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An overview of NIOSH CBRN Respiratory Protection Standards

Geoff Betsinger, C.I.H.

Industrial Hygienist with the 3M OH&ESD Technical Service and Regulatory Affairs.

Introduction

As of September 2007, NIOSH has developed voluntary CBRN respirator standards for air purifying respirators (APR), air purifying escape respirators (APER), powered air purifying respirators (PAPR), and self contained breathing apparatus (SCBA). The most recent standard is the CBRN PAPR standard which was released in October of 2006.

Background

The driving force behind development of these standards came from the first responder communities' concern that industrial respiratory protection standards did not meet their specific needs. In April 2000 NIOSH entered into a Memorandum of Understanding (MOU) with the National Institute for Standards and Technology (NIST), the Occupational Safety and Health Administration (OSHA), and the National Fire Protection Association (NFPA) to work on the development of standards for all types of counter-terrorism respiratory protective equipment. NIOSH and NIST initiated Interagency Agreements with U.S. Army Research Development and Engineering Command (RDECOM) for development of respiratory protection standards, test procedures and laboratory support.

NIOSH initiated these voluntary approval programs pursuant to Title 42, Code of Federal Regulations, 84.60(b), 84.63(c), and 84.110(c). These sections provide NIOSH with the authority to issue approvals for respirators not specifically addressed in Part 84 and to develop additional requirements that the agency determines are "necessary to establish the quality, effectiveness and safety of any respirator used as protection against hazardous atmospheres."

What does CBRN mean?

CBRN is an acronym for Chemical, Biological, Radiological and Nuclear. It has developed into a broad term that first responders use to refer to chemical, biological or radiological hazards that are released with the intent to cause harm to the general public and infrastructure.

Do Workers have to Use a CBRN Approved Respirator?

If workers are required to respond to an event that could expose them to chemical, biological or radiological hazards then the PPE selected should provide adequate protection for the anticipated hazards. While OSHA has not yet updated its standards to require respiratory protection specifically approved by NIOSH for CBRN exposures, it has stated the use of such respirators is highly desirable. A list of CBRN approved respiratory protection can be obtained from the NIOSH website at; **http://www.cdc.gov/niosh/npptl/default.html.** Additionally, most government grant money ear marked for personal protective equipment requires CBRN approved equipment to be purchased. The Responder Knowledge Database (RKB) provides a comprehensive list of personal protective equipment that has been approved for use by first responders **https://www.rkb.mipt.org/** for emergency response to CBRN events.

What's Different in the Respiratory Protection Equipment CBRN Standards?

The NIOSH CBRN Standards introduced three special test requirements.

- Gas Life Testing (Air Purifying Respirators Only)
- Chemical Warfare Agent (CWA) Penetration/Permeation
- Laboratory Respiratory Protection Level (LRPL) testing

PPE selected should provide adequate protection for the anticipated hazards

Gas Life Testing

Canister versus Cartridge

NIOSH set test criteria for CBRN approvals of cartridges and canisters in the APR and PAPR CBRN standards. Cartridge approval (23C) is given to loose fitting PAPRs and may be used for escape from up to IDLH concentrations assuming the atmosphere is >19.5% oxygen..

Canister (14G) approval is given to CBRN APRs and tight fitting PAPRs and may be used for escape from greater than IDLH concentrations assuming the atmosphere is >19.5% oxygen. NIOSH approves CBRN cartridges and canisters by challenging them with CBRN Standard test agents at known concentrations and for a pre-selected time period of either 15, 30, 45 or 60 minutes. These selected times are classified as CAP 1 (15 minutes), CAP 2 (30 minutes), CAP 3 (45 minutes) and CAP 4 (60 minutes). In order to receive a CAP 1 approval on a canister or cartridge it must not exceed breakthrough concentrations when challenged for a minimum of 15 minutes. Cartridges/canisters rated over 60 minutes are approved to 30 minute intervals.

CAP 1 versus CAP 2 versus CAP 3 etc.

CAP 1 approved canisters/cartridges must provide at least 15 minutes of capacity while challenged with the NIOSH test agents. CAP 2 must provide 30 minutes, CAP 3 must provide 45 minutes and CAP 4 must provide 60 minutes. With regard to selection of canisters/cartridges, CAP 3 offers more capacity than CAP 2 which offers more capacity than CAP 1. However, more capacity generally means a heavier cartridge. It is important to understand that laboratory gas challenges do not correlate to real world use conditions. For example, the challenge concentrations of the NIOSH test agents are often 2–3 times IDLH concentrations. In addition, variability in humidity, and the flow rates which occurs while a device is worn are not considered. Therefore, a cartridge or canister that provides 15 minutes of capacity at very high concentrations may provide more than enough capacity for real world exposures which are typically exposures to lower concentrations for longer periods of time.

Cartridge and Canister Test Conditions

CBRN APR Canister gas life tests are performed at room temperature, 25±5° C (77±9° F) and two relative humidity's: 25±5 percent relative humidity and 80±5 percent relative humidity. Canisters are tested at each specified humidity with a flow rate of 64 liters per minute (lpm) continuous flow. In addition, canisters must provide a service life of 5 minutes when tested at a flow rate of 100 liters per minute, 50±5 percent relative humidity and 25±5° C (77±9° F) for each of the test agents at the Canister Test Challenge and Test Breakthrough Concentrations.

CBRN PAPR Cartridges and Canisters capacity tests are performed at room temperature, 25 ºC ± 2.5 °C (77 ± 9 °F); and at 25% ± 2.5% relative humidity and 80% ± 2.5% relative humidity. Three canisters are tested at each specified humidity. Canister test times shall be identified in 15-minute intervals (15 minutes, 30 minutes, 45 minutes). For a service life of 60 minutes or greater, applications shall be identified in 30-minute intervals (60 minutes, 90 minutes, 120 minutes). Canister capacity testing is tested at a flow rate of 115 lpm and cartridge capacity testing is tested at a flow rate of 170 lpm. The flow rates are divided by the least number of canisters/cartridges used on any configuration of the system for which approval is sought. Cartridge and canister capacity testing is performed following the durability conditioning.

Table 1 -Canister test challenge and test breakthrough concentrations

Test Concentration (ppm)		Breakthrough Concentration (ppm)
Ammonia	2,500	12.5
Cyanogen chloride	300	2
Cyclohexane	2,600	10
Formaldehyde	500	1
Hydrogen cyanide	940	4.7*
Hydrogen sulfide	1,000	5.0
Nitrogen dioxide	200	1 ppm NO_2 or 25 ppm NO†
Phosgene	250	1.25
Phosphine	300	0.3
Sulfur dioxide	1,500	5

* Sum of HCN and C_2N_2

† Nitrogen Dioxide breakthrough is monitored for both NO_2 and NO. The breakthrough is determined by which quantity, NO_2 or NO, reaches breakthrough first.

Table 2 -Cartridge test challenge and test breakthrough concentrations

Test Concentration (ppm)		Breakthrough Concentration (ppm)
Ammonia	1,250	12.5
Cyanogen chloride	150	2
Cyclohexane	1,300	10
Formaldehyde	250	1
Hydrogen cyanide	470	4.7*
Hydrogen sulfide	500	5.0
Nitrogen dioxide	100	1 ppm NO_2 or 25 ppm NO†
Phosgene	125	1.25
Phosphine	150	0.3
Sulfur dioxide	750	5

* Sum of HCN and C_2N_2

† Nitrogen Dioxide breakthrough is monitored for both NO_2 and NO. The breakthrough is determined by which quantity, NO_2 or NO, reaches breakthrough first.

How did NIOSH determine the 10 test chemicals?

One of the challenges NIOSH faced in developing the CBRN respiratory protection standards was determining test chemicals to challenge the cartridge/canister. NIOSH approached this challenge by deriving a list of toxic industrial chemicals (TICs) and toxic industrial materials (TIMs) and chemical warfare agents from a comprehensive review of available technical data and government agencies. This review established 151 TICs and TIMs that included chemical warfare agents. The initial list was reduced from 151 to 139 substances. In an effort to reduce the number of certification tests necessary for the CBRN standard, 139 respiratory hazards were categorized into families. Test representative agent(s) (TRA) were then determined for each family of compounds. Biological and radiological agents were addressed as part of the particulate agent family and require P-100 (PAPR High Efficiency Filter) media.

TIC / TIM Breakdown by Family

# of Compounds	Family
61	Organic vapor family with vapor pressures less than that of cyclohexane
32	Acid gas family
4	Base gas family
4	Hydride family
5	Nitrogen oxide family
1	Formaldehyde family (only member of family)
32	Particulate family

Test Representative Agents (TRA)

Family	TRA
Organic vapor family	Cyclohexane
Acid gas family	SO_2, H2S, CNCl, $COCl_2$, HCN
Base gas family	Ammonia
Hydride family	Phosphine
Nitrogen oxide family	nitrogen dioxide
Formaldehyde family	Formaldehyde
Particulate family	DOP

Chemical Warfare Agent (CWA) Penetration/Permeation

Permeation and penetration testing with CWA's is a component in all of the NIOSH CBRN Respiratory Standards. The two agents selected for this testing were sulfur mustard and sarin. Sulfur mustard was selected because of its invasive properties and is used to challenge the respirators' material permeation resistance. Testing with sulfur mustard is done in two phases, a vapor phase and then a liquid phase. Sarin testing is performed in the vapor phase over an extended period of time.

Summary of CWA Penetration/Permeation Testing

Type of CBRN Respiratory Approval	SCBA			PAPR ad APR		
Challenge Agent	**GB**	**HD-Vapor**	**HD-Liquid**	**GB**	**HD-Vapor**	**HD-Liquid**
Concentration	2,000 mg/m^3	300 mg/m^3	0.86 ml	210 mg/m^3	50 mg/m^3	0.43-0.86 ml
Challenge Time (minutes)	30	30	360	30	30	120
Breathing Machine Airflow Rate (L/min)	40	40	40	40	40	40
Maximum Peak Excursion mg/m^3	0.087	0.60	0.60	0.044	0.30	0.30
Maximum Breakthrough (concentration integrated over Minimum Service Life) ($mg\text{-}min/m^3$)	2.1	6.0	6.0	1.05	3.0	3.0
Minimum Service Life (hours)	6	6	6	8	8	2

Systems are challenged with the CWA's for the allotted challenge time. The systems are then monitored for the service life time allocated. Break through concentrations must not exceed maximum peak excursion or the integrated service life concentration during the test.

Laboratory Respiratory Protection Level (LRPL)

LRPL testing is a modified fit factor study performed while a group of subjects perform a series of exercises. The exercises were selected to simulate movements that first responders may need to perform while wearing respiratory protection. Test subjects are selected following developed protocols. Measured LPRL results for the different approvals are summarized below:

APR- Full face: The LPRL must be at least 2000 when the APR facepiece is tested in an atmosphere containing 20–40 mg/m3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers.

Tight Fitting and Loose Fitting PAPRs: The LPRL must be at least 10,000 for > 95% trials with the blower operating (blower on mode). Additionally, tight fitting PAPRs shall have a measured LRPL of 2,000 for > 95% trials with the blower not operating (Blower Off mode). A modified LRPL using a sample size of 8 subjects will be used for this evaluation. PAPR LRPL testing is performed in an atmosphere containing 20–40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4–0.6 μm.

SCBA: The LPRL must be at least 500, when the SCBA facepiece is tested in a negative pressure mode in an atmosphere containing 20–40 mg/m3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers.

Additional Testing

There are additional requirements in the standards which include field of vision, durability, and environmental conditioning. These additional tests are outlined in the standards which can be found at the NIOSH NPPTL website; *http://www.cdc.gov/niosh/npptl/standardsdev/cbrn/default.html.*

Industrial Use

NIOSH issued interim guidance for using CBRN Canisters for activities other than response to terrorist events in September of 2005.

In this guidance NIOSH states that the "unique protective qualities of the canister make it a 'dual purpose' canister, allowing it to also be used to effectively protect against the same toxic industrial chemicals/materials that may be encountered in non-terrorist environments (industrial and disaster site environments) as well as terrorist environments." NIOSH CBRN canister/cartridge approvals incorporate the following toxic industrial chemical or particulate protections:

- Organic Vapors (OV)
- Acid Gases (AG)
- Base Gases (consisting of allyl amine, ammonia, dimethyl hydrazine, 1, 2, methyl hydrazine)
- hydrides (consisting of arsine, germane, phosphine, stibine)
- nitrogen oxides (consisting of nitric acid, fuming nitric acid, nitrogen dioxide, nitrogen tetraoxide, and nitrogen trioxide)
- formaldehyde
- Particulates (P100, PAPR HE)

CBRN canisters/cartridges are air-purifying elements and time of use is limited by their mechanisim for capturing the type of substance being removed, the concentration of the substance being removed, the ambient temperature and humidity at the time of removal, carbon porosity, and the air-flow rate. The OSHA Respiratory Protection Standard [29 CFR 1910.134] requires that employers implement change schedules for canisters

SCBA facepiece is tested in a negative pressure mode

where end-of-service-life indicators (ESLI) do not exist or are not appropriate for the work environment. The respirator manufacturer should be contacted for appropriate guidance on a CBRN canister change schedule for the intended use. Once the change schedule has been determined, it must be implemented by the user.

As with all NIOSH-approved respirators, CBRN cartridges/canisters should be used in accordance with the NIOSH cautions and limitations specified on the NIOSH approval label which accompanies each respirator. The manufacturer's user instructions should also be followed.

Escape CBRN Approvals

NIOSH has developed a CBRN standard for escape respirators. The standard can be found on the NIOSH NPPTL website. Escape respirator approvals are a bit different since these respirators are for shorter durations and will be used more by general office workers and not first responders or first receivers. Approvals are for 15 minute time durations claimed by the manufacturers. Gas and vapor service life testing is similar to canister service life testing for the APR full face CBRN standard. The difference in service life testing is mainly the challenge times.

Pending CBRN Approval Standards

NIOSH has a proposed CBRN standard for closed circuit self contained breathing apparatus' (CC-SCBA). The proposed standard can be found on the NIOSH NPPTL website. There have also been discussions for developing respiratory protection approval standards for combination respirators, for example a PAPR/SCBA system.

Conclusion

Over the past several years NIOSH has developed and published CBRN Respiratory Protection Approval standards for APR, APR- escape, PAPR and SCBA respirators. The article is meant as a general over view of these standards and is not a substitute for the actual standards. Complete and proposed standards are available at the NIOSH NPPTL web site *http://www.cdc.gov/niosh/npptl*.

References

OSHA Letter of Clarification. *Application of HAZWOPER (1910.120) to terrorist and weapons of mass destruction incident responses.* (2003, November 24).

OSHA/NIOSH Interim Guidance - (February 2006) Chemical - Biological - Radiological - Nuclear (CBRN) Personal Protective Equipment Selection Matrix for Emergency Responders - Nerve Agents

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