NIOSH CBRN RESPIRATORS

I. HISTORY

A. Since 9/11, America has been in a war against terrorism. However, before then, in May 1998 President Clinton issued Presidential Directive 62 "Combating Terrorism" which created a systematic approach to fight terrorism in the 21st century with the same rigor that the United States met military threats in the 20th century. (See NIOSH Pub. # 2000-122.)

World Trade Center

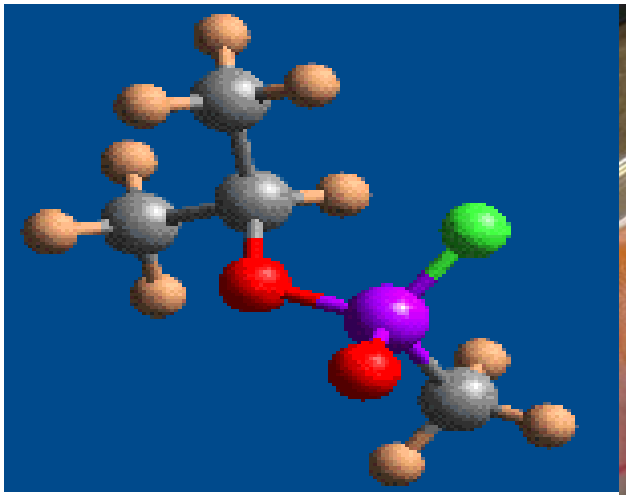
World Trade Center

Pentagon

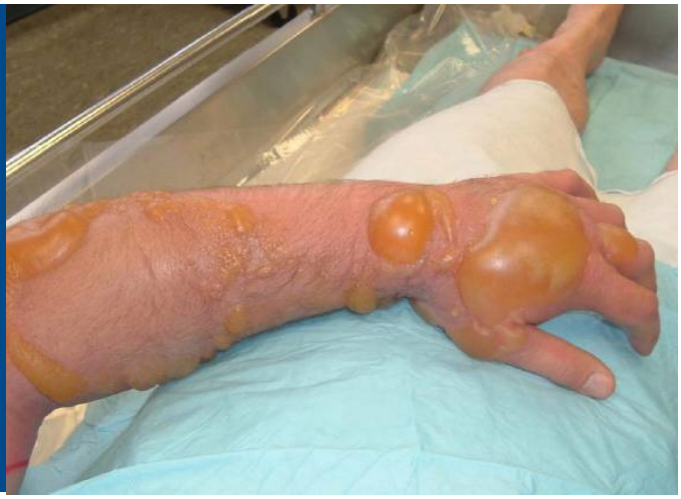
B. Since the issuance of Presidential Directive 62, municipal and state responder groups have been developing response plans for procedures and equipment to respond to chemical, biological, radiological, and nuclear (CBRN) terrorism. Emergency first responders are required by the Occupational Safety and Health Administration (OSHA) in paragraph (d)(1)(ii) of 29 CFR 1910.134 to wear respirators approved by the National Institute for Occupational Safety and Health (NIOSH). However, there had been no need for these types of respirators for civilian first responders up until that time; therefore, there were no respirators approved by NIOSH as protection against CBRN agents (e.g., Mustard agent and Sarin). NIOSH responded quickly to this need and took on the monumental task to develop NIOSH CBRN Respirator Standards to protect American emergency responders during response to CBRN terrorist attack.

II. REASONS FOR CERTIFYING RESPIRATORS AS PROTECTION AGAINST CBRN AGENTS

A. The following brief discussion of Mustard Agent and Sarin is provided to emphasize the severe physiological health hazards resulting from exposure to these chemical agents and why NIOSH CBRN respirator evaluation and certification testing is so critical. Mustard agent was named after its characteristic odor and was used in World War I to blister the skin, eyes and lungs. The picture below shows the horrific results from dermal contact with mustard agent. Imagine a similar physiological reaction in the respiratory system.



Sarin (courtesy of CBIAC)



Dermal reaction to Mustard Agent

B. This historical picture of "walking-wounded" British solders being evacuated after being blinded by mustard gas during World War I brings to mind the term *"The Blind Leading the Blind."* Solders suffering from respiratory distress caused by mustard agent are not shown because they are on litters and cannot walk due to their injuries.

British solders being evacuated after exposure to Mustard agent in WW I

C. Nerve gas existed but was not used during WWII because of manufacturing problems. Sarin ($C_4H_{10}FO_2P$) was actually the second nerve gas that was developed. Tabun was the first nerve agent, which was discovered on 23 December 1936 by the German Dr. Gehard Schrader, while developing new types of insecticides. In 1938, Sarin, the second organophosphate nerve agent was developed and named for its four discoverers: ***S***chrader, ***A***mbros, ***R***udriger, and van der L***in***de.

D. Sarin works by interfering with acetyl-cholinesterase (AChE), an important enzyme that allows effective control and function of glands and muscles (AChE acts as the body's "off switch" for glands and muscles). Sarin can cause constant stimulation of glands and muscles causing confusion, sweating, vomiting, involuntary defecation and urination, convulsions, and eventually death due to muscles tiring to the extent that they can no longer sustain breathing. Sarin is 26 times more deadly than cyanide gas and a pinprick size droplet can kill an adult human.

III. NIOSH CBRN RESPIRATOR APPROVAL SCHEDULES

A. On 10 - 12 March 1999, NIOSH, Department of Defense, and OSHA held a Chemical and Biological Respiratory Protection Workshop in Morgantown, West Virginia. More than 140 subject-matter experts from 63 different emergency responder, fire fighter, domestic preparedness, equipment manufacturing, federal research, and state and federal regulatory organizations discussed issues concerning respiratory protection associated with incidents involving chemical and biological agents. NIOSH published a report summarizing this meeting. This was the first of many stakeholder and interagency meetings held by NIOSH to understand emergency responders' protection needs and to build partnerships between agencies.

B. As result of these meetings, NIOSH, US Army Research Development and Engineering Command (RDECOM), and National Institute of Standards and Technology joined forces to develop methods for NIOSH to certify respirators approved as protection against CBRN agents. Since then, NIOSH has developed approval schedules for five

classes of CBRN respirators, which are listed below. Early efforts of the stakeholder and interagency meetings determined that first responders urgently needed self-contained breathing apparatus (SCBA) and that NIOSH approved CBRN air-purifying respirators were the next priority.

SEQUENCE OF CBRN RESPIRATOR STANDARDS PROMULGATION	
Respirator Class	**Standard Promulgation Date**
Open-Circuit Self Contained Breathing Apparatus (SCBA)	12/28/2001
Air-Purifying Respirators (APR)	04/04/2003
Air-Purifying Escape Respirators (APER)	10/08/2003
Closed-Circuit Escape Respirators (CCER)	10/08/2003
Powered Air-Purifying Respirators (PAPR)	10/06/2006

C. In addition to the approval schedules listed above, NIOSH is planning an approval schedule for Positive-Pressure Closed Circuit Self-Contained Breathing Apparatuses with CBRN protection, CBRN Combination Respirator Unit that will combine SCBA/PAPR/ APR modes of operation, and a new Powered-Air Purifying (PAPR) standard that will further address CBRN PAPR approvals.

IV. NIOSH APPROVED CBRN SCBA

A. Open-circuit, pressure demand SCBAs must meet requirements of subparts H through L of 42 CFR 84, which demonstrate that the SCBA is approved for traditional industrial workplace usage. Under 42 CFR 84, regulators are tested at the traditional NIOSH 40 lpm breathing rate at the NIOSH, National Personal Protective Technology Laboratory (NPPTL). SCBAs must also meet the current edition requirements of National Fire Protection Association (NFPA) 1981, *Standard on Open-Circuit SCBA for Emergency Services*. NFPA 1981 compliant SCBAs have demonstrated that they can withstand/meet the flame, heat resistance, and other technical requirements of NFPA 1981 that are important for protection against hazards that may be present for first responders reacting to a terrorist incident. Under NFPA 1981, regulators are tested at 103 lpm.

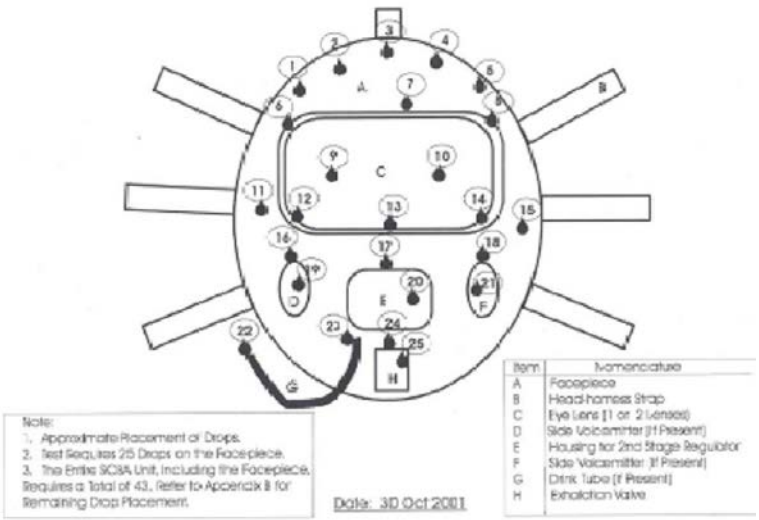
MSA CBRN SCBA

B. Amendments to the 2007 edition of NFPA 1981 require NIOSH CBRN SCBA approval as a new requirement of NFPA 1981 compliance. The combined effect of these two standards is that NFPA 1981 compliance and NIOSH CBRN approval must be issued jointly. Both NFPA 1981 compliant SCBAs and NIOSH approved CBRN SCBAs must pass a three tiered approval process, which includes: (1) initial NIOSH 42 CFR Part 84 certification; (2) followed by joint issuance of NFPA 1981 compliance testing; and (3) NIOSH special chemical warfare agent testing, plus laboratory respirator protection level testing. One solution is for candidate CBRN SCBA approval applications and NFPA

1981 SCBA compliance certification applications to be submitted to NIOSH and NFPA at the same time as the 42 CFR Part 84 application for approval. Please see the following website for more information on the NIOSH and NFPA joint approval process.

C. As part of NIOSH CBRN approval, SCBAs must pass chemical agent penetration and permeation testing at RDECOM. SCBAs are operated in a simulated pressure demand breathing mode on the Simulant Agent Resistant Test Manikin (SMARTMAN) in an enclosed air-tight exposure chamber.

SMARTMAN



HD Placement on SCBA Facepiece During Permeation Testing

1. All SCBA components (except the air cylinder) are tested for 6 hours against initial challenge concentrations of 2,000 mg/m^3 Sarin (GB) vapor and 300 mg/m^3 Distilled Sulfur Mustard (HD) vapor, plus 0.860 milliliters liquid HD applied directly to the SCBA while the SCBA is operated in a simulated pressure demand breathing mode on the SMARTMAN. Because of the length of the test, air cylinders are replaced with a long term Grade D quality compressed air supply. Liquid application of HD droplets occurs before the vapor challenge of HD begins since it is likely that in an actual CBRN incident that liquid HD droplets will be dispersed first followed by exposure to the HD vapor.

   a. Sampling ports in the eye and oral/nasal regions of SMARTMAN are used to detect the presence of agent inside the SCBA facepiece. Infrared absorption is used to detect GB and flame ionization detection detects the HD.

   b. Forty-three drops of liquid mustard are applied to the SCBA, including 25 drops on the facepiece. Eighteen other drops are strategically placed from the second stage regulator facepiece connector down to the air cylinder neck valve to specifically target air-pressure boundary joints, crevices, material seams, and material overlaps.

D. Following successful completion of live-agent testing, the candidate CBRN SCBA facepiece undergoes NIOSH Laboratory Respirator Protection Level (LRPL) testing against a known concentration of corn-oil particulates. Probed, SCBA facepieces equipped with P100 filters are donned by 25 to 50+ human test subjects with representative facial sizes and shapes and then quantitatively fit tested in a corn oil chamber to ensure good face-fitting characteristics. Size selection and ease of donning per respirator manufacturer's user instructions are also evaluated during LRPL testing.

Quantitative Fit Test Corn Oil Chamber

1. Each test subject performs the following eight exercises for one-minute each:

* Normal Breathing
* Turn Head Side to Side
* Recite the Rainbow Passage
* Grimace Exercise
* Reach for the Floor and Ceiling
* Deep Breathing
* Move Head Up and Down

2. Also, the three additional first responder exercises, designed to replicate minimal first responder head, arm, and leg movements include:

* Sighting a rifle
* On hands and knees, turning head from side to side
* Climbing stairs at a regular pace

3. The SCBA is in compliance if 95% of the test subjects achieve LRPL values (i.e., fit factors) that are equal to or greater than 500.

E. The following website link lists NIOSH approved CBRN SCBA. At the time of this writing, there were 113 NIOSH approved CBRN SCBA. According to Navy policy, NIOSH approved CBRN SCBA service life must be rated for 60 minutes.

F. Below is an example of a CDC/NIOSH adhesive approval label required to be located on the backframe of approved CBRN SCBA.

1. A similar but separate adhesive label is also required to be on a field deployed SCBA that has been upgraded/retrofitted to NIOSH CBRN protections. That label shows the words (RETROFIT) immediately underneath the "CBRN Agent approved" text.

CBRN SCBA Approval Label

G. Each respirator that NIOSH approves is assigned a unique testing and certification number commonly known as the "TC" number. The TC number for NIOSH approved CBRN SCBAs always includes the CBRN suffix. For example: TC-13F-476CBRN

H. NIOSH emphasizes that there are cautions and limitations associated with the use of these respirators, which include the following advisories paraphrased below:

1. Many chemical warfare agents can be absorbed through the skin or can cause severe damage to the skin. Even though the SCBA may be resistant to warfare agents, the parts of the body not covered by the SCBA are still vulnerable to exposure. Therefore, the end user must also protect against dermal exposure including wearing appropriate levels of personal protective ensembles (i.e., Level A (Class 1) or Level B (Class 2) ensembles) and ensuring dermal protection against contact with SCBA after use.

2. The respirator should not be used beyond 6 hours after initial exposure to vapor or liquid chemical warfare agents to avoid the possibility of chemical agent permeation.

3. If the SCBA is contaminated with liquid chemical warfare agents, dispose of the SCBA after decontamination.

4. All NIOSH Cautions and Limitations appearing on the approval label must be strictly followed or the NIOSH approval is void.

V. NIOSH APPROVED CBRN FULL FACE, AIR-PURIFYING RESPIRATORS

A. NIOSH certifies these negative pressure full face air-purifying CBRN respirators under their *Gasmask Approval Schedule TC-14G*. These gasmasks are approved for use during entry into CBRN atmospheres that are not immediately dangerous to life or health (IDLH) and approved for escape from a one time exposure to an IDLH atmosphere.

MSA Millennium

B. NIOSH and DOD vulnerability assessments during early development of CBRN respirator standards identified 139 potential respiratory hazards of possible concern during terrorist attack. This list of chemicals was generated from both national and international sources and includes not only traditional CBRN agents but also toxic industrial materials/chemicals (TIMs/ TICs), radioactive particulate isotopes, and biological particulates.

C. To reduce the number of certification tests, NIOSH has grouped the respiratory hazards into families of chemicals and has researched and determined which representative chemicals from each family to test the canisters during the respirator certification process. By testing respirator canister filtration media against representative test agents of each chemical family, respirators can be approved as protection against a total of 139 chemical warfare agents and TICs/TIMs by testing the respirators against only 11 representative test agents.

1. Cyclohexane was selected to represent the family of 61 organic vapors. The filtration performance against chemical vapors is dependent on the vapor pressure and the reaction chemistry of the chemicals. Chemicals with relatively low vapor pressures are effectively removed by physical adsorption in the pores of the activated carbon. Cyclohexane was selected to represent the family of organic vapors because of its high vapor pressure. Canisters passing the certification test for cyclohexane will meet the approval criteria for organic vapors. There are 61 organic chemicals in this family (including the nerve agent Sarin and the blister agent Distilled Sulfur Mustard), all of which have vapor pressures lower than cyclohexane.

Organic Vapor Family		
Acetone cyanohydrin	Ethyl chloroformate	Parathion
Acrylonitrile	Ethyl chlorothioformate	Perchloromethyl mercaptan
Allyl alcohol	Ethyl phosphonothioicdichloride	Phenyl mercapatan
Allyl chlorocarbonate	Ethyl phosphorodichloridate	Phenylcarbylamine chloride
Bromoacetone	Ethylene dibromide	Phenyldichloroarsine
Bromobenzylcyanide	Hexachlorocyclopentadiene	Phosgene oximedichloroforoxime
Chloroacetone	Hexaethyl tetraphosphate	Phosphorus oxychloride
Chloroacetonitrile	Iso-butyl chloroformate	Sarin
Chloroacetophenone	Iso-propyl chloroformate	Sec-butyl chloroformate
Chloroacetyl chloride	Lewisite	Soman
Chloropicrin	Methanesulfonyl chloride	Tabun

Organic Vapor Family		
Chloropivaloyl chloride	Methyl orthosilicate	Tert-octyl mercapatan
Crotonaldehyde	Methyl parathion	Tetraethyl dithiopyrophosphate
Cyclohexyl methyphosphonate	Methyl phosphonic dichloride	Tetraethyl lead
Dibenz-(b,f)-1,4-oxazepine	Mustard, lewisite mixture	Tetramethyl lead
Diketene	Nitrogen mustard hn-1	Tetranitromethane
Dimethyl sulfate	Nitrogen mustard hn-2	Trimethoxysilane
Diphenylchloroarsine	Nitrogen mustard hn-3	Trimethylacetyl chloride
Diphenylcyanoarsine	N-propyl chloroformate	VX
Diphosgene	O-chlorobenzylidene malononitrile	
Distilled mustard	O-ethyl-s-(2isopropyaminoethyl) methyl phosphonthiolate	

2. Many of the acid gases (e.g., chlorine, phosgene) possess high vapor pressures (> 100 mm Hg) and undergo poor physical adsorption in activated carbon beds. Therefore, laboratory service life values and filtration effectiveness depends on the ability of the materials used in treating the charcoal to react with these chemicals by either decomposing them into non-hazardous gases or converting them into chemical compounds which are retained on the carbon impregnated surface. There are 32 acid gases that are represented by subjecting canisters to cyanogen chloride, phosgene, hydrogen cyanide, hydrogen sulfide, and sulfur dioxide.

Acid Gas Family		
Boron tribromide	Cyanogen chloride	Phosgene
Boron trichloride	Dichlorosilane	Phosphorus trichloride
Boron trifluoride	Ethyl phosphonous dichloride	Silicon tetrafluoride
Bromine	Fluorine	Sulfur dioxide
Bromine chloride	Hydrogen bromide	Sulfur trioxide
Bromine trifluoride	Hydrogen chloride	Sulfuric acid
Carbonyl fluoride	Hydrogen cyanide	Sulfuryl chloride
Chlorine	Hydrogen fluoride	Titanium tetrachloride
Chlorine pentafluoride	Hydrogen iodide	Tungsten hexafluoride
Chlorine trifluoride	Hydrogen selenide	Bromine pentafluoride
Chlorosulfonic acid	Hydrogen sulfide	

3. Nitrogen dioxide is the representative test agent for the nitrogen oxide family, which includes nitric acid, fuming nitric acid, nitrogen dioxide, nitrogen tetraoxide, and nitrogen trioxide.

4. Ammonia is the representative test agent for the base gas family, which includes allyl amine, ammonia, 1,2-dimethyl hydrazine, and methyl hydrazine.

5. Phosphine, a hydride that must be removed catalytically, is the representative test agent for the hydride family, which includes arsine germane, phosphine, and stibine.

6. Formaldehyde is the test agent the Formaldehyde family.

7. The chemical particulate, dioctyl phalthate (better known as “DOP”) is used to test for the 32 members of the particulate family, which include biological agents and radiological/nuclear agents.

Particulate Family Particulate Chemicals		
Adamsite	Sodium azide	Sodium fluoroacetate

Particulate Family Biological Agents			
Anthrax	Brucellosis	Glanders	Pneumonic Plague
Tularemia	Q Fever	Smallpox	Botulism
Ricin	T-2 Mycotoxins	Viral Hemorrhagic Fevers	
Staphylococcus Enterotoxin B	Venezuelan Equine Encephalitis		

Particulate Family Radiological/Nuclear Agents			
Hygrogen 3	Carbon 14	Phosphorous 32	Cobalt 60
Nickel 63	Strontium 90	Technetium 99m	Iodine 131
Cesium 137	Promethium 147	Thallium 204	Radium 226
Thorium 232	Americium 241	Uranium 235 & 238	Plutonium 239

D. As shown below, candidate CBRN canisters are tested at laboratory service life challenge concentrations that are normally 2, 3, or 10 times greater than the IDLH concentrations. This ensures the escape protection against atmospheres at or greater than IDLH.

Challenge/Breakthrough Concentrations			
Representative Test Agent	**Challenge Concentration (ppm)**	**IDLH Concentration (ppm)**	**Breakthrough[1] Concentration (ppm)**
Cyclohexane	2600	1300	10
Sulfur dioxide	1500	100	5
Hydrogen sulfide	1000	100	5
Cyanogen chloride	300	ND[2] REL Ceiling 0.3	2
Phosgene	250	2	1.25
Hydrogen cyanide	940	50	4.7
Ammonia	2500	300	12.5
Phosphine	300	50	0.3
Nitrogen dioxide	200	20	1 ppm NO_2 or 25 ppm NO
Formaldehyde	500	20	1
P100 filter >99.97% efficient			
[1] CBRN canisters are not evaluated to breakthrough, only to the capacity time of intervals of 15 minutes.			
[2] IDLH for cyanogen chloride has not been determined. The NIOSH Recommended Exposure Limit (REL) ceiling value is 0.3 ppm. The ceiling value should not be exceeded at any time.			

1. Canisters are tested at 64 lpm. In addition, there is a high flow service life testing requirement in which the canisters must provide a minimum service life of five minutes when tested at 100 lpm. The canister service life is measured in increments of 15 minutes up to one hour and then in 30 minute increments for service life lasting over an hour. The service life approvals are referred to as "CAP," meaning capacity. For example, a canister with a 15 minute laboratory service life is referred to as having a "CAP-1" capacity, a "CAP-2" approval is for 30 minute

capacity, and a "CAP-6" approval is for 120 minutes of laboratory capacity. Canisters can be either facepiece mounted or back or chest harness mounted.

A. Currently all CBRN APR canisters are facepiece mounted except for the MSA FireHawk M7 Responder, which is a respirator system that can be converted between CBRN SCBA/PAPR/APR modes of operation. CBRN approvals were obtained independently for each component (SCBA, APR, and PAPR). Users are required to manually convert between the operational modes in an uncontaminated environment. NIOSH and its stakeholders are working to develop a respirator certification standard for approving next generation respirators that integrate available technologies to allow users to safely convert between SCBA/PAPR/APR modes of operation based on heads-up-display ambient air readings or other end-of-service-life indicators and end-of-service-time indicators.

MSA FireHawk M7 Responder[1]

B. NIOSH requires that CBRN gasmask canisters all have 40 mm threads so that they are interoperable between different manufacturers' makes and models of CBRN gasmasks. Using a CBRN gasmask with a canister from a different manufacturer voids the NIOSH approval and this practice is in violation of the OSHA Respirator Standard. However, NIOSH incorporates this provision to help alleviate logistical complications caused by potential shortages of canisters for a specific manufacturer's respirator at emergency response scenes involving large numbers of first responders. In these situations, several different brands of gasmasks may be used and this provision allows for interchanging canisters when the incident commander decides it is appropriate.

1. More specifically, CBRN gasmask canister interoperability is only allowed when authorized by the incident commander; when the CBRN canister being used in place of the original canister is of the same capacity as the one approved with the respirator being used, (e.g., both canisters are CAP 1); and this interoperability provision only applies to CBRN gasmask canisters - **IT DOES NOT APPLY TO CBRN PAPR CANISTERS OR CARTRIDGES**. Although this practice voids the NIOSH approval, intuitively it should provide adequate respiratory protection since the APR CBRN canisters are all tested against the same challenge agents at the same concentrations and must also meet the same size, weight, and thread requirements (CBRN gasmask canisters must have a maximum weight of 500 grams and the canisters must be able to pass through a five inch opening with threads perpendicular to opening.).

[1] This photograph is courtesy of Mr. Terry Cloonan NIOSH, NPPTL and CMSgt Joe Rivera USAF. It was taken of the MSA FireHawk M7 Responder during a NIOSH visit to the USAF Silver Flag Exercise Site, Tyndall during Joint Firefighter's Integrated Response Ensemble training.

C. Air-purifying respirators must also pass the SMARTMAN chemical agent penetration and permeation testing performed by RDECOM according to published NIOSH standards.

1. CBRN air-purifying respirators are tested at the following challenge conditions:

   a. 210 mg/ m^3 Sarin (GB) vapor challenge for 8 hours;

   b. 50 mg/ m^3 Distilled Sulfur Mustard (HD) vapor for 8 hours;

   c. 0.43 to 0.860 milliliters liquid HD (applied during last 2 hours of the HD vapor challenge).

SMARTMAN in RDECOM Laboratory

D. According to NIOSH: "*Warfare agents, sarin (GB) and distilled sulfur mustard (HD) are aggressive penetrating and permeating substances. In order to ensure that the integrity of the respirator is maintained during and after exposure to these agents, all parts that form a boundary between the breathing gas and ambient conditions must be tested. Pressure boundary parts identical in configuration but made from different materials are individually tested as separate respirator configurations. For example, the same facepiece made from two different materials, natural rubber and EPDM [Ethylene Propylene Diene Monomer], must be tested as separate respirator configurations*[2]."

E. Additional certification testing is performed for rough handing, including tests for cold, humidity, vibration and dropping, fogging, breathing resistance, carbon dioxide, communication, and visual acuity. Face-fitting characteristics are determined by performing laboratory respirator protection level (LRPL) testing modified from the CBRN SCBA LRPL test described earlier. CBRN approved air-purifying respirators, equipped with their CBRN canisters, must pass LRPL testing with a minimum fit factor of 2,000. CBRN canisters are much heavier than HEPA filters. This weight on the

[2] Test agents can attack materials causing them to deteriorate and fail. A facepiece head harness that fails during use could affect the user to facepiece seal. Consequently, head harnesses manufactured from different materials must be individually tested as separate respirator configurations.

facepiece makes a difference as to how the respirator seals to the wearer's face (CBRN canisters can weigh up to 500 grams (17.64 oz.)).

LRPL Testing

F. CBRN APR canister approval labels are olive drab in color and marked with a CBRN Capacity (Cap) rating as determined by service life testing under laboratory conditions. An example of an approval label for canisters meeting the 15-minute test requirement (CAP-1) is shown below.

CBRN canister/label color shall be olive (Munsell notation 7.5 Y 5/6).
For canisters where the color markings are achieved by labeling, the canister body can be any color.

G. NIOSH maintains their list of NIOSH approved CBRN air-purifying respirators at this web link. There are currently 13 CBRN approved APR/gasmasks.

H. According to Navy policy, MSA Millennium Full Facepiece APR CBRN CAP 1 is the NIOSH approved CBRN gas mask of choice for Navy installation first responders.

The Millennium certification number, TC-14G-0270, also includes approval of Ultra Elite facepiece with rubber or Kevlar Speed-On head harness.

I. As with all NIOSH-approved respirators, NIOSH emphasizes that there are cautions and limitations associated with the use of these respirators, which include the following advisories paraphrased below:

1. Must not be worn in IDLH atmospheres.

2. Must not be worn in atmospheres < 19.5% oxygen.

3. Must not be used beyond eight hours after initial exposure to chemical warfare agents to avoid the possibility of agent permeation.

4. The respirator shall not be used for more than two hours if liquid chemical warfare agent exposure is encountered.

5. Must use with personal protective ensembles that provide appropriate levels of protection against dermal hazards (i.e., Level C (Class 3) protective ensembles).

6. If contaminated with liquid chemical warfare agents, dispose of the respirator after decontamination.

7. All NIOSH Cautions and Limitations appearing on the approval label must be strictly followed or the NIOSH approval is void.

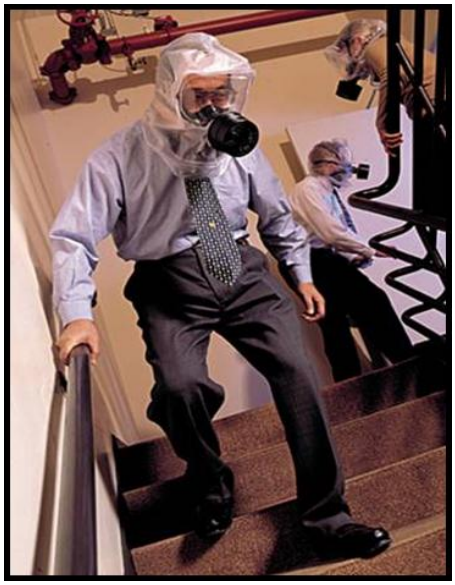
J. NIOSH supports the use of CBRN APRs for protection in other applications besides terrorist events, such as protection during industrial operations and hazmat response as long as all elements of an effective OSHA compliant respiratory protection program are established and are being enforced, including respirator canister change out schedules. The CBRN APR can only be used in its approved configuration. For more information please read NIOSH's interim guidance on this issue.

VI. NIOSH APPROVED CBRN ESCAPE RESPIRATORS

A. There are three categories of NIOSH approved CBRN escape only respirators, which include Air-purifying (APER) "General Category," Air-purifying "Specific Category," and Self-Contained Escape Respirator (SCER). These respirators are approved for protection of the general working population during escape from terrorist events involving possible CBRN agents.

B. The respiratory inlet covering for respirators approved for escape from terrorist events must be hooded, protecting the wearer's entire head, eyes, and respiratory system. The hood must include an area for field of vision and be compatible with wearing prescription glasses.

1. The respiratory system must be connected to the incoming respirable air by either the hood itself or inside the hood by nose cup or mouthpiece with nose



MSA CBRN Escape Only Respirator

clip. Once fully donned, wearing the respirator must not require the use of hands to maintain it in position.

2. Service life duration ratings for escape respirators will be specified by the manufacturer and tested by NIOSH for ratings of 15, 30, 45, or 60-minute durations. Respirators are tested at 64 liters per minute. Per paragraph 4.5 of the certification standard, escape respirators will also provide high flow "Panic Demand" protection in which they must provide a service life of at least five minutes at a breathing rate of 100 liters per minute.

C. **General category** air purifying escape respirators are approved for escape from low concentrations of chemical warfare agents and toxic industrial materials. As shown below, air purifying escape respirators are tested against the same representative test agents as CBRN agent approved air-purifying respirators; however, escape respirators are tested at half the concentrations. These test concentrations are still at or above the IDLH concentrations for the representative test agents. Air purifying escape respirators are not for use in atmospheres containing less than 19.5% oxygen.

Challenge/Breakthrough Concentrations for General Category APERs and Specific Category APERs

Representative Test Agent	General Category Challenge Concentration (ppm)	Specific Category Challenge Concentration (ppm)	IDLH Concentration (ppm)	Breakthrough[1] Concentration (ppm)
Ammonia	1250	2500	300	25
Cyanogen chloride	150	300	ND[1] REL Ceiling 0.3	2
Cyclohexane	1300	2600	1300	10
Formaldehyde	250	500	20	10
Hydrogen cyanide	470	940	50	10 (Sum of HCN and C_2N_2)
Hydrogen sulfide	500	1000	100	30
Nitrogen dioxide	100	200	20	1 ppm NO_2
Phosgene	125	250	2	1.25
Phosphine	150	300	50	0.5
Sulfur dioxide	750	1500	100	5
P100 filter >99.97% efficient				

[1] IDLH for cyanogen chloride has not been determined. The NIOSH Recommended Exposure Limit (REL) ceiling value is 0.3 ppm. The ceiling value should not be exceeded at any time.

D. **Specific category** air purifying escape respirators are tested against the same challenge agents and concentrations as those for approval of general category escape respirators. In addition, they are tested against specific hazard(s) at the concentrations listed above, which are twice as high as the general category challenge concentrations:

1. Both general and specific category air purifying escape respirators can optionally be tested against 3,600 ppm and 6,000 ppm carbon monoxide, respectively. Air-purifying escape respirators submitted for approval for carbon monoxide protection are also tested for flammability and heat resistance using the test equipment specified in *EN 136, Full Face Masks*. No component of the

respirator can have an after flame after five seconds. Also, no component of the escape respirator can drip, melt, or develop a visible hole.

SMARTMAN

2. As with all NIOSH approved CBRN agent respirators, air-purifying escape only respirators must pass chemical agent permeation and penetration testing at RDECOM. All components of the respirator are tested against a 210 mg/m^3 Sarin (GB) vapor challenge and against 50 mg/m^3 Distilled Sulfur Mustard (HD) vapor for either 30, 60, 90, or 120 minutes plus 0.43 to 0.860 milliliters of liquid HD drops are applied while the mask is operated by a simulated breathing machine like the SMARTMAN in an enclosed air-tight exposure chamber. The liquid HD is applied first followed by the vapor challenge for the complete duration of the each three test trials per agent.

3. Additional certification testing is performed for rough handing, which include tests for heat, cold, humidity, vibration, dropping, fogging, breathing resistance, carbon dioxide, and visual acuity. Escape only respirators must also pass tests for 30 second donning time.

4. Face-fitting characteristics are determined by performing LRPL testing that requires probing the APER in two locations; the breathing zone and the upper head area/ocular area. CBRN air-purifying escape respirators must pass quantitative laboratory protection level testing with a minimum LRPL value of 2,000 in the breathing zone of the respirator (such as in the nose cup), and shall be 150 or greater sampled outside the breathing zone (under the hood).

5. "Useful life" is defined as the length of time a unit can remain deployed in the "ready-to- use" stowed condition. According to NIOSH, useful life for these devices is not to exceed five years. However, the useful life may be extended by the approval holder during the last year of the initial useful life. In order for an escape respirator to receive an "incremental useful life extension," some service action must be performed on each unit, followed by performance testing.

6. Training is critical to properly use these escape devices. Manufacturers must include an instruction manual, which addresses donning procedures, respirator use, maintenance, length of useful life, cautions and limitations. Manufacturers must also provide a training respirator that mimics the performance of the approved respirator, including the same inhalation and exhalation breathing resistance that will develop user proficiency in operating the equipment, as well as identifying periodic refresher training requirements to maintain user proficiency. All cautions and limitations must be followed.

7. NIOSH requires that air-purifying escape respirator labels be marked with a CBRN service life rating. With all the various combinations of general and specific category approvals and the additional carbon monoxide approvals, there exists a variety of possible markings on any given model of CBRN APER. However, there are only two duration ratings approved to date: Escape only CBRN 15 and Escape only CBRN 30. Examples of CBRN APER approval markings include:

a. General category air purifying escape respirators approved for a 30 minute duration rating are marked: *ESCAPE ONLY NIOSH CBRN 30*

b. Respirators receiving approval for a 30 minute duration rating with carbon monoxide protection are marked: *ESCAPE ONLY NIOSH CBRN 30 with Carbon Monoxide*

c. Respirators receiving approval for a 30 minute duration rating with a specific category (e.g., NH_3, NO_2, HCN, etc.) are marked: *ESCAPE ONLY NIOSH CBRN 30 with "chemical" Specific*

d. Respirators receiving approval for a 30 minute duration, with a specific category, and carbon monoxide are marked: *ESCAPE ONLY NIOSH CBRN 30 with "chemical" Specific and with Carbon Monoxide*

8. NIOSH maintains their list of NIOSH CBRN air-purifying escape respirators at this web link. There are currently six CBRN air-purifying escape respirators and one *ESCAPE ONLY NIOSH CBRN 30 with Carbon Monoxide* with powered-air filtration.

E. **NIOSH Approved CBRN Self-Contained Escape Respirator (SCER)** are escape respirators approved for the general working population to escape from unknown conditions and oxygen deficiency. These atmosphere supplying hooded escape devices will have either nose cups, a mouthpiece with a method of preventing nasal breathing (e.g., nose clip), or a hood only. These self-contained escape respirators may be either closed circuit or open circuit devices. The minimum service life is 15 minutes.

1. Self-contained escape respirators must pass chemical agent penetration and permeation testing at RDECOM. These devices are tested against a total CT (integrated concentration over time) of 10,000 mg/m^3 Sarin (GB) vapor challenge for the duration of the test, while being operated on a metabolic breathing simulator (e.g., SMARTMAN) enclosed in an air-tight exposure chamber. During this test, candidate respirators are also challenged against 300 mg/m^3 Distilled Sulfur Mustard (HD) vapor plus 0.50 milliliters liquid HD. The 0.50 milliliters liquid HD, is applied initially to the device in 25 drops of equal size followed by the vapor challenge.

2. In addition to testing for rough handing, fogging, breathing resistance, carbon dioxide, 30 second donning time, and visual acuity, all CBRN self-contained escape respirators are tested for flammability and heat resistance.

3. The measured LRPL value for each CBRN self-contained escape respirator must be 3,000 or greater for 95% of the test trials, sampled in the breathing zone of the respirator (such as in the nose cup). In addition, the LRPL value must be at least 150 for 95% of trials sampled outside the breathing zone (under the hood).

4. Manufacturers must provide instruction manuals and training respirators that mimic the performance of the approved respirator, including the same inhalation and exhalation breathing resistance. All cautions and limitations must be followed.

5. Useful life, defined as the length of time a unit can remain deployed in the "ready to use" stowed condition, shall not to exceed five years. However, the useful life may be extended. In order for an escape respirator to receive an incremental useful life extension, some service action must be performed on each unit, followed by performance testing. At the time of writing this article, there were no NIOSH approved CBRN self-contained escape respirators.

VII. NIOSH-APPROVED CBRN POWERED AIR PURIFYING RESPIRATOR (PAPR)

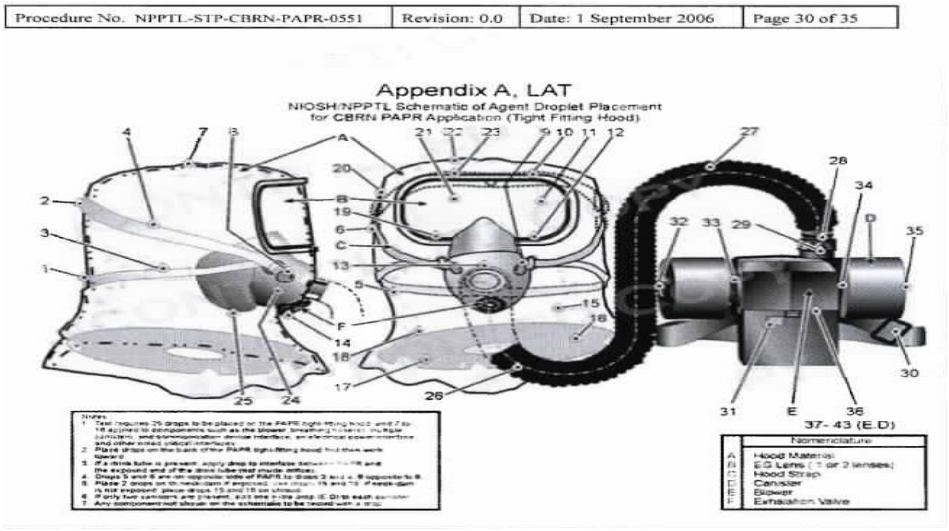
CBRN PAPR

A. Unlike the emergency provision for CBRN APR canisters and facepieces to be interoperable when authorized by the incident commander; NIOSH does not support interoperability of CBRN PAPRs and PAPR canisters. The NIOSH CBRN PAPR approval standard sets forth CBRN approval criteria for both tight-fitting PAPRs and loose-fitting PAPRs. NIOSH classifies both full face CBRN PAPRs and tight neck-sealing hooded CBRN PAPRs as tight-fitting PAPRs. **Tight-fitting CBRN PAPRs were designed for first responders, are equipped with canisters,** and receive approval under the *Gasmask Approval Schedule 14G*. **Loose-fitting CBRN PAPRs were designed for hospital first receivers, are equipped with cartridges,** and are approved under the *Chemical Cartridge Respirator Approval Schedule 23G*. Loose-fitting CBRN PAPRs must not to be confused with non-CBRN, loose-fitting facepiece PAPRs. Under the CBRN PAPR approval standard, loose-fitting CBRN PAPRs can be hooded devices. Tight sealing hooded CBRN PAPRs seal tightly around the neck; but loose-fitting CBRN PAPRs, do not have any tight sealing surface. On some loose-fitting units, the outer shroud hangs outside the clothing and the inner shroud is tucked under the protective clothing.

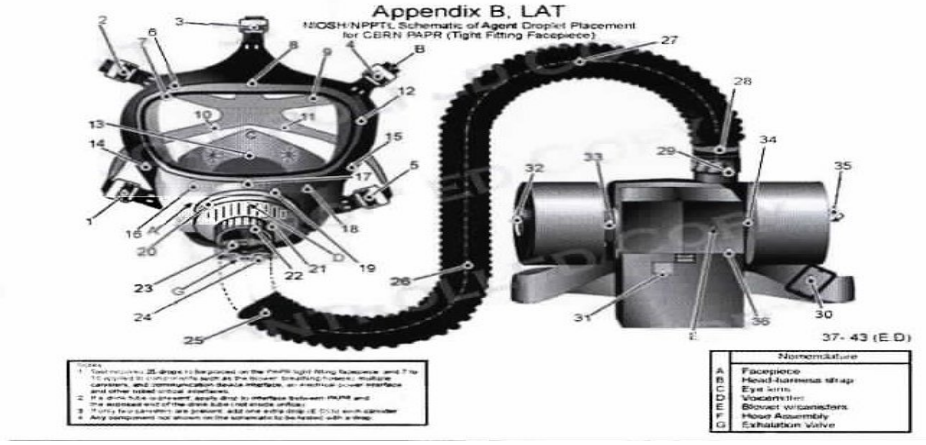
1. Tight-fitting CBRN PAPR canisters are tested against the same representative test agents and the same concentrations as CBRN non-powered full face, air-purifying respirators.

2. In contrast, loose fitting CBRN PAPRs, are not tested as stringently as tight-fitting CBRN PAPRs. Although tested against the same representative test agents as tight-fitting CBRN PAPRs, loose fitting CBRN PAPRs are tested at half the concentrations.

B. All CBRN PAPRs must undergo and pass the same **vapor** HD and GB chemical agent penetration and permeation testing as performed on the CBRN APRs at RDECOM while the blowers are operating at 40 L/min and with all components and accessories except for the battery (or batteries). However, only tight-fitting CBRN PAPRs are tested against liquid mustard agent, which is applied during the last two hours of the eight hour penetration/permeation test. In the picture below, indicating where drops of liquid mustard agent are placed, notice the neck dam, which tightly seals the hood to the wearer. Since loose-fitting PAPRs are not subjected to liquid mustard agent permeation testing as is required for the tight-fitting CBRN PAPRs; they must NOT be worn where liquid droplet exposure is encountered.



HD placement on tight fitting hooded CBRN PAPR



HD PLACEMENT ON FULLFACE CBRN PAPR

C. Another distinction between loose and tight-fitting CBRN PAPRs is the LRPL. Tight-fitting CBRN PAPRs are tested both with the blower running and then again with the blower off.

1. Both loose- and tight-fitting CBRN PAPRs must pass LRPL testing with at least 95% of the test subjects achieving LRPL values of 10,000. Tight-fitting CBRN PAPRs must also pass LRPL testing with a fit factor of 2,000 while the blower is off.

2. In contrast, loose-fitting CBRN PAPRs are only tested with the blower running. If power is lost to loose-fitting PAPRs the wearer cannot pull contaminated air through the filters; but if power is lost to tight fitting full face PAPRs the negative pressure produced during inhalation will still pull contaminated air through the air-purifying filters.

3. Also, hooded PAPRs only have an assigned protection factor (APF) of 25 unless testing demonstrates that the hooded PAPR provides an APF of 1,000. OSHA accepts respirator manufacturers' empirical test data demonstrating that hooded CBRN PAPRs provide an APF of 1,000.

4. Tight-fitting CBRN PAPRs may be used for escape from IDLH atmospheres; but loose-fitting CBRN PAPR may not be used for escape from IDLH atmospheres.

5. Durability conditioning such as rough handing, including tests for heat, cold, humidity, vibration, and dropping; resulting in minimum packaging requirements are only required for tight-fitting 14G CBRN PAPR.

D. A limitation of both tight- and loose- fitting CBRN PAPRs is that neither is intrinsically safe because of the powerful batteries needed to pull contaminated air through the large amount of sorbent materials used in the canisters and cartridges. NIOSH did not provide a separate listing of cautions and limitations for CBRN PAPRs. Instead they are available under the NIOSH "Complete list of Cautions and Limitations."

E. NIOSH maintains their list of NIOSH CBRN PAPRs at this web link. There are currently 15 tight-fitting CBRN PAPRs, certified under the *Gasmask Approval Schedule 14G* and two CBRN loose-fitting PAPRs certified under the *Chemical Cartridge Respirator Approval Schedule 23C*.

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