot”, and ready for operating mode. Annotate the check shot time and concentration percentage.
- 5.1.17 Ensure that the challenge concentration instrument is calibrated and it is ready for analysis. Monitor chamber concentration during the 60 minute Background Characterization period. Characterization readings should reflect steady state conditions.
- 5.1.18 Time zero, or start of the agent test, is when the syringe pump is turned on and agent is allowed into the agent exposure chamber. Annotate this time.
- 5.1.19 Introduce agent challenge [Sarin (GB)] 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 80 L/min from Miller Nelson, which includes enough excess to make up for the clean air exhausted from the respirator into the chamber and maintain the constant challenge as required. The concentration of challenge agent monitored using the appropriate Miran detector. The syringe flow rate is set to introduce the quantity of agent necessary to generate the challenge concentration required. Record the time when the MINICAMS begin

monitoring the interior of the mask. It is required to start the MINICAMS before introducing agent into the chamber so that the first sampling period will coincide with the first agent challenge.

- 5.1.20 The syringe pump should run for the prescribed challenge period of 30 minutes, but no more than 31 minutes. At the end of the challenge period, turn off the syringe pump. Record the total volume used by the syringe pump, the elapsed time and the air flow rate delivered from the Miller-Nelson. These values will be recorded in the laboratory notebook and test data sheets (Appendix C & D). Ensure the syringe flow is off and the mixing chamber airflow line is bypassed so Miller-Nelson uncontaminated air flow is going to the agent exposure chamber.
- 5.1.21 The Miran Detector will be used to monitor the challenge concentration in the exposure chamber. This will be recorded on a computer with compatible software capable of accurately depicting the agent concentration verses time.
- 5.1.22 System Hold or Monitor Time: Continue flushing the agent exposure chamber with the Miller-Nelson uncontaminated air to allow the simulation of the natural effects of ambient environmental conditions and the actual nonpersistent vapor effects of GB. Ensure the breathing machine operates at the same rate for the remaining 5.5 hours.
- 5.1.23 Test Surveillance: The laboratory technicians should monitor entire the test to make sure all components of the system function, collect data as required and monitor the breakthrough concentration to protect the minicam against saturation. If the system is failing, the MINICAMS must capture three maximum peak excursions to document the SCBA's failure before MINICAMS can be taken off the detection line.
- 5.1.24 Termination of Test
- 5.1.24.1 The test should be terminated when the full time for the test has elapsed. Turn off breather pump. Depressurize the SCBA by closing the compressed air feed or allowing the automatic high-pressure air system to cycle down air pressure. 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 zero 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.

5.1.24.2 Turn off the MINICAMS per laboratory SOP. Turn off Miller-Nelson airflow through the exposure chamber. Remove the test respirator, separate it into components and double-bag the components in accordance with local laboratory SOP. Remove the bagged components to the decontamination hood for temporary storage. If requested, a manufacture representative may review the items at this time to perform reverse engineering analysis. This review must be approved by the laboratory manager. The test respirator will then be decontaminated, monitored and disposed according to laboratory SOP. Wipe down the interior of the agent exposure chamber and the SMARTMAN using approved decontaminating solution. Dispose of cleaning materials according to laboratory SOP.

5.1.25 Step Sequence of Activities for GB Vapor CBRN SCBA Test.

1. Conduct M40 preparation and background contamination assessment.
2. Install SCBA in clean exposure chamber.
3. Close clean exposure chamber, ensure SCBA is breathing.
4. Challenge clean SCBA with TDA-99M for 30 minutes
5. Verify that clean SCBA has passed TDA-99M, retest/refit, go to next step or if failure, substitute failed SCBA with a new untested SCBA.
6. Install SCBA in agent exposure chamber
7. Close agent exposure chamber, ensure SCBA is at maximum pressure limit and start breathing.
8. Challenge SCBA with TDA-99M for 30 minutes
9. Start MINICAMS
10. Monitor background inside the mask and chamber concentration/check shot
11. Conduct characterization for 60 min
12. Start makeup air using Miller-Nelson
13. Start syringe pump
14. Record start time of MINICAMS
15. Initiate challenge agent
16. Record challenge agent start time, vapor exposure
17. Simultaneously start ambient challenge concentration profile software

18. Monitor MINICAMS for detection, noted penetration peaks and saturation prevention.
19. Stop syringe pump at 30-minute mark.
20. Record stop time for challenge agent vapor exposure.
21. Record hold time start (5.5 hours)
22. End test
23. Record end time at 6.0 hours
24. Conduct check shot instrumentation
25. Record check shot results.
26. Prepare system for decon and removal of tested components.

5.1.26 Data Analysis

- 5.1.26.1 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.
- 5.1.26.2 Laboratory manager and 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. NIOSH DEIMS is updated at the minimum, every three days by the lab technician supervisor/principal investigator or equivalent, while an application is active and has information for update, ideally, the DEIMS should be updated daily with all applicable information to allow timely feedback and prevention of miscommunication.
- 5.1.26.3 Transfer the permeation data from the MINICAMS computer into a computer for analysis by Microsoft Excel. This analysis will contain data from the nasal area and associated time markers. The resulting table will each have four columns: 1) elapsed time 2) volume collected 3) sample collection time and 4) nanograms per sample. 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 (Example: $1.73 \text{ ng} \times 1/0.2 \text{ L} = 8.65 \text{ ng/L}$). Convert nanograms/liter to milligrams/cubic meter by dividing by 1000 (Example: $8.65 \text{ ng/L} / 1000 = 0.0865 \text{ mg/m}^3$). CT (Concentration Time) is calculated by multiplying the collection

duration time times the concentration (Example: $0.0865 \text{ mg/m}^3 \times 2 \text{ min} = 0.173 \text{ mg-min/m}^3$). The cumulative CT is calculated by adding the CT value for each sample time successively. Using Excel's Chart Wizard feature, a plot of concentration vs. time and the CT vs. time can be generated and printed using all the data in the table.

5.1.26.4 Challenge Concentration Data: Using the computations generated from para 5.1.26.3 above. Plot the challenge concentration versus time and produce two data graphs that track total detection events covering any maximum peak excursions over 6 hours and total concentration over time known, as cumulative CT, covering the total 6 hours of potential cumulative and instantaneous dosages. If the test is terminated prior to the completion of 6 hours due to MINICAMS preventive measures, the laboratory technician supervisor or equivalent is responsible for accurately recording all applicable maximum peak excursions and cumulative CT detected in the tested time.

5.2 Vapor Challenge HD (0201)

- 5.2.1 Assemble SCBA per manufacturer's instructions with the exception of the air cylinder. Air cylinders are not tested according to these standard testing procedures. Only the air cylinder neck valve and gaskets are tested using the high-pressure adaptor.
- 5.2.2 Take two digital photographs of assembled unit. One photograph is of the complete unit; the other is a close up of the facepiece with the regulator attached and all other tested accessories required by the application.
- 5.2.3 Mount the unit on the SMARTMAN in the clean exposure chamber. The facepiece should be mounted to the SMARTMAN per the manufacturers' operating/user instructions. Ensure all parts of the facepiece are mounted/seated correctly on the headform. If a shroud or other accessory is being tested as part of the respirator system, ensure that they are mounted properly and serviceable. Batteries must be removed from a PASS device before testing begins.
- 5.2.4 The test SCBA must be connected to the compressed air supply system using an air cylinder valve-mounting adapter. See Appendix E for a drawing of the adaptor. Different high-pressure air cylinders and rated

SCBA respirators require different cylinder adapter dimensions. Ensure that the correct adapter is being used according to the manufacturer specifications. A properly calibrated torque wrench is used to exert the required foot-pounds of torque pressure. This adaptor will stay with the SCBA unit through out the complete testing process. 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. 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 ± 10 psig. Insure SCBA air pressure gauge reads in the full range. The responsible technician must insure that the inlet air pressure gauge is at maximum rated pressure for the start of test and ample high-pressure air is available for the duration of the test.

- 5.2.5 Insure inlet pressure gauge from high-pressure air source does not exceed the SCBA rated service pressure at any time.
- 5.2.6 Turn on the breathing pump. Insure that the SCBA is in the pressure demand mode. This can be confirmed by visually checking the integrated SMARTMAN magnehelic pressure gauge needle movement. Magnehelic pressure gauge should be used only as a qualitative indicator of SCBA positive pressure. Lack of positive pressure in the SCBA will result in the magnehelic gauge reading in the negative pressure range.
- 5.2.7 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, allow the SCBA to breath and create stable value on the TDA-99M. When the 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 by the authorized laboratory technician or manager only. 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 the aerosol challenge inside the chamber for thirty (30) minutes of continuous TDA-99M operations below 0.0010% penetration. If penetration exceeds 0.0010%, the TDA-99M alarm sounds, and/or the digital readout shows higher values, stop the 30 minute test, reanalyze the system and restart a new 30 minute test period. The SCBA must pass a continuous 30 minute test at ≤ 0.0009 % penetration parameters in separate clean exposure chamber and agent exposure chamber to be considered "qualified" to progress on in the agent testing. If after repeated attempts a successful leakage test cannot be

achieved, the laboratory manager may use alternative means to seal the facepiece to the headform, with the concurrence of the applicant.

- 5.2.8 Before the SCBA respirator facepiece can be placed on the SMARTMAN in the agent exposure chamber, the MINICAMS must have shown a steady state background lower than the lowest point on the calibration curves. This is accomplished by installing a M40 respirator on the SMARTMAN. The SMARTMAN should be allowed to breathe until the steady state background is lower than the lowest calibration curve point indicated on the respective MINICAMS.
- 5.2.9 Remove SCBA from clean exposure chamber and install on SMARTMAN in the HD agent exposure chamber. The neck cylinder valve and assigned adaptor must stay together and transfer with the testing SCBA.
- 5.2.10 Mount unit on the SMARTMAN in the agent exposure chamber. Conduct a TDA-99M 30 minute test by repeating steps 5.2.3 - 5.2.7, with the exception that once the agent exposure chamber is sealed and no leaks are confirmed with the TDA-99M. The TDA-99M aerosol challenge is discontinued. Insure that the removal of the TDA-99M test hardware does not disturb the established seal of the SCBA facepiece to the SMARTMAN system.
- 5.2.11 Turn on the Miller Nelson Flow temperature and humidity controller.
- 5.2.12 MINICAMS Background Characterization. A background characterization must be run before every agent test. The MINICAMS should be monitored for a period of 60 minutes prior to the initiation of the chemical agent warfare test. Confirm that background level is less than the lowest point on the MINICAM calibration curve. If the background level is not less than required, trouble shoot the SMARTMAN system, do not start the test, advise laboratory manager and if necessary remove the SCBA facepiece, decon the headform, redon the facepiece and restart the procedure for characterization as necessary.
- 5.2.13 Set up standard operational mode of test equipment. Ensure all test equipment is within calibration.
- 5.2.14 Set Miller-Nelson for air flow into exposure chamber set to deliver required rates. See paragraph 4.2.3
- 5.2.15 Load liquid agent in syringe and set syringe pump to correct flow rate to achieve the required agent challenge concentration. See items 4.2.6.2.

- 5.2.16 Ensure MINICAMS is calibrated, performing “check shot”, and ready for the operating mode. Annotate the check shot times and concentrations.
- 5.2.17 Ensure that the challenge concentration instrument is calibrated and is ready for analysis. Monitor agent exposure chamber during the 60 minutes background characterization period. Characterization reading should reflect a steady state condition.
- 5.2.18 Time Zero or start of the agent test is when the first drop of liquid HD is applied to the surface of the SCBA and the MINICAMS are actively sampling. Conduct of the liquid HD droplet application must be performed expeditiously to allow the agent exposure chamber to be closed and the total exposure of the SCBA under specified conditions. Annotate the starting time.
- 5.2.19 Liquid Application of HD droplets:
- 5.2.19.1 Liquid drops are delivered to the surface of the SCBA to test permeation of material surfaces. 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). The droplets will be placed on the equipment starting at the top of the SCBA as it is mounted on the SMARTMAN, to the far back and working down to the bottom front. Photographs must be maintained in the Task Folder. **Liquid application of HD occurs before the vapor challenge of HD begins.**
- 5.2.19.2 Twenty five (25) drops will be placed on the facepiece. This will follow the sequence in Appendix A. The droplet placement sequence will be starting at the top of the face blank, working left to right, to the bottom of the face blank following the number sequence marked on Appendix A. Prior to actual droplet application, technicians should prepare by marking location of actual droplets on a digital photograph of the equipment being tested. If an external shroud is mounted on the face blank, apply droplets per standard diagram but on surfaces of the shroud that mirror the routine face blank areas.
- 5.2.19.2 The remaining eighteen (18) droplets are placed on the specific SCBA hardware equipment that is an obvious pressure boundary concern and any protective material surface that is a noted concern related to penetration or permeation. The droplet placement is performed following the sequence in Appendix B.

- 5.2.19.3 Once the last droplet is applied, conduct a visual check of the breathing SCBA to ensure it is still in positive pressure mode, no parts or accessories are out of place and that there is no immediate destruction of material due to the recent exposure to HD droplets. Mount the front panel of the agent exposure chamber. If SCBA starts to disintegrate immediately during or just after droplet application occurs, finish the droplet application process and close up the box immediately. If the disintegration of the SCBA presents a perceived safety hazard, the technician should terminate the test at his discretion.
- 5.2.20 Start of the 30 minute vapor exposure is when the vapor HD is injected into the HD exposure chamber. Annotate this starting time. Ensure time management is accomplished that allows the efficient tracking of two simultaneous events: one clock for HD liquid for 6 hours and another clock for HD Vapor at 30 minutes.
- 5.2.21 Introduce HD vapor agent challenge to the agent exposure chamber. Turn the valve inline from bypass of the mixing chamber to direct flow from the mixing chamber to the internal ambient space of the agent 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 monitored using the appropriate Miran detector. The syringe flow rate is set to introduce the quantity of agent necessary to generate the challenge concentration required. Record when the MINICAMSs begin monitoring the interior of the mask. It is required to start the MINICAMSs before introducing agent into the chamber so that the first sampling period will coincide with the first agent challenge.
- 5.2.22 The syringe pump should run for the prescribed challenge period of 30 minutes, but no more than 31 minutes. At the end of the challenge period, turn off the syringe pump. Record the total volume used by the syringe pump, the elapsed time and the air flow rate delivered from the Miller-Nelson. These values will be recorded in the laboratory notebook and test data sheets (Appendix C & D). Ensure syringe flow is off and the mixing chamber airflow line is bypassed so Miller-Nelson uncontaminated air is flowing to the agent exposure chamber.
- 5.2.23 The Miran Detector will be used to monitor the challenge concentration in the exposure chamber. This will be recorded on a computer with

compatible software capable of accurately depicting the agent concentration versus time.

5.2.24 System Hold or Monitor Time: Continue flushing the agent exposure chamber with the Miller-Nelson uncontaminated air to allow the simulation of the natural effects of ambient environmental conditions and the persistent vapor effects of HD. Ensure the breathing machine operates at the same rate for the remaining 5.5 hours.

5.2.25 Test Surveillance: The laboratory technicians should monitor the entire test to make sure all components of the system function, collect data as required and monitor the breakthrough concentration to protect the MINICAMS against saturation. If the system is failing, the MINICAMS must capture three maximum peak excursions to document the SCBA's failure before MINICAMS can be taken off the detection line. If disintegration of the SCBA during the test is perceived as a safety hazard, the test technician may terminate the test at his discretion.

5.2.26 Termination of Test

5.2.26.1 The test should be terminated when the full time for the test has elapsed. To terminate the test, turn off breather pump. Depressurize the SCBA by closing the compressed air feed or allowing the automatic high-pressure air system to cycle down air pressure. 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 zero 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.

5.2.26.2 Turn off the MINICAMS per laboratory SOP. Turn off Miller-Nelson airflow through the exposure chamber. Remove the test respirator, separate it into components and double-bag the components in accordance with laboratory SOP. Remove the bagged components to the decontamination hood for temporary storage. If requested, a manufacture representative may review

the items at this time to perform reverse engineering analysis. This review must be approved by the laboratory manager. The test respirator will then be decontaminated, monitored and disposed according to laboratory SOP. Wipe down the interior of the agent exposure chamber and the SMARTMAN using approved decontaminating solution. Dispose of cleaning materials according to laboratory SOP.

5.2.27 Step sequence of activities for HD liquid and vapor CBRN SCBA test.

1. Conduct M40 preparation and background contamination assessment.
2. Install SCBA in clean exposure chamber.
3. Close clean exposure chamber, ensure SCBA is breathing.
4. Challenge clean SCBA with TDA-99M for 30 minutes
5. Verify that clean SCBA has passed TDA-99M, retest/refit, go to next step or if failure, substitute failed SCBA with a new untested SCBA
6. Install SCBA in agent exposure chamber.
7. Photograph SCBA.
8. Close agent exposure chamber, ensure SCBA is at maximum pressure limit and start breathing.
9. Challenge SCBA with TDA-99M for 30 minutes
10. Start MINICAMS
11. Monitor background inside the mask and chamber concentration/check shot
12. Conduct characterization for 60 min
13. Ensure front panel is readily available for replacement on agent exposure chamber
14. Add drops of HD per digital photo
15. Record 6 hour vapor start time
16. Start makeup air using Miller-Nelson Controller
17. Start syringe pump
18. Record start time of MINICAMS
19. Record 30 minute vapor start time
20. Initiate challenge agent
21. Record challenge agent start time, vapor exposure
22. Simultaneously start ambient challenge concentration profile software
23. Monitor MINICAMS for detection, noted penetration peaks and saturation prevention.
24. Stop syringe pump at 30-minute mark, but no later 31 minutes.
25. Record stop time for challenge agent vapor exposure.
26. Record hold time start (5.5 hours)
27. End test
28. Record end time at 6.0 hours
29. Conduct check shot instrumentation

30. Record check shot results.

31. Prepare system for decon and removal of tested components.

5.2.28 Data Analysis

5.2.28.1 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.

5.2.28.2 Laboratory manager and 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. NIOSH DEIMS is updated, at the minimum, every three days by the lab technician supervisor/principal investigator or equivalent. While an application is active and has information for update, the DEIMS should be updated daily with all applicable information to allow timely feedback and prevention of miscommunication.

5.2.28.3 Transfer the permeation data from the MINICAMS computer into a computer for analysis by Microsoft Excel. This table will contain data from the nasal area and associated time markers. The resulting table will each have four columns: 1) elapsed time 2) volume collected 3) sample collection time and 4) nanograms per sample. 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 (Example: $1.73 \text{ ng} \times 1/0.2 \text{ L} = 8.65 \text{ ng/L}$). Convert nanograms/liter to milligrams/cubic meter by dividing by 1000 (Example: $8.65 \text{ ng/L} / 1000 = 0.0865 \text{ mg/m}^3$). CT (Concentration Time) is calculated by multiplying the collection duration time times the concentration (Example: $0.0865 \text{ mg/m}^3 \times 2 \text{ min} = 0.173 \text{ mg-min/m}^3$). The cumulative CT is calculated by adding the CT value for each sample time. Using Excel's Chart Wizard feature, a plot of concentration vs. time and the CT vs. time can be generated and printed using all the data in the table.

5.2.28.4 Challenge Concentration Data: Using the computations generated from para 5.1.28.3 above. Plot the challenge concentration versus time and produce two data graphs that

track total detection events covering any maximum peak excursions over 6 hours and total concentration over time known, as Cumulative CT, covering the total 6 hours of potential cumulative and instantaneous dosages. If the test is terminated prior to the completion of 6 hours due to MINICAMS preventive measures, laboratory technician supervisor or equivalent is responsible for accurately recording all applicable maximum peak excursions and cumulative CT detected in the tested time.

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 for GB and HD testing. The criterion is:

6.1.1. Sarin (GB) Penetration Test:

minutes) Challenge: 2000 mg/m³ ± 10 % for 30 minutes (but not more than 31

concentration) Test Time: 6 hours
Dual Pass/Fail Criteria:
a) Maximum agent breakthrough: 2.1 mg-min/m³ (integrated over time or cumulative CT)

b) Maximum Peak Excursions: 0.087 mg/m³: Three consecutive data points at or exceeding the peak value constitutes a failure.

Note: Overall CT limit of 2.1 mg-min/m³ including peaks cannot be exceeded during the 6 hour test time.

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

Challenge: 300 mg/m³ ± 10 % for 30 minutes (but not more than 31 minutes) preceded by a forty three (43) 20 μl liquid droplet application

concentration) Test Time: 6 hours
Dual Pass/Fail Criteria:
a) Maximum agent breakthrough: 6.0 mg-min/m³ (integrated over time or Cumulative 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 during the 6 hour test time.

6.1.3 Precision and accuracy must be determined for each instrument in accordance with laboratory procedures.

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(a)(c)(d).

7. RECORDS\TEST SHEETS

7.1. All test data will be recorded in the NIOSH DIEMS using on the test data sheet formats (Appendix C, D & F). All applicable data, graphs and photographs taken/made by laboratory technicians, technician supervisors or the equivalent will remain on file at the actual lab where the test was conducted and will be retrievable within 24 hour notification to the storing lab and be maintained in accordance with local administrative SOPs.

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.

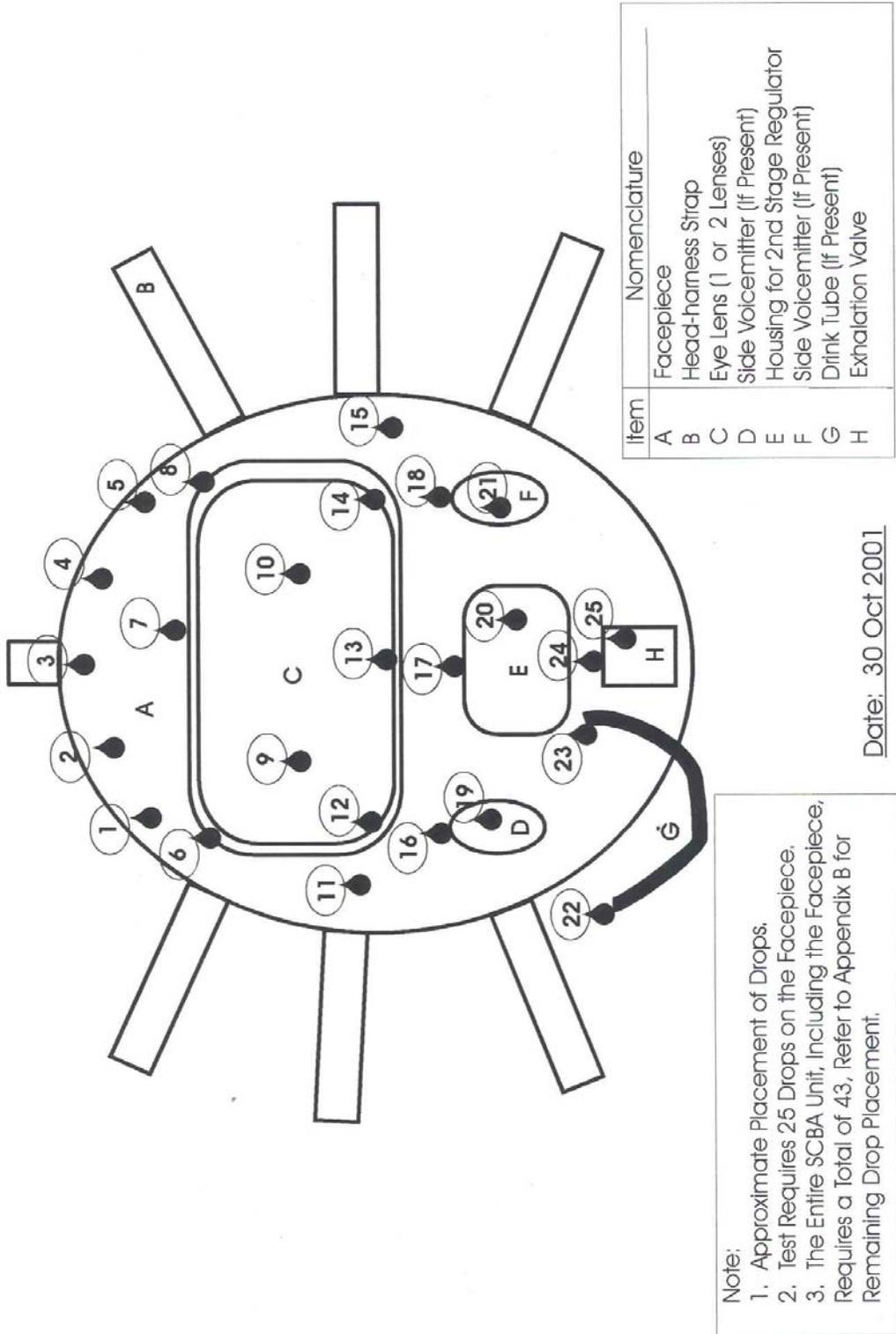
7.3. All equipment failing any portion of this test will be handled as follows;

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 NIOSH Certification Team 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 the laboratory technician and the 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:

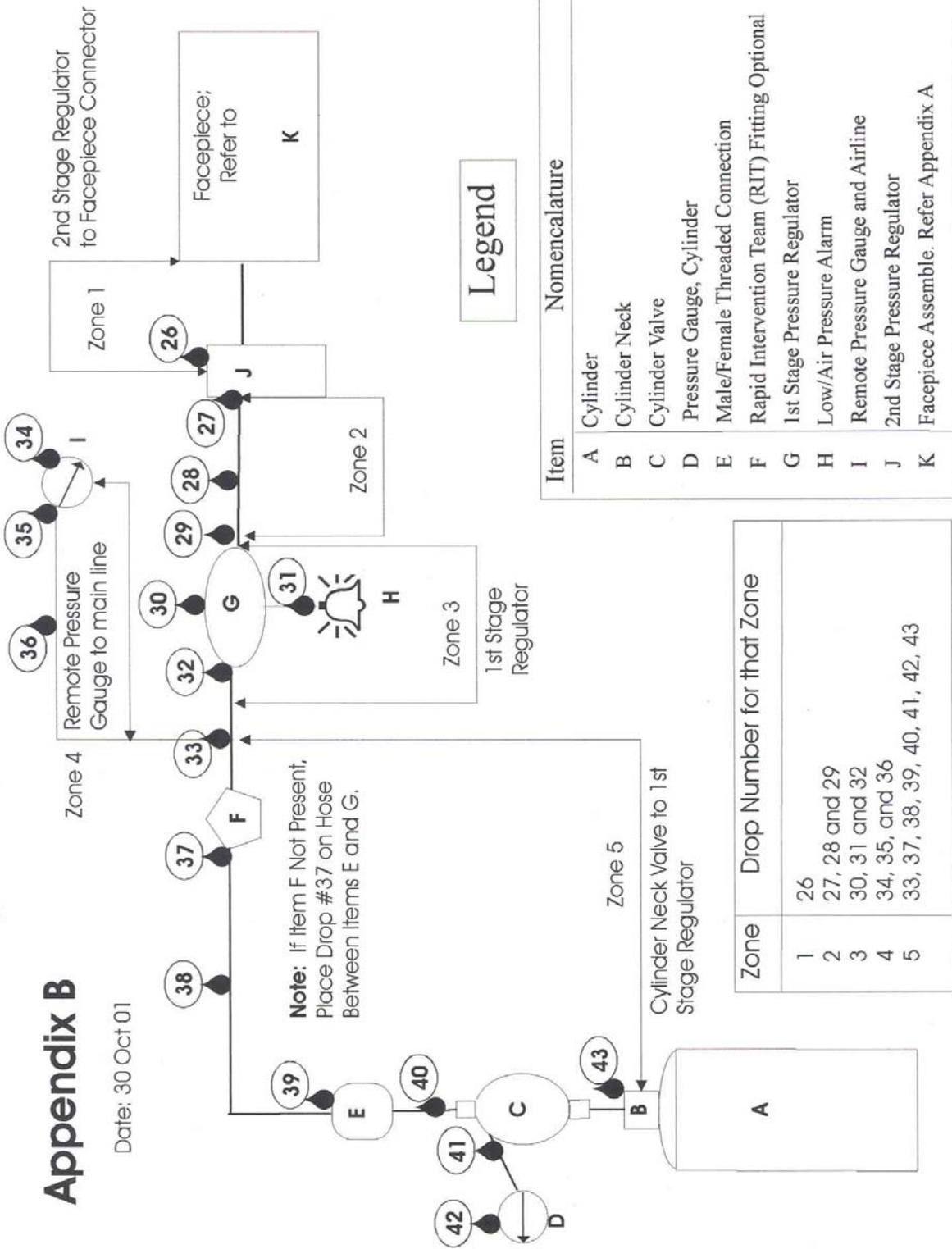
1. Approximate Placement of Drops.
2. Test Requires 25 Drops on the Facepiece.
3. The Entire SCBA Unit, Including the Facepiece, Requires a Total of 43, Refer to Appendix B for Remaining Drop Placement.

Date: 30 Oct 2001

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		Yes/No	Operators Initials	Test Date
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 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				
Respirator /Class	Requirements		Supervisors Initials	
		Test Time Minimum	Maximum Peak Excursion (3 consecutive data points >= to)	Pass
CRBN-SCBA	360 Minutes	0.087 mg/m3		
		Maximum GB Breakthrough (integrated concentration over time ICD)	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
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

		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 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				
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

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

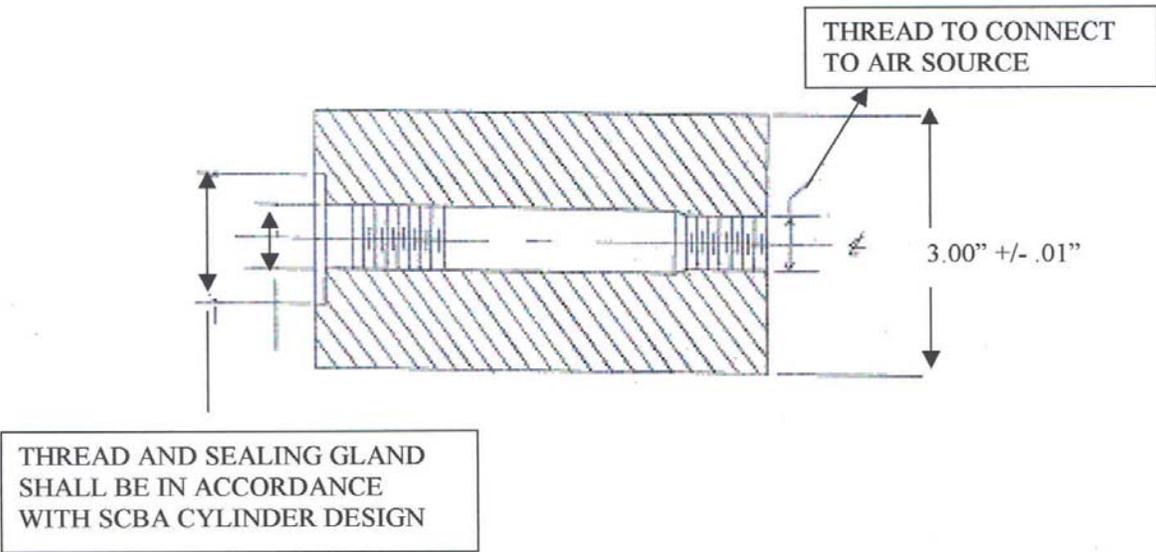
Requirement:

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



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
1.0	22 May 2002	Multiple clarifications and corrections to the STP based upon the initial SCBA testing and approval evaluation processes.
1.1	3 June 2005	Update header information and format No changes to method