Chemical, Biological, Radiological, and Nuclear (CBRN) Respiratory Protection Handbook

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U.S. Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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Preface

Chemical, biological, radiological, and nuclear (CBRN) hazards are constantly evolving in type, intent of use, and ways of dissemination. Emergency responders would most likely use air-purifying respirators (APRs) with CBRN cannisters against all hazards in an intentional or unintentional event. Thus, new and emerging hazards must be identified to ensure APRs with CBRN canisters continue to provide protection to those responders.

This 2025 handbook updates the original *CBRN Respiratory Protection Handbook* (former Publication No. 2018-166). This handbook reflects new and emerging chemical and radiological hazards information identified during a recent hazard assessment conducted by the National Institute for Occupational Safety and Health (NIOSH), Department of Homeland Security, and Department of Defense. As a result of this hazard assessment, NIOSH expanded its CBRN APR Protection List to capture additional hazards that NIOSH Approved® APRs with CBRN canisters would provide protection against. The changes to NIOSH's CBRN APR Protection List are captured in Chapter 2, Table 2-1. Additionally, changes in Chapter 3 reflect updates to National Fire Protection Association (NFPA) standards involving respirators with CBRN protections.

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Acronyms and Abbreviations

ANSI	American National Standards Institute
APER	air-purifying escape respirator
APF	assigned protection factor
APR	air-purifying respirator
ASTM	American Society for Testing and Materials
ATP	adenosine triphosphate
BB	Buddy Breather
C&L	cautions and limitations
CAP	capacity
CBRN	chemical, biological, radiological, and nuclear
CDC	Centers for Disease Control and Prevention
CFR	United States Code of Federal Regulations
CO	carbon monoxide
CS	2-chlorobenzylidene malononitrile
CWA	chemical warfare agent
DOP	dioctyl phthalate
EBSS	Emergency Breathing Support System
EMS	emergency medical services
EN	European Standards
EPA	Environmental Protection Agency
EPDM	ethylene propylene diene monomer
ESLI	end-of-service-life indicator
FF	fit factor
GB	sarin
HAZWOPER	Hazardous Waste Regulation
HD	distilled sulfur mustard
HR	hazard ratio
IAB	InterAgency Board for Equipment Standardization and Interoperability
IDLH	immediately dangerous to life or health

Li-ion	lithium-ion
$LiMnO_2$	lithium-manganese dioxide
$LiSO_2$	lithium-sulfur dioxide
lpm	liters per minute
LRPL	Laboratory Respirator Protection Level
MPC	minimum packaging configuration
MSHA	Mine Safety and Health Administration
NFPA	National Fire Protection Association
NiMH	nickel-metal hydride
NIOSH	National Institute for Occupational Safety and Health
NPPTL	National Personal Protection Technology Laboratory
OSHA	Occupational Safety and Health Administration
PAPR	powered air-purifying respirator
PEL	permissible exposure limit
PLHCP	physician or other licensed health care professional
PPE	personal protective equipment
RDECOM	Research, Development, and Engineering Command
REL	recommended exposure limit
RFT	respirator fit test
RPD	respiratory protective device
SAR	supplied-air respirator
SCBA	self-contained breathing apparatus
TIC	toxic industrial chemical
TRA	Test Representative Agent
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
UEBSS	Universal Emergency Breathing Support System
VX	O-ethyl S-[2-(diisopropylamino)ethyl] methylphosphonothioate

Chapter 1: Introduction

Since 2001, the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH) has established and maintained performance and design standards for respiratory protective devices (RPDs) to protect against chemical, biological, radiological, and nuclear (CBRN) hazards and toxic industrial chemicals. No standards for the use of RPDs by U.S. emergency response personnel that covered the full range of expected CBRN threats existed prior to 2001.

Federal regulations require emergency response personnel to use respirators approved by NIOSH for the expected hazards. Equipment performance standards were needed to protect against CBRN threats. Neither industrial nor military respirators provided protection from all potential CBRN respiratory hazards.

Research and testing to produce the necessary standards involved the partnership of several federal departments and agencies: Department of Justice; Department of Homeland Security; Department of Defense, U.S. Army Research, Development and Engineering Command (RDECOM);[a] Department of Commerce, National Institute for Standards and Technology (NIST); and the Department of Labor, Occupational Safety and Health Administration (OSHA).

The NIOSH RPD approval standards and tests developed for CBRN protections are highly specialized. The advanced CBRN respirators have unique characteristics related to selection, use, and maintenance compared to NIOSH Approved® respirators that do not offer CBRN protections. Due to the enhanced protection afforded by NIOSH Approved CBRN respirators, it is likely that the respirators will also be used in industrial applications.

Nationally prominent organizations have identified the need for advice and training on CBRN respirators. Among these are the RAND Corporation, Science and Technology Policy Institute, and the Federal InterAgency Board (IAB) for Equipment Standardization and Interoperability. Responders in several RAND studies clearly expressed the need for guidelines related to personal protective equipment (PPE), including respirators [Bartis et al. 2005; Jackson et al. 2002; Jackson et al. 2004; LaTourrette et al. 2003; Willis et al. 2006]. As early as 2002, RAND reported:

> One of the clear messages of the conference (December 10, 2001) was that most emergency workers do not believe that they are prepared with the necessary information, training, and equipment to cope with many of the challenges associated with the response to a major disaster such as the World Trade Center attack or for threats associated with anthrax, and similar agents [Jackson et al. 2002].

Another RAND study indicated:

> In sum, community representatives stressed that a greater amount of training and education must be part of any policy to improve the protection of emergency responders in the line of duty [LaTourrette et al. 2003].

An IAB annual report also underscored the need for guidance:

> The emergency responder community has a need for guidance and information on the selection, use, and maintenance of CBRN respirators to ultimately reduce incidences of respiratory related injury for nearly 4 million career and volunteer corrections, emergency medical services, firefighting, and law enforcement responders [IAB 2009].

[a] Formerly U.S. Army Soldier and Biological Chemical Command (SBCCOM)

Objective

This handbook fills the critical need for authoritative technical information on CBRN RPDs and will assist any user of CBRN respirators to improve selection, use, and maintenance. This information is particularly useful to individuals responsible for administering respirator protection programs or developing training programs.

The handbook is intended for organizations that use CBRN respirators in emergency response applications (e.g., fire service, law enforcement, emergency medical services, and corrections officers). Others who use CBRN respirators in industrial, public works, construction, utility, and other non-emergency applications will also benefit from this information. This handbook does not include information on how to conduct response activities.

The following chapters can be used to develop a more effective CBRN respiratory protection program and establish effective training programs in support of other requirements such as relevant National Fire Protection Association (NFPA) and OSHA standards. A relevant NFPA standard is NFPA 470 (Hazardous Materials/Weapons of Mass Destruction (WMD) Standard for Responders). Relevant OSHA and Environmental Protection Agency (EPA) standards include Title 29 Code of Federal Regulations (CFR) 1910.134 (Respiratory Protection) and 1910.120 (Hazardous Waste Operations and Emergency Response); and Title 40 CFR Chapter 1, Part 311 (Worker Protection).

The Need for Special CBRN RPD Standards and Tests

Pre-9/11

From March 10 to 12, 1999, NIOSH, RDECOM, and OSHA jointly sponsored a technical workshop to explore potential hazards, respiratory protection needs, RPD standards, and public health and medical community concerns associated with chemical and biological terrorism and other crisis situations. The workshop was one of the first national forums to systematically identify emergency responders and define their respiratory protection needs [NIOSH 2000].

More than 140 representatives from 63 emergency responder, firefighter, domestic preparedness, equipment manufacturing, federal research, and state and federal regulatory organizations participated. This workshop marked the beginning of NIOSH standards development activities to add CBRN protection to several respirator classes.

Earlier that same year, the International Association of Fire Chiefs (IAFC) asked NIOSH if a NIOSH Approved, NFPA-compliant, self-contained breathing apparatus (SCBA) would protect firefighters against chemical and biological warfare agents. NIOSH did not know the answer but suspected that the apparatus would not provide the needed protection. Neither NIOSH (42 CFR 84) nor NFPA RPD standards included an SCBA performance evaluation against CBRN agents. The IAFC and International Association of Fire Fighters urged NIOSH to provide leadership to bring appropriate military, safety, and health experts together to answer this question and develop the standards necessary to protect the nation's emergency responders.

In response, NIOSH established partnerships with organizations whose expertise and resources were required to address the gaps in knowledge, technology, standards, and training. The principal federal agencies that collaborated with NIOSH were:

- Department of Justice, Office of Justice Programs, Office for Domestic Preparedness
- Department of Commerce, NIST
- Department of Defense, U.S. Army RDECOM
- Department of Labor, OSHA

Other organizations whose support was essential for the successful development and implementation of the NIOSH CBRN RPD standards were:

- IAFC
- International Association of Fire Fighters
- International Safety Equipment Association
- Memorial Institute for the Prevention of Terrorism (Oklahoma City)
- National Fire Protection Association (NFPA)

The collaboration with NIST and RDECOM was of foremost importance. NIST administered federal funds made available from the Department of Justice to substantially finance the research and technical activities required to develop new standards. RDECOM applied its expertise with military warfare agents and its highly specialized laboratories to conduct respirator evaluations, analyses of human factor requirements, and CBRN hazard assessments of possible chemical warfare agent (CWA) incidents.

The hazard assessments conducted by RDECOM and NIOSH considered physical chemistry characteristics, vapor pressure-based saturation estimates, and terrorism venue modeling techniques to generate information about potential hazards at an incident involving CWAs. For these assessments, RDECOM considered the means of delivery and dissemination (i.e., explosion, spill, spray) of the CWA combined with other variables, including the amount of CWA (i.e., small containers, large drums) and the environmental and physical characteristics of the area where the incident occurred (i.e., small rooms, large shopping centers, airport concourses). RDECOM also modeled conditions related to climate control (air circulation, etc.) for the various incident sites. A team of experts from the collaborating agencies agreed on the potential exposures.

Hazards and test procedures were established based upon exposure projections. SCBAs approved by NIOSH and NFPA standards were evaluated. The initial benchmark test results answered the key question raised by the IAFC: new standards and test procedures were needed to enhance industrial SCBA performance by adding CBRN protection. Thus, the NIOSH standards development process began with a sense of urgency.

A multi-agency CBRN standards development team was established. The team began development efforts to define an appropriate set of performance and design standards for respiratory protective equipment with CBRN protection in July 2000.

Lessons Learned from 9/11

Before completion of the first series of CBRN respirator standards, the nation and world were stunned by the devastating terrorist attacks on the World Trade Center complex and the Pentagon, and the crash of United Airlines flight 93 over Pennsylvania on September 11, 2001. Fortunately, these attacks did not involve the deliberate use of CBRN hazards against the U.S. population, and respirators with

highly specialized CBRN protection were not required for the response. However, this highlighted the need for new standards and CBRN RPDs approved by NIOSH.

Along with the ongoing CBRN RPD standards development process, NIOSH commissioned a series of studies with the RAND Corporation to identify gaps in PPE and RPD technology, standards, and training. The first of these studies involved lessons learned from terrorist attacks. NIOSH and RAND held a conference in New York City from December 9 to 11, 2001. Attendees included persons who responded to the 1995 attack on the Alfred P. Murrah Federal Building in Oklahoma City, the 9/11 attacks on the World Trade Center and the Pentagon, and the anthrax incidents that occurred in 2001. The first of four studies published by NIOSH and RAND provided key information about the shortcomings of PPE and RPDs used for large-scale, complex tasks having long duration [Jackson et al. 2002].

The studies revealed the need for an integrated respiratory protection program, RPD equipment standardization, and interoperable use of facepieces and air-purifying components. These findings were incorporated into the CBRN RPD standards development process.

For example, an interoperability requirement was added to address the respirator component supply shortages that occurred at the World Trade Center response operation. In September 2001, only components of a NIOSH Approved complete respirator assembly, as defined in the NIOSH certificate of approval, were permissible even when components from other manufacturers' respirators of the same type were available. The lack of availability of some components during the extended World Trade Center response may have reduced the equipment available to workers. The shortages caused delays in response activities while the proper components were obtained, alternate respirators were employed, and proper retraining was provided. In response, the standards established for CBRN air-purifying respirators (APRs), commonly referred to as CBRN gas masks, included special design requirements to ensure that all NIOSH Approved CBRN APR facepieces and filtering components (canisters), regardless of manufacturer, could be used together during an emergency and still provide the NIOSH-defined necessary level of CBRN protection.

Other findings noted the need for RPDs with scratch-resistant lenses, improved field of view, upgraded communications accessories, and more durable components for use in arduous environments.

The aftermath of the terrorist attacks revealed the need for escape respirators for public use during emergencies. Workers in buildings and private citizens may also need to evacuate the scene of a terrorist attack. In addition to the types of RPDs used by emergency responders, the multi-agency team added escape respirators to the list of RPDs that required enhanced standards and tests for CBRN protection.

CBRN Standards and Test Development and Implementation

The multi-agency team held joint public meetings and solicited public comments via NIOSH Docket-002 concerning standards and test requirements for SCBAs with CBRN protection (commonly referred to as CBRN SCBAs). Through this public process and the RDECOM testing, NIOSH identified the performance and design requirements desired in CBRN SCBAs.

NIOSH determined that all requirements could be met by applying the following standards and tests:

- Title 42, CFR, Part 84 (42 CFR 84)
- NFPA Standard 1981 for Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters
- Special tests including Chemical Agent Permeation and Penetration Resistance Against Sarin (GB) and Distilled Sulfur Mustard (HD), and Laboratory Respiratory Protection Level (LRPL)

On December 28, 2001, NIOSH issued a letter to all interested parties, notifying them of the acceptance of applications for testing and evaluating SCBAs for use against CBRN agents [NIOSH 2001]. These standards were adopted in 2003 by the IAB[b] and incorporated into the DHS[c] grants program.

CBRN RPDs and CBRN SCBAs were the first respirators used in non-military applications with protection against a broad range of chemical warfare agents, toxic industrial chemicals, and biological hazards. Subsequently, standards and tests were also developed and implemented for APRs, powered air-purifying respirators (PAPRs), and air-purifying escape respirators (APERs) [NIOSH 2003a,b, 2006].

The NIOSH standards development and respirator certification programs led to an increase in the national inventory of CBRN protection for emergency response personnel. This better protects emergency responders against various respiratory hazards. Multiple respirator models from several manufacturers are certified to the CBRN respirator standards. Additional information on approved models is available through the NIOSH Certified Equipment List website: https://www.cdc.gov/niosh/npptl/topics/respirators/cel/default.html.

The Department of Homeland Security, NFPA, and the IAB have endorsed and incorporated the CBRN respirator standards. The Department of Homeland Security grants now link to NIOSH's CBRN respirator performance standards. The performance requirements for CBRN respirators are also being included in the development of international standards (British Standards Institution).

Improved information and training on RPD selection, use, and maintenance are needed to address unique characteristics of CBRN RPDs. The information contained in this handbook will support the establishment of training programs compliant with:

- NFPA 470 (Hazardous Materials/Weapons of Mass Destruction [WMD] Standard for Responders)
- OSHA and EPA standards, including Title 29 CFR 1910.134 (Respiratory Protection) and 1910.120 (Hazardous Waste Operations and Emergency Response), and Title 40 CFR Chapter 1, Part 311 (Worker Protection)

[b] Sanctioned by the Attorney General of the United States, the InterAgency Board for Equipment Standardization and Interoperability (IAB) was founded by the Department of Defense Consequence Management Program Integration Office and the Department of Justice Federal Bureau of Investigation Weapons of Mass Destruction Countermeasures program on October 13, 1998. The mission objectives related to PPE were being drafted at the time of the NIOSH-Department of Defense-OSHA sponsored Chemical and Biological Respiratory Protection Workshop, March 10–12, 1999.

[c] On July 16, 2002, U.S. President George W. Bush established the Office of Homeland Security. The Homeland Security Act of 2002 established the Department of Homeland Security on November 25, 2002. It consolidated U.S. executive branch organizations related to homeland security into a single Cabinet agency.

More information about the standards and test procedures established for CBRN respirators may be found on the NIOSH website at: https://www.cdc.gov/niosh/npptl/RespStds.html.

The listing of all NIOSH Approved respirators that contain CBRN protection can be found on the NIOSH website at: https://www.cdc.gov/niosh/npptl/topics/respirators/CEL.

Chapter Summaries

Chapter 2 – NIOSH CBRN Respiratory Protective Device Approval Program describes the NIOSH RPD approval program, including the highly specialized performance and design standards and unique test procedures that ensure an RPD has CBRN protection capability. Understanding the standards and tests applicable to CBRN RPDs (including SCBAs, APRs, PAPRs, and APERs) provides knowledge about the respirators' cautions and limitations. This knowledge can be applied to establish an effective respiratory protection program and training programs tailored to the intended user when used with the specific instructions provided by the manufacturer and NIOSH approval labels.

Chapter 3 – CBRN Respirators introduces CBRN equipment. This chapter presents information for each CBRN RPD class, including information on the major components, uses and limitations, markings and labels, maintenance, and storage requirements. It also describes common uses of the RPD class and provides pictures to illustrate key characteristics of the respirators. For example, the chapter places special emphasis on information related to battery care for CBRN PAPRs. This chapter also describes the characteristics of each RPD that meet the CBRN standards and test requirements.

Chapter 4 – CBRN Respirator Selection provides key information about characterization of hazards and appropriate selection of CBRN RPDs. This chapter describes the steps required in a selection process, including knowledge of the hazard, workplace considerations, human factors, and the performance capabilities of the CBRN RPD. A decision logic flowchart provides further direction.

Chapter 5 – CBRN Respiratory Protection Program Requirements explains the importance of a complete program. It integrates information from Chapters 1 and 2 for administering the selection, use, and care of respirators in the workplace. This chapter describes the required elements of programs that are compliant with OSHA and the American National Standards Institute. Sample programs illustrate the diversity and level of detail typically found in compliant programs.

Chapter 6 – CBRN Respirator Fit Testing Methods gives a short history of fit testing and demonstrates the value of testing the fit of a respirator to each specific individual to ensure proper performance. This chapter covers the purpose of fit testing, frequency, various fit test methods, and exercises. Information about the qualifications of the fit test operator and record keeping is also presented.

Chapter 7 – CBRN Equipment and the Wearer covers fundamental information related to human physiology and aspects of respirator performance that affect a person's ability to wear CBRN RPDs. CBRN respirators and protective clothing are designed, assembled, and tested to ensure they meet the level of protection that first responders and ancillary personnel require to respond appropriately and safely to the emergency. Topics include the effects of breathing resistance, work rate/breathing ventilation rates, and tolerance to carbon dioxide buildup in the respirator. Knowledge of the physiological impact can aid in the selection and use of CBRN RPDs.

Chapter 8 – Respirator Decontamination and Disposal provides information about the various decontamination methods, cautions, and limitations. Decontamination is important for avoiding cross-contamination and potentially allows reuse of equipment that is expensive and difficult to

replace. It is also important when properly disposing of contaminated PPE. In every case, decontamination must be performed to allow for the safe removal of the protective ensemble. Decontamination approaches depend on many factors including the protective ensemble used, the known or suspected CBRN agent, the available decontamination resources, and the urgency of the situation.

Chapter 9 – CBRN Respirator User Training describes the goals and importance of training programs and provides information to help establish effective training for respirator users. The NIOSH respirator approval program ensures CBRN respirators are capable of protecting users from a wide range of potential hazards, but the expected level of protection cannot be achieved if users do not use the respirators properly. Initial and ongoing training are necessary to ensure each user is able to don and wear the respirator and other protective equipment while performing assigned duties. This chapter also describes the minimum requirements for achieving compliance with OSHA and NFPA standards.

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Chapter 2: NIOSH CBRN Respiratory Protective Device Approval Program

Introduction

The U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH) administers Title 42, Code of Federal Regulations (CFR), Part 84 (42 CFR 84), rules for approval of respiratory protective devices (RPDs). This administrative authority is jointly held by the U.S. Department of Labor, Mine Safety and Health Administration for RPDs used for mine rescue and other mine emergencies, as defined in the Memorandum of Understanding between the Mine Safety and Health Administration and NIOSH [Approval of respiratory protective devices, 1995].

42 CFR 84 specifies the mandatory minimum requirements NIOSH uses in conducting inspections, examinations, and tests to determine the effectiveness of respirators used during entry into or escape from hazardous atmospheres (§84.1[d]). It also outlines the requirements for applications for approval fees, packaging labels, product markings, respirator general construction and performance, and quality assurance. These minimum design, performance, test, and quality assurance standards define the protection levels of various types of respirators approved by NIOSH.

NIOSH Approved respirators are classified (§84.50) by the standards and testing requirements described in 42 CFR 84 Subparts G through L, N, O, and KK. These requirements have been found to provide respiratory protection for fixed periods of time against the hazards specified in the approval. The following are common types of respirators for which NIOSH prescribes requirements in 42 CFR 84: self-contained breathing apparatus (SCBAs) (Subpart H); gas masks (Subpart I); supplied-air respirators (Subpart J); non-powered air-purifying particulate respirators (Subpart K), and chemical cartridge non-powered air-purifying respirators (APRs) and powered air-purifying respirators (PAPRs) (Subpart L, KK); combination respirators with gas, vapor and/or particulate (various Subparts); special use respirators such as vinyl chloride respirators (Subpart N); and closed-circuit escape respirators (Subpart O).

NIOSH inspects and examines respirators and approval application content (technical specifications, drawings, user instructions), and it tests respirators to determine that the applicable requirements are met for *individual, completely assembled respirators*, described in §84.30(a). Certificates of approval are issued to an RPD that meets the applicable requirements of 42 CFR 84. Certificates of approval are not issued for any individual respirator components (§84.30[b]). Each certificate of approval includes labels to be used by the applicant with each approved respirator assembly (§84.31[d]). Use of the NIOSH label obligates the applicant to whom it was issued to maintain the quality level of manufactured respirators and assure the RPD is manufactured to the drawings and specifications upon which the certificate of approval is based (§84.33[f]).

In addition to those requirements, NIOSH performs the following functions:

- Conducts post-approval audits of respirators to assure they are produced in accordance with the manufacturer's product specifications as described in the approval records maintained by NIOSH
- Conducts post-approval manufacturing site audits to ensure the manufacturer's quality assurance system is as described in the approval records maintained by NIOSH
- Investigates complaints related to a respirator conforming to the certificate of approval, including NIOSH standards, performance, design, product and packaging markings, and test requirements
- Investigates conformity to NIOSH standards and test requirements of respirators involved in injuries and fatalities, when requested to do so
- Issues public notices such as safety alerts and announcements of respirator recalls or retrofits, or the revocation of the NIOSH certificate of approval

Information about the NIOSH RPD approval program—including lists of NIOSH Approved respirators (referred to as the NIOSH Certified Equipment List), NIOSH public announcements concerning approved respirators, standard test procedures for each RPD type, and other investigative reports—is available on the NIOSH website: https://www.cdc.gov/niosh/npptl. More information regarding CBRN resources can be found on the NIOSH CBRN respirator approval resources website: https://www.cdc.gov/niosh/npptl/CBRNrespApprovalResources.html.

Types of RPDs

NIOSH has only limited authority and flexibility specified in 42 CFR 84 (§84.60[b], §84.63[c], and §84.110[c]) to approve types of respirators not prescribed in 42 CFR 84, such as respirators for protection against chemical, biological, radiological, and nuclear (CBRN) hazards. These sections provide NIOSH with the limited authority 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."

These sections specify:

- 84.60(b) – "In addition to the types of respirators specified in subparts H through L of this part, the Institute shall issue approvals for other respiratory protective devices not specifically described in this part subject to such additional requirements as may be imposed in accordance with 84.63(c)."
- 84.63(c) – "In addition to the minimum requirements set forth in subparts H through L of this part, the Institute reserves the right to require, as a further condition of approval, any additional requirements deemed necessary to establish the quality, effectiveness, and safety of any respirator used as protection against hazardous atmospheres."
- 84.110(c) – "Gas masks for respiratory protection against gases and vapors other than those specified in paragraph (b) of this section, may be approved upon submittal of an application in writing for approval to the Certification and Quality Assurance Branch listing the gas or vapor and suggested maximum use concentration for the specific type of gas mask. The Institute will consider the application and accept or reject it

> because of on the basis of effect on the wearer's health and safety and any field experience in use of gas masks for such exposures. If the application is accepted, the Institute will test such masks in accordance with the requirements of this subpart" [Approval of respiratory protective devices, 1995].

To approve respirators with CBRN protection (commonly referred to as CBRN RPDs), NIOSH and its federal partners researched hazards, defined appropriate standards for each type of respirator, established test procedures, defined product and packaging markings, and determined appropriate cautions and limitations of use. Because these CBRN RPD requirements are not prescribed in 42 CFR 84, the standards, tests, applications for approval, and other requirements (e.g., fees) are voluntary, not mandatory. All other requirements of 42 CFR 84 (e.g., Subpart A: General Provisions, Subpart B: Application for Approval, Subpart D: Approval and Disapproval, Subpart E: Quality Control, Subpart F: Classification of Approved Respirators, and Subpart G: General Construction and Performance) and the NIOSH approval program investigative activities described above also apply to NIOSH Approved CBRN RPDs and the applicant to whom the certificate of approval is issued. Applicants submitting an application for a NIOSH CBRN RPD approval do so with this knowledge.

NIOSH established additional voluntary requirements for several types of RPDs with CBRN protection to meet the needs of a diverse range of emergency responders (firefighters, law enforcement, and emergency medical services), work activities, durations of use, and hazards. These RPD types include SCBAs [NIOSH 2001], APRs (gas masks) [NIOSH 2003b], PAPRs [NIOSH 2006b], and air-purifying escape respirators (APERs) (see Figures 2-1 through 2-4) [NIOSH 2003a]. NIOSH continues to establish standards and test requirements for other types of respirators, such as those with a combination of respirator types.

Figure 2-1. CBRN SCBA

Figure 2-2. CBRN APR

Figure 2-3. CBRN PAPR

Figure 2-4. CBRN APER

CBRN Protection – Key Standards and Tests

To acquire a NIOSH certificate of approval for a respirator with CBRN protection, an applicant must first obtain a NIOSH approval for the respirator type meeting the applicable requirements in 42 CFR 84. The applicant must also voluntarily meet additional national or international requirements (e.g., National Fire Protection Association, ASTM International, military, and European standards) and special tests for CBRN protection specified by NIOSH in accordance with §84.60[b], §84.63[c], or §84.110[c] as applicable to the respirator type. For information on the details of the 42 CFR 84 requirements, refer to Title 42 Code of Federal Regulations Part 84, Respiratory Protective Devices;

Final Rules and Notice [Approval of respiratory protective devices, 1995]. This chapter describes the key additional requirements for CBRN protection, including:

1. Chemical agent permeation and penetration resistance against distilled sulfur mustard (HD) and sarin (GB)—commonly referred to as "live agent tests" (all CBRN RPD types)
2. Laboratory respirator protection level (LRPL) test (all CBRN RPD types)
3. Canister gas/vapor challenge and breakthrough concentration service life tests and particulate filter efficiency tests (APR, PAPR, APER)
4. National/international requirements:
    - Durability/environmental conditioning (APR, PAPR [tight-fitting], APER)
    - Minimum packaging configurations (APR, PAPR [tight-fitting], APER)
    - Breathing resistance (SCBA, APR, PAPR [tight-fitting], APER)
    - Carbon dioxide and oxygen levels (PAPR [loose-fitting], APER)
    - Canister/cartridge color code (APR, PAPR)
    - Mechanical connector, gasket, tolerance analysis (APR)
    - Field of view, lens material haze, luminous transmittance, and lens abrasion resistance (APR)
    - Communications (APR)
    - Fogging (APR, APER)
    - Flammability and heat resistance in accordance with National Fire Protection Association (NFPA) Standard 1981 (SCBA, APER with carbon monoxide protection)
    - Training and donning time (APER)
    - Useful life (APER)
    - Hydration (APR)
    - Emergency Breathing Safety System (EBSS) (SCBA with EBSS Accessory)
    - Optional testing

Each of these additional requirements applicable to NIOSH Approved RPDs with CBRN protection is briefly described in the following sections. Detailed specifications for the standards and national or international requirements are available through the Standard Respirator Testing Procedures at: https://www.cdc.gov/niosh/npptl/stps/respirator_testing.html

Chemical Agent Permeation and Penetration Resistance Against Distilled Sulfur Mustard and Sarin (all CBRN RPD types)

NIOSH and its standards development partners (see Chapter 1: Introduction) carefully considered comments made by the public during public meetings and comments provided to the NIOSH Docket 002 (https://www.cdc.gov/niosh/docket/default.html). The emergency response community (e.g., International Association of Fire Chiefs; International Association of Fire Fighters) required that any standards and tests for NIOSH Approved CBRN RPDs include performance testing using chemical warfare agents (CWAs).

Anything less was considered unacceptable. Excluding performance testing using CWAs would leave responders with a level of uncertainty about the RPD protection, potentially leading to a lack of confidence in the protective equipment.

Based on this input, a systematic evaluation was performed on the physical characteristics of CWAs and toxic industrial chemicals (TICs) identified in several sources. These sources include the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Technical Guide 244 and the NFPA Standard 1994 on Protective Ensembles for Chemical/Biological Terrorism Incidents – 2000 Report on Proposals. A total of 151 CWAs/TICs were initially identified as potential candidates for test agents. As part of the review of physical properties, the chemicals were evaluated for permeation (molecularly diffusing through respirator materials) and penetration (seeping through respirator interfacing components). These are commonly referred to as live agent tests.

Sarin (GB) and sulfur mustard (HD) were selected due to their physical properties and molecular structure as the two representative agents for use during laboratory permeation and penetration tests of RPDs. GB and HD represent challenge agents based on their permeation and penetration characteristics, relative ease to produce, and their worldwide availability in thousands of metric tons.

GB is representative of nerve agents, including tabun, soman, and O-ethyl *S*-{2-[Di(propan-2-yl)amino]ethyl}*O*-ethyl methylphosphonothioate VX. Since GB is the most volatile (having a volatility of 22,000 mg/m^3) of the nerve agents and evaporates rapidly, it is used in testing only as a vapor agent. GB also permeates through materials more readily than G and V nerve agents.

HD was selected as a representative test agent because of its permeation characteristics. HD is a linear molecule (as compared to GB, which has a branched configuration) and is expected to permeate most materials faster than GB. A combination liquid droplet and vapor test was defined for HD testing. The test chamber used for conducting these tests is shown in Figure 2-5. Figure 2-6 illustrates where liquid droplets of HD are placed on the respirator and its components during testing. An HD vapor challenge is introduced into the test chamber containing the respirator with liquid HD droplets on it.

To determine the applicable level of chemical concentrations of GB and HD for laboratory testing, the U.S. Army Research, Development and Engineering Command (RDECOM; now referred to as the Combat Capabilities Development Command Chemical Biological Center) developed plausible incident scenarios. RDECOM considered possible venues (e.g., small room, large room, arena, and open air areas), dissemination devices for release of CWAs, and a wide variation in hazardous vapor concentration-time profiles. Scenarios evaluated included worst case (chemical saturation limit), high concentrations, Department of Defense military mask concentrations, and U.S. Army Domestic Preparedness evaluation levels.

RDECOM examined concentration-time profiles by evaluating the cumulative dose for time periods associated with various response activities. For example, for first responders wearing SCBAs, a period of 30 minutes was used; that time period is based on the capacity of a typical SCBA air cylinder. The initial 30 minutes will also generally be the time frame with the highest concentration as the agent dissipates over time.

Based on these factors and others (e.g., RPD types), “most credible event concentrations” were defined and used as test challenge concentrations during laboratory testing of NIOSH Approved RPDs against GB vapor, HD liquid droplets, and HD vapor.

The evaluation also considered concentration level impact on human health to determine an appropriate level of protection. Toxicological analysis drawing on test data for GB and HD exposures was used to define acceptable limits based on Acute Emergency Guideline Levels, established by the National Advisory Committee for Acute Emergency Guideline Levels for Hazardous Substances. CBRN RPD test criteria for each agent were based on a total exposure value (concentration over time), combined with maximum (peak) exposure values.

Figure 2-5. Live agent test chamber

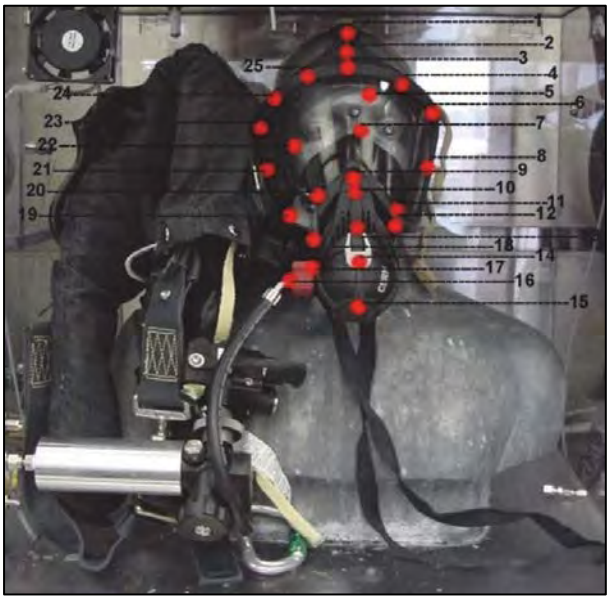

Figure 2-6. SCBA in live agent test chamber

The criteria established a cumulative exposure level over a specified period of time for each respirator type. The cumulative value was combined with maximum (peak) exposure value that could not be exceeded during the test period. Each RPD type has a defined CWA exposure test for specified periods based on this analysis and agreed upon by NIOSH and U.S. Army toxicologists.

Thus, the Chemical Agent Permeation and Penetration Resistance Performance Against Distilled HD and GB Test defines the performance of various types of NIOSH Approved respirators with CBRN protection [NIOSH, 2006a, 2015a,b]. Based on these laboratory tests specifically defined for each respirator type, the following cautions and limitations are placed on the use of the NIOSH Approved CBRN RPDs:

- CBRN SCBAs should not be used beyond six hours after initial exposure to chemical warfare agents (liquid or vapor) to avoid the possibility of agent permeation.
- CBRN SCBAs with Emergency Breathing Safety System (EBSS) accessory - EBSS activation or engagement of EBSS in either the donor or receiver mode changes the SCBA use to Escape-Only, approved service time for either the donor, or the receiver is no longer applicable. Additional critical cautions and limitations apply. Refer to section EBSS in the user's manual.

- CBRN APRs (14G approval[a]) should not be used beyond eight hours after initial exposure to chemical warfare agents to avoid the possibility of agent permeation or penetration. If liquid droplet exposure is encountered, the CBRN APR must not be used for more than two hours.
- Tight-fitting (14G approval) and loose-fitting (23C approval[b]) CBRN PAPRs must not be used beyond eight hours after initial exposure to chemical warfare agents to avoid the possibility of agent permeation or penetration. If liquid droplet exposure is encountered, the 14G CBRN PAPR demonstrated the ability to be used for up to but no more than two hours. The 23C CBRN PAPR must not be used where liquid droplet exposure is encountered.

Laboratory Respirator Protection Level Test (all CBRN RPD types)

The multi-agency CBRN standards development team established several performance and/or design requirements applicable to various CBRN RPD types to address a formidable list of potential chemical and biological exposures and accommodate a variety of response activities. The team recognized that the substantial level of care and expertise in the design, performance, manufacture, and approval-related engineering activities could be undermined if the respirator did not provide an appropriate fit between the respirator's facepiece and the wearer's face.

The 42 CFR 84 standards specified a qualitative fit test to evaluate the ability of RPDs to fit a variety of facial sizes. The qualitative tests are described in §84.104 [Gas tightness test, 1995] for SCBAs and §84.124 [Facepiece tests, 1995] for tight-fitting APRs, including PAPRs. The tests relied on the wearers' abilities to smell isoamyl acetate (i.e., banana oil) and are considered less reliable than modern quantitative fit test methodologies.

The team investigated alternate quantitative fit test methods as a more effective means of measuring the respirator facepiece fit to the wearer. NIOSH research comparing various respirator fit test methods found that the continuous high-flow deep probe method demonstrated high correlation with an actual measurement of exposure in a simulated health care setting (laboratory) [Coffey et al. 1998]. The team decided to merge the best characteristics of NIOSH and military respirator protection/face-fit testing in defining a new LRPL test. Figure 2-7 displays an LRPL test in progress. The test provides important information on the clarity of the manufacturer's user instructions and relies on feedback from human test subjects. Therefore, the LRPL test is a practical performance test. The

[a] NIOSH issues certificates of approval, referred to as a "14G approval," to APRs, PAPRs, and APERs as tight-fitting full facepiece gas mask respirators with canisters. The "14G" refers to the original U.S. Bureau of Mines test schedule (number) and revision level (letter) for tight-fitting gas mask respirators with canisters. CBRN APRs, PAPRs, and APERs with a 14G approval must not be used in oxygen-deficient atmospheres. These respirators may be used for escape from immediately dangerous to life or health (IDLH) atmospheres, but not for entry into them.

[b] NIOSH issues certificates of approval, referred to as a "23C approval," to APRs with cartridges and to PAPRs with loose-fitting hoods and helmets with cartridges. The "23C" refers to the original U.S. Bureau of Mines test schedule (number) and revision level (letter) for chemical cartridge respirators. CBRN PAPRs with a 23C approval must not be used in oxygen-deficient atmospheres. These respirators may not be used for escape from IDLH atmospheres.

test subjects use the instructions provided with the CBRN RPD to guide them in the proper preparation, donning, and wearing of the CBRN RPD.

This LRPL test assesses the ability of a CBRN RPD facepiece to fit a respirator wearer's face and does not rely on the wearer's ability to sense a proper fit. It measures the fit and produces a quantitative measurement. For each CBRN RPD type, an LRPL value is defined in a laboratory test atmosphere

Figure 2-7. LRPL test chamber

containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers (µm). The test procedure utilizes a quantitative corn oil method to measure the concentration of corn oil both outside (in the test chamber) and inside the facepiece when donned on 25 to 38 human test subjects, depending on the number of facepiece sizes offered by the manufacturer. The human subjects perform 11 one-minute exercises, including normal breathing, deep breathing, moving head side to side, moving head up and down, talking, sighting a mock rifle, reaching for the floor and ceiling, looking side to side on hands and knees, making a facial grimace, climbing stairs, and repeating normal breathing. The human subjects are selected using a recommended anthropometric facial size fit test panel. The exercises include the eight exercises (one repeated twice) defined in Occupational Safety and Health Administration (OSHA) requirements and three additional exercises: sighting a mock rifle, climbing stairs, and looking side to side on hands and knees (to represent crawling through low spaces).

The acceptable LRPL value (protection level) and test conditions vary depending on the CBRN RPD type [NIOSH 2001,2003a,b,2006b]. The following represents LRPL test specifications for each CBRN RPD type:

- SCBA - The measured overall LRPL value for each open-circuit, positive pressure SCBA shall be $\geq$ 500 when the SCBA facepiece is tested without the benefits of the air cylinder and the positive pressure inside the mask (negative pressure mode) in an

atmosphere containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4-0.6 µm.

- APR gas mask - The measured overall LRPL for each APR respirator shall be ≥2000 for greater than 95 percent of trials when the APR facepiece is tested in an atmosphere containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4-0.6 µm.
    - Some tests are performed to confirm that the facepiece can be used effectively with a canister of the maximum allowable weight of 500 grams and dimensions permitted by NIOSH requirements. This additional modified test for CBRN APRs evaluates the ability of the respirator facepiece to properly fit if used in an emergency interoperable configuration with a canister from another manufacturer's NIOSH Approved CBRN APR.

- Tight- and loose-fitting PAPR – The overall LRPL for each PAPR shall be > 10,000 for 95 percent of trials with the blower operating in an atmosphere containing 20-40 mg/m3 corn oil aerosol of a mass median aerodynamic diameter of 0.4-0.6 µm. For tight-fitting PAPRs only, the LRPL shall be ≥ 2,000 for 95 percent of trials with the blower not operating. A modified LRPL using a sample size of eight subjects will be used for evaluation. The respirator is tested in an atmosphere containing 20-40 mg/m3 corn oil aerosol of a mass median aerodynamic diameter of 0.4-0.6 µm.

- APER - The measured overall LRPL for each APER shall be ≥ 2,000 for 95 percent of trials, sampled in the breathing zone of the respirator, and shall be ≥150 for 95 percent of trials sampled outside the breathing zone (under the hood). The respirator is tested in an atmosphere containing 20-40 mg/m3 corn oil aerosol of a mass median aerodynamic diameter of 0.4-0.6 µm.

- User instructions provided by the manufacturer are crucial for properly selecting and donning the respirator facepiece, as well as for preparing the respirator for use. The respirator manufacturer may provide unique instructions for qualifying the respirator for use by an individual wearer. This could include instructions for adjusting the facepiece to fit small or large faces, such as inserting an additional sizing component (called an insert) into the mask. Some manufacturers may have additional components to use during storage to retain the shape of the facepiece.

- Some manufacturers of CBRN RPDs also recommend fit factors during fit testing of individual wearers much higher than those typically required of industrial respirators of the same RPD type. For example, where industrial tight-fitting full facepiece APRs require an individual fit factor of 500 (i.e., 10 times the class assigned protection factor of 50), some manufacturers of tight-fitting full facepiece CBRN APRs recommend an individual fit factor up to 2,500 for the CBRN APRs to be used for protection against CWAs. Failure to follow manufacturers' user instructions may result in improperly fitting facepieces for certain individual respirator wearers.

Canister Gas/Vapor Challenge and Breakthrough Concentration Service Life Tests and Particulate Filter Efficiency Tests (CBRN APR, PAPR, and APER)

NIOSH chose gases, vapors, and particulates for use in laboratory test evaluations of CBRN RPDs based on a comprehensive review of available technical data and consultations with other government agencies in the early 2000s (Department of Defense, Department of Justice, and Department of Energy). NIOSH also analyzed various chemical data lists, including lists from the Environmental Protection Agency, Agency for Toxic Substances and Disease Registry, NFPA 1994 Standard, USACHPPM Technical Guide 244, and other military classified sources [DoD 2001]. This review established a total of 151 TICs/CWAs as candidates for test challenge agents.

NIOSH also evaluated various lists of chemicals that could be used in a terrorist incident. In an effort to reduce the number of laboratory tests required to evaluate CBRN APRs, PAPRs, and APERs, NIOSH and its multi-agency team categorized potential respiratory hazards into chemical families with a test representative agent (TRA) identified for each family.

In categorizing the potential hazards into representative chemical families, NIOSH gathered a panel of respirator testing experts who developed a consensus position in the classification of possible respiratory hazards. A list of chemicals, biological hazards, and radiological hazards that were considered in developing standard requirements were covered in a presentation entitled, "CBRN Canister Requirements," delivered at the 2003 NIOSH public meeting [NIOSH 2003b]. In categorizing the potential hazards into representative families, NIOSH deliberated the classification of possible respiratory hazards. As a result of that deliberation, it was determined to relate the classification of the test representative agents to the sorbents[c] required to remove the challenge chemicals from the breathing zone of the respirator. The identified chemicals were classified into 1) Organic Vapors/Hydrocarbons; 2) Acid Gases; 3) Basic Gases; 4) Special Families (e.g., formaldehyde that requires special impregnated carbon); and 5) Unknowns (chemicals which require further study). Figures 2-8 and 2-9 show the test chamber and instrumentation used to assess the service life of air-purifying canisters and cartridges.

Figure 2-8. NIOSH service life test chamber

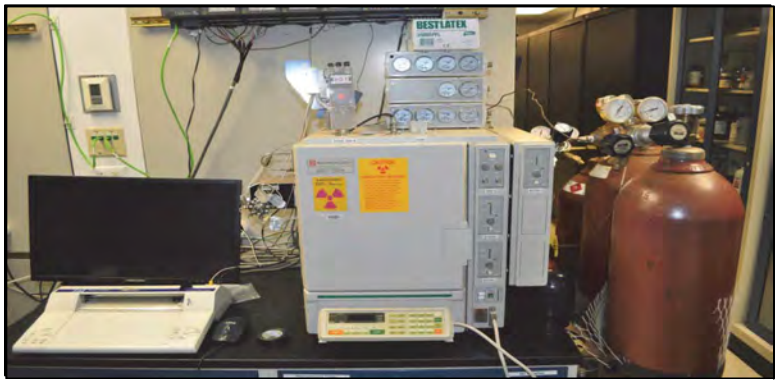

Figure 2-9. NIOSH gas chromatograph

[c] Vapor- and gas-removing respirators normally remove the contaminant by interaction of its molecules with a granular, porous material, commonly called the sorbent. The general method by which the molecules are removed is called sorption [NIOSH 1987]. The sorbent used in canisters and cartridges generally consists of activated carbon. Other materials, such as synthetic polymers and zeolite, have been tested for filtration, but no other absorbent has proven to be as widely applicable as activated carbon.

In 2018, NIOSH, the Department of Defense, and the Department of Homeland Security completed an updated hazard assessment. From 2016 to 2018, NIOSH partnered with these agencies to identify and evaluate new/emerging chemical and radiological respiratory hazards that may pose a risk to emergency responders [NIOSH 2022]. The project team included several individuals present during the original hazard assessment.

NIOSH and its partners first identified and compiled hazards by reviewing various hazard assessments available to the Department of Homeland Security. To assess each hazard, the team then developed a four-step evaluation process:

1. Evaluate its chemical and physical properties.
2. Evaluate its actual or anticipated filtration behavior within the CBRN canister (i.e., physical adsorption, chemisorption, or mechanical filtration).
3. Categorize it into one of NIOSH's Chemical Families.
4. Compare it against the existing TRA in its respective Chemical Family and determine if additional testing is needed

The team identified a total of 238 hazards (192 chemicals and 46 radiologicals). Of the 238 hazards, 203 could be grouped into one of the existing seven NIOSH Chemical Families—29 hazards were too unstable in the emergency responder operational environment (e.g., quick decomposition) and 5 needed further testing and evaluation to confirm NIOSH Approved APRs would adequately filter out these hazards [Greenawald et al. 2020]. Testing and further evaluation as part of this study concluded that current NIOSH Approved CBRN APR technology would provide protection against these five hazards.

After reviewing each of these 238 hazards, the key finding of this updated assessment was that the current 11 CBRN TRAs continued to represent the known CBRN hazards and should remain the basis for NIOSH respirator approval testing. Thus, no changes were needed to NIOSH's original 11 CBRN TRAs or NIOSH's CBRN APR, APER, or PAPR Statements of Standard. However, as a result of the described evaluation, NIOSH expanded its original CBRN APR Protection List of 139 hazards to include those additional hazards identified. It combined the two lists and removed duplicate chemicals. A total of 286 hazards now make up NIOSH's CBRN APR Protection List. The NIOSH CBRN TRAs and list of hazards in each NIOSH Chemical Family, constituting NIOSH's updated CBRN APR Protection List, can be seen in Table 2-1.

Actual CBRN incident responses may lead to adjustments to the CBRN APR Protection List. The service life of a CBRN canister depends upon many factors including environmental conditions (e.g., temperature, percent relative humidity), breathing rate, filtering capacity, and the type and concentration of contaminant(s) in the air. Filtering capacity is based on many product-specific criteria. It is important for users to follow the manufacturer's guidance and consult their respiratory protection program administrator for additional guidance on determining change-out schedules.

The Organic Vapor/Hydrocarbon class is diverse in its ability to be adsorbed and bound in activated carbon. The multi-agency team concluded that a method to determine the relative absorption affinity of carbon was required. Physical properties of the chemicals were the means of classification. The team considered a number of properties, including molecular weight, boiling

point, vapor pressure, relative toxicity, and polar/non-polar characteristics. Vapor pressure continues to be a key indicator of the ability to be adsorbed on activated carbon through physical adsorption [Karwacki and Jones 2000]. A benefit of this approach is that vapor pressure data of most compounds is readily available in literature or via laboratory determinations. Vapor pressure limits for acceptability were set at the value of carbon tetrachloride (92 mmHg @ 20°C). The lower the vapor pressure, the greater the affinity for the organic vapor/hydrocarbon to activated carbon; the higher the vapor pressure, the lesser the affinity to activated carbon.

When the Statements of Standards were being developed, the standards for gas masks in Europe and the United States (NIOSH) were reviewed. These included reviews of military purchasing specifications for ASZM-T carbon for C2A1 military canisters. The review had several key findings:

- Some of the chemicals used in testing were redundant, since other test chemicals would ensure carbon effectiveness against the gases in question (chlorine, hydrogen chloride, hydrogen fluoride, and arsine, as well as CS and CN tear gases).
- Cyclohexane is commonly used as an organic vapor test representative agent in European and Japanese standards. Meeting the organic vapor test for a canister and cartridge provides protection for all organic vapors having vapor pressures less than that of cyclohexane, which includes approximately 109[d] organic chemicals from the TIC/CWA list including GB and HD.
- The adsorption of acid gases (48[e] chemicals) is effectively addressed by laboratory testing using cyanogen chloride, hydrogen cyanide, hydrogen sulfide, and sulfur dioxide, each as a TRA.
- Ammonia is an effective TRA for the base gases: ammonia; ally amine; 1,2 dimethyl hydrazine; and methyl hydrazine.
- Formaldehyde, phosgene, phosphine, and nitrogen dioxide are considered special case chemicals and must be individually used as TRAs in testing.
- Phosphine is a hydride and must be removed catalytically (copper+2 and silver impregnants on carbon). It is individually used as a TRA.

Particulate biological hazards, particulate radiological/nuclear hazards, and other particulates were also considered as part of the development of test representative agents. The respiratory hazard posed by radiological or nuclear material results primarily from the dispersion of radioisotope dust particulates. The respiratory route of exposure to biological hazards may be through the dispersion of aerosols or droplets. NIOSH Approved P100® filters[f] are appropriate for filtration of these particles. Thirteen biological hazards including bacteria, viruses, and toxins that could be used as biological weapons are addressed as part of the standard [NIOSH 2002]. Radiological/nuclear hazards and chemical particulates are also addressed as part of the standard.

[d] Chemicals in the Organic Vapor Chemical Family were expanded from 61 to 109 as a result of the 2018 CBRN hazard assessment.
[e] Chemicals in the Acid Gas Chemical Family were expanded from 32 to 48 as a result of the 2018 CBRN hazard assessment.
[f] 42 CFR 84, Subpart K [§84.179(3)] defines a P100 filter as one having 99.97 percent efficiency with a label color of magenta, indicating it is a high efficiency particulate air (HEPA) filter.

Particulate filter efficiency testing described in 42 CFR 84, Subpart K was determined to be appropriate for filters of a CBRN RPD.

In summary, the chemical respiratory inhalation hazards can be addressed through testing the identified TRAs listed in the Table 2-1. This list was updated as a result of a 2018 comprehensive hazard assessment and evaluation process conducted by NIOSH and the Departments of Defense Homeland Security. The methodology and findings of this evaluation can be found in Greenawald 2020 [Greenawald et al. 2020].

A NIOSH Approved CBRN APR canister provides protection against a minimum of 286 identified CBRN hazards, which are classified into the following seven families: Acid Gases (48), Nitrogen Oxides (6), Base Gases (4), Hydrides (4), Formaldehyde (1), Organic Vapors (109), and Particulates (113) [composed of 56 chemical, 13 biological, and 44 radiological and nuclear particulate threats].

Table 2-1. NIOSH CBRN APR canister protection list

Acid Gas Family (48 hazards) *NIOSH certification testing uses 5 TRA chemicals to represent the Acid Gas Family. They include Cyanogen Chloride, Hydrogen Cyanide, Hydrogen Sulfide, Phosgene, and Sulfur Dioxide.*	
Boron tribromide	Hydrogen iodide
Boron trichloride	Hydrogen selenide
Boron trifluoride	Hydrogen sulfide
Bromine	Iodine (131/133)* ¥
Bromine chloride	Methanesulfonyl chloride*
Bromine pentafluoride	Methanesulfonyl fluoride*
Bromine trifluoride	Methanethiol (methyl mercaptan)*
Carbonyl fluoride	Methyl iodide (133/131)*¥
Chlorine	Methyl isocyanate*
Chlorine dioxide*	Methylphosphonic difluoride (DF)*
Chlorine pentafluoride	Pentacarbonyl iron*
Chlorine trifluoride	Perfluoroisobutylene*
Chlorosulfonic acid	Phosgene (CG)
Cyanogen chloride (CK)	Phosphorus trichloride
Cyclohexyl isocyanate*	Silicon tetrafluoride
Dichlorosilane	Sulfur dioxide
Ethyl chloroformate*	Sulfur trioxide
Ethyl isocyanate*	Sulfuric acid
Ethyl phosphonous dichloride	Sulfuryl chloride
Fluorine	Titanium tetrachloride
Hydrogen bromide	Tungsten hexafluoride
Hydrogen chloride	Thionyl chloride*
Hydrogen cyanide (AC)	Trichloromethylsilane*
Hydrogen fluoride	Trimethylchlorosilane*
"*" = added as a result of the 2018 CBRN Hazard Assessment ¥ = Radiological vapor	

Nitrogen Oxide Family (6 hazards) *NIOSH certification testing uses 1 TRA chemical (nitrogen dioxide) to represent the Nitrogen Oxide Family.*	
Nitric acid	Nitrogen monoxide*
Nitric acid, fuming	Nitrogen tetraoxide
Nitrogen dioxide	Nitrogen trioxide
"*" = added as a result of the 2018 CBRN Hazard Assessment	
Base Gas Family (4 hazards) *NIOSH certification testing uses 1 TRA chemical (Ammonia) to represent the Base Gas Family.*	
Allyl amine	Dimethyl hydrazine, 1,2
Ammonia	Methyl hydrazine
Hydride Family (4 hazards) *NIOSH certification testing uses 1 TRA chemical (Phosphine) to represent the Hydride Family.*	
Arsine	Phosphine
Germane	Stibine
Formaldehyde Family (1 hazard) *NIOSH certification testing uses 1 TRA chemical (Formaldehyde) to represent the Formaldehyde Family.*	
Formaldehyde	
Organic Vapor (OV) Family (109 hazards) *NIOSH certification testing uses 1 TRA chemical (Cyclohexane) to represent the Organic Vapor Family.* NOTE: Chemical warfare agents are in this TRA Organic Vapor Family.	
Acetone cyanohydrin	Hydroxyacetonitrile*
Acetylene tetrabromide*	Iso-butyl chloroformate
Acrolein*	Iso-propyl chloroformate
Acrylonitrile	Isobutyronitrile*
Allyl alcohol	Lewisite (L, L-1, L-2, L-3)
Allyl chlorocarbonate	Malathion*
Aniline*	Mercury*
Benzenethiol*	Methanesulfonyl chloride
Bis-Chloromethyl ether*	Methyl acrylonitrile*

Bromoacetone	Methyl fluoroacetate*
Bromobenzylcyanide (CA)	Methyl orthosilicate
Bromomethane (methyl bromide)*	Methyl parathion
Carbon disulfide*	Methyl phosphonic dichloride
Chlorfenvinphos*	Methyl thiocyanate*
Chloroacetone	Methyl vinyl ketone*
Chloroacetonitrile	Mustard, lewisite mixture
Chloroacetophenone (CN)	N-propyl chloroformate
Chloroacetyl chloride	Nicotine*
Chloroform*	Nitrogen mustard (HN-1, HN-2, HN-3)
Chloromethyl methyl ether*	O-anisidine*
Chloropicrin (PS)	O-chlorobenzylidene malononitrile (CS)
Chloropivaloyl chloride	O-ethyl-s-(2isopropyaminoethyl)methyl phosphonthiolate
Chlorosarin*	Octamethyl pyrophosphoramide (OMPA)*
Chlorosoman*	Parathion
Crotonaldehyde	Perchloromethyl mercaptan
Cyclohexane	Phenyl mercaptan
Cyclohexyl methyphosphonate	Phenylcarbylamine chloride
Cyclohexylamine*	Phenyldichloroarsine
Cyclosarin*	Phosgene oximedichloroforoxime
Dicrotophos*	Phosphorus oxychloride
Dibenz-(b,f)-1,4-oxazepine (CR)	Phorate*
Diisopropylfluorophosphate (DFP)*	Phosphamidon*
Dimethyl mercury*	Propionitrile*
Diketene	Propyleneimene*
Dimethyl sulfate	Sarin (GB)
Diphenylchloroarsine	Sec-butyl chloroformate
Diphenylcyanoarsine	Soman (GD)

Diphosgene (DP)	Sulfotep*
Distilled mustard (sulfur mustard; HD)	Tabun (GA)
Disulfoton*	Tert-octyl mercaptan
Epichlorohydrin*	Tetraethyl dithiopyrophosphate
Ethylenediamine*	Tetraethyl lead
Ethyl chloroacetate*	Tetraethyl pyrophosphate*
Ethyl chloroformate	Tetramethyl lead
Ethyl chlorothioformate	Tetranitromethane
Ethyl dichloroarsine*	Toluene-2,4-diisocyanate*
Ethyl phosphonothioicdichloride	Trimethoxysilane
Ethyl phosphorodichloridate	Trimethylacetyl chloride
Ethylene dibromide	1,1,2,2-Tetrachloroethane*
Ethylene oxide*	3-(Triethoxysilyl)propyl isocyanate*
Fluorotrichloromethane*	VM (EDEMO)*
2-fluoroethanol*	VX
Hexachlorocyclopentadiene	R-VX*
Hexaethyl tetraphosphate	VG (Amiton)*
Hexafluoroacetone*	"*" = added as a result of the 2018 CBRN Hazard Assessment

Particulate Family - Chemical (56 hazards) *NIOSH certification testing used 1 TRA chemical (dioctyl phthalate/DOP) to represent the Particulate Family.*	
1-Phenylsilitrane*	Fentanyl*
2,4-dinitrophenol*	Fluoroacetamide*
4-Aminopyridine*	Malononitrile*
4-t-Butyl bicylcophosphate*	Mercuric chloride*
Acetylfentanil*	Methamidophos*
Adamsite	Metham-sodium*
Aldicarb*	Methomyl*
Alfentanil*	N-ethylmaleimide*
Aluminum phosphide*	Osmium tetroxide*
Ammonium metavanadate*	Paraquat*
Anatoxin*	p-Chlorophenylsilitrane
Arsenic Trioxide*	Pentachlorophenol*

Azinphosmethyl*	Phenyl isocyanate*
Bifenthrin*	Phosgene oxime*
Brodifacoum*	Picrotoxin*
Bromadiolone*	Potassium cyanide*
3-Quinuclidinyl benzilate (BZ) *	Remifentanil*
Cadmium oxide*	Sodium arsenite*
Caffeine*	Sodium fluoride*
Carbofuran*	Sodium fluoroacetate
Carfentanil*	Sodium selenate*
Chlorpyrifos*	Strychnine*
Diacetylmorphine*	Sufentanil*
Diphacinone*	TETS*
Diphenylchloroarsine*	Thallium sulfate*
Diphenylcyanoarsine*	Vanadium pentoxide*
Epibatidine*	Ziram*
Particulate Family – Radiological/Nuclear (44 hazards)	
Americium (Am 241, 242*)	Mercury (Hg 197, 194)*
Antimony (Sb 124)*	Neptunium (Np 239)*
Argon (Ar-41)*	Nickel (Ni 63)
Berkelium (Bk 249)*	Phosphorous (P 32)
Calcium (Ca 47)*	Plutonium (Pu 238*, 239)
Californium (Cf 252)*	Polonium (Po 210)*
Carbon (C 14)	Promethium (Pr 147)
Cesium (Ce 137)	Radium (Ra 226)
Chromium (Cr 51)*	Samarium (Sm 153)*
Cobalt (Co 60, 58*, 57*)	Scandium (Sc 48)*
Copper (Cu 64)*	Selenium (Se 75)*
Gadolinium (Gd 148)*	Silver (Ag 110)*
Gallium (Ga 67)*	Sodium (Na 24)*
Gold (Au 198)*	Strontium (Sr 85*, 90)
Hydrogen (H 3)	Sulfur (S 35)*
Indium (In 111, 114)*	Technetium (Te 99)
Iodine (Io 131, 133*)	Thallium (Tl 202*, 204)
Iridium (Ir 192)*	Thorium (Th 232)
Iron (Fe 55)*	Uranium (Ur 235, 238)
Krypton (Kr 85)*	Ytterbium (Yb 169)*
Lanthanum (La 140)*	Yttrium (Y 88, 90)*
Manganese (Mn 53)*	Zinc (Zn 65)*

"*" = added as a result of the 2018 CBRN Hazard Assessment

In contrast to particulate filters, which are effective no matter what the particulate, cartridges and canisters used for vapor and gas removal protect against specific contaminants. To establish a test concentration and acceptable breakthrough level (pass/fail criterion) for each TRA, laboratory benchmark evaluations of existing NIOSH Approved gas mask canisters were analyzed to generate baseline performance data. The gas and vapor removal mechanisms (adsorption, absorption,

chemisorption, and catalysis) were also considered for various canisters and gas and vapor TRAs.[g] Where a canister uses a catalyst in the sorbent to influence the rate of reaction, there is a potential to create daughter byproducts that are toxic. These byproducts could potentially be as toxic as or more toxic than the atmospheric contaminant to be filtered. Thus, for the TRA where there is a concern for breakthrough of daughter byproducts, both the test agent and daughter products are monitored during NIOSH testing (i.e., for hydrogen cyanide testing, cyanogen is also monitored; for nitrogen dioxide testing, nitric oxide is also monitored).

The test concentration levels for a respirator cartridge were calculated by comparing the higher of a safety factor multiplier (varied depending on the TRA) on the NIOSH recommended exposure limit (REL) or OSHA permissible exposure limit (PEL), or three times the IDLH[h] value. In the instances where values other than the higher REL/PEL or IDLH values were used, the selection of an alternate value was based on test technology limitations or OSHA advice. Breakthrough concentrations were determined by doubling the REL/PEL or IDLH values. To establish the test and breakthrough concentrations, several iterations of NIOSH benchmark testing of cartridges and canisters were conducted.

Table 2-2 summarizes the standard established for gas life test challenge and breakthrough concentrations for canisters used on CBRN APRs and tight-fitting CBRN PAPRs, as well as cartridges used with loose-fitting CBRN PAPRs. NIOSH cartridge and canister gas life tests are performed using a single TRA challenge concentration. The gas life tests are conducted individually, and agents are not combined to simplify the testing process.

To determine an appropriate capacity for the CBRN APR canister, NIOSH reviewed national and international standards. All standards organizations require that industrial respirators be labeled to identify the specific chemical or classes of gases and vapors for which the respirator affords protection. The military standards, by contrast, focus on a battery of CWA challenges and filtration capacity over time. Canister/cartridge gas life is a function of the mass of sorbents, type of sorbents utilized, sorbent bed structure, and gas or vapor residence time.

The European Committee for Standardization and Australian standards limit the mass of replacement filters to 300 grams for half-mask protection and 500 grams for full facepiece protection. NIOSH performance requirements in 42 CFR Part 84 and the Japanese industrial standard (JIS T 8152:2012 [JSA 2024]) stipulate the minimum gas absorption capacities for each gas or vapor without stipulating the mass of the canister and cartridge.

NIOSH established a standard requiring the applicant, as part of the application for CBRN RPD approval, to specify a gas life (i.e., service life under test conditions) period for the canister. Short duration capacities are required to be identified in 15-minute intervals (15, 30, and 45). Long duration capacities are identified in 30-minute intervals (60, 90, and 120). The canister capacity maximum size

[g] Cyclohexane was chosen as a TRA because of the health issues associated with using carbon tetrachloride in laboratory tests, and the use of Cyclohexane by other standards organizations worldwide.

[h] OSHA defines an IDLH value in their hazardous waste operations and emergency response regulation as follows: An atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere (29 CFR 1910.120).

limitation is based on a maximum canister mass of 500 grams. Figures 2-10 and 2-11 show samples of CBRN canisters. In addition, the particulate filter is required to conform to the P100 filter requirements, as described in 42 CFR 84.

Table 2-2. Gas life test challenge and breakthrough concentrations for canisters and cartridges*

Test Representative Agent	Test Concentration (ppm) Concentration (ppm)		Breakthrough
	Cartridge	Canister	
Ammonia	1250	2500	12.5
Cyanogen chloride	150	300	2
Cyclohexane	1300	2600	10
Formaldehyde	250	500	1
Hydrogen cyanide	470	940	4.7**
Hydrogen sulfide	500	1000	5
Nitrogen dioxide	100	200	1 ppm NO_2, or 25 ppm NO***
Phosgene	125	250	1.25
Phosphine	150	300	0.3
Sulfur dioxide	750	1500	5

* Test samples are tested separately against each single TRA

** Sum of HCN and C2N2

***Nitrogen dioxide tests are monitored for both NO_2 and NO breakthrough. The breakthrough is determined by which quantity, NO_2 or NO, reaches breakthrough first.

Figure 2-10. CBRN CAP 1 canister

Figure 2-11. CBRN Cap 1 canister

National/International Requirements (CBRN RPD types shown below)

The key standards and tests described above assure that NIOSH Approved CBRN respirators provide protection against CWAs, TICs, biological/radiological/nuclear particulates, and other hazardous particulate matter. NIOSH established additional requirements to address product durability,

environmental conditions, and human interface requirements. These additional requirements derive from a variety of national and international standards. The requirements vary depending on the RPD type and its intended use. The following is a summary of each additional requirement.

Durability/Environmental Conditioning (APR, PAPR [tight-fitting], APER)

Prior to performing the laboratory evaluations of RPDs that have been submitted to NIOSH for CBRN RPD approval, NIOSH subjects the respirator assembly to a number of environmental and rough handling conditions. Table 2-3 below provides a synopsis of the rough handling tests.

Table 2-3. Rough handling (transportability, temperature range, survivability)

Test	Test Method	Test Condition	Duration
Hot Diurnal	Mil-Std-810F, 501.4	71°C max, cyclical	3 Weeks
Cold Constant	Mil-Std-810F, 502.4	Basic Cold,-32 °C	3 Days
Humidity	Mil-Std-810F, 507.3	Table 507.3-II, Natural Cycle, Cycle 1	5 Days Quick Look
Vibration	Mil-Std-810F, 514.5	US Highway Vibration, Unrestrained Figure 514.5C-1	12 Hours/Axis, 36 Hours Total (12,000 Miles)
Drop	3 foot drop onto concrete	Filter Only, 3 Axis	N/A

Note: RPDs are subjected to a hot, cold, humidity, vibration, and drop environmental exposure sequence order prior to Service Life High Flow; Service Life, particulate rating and permeation/penetration tests. Figures 2-12 and 2-13 show a NIOSH environmental conditioning chamber used to perform these tests.

Figure 2-12. Outside view of NIOSH environmental conditioning chamber

Figure 2-13. Inside view of NIOSH environmental conditioning chamber

Minimum Packaging Configurations (APR, PAPR [tight-fitting], APER)

NIOSH subjects the CBRN APRs and required components to environmental and durability conditioning tests in the manufacturer-specified minimum packaging configuration (MPC) (i.e., the canister is conditioned while stored in its original packaging as released by the manufacturer). NIOSH also subjects CBRN canisters to rough handling drop tests in their designated MPCs. The MPC is the protective packaging in which the end user will store or maintain the APR and required components after the APR has been issued for use. The end user is the person who will wear the respirator and derive protection from it. Failure to store the APR in the manufacturer's recommended MPC may

allow damage to occur and could affect the ability to provide the expected level of protection. The damage may not be detectible by the user prior to use.

Examples of common MPCs include hard plastic mask carriers, clamshell containers, drawstring plastic bags, cardboard/plastic containers, and hermetically sealed or vacuum-sealed canister bags. Each manufacturer is likely to have unique MPC requirements. The manufacturer's user instructions will identify the MPC requirements.

Breathing Resistance (SCBA, APR, PAPR [tight-fitting], APER)

Breathing resistance is an important performance characteristic of any CBRN respirator. For each respirator type, NIOSH specifies maximum allowable inhalation and exhalation breathing resistances, as shown in Table 2-4. The allowable resistances before and after the NIOSH test are described in the applicable standard for each respirator type. For example, the resistance to airflow for a CBRN APR is measured in the facepiece of the APR mounted on a test fixture with air flowing at a continuous rate of 85 liters per minute both before and after each gas service life bench test. An example of this test is shown in Figure 2-14. The maximum allowable resistance to airflow is as follows:

Table 2-4. Inhalation and exhalation breathing resistance requirements

	Chin Style Mounted	Non Facepiece
Inhalation		
Initial	65 mm H_2O	70 mm H_2O
Final [(1)]	80 mm H_2O	85 mm H_2O
Exhalation:	20 mm H_2O	20 mm H_2O

[(1)] Measured at end-of-service-life according to the CAP level

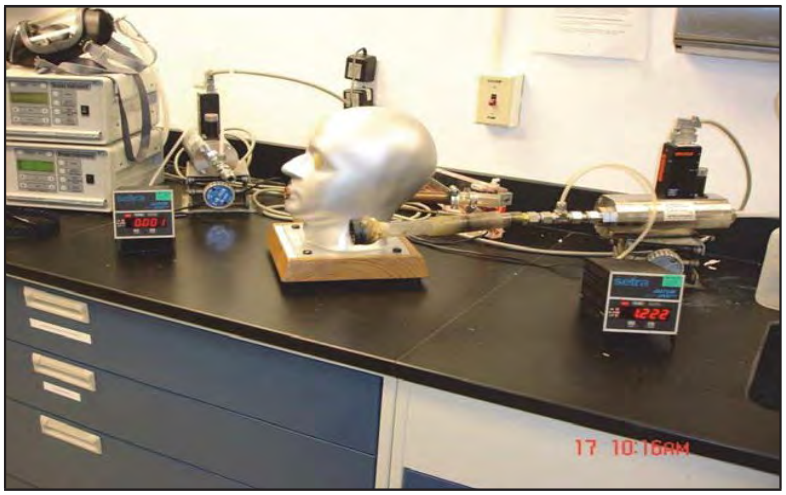

Figure 2-14. NIOSH breathing resistance measurement setup

Carbon Dioxide and Oxygen Levels (APR, PAPR [loose-fitting], APER)

The maximum allowable average inhaled carbon dioxide concentration is less than or equal to one percent. This measurement is taken at the mouth, while the respirator is mounted on a dummy head operated by a breathing machine. Figure 2-15 shows the test equipment used to measure carbon dioxide. The breathing rate is 14.5 respirations per minute with a minute volume of 10.5 liters. Tests

are conducted at an ambient temperature of 25 ± 5°C. A concentration of five percent carbon dioxide in air is exhaled into the facepiece. The minimum allowable oxygen concentration is 19.5 percent.

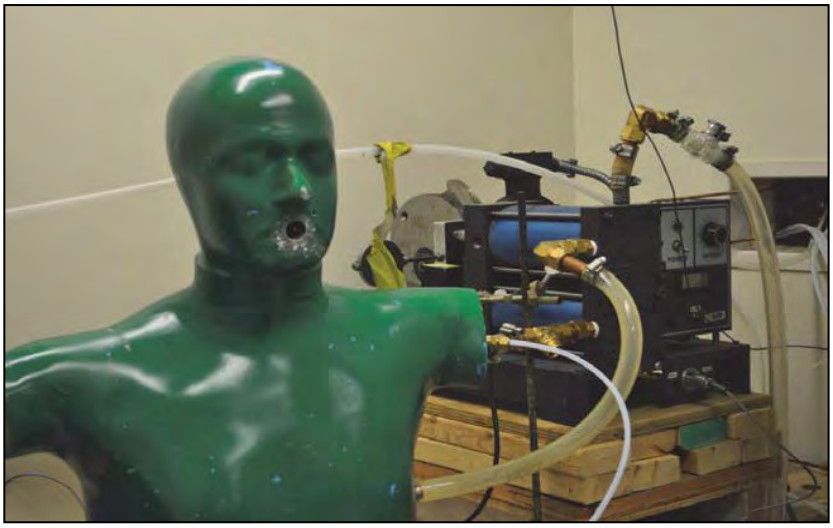

Figure 2-15. NIOSH CO_2 test apparatus

Canister/Cartridge Color Code (APR, PAPR)

The canister component/container label is usually an adhesive label placed on the canister and a printed label placed on the canister container. It contains less information than a full label. This abbreviated label contains the applicant's name and address; an approval number assigned by NIOSH; and protections, cautions, or limitations of use placed on the RPD by NIOSH. This label does not contain the unique configurations of components approved by NIOSH.

The labels placed on canisters are also color-coded. The color of a CBRN APR or PAPR canister is olive (Munsell notation 7.5 Y 5/6). The color marking can be achieved by either the color of the label or the body of the component. Where the color marking is achieved by label color, the body of the component may be any color.

Other individual components of the CBRN APR or PAPR assembly are not required to contain the NIOSH emblem or CBRN marking. However, NIOSH requires that each respirator, respirator component, and container be labeled distinctly to show the lot number, serial number, or approximate date of manufacture of the component.

Mechanical Connector, Gasket, Tolerance Analysis (APR)

To address response community interest in interoperable use of canisters and CBRN RPD facepieces during emergencies, NIOSH established design criteria for NIOSH Approved CBRN RPD facepieces and canisters. The requirements address the interface between the canister and the respirator facepiece and evaluate it as a complete assembly. The respirator assembly is required to use a standard thread in accordance with European Standard EN148-1:2018 [European Standards 2018].

Thread dimensions are measured with the instrumentation shown in Figure 2-16. The canister is required to be readily replaceable without use of special tools. The interface connector on the facepiece is required to be the female thread and gasket-sealing gland as identified in EN148-1. The canister shall use a male thread in accordance with EN148-1. For respirator assemblies where the filter canister is not directly attached to the facepiece (i.e., not mask-mounted), a female thread and gasket

Figure 2-16. NIOSH optical thread comparator

sealing gland connector complying with EN148-1 must be securely attached to a harness system to provide strain relief between the canister and the remaining respirator assembly. In addition to the requirements of EN 148-1, the gasket material shall be ethylene propylene diene monomer with a hardness of 65 + 10 shore A durometer at room temperature.

Field of View, Lens Material Haze, Luminous Transmittance, and Lens Abrasion Resistance (APR)

The full facepiece must have an effective field of vision not less than 70 percent of the natural field of vision. The overlapped field of vision must not be less than 20 percent of the natural overlapped field of vision. The field of view test procedure is based on procedures of EN136:1998 [European Standards 1998]. Figure 2-17 shows the instrumentation used for measuring the field of view.

Specimen CBRN APR facepiece lenses are tested for abrasion resistance. The average value of the tested specimens must not exhibit a delta haze greater than 14 percent. The applicant provides test data demonstrating compliance with the haze requirement when tested in accordance with NFPA 1981 Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services, 2019 edition, Section 8.9, Facepiece Lens Abrasion Test. Figure 2-18 shows the instrumentation used for performing the abrasion resistance and haze measurement.

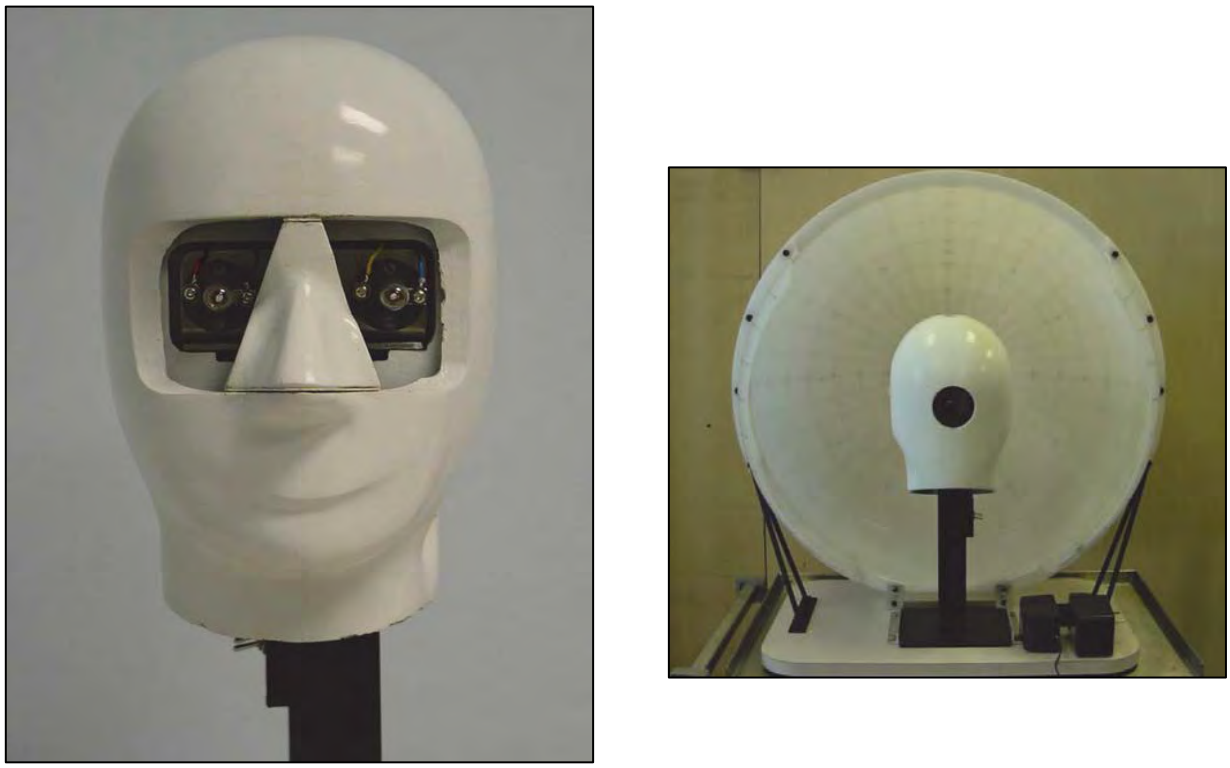

Figure 2-17. Stoll apertometer test fixture

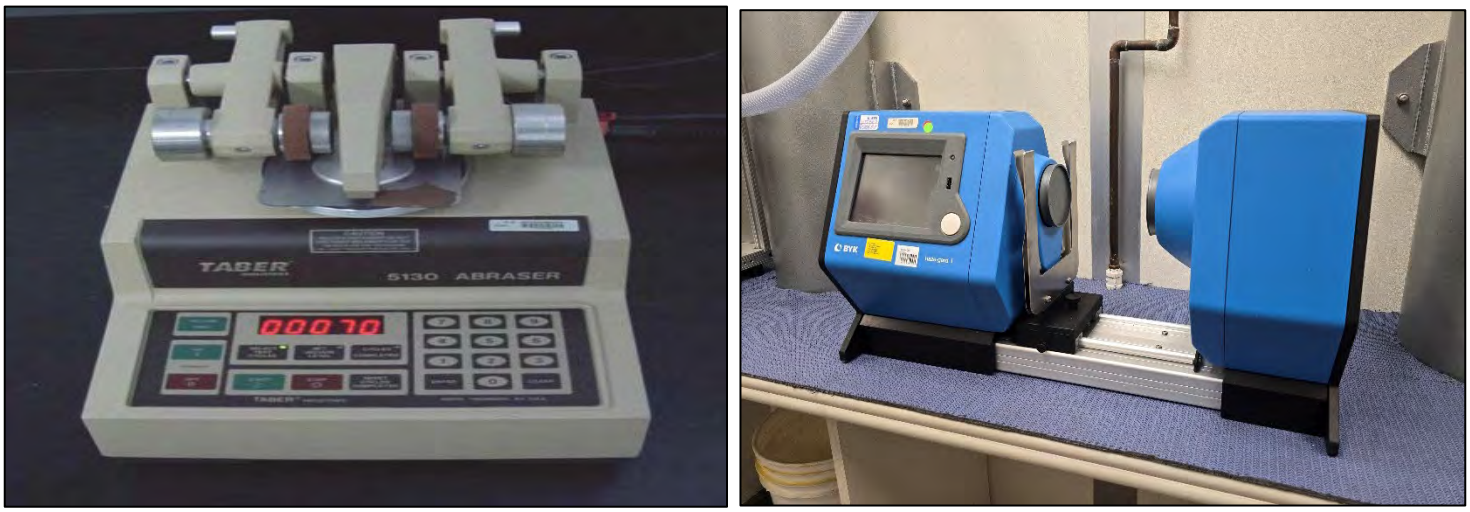

Figure 2-18. Haze apparatus

Communications (APR)

Speech intelligibility testing is accomplished using the Modified Rhyme Test [ANSI 1989], which evaluates a listener's ability to comprehend single words, providing an indication of speech transmission of the selected words. The Modified Rhyme Test consists of multiple lists of 50

monosyllabic, phonetically balanced words each. Each individual listener's average score with the respirator is divided by their average unmasked Modified Rhyme Test score to calculate a performance rating. The respirator performance rating for communications must be greater than or equal to 70 percent when tested in accordance with the communications test procedure.

Fogging (APR, APER)

The fogging test assesses the visual acuity of human test subjects with and without a CBRN RPD that has been laboratory conditioned in an environmental chamber at 15.5°C (60°F), 75 percent RH for four hours. A test participant enters a test chamber (maintained at -21°C) and sits quietly for five minutes. After the five-minute rest period, the participant self-dons the assigned respirator. A visual acuity test is then administered to quantify the impact of any lens fogging on vision. Figure 2-19 shows a fogging test chamber and visual acuity test chart. The respirator performance rating for resistance to fogging must be greater than or equal to 70 percent when tested in accordance with the fogging test procedure.

Figure 2-19. Low temperature/fogging test

Training and Donning Time (APER)

The applicant/manufacturer is required to identify training requirements associated with their APERs. At a minimum, this includes an instruction manual that addresses donning procedures, respirator use, maintenance (care and useful life), and cautions and limitations. The applicant must provide training aids to include a training respirator that mimics the performance of the NIOSH Approved RPD, such as inhalation and exhalation breathing resistance that will develop user proficiency in operation of the equipment. The applicant must also identify periodic refresher training requirements necessary to maintain user proficiency. The training materials are used by NIOSH as the basis for preparing the human test subjects in other test procedures such as breathing gas, LRPL testing, and donning.

The time to don the respirator from the ready-to-use configuration must be no greater than 30 seconds. The ready-to-use configuration is the state of the operational packaging prior to use, and means that immediately upon opening the packaging, users can don the respirator.

Useful Life (APER)

NIOSH defines useful life as the length of time a unit can remain deployed in the manufacturer's specified ready-to-use, stowed (i.e., stored) condition. NIOSH requires an initial useful life period of no greater than five years. However, this period can be extended by the manufacturer through an additional approval extension application to NIOSH. The expiration date is provided on packaging and may be located on the outside of the storage box and/or on the innermost vacuum-sealed package.

Hydration (APR)

For CBRN APRs equipped with a hydration facility (shown in Figure 2-20), the CBRN APR respirator must meet all requirements of the CBRN APR standard with the hydration facility in place. In addition, dry drinking tube valves, valve seats, or seals are subjected to a suction of 75 mm water column height while in a normal operating position. Leakage between the valve and the valve seat may not exceed 30 milliliters per minute.

Figure 2-20. CBRN APR with hydration tube

Emergency Breathing Safety System (SCBA with EBSS Accessory)

The 2014 Letters to All Interested Parties revised the policy regarding the use of Emergency Breathing Support Systems (EBSS) to align with applicable NFPA standards [NIOSH 2014]. All components of the EBSS must be able to operate at the specified low temperature limit without adversely affecting the operation of the SCBA, as determined by testing conducted in accordance with the current revision of Standard Testing Procedure TEB-CBRN-ASR-STP-0219.

At the minimum activation pressure with the EBSS receiver line held open to atmosphere, the donor unit must be able to meet pressure-demand performance requirements through the remainder of the air supply, as determined by testing in accordance with the current revision of Standard Testing Procedure TEB-CBRN-ASR-STP-0220.

Starting from a full cylinder and prior to the minimum End-of-Service-Time-Indicator activation pressure, the EBSS donor/receiver line will be opened to atmosphere and held open. The duration for which the host unit performance meets pressure-demand performance requirements will be measured and recorded, as determined by testing in accordance with the current revision of Standard Testing Procedure TEB-CBRN-ASR-STP-0220.

Optional Testing

At the time of this writing, updates made to NFPA 1986 and 1987 proposed optional tests for other chemical hazards [NFPA 2023a,b]. The performance requirement and test procedures for these optional tests are defined in those respective standards.

The information provided in this chapter is not a complete description of the standards, tests, and additional requirements for NIOSH Approved CBRN RPDs. This chapter provides only a summary of the key requirements. For each of the requirements applicable to NIOSH Approved RPD with CBRN protection and background information on the standards, visit: https://www.cdc.gov/niosh/npptl/respmanuf. For details on the applicable test procedures visit: https://www.cdc.gov/niosh/npptl/stps/respirator_testing.

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Chapter 3: CBRN Respirators

Introduction

Chemical, biological, radiological, and nuclear (CBRN) respirators provide respiratory protection against warfare and chemical agents that may be present in terrorist attacks or other hazardous material emergencies. These are the types of respiratory protection equipment subject to the requirements of standards developed by the National Institute for Occupational Safety and Health (NIOSH) in voluntary approval programs pursuant to 42 Code of Federal Regulations (CFR) [Approval of respiratory protective devices, 1995]. NIOSH developed CBRN standards (as explained in Chapter 2) for self-contained breathing apparatus (SCBAs) [NIOSH 2002], air-purifying respirators (APRs) [NIOSH 2003b], powered air-purifying respirators (PAPRs) [NIOSH 2006b], and air-purifying escape respirators (APERs) [NIOSH 2003a].

This chapter describes different types of CBRN respirators and the unique characteristics that distinguish them from similar industrial respirators. This information will help users and the authorities with jurisdiction to develop written respiratory protection programs that meet the requirements of the Occupational Safety and Health Administration (OSHA) respiratory protection regulation [OSHA 1999]. This information can also be used in training programs for CBRN respirators, as stated in OSHA's Hazardous Waste regulation (HAZWOPER) [OSHA 2006] and National Fire Protection (NFPA) standards 470 [NFPA 2022] and 1404 [NFPA 2018]. NFPA1404 will be consolidated into a future new standard, NFPA1400. Chapters 5 and 9 describe these requirements in more detail.

In order to use CBRN respiratory protective devices (RPDs) effectively, a user must understand important performance, design, and use characteristics:

- Ways to recognize that a respirator has CBRN protection
- The limitations of the equipment and where to find them
- The shelf and service life of canisters or cartridges
- Maintenance requirements and schedules
- Disposal practices for CBRN RPDs

Proper selection and usage of CBRN RPDs should not interfere with other personal protective equipment (PPE) ensembles, such as a body protection. The adequate selection of PPE should complement the respiratory protection needed for a particular protection level. Responders should select PPE by carefully considering the expected type of hazard(s) that may be present at the scene and the potential impact on the responder's life in any given response situation. The NIOSH Publication No. 2008-132, "Guidance on Emergency Responders Personal Protective Equipment (PPE) for Response to CBRN Terrorism Incidents," presents information on emergency responder PPE [NIOSH 2008].

CBRN Unique Features

The testing procedures used by NIOSH during the approval process relate to the unique features of a CBRN RPD. Depending on the type of CBRN RPD, the RPDs must pass tests such as chemical warfare agent (CWA) permeation resistance, laboratory respirator protection level (LRPL), and environmental conditioning to gain CBRN approval. The standard testing procedures for each CBRN device can be found the NIOSH Standard Respirator Testing Procedures website [NIOSH 2024].

The NIOSH Certified Equipment List identifies approved CBRN respirators [NIOSH 2020]. Approved CBRN respirator types include:

- CBRN SCBA
- CBRN PAPR
- CBRN APR
- CBRN APER

This chapter will focus on these four types of CBRN RPDs. Information will be provided, as appropriate, in the following areas:

- Description
- Approval labels
- Testing, cautions, and limitations
- Canister packaging and shelf life
- Canister service life
- Minimum packaging configuration (MPC)

Components and accessories for CBRN APRs are also discussed. These include CBRN PAPR batteries, CBRN PAPR retrofit kits, and CBRN APR accessories. It is important to confirm the components required in a NIOSH Approved® configuration. Manufacturers may offer additional components that are optional accessories. For example, one manufacturer may offer a lens cover (outsert) as an optional component to the facepiece, whereas another manufacturer's RPD may require the lens outsert as a condition of approval.

CBRN SCBA

The CBRN SCBA was first adopted as an upgrade or option to firefighters' SCBA, as compliant with the performance requirements of NFPA 1981, 2002 Edition [NFPA 2002]. However, NIOSH approved the first CBRN SCBA equipment configurations based on NFPA 1981, 1997 Edition [NFPA 1997]. When this standard was revised in 2007, CBRN protection became a mandatory requirement for the NFPA 1981, 2007 Edition [NFPA 2007], in accordance with the NIOSH Statement of Standard for NIOSH CBRN SCBA Testing. The subsequent 2019 Edition of NFPA 1981 also contains CBRN requirements. In the future, NFPA 1981 will be consolidated into a new document NFPA 1990.

SCBAs that are compliant with the later edition can be used to protect users during structural fires and other types of emergencies requiring SCBA (e.g., hazardous materials operations), as well as to provide respiratory protection from CBRN hazards during a terrorist attack [NFPA 1997].

SCBAs that are compliant with the current edition of NFPA 1986: Standard on Respiratory Protection Equipment for Tactical and Technical Operations have CBRN protections incorporated in the standard. In May 2017, NIOSH published a Letter to Manufacturers informing stakeholders on the updated policy statement for CBRN SCBA regarding the incorporation of NFPA 1986:2017 to begin accepting applications for the testing and evaluation of SCBAs with CBRN protections [NIOSH 2017]. A new edition of NFPA 1986 was published in 2023 and will likewise be addressed. Similarly, another NFPA standard (NFPA 1987: Standard on Combination Unit Respirator Systems for Tactical and Technical Operations) includes CBRN protections.

SCBAs are the only class of CBRN respirator that may be used for both entry into and escape from hazardous atmospheres that are immediately dangerous to life or health (IDLH). The OSHA Hazardous Waste Operations and Emergency Response regulation defines an IDLH atmosphere as an atmospheric concentration of any toxic, corrosive, or asphyxiating substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere [OSHA 2006]. This includes atmospheres that:

- Contain a contaminant (or contaminants) at concentrations above its listed IDLH concentration
- Contain an unknown contaminant (or contaminants) or an unknown concentration of known contaminant (or contaminants)
- Contain less than 19.5 percent oxygen

The specific designs of CBRN SCBAs differ, but all include the same basic components, shown in Figure 3-1.

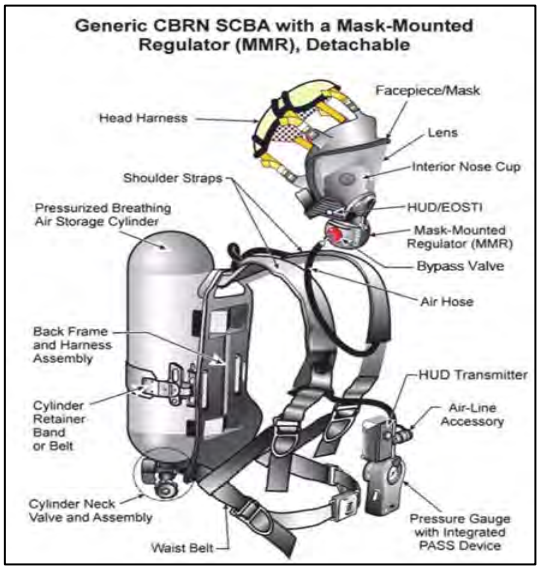

Figure 3-1. CBRN SCBA detachable regulator model compliant with NFPA 1981 and 1982, Edition 2007. Adapted from MSA.

- Breathing air cylinder

- Backframe/harness assembly
- Regulator
- Pneumatic lines
- Facepiece assembly with exhalation valve

Figure 3-2 shows a CBRN SCBA worn by an emergency responder. It is important for the user to understand the cautions and limitations of the CBRN SCBA and become familiar with all the labels required by NIOSH and NFPA standards to identify the capabilities and limitations of the equipment.

Figure 3-2. CBRN SCBA equipment used in an emergency response in which the contaminants are not known. Photo by Dupont.

CBRN SCBA NIOSH Approval for Universal Emergency Breathing Safety System –Emergency Breathing Safety System –Buddy Breather

Current SCBA technology makes tethering apparatus possible, thus enabling two SCBA users to share breathing air from a donor SCBA. The hardware used for this is the Universal Emergency Breathing Safety System (UEBSS)–Emergency Breathing Safety System (EBSS)–Buddy Breather (BB). However, the unknown condition of a receiver CBRN SCBA at the time of tethering limits the level of protection for UEBSS-EBSS-BB apparatus. The following are the levels of NIOSH Approved® respiratory protection for tethered CBRN SCBA:

- A tethered donor CBRN SCBA is approved by NIOSH as an escape-only device.
- A tethered receiver CBRN SCBA is not approved by NIOSH to provide respiratory protection.

Background

The use of BB connectors to tether two SCBAs can be a life-saving tool. However, incorrect interpretation and application of the NIOSH policy regarding CBRN SCBA equipped with UEBSS-EBSS-BB hardware may lead to a false sense of protection for a tethered receiver CBRN SCBA.

NFPA standards—NFPA 1981 Standard on Open-Circuit Self-Contained Breathing Apparatus for Emergency Services, 2013 edition; NFPA 1986 Standard on Respiratory Protection Equipment for Tactical and Technical Operations, 2017 Edition; and subsequent editions of these standards—include requirements related to the use and operation of UEBSS-EBSS-BB. In support of the NFPA standards addressing UEBSS-EBSS-BB, a NIOSH Letter to All Interested Parties dated February 18, 2014 [NIOSH 2014]), announced a revision to the NIOSH November 1984 policy for the use of EBSS. The NIOSH Letter stated:

> NIOSH will recognize NFPA 1981, 2013-compliant EBSS systems as part of the NIOSH SCBA approval for users who have received the appropriate level of training. Users will be able to identify approvals for SCBA which incorporate the required hardware by the explicit listing of an additional EBSS statement to the standard cautions and limitations on the approval label. The statement will signify the EBSS components have been evaluated by NIOSH and accepted as meeting the requirements for EBSS under the requirements of NFPA 1981, Revision 2013 [NIOSH 2014].

The 2014 NIOSH policy is consistent with provisions of 42 CFR Part 84, which describes the purpose of NIOSH respirator approval to provide for the issuance of certificates of approval for respirators which have met applicable construction, performance, and respiratory protection requirements of the regulation.

The 2014 NIOSH policy requires NFPA 1981 or NFPA 1986 standards as construction evaluation criteria, performance testing to ensure safe operation at low temperature, and positive pressure testing to establish the level of protection. The NIOSH tests validate that UEBSS-EBSS-BB connector engagement does not affect the performance of a donor CBRN SCBA in its normal, one-person-use mode of operation. However, the NIOSH policy does not evaluate the level of protection for a tethered receiver unit.

Cautions and Limitations

The NIOSH approval label Caution and Limitation statement used to identify apparatus equipped with the UEBSS-EBSS-BB accessory is:

> EBSS - Activation or engagement of EBSS in either the donor or receiver mode changes the SCBA use to Escape-Only, approved service time for either the donor, or the receiver is no longer applicable. Additional critical cautions and limitations apply. Refer to section EBSS in the users' manual.

The 2014 NIOSH policy further requires the following additional Caution and Limitation statements to appear in the EBSS section of the users' manual:

- EBSS may not be engaged or activated in donor mode after the donor End-of Service-Time-Indicator (EOSTI) has activated.
- Users must be fully trained in the operation of EBSS in accordance with a training program conforming to the requirements of NFPA Standards 1404, Fire Service Respiratory Protection Training and 1500, Fire Department Occupational Safety and Health Program.

- Simultaneous connection of more than two users, one donor, and one receiver, is not permitted.

Training

The 2014 NIOSH policy recognizes the importance of appropriate training programs developed and incorporated by the Fire Service. These programs conform to National Fire Protection Association Standards 1404 [NFPA 2018], Fire Service Respiratory Protection Training and 1500, Fire Department Occupational Safety and Health Program [NFPA 2021]. The topic of buddy breathing is complex and subject to change with evolving technology and user awareness. The NFPA standards revision process provides a means to address the changing needs of UEBSS-EBSS-BB training.

SCBA Approval Labels

NIOSH Approved® CBRN SCBAs can be easily recognized by their approval labels. The full NIOSH approval label for a CBRN SCBA is shown in Figure 3-3. It is included as a paper insert or part of the CBRN SCBA user instructions. This label shows the approved configurations based on their NIOSH TC-XXX approval numbers, the approved protection, component part numbers, and the cautions and limitations for each approved assembly.

In addition to the full label, two NIOSH sticker labels (abbreviated) are affixed to the backframe/harness. Figure 3-4 shows the TC-13F NIOSH adhesive label listing the approval numbers and cautions and limitations. Figure 3-5 shows the NIOSH CBRN protection approval and upgrade labels by NIOSH or the CBRN retrofit sticker label when the equipment has been upgraded for CBRN protection.

One or more sticker labels affixed to the backframe/harness show compliance with NFPA 1981. This label bears the logo of the Safety Equipment Institute, a third-party organization that administers the NFPA certification program for SCBAs. This label is shown in Figure 3-6.

Example Approval Label for CBRN Self-Contained Breathing Apparatus Respirators

Double Wing Manufacturing Company
Almost Heaven, West Virginia, USA
1-800-123-4567
1900 Series CBRN SCBA
Open-Circuit, Pressure-Demand, Entry and Escape CBRN Self-Contained Breathing Apparatus

These Respirators are Approved Only in the Following Configurations:

Respirator Components																				
TC-	Protection [1]	Alternate Facepiece				Alternate Harness					Alternate Cylinder				Alternate Regulator			Accessories			Cautions and Limitions[2/3]
		1000	2000	3000	4000	H95	H96	H97	H98	H99	C001	C002	C003	C004	R111	R222	R333	Lens10	Alarm50	Case20	
13F-AARa-CBRN	30 min/ 2216 psi/ SC/PD/ EOSTI 33	X	X			X	X	X	X	X	X				X			X		X	IJMNOS, ORTUEBSS
13F-AARb-CBRN	30 min/ 4500 psi/ SC/PD/ EOSTI 33	X		X	X		X	X	X	X						X	X	X	X	X	IJMNOS, ORTUEBSS
13F-AARc-CBRN	45 min/ 2216 psi/ SC/PD/ EOSTI 33	X		X		X	X						X			X	X	X	X	X	IJMNOS, ORTUEBSS
13F-AARd-CBRN	60 min/ 2216 psi/ SC/PD/ EOSTI 33	X						X	X					X		X	X	X	X	X	IJMNOS, ORTUEBSS

1. PROTECTION

PD - Pressure-Demand EOSTI - End-of-Service-Time Indicator
SC - Self-Contained CBRN – Chemical, Biological, Nuclear and Radiological

2. CAUTIONS AND LIMITATIONS

I - Contains electrical parts which have not been evaluated as an ignition source in flammable or explosive atmospheres by MSHA/NIOSH.
J- Failure to properly use and maintain this product could result in injury or death.
M- All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.
N- Never substitute, modify, add, or omit parts. Use only exact replacement parts in the configuration as specified by the manufacturer.
O - Refer to User Instructions, and/or maintenance manuals for information on use and maintenance of these respirators.
S - Special or critical User Instructions and/or specific use limitations apply. Refer to User Instructions before donning.

3. CAUTIONS AND LIMITATIONS OF USE FOR CBRN SCBA

Q - Use in conjunction with personal protective ensembles that provide appropriate levels of protection against dermal hazards.
R - Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
T - Direct contact with CBRN agents requires proper handling of the SCBA after each use and between multiple entries during the same use. Decontamination and disposal procedures must be followed. If contaminated with liquid chemical warfare agents, dispose of the SCBA after decontamination.
U - The respirator should not be used beyond 6 hours after initial exposure to chemical warfare agents to avoid possibility of agent permeation.
EBSS - EBSS Activation or engagement of EBSS in either the donor or receiver mode changes the SCBA use to Escape-Only, approved service time for either the donor, or the receiver

Figure 3-3. Full NIOSH Label for a CBRN SCBA (The original form can be accessed through the manufacturer of the specific RPD.)

Example Approval Label for Self-Contained Breathing Apparatus Harness

Double Wing Manufacturing Company
Almost Heaven, West Virginia, USA
1-800-123-4567

Model FFCBRN SCBA
Open-Circuit, Pressure-Demand, Entry and Escape Self-Contained Breathing Apparatus

TC-13F-XXXCBRN 30 MINUTE 2216 PSIG
TC-13F-YYYCBRN 30 MINUTE 4500 PSIG
TC-13F-ZZZCBRN 45 MINUTE 4500 PSIG
TC-13F-AAACBRN 60 MINUTE 4500 PSIG

(Refer to the Approved User Instructions for the Complete List of Components that Make Up the Approved Assembly)

Cautions and Limitations

I - Contains electrical parts which have not been evaluated as an ignition source in flammable or explosive atmospheres by MSHA/NIOSH.

J - Failure to properly use and maintain this product could result in injury or death.

M - All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.

N - Never substitute, modify, add, or omit parts. Use only exact replacement parts in the configuration as specified by the manufacturer.

O - Refer to User Instructions, and/or maintenance manuals for information on use and maintenance of these respirators.

S - Special or critical User Instructions and/or specific use limitations apply. Refer to User Instructions before donning.

Q - Use in conjunction with personal protective ensembles that provide appropriate levels of protection against dermal hazard.

R - Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.

T - Direct contact with CBRN agents requires proper handling of the respirator after each use and between multiple entries during the same use. Decontamination and disposal procedures must be followed. If contaminated with liquid chemical warfare agents, dispose of the respirator after decontamination.

U - The respirator should not be used beyond 6 hours after initial exposure to chemical warfare agents to avoid possibility of agent permeation.

Figure 3-4. *NIOSH 13F Approval Harness Label*

Figure 3-5. NIOSH "CBRN Agent Approved" label (adhesive) for new and retrofitted CBRN SCBA

It is important to check all these approval labels to be sure that the SCBA is CBRN approved by NIOSH. If these labels do not show the CBRN designation, the respirator is not approved to provide protection against CBRN agents.

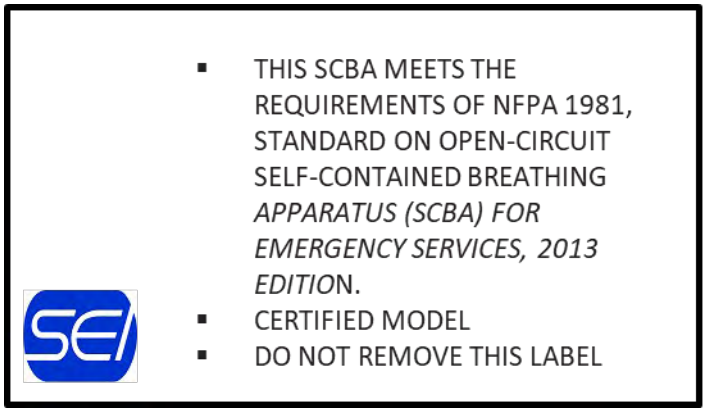

Figure 3-6. Example of the NFPA compliance label issued by the Safety Equipment Institute

Facepieces, regulators, valves, hoses, and cylinder connections are the main components that may differ in materials or construction from non-CBRN SCBAs. Thus, only those components with exact part numbers shown on the full NIOSH Approved CBRN SCBA label provide CBRN protection and maintain NIOSH approval.

It is important to emphasize the unique features of CBRN SCBAs that set them apart from their industrial counterparts. These are explained in detail in the CBRN SCBA standards and test procedures, which are posted on the NIOSH website [NIOSH 2024].

Testing

Chemical Agent Permeation and Penetration Resistance Tests

Chemical agent permeation and penetration tests ensure that, under specified laboratory conditions, the materials used in the CBRN SCBAs resist CWA migration into the respirator assembly according to NIOSH Standard Test Procedure RCT-CBRN-STP-0200 and 0201, covered in Chapter 2.

LRPL

The fit of each NIOSH Approved CBRN SCBA facepiece is evaluated to ensure a minimum LRPL under specified laboratory conditions. This test assesses the respirator's ability to fit a wide range of facial sizes and shapes. It also ensures that user instructions can be understood. Chapter 2 provides details on the LRPL test procedures found in the NIOSH Standard Testing Procedure document TEB-CBRN-APR-STP0352 [NIOSH 2021].

LRPL testing ensures CBRN SCBAs have generally good fitting characteristics for a variety of facial sizes and shapes. However, individual fit testing must be done to select the correct facepiece model and size for each individual wearer. Quantitative fit tests are acceptable to OSHA for CBRN SCBAs. The user instructions must be consulted for additional details on fit testing to properly select the equipment and to perform the recommended fit testing protocol.

NIOSH Cautions and Limitations Statements

NIOSH requires specific cautions and limitations (C&L) statements for 42 CFR 84 13F SCBAs and additional specific statements for CBRN SCBAs. Each C&L statement is identified by a letter code [NIOSH 2006a]. These codes and statements, shown in Table 3-1, are the same for all manufacturers that produce NIOSH Approved SCBAs. In practice, the wording of the statements may vary slightly among SCBA manufacturers, and additional C&L statements may be added by the manufacturer for a specific product. Therefore, the user instructions must be consulted to gain a complete understanding of the C&L for that respirator.

Table 3-1. C&L statements for CBRN SCBAs

I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres.
J	Failure to properly use and maintain this product could result in injury or death.
M	All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.
N	Never substitute, modify, add, or omit parts. Use only exact replacement parts in the configuration specified by the manufacturer.
O	Refer to user instructions and/or maintenance manuals for information on use and maintenance of these respirators.
S	Special or critical user instructions and/or specific use limitations apply. Refer to user instructions before donning, due to unique or unusual design or critical operation requirements.
Q*	Use in conjunction with personal protective ensembles that provide appropriate levels of protection against (CBRN agent) dermal hazards.
R*	Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
T*	Direct contact with CBRN agents requires proper handling of the SCBA after each use and between multiple entries during the same use.
U*	The respirator should not be used beyond 6 (six) hours after initial exposure to chemical warfare agents to avoid possibility of continued agent permeation."
EBSS*	Activation or engagement of EBSS in either the donor or receiver mode changes the SCBA use to Escape-Only, approved service time for either the donor, or the receiver is no longer applicable. Additional critical cautions and limitations apply. Refer to EBSS in the User's Manual.

*CBRN-specific C&L.

CBRN PAPRs

The CBRN PAPR has a blower to provide purified air to the user by drawing the contaminated air through an air-purifying canister(s) or cartridge(s). Important design differences separate CBRN PAPRs from their industrial counterparts.

PAPR Approval Labels

NIOSH approves CBRN PAPRs in two categories: tight-fitting (NIOSH 14G approval) or loose-fitting (NIOSH 23C approval). Tight-fitting coverings are called facepieces, such as full face masks. They cover the user's face and eyes and form a seal with the face. The loose-fitting coverings cover at least the head and neck or the head, neck, and chest. They are called hoods if they are made of a flexible material such as rubber, or helmets if they include a rigid protective headgear [NIOSH 1987].

> *CBRN PAPRs with NIOSH 14G approvals may be used for escape from IDLH atmospheres that contain at least 19.5 percent oxygen. PAPRs with 23C approvals may not be used for escape from IDLH atmospheres. Neither class of CBRN PAPR can be used to enter an atmosphere that is IDLH.*

During NIOSH laboratory evaluation, the same test agents and concentrations are used to evaluate PAPR canisters (14G) and cartridges (23C), except that the concentrations are reduced by one half for loose-fitting PAPR with cartridges.

To gain CBRN approval, NIOSH subjects CBRN PAPRs to special tests:

- Chemical agent permeation and penetration resistance against distilled sulfur mustard (HD) and sarin (GB)
- LRPL
- Canister/cartridge test challenge and test breakthrough concentrations for the 10 test representative agents described in Chapter 2
- Durability conditioning for CBRN tight-fitting PAPRs only

When the types of inhalation hazards are known, their concentrations do not exceed IDLH levels, and there is at least 19.5 percent oxygen, these CBRN PAPRs may be used to enter contaminated atmospheres.

NIOSH Approved® CBRN PAPRs can be recognized by their labels. Two types of NIOSH approval labels provide information on the PAPR protections and the list of required component configurations: 1) the full NIOSH approval label for the CBRN respirator, and 2) the full NIOSH approval label for the CBRN canister and cartridge. These are paper labels included with the facepiece and air-purifying component packaging and/or provided with the user instructions. Both full labels contain the following information:

- Department of Health and Human Services and National Institute for Occupational Safety and Health logos
- Respirator components, protections, accessories, and cautions and limitations
- Part numbers of components for each NIOSH Approved CBRN APR or canister configuration/system
- The NIOSH approval number (TC-14G-XXX or TC-23C-XXX), is shown as a row of component parts—each row represents required components for a specific approved configuration
- Type and level of protection
- The configuration(s) of components that are approved for CBRN level of protection are listed with “CBRN” and a capacity level (i.e., CAP1, CAP2, etc.)
- Specified cautions and limitations

There is also an abbreviated adhesive NIOSH approval label on CBRN PAPR canisters and cartridges. This label does not contain the approved configuration of components. In addition, the information of this label may be split between the CBRN canister/cartridge component and its packaging.

The full NIOSH approval label is the most important document to define the correct configuration of the CBRN PAPR. As stated before, the full NIOSH approval label may be included in the user instructions or as a paper insert. The full respirator approval label is usually provided with the PAPR blower unit and/or facepiece packaging.

The full NIOSH approval labels (respirator, canister, and cartridge) should be reviewed to check that the components of the CBRN PAPR meet the NIOSH Approved CBRN configuration suitable for the application for which it was selected.

The NIOSH approval number shows the unique protections for each configuration of the CBRN PAPR. The components are marked in the matrix grid. Any components that are not marked in the grid for a given approval number are not permitted.

CBRN PAPR canisters or cartridges must have a NIOSH approval label with a "CBRN" designation. The color of the canister or cartridge label will be olive and contain all the information of the full label except for the component configurations, as shown in Figure 3-7.

Canister/cartridge packaging is also labeled "CBRN." Blower units, breathing tubes, and facepieces do not have markings or adhesive labels indicating that they are CBRN components. They are marked with a component number, which is listed on the full label identifying that component is in the NIOSH Approved® configuration.

Testing

NIOSH tests CBRN canisters or cartridges for PAPRs against 10 test agents representing over 131 chemicals: ammonia, cyanogen chloride, cyclohexane (organic vapors), formaldehyde, hydrogen cyanide, hydrogen sulfide, nitrogen dioxide, phosgene, phosphine, and sulfur dioxide. They are also tested against GB, HD, and dioctyl phthalate (DOP) for P100 particulate filtration efficiency.

These tests evaluate the capacity (CAP) of the canisters, as specified by their manufacturer. They are evaluated in 15-minute intervals up to 60 minutes. NIOSH assigns numerical ratings to indicate the duration of the tests for which the canister prevented unacceptable chemical breakthrough: CAP1 = 15 minutes, CAP2 = 30 minutes, and CAP3 = 45 minutes. For CAP ratings of 60 minutes or greater, the canisters are evaluated at 30-minute intervals up to 120 minutes. Actual service life in use will be affected by the specific chemical exposure, airflow rate, and environmental conditions.

Figure 3-7. CBRN canisters showing the adhesive NIOSH approval label

All NIOSH Approved CBRN PAPRs are evaluated to ensure a minimum LRPL and clarity of user instructions. Tight-fitting 14G PAPRs are tested with the blower running and with it turned off. The

loose-fitting 23C PAPRs are tested with their blower running, under specified laboratory conditions. NIOSH also assesses the tight- and loose-fitting PAPR's ability to fit a wide range of facial sizes and shapes. NIOSH also ensures that instructions for the facepiece size selection and donning can be understood.

Although LRPL testing ensures CBRN PAPRs have generally good fitting characteristics, individual fit testing must be done to select the correct tight-fitting facepiece model and size for each user. Individual fit testing is not required for loose-fitting PAPRs. Procedures for conducting qualitative and quantitative fit tests can be found in OSHA's Respiratory Protection regulation [OSHA 1999] and Chapter 6 of this handbook. Qualitative fit tests rely on the user's senses to detect unacceptable leakage of a test agent. Quantitative fit tests are similar to the LRPL test, using instrumentation to measure "fit factors," which are numerical expressions of fit.

> *A minimum fit factor of 500 is required to demonstrate acceptable fit for a tight-fitting CBRN PAPR. Higher values represent "better" fit. While the minimum fit factor of 500 satisfies OSHA's regulation, manufacturers of CBRN PAPRs may specify higher minimum values (up to 2500) for their products. The user instructions must be consulted to determine the minimum acceptable fit factor for a specific CBRN PAPR.*

NIOSH Cautions and Limitations Statements

NIOSH requires a standardized list of C&L for each respirator class. The tables below show C&L statements for tight- and loose-fitting CBRN PAPRs. Individual manufacturers often have additional C&L statements unique to specific respirator models. These are provided in the manufacturer's user instructions. At a minimum, NIOSH requires the C&L statements shown in Tables 3-2 and 3-3 for CBRN PAPRs [NIOSH 2006a].

Table 3-2. NIOSH C&L statements for tight-fitting CBRN PAPRs (14G Approval Schedule)

A	Not for use in atmospheres containing less than 19.5 percent oxygen.
F	Do not use powered air-purifying respirators if airflow is less than four (4) cfm (115 lpm) for tight fitting facepieces or six (6) cfm (170 lpm) for hoods and/or helmets.
H	Follow established cartridge and canister change schedules or observe ESLI to ensure that cartridges and canisters are replaced before breakthrough occurs.
I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres.(Note - Applies if the respirator contains electrical components and the intrinsic safety has not been evaluated and approved by MSHA or a recognized independent laboratory.
J	Failure to properly use and maintain this product could result in injury or death.
L	Follow the manufacturer's user instructions for changing cartridges, canister, and/or filters.
M	All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.
N	Never substitute, modify, add, or omit parts. Use only exact replacement parts in the configuration as specified by the manufacturer.
O	Refer to user instructions, and/or maintenance manuals for information on use and maintenance of these respirators.
R*	Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
S	Special or critical user instructions and/or specific use limitations apply. Refer to user instructions before donning, due to unique or unusual design or critical operation requirements.
Y*	The respirator provides respiratory protection against inhalation of radiological and nuclear dust particles. Procedures for monitoring radiation exposure and full radiation protection must be followed.
Z*	If during use, an unexpected hazard is encountered such as a secondary CBRN device, pockets of entrapped hazard or any unforeseen hazard, immediately leave the area for clean air.
BB	Not for use for entry into atmospheres immediately dangerous to life or health.
CC	For entry, do not exceed maximum use concentrations established by regulatory standards.
GG*	Direct contact with CBRN agents requires proper handling of the respirator after use. Correct disposal procedures must be followed.
UU*	The respirator should not be used beyond eight (8) hours after initial exposure to chemical warfare agents to avoid possibility of agent permeation. If liquid exposure is encountered, the respirator should not be used for more than two (2) hours.
VV*	PAPRS with TC-23C approvals may NOT be used for escape from IDLH atmospheres.

** CBRN-specific C&L.*

Table 3-3. NIOSH C&L statements for loose-fitting CBRN PAPRs (23C Approval Schedule)

A	Not for use in atmospheres containing less than 19.5 percent oxygen.
B	Not for use in atmospheres immediately dangerous to life or health.
C	Do not exceed maximum use concentrations established by regulatory standards.
F	Do not use powered air.
H	Follow established cartridge and canister change schedules or observe ESLI to ensure that cartridges and canisters are replaced before breakthrough occurs.
I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres. (Note: Applies if the respirator contains electrical components and the intrinsic safety has not been evaluated and approved by MSHA or a recognized independent laboratory.)
J	Failure to properly use and maintain this product could result in injury or death.
L	Follow the manufacturer's user instructions for changing cartridges, canister, and/or filters.
M	All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.
N	All approved respirators shall be selected, fitted, used, and maintained in accordance with
O	Refer to user instructions, and/or maintenance manuals for information on use and maintenance of these respirators.
R*	Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
S	Special or critical user instructions and/or specific use limitations apply. Refer to user instructions before donning, due to unique or unusual design or critical operation requirements.
Y*	The respirator provides respiratory protection against inhalation of radiological and nuclear dust particles. Procedures for monitoring radiation exposure and full radiation protection must be followed.
GG*	Direct contact with CBRN agents requires proper handling of the respirator after use. Correct disposal procedures must be followed.
QQ*	Use in conjunction with personal protective ensembles that provide appropriate levels of protection against dermal hazard. Failure to do so may result in personal injury even when the respirator is properly fitted, used, and maintained.
UU*	The respirator should not be used beyond eight (8) hours after initial exposure to chemical warfare agents to avoid possibility of agent permeation. If liquid exposure is encountered, the respirator should not be used for more than two (2) hours.
VV*	PAPRS with TC-23C approvals may NOT be used for escape from IDLH atmospheres.

**CBRN-specific C&L.*

Canister/Cartridge Packaging and Shelf Life

Packaging for CBRN PAPR canisters and cartridges carries a CBRN designation. The box and the sealed wrapping for the canister or cartridge are commonly marked with a shelf-life date, which is the time period for which the canister or cartridge can be used if it has been maintained as specified by its manufacturer. Figure 3-8 shows the expiration date of a canister or cartridge. The shelf life varies among manufacturers. The time period for a specific canister or cartridge should also be found in the user instructions. Canisters and cartridges should be removed from possible service if their expiration period has passed.

To reduce the impact of environmental conditions on service life, canisters should be stored as specified by their manufacturer and remain sealed until fitted to the respirator just prior to use. Canisters that have had the vacuum seal broken or are otherwise damaged should be removed from possible service.

In-Use Service Life of CBRN Canisters

When put into use, the service life of canisters depends on the rate of airflow; specific type, volatility, and concentration of the contaminants; and environmental conditions, such as humidity and temperature.

Canisters must be replaced in accordance with an established change schedule or P100 filter time-use restriction as may be required by manufacturer's instructions [NIOSH 1997]. Canisters should also be replaced immediately if smell, taste, or irritation from contaminants is detected; if they are damaged; or if there is a noticeable decrease in PAPR airflow. Chapter 4 of this handbook explains service life estimation and establishing change schedules.

Figure 3-8. CBRN canister shelf-life label

Minimum Packaging Configuration

The tight-fitting CBRN PAPR and its required components are subjected to environmental and durability conditioning in the manufacturer-specified minimum packaging configuration (MPC).

Canisters are also subjected to a rough handling drop test in a designated MPC. This test is not done for loose-fitting NIOSH Approved CBRN PAPR and cartridges.

The MPC is the protective packaging configuration in which the end user will store or maintain the CBRN PAPR and its required components after it has been issued for immediate use. The type of MPC, if any, is left to the discretion of the manufacturer.

Examples of common MPCs are mask carriers, clamshell containers, drawstring plastic bags, hermetically sealed canister bags, and cardboard containers, as shown in Figure 3-9.

Figure 3-9. Minimum packaging configuration for CBRN canister and CBRN PAPR system

CBRN APRs

CBRN APR RPDs consist of a full facepiece made of materials resistant to permeation of chemical agents and a canister to remove hazardous chemicals and particulates [NIOSH 2003b]. Only canisters are approved with CBRN APRs; cartridges are not used. Canisters can be mounted on the front or on either side of the facepiece. Figures 3-10 and 3-11 show typical CBRN APRs.

APR Approval Labels

NIOSH approves these respirators under Schedule 14G (Gas Masks). When the inhalation hazards are known and their concentrations do not exceed IDLH levels, and sufficient oxygen (greater than 19.5 percent) is present, CBRN APRs may be used. They may also be used for escape from IDLH atmospheres when adequate oxygen is present.

Figure 3-10. CBRN APR protection for police responders. Photo courtesy Avon Protection Systems

Figure 3-11. CBRN APR protection for emergency responders. Photo courtesy MSA – The Safety Company)

Testing

NIOSH subjects CBRN APRs to a range of tests based on existing national and international standards. These tests evaluate mechanical connector and gasket properties; canister properties, including breathing resistance; dimensions and weight; facepiece field of view; lens material haze, luminous transmittance, and abrasion resistance; carbon dioxide level; and hydration.

Special test requirements for CBRN use include canister challenge and breakthrough concentrations; service life; low temperature/fogging (visual acuity score); communications modified rhyme test; chemical agent permeation and penetration resistance against distilled HD and GB agent; LRPL; and environmental conditioning (transportability, temperature range, survivability).

The 14G approval for CBRN APR is shown in the full NIOSH approval label for the facepiece and canister, found with the manufacturer's user instructions or as an insert in the MPC. The user instructions and the full NIOSH respirator approval label are distributed with the facepiece, and the full NIOSH canister approval label is distributed with the canister.

Most CBRN APR components, including facepieces, are not marked "CBRN." NIOSH only requires the canister to be labeled and marked "CBRN" and requires the color of the canister or its label to be olive.

NIOSH Approved® CBRN APR canisters must provide protection at the same level as the canister specified on the NIOSH CBRN approval label. For a service life less than 60 minutes, the canister capacity is specified in 15-minute intervals, identified by a capacity level. A capacity level of CAP1 designates a laboratory-rated service life of 15 minutes; CAP2 is 30 minutes; and CAP3 is 45 minutes.

The canister must meet or exceed the manufacturer's specified service life during the laboratory test without exceeding the NIOSH-identified breakthrough concentration level for the test gas or vapor.

CBRN APR canisters are unique as they are interoperable among manufacturers. This interoperability provision does not apply to NIOSH Approved industrial gas masks. *Users should not interchange canisters until instructed to do so by incident commander/other designated command authority.*

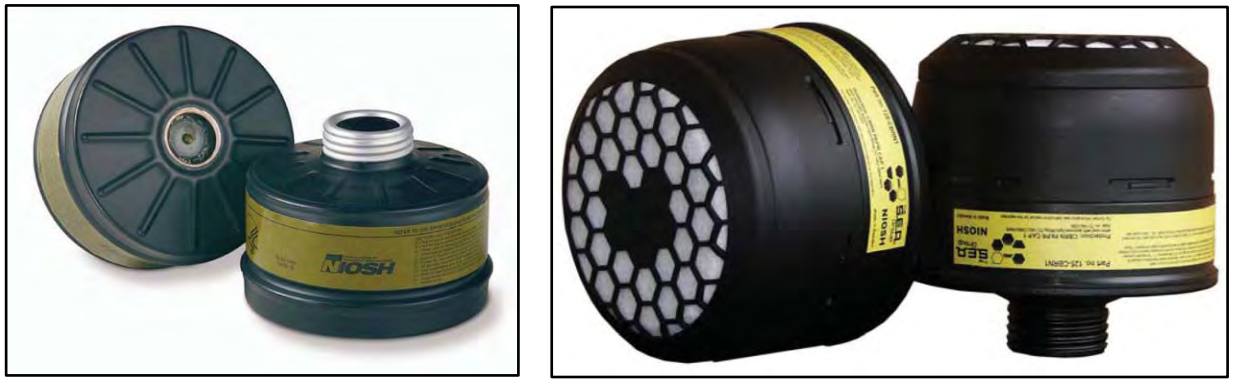

Figure 3-12. CBRN canisters showing the threaded connection and abbreviated adhesive label.

The interoperability requirement for CBRN canisters is intended to ensure that canisters from different manufacturers' NIOSH Approved CBRN APR will provide the same protection level as the canister specified on the NIOSH CBRN approval label. The RD-40-1/7" thread used for the canister connectors, shown in Figure 3-12, is the round standard thread defined by the European Standard EN148-1:2018 [BSI 2018].

NIOSH evaluates the fit of each NIOSH Approved CBRN APR to ensure a minimum LRPL under laboratory-specified conditions as described for CBRN PAPRs with tight-fitting facepieces. Figure 3-13 shows the LRPL testing for APRs. Manufacturers may require fit factors higher than 500 to qualify users when individual fit testing is conducted.

Since different fit factors are required by manufacturers for CBRN APRs (ranging from 500 to 2500), the user instructions for the particular device must be consulted.

NIOSH Cautions and Limitations Statements

At a minimum, NIOSH requires the C&L statements shown on Table 3-4 for CBRN APRs [NIOSH 2006a].

A	Not for use in atmospheres containing less than 19.5 percent oxygen.
I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres. Applies if the respirator contains electrical components and the intrinsic safety has not been evaluated and approved by Mine & Safety Administration (MSHA) or a recognized independent laboratory.
J	Failure to properly use and maintain this product could result in injury or death.
L	Follow the manufacturer's instructions for changing cartridges, canister, and/or filters.
M	All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations.
O	Refer to user instructions and/or maintenance manuals for information on use and maintenance of these respirators.
R*	Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
S	Special or critical user instructions and/or specific use limitations apply. Refer to user instructions before donning, due to unique or unusual design or critical operation requirements.
T*	Direct contact with CBRN agents requires proper handling of the respirator after each use and between multiple entries during the same use. Decontamination and disposal procedures must be followed. If contaminated with liquid chemical warfare agents, dispose of the respirator after decontamination.
V*	Not for use in atmospheres IDLH, or where hazards have not been fully characterized.
W*	Use replacement parts in the configuration as specified by applicable regulations and guidance.
X*	Consult manufacturer's user instructions for information on the use, storage, and maintenance of these respirators at various temperatures.
Y*	The respirator provides respiratory protection against inhalation of radiological and nuclear dust particles. Procedures for monitoring radiation exposure and full radiation protection must be followed.
Z*	If during use, an unexpected hazard is encountered such as a secondary CBRN device, pockets of entrapped or any unforeseen hazard, immediately leave the area for clean air.
CC	For entry, do not exceed maximum use concentrations established by regulatory standards.

HH*	When used at defined occupational exposure limits, the rated service time cannot be exceeded. Follow established canister change out schedules or observe End-of-Service-Life Indicators to ensure that canisters are replaced before breakthrough occurs.
QQ*	Use in conjunction with personal protective ensembles that provide appropriate levels of protection against dermal hazard. Failure to do so may result in personal injury even when the respirator is properly fitted, used, and maintained.
UU*	The respirator should not be used beyond eight (8) hours after initial exposure to chemical warfare agents to avoid possibility of agent permeation. If liquid exposure is encountered, the respirator should not be used for more than two (2) hours.

**CBRN-specific C&L.*

Canister/Cartridge Packaging and Shelf Life

Packaging boxes for CBRN canisters carry a CBRN designation, as shown in Figure 3-14. The canister box and the canister sealed wrapping are commonly marked with a shelf-life date, as explained for CBRN PAPRs.

Figure 3-14. CBRN canister shelf-life label

In-Use Service Life of CBRN APRs

Because of the limitations of the permeation and penetration testing, CBRN APRs must not be used beyond eight hours after initial exposure to CWA(s) to avoid the possibility of agent permeation. If liquid exposure is encountered, the respirator must not be used for more than two hours.

Minimum Packaging Configuration

Similar test procedures are used for CBRN APRs as those used for CBRN PAPRs, which are explained above. Figures 3-15 and 3-16 show examples of MPCs.

CBRN APERs

CBRN APERs consist of a hood made of materials resistant to permeation of chemical agents and a canister with media to remove hazardous chemicals and particulates. They typically include an oral/nasal cup or mouthpiece to further protect the respiratory system. NIOSH approves these devices as 14G gas masks. These devices may be used for escape from IDLH environments but not for entry into or working in an IDLH atmosphere.

CBRN APER canisters are designed to remove a wide variety of air contaminants but are ineffective for some chemicals. CBRN APERs with carbon monoxide protection and heat and flame resistance are not commonly available.

These RPDs are designed for the general working population and provide escape protection against CBRN agents. The NIOSH standard does not address special populations, such as children and adults with respiratory or other health conditions that may adversely affect the ability to don and use CBRN APERs effectively. Figures 3-17 and 3-18 show examples of CBRN APERs.

The useful life of the APER in the ready-to-use, stowed condition must be specified by the manufacturer.

Figure 3-15. CBRN canister MPC

Figure 3-16. CBRN facepiece with its clamshell packaging

Figure 3-17. Different designs for CBRN APERs

Manufacturers' user instructions may contain special requirements for the type or frequency of training necessary for a given APER. Periodic retraining and/or review of instructions for donning, fitting, and doffing must be performed as required by the manufacturer. For example, some manufacturers may require retraining every 30 days, while others may require periodic review of instructions or inspection, or stipulate inspection requirements without specifying a time interval.

It is important to check the "wearability" of the APER hood to select the proper device for each potential user. Hoods that fit too tightly around the head or neck can contribute to feelings of claustrophobia or choking. To mitigate these problems, some CBRN APER hoods come in more than one size.

Manufacturers typically provide information on neck and/or head sizes that a particular APER hood might best fit. Manufacturers' user instructions and training materials must be followed to select a properly fitting hood and for special instructions on how to don, wear, doff, and store the respirator. Training units (not intended to provide respiratory protection) are available to assist learning these activities.

To determine proper fit, it is important to keep the following considerations in mind:

- For APERs that contain an oronasal cup, it is important that the cup fits properly over the wearer's nose and mouth to prevent the buildup of carbon dioxide inside the hood.
- If the wearer's head is too large for the hood, it may not fit properly.
- If the wearer's neck is small, the APER may not seal properly; if it is too large, the APER may choke the wearer.
- Some manufacturers require that the wearer cross-check the fit of the APER with another person.

Figure 3-18. Shows a CBRN APER with a clear plastic hood and face panel.

APER Approval Labels

CBRN APERs with a 14G approval may be used for escape only from IDLH atmospheres that contain at least 19.5 percent oxygen. CBRN APERs should not be used to enter, or to remain in, a contaminated environment. There are four NIOSH approval categories for CBRN APERs [NIOSH 2003b]:

- General category consisting of multi gas/vapor and particulate protections: ammonia, cyanogen chloride, cyclohexane (organic vapors), formaldehyde, hydrogen cyanide, hydrogen sulfide, nitrogen dioxide, phosgene, phosphine, sulfur dioxide, GB, HD, and particulates (P100® particle filter)
- General category with carbon monoxide (CO) protection
- Specific category for chemicals and particulates in the general category with additional protections for any combination of the specific chemicals (e.g., additional protection for ammonia)
- Specific category with CO protection

The CBRN APER full NIOSH approval label, as explained for the other RPDs, contains the information that the user needs to consult to determine if an APER has been tested and certified by NIOSH for use in CBRN environments. This label is found in the manufacturer's packaging or with the user instructions. The full NIOSH approval label and manufacturer's user instructions must be carefully reviewed to determine the protections applicable to each APER model.

In addition to the information shown on the NIOSH full approval label for all RPDs, the NIOSH full approval label for CBRN APERs should include the type and level of protection, as shown in Table 3-5.

Table 3-5. CBRN APER label examples for different types of protection

Category	Label Example
APER with approval for 15-minute duration rating	ESCAPE ONLY NIOSH CBRN 15
APER with approval for a 15-minute duration rating with CO protections	ESCAPE ONLY NIOSH CBRN 15 with CO
APER with approval for a 30-minute duration rating with specific category	ESCAPE ONLY NIOSH CBRN 30 with "chemical" Specific
APER with approval for 30-minute duration, with specific category, and CO	ESCAPE ONLY NIOSH CBRN 30 with "chemical" Specific and with CO

Testing

CBRN APERs are tested for permeation and penetration resistance with liquid and vapors of distilled HD and GB. LRPL tests are also conducted. Each one of these tests is explained in Chapter 2. NIOSH Cautions and Limitations Statements for CBRN APER

At a minimum, NIOSH requires the C&L statements shown on Table 3-6 for CBRN APERs [NIOSH 2006a]

Table 3-6. NIOSH C&L statements for CBRN APERs (Approval Schedule 14G)

A	Not for use in atmospheres containing less than 19.5 percent oxygen.
I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres. (NOTE: Applies if the respirator contains electrical components and the intrinsic safety has not been evaluated and approved by Mine & Safety Administration (MSHA) or a recognized independent laboratory.)
J	Failure to properly use and maintain this product could result in injury or death.
L	Follow the manufacturer's instructions for changing cartridges, canister, and/or filters.
M	All approved respirators shall be selected, fitted, used, and maintained in accordance with MSHA, OSHA, and other applicable regulations
O	Refer to user instructions and/or maintenance manuals for information on use and maintenance of these respirators.
R*	Some CBRN agents may not present immediate effects from exposure, but can result in delayed impairment, illness, or death.
S	Special or critical user instructions and/or specific use limitations apply. Refer to user instructions before donning, due to unique or unusual design or critical operation requirements.
X*	Consult manufacturer's user instructions for information on the use, storage, and maintenance of these respirators at various temperatures.
AA	This respirator is to be used for escape only and will protect against the inhalation of certain respiratory hazards.
DD*	This respirator provides respiratory protection against inhalation of certain gas and vapor chemical agents, biological particulates, and radiological and nuclear dust particles. This respirator provides limited dermal (skin) protection to the head area and eyes.
EE*	Eye irritation may be experienced based upon the CBRN agent and exposure (concentration and duration).
GG*	Direct contact with CBRN agents requires proper handling of the respirator after use. Correct disposal procedures must be followed.
II*	This respirator provides protection from certain inhalation hazards associated with fire.
JJ*	CBRN agents, depending on how they are used, may provide a disabling effect as a result of skin exposure.
NN*	This respirator is a one-time-use device with no replaceable parts. Discard after use regardless of contaminant exposure.

**CBRN-specific C&L.*

Figure 3-19. CBRN APER Packaging

Packaging and Shelf Life

Several types of packaging may be used for CBRN APERs: shipping boxes, storage boxes, carry pouches, and/or foil vacuum-sealed bags. The shelf-life date is on the storage container and typically on the foil vacuum-sealed package. This date indicates the time period for which the APER can be used if it is stored as specified by the manufacturer.

All CBRN APERs are contained in a vacuum-sealed package to prevent the canister from being degraded by exposure to ambient conditions. The sealed packaging is normally protected by external packaging to prevent damage. CBRN APERs should remain sealed until needed for use. The APER should not be used if the expiration period has been exceeded, if the vacuum seal is broken, or if the respirator is otherwise damaged. Examples of the CBRN APER packaging are shown in Figure 3-19.

Service Life and Useful Life Information

Each CBRN APER is approved for a specified laboratory-rated service life. These service lives are 15, 30, 45, or 60 minutes. The actual performance time during an escape depends on the breathing rate through the canister; specific type, volatility and concentration of the contaminants; and environmental conditions, such as humidity and temperature. Planning for potential hazards and evacuation routes is critical in selecting the most appropriate CBRN APER model. The service life required for a specific evacuation scenario should be determined by careful planning and trial exercises.

In addition to its service life rating, each CBRN APER has a specified “useful life” period or shelf life printed on the CBRN APER label, as shown in Figure 3-20. The shelf or useful life of a CBRN APER is defined as the length of time a unit can remain deployed in the ready-to-use condition, as specified by the manufacturer.

Figure 3-20. CBRN APER useful life label

It is important to note that "service life" and "useful life" describe very different characteristics of CBRN APERs. Service life (laboratory-rated duration) relates to the performance of the device in the laboratory when it is challenged with a chemical and breakthrough is monitored, whereas "useful life" relates to reliability. The useful lives of escape respirators vary among manufacturers' different APER models. It is important to carefully review and follow the manufacturer's instructions for the specific CBRN APER in use.

Potential CBRN APER users with certain medical conditions (e.g., asthma, chronic obstructive airway disease) may not be able to tolerate the increased breathing resistance of the APER. There is at least one APER available with a blower that may be suitable for these individuals.

CBRN APERs require no maintenance and should not be removed from the protective packaging until used. After use, the APER should be properly discarded. The CBRN APER should not be used if the packaging is damaged in any way or if the expiration date is exceeded.

Components for CBRN Powered Air-Purifying Respirators (PAPRs)

CBRN PAPR Batteries

Batteries are the power source for the CBRN PAPR blowers. Several different types of batteries are used by CBRN PAPR manufacturers.

PAPR Battery Types

Both rechargeable and non-rechargeable battery types used in CBRN PAPRs are listed in Table 3-7.

General Battery Cautions and Limitations

The manufacturers' user instructions describe the proper care and conditioning required for the PAPR batteries. Failure to carefully follow these instructions may result in low performance of the PAPRs. To achieve the CBRN PAPR performance specified by the manufacturer and avoid personal injury, it is crucial that the batteries are properly stored, used, and conditioned (where applicable). In addition, because batteries contain chemicals to produce their rated voltage and ampere-hour capacities, proper disposal practices must be followed to prevent personal injury and damage to the environment.

Table 3-7. Battery types and their CBRN PAPR manufacturers

	Battery Type	PAPR's Manufacturers
Rechargeable Battery	**Nickel-metal hydride (NiMH)**	3M AirBoss AVON Dräger ILCD MSA SCOTT SEA Honeywell - SPERIAN
	LithiumIon (Li-ion)	AVON 3M
Non-rechargeable Battery Type	**Alkaline (Zn/MnO_2)**	Honeywell - SPERIAN ILCD
	Lithium-Sulfur Dioxide ($LiSO_2$)	AirBoss AVON Dräger MSA SCOTT Honeywell – SPERIAN
	Lithium Manganese Oxide ($LiMnO_2$)	3M ILCD

The NIOSH C&L statements required on approval labels for CBRN PAPRs do not directly address battery requirements such as storage, conditioning, usage, and disposal. However, the following NIOSH C&L statements, shown in Table 3-8, are indirectly associated with battery performance.

Table 3-8. NIOSH C&L statements indirectly associated with battery performances

F	Do not use powered air-purifying respirators if airflow is less than four (4) cfm (115 lpm) for tight-fitting facepieces or six (6) cfm (170 lpm) for hoods and/or helmets
Comment: If the batteries are not properly charged, these airflow rates may not be achievable.	
I	Contains electrical parts that may cause an ignition in flammable or explosive atmospheres.
Comment: Not all batteries used with CBRN PAPRs are intrinsically safe.	
J	Do not use powered air-purifying respirators if airflow is less than four (4) cfm (115 lpm) for tight-fitting facepieces or six (6) cfm (170 lpm) for hoods and/or helmets.
Comment: If batteries are not stored and conditioned properly, they can be damaged and cause personal injury.	
X	Consult manufacturer's user instructions for information on the use, storage, and maintenance of these respirators at various temperatures.
Comment: Battery storage conditions and charging methods can adversely affect battery performance or damage the battery.	

o	Refer to user instructions and/or maintenance manuals for information on use and maintenance of these respirators.

Comment: It is very important to refer to the manufacturer's user instructions and supplemental battery instructions (provided with the battery and battery charger) to properly store, condition, use, and dispose of batteries

Manufacturers may use different color battery caps or different length caps to help identify the correct battery that a particular CBRN PAPR will use, as shown in Figure 3-21. A battery not listed on the PAPR's full NIOSH approval label should never be used.

Battery life depends on many factors, including conditioning (if needed), maintenance, temperature, age, and number of charge/discharge cycles. Spent CBRN PAPR batteries should be disposed of properly. The manufacturers' user instructions provide information for proper disposal.

Although batteries cannot be repaired, rechargeable batteries can be recharged and conditioned for reuse if they are in good condition. Manufacturers' user instructions typically describe specific recharging and conditioning procedures. NIOSH Approved CBRN PAPRs must demonstrate a battery service life of at least four hours when tested on a breathing machine operating at 24 respirations per minute with a minute volume of 40 l/min [NIOSH 2021].

This performance is not guaranteed in use situations. The actual in-use service life of a CBRN PAPR will depend on a number of factors, including:

- Charge level of the battery
- Battery condition
- Battery operating temperature
- User workload
- Resistance to airflow

Figure 3-21. This NIOSH Approved® CBRN PAPR blower can be operated with different types of batteries. To identify the type of battery to be used, manufacturers supply battery covers of different colors or lengths. This picture shows the short cover for non-rechargeable batteries and the longer cover for rechargeable batteries.

Manufacturers' user instructions provide estimates of how long batteries will supply sufficient power to the CBRN PAPR in use and describe procedures to check for proper airflow rate. Some CBRN PAPRs have battery or airflow indicators on the blower to alert the wearer when the flow rate falls below minimum required specifications. Alternatively, manufacturers may indicate a maximum length of time a CBRN PAPR can be used before leaving the contaminated environment to check the airflow rate or replace the battery. Other manufacturers may simply specify a minimum runtime (e.g., four hours for a NiMH battery). The instructions provided with the PAPR blower, battery, and/or battery charger will provide information on battery use, care, and storage.

Battery Chargers

Different types of battery chargers are available for CBRN PAPRs. These can include quick charge, trickle charge, post-trickle charge, and combinations of these.

User instructions should be followed carefully to ensure proper battery performance and to avoid damage to the batteries. For example, some chargers are made to constantly condition (charge and discharge) batteries.

Thus, the batteries can remain in the charger until needed for use. Other chargers are made only to quick-charge batteries. Batteries should be removed from these chargers when a full charge is achieved to avoid damage.

Some manufacturers produce "gang" battery chargers, which can charge or condition multiple batteries. Heat is generated during the charging of a battery and must be dissipated to prevent overheating. Care must be taken to ensure there is ample ventilation where the charger is placed, and sources of heat are not adjacent to the charger.

Battery Service Life

Rechargeable batteries can have a service life of several hundred discharge/charge cycles if properly used and maintained. Actual service life will vary, depending how the battery has been stored, used, and conditioned. Rechargeable batteries should not be completely discharged, as this can cause permanent damage.

Acceptable temperatures for storage, operation, and charging vary among battery types and PAPR design. These temperatures are specified in the manufacturers' user instructions. Exposing the PAPR and battery to temperatures outside the specified ranges can damage the battery or shorten its usable life. Temperature specifications for two CBRN PAPR manufacturers are shown in Table 3-9. Other manufacturers may specify different temperatures.

Table 3-9. Sample temperature ranges for storing, using, and charging batteries

Battery	NiMH	Li-Ion
In Storage	-4° to 115°F (-20° to 45°C) Less than 85% relative	Below 86°F (30°C)
Operating	10° to 120°F (-12° to 49°C)	Do not use above 158°F (70°C)
Charging	50° to 90°F (10° to 32°C)	Below 194°F (90°C)

Battery Recharging

Periodic recharging is recommended to maintain fully charged batteries. Charging times vary, depending on the level of partial charge of the battery and charger characteristics. User instructions for recommended charging time should be followed.

In many cases it is necessary to discharge batteries before recharging them. This is typically done by running the PAPR until the low battery warning comes on, or the airflow rate drops below the manufacturer's specified level. Discharging is not necessary for battery chargers that are able to properly condition batteries through the discharge/charge cycle. Not all battery chargers have this capability.

Battery Reconditioning

New batteries, or batteries not used for extended periods, may require "reconditioning" before they can be fully charged. This generally involves subjecting the battery to several discharge and charge cycles. In most cases, batteries are discharged by connecting them to the PAPR blower and running it until the low battery or flow indicator indicates performance below required specifications. Manufacturers' reconditioning procedures may differ from these general guidelines for specific PAPR batteries.

Disposal of Rechargeable Batteries

Spent CBRN PAPR batteries must be recycled or discarded in accordance with federal, state, and local regulations. Manufacturers provide guidance for battery disposal procedures. The PAPR manufacturer's instructions should be consulted for proper procedures.

Non-rechargeable Batteries

These three types of disposable batteries are currently used in CBRN PAPRs:

- Alkaline
- Lithium-sulfur dioxide (Li-SO_2)
- Lithium-manganese dioxide (Li-MnO_2)

Alkaline Batteries

Alkaline cells are subject to both self-discharge and possible decomposition of the chemical contents. They should be kept cool or refrigerated during storage. A temperature range of 32°F to 50°F (0°C to 10°C) is optimal since it prevents freezing and overheating of the aqueous electrolyte. For prolonged storage, the batteries should be stored in vapor-proof packing to help alleviate the problem of electrolyte loss. Manufacturers may provide special containers for placing batteries in temporary storage.

Commercially available, D-cell alkaline batteries can provide PAPR operating times up to 12 hours. Increased resistance to airflow through the cartridges or canisters from clogging can reduce the service time of the batteries. Only batteries within their expiration date should be used.

Li-SO_2 Batteries

Li-SO_2 batteries are designed for extended shelf life. A shelf life of 10 years or longer is possible if the batteries are stored in accordance with the manufacturer's instructions. Fresh Li-SO_2 batteries should be kept in their original packaging until used.

Ideally, Li-SO_2 batteries should be stored in a dry, cool environment. CBRN PAPR manufacturers' user instructions specify acceptable ranges of temperature and humidity for batteries in storage. These recommendations are typically in the range of -22°F to 131°F (-30°C to 55°C). Heat sources such as furnaces and heating pipes should be avoided.

Li-SO_2 single-use batteries can operate the CBRN PAPR up to eight hours under favorable conditions. However, after four hours of use, the user must leave the contaminated area, decontaminate if required, and check the PAPR airflow with cartridges installed according to the manufacturer's instructions. Thereafter, the airflow must be checked at least every two hours of use.

Li-MnO_2 Batteries

Li-MnO_2 batteries are designed for extended shelf life. A shelf life of 10 years or longer is possible if the batteries are stored in accordance with the manufacturer's instructions. Special battery storage containers may be available from some manufacturers.

Manufacturers specify acceptable ranges of temperature and humidity for Li-MnO_2 batteries in storage. Temperature extremes and exposure to heat sources should be avoided; a cool, dry storage area is desirable.

Li-MnO_2 batteries may be used up to 12 hours under appropriate conditions. These batteries may have a label with a grid to mark the number of hours used. When the discharged batteries are exhausted, they should be prepared for disposal in accordance with their manufacturer's instructions. Some manufacturers recommend checking the PAPR airflow using the same procedures and time intervals described above for Li-SO_2 batteries.

Disposal of Non-rechargeable Batteries

Alkaline batteries can be discarded with regular domestic waste in some locations. However, all batteries should be discarded or recycled in accordance with federal, state, and local regulations.

Non-rechargeable Li-SO_2 batteries must be discarded on termination of use. They should be removed from the PAPR and discharged according to the manufacturer's instructions. $LiMnO_2$ batteries are generally not hazardous waste, and the Department of Transportation does not regulate them as hazardous materials.

CBRN respirator manufacturers provide specific instructions for disposal of non-rechargeable batteries, and these instructions should be followed.

CBRN PAPR Retrofit Kits

In some cases, previously purchased NIOSH Approved® 42 CFR 84 industrial PAPRs can be upgraded to provide CBRN PAPR protection. These upgrades must be performed using the manufacturer's retrofit kit for a specific PAPR model.

The upgrades must be performed in accordance with the manufacturer's instructions to ensure the retrofit complies with the approved CBRN PAPR configuration, quality assurance, and performance requirements.

PAPRs to be retrofitted must be in fully operational and protective condition, in service for no more than five years, and used for respiratory protection as part of an OSHA-compliant respirator program.

The CBRN PAPR retrofit kit must, at a minimum, contain the following:

- CBRN PAPR retrofit kit instructions
- Replacement packaging, components, parts, materials, CBRN canisters or cartridges (as applicable), and operation instructions required to retrofit the PAPR to the identical configuration as the approved CBRN configuration level (including minimum packaging configuration for tight-fitting CBRN PAPRs)
- CBRN PAPR retrofit approval label(s) for the respirator retrofit kit

Accessory Products for Air-Purifying Respirators

There are different accessory products available from manufacturers for CBRN APRs. Accessories such as outserts or covers for the facepiece lenses, rubber hoods, and voice amplifiers can add extra functionality and extend user protection during a CBRN emergency.

Some manufacturers will require the use of lens covers and skin to meet the CBRN approvals for a particular facepiece, and these components will be included in their package. In this case, these components are required for the RPD to be in the NIOSH Approved® configuration and provide the specified protection. Other manufacturers' facepieces may not need to have these outserts or lens covers to meet the requirements of the CBRN standards, and they are optional accessories in these cases to provide an additional protection for the user.

> *It is important to read the manufacturer user instructions and NIOSH approval labels to determine if the accessories are required components of an approved CBRN configuration or optional.*

Lens Covers

Lens covers protect the standard facepiece lenses from impact or scratches. They are made of polycarbonate and normally come clear or shaded. These lens covers can easily be mounted on top of the facepiece lens to provide additional impact protection. This is a good accessory for a facepiece in which the lenses are of flexible design. Figure 3-22 shows a dark shade lens cover to conceal the face of the user.

Figure 3-22. Man wearing a CBRN RPD with shaded lens cover obscuring his face. Photo courtesy MSA – The Safety Company

Rubber Hoods

Rubber hoods, as shown in Figure 3-23, provide additional protection to the protective clothing selected for the user involved in a CBRN event.

Figure 3-23. Rubber hood with straps and clips for attachment to other clothing. Photo courtesy of 3M

Amplifier

CBRN facepieces have a speaking diaphragm designed to enhance the quality of communication. Nevertheless, there are situations in which an amplifier attached to the facepiece will be of great convenience and allow for clearer communication among users during an emergency.

Maintenance and Storage of CBRN RPDs

CBRN SCBA

All CBRN SCBAs must be maintained and tested in accordance with their manufacturer's user instructions. Some procedures may only be performed by authorized service technicians using specialized equipment. Typical annual maintenance for CBRN SCBAs includes:

- Regulator flow tests
- Facepiece inspection and flow tests
- Installation of upgrades

There are other maintenance requirements regarding the hydrostatic cylinder check, which must be followed according to the user instructions and U.S. Department of Transportation regulations [Qualification, maintenance and use of cylinders, 2000]. Furthermore, SCBAs must be visually inspected and functionally tested as dictated by the manufacturer's user instructions and OSHA regulations [OSHA 1999]. OSHA also requires documentation of monthly inspections of all respirators maintained for emergencies.

CBRN Air-Purifying Devices

Routine maintenance requirements for the facepiece and other components of CBRN PAPRs, APRs, and APERs may differ among manufacturers. Some manufacturers require periodic testing of the complete facepiece on a pressure decay test apparatus. The user instructions must be strictly followed.

Manufacturers may specify some maintenance procedures for many serviceable items that can only be performed by specially trained technicians or by the manufacturer. Repairs to CBRN PAPRs and APRs must be done using only components whose part numbers are listed on the full NIOSH approval label. The user should never substitute, modify, add, or omit parts. Only exact replacement parts should be used in the configuration as specified by the manufacturer.

The user instructions must be consulted for the proper manner to store the tight-fitting CBRN PAPRs and APRs and their required components. Cleaning of the facepiece and its components must be done only with solutions recommended by the manufacturer.

CBRN APERs are not intended to be serviced or repaired in the field. They are single-use devices and should never be reused. CBRN APERs must be stored and periodically inspected as specified by the manufacturer and OSHA.

Storage instructions vary among manufacturers and models of APERs. The manufacturer's user instructions describe storage conditions required to ensure the device is ready for use. Typical storage guidelines address the storage duration; acceptable ranges of temperature and humidity; protection from dust, dirt, sunlight, and chemicals; and protection from mechanical vibration, abrasion, and crushing.

Summary

CBRN RPDs have unique features that make them different from industrial respirators. CBRN respirators are designed to protect the user against a large number of highly toxic contaminants that may be present in a terrorist attack or accident.

As discussed in this chapter, it is important to learn the unique features of a CBRN respirator and understand the NIOSH approval labels. These labels will guide the user in selecting appropriate and approved components to protect against CBRN contaminants.

It is also important to understand the cautions and limitations of each device and component configuration. NIOSH C&L statements and manufacturer user instructions provide the necessary information.

Finally, the manufacturer user instructions should be read carefully. They provide specific instructions and recommendations for the particular CBRN respirator.

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Chapter 4: CBRN Respirator Selection

Introduction

Selection of the appropriate chemical, biological, radiological, and nuclear (CBRN) respirator for an initial emergency response is generally straightforward. In most of these situations, both the air contaminant and its concentration are unknown. Since any unknown environment can be immediately dangerous to life or health (IDLH), both safe practice and regulation [OSHA 1999] require that it be treated as such. As described in Chapter 2, only CBRN self-contained breathing apparatus (SCBAs) are certified for entry into IDLH atmospheres. Maximum skin protection (a totally encapsulating chemical-protective suit) must also be used for unknown contaminants. This protective ensemble is commonly referred to as "Level A" protection.

It is important to note that CBRN test methods and criteria have been developed by other regional and national standard bodies for respirators. However, based on NIOSH review of these other standards, they are not fully equivalent to the criteria and procedures provided in the NIOSH Statements of Standard for CBRN respirators and consequently are not substitutes. Respirators selected should be approved by NIOSH.

Further, protective ensembles for CBRN and hazardous materials operations are specified in National Fire Protection Association (NFPA) 1990 [NFPA 2022], Standard for Protective Ensembles for Hazardous Materials and CBRN Operations, which consolidates NFPA 1991, NFPA 1992, and NFPA 1994. These ensembles can only be NFPA-certified with specified NIOSH Approved® CBRN respirators. When SCBAs are specified, NFPA 1990, NFPA 1981, or NFPA 1986 applies.

As information on the contaminant and its concentration is gathered during initial response, decisions can be made to establish site control (e.g., hot, warm, and cold zones) and determine appropriate CBRN respirators for remediation and ancillary work activities (such as crowd control and providing medical assistance to victims). This chapter describes the information and decision framework necessary to determine which CBRN respirator can be safely used for a given task. The same logic can also be used to determine if a CBRN device is suitable for an industrial environment.

Selection Overview

Four categories of information must be considered to select the correct respirator for use in any hazardous atmosphere:

- Hazard analysis
- Work area conditions
- Human factors
- Respirator capabilities and limitations

The following sections describe how to address each category in the context of a CBRN response.

Hazard Analysis

At the point of notification of a potential CBRN incident, efforts to characterize the respiratory hazard should begin. Answers to basic questions about the physical state of the suspected agent (i.e., liquid, gas, or particle) can start the process of identifying the contaminant(s). Reports of odors, a description of the agent's container or delivery device, and reports of symptoms of people exposed can provide useful clues to help identify the hazardous material. Oxygen deficiency must also be considered for incidents occurring in small indoor areas with limited natural ventilation. As noted earlier, if site entry must be made, the Level A ensemble with CBRN SCBA must be used. Direct-reading instruments should be used to measure oxygen content and, if possible, identify and quantify the contaminant and extent of contamination.

In many cases, it may be necessary to collect air or bulk contaminant samples for laboratory analysis to make these determinations. *Until the contaminant can be identified and its concentration measured or estimated, the only permissible respirator is the CBRN SCBA*. When these steps are complete, further steps can be taken to determine if CBRN powered air-purifying respirators (PAPRs) or air-purifying respirators (APRs) can be safely used.

As described in Chapter 2, CBRN PAPRs and APRs share approvals for particulate hazards (e.g., biological and radiological hazards), plus a wide range of chemical warfare agents (CWAs) and toxic industrial chemicals (TICs). Table 2-1 displays the CWAs and TICs covered by the CBRN approval. If the contaminant in question is covered by the CBRN approval, further analysis can determine if CBRN PAPRs or APRs are suitable to enter and work in the contaminated area. To make this decision, the following information is required:

- An atmospheric concentration of the contaminant that is considered IDLH. These values can often be found in the NIOSH Emergency Response Safety and Health Database [NIOSH 2010] or the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2020]. If the measured concentration exceeds the listed IDLH value, neither CBRN PAPRs nor CBRN APRs are acceptable. Only CBRN SCBAs can be used.
- An atmospheric concentration of the contaminant that is defined as acceptable, generally called an occupational exposure limit. For most TICs, these values are listed as recommended exposure limits (RELs), Threshold Limit Values, and permissible exposure limits (PELs). These values can be found in one or more commonly available references [ACGIH 1991; NIOSH 2020; OSHA 2010a]. Equivalent information for CWAs can often be found in the NIOSH Emergency Response Safety and Health Database [NIOSH 2010]. Note: Because occupational exposure limits do not exist for biological hazards, NIOSH makes specific, risk-based protective ensemble recommendations for these materials [NIOSH 2009].
- Once a measured or estimated contaminant exposure is determined, it is divided by the selected limit of acceptable exposure to determine the hazard ratio (HR):

$$HR = \frac{\text{Measured or estimated exposure}}{\text{Occupational exposure limit}}$$

- The HR describes how much reduction in airborne exposure (i.e., protection) the selected respirator must provide.

- Assigned protection factors (APFs) for CBRN respirators.

> *APFs represent the level of respiratory protection that a class of respirators is expected to provide to employees when a continuing, effective respiratory protection program is in place [OSHA 1999].*

Note that APFs cannot be used if an effective respiratory protection program is not in place.

Stated mathematically, an APF is the ratio of the contaminant concentration outside the respirator (C_o) to the maximum amount of contamination expected to penetrate to the inside of the respirator(C_i):

$$APF = \frac{C_o}{C_i}$$

With the exception of military operations, most employers and responder organizations in the United States are regulated by OSHA or an equivalent state agency. The APFs OSHA lists for CBRN respirators are shown in Table 4-1. A CBRN respirator with an APF equal to or greater than the calculated HR can be selected for contaminant concentrations below the IDLH value.

Table 4-1. Assigned Protection Factors (APFs) for CBRN respirators

CBRN Respirator Type	APF
Self-contained breathing apparatus (SCBA)	10000
Powered air-purifying respirator (PAPR)	1000
Air-purifying respirator (APR)	50

Example, Part 1

Responders wearing CBRN SCBAs have identified a liquid spilled in a storeroom as allyl alcohol. After securing the area and performing initial cleanup, an airborne concentration of 5 parts per million (ppm) remains. Additional cleanup of the area is expected to take three hours. The NIOSH REL for allyl alcohol is 2 ppm (up to 10-hour exposure) and the IDLH concentration is 20 ppm. What is the minimum acceptable CBRN respirator for the cleanup crew?

Solution

The allyl alcohol concentration is below the IDLH value, but greater than the REL. The hazard ratio is calculated as:

$$HR = \frac{5\ ppm}{2\ ppm} = 2.5$$

From Table 4-1, both the CBRN PAPR and CBRN APR have APFs greater than the hazard ratio. Allyl alcohol is an organic vapor covered by both CBRN approvals. The CBRN APR is the minimum acceptable respirator if a canister change schedule is developed and implemented (see discussion below).

These portions of the selection process are summarized graphically in Figure 4-1.

Work Area Conditions, Human Factors and Respirator Considerations

The protective capability of a CBRN respirator is only one consideration in the selection of a "most appropriate" device in a specific situation. The physical layout of the work (or response) area, environmental conditions such as temperature extremes and humidity, and the level of work effort required can act alone or in combination to affect which CBRN respirator is most suitable. For example, while CBRN SCBAs can be highly protective, they are not well suited to long-term use because of their limited-service life. Their bulk makes their use in confined or cluttered work areas difficult, and their weight adds significantly to cardiovascular stress. The combination of heavy work, high temperature, and full-body protective ensembles can contribute to physical stress as well. CBRN PAPRs mitigate the problems of weight and bulk, but they are not suitable for all contaminants. Battery-service time, charging, and maintenance must be considered. Additionally, the service life of the canister or cartridge must be estimated and a change schedule developed.

While they are the simplest and lightest of CBRN respirators, APRs have the same canister concerns as PAPRs. Since air is drawn through the canister by the wearer's inhalation, they can have significant breathing resistance, which can add to physical stress and reduce worker comfort. Finally, any respirator must be selected to maximize compatibility with the remainder of the protective ensemble.

Duration of CBRN Respirators' Use

Four "duration values" are associated with CBRN respirators:

1. The 2-hour, 6-hour, or 8-hour use limitation on CBRN devices exposed to CWAs. As described in Chapter 2, the limitation that applies is based on the type of CBRN device and whether the CWA exposure is to the liquid or vapor state.
2. The nominal duration of the breathing air supply of a CBRN SCBA (i.e., 30, 45, or 60 minutes). These values are based on laboratory testing and are not accurate predictors of how long users will receive air from the devices. For example, high work rates shorten SCBA service time substantially.
3. The rated capacity (CAP) of PAPR and APR canisters and cartridges (i.e., CAP1 = 15 min, CAP2 = 30 min, etc.). These values indicate how long the air-purifying elements prevent breakthrough (i.e., detection downstream of the cartridge or canister) of specific test agents under stated laboratory conditions (see Chapter 2). They do not predict how long the canisters or cartridges will last in actual use when contaminants and their concentrations, as well as environmental conditions, differ from the test conditions.
4. The canister or cartridge end-of-service-life indicator (ESLI) or change schedule. Because ESLIs are not yet available on any CBRN device, a change schedule must be determined whenever CBRN PAPRs or APRs are used [NIOSH 2006]. This is simply the time interval at which the canister(s) or cartridge(s) are replaced with new ones, and it must be established based on the site-specific conditions of use. It should also be noted that the same requirement is found in the OSHA respiratory protection regulation [OSHA 1999].

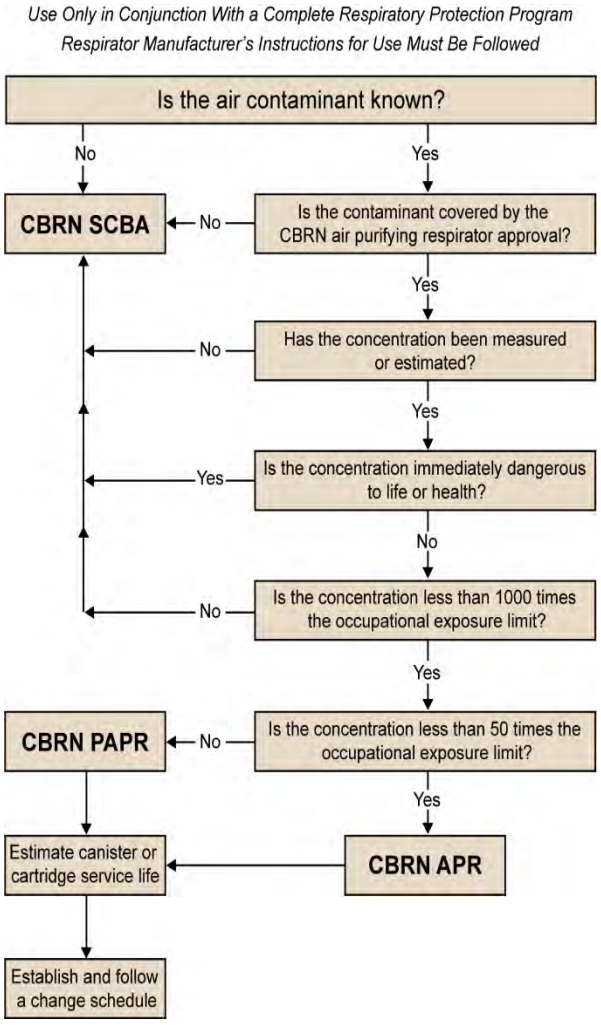

Figure 4-1. The flow chart shows a sequential series of yes/no questions to help responders choose among CBRN SCBAs, CBRN PAPRs, and CBRN APRs.

Canister/Cartridge Change Schedules

Change schedules are separate from CAP ratings. They must be based on objective data, ensuring the canisters or cartridges are changed before contaminant breakthrough. The data necessary to set a change interval include estimates of:

- The specific CBRN device in use
- The air contaminant(s) and concentration at the worksite
- Environmental conditions, including temperature and relative humidity
- Work rate or PAPR airflow rate
- Acceptable breakthrough concentration
- Appropriate safety factors

Determination of the breakthrough time for a specific set of conditions is best done using computer applications or equivalent tools developed by CBRN respirator manufacturers [3M 2010; MSA 2010; Scott 2010].

Different manufacturers' canisters may have different physical characteristics and different sorbents, and their software may use different assumptions or default values when performing calculations. For these reasons, each manufacturer's software must be considered unique to its own CBRN devices and cannot be used to estimate breakthrough time for another manufacturer's device. It is critical to work with the manufacturer before an incident occurs to learn which breakthrough estimation tools are available and how to use them. If an incident should occur, the breakthrough time can be quickly determined for the site-specific conditions. This estimate can then be used to set a change schedule that is both protective (i.e., it ensures users are not exposed to hazardous contaminant concentrations) and administratively feasible (i.e., it coincides with users' break times or end of the work shift).

Example, Part 2

A CBRN CAP1 APR was selected for the allyl alcohol clean-up crew in Part 1 of this example. The Cartridge Life Calculator [MSA 2010] was used to estimate breakthrough time with the following assumptions:

- Inlet concentration: 5 ppm allyl alcohol
- Environmental conditions—Temperature: 68°F, Relative humidity: 60%
- Atmospheric pressure: 760 Torr
- Work (breathing) rate: 60 L/min (moderate work rate)
- No safety factor selected

Calculated service time to 10% of occupational exposure limit: 8108 minutes

Change schedule: The estimated breakthrough time is well beyond the 180 minutes the respirators are expected to be used. The canisters should be discarded at the end of the task in accordance with procedures described in Chapter 8. This allows a very large margin of safety to account for uncertainty in the assumptions used for the calculation.

Used canisters should not be kept for use beyond a single shift, regardless of the estimated breakthrough time. This is because organic vapors may desorb from (come off) the activated carbon during periods of nonuse. The vapors may migrate through the bed and potentially expose the wearer to the contaminant if reused. Desorption and migration are most likely to occur with organic vapors with relatively low boiling points (< 65°C).

If manufacturer applications to estimate breakthrough times for organic vapors are not available, OSHA and NIOSH both offer service life calculators [NIOSH 2024; OSHA 2010b]. In addition to the input data manufacturers' applications require, these programs require the user to enter data on the physical characteristics of the canister or cartridge in use, as well as specific characteristics of the activated carbon it contains. If either of these programs is to be used, it is still necessary to work

closely with the respirator manufacturer before an incident occurs to ensure the end user has the necessary information.

If other information is not available, a rough estimate of breakthrough time can be made using information from NIOSH testing and worksite conditions. This might be the case, for example, if for emergency reasons, an APR canister from one manufacturer is used on another manufacturer's facepiece. As described in Chapter 2, canisters and cartridges are tested with test representative agents (TRAs) for six families of gases and vapors. An underlying assumption is that each TRA will have a breakthrough time no greater than other members of its family [NIOSH 2002]. Therefore, a breakthrough estimate can be made for all members of a family using the TRA as a surrogate for the family member. A simple ratio of the NIOSH challenge concentration to the site concentration, multiplied by the minimum required breakthrough time in the NIOSH certification test provides a rough estimate of how long a canister or cartridge will last before breakthrough. Because service time is inversely proportional to flow rate [Colton and Nelson 1997, p. 974–1000], it is acceptable to adjust the result for breathing rates significantly higher or lower than the test flow rate of 64 L/min.

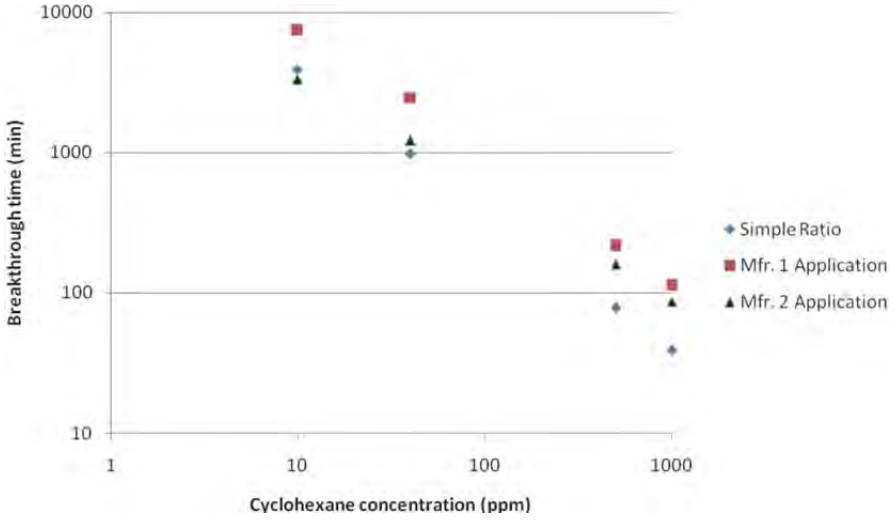

Figure 4-2. The bar chart shows breakthrough time in minutes on the y-axis and cyclohexane concentration in ppm on the x-axis. Points on the chart compare Mfr. 1 Applications, Mfr. 2 Applications, and the simple ratios.

This procedure was compared with two manufacturers' software breakthrough estimates for their respective CAP1 canisters over a range of cyclohexane concentrations. Input conditions were 60 L/min breathing rate, sea level pressure, and 60 percent relative humidity. Figure 4-2 shows that the results were similar at each concentration, with the simple ratio method at or near the shortest breakthrough estimate.

This simple ratio method must be used with caution, and appropriate safety factors applied when setting a change schedule.

Example, Part 3

A generic CBRN CAP1 APR was selected for the allyl alcohol cleanup crew in Part 1 of this example. The organization cannot locate specific service life information or data to allow use of the OSHA or NIOSH service life calculators. A rough estimate of service life can be made as follows:

Inlet concentration: 5 ppm allyl alcohol (now assumed to be 5 ppm cyclohexane)

Work (breathing) rate: 60 L/min (moderate work rate)

$$\frac{2600\ \text{ppm}}{5\ \text{ppm}} \times 15\ \text{min} = 7800\ \text{min} \times \frac{1}{3} = 2600\ \text{min}$$

Change schedule: The estimated breakthrough time is well beyond the 180 minutes the respirators are expected to be used, even with a safety factor of 3 to account for the use of a surrogate vapor and the very approximate nature of the method used. The canisters should be discarded at the end of the task.

> *Users must recognize that a change schedule represents an estimated maximum amount of time that cartridges or canisters should be used. Replacement must be done before the scheduled time if a wearer detects chemical odor or experiences symptoms of exposure, or if the respirator is damaged in any way.*

Industrial Use of CBRN Respirators

As noted earlier in this chapter, the same selection considerations apply to both CBRN and industrial respirator use. CBRN APRs hold an advantage in the broad range of contaminants for which they are tested and approved, and they are approved for some contaminants for which industrial APRs are not commonly available (e.g., phosgene). However, CBRN devices tend to be larger and heavier than cartridge-style industrial respirators, and CBRN APRs may have higher breathing resistance. All of these can add unnecessary physiological burden to the wearer. Higher cost may also be a disadvantage of CBRN devices.

Air-Purifying Escape Respirators

Air-purifying escape respirators (APERs) are tested and approved for escape only from the same air contaminants as are CBRN PAPRs and APRs, and APERs might also be approved for carbon monoxide. It must be emphasized that "escape" refers to the act of leaving the contaminated area as quickly as practical to get to respirable air [Janssen 2001, p. 71–74]. Entry into a contaminated area or performing work of any sort is not permitted while using an APER.

There is no specific regulation or guideline that dictates when CBRN APERs should be made available. Careful hazard analysis is necessary to identify when or if these devices would enhance worker protection during escape from a contaminated atmosphere. Particular emphasis must be placed on the identity of the potential air contaminant (i.e., will it be removed by an APER) and the time required to reach a respirable atmosphere. Identification of potential evacuation routes is essential to make this determination. Assigned protection factors and requirements for change schedules do not apply to APER selection and use. As is the case with any respirator selection, fit, training requirements, and use characteristics of individual APER products must be considered before a specific device is purchased.

Summary

The factors that influence selection of CBRN respirators are the same as those that affect respirator selection in any work environment. Users must understand these principles and the unique characteristics of CBRN respirators to make the most appropriate selection for a given set of use conditions. All respirators chosen must be used in the context of a complete respiratory protection program.

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Chapter 5: CBRN Respiratory Protection Program Requirements

Introduction

Emergency responder organizations that respond to emergencies that require respirators, and that are subject to Occupational Safety and Health Administration (OSHA) regulations, must implement a respiratory protection program as defined in the:

- OSHA Respiratory Protection standard, 29 Code of Federal Regulations (CFR) 1910.134 [OSHA 1999]
- OSHA Hazardous Waste Operations and Emergency Response standard, 29 CFR 1910.120 [OSHA 1990]

These organizations employ law enforcement officers, firefighters, and emergency medical technicians who respond to chemical, biological, radiological, and nuclear (CBRN) and other hazardous material emergencies. The Environmental Protection Agency (EPA) Worker Protection regulation, 40 CFR Chapter 1, Part 311 [Worker protection, 2011] also clearly identifies the OSHA Respiratory Protection regulation, 29 CFR 1910.134, as a requirement for organizations that respond to CBRN and other hazardous material incidents. National Fire Protection Association (NFPA) 470 (Hazardous Materials/Weapons of Mass Destruction [WMD] Standard for Responders) also references this standard.

T.K. Cloonan, a National Institute for Occupational Safety and Health (NIOSH) physical scientist, presented his findings on the use of CBRN respiratory protection equipment by a number of large U.S. fire and police departments. As part of this unique assessment of 155 organizations, he interacted directly with these organizations and evaluated the current content and implementation of their CBRN respiratory protection programs [Cloonan 2011]. In his interaction with the 42 fire service organizations contacted, he noted:

- U.S. Tier I fire service organizations continue to use variations of written/non-written respiratory protection programs.[a]
- U.S. Tier II and III cities rely on partial/incomplete respiratory protection programs using policy letters; standard operating procedures; and standards, objectives, and goals.[a]
- The use of written respiratory protection programs is not as common in states that have not implemented a state OSHA program.
- "NIOSH-approved" is misunderstood; many incorrectly equate it with a respirator approved by NIOSH with CBRN protection.
- Field self-contained breathing apparatus upgraded to CBRN Agent Approved (retrofit) require quality assurance inspections to ensure the upgrade was done correctly.

In his interaction with the 15 law enforcement organizations contacted, Cloonan noted:

[a] Tier I through Tier III classification refers to various Homeland Security risk assessment processes [Cummings et al. 2006].

- Written respiratory protection programs are in development, Federal Bureau of Investigations (FBI) HAZMAT response continues to set the readiness standard, and CS (tear gas) is still being used for respiratory protection training.
- Police departments require respiratory protection from the effects of clandestine drug labs, hydrogen sulfide suicide incidents, and biological powder incidents.

Cloonan's findings identify the need to develop a compliant respiratory protection program for CBRN applications for various emergency responder organizations.

The purpose of a CBRN respiratory protection program is to ensure the correct and functional CBRN respiratory protection is provided to the trained respirator user. The program provides an organized set of elements to implement to accomplish this purpose. CBRN respiratory protection programs provide a safety net for emergency responders. The programs ensure they are properly qualified and trained and their equipment is properly selected and maintained. Proper training and selection will protect them in emergency situations.

A 1938 American Standard Safety Code [ASA 1938] first recognized the need for various respiratory protection program elements. A 1959 revision of that code expanded on its work [ASA 1959]. The specific requirement for a comprehensive respirator program was first laid out in the American National Standards Institute (ANSI) Z88.2-1969 Standard, "Practices for Respiratory Protection" [ANSI 1969], which was adopted by OSHA as 1910.134 in 1971 [OSHA 1971]. This OSHA respiratory protection regulation was revised in 1998 [OSHA 1998] and 2006 [OSHA 2006]. An OSHA-compliant CBRN respiratory protection program currently contains nine elements:

1. Procedures for selecting respirators for use in the workplace
2. Medical evaluations of employees required to use respirators
3. Fit testing procedures for tight-fitting respirators
4. Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations
5. Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators
6. Procedures to assure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators
7. Training of employees in respiratory hazards to which they are potentially exposed during routine and emergency situations
8. Training of employees in the proper use of respirators, including putting on and removing them, any limitation of their use, and their maintenance
9. Procedures for regularly evaluating the effectiveness of the program

This written respiratory protection program is required to be updated on a regular basis to reflect changes in the workplace.

This chapter addresses each of these program elements, some of them will be expanded in separate chapters of this handbook. To implement each respiratory protection program element, organizations typically prepare a standard operating procedure (defined as a set of written instructions to document a routine or repetitive activity followed by the organization) for each program element. The benefit of developing standard operating procedures for each respiratory protection program

element is that it minimizes variation and promotes quality through consistent implementation of well-defined procedures. Specific reference documents are available to provide recommendations in the preparation of standard operating procedures [EPA 2007; FEMA 1999; SAFECOM 2006].

CBRN Respiratory Protection Program Elements

General Requirements

OSHA requires the employer to designate a respiratory protection program manager who is responsible for administering or overseeing the CBRN respirator protection program. The qualifications for this individual can be met by appropriate experience and training corresponding to the complexity of the program. This individual should have a management position or rank that allows the appropriate interaction with other parts of the organization assigned responsibility for any of the program elements. Emergency responders must only use NIOSH Approved respirators, such as:

- CBRN self-contained breathing apparatus (SCBAs)
- Powered air-purifying respirators (PAPRs)
- Full facepiece air-purifying respirators (APRs) (gas masks)
- Air-purifying escape respirators (APERs)

Use of these respirators requires a complete respiratory protection program. The employer is required to provide CBRN respirators, training, and medical evaluations at no cost to the employee.

Procedures for Selecting Respirators for Use in a CBRN Response

Written procedures for CBRN respirator selection must be comprehensive, task-specific, and updated on a regular basis. These procedures are not intended only to meet a regulatory requirement and placed on a shelf. They need to be of value at the working level and referred to on a regular basis. Many organizations use checklists to present the information in an easy-to-use format.

The hazards assessment process is a very important part of respirator selection. When completing the hazards assessment for toxic materials such as CBRN agents, consider the following factors:

- Physical and chemical properties
- Adverse health effects
- Occupational exposure level
- Results of workplace sampling
- Work operation
- Time period of respirator wear
- Work activities and stresses on the wearer
- Warning properties
- Capabilities and limitations of CBRN respirator types

Chapter 4 on CBRN respirator selection addresses these four categories of information: hazard analysis, work area conditions, human factors, and respirator capabilities. This chapter provides more

detailed information about the respirator selection process and these four categories of information, including specific examples of how to utilize them for respirator selection.

Medical Evaluations of Employees Required to Use CBRN Respirators

Medical evaluations are required to ensure workers can safely wear a specific type of respirator. This initial medical evaluation can be completed several different ways following OSHA recommendations.

The employee can complete the initial step of filling out the OSHA Medical Evaluation Questionnaire (OSHA 1910.134, Appendix C) alone or with the help of a physician or other licensed health care professional (PLHCP). The PLHCP reviews the answers, and any additional tests the PLHCP feels necessary for the evaluation are administered. The employer is also required to provide the PLHCP with the following information:

- Type and weight of the respirator being used
- Duration and frequency of use (including use during rescue and escape)
- Expected physical work effort
- Additional protective clothing and equipment to be worn
- Temperature and humidity extremes that may be encountered
- Copy of the written respirator program

The PLHCP reviews this information and provides the employer with a determination for each employee, including whether the employee cannot use a respirator (no usage), full respirator usage, or limited respirator usage (with specific restrictions). Assessing the ability of the worker to safely tolerate the physiological burden created by wearing a CBRN respirator is the purpose of the medical evaluation. Additional information on this subject is available in Chapter 8.

The pre-placement medical evaluation must occur prior to fit testing and the use of any respirator. There is no specific time interval for additional medical evaluations, but they must be provided based on observations or a request by the PLHCP, respirator program administrator, respirator fit tester, supervisor, or the worker. An additional evaluation is also required if the worker is assigned to a different job with a greater physiological burden (e.g., higher work rate, additional protective clothing, or higher temperatures).

Specific medical evaluation requirements for the Fire Service are provided in NFPA 1582, "Standard on Comprehensive Occupational Medical Program for Fire Departments" [NFPA 2013b]. ANSI Z88.6-2006, "American National Standard for Respiratory Protection-Physical Qualifications for Respirator Use,"[ANSI 2006] provides additional information related to medical evaluations for workers required to use respirators.

Fit Testing Procedures for Tight-Fitting CBRN Respirators

Respirator fit testing is a very important part of the respiratory protection program because it confirms and documents that the specific respirator model selected for the worker fits properly. OSHA requires that a worker receive an initial fit test before beginning work using the same make, model, style, and size of respirator that will be used in the workplace. Fit testing also provides a good opportunity to train the worker on how to don and wear the respirator properly. The results of

improper donning can be demonstrated quickly by smell, taste, or with direct readout instrumentation.

The two general types of fit testing techniques are qualitative and quantitative. Qualitative fit testing utilizes the worker's senses of taste or smell to detect the test agent and to determine success of proper respirator fit. Quantitative fit testing, on the other hand, uses a separate analytical instrument to determine if there has been a measurable leak of the respirator.

Additional fit testing is required when a different respirator facepiece (size, style, model, or make) is used, or at least annually after the initial test. Additional fit tests must also be provided when observations are made that identify changes in the respirator user's physical condition that could affect respirator fit. Such conditions include, but are not limited to, facial scarring, dental changes, cosmetic surgery, facial piercings, or an obvious change in body weight. Fit testing is required for all tight-fitting respirators, such as CBRN SCBAs, PAPRs equipped with a tight-fitting full facepiece, and APRs.

Differently than a fit test, another way to evaluate respirator fit is by checking the facepiece seal of a CBRN respirator. OSHA requires the positive or negative pressure user seal check test be successfully completed after each donning of a CBRN tight-fitting respirator.

Additional information and details on respirator fit testing are provided in Chapter 6.

Procedures for Proper Use of CBRN Respirators in Routine and Reasonably Foreseeable Emergency Situations

Procedures are necessary to instruct the worker on the proper use of CBRN respirators in routine and reasonably foreseeable emergency situations. These procedures must ensure the worker knows how to use the CBRN respirator properly to obtain the necessary level of protection. A clean and unobstructed respirator-sealing surface on the wearer's face is pivotal in ensuring the respirator seals properly. When other personal protective equipment is provided, the employer shall ensure that it does not interfere with the seal of the facepiece.

CBRN respirator use procedures should forbid facial hair that interferes with the respirator-sealing surface. Controlling facial hair has presented ongoing respirator program issues for decades. A personnel policy that clearly states that facial hair is not permitted for specific jobs that require the use of CBRN respirators with tight-fitting facepieces is the best way to address this issue. Some accommodation can be made for facial hair by using a PAPR equipped with a hood, but this respirator cannot be used in an immediately dangerous to life or health (IDLH) environment or when concentrations exceed 1000 times the OSHA permissible exposure limit.

The procedures should also forbid the use of eyeglass temple bars or straps that interfere with the respirator-sealing surface. If the user requires corrective lenses, specific manufacturer spectacle insert kits with the appropriate prescription lenses shall be provided. Alternatively, contact lenses can be worn.

Another required procedure should lay out an ongoing activity to determine the effectiveness of CBRN respirators in use. This activity requires an evaluation of how the respirators are used and maintained in the field as well as how the worker behaves when using the respirator. When respirator performance or use problems are observed in the field, the employer must make sure the worker

leaves the respirator use area before removing the respirator to address the issue. Any issues identified should be documented and corrected. OSHA requires a separate procedure for entry into IDLH atmospheres that lists the specific requirements and details to be followed. This IDLH procedure should address:

- Dedicated outside standby person
- Communication between entrant and outside standby
- Appropriate training and equipment (SCBA or positive pressure airline respirator with five minute escape cylinder) for the entrant(s) and outside standby to provide effective emergency rescue
- Communication with the employer by the outside standby before undertaking a rescue
- Appropriate employer action when informed of a rescue being initiated
- Appropriate entrant retrieval equipment, where appropriate
- Equivalent means for rescue where retrieval equipment is not required

The IDLH environment for structural firefighting requires at least two firefighters be located on the outside of the IDLH environment when two or more firefighters enter the IDLH environment. All firefighters involved in structural firefighting must be equipped with SCBAs. Checklists that summarize the requirements of these procedures make good training aids and improve the understanding, performance, and compliance.

Procedures and Schedules for Cleaning, Disinfecting, Storing, Inspecting, Repairing, Discarding, and Otherwise Maintaining CBRN Respirators

Maintenance and care procedures should address the how and when of these processes to ensure CBRN respirators function properly after routine use or storage. CBRN respirators that come in direct contact with a CBRN agent are typically bagged, isolated, and decontaminated or disposed of on a case-by-case basis. Procedures that follow the manufacturer's directions for routine cleaning, disinfecting, and repair of respirators should be incorporated into respirator maintenance procedures and implemented. Appendix B-2 of OSHA 29 CFR 1910.134 provides an alternate method for cleaning and disinfecting of respirators. After cleaning and disinfection, the respirators should be inspected, tested, and repaired where necessary to ensure each respirator is functional and ready to use before it is returned to service. Respirators that are found to be defective and cannot be repaired should be discarded. Properly trained individuals following the manufacturer's directions and using NIOSH Approved® parts designed for that respirator must perform any respirator repairs. Reducing and emission valves, regulators, and alarms must be adjusted or repaired only by the manufacturer, or a technician trained by the manufacturer. Respirator components must not be replaced with others that are not listed on the NIOSH approval label, even if they appear to be similar.

Canisters of CBRN respirators are interoperable among NIOSH Approved CBRN APRs. This is due in part to the adoption of facepiece mechanical connector design specifications and standardized threads which match canister specifications on all NIOSH Approved CBRN APRs. These interoperability requirements do not apply to NIOSH Approved industrial gas masks. Interoperable use of CBRN canisters is only acceptable when authorized by OSHA during an emergency, provided

that the NIOSH Approved CBRN APR canister selected provides protection at the same level (e.g., CAP 1 or Cap 2, etc.) as the canister specified on the NIOSH CBRN approval label.

> *Use of components not listed on the full NIOSH approval label for the CBRN respirator constitutes configurations not included in the NIOSH CBRN approval and may result in serious injury and/or death of the wearer.*

Respirators must be stored to protect them from damage, contamination, dust, sunlight, extreme temperatures, excessive moisture, and damaging chemicals. They must also be packed or stored to prevent deformation of the facepiece and exhalation valve.

CBRN respirators and cartridges must be kept in their original packages per the manufacturer's instructions. CBRN respirators maintained for emergency response purposes must be inspected at least monthly and immediately prior to use. Emergency escape respirators must be inspected before being taken into the workplace for use.

Procedures to Ensure Adequate Air Quality, Quantity, and Flow of Breathing Air for Atmosphere-Supplying CBRN Respirators

Breathing air for CBRN atmosphere-supplying respirators is required to meet purity and quality levels for content and not exceed certain contaminant levels and moisture requirements. OSHA requires that CBRN respirator breathing air meet the requirements for Grade D breathing air described in ANSI G-7.1-2011 [ANSI/CGA 2001].

Cylinders used to supply breathing air to respirators must be tested and maintained as prescribed by the Department of Transportation [Transportation specifications, 2006]. When air is purchased in cylinders, a certificate of analysis must be obtained from the supplier to assure that the breathing air meets the Grade D specification. The moisture content in the cylinders must not exceed a dew point of -50°F (-45.6°C) at one atmosphere pressure.

If a compressor is used to supply breathing air for SCBA tank filling or for airline respirators, the compressor should be located so that contaminated air does not enter the air supply system. Moisture content should be controlled so that the dew point at one atmosphere pressure is 10°F below ambient temperature. The compressor should also be equipped with suitable in-line air-purifying sorbent beds and filters to further ensure breathing air quality. Carbon monoxide breathing air levels must not exceed 10 parts per million (ppm) for non-oil-lubricated compressors. Oil-lubricated compressors must be equipped with a high-temperature or carbon monoxide monitor or both to monitor for carbon monoxide. If only a high-temperature alarm is used, the breathing air must be monitored at intervals to prevent carbon monoxide levels in the breathing air from exceeding 10 ppm. Breathing air hose couplings shall be unique to prevent the connection to non-respirable air or other gas systems. Breathing air cylinders shall be marked in accordance with the NIOSH certification standard, 42 CFR Part 84.

NFPA 1989, "Standard on Breathing Air Quality for Emergency Service Respiratory Protection,"[NFPA 2013e] requires quarterly air sampling from breathing air systems to confirm compliance with requirements for oxygen, carbon monoxide, carbon dioxide, condensed oil and particulate content, water content, non-methane volatile organic compounds, odor, and nitrogen content. Commercial

contractors provide this quarterly sampling service utilizing a sampling system that is returned for analysis after the sample is collected. Sample results from some services are available on the web within a short period of time.

Procedures for Training

OSHA requires that the employer provide effective training to employees who must wear CBRN respirators. The training must be comprehensive, understandable, and recur annually or more often if necessary. For the training to be judged successful, the employees must be able to demonstrate knowledge and understanding in the following areas:

- Why is the CBRN respirator necessary?
- How can improper fit, usage, and maintenance compromise the protective effect of this respirator?
- What are the limitations and capabilities of this respirator?
- How do employees use this respirator effectively in emergency situations, including situations in which the respirator malfunctions?
- How do employees inspect, put on, remove, use, and check the seals of the respirator?
- What are the procedures for the maintenance and storage of this respirator?
- How do employees recognize medical signs and symptoms that may limit or prevent effective use of this respirator?
- What are the general requirements of 1910.134?

NFPA provides specific firefighter training requirements for SCBAs in NFPA 1404, "Standard for Fire Service Respiratory Protection Training" [NFPA 2013a]. Additional information on employee training can be found in Chapter 9.

Procedures for Regularly Evaluating Effectiveness of the Program

Regular evaluations of the workplace are required to ensure that the written CBRN respiratory protection program is being properly implemented and workers are using the respirator properly. Consulting with employees who use the respirators is necessary to identify any concerns they have with the program. This evaluation should review, at a minimum, respirator fit, appropriate respirator selection for the hazards to which the employee is exposed, proper respirator use, and proper maintenance and storage. A written report should be prepared summarizing the findings and recommended corrective actions. A follow up report closing out the corrective actions should also be prepared. As a rule of thumb, these evaluations should be done at least annually or more frequently if significant issues are identified.

Recordkeeping

OSHA requires the employer to establish and retain written information regarding medical evaluations, fit testing, and the respiratory protection program. Medical records must be preserved and maintained for at least the duration of employment plus 30 years, with several exceptions noted in the section addressing access to employee exposure and medical records, 29 CFR 1910.1020 [Access to employee exposure records, 2006]. Qualitative and quantitative fit test results must be

kept until the next fit test is administered. A written copy of the respiratory protection program must also be retained.

Summary

A major task of the emergency services respiratory protection program manager is the preparation, implementation, and revision of the elements of the respiratory protection program and the various standard operating procedures identified in the respiratory protection program. Each of the nine OSHA respiratory protection program elements can require one or more standard operating procedures. The addition of CBRN respiratory protection requires the inclusion of additional information and in some cases the creation of additional standard operating procedures. Appendix C contains two respirator program examples from a fire and police organization for review: Sonoma County Fire and Emergency Services Department, Respiratory Protection Program, Revised 2/20/11; [Sonoma County Fire and Emergency Services Department 2011] and the Fort Collins Police Services, Office of Chief of Police, Directive No. D-6, Respiratory Protection Policy, March 24, 2009 [Fort Collins Police Services 2009]. These examples are provided to illustrate how different organizations address standard operating procedures and a respiratory protection program.

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Chapter 6: CBRN Respirator Fit Testing Methods

Introduction

Respirator fit is a critical component in providing adequate chemical, biological, radiological, and nuclear (CBRN) respiratory protection. A variety of techniques have been used since 1934 [USBM 1934] to evaluate respirator fit. In 1971, the Occupational Safety and Health Administration (OSHA) adopted American National Standards Institute (ANSI) Z88.2-1969 [ANSI 1969] as its respiratory protection regulations as well as 29 Code of Federal Regulations (CFR) 1910.134 "Respiratory Protection" [OSHA 1971] with essentially no changes related to respirator fit testing. The revision of ANSI Z88.2 in 1980 [ANSI 1980] introduced the terms qualitative and quantitative fitting tests. A qualitative fit test is a pass/fail test method that relies on the subject's sensory response to detect a challenge agent to assess the adequacy of respirator fit. A quantitative fit test uses an instrument to assess (quantify) the amount of face seal leakage into the respirator to assess adequacy of its fit. Each fit test method has advantages and disadvantages. Qualitative fit tests do not require expensive equipment, but the test subject can influence the results. Quantitative fit tests require expensive equipment, but the results are independent of any test subject influence. These two general types of respirator fit tests provide the basis for measuring respirator fit.

Respirator Fit Testing

The primary purpose of respirator fit testing is to choose a specific make, model, style, and size of a tight-fitting CBRN full facepiece respirator that properly fits the wearer and provides protection. Currently, NIOSH Approved® CBRN respirators that require fit testing only use tight-fitting full facepieces. OSHA requires that both positive and negative pressure tight-fitting full facepiece respirators be fit tested. To fit test positive pressure tight-fitting full facepiece respirators, a negative pressure full facepiece respirator that matches the positive pressure full facepiece respirator can be substituted. Adaptors are also available from respirator manufacturers to permit a negative pressure fit test using the positive pressure tight-fitting facepiece.

The fit test methods chosen for negative pressure full facepiece respirators must be able to detect a leak (penetration) into the respirator of at least 0.2 percent to determine if the respirator is providing the pass/fail required fit factor (FF) of 500. A measured leak of 0.2 percent results in a fit factor of 500 (FF = 1 ÷ % leakage = 1 ÷ 0.002 = 500). A fit factor of 500 divided by a required safety factor of 10 results in an assigned protection factor of 50. OSHA requires that fit testing of negative pressure full facepiece respirators be carried out using quantitative fit test procedures when a protection factor of 50 is required. This is because existing qualitative fit test procedures were developed to screen for a fit factor of 100. That is, they can detect a leak into the respirator of one percent or greater.

For positive pressure tight-fitting full facepiece respirators, OSHA regulations and National Fire Protection Association standards permit the use of a qualitative or quantitative fit test.

This means powered air-purifying respirators equipped with tight-fitting full facepieces and CBRN self-contained breathing apparatus (SCBAs) can be fit tested using a qualitative or quantitative test. To achieve the required level of respiratory protection for CBRN agents, some respirator manufacturers

specify a fit factor higher than 500 for their full facepiece respirators in the user instructions. Manufacturer-specified fit factors currently range from 500 to 2500 and must be identified by the respirator program manager and used by the respirator fit test (RFT) operator to determine the correct pass/fail value for that specific respirator. As noted previously, OSHA requires the minimum pass level of 500 for quantitative fit tests for tight-fitting full facepiece respirators, but it would allow a manufacturer's higher pass level to be used. Because of the positive pressure maintained inside the full facepiece for these classes of respirators, a qualitative fit test is permitted. The general purpose for these tests on positive pressure respirators is to identify significant facepiece-to-face leaks. The quantitative fit test is only required when the fit test is used for negative pressure CBRN air-purifying respirator facepieces.

Respirator fit testing provides the opportunity for hands-on training of the respirator wearer. This training complements normal classroom or computer-based training typically provided to respirator users. In either a qualitative or quantitative fit test, a RFT operator observes the wearer as they put on the respirator, adjust the strap tightness, position the respirator on the face and the straps on the head, and carry out a positive and/or negative user seal check. During the mask donning and checking process, the RFT operator can provide hands-on instruction, as needed, to ensure the mask is worn properly and the user seal checks are conducted correctly. The RFT operator can also demonstrate the test results (and thus the danger) of improper donning.

To achieve the required level of respiratory protection for CBRN agents, some respirator manufacturers specify a fit factor higher than 500 for their full facepiece respirators in the user instructions. Manufacturer-specified fit factors currently range from 500 to 2500 and must be identified by the respirator program manager and used by the RFT operator to determine the correct pass/fail value for that specific respirator. As noted previously, OSHA requires the minimum pass level of 500 for quantitative fit tests for tight-fitting full facepiece respirators but would allow a manufacturer's higher pass level to be used.

Fit Test Methods

The OSHA regulation, 29 CFR 1910.134, recognizes the following qualitative fit test and quantitative fit test methods.

Qualitative fit test methods:

- Isoamyl acetate
- Saccharin
- Bitrex (denatonium benzoate)
- Irritant smoke (stannic chloride)

Quantitative fit test methods:

- Generated aerosol
- Ambient aerosol
- Controlled negative pressure

The general qualitative fit test and quantitative fit test requirements and instructions for both the person being fit tested and the person conducting the fit test are provided in the mandatory Appendix

A [OSHA 1998] of 29 CFR 1910.134. This standardizes the methods used and provides more consistent fit test results.

Before being fit tested, the test subject must first pass a user seal check. A general overview of each test is provided below with specific procedural details, where appropriate.

Qualitative Fit Test Methods

Isoamyl Acetate Method

Isoamyl acetate is an organic liquid that makes a very good qualitative test agent because it has a distinctive banana-like odor at low concentrations and is easily adsorbed by air-purifying organic vapor cartridges. The steps in an isoamyl acetate test are as follows:

5. RFT operator verifies that the test subject can detect isoamyl acetate at a predetermined low concentration.
6. Test subject puts on the CBRN full facepiece respirator equipped with organic vapor cartridges in a room separated from the test chamber and performs a user seal check.
7. Test subject enters the test chamber, exposes a known volume of isoamyl acetate in the test chamber, and waits two minutes for the test atmosphere to stabilize.
8. Test subject begins the prescribed fit test exercises. If at any time the test subject detects a banana-like odor, the test is failed, and the test subject exits the test chamber. If the test subject completes all the required exercises to pass the test, the respirator seal is broken before exiting the chamber to demonstrate the efficiency of the respirator.

Saccharin Method

Saccharin is an artificial sweetener that can be aerosolized easily using a nebulizer to make a small aerosol test atmosphere. The steps in a saccharin test are as follows:

9. RFT operator verifies the sensitivity of the test subject to the taste of saccharin.

- Test subject replaces a small portable enclosure placed over their head. The enclosure has a ¾-inch hole at nose level.
- RFT operator fills a specified commercially available nebulizer with a specified solution of saccharin and distilled water, inserts the nebulizer outlet nozzle into the ¾-inch hole, and squeezes it 10 times.
- If the test subject detects a sweet taste, they are ready to proceed with the test.
- RFT operator can administer two additional 10-squeeze exposures to determine if the test subject can taste the saccharin. RFT operator notes the number of 10-squeeze exposures and uses this information for the respirator test.
- If the subject tastes nothing after three tries, the test may not be performed on that subject

10. The qualified test subject dons the CBRN full facepiece respirator equipped with the appropriate filter, performs a user seal check, and places the enclosure over the respirator and their head.
11. RFT operator inserts the nebulizer nozzle into the ¾-inch hole and completes one, two, or three 10-squeeze exposures, based on the taste test.

12. Test subject carries out the required fit test exercises, and the test atmosphere is replenished every 30 seconds with one half of the original number of nebulizer squeezes used (5, 10, or 15). If the taste of saccharin is detected at any time during the required exercises, the fit is deemed unsatisfactory, and the test is failed. If the taste of saccharin is not detected throughout all of the required exercises, the test is passed.

Bitrex (Denatonium Benzoate) Method

Bitrex is bitter-tasting chemical that is widely used as a taste aversion agent in household liquids. It can be aerosolized easily using a nebulizer to make a small aerosol test atmosphere. The steps in a Bitrex test are as follows:

13. RFT operator verifies the sensitivity of the test subject to the taste of Bitrex.

- Test subject places a small portable enclosure placed over their head. The enclosure has a ¾-inch hole at nose level.
- RFT operator fills a specified commercially available nebulizer with a specified solution of Bitrex and five percent salt water. RFT operator inserts the nebulizer outlet nozzle into the ¾-inch hole and squeezes it 10 times.
- If the test subject detects a bitter taste, they are ready to proceed with the test.
- RFT operator can administer two additional 10-squeeze exposures to determine if the test subject can taste the Bitrex. The RFT operator notes the number of 10-squeeze exposures and uses this information for the respirator test.
- If the subject tastes nothing after three tries, the test may not be performed on that subject.

14. The qualified test subject dons the CBRN full facepiece respirator, equipped with the appropriate filters, performs a user seal check, and places the enclosure over the respirator and their head.
15. RFT operator inserts the nebulizer nozzle into the ¾-inch hole and completes one, two, or three ten-squeeze exposures, based on the taste test.
16. Test subject carries out the required fit test exercises and the test atmosphere is replenished every 30 seconds with one-half of the original number of nebulizer squeezes used (5, 10, or 15). If the taste of Bitrex is detected at any time during the required exercises, the fit is deemed unsatisfactory, and the test is failed. If the taste of Bitrex is not detected throughout all the required exercises, the test is passed.

Irritant Smoke (Stannic Chloride) Method[13]

Irritant smoke tubes contain a mixture of vermiculite and stannic chloride. When the ends of the tube are removed and a squeeze bulb is attached to one end, the ambient humidity of the air forced through the tube produces a white smoke consisting of hydrogen chloride and tin compounds. Exposure to this test agent causes an immediate involuntary cough in the test subject. The test must be performed in an area with adequate ventilation to prevent test agent exposure to the RFT operator. The CBRN full facepiece respirator must be equipped with P100® filters. The steps in an irritant smoke test are as follows:

[13] NIOSH does not recommend the use of this test method because of the health risk associated with the exposure to irritant smoke, hydrochloric acid [NIOSH 2005].

17. RFT operator uses a weak concentration of the irritant smoke to confirm the test subject's response.
18. Test subject dons the respirator and performs a user seal check to confirm the seal integrity.
19. RFT operator directs a stream of irritant smoke toward the face seal area and moves the smoke stream around the perimeter of the mask.
20. Test subject carries out the required fit test exercises and if any irritant smoke is detected the test is failed. If no irritant smoke is detected throughout the required fit test exercises and a final sensitivity response is confirmed, the fit test is passed.

Quantitative Fit Test Methods

Generated Aerosol Method

The generated aerosol quantitative fit test method uses a generated aerosol, such as corn oil, as the test agent in an enclosed space. The steps in a generated aerosol test are as follows:

21. Test subject dons the probed respirator equipped with P100 filters and related sampling equipment if required.
22. Test subject performs a user seal check before entering the enclosure.
23. Once inside the enclosure, test subject connects the sampling hose to the aerosol monitor sampling port.
24. Test subject performs the required set of exercises. The interior of the respirator is monitored for aerosol leakage with an aerosol monitor, such as a forward light-scattering photometer, during each exercise.
25. RFT operator compares the inside aerosol concentration to the outside aerosol concentration for each exercise and averages them to determine the average leak rate (penetration) and fit factor for the respirator.

Respirators used in quantitative fit testing are modified by adding a sampling probe centered between the nose and the upper lip. This allows a sample to be collected from the breathing zone inside the facepiece/nose cup of the respirator. Probed respirators are available from individual respirator manufacturers to use for quantitative fit testing. Sampling probe kits are also available to permanently or temporarily modify the respirator to install a sampling probe.

Ambient or Generated Aerosol Method

The ambient aerosol quantitative fit test method uses ambient aerosol as the test agent. In some cases, the ambient aerosol concentration has to be supplemented to provide an adequate challenge concentration to assure valid measurements. Sometimes this can be accomplished by simply burning a candle in the room in which the fit test is performed. Special aerosol generators are also available for this purpose. The steps in an ambient or generated aerosol test are as follows:

26. Test subject dons the probed respirator equipped with P100 filters and performs a user seal check.
27. Test subject takes the attached sampling hose, connects it to the ambient aerosol monitor instrument, and carries out the required set of exercises.
28. RFT operator monitors the interior of the respirator for aerosol leakage with an aerosol monitor, such as a condensation nuclei counter (e.g., TSI Portacount).

29. RFT operator compares the inside concentration to the outside concentration for each exercise and averages them to determine the average leak rate (penetration) and fit factor for the respirator. These calculations can be automated using a computer and software provided by the equipment manufacturer.

Controlled Negative Pressure Method

The controlled negative pressure quantitative fit test method uses air molecules as the test agent. An instrument is used to generate a negative pressure inside the facepiece of the respirator, while the subject holds their breath to measure the resulting volumetric air leak rate.

The negative pressure generated in the respirator facepiece corresponds to a specific predetermined inspiratory flow rate. To perform this test, the respirator must be modified with the appropriate controlled negative pressure test adaptors before the test subject dons it.

The steps in a controlled negative pressure test are as follows:

30. Test subject dons the modified respirator.
31. Test subject completes a required set of exercises, stopping at the completion of each exercise to permit the controlled negative pressure measurement device to determine the leak rate. Before the measurement is initiated, the test subject takes a breath and holds it. The controlled negative pressure monitor is started, produces a negative pressure in the respirator, and measures the flow of air exhausted to maintain a constant pressure during the test period.
32. RFT operator measures the exhausted air after each exercise and uses the measurement to calculate the leak rate (penetration) and fit factor for the respirator (e.g., OHD Fit Tester 3000).

Fit Test Exercises

OSHA requires the test subjects to perform the following exercises in the various test environments.

33. Normal breathing. In a normal standing position, without talking, the subject must breathe normally.
34. Deep breathing. In a normal standing position, the subject must breathe slowly and deeply, taking caution so as not to hyperventilate.
35. Turning head side to side. Standing in place, the subject must slowly turn their head from side to side between the extreme positions on each side. The subject must hold their head at each extreme momentarily, so they can inhale at each side.
36. Moving head up and down. Standing in place, the subject must slowly move their head up and down. The subject must inhale in the up position (i.e., when looking toward the ceiling).
37. Talking. The subject must talk slowly and loudly enough to be heard clearly by the test conductor. The subject can read from a prepared text such as the Rainbow Passage, count backward from 100, or recite a memorized poem or song.
38. Grimace. The test subject must grimace by smiling and frowning.
39. Bending over or jogging in place. The test subject must bend at the waist as if they were touching their toes.
40. Normal breathing. Same as exercise number 1.

In 29 CFR 1910.134, Appendix A, OSHA provides a modified set of exercises for the controlled negative pressure method, with a set of five exercises that include respirator redonning. The three

quantitative fit test methods previously described require each exercise to be carried out for one minute, except the grimace exercise that must be performed for 15 seconds. The grimace exercise is not required for any of the qualitative fit test methods, and the results from this test are not used in calculating the overall respirator fit factor for the quantitative fit tests. One can expect the results from the individual fit test exercises to vary, but it is the overall fit factor of the respirator that is used to determine pass or fail of a quantitative respirator fit test.

User Seal Check

An adequate facepiece seal is necessary for a CBRN respirator to provide the proper level of protection. The positive or negative user seal check test must be completed successfully as part of a qualitative or quantitative fit test and in the field after each donning of a CBRN tight-fitting respirator. To carry out a positive pressure user seal check, the wearer closes off the exhalation valve or the SCBA mask-mounted regulator opening on the respirator with the palm of the hand and exhales gently into the facepiece. The fit is considered satisfactory if a slight positive pressure builds up inside the facepiece without any evidence of outward leakage of air at the seal.

To carry out a negative pressure user seal check, the wearer closes off the inlet opening of the cartridges, canister, or SCBA mask-mounted regulator opening with the palm of the hand and inhales gently so that the facepiece collapses slightly, and the user then holds their breath for 10 seconds. If the facepiece remains in its slightly collapsed condition and no inward leakage of air is detected, the tightness of the respirator is considered satisfactory. If the palm of the hand cannot effectively cover the canister or mask-mounted regulator opening, a thin latex or nitrile glove can be used to cover it. When performing a user seal check without the SCBA regulator in place, only the air tightness of the sealing surface of the mask to face can be evaluated. When carrying out the user seal check, the worker should be trained to examine the respirator for any defective parts (e.g., facepiece, head straps, valves, connecting tube, and cartridges or canisters) that are not functioning properly. If any problems are identified, the respirator should be repaired or replaced.

See Chapter 5 for specific details on implementing qualitative and/or quantitative fit testing as part of the respirator program. ANSI/AIHA Z88.10-2010, “Respirator Fit Testing Methods,” provides additional help on how to conduct fit testing of tight-fitting respirators [AIHA/ANSI 2010].

Summary

Respirator fit is a critical component for providing adequate CBRN respiratory protection and a major part of any respirator program. The primary purpose of respirator fit testing is to choose a specific make, model, style, and size of a tight-fitting CBRN full facepiece respirator that properly fits the wearer. Qualitative and quantitative fit test procedures and equipment, as well as specific test exercises, should be followed to determine if a respirator fits properly. Positive and negative pressure user seal checks are also available to confirm the respirator is being worn correctly. Initial and annual respirator fit testing and use of a user seal check as part of each donning are major components in providing respiratory protection to workers wearing CBRN respirators.

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Chapter 7: CBRN Equipment and the Wearer

Introduction

Appropriate equipment and effective chemical, biological, radiological, and nuclear (CBRN) respiratory protection programs are necessary to provide and maintain the protection needed to survive emergency disasters when toxic materials are involved. CBRN respirators and protective clothing are designed, assembled, and tested to ensure they are capable of the level of protection that first responders and ancillary personnel need to respond appropriately to emergencies and to respond without damage to themselves [Johnston et al. 2001].

This chapter focuses on the wearers of protective equipment and how their abilities are affected by the equipment that keeps them alive [Johnson and Dooly 1995a; Johnson and Dooly 1995b, pp. 2321–2334].

However, the protection afforded by the equipment comes with a price: For each additional piece of protective equipment worn to separate the wearer from the hazard, there is a performance penalty. Once adequately protected, wearers must cope with the burdens of protective equipment that affects their abilities to perform assigned tasks. Understanding of normal physiological adjustments to exertion and the alterations imposed by protective equipment are of the utmost importance. A solid understanding of how equipment affects performance will help:

- The individual responder form more realistic self-expectations in an emergency
- The supervisor or crew chief form realistic expectations of their first and second responders
- Emergency management personnel plan realistically for means to deal with emergencies
- Medical personnel (first receivers) recognize the challenges they face when dealing with the aftermath of a catastrophe
- Program managers who procure personal protective equipment make informed choices that minimize detriment to performance

At the end of this chapter is a summary of physiological adjustments to exercise. This summary explains what goes on inside the body when working and aids understanding of the effects of respirators and other personal protective equipment (PPE) on responders in emergency situations.

The Threat to Health

Contaminants of many kinds may be present at the site of an emergency. As the description “chemical, radiological, biological, and nuclear” suggests, contaminants may be any of these types, each with its own particular threat to the health of the responder. This section explains possible health effects of some contaminants likely to be encountered by emergency responders. It is important for wearers of CBRN PPE to understand the threats they face and the repercussions of improper protection. Respirator filter cartridges are constructed to remove each of these airborne contaminants from the air that is breathed.

Gases/Vapors

Many of the gases and vapors produced in a fire are classified as asphyxiants or irritants [Harrison and Elkabir 2006]. The most common are carbon monoxide and hydrogen cyanide.

Carbon monoxide, like oxygen, links to hemoglobin in the red blood cells but, unlike oxygen, does not release easily. Carbon monoxide, a product of incomplete combustion of hydrocarbons, is about 200 times more tightly bound to hemoglobin than is oxygen. If enough hemoglobin sites for oxygen are filled with carbon monoxide, body cells can no longer be supplied with sufficient oxygen, and death is imminent. If exposure to carbon monoxide is nonlethal, it can still lead to serious complications even at low carbon monoxide concentrations. The victim must either be placed in hyperbaric oxygen chamber for a long time to force the carbon monoxide to leave the hemoglobin sites or be given supplemental oxygen through some other means. Even then, some central nervous system damage may persist.

Hydrogen cyanide is also dangerous [Caretti et al. 2007; Harrison and Elkabir 2006]. Cyanide irreversibly binds to an enzyme in cells critical for the metabolism of glucose to form energy. As a result, cells cannot use oxygen from the blood, and the person can die if enough hydrogen cyanide is inhaled. Humans, as well as other animals, have a small tolerance to cyanide, but the concentration of cyanide in a fire can cause death [Jones et al. 1987].

Irritants may be either inorganic or organic and are usually produced when organic materials in furniture, wallboard, resins, adhesives, paint, pesticides, petroleum, plastics, solvents, and other construction materials are burned [Harrison and Elkabir 2006; Sumi and Tsuchiya 1973]. This class of contaminants causes immediate irritation of the respiratory tract. Those that are water-soluble irritate the upper airways, whereas insoluble gases irritate the lower airways. Depending on the nature of the gas or vapor, irritation may range from mild to severe. The bronchial airways may constrict in response to serious irritation, cutting off air to the lungs.

Rescue workers and others exposed to the dusts, gases, and fumes at the World Trade Center site in New York were tested, and some were found to lack the ability to detect odors and irritants years after they left the area [LaTourrette et al. 2003; NIOSH 2024]. The insidious property of irritating gases is a major reason why implementing change schedules for canisters, rather than relying on responders' sensory warnings, is necessary in emergency response situations where responders use air-purifying respirators. Responders may not realize they are being affected by the irritants.

Chemical agents may also be present at the site of a terrorist attack. There are a number of possible effects with gases or vapors, including neuromuscular (e.g., sarin), irritating (e.g., tear gas, chlorine), asphyxiants (e.g., cyanide), and lung dysfunction (phosgene) as only some of the many possible examples. Sarin vapors were released in an attack in Tokyo in 1995 killing 12 people and severely injuring 50 [Wikipedia 2012].

Particulates/Dusts

Many particulates form in events such as fires and structural collapse [Savolainen and Kirchner 1997]. These can range in size from nanoparticles (on the order of 10^{-9} meters, or 10^{-7} inches) to 50-100 microns (10^{-6} meters, or 10^{-4} inches). Larger particles require the turbulence of flame and smoke convection to remain airborne. Inhaled particles larger than 5-10 microns can be deposited on the

walls of the respiratory system. The deposited particles are entrapped in mucous lining the epithelium, and cila in the epithelial cells vibrate to move the particle-laden mucous toward the throat. When at the throat, they can be swallowed or expelled. Smoking cigarettes can impair cilia function reducing their ability to remove particles from the lung.

Inhaled particles smaller in size than 10 microns are called “respirable dust.” Some of these particles may not impact the airway walls and can reach the alveolar level (bottom level) of the lung.

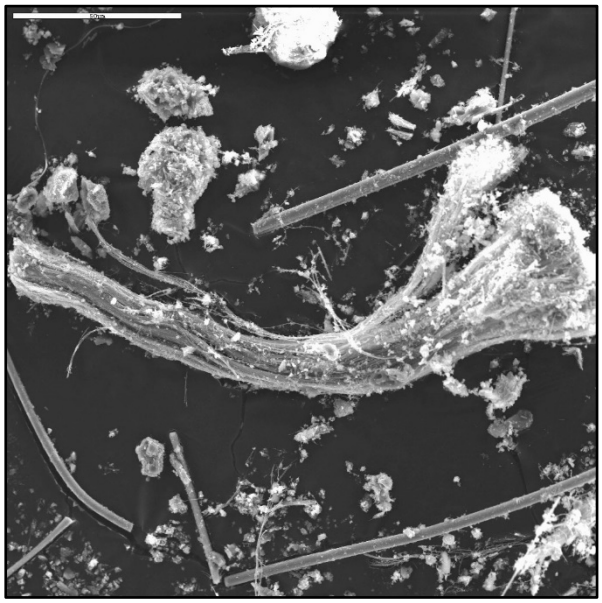

Figure 7-1. A magnified photo of dust from the World Trade Center shows a chrysotile bundle. Photo by USGS (https://usgsprobe.cr.usgs.gov/picts2.html)

There they can stay and cause lung damage or be dissolved and absorbed into the body. Even chemically relatively inert substances such as gold or titanium dioxide can become toxic in these small sizes [Karn and Mathews 2007]. Some nanoparticles have been shown to be carcinogenic in animals.

The dusts and other contaminants to which emergency workers were exposed at the World Trade Center site were hazardous but not unusual, and the concentrations of individual contaminants in the dust were not unusually high [LaTourrette et al. 2003; Westfeld 2006]. Workers had prolonged exposure to a complex mixture, and many did not wear respirators. Inhalation of toxic, highly alkaline dust (pH 10–11) is the probable cause of much of the upper and lower respiratory injury in rescue and recovery workers. According to the World Trade Center Health Program at a Glance [NIOSH 2024], as of March 31, 2024, over 11,800 responders still suffer from respiratory disorders and/or pulmonary disease. Chrysotile asbestos fibers (Figure 7-1) were also present in the debris from the World Trade Center collapse. Chrysotile asbestos is the most used form of asbestos in developed countries. Reactions in the lungs caused by asbestos fibers can result in asbestosis (thickening and scarring of tissue that is called fibrosis which makes breathing difficult), lung cancer, or mesothelioma (a lethal cancer that affects the pleura [covering] of the lung) after a significant lag period [NIH 2011].

Particulates can also cause a condition known as chronic obstructive pulmonary disease, in which the tissue structure of the lung breaks down until it becomes difficult to exhale [NIH 2010]. chronic

obstructive pulmonary disease is the fourth leading cause of death in the United States [ALA 2012; NIH 2010].

Radiological Products

The danger posed by radiological products depends on the type of radiation (alpha, beta, or gamma) emitted by the particular contaminant. Even the most energetic alpha particle from radioactive decay can be stopped by the outermost layer of dead skin that covers the body. Therefore, exposure to most alpha particles originating outside the body is not a serious hazard. On the other hand, if alpha-emitting radioactive materials are taken inside the body by inhalation, they can be the most damaging source of radiation exposure. Respirators will provide protection against the inhalation of radiological particles, however, they won't negate the effect of radiation (e.g., if beta or gamma emitters are present).

The short range of the alpha particle causes the damaging effects of the radiation to be concentrated in a very localized area as small as few cells.

Beta radiation is a light, short-range particle and is actually an ejected electron. Beta radiation may travel several feet in air and is moderately penetrating and can penetrate human skin to the "germinal layer," where new skin cells are produced. Like alpha-emitters, beta-emitting contaminants are the most harmful if deposited internally through inhalation.

Gamma rays emit extremely high-energy photons which can travel through most forms of matter because they have no mass. When inhaled, the ionizations caused by gamma-emitters take place over a greater area compared to alpha- and beta-emitters.

Plutonium is often mentioned as a potential terrorist threat [Sutcliffe et al. 1995]. Inhaled plutonium is much more dangerous than is ingested plutonium because small particles of respirable size can penetrate the lung and enter body cells via the blood stream. A typical respirable plutonium particle that is three microns in size has a mass of about 1.4×10^{-10} grams and has a risk of increasing cancer in the person inhaling the particle of only 0.00017 percent [Sutcliffe et al. 1995].

Biological Agents

Almost any bacterium, virus, or prion that causes human disease can be used by terrorists to provoke panic in the population. Prions are abnormal proteins that are implicated in Jakob-Cruetzfeldt and Alzheimer's diseases in humans [Johnson 2011]. As long as respiratory protection is used and worn properly, sufficient protection is available to stop the threat.

The most notorious bacterial agent used in the recent past is anthrax, caused by a bacterium belonging to a class of toxin-producing microbes. Others in this class, such as *Salmonella*, *Listeria*, and *Clostridium*, produce food poisonings of various kinds. The recent outbreaks of Ebola and Zika were caused by viruses.

Anthrax is particularly dangerous because its endospore form is hardy and respirable, measuring one to five microns in diameter. The endospores can cause the anthrax disease if they contact the skin or if they are inhaled. They are much more dangerous if inhaled. It takes an inhalation of 8,000-10,000 endospores to kill an average person. As few as 100 endospores may kill those most susceptible [Park 2001]. As with most, but not all biological agents, these bacteria need time to grow to a dangerous population size within the body, and therefore are not immediately lethal.

Another biological agent of interest is ricin, a toxic material derived from castor beans. Ricin interferes with cellular metabolism and can be particularly dangerous if swallowed or inhaled as a dust or mist. Respirator high-efficiency particulate filters can easily remove these particles from the air.

Heat

Heat can dry and burn unprotected skin. It can also damage lung tissue to the point that oxygen and carbon dioxide can no longer be exchanged.

CBRN Equipment Effects

How CBRN Equipment Affects the Cardiovascular System

Data from multiple studies have shown that the use of respirators alone has no effect on heart rates of the wearers [Johnson et al. 2003]. From this, it appears that respirators do not impose additional stress on the heart. However, for respirators and protective clothing with significant weight, the additional weight can impose an ergonomic burden that translates into cardiac stress. This additional weight acts equivalently to body weight as long as it is carried close to the body.

Each kilogram (2.2 pounds) of extra weight can be expected to reduce the work performance time by two-and-a-half minutes if walking at a high speed [Johnson et al. 2006].

If extra weight is carried awkwardly away from the body, then the energetic penalty can be an additional 50-60 percent of energy expended vs. carrying the load next to the body [Johnson 2007; Johnson et al. 2006]. Extra heavy loads also add to the nonproportional energy cost of carrying them. Loads carried by the hands are less burdensome than loads carried on the feet. Heavy protective clothing carries with it a higher energy penalty than can be accounted for by its weight alone. Bulk and friction from the heavy clothing can also be an important factor [Johnson 2007].

Translating the energy requirement of wearing protective clothing and carrying (or dragging) extra weight into cardiac burden is not a straightforward procedure. A lot depends on whether the wearer is climbing stairs or descending stairs or walking on level ground; the texture and compositions of walking surfaces; the speed of movement; and the body temperature of the wearer. Under relatively easy walking conditions, while carrying an extra 60 pounds (27 kilograms) of weight, the heart rate increase is 10 percent of the maximum.

How Respirators Affect Respiration

Air-purifying respirators (APRs), except filtering facepiece respirators, have inspiratory resistances dominated by filter resistances, with a typical value of 3.5 centimeters (cm) of water-seconds (H_2O-sec) per liter (L) (or 50 millimeters H_2O at 85 L/min flow rate) [Johnson et al. 1999b]. Exhalation resistances of the exhalation valves may be somewhat less than 1.5 cm H_2O-sec/L [Caretti et al. 2001]. Powered air-purifying respirators (PAPRs) may have much lower inhalation resistance, but the same exhalation resistance [Johnson et al. 2005a]. Self-contained breathing apparatus (SCBAs) may have zero or negative equivalent resistance but very high pressures to exhale against. Although exhaling against high pressures is uncomfortable at rest (when respiration usually includes passive exhalation), high exhalation pressures can be tolerated better during exercise (when the respiratory muscles for

exhalation contract actively). Previous work seems to indicate that inspiratory and expiratory resistance effects are equivalent [Caretti et al. 2007], although testing using very high expiratory resistance resulted in severely degraded performance [Johnson et al. 1997d].

The effects of APR inspiratory resistance on performance are felt most at very intense exercise (80-85 percent maximum oxygen consumption) [Johnson et al. 1992a, 1999a, 2000b]. Performance time decreases linearly with increased inspiratory resistance at this exercise intensity. A resistance level of 3.5 cm H_2O-sec/L is expected to result in a 30 percent performance decrement [Johnson et al. 1999b]. Because of this, one might expect performance with PAPRs to be better than with APRs, but this has yet to be definitively shown. In addition, the extra weight of the blower and tubing may counteract at least some of the advantage of lower resistance [Johnson et al. 1999a].

Extreme environmental conditions may drastically shorten PAPR battery capacity. If the battery fails to provide sufficient current to power the blower motor, the filtration capacity of the device would still be present. However, it would become an unpowered APR with significant inspiratory resistance and dead volume and carbon dioxide accumulation (especially if there is no check valve located between the blower and the wearer). Breathing under this circumstance may become more of a burden, but the respirator must still be worn to provide respiratory protection. Wearers must be trained to leave the contaminated area immediately if this occurs.

Extra inspiratory resistance promotes hypoventilation of the wearer (lower volumes of air breathed and smaller amounts of oxygen used). This can result in an earlier transition from aerobic (using oxygen) to anaerobic (no oxygen needed) respiration and faster progress toward the maximum tolerance for exercise (maximum oxygen debt) [Johnson et al. 1999a]. Consequently, higher resistance filters can be expected to need smaller filtering capacity because of the reduced air breathed through them.

Exhaled carbon dioxide (dead volume) accumulates in the voids between the respirator and the face and returns it to the respiratory system during the next inspiration. This carbon dioxide then acts as a respiratory stimulant. Because carbon dioxide is a psychoactive gas, dead volume may also produce discomfort and a performance decrement at low-intensity work [Billings 1973, pp 35–63]. A typical value for APR respirator dead volume is 350 milliliters. Such a dead volume is expected to reduce performance time by 19 percent at 80 to 85 percent of maximum oxygen uptake [Johnson et al. 2000a]. Dead volume may be reduced by choosing a PAPR over an APR.

Intense exercise uses more air than does moderate exercise [Mackey et al. 2005], and because very intense exercise metabolism has a higher anaerobic component than does moderate exercise metabolism, the air that is used is not consumed as efficiently as it is at lower intensity [Johnson et al. 2005d]. This can severely limit the time spent immersed in the emergency environment. Some SCBAs recycle spent air, but there is still some air blown off through exhalation valves (no closed-circuit SCBAs have been approved for CBRN use as of this writing). The net result of spent air expulsion is that tank air depletes much more rapidly at high work rates than at moderate work rates.

Heat and Cold and CBRN Equipment

Use of respirators in non-temperate conditions can lead to special problems [Johnson et al. 1992b]. Cold conditions can cause fogging of full facepiece respirators, which leads to severe dissatisfaction with respirator use [Johnson et al. 1994, 1997b]. Nose cups inside the facepiece are designed to

eliminate fogging but are not always effective. Fog-proof lenses are available on some models. Fog-proofing solutions that can be applied to the face shield are also available. Cold can also cause valve sticking and stiffen the rubber facepiece material to the point that it prevents a good facial seal. Cold rubber has a higher thermal conductivity than does still air, so in still, cold air the face may be cooled by the respirator. In a cold wind, however, the facepiece may add a small amount of insulation to the face.

Use of respirators in hot conditions leads to several difficulties:

1. Facial temperatures inside the facepiece can cause discomfort. Facial skin temperatures are more important for comfort than skin temperatures in other parts of the body. PAPR blowers send filtered air over the face that evaporates sweat and cools the face [Johnson et al. 1999a, 2005a]. SCBA air expands and cools when released from the cylinder; this cool air can help alleviate facial discomfort. Some SCBAs have coolant packs used to further cool supplied air before it reaches the facepiece. APRs, however, have been found to be uncomfortable in the heat because they do not supply cool air.

2. At moderate work rates (50 to 70 percent of maximum oxygen uptake, or maximum exercise capacity), respirators impede the loss of heat from the face and can result in hyperthermia occurring sooner. This is not usually a problem except when the rest of the body is sealed in protective clothing. With no easy means to lose heat, the body can overheat, especially in hot and active conditions.
3. Sweat produced inside the facepiece can accumulate and cause discomfort, interfere with breathing, and cause exhalation valve sticking [Johnson et al. 1997c]. Accumulated sweat can cause a respirator facepiece to slip on the face and promote leakage.

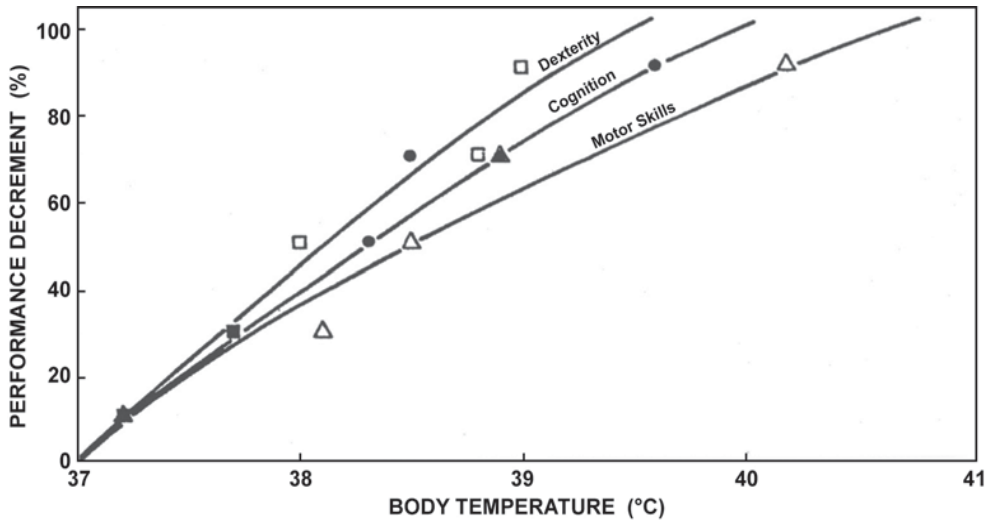

Figure 7-2. Effect of body temperature on dexterity, cognition, and motor skills. The x-axis of the line chart shows body temperature in degrees Celsius; the y-axis shows performance decrement as a percentage. Three lines represent worsening dexterity, cognition, and motor skills as body temperature increases.

Heat can also affect the ability to recognize dangers, make coordinated movements, and perform manual tasks. As deep body temperature increases, dexterity, cognition, and motor skills degrade significantly, as shown in Figure 7-2 [Johnson et al. 1992b]. One of the most dangerous effects of overheating is disorientation and not being able to recognize the direction to safety in the event of extreme danger. This inability to recognize safe passage has contributed to past deaths [MSHA 2002].

Humidity in the air has a profound effect on the ability of the body to lose heat when there is exposed skin or when the respiratory system breathes ambient air directly. When humidity tends toward saturation (100 percent relative humidity), it is more difficult for moisture to evaporate into the air. Loss of heat through sweating and loss of moisture through breathing are inversely related to the amount of moisture in the air.

When fully encapsulated in CBRN protective gear, however, the likelihood that there will be areas of exposed skin is small. In that case, the effect of ambient relative humidity on heat loss is little to none. APR and PAPR filters remove at least some of the humidity from the air that is inhaled by the wearer. High humidity conditions may promote respirator lens fogging.

Intense Activity with CBRN Equipment

First responders can never be sure what conditions await them when called to an emergency. In at least some of these incidents, there will be a need for urgency and extraordinary measures. High exertion would be appropriate until the situation can be controlled. Under these extreme haste conditions, several problems may occur: protective equipment may be put on incorrectly, exertion may reach levels that cannot be sustained, personal overheating may occur, and respirators may slip on the sweaty face. Each of these can have severe consequences, but these occurrences are less likely with ongoing training and drills. The responder should be careful with their CBRN equipment as it can prevent loss of life or injury.

Some respirator leakage is expected to occur, especially as sweat builds up on the face and the respirator does not follow sudden head movements exactly. Some leakage can take place through the exhalation valve, especially when it becomes wet from sweat. Both SCBAs and PAPRs are positive-pressure devices, but this does not mean they cannot leak at local spots around the peripheral face seal. Respirator leakages have been measured in the workplace, but they have not been found to significantly affect the overall protection given [Janssen and McCullough 2010]. This issue may become a little more critical in situations where the contaminant is more dangerous than those in industrial environments. Of particular interest is the leakage from the face seal of oxygen-enriched gases in SCBAs into combustible atmospheres. Although SCBA gases are kept to an oxygen concentration that does not promote fire, the emergency responder should be aware of the possibility that a dangerous condition could suddenly arise.

Communications with Respirators

Full facepiece respirators interfere with visual cues during speaking and listening. It thus becomes more difficult not only to recognize what is said, but also who is saying it. When wearing respirators, the further away individuals are from one another the harder it is to clearly understand speech. Speakers and listeners should talk in sentences where the message can be conveyed by context as well as by word recognition. Sentence context allows speakers and listeners to be separated by 10

times the distance compared to communicating by single words [Coyne et al. 1998]. Simple words and phrases are unable to be understood 27 percent of the time at distances as close as two feet.

When telephones or radios are used for long-distance communication, a 10 percent error rate in recognition of words and a 50 percent increase in the time required to recognize the words can be expected [Johnson et al. 2000c,d, 2001b]. Because standard telephone and radio equipment dimensions are not entirely compatible with respirator facepieces, protocols should be established to let the user know when to move the earpiece from the ear and to move the mouthpiece in front of the speech diaphragm. Training in the use of these protocols is essential.

Special communication equipment is available from some manufacturers, and some respirators include speech diaphragms or are made of materials that enhance speech transmission.

If responders are close enough to see each other, a lot of communication can take place with hand signals. There are some generally accepted hand signals that denote easily understood, simple messages (examples of these are thumbs up for agreement, a finger across the throat for danger, an upright palm to indicate "stop," and pointing to indicate direction). These will be harder to see in a smoky environment and with gloves on, so there is a distance penalty even with hand signals.

One of the most difficult impediments to clear communication is accented speech. If speech cannot be clearly understood without a respirator, it will be nearly impossible with a respirator. Hand signals may serve to overcome speech understanding, but different cultures may also have different interpretations of hand signals.

Vision and Respirators

Sharp vision is important for some of the tasks required during an emergency. A natural tunneling of vision occurs during intense exertion: attention is focused on objects straight ahead. Consequently, degradation of vision due to respirator use during high exertion has little effect on the ability to complete the required task [Johnson et al. 1997a]. Under normal conditions, this might be advantageous to task performance. In a situation where dangers can come flying in from all directions, there may be difficulty recognizing peripheral threats.

Vision is extremely important for performing low-physical intensity tasks, such as computer work, console monitoring, and reading [Dooly et al. 1994; Johnson et al. 1993, 1994, 1997b, 1998]. There are many aspects of vision, including visual acuity, peripheral vision, and color detection, and some or all of these may be needed. Respirators should be selected to accommodate requirements for peripheral vision, acuity, and color recognition.

Responders requiring corrective lenses while wearing respirators must not wear spectacles with temple bars or straps that come between the sealing surface of the respirator and the face. Instead, special corrective lens mounting kits may be used with full facepiece respirators. These may not be entirely satisfactory for some wearers. Those who can wear contact lenses can usually do so while wearing a respirator mask. As long as the insides of respirators are kept clean, dust particles will not be present to cause difficulties with contact lenses.

Dust, mist, smoke, condensation, or water flowing down over the facepiece lenses can reduce vision during an emergency and in turn negatively impact, task performance as shown in Figure 7-3 [Johnson et al. 1994]. Extra training under these conditions might be warranted. Disorientation in a low-visibility environment is common and may make it difficult to know how to move or which is the

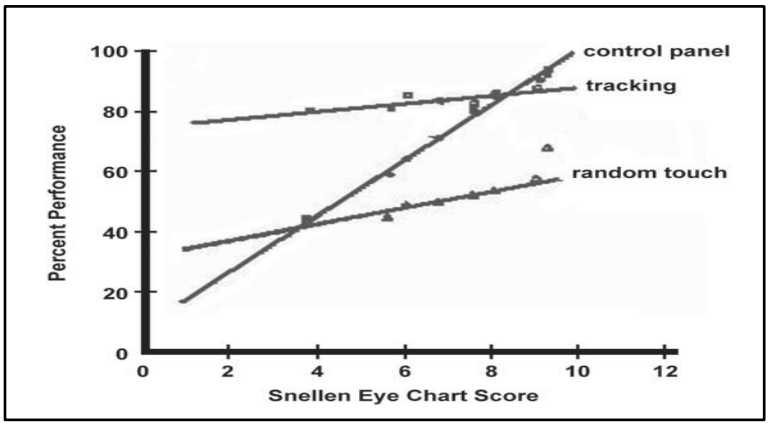

Figure 7-3. The x-axis of the line chart shows Snellen eye chart scores from 0 to 12; the y-axis shows performance as a percentage. Three lines chart control panel recognition, tracking, and random touch.

safest direction to go. Although visual acuity has little to no effect on performance of intense physical activity, wearing a full facepiece respirator while walking, running, or driving can erode visual acuity somewhat, probably due to the pull of the facepiece on the face [Johnson et al. 1997a]. Recognition of objects or signs while wearing a respirator and walking or driving cannot be expected to happen as quickly as without a respirator.

Other Use Factors

Respirators can interfere with responder activities because of their bulk or weight. Use of respirators in tight places is difficult and can temporarily disrupt facial seals when bumping against other objects.

The impact resistance of the lenses of many full facepiece respirators can be a positive attribute in situations where objects or debris may hit the face.

CBRN protective clothing is also bulky and heavy and can impede responder progress. Small spaces must be larger for a protected responder to fit through. Gloves make fine hand or finger movements nearly impossible.

Respirators may interfere with sighting equipment or with other measuring devices.

Anxieties

Anxious individuals should not be asked to wear respirators. Studies have shown that anxiety level is a very reliable indicator of difficulty encountered while wearing a respirator [Morgan and Ravan 1985]. Extremely anxious individuals do not perform for as long or at the same work rate as low-anxiety wearers [Johnson et al. 1995a]. A supervisor, therefore, should probably avoid these problems by allowing their anxious employees to perform jobs that do not require respirators to be worn.

Personal Procedures [Johnson et al. 2001a]

The facial area inside a respirator is usually not accessible from the outside unless the face seal is broken. Thus, eating, drinking, scratching one's face, blowing one's nose, or rubbing an eye is not possible while wearing full facepiece respirators. One exception to this is certain respirators that have a drinking tube incorporated into their designs.

As long as periodic breaks are allowed, respirators should not add to the fatigue that accompanies long-term work [Johnson et al. 1997b]. Food or drink can be ingested during those breaks and energy levels maintained. While it is unlikely that responders would need to work for hours at a time without breaks, if such were the case, then blood glucose could fall to dangerously low levels (hypoglycemia) and work could not continue efficiently.

The inaccessibility of the face may generate considerable tension in the mind of the wearer, especially if the reason to access the face is due to some particularly sensitive need. Dust or dryness in the eyes of contact lens wearers, runny noses, or unbearable pressure to parts of the face can be particularly distressing [Johnson and Cummings 1975]. If the situation does not allow the wearer to leave the hazardous environment to take care of the problem, then considerable anxiety may develop.

Another personal issue that generates much controversy is the presence of facial hair (e.g., beards or goatees) on a person who must wear a respirator. Every respirator use regulation or standard prohibits use of tight-fitting respirators with facial hair that comes between the sealing surface of the facepiece and the face or that interferes with valve function. Many experimental studies with negative-pressure respirators (including air-purifying and atmosphere-supplying respirators) show the protection provided by the respirator is reduced when facial hair is lying between the sealing surface of the respirator facepiece and the wearer's skin. Some studies have found that when pressure inside the facepiece was positive, there was no degradation of the protection provided. However, not all positive-pressure respirators can maintain positive pressure inside the facepiece during the entire breathing cycle and at all work rates. For this reason, use of tight-fitting, positive-pressure respirators by people with facial hair is unacceptable. The protection provided by respirators with hoods and helmet is not affected by facial hair.

Control and Training Issues

The special nature of total protection required by CBRN emergencies adds additional burdens on the responders and on those who are managing the effort. Wearing the full CBRN protective gear ensemble makes activities much more burdensome than if the gear were not worn. Training in the fully protected mode can familiarize the responder with this burden so that it does not come as a surprise during an actual emergency [Johnson et al. 2005b; Rebar et al. 2004]. Similarly, line supervisors and emergency managers must take special care to protect those who are placing themselves at risk. Additional manpower is required to ensure that each individual is not overwhelmed by the challenges present. Every effort must be made to remain in contact with each responder under the supervisor's responsibility.

According to the RAND report in the aftermath of the World Trade Center attacks, communications among firefighters to and from control centers were among the biggest issues requiring improvement [LaTourrette et al. 2003]. As mentioned before, communications while wearing respirators are

difficult at best, and, unless first responder training includes communications training, this issue could repeat in the next general emergency.

The uncontrolled nature of extreme emergencies and terrorist actions makes precise planning and training very difficult. CBRN equipment is only one element to be considered . Maintaining some semblance of order and situational control can be challenging. Understanding the limitations imposed by normal physiological adjustments to exercise, as modified by CBRN equipment use, can help planning and training programs.

Physical stress during the World Trade Center response accounted for one quarter of the firefighter injuries and one half of their immediate deaths [Park 2001]. Currently, there are no effective solutions to this problem. CBRN equipment is heavy and hot and not likely to become lighter or cooler any time soon. The immediate concern is protection, which the equipment provides. Training and responder tactics must be used as much as possible to overcome the limitations imposed by the equipment. It cannot be expected that first responders operate as if they were not wearing the equipment.

Physiological Responses to Work Activity

Before a brief discussion of ergonomics and work physiology, there are two things to keep in mind about heavy exertion while wearing respirators and protective clothing:

1. Work cannot usually be performed as long or as hard while wearing a respirator compared to while not wearing a respirator. Wearing protective clothing plus respirators makes this situation even worse. Either more time must be allowed for a particular task or more responders must be assigned to the same task.
2. There is a great deal of wearer variability. Some wearers can tolerate respirator high inspiratory or expiratory resistance or pressure levels, while others cannot. Some wearers are much more anxious about wearing respirators than others. Some wearers can tolerate hot, humid conditions inside protective clothing, whereas others cannot. Even with the stringent selection process for many emergency personnel, this variability persists. Additionally, emergencies sometimes require people to respond who have not been through the selection process. Because of this variability, each responder must be treated as an individual.

Work/Performance Time Tradeoff

Very hard work cannot be performed for as long a time as work of lesser intensity [Johnson 1976, 2007; Johnson and Dooly 2006, pp. 65-1 to 65-9]. This is true even when unencumbered by CBRN equipment. Figure 7-4 shows that for different activity levels, there are corresponding physiological limitations consisting of a cardiovascular limitation for very intense work, respiratory limitation for intense work, thermal limitation for moderate work, and what is generally called irritation limits for low-level activity. Protective masks and clothing generally shorten the time that a particular activity level can be sustained.

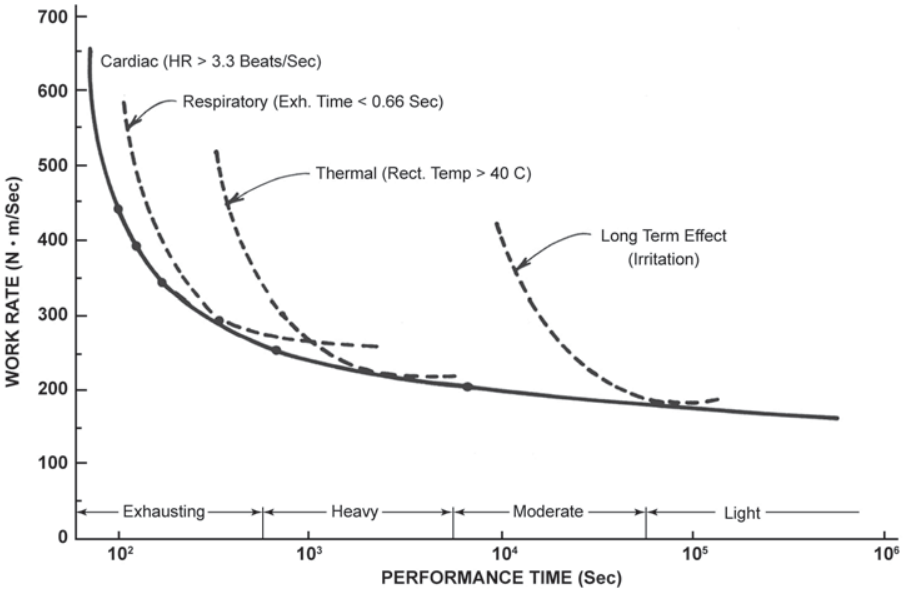

Figure 7-4. The x-axis of the line chart shows performance time in seconds; the y-axis shows work rate (N m/Sec). Four lines track cardiac, respiratory, thermal, and long term (irritation) effects. [Johnson and Cummings 1975]

Physiological Adjustments

The human body is attuned to performing physical labor [Hurley and Johnson 2006, pp. 66-1 to 66-10]. What follows the start of muscular activity is a coordinated series of adjustments involving all parts of the body, including the heart, blood vessels, lungs, digestive system, nervous system, and kidneys. The ones with the most direct bearing on exercise adjustments are described below.

Metabolism

Muscular movement requires energy. This energy comes from an energy storage molecule called adenosine triphosphate (ATP). When the supply of ATP is exhausted, muscle activity ceases. It is important, therefore, to replenish the ATP supply as quickly as possible to maintain muscular work. There is also another energy-rich compound in the muscles called creatine phosphate that can act to replenish the ATP supply extremely quickly. When the muscle starts working, there is enough ATP in the muscle to sustain the work for 0.5 seconds. There is enough creatine phosphate present to keep the muscle working for up to 2 minutes. After that, other energy-forming mechanisms are necessary to replenish the ATP supply.

This other energy comes from stores of glucose in the blood, glycogen (an animal form of starch) in the muscles and liver, fats in the form of triglycerides in fat tissue, and body proteins. In order to extract the energy from these compounds, they must be respired. There are two kinds of cellular metabolism (sometimes called cellular respiration): anaerobic and aerobic. The difference between the two is that aerobic metabolism requires oxygen and anaerobic metabolism does not. Oxygen delivery to the muscles begins in the lungs, continues in the blood, and is finally delivered to the muscles, as shown in Figure 7-5. If enough oxygen can be delivered to the tissues, then aerobic metabolism can keep up with the energy demands of the muscles. However, there are limits to the

rate that oxygen can be supplied, called the maximum oxygen uptake. Once the maximum oxygen uptake is reached, additional muscular energy must come from anaerobic metabolism.

Very heavy exertion requires at least some anaerobic metabolism because oxygen demand exceeds the maximum oxygen uptake. This is called the anaerobic threshold. Anaerobic metabolism yields 18 times

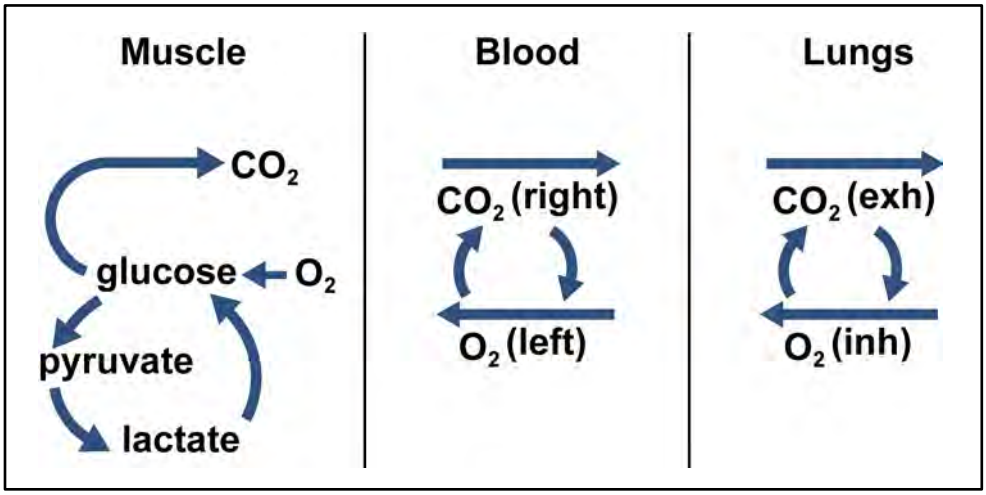

Figure 7-5. The flowchart depicts oxygen delivery across three areas: lungs, blood, and muscle.

fewer ATP molecules than aerobic respiration, and so is not nearly as efficient. However, it does allow movement to continue, at least for a while.

One of the end products of aerobic metabolism is carbon dioxide, which can be removed during exhalation. Carbon dioxide levels in the exhaled breath rarely reach more than four or five percent, even at the extreme. However, if these levels were to climb much higher, carbon dioxide could cause disorientation, confusion, and even death.

The main end product of anaerobic metabolism is lactic acid that is released from the muscles into the blood. There are buffering mechanisms in the body that tolerate lactic acid additions, but these mechanisms have limited capacity. Once this capacity is reached, there is no other source of energy for the muscles and all muscular activity must cease. This capacity to tolerate lactate is called the maximum oxygen debt because all the lactic acid must be reformulated into glucose at the end of exercise, and this requires oxygen.

Buffering the blood against lactic acid formation during anaerobic metabolism produces extra carbon dioxide that can be exhaled. This extra carbon dioxide acts as a respiratory stimulant that leads to hyperventilation, or harder and deeper breathing.

All these processes proceed each time a person moves actively [Dooly et al. 1996; Johnson et al. 1995b]. They are much more efficient for younger people than for older people. Maximum oxygen uptake is about 2.5 liters per minute for 20-year-olds but declines nearly linearly to about 1.7 liters per minute at age 65. Well-trained individuals can have maximum oxygen uptakes up to twice these values. In addition, the maximum oxygen debt that can be incurred by an individual declines with age and is also affected by training.

Metabolic responses during exercise, and especially during emergencies, are modified by the release of the adrenal hormones adrenalin (epinephrine) and cortisol. These hormones increase metabolic

rate, increase the rate and force of heart contractions, enhance the availability of blood glucose, reroute blood from the gut to the muscles, and mobilize the nervous system.

The combined actions of these hormones can affect physical, emotional, and cognitive functions. Muscular strength declines with age, making task performance less efficient when more muscles must be recruited to perform a task [Hurley and Johnson 2006, pp. 66-1 to 66-10]. Muscular power can be restored relatively rapidly with strength training.

Drugs and medicines can also affect body metabolism, as can illness. Products of cigarette smoking and caffeine also affect metabolic rate [Scott et al. 2002].

Cardiovascular Adjustments

The heart adjusts to the physical demands of exertion by increasing its cardiac output, or the volume rate of blood flow through the arteries, capillaries, and veins. This increases the rate of glucose and oxygen supplied to the muscles and the rate of removal of lactate and carbon dioxide from the muscles. The heart rate increases nearly linearly with work rate, beginning to increase nearly as soon as work rate increases. This is due to kinesthetic neural sensors in the muscles and joints that signal the fact that increased oxygen demand is on its way, despite the fact that there is as yet no reduction in blood oxygen concentration or rise in carbon dioxide concentration. Once the concentrations of these gases change, then control of heart response is determined by chemical sensors in the aorta, in the carotid arteries in the neck, and in the brain.

The stroke volume of the heart or the volume of blood pumped for each heartbeat increases initially at the start of exercise but soon reaches its maximum level. Thereafter, increases in cardiac output are determined only by heart rate. Cardiac output at rest is about five or six liters per minute but can rise to 25 liters per minute during strenuous activity. Blood volume in a 150-pound (70 kg) person is about 5.6 liters. Hence, it takes about one minute at rest and 12 seconds during exercise for blood to make the loop of the whole circulatory system.

Larger people generally have larger hearts and larger stroke volumes. Well-trained individuals have lower resting heart rates and higher resting stroke volumes. Older individuals can have somewhat lower cardiac efficiencies than younger individuals.

If body temperature rises due to overheating, then there is a secondary rise in heart rate, which puts additional stress on the heart. The water from sweat is derived from the blood plasma, causing the blood to thicken somewhat during prolonged exercise. This also increases stress on the heart but is alleviated by drinking sufficient amounts of liquid, some of which can be consumed before the responder answers the emergency.

Cardiovascular adjustments also include shunting the blood from maintenance activities, such as digestion and kidney function, to working muscles where it is needed. Much of the blood in the circulatory system at rest is in the leg veins; during exercise, most of the blood is shifted to the arteries. These changes occur very quickly after activity begins. Release of the hormones epinephrine and cortisol in an emergency speeds the heart and constricts some blood vessels to shunt blood to the arms and legs.

Oxygen delivery to the working muscles can be limited by the maximum cardiac output, given as the maximum heart rate times the maximum stroke volume. Once this maximum has been reached,

metabolism continues anaerobically. Depending on the muscles being used and the vascular structure serving those muscles, there may be local regions of anaerobic metabolism occurring while the muscles as a whole are still aerobic.

Respiration

Respiration also increases as exercise progresses, but respiratory responses lag behind activity level changes by about 45 seconds. Many respiratory responses occur: the respiration rate increases [Christie 1953]; the tidal volume (or the amount of air breathed during each breath) increases up to a maximum amount [Brokaw et al. 2011; Coyne et al. 2006; Johnson 2006; Johnson et al. 2005c]; the respiratory waveform changes; there are adjustments to the airways; and lung volumes change [Johnson 1995]. Many of these changes appear to be stimulated by carbon dioxide concentration of the blood, but initial respiratory adjustments occur too quickly for that to be the only determinant; kinesthetic sensors may also be important for initial respiratory adjustments [Saunders et al. 1980].

Respiration is a multistep process, whereby air is breathed in, travels through the airways, reaches the alveoli (the sacs at the end of the lung where gas exchange takes place), diffuses across the alveolar membrane, dissolves in the blood, and is absorbed by the hemoglobin in the red blood cells. Carbon dioxide diffuses rapidly into the blood, so the concentration of carbon dioxide in the alveoli and the blood equilibrate rapidly, even during the most intense activity level. Oxygen, on the other hand, diffuses more slowly than carbon dioxide, so its concentration in the blood is lower than in alveolar air during inhalation. Diffusion rates of both gases change somewhat with activity level, with those for men being somewhat higher than those for women.

Inhaled air is oxygen rich and carbon dioxide poor. Exhaled air is oxygen poor and carbon dioxide rich. Because airflow in the airways is bidirectional, the first air that reaches the alveoli is the same as the last air that was exhaled during the previous exhalation. This is an indication of the dead volume of the lung, or that volume that stores carbon dioxide from the previous breath. Dead volume for the average adults is about 180 milliliters, but dead volume of respirators can add to the effective dead volume of the respiratory system and affect performance.

Carbon dioxide is a very powerful respiratory stimulant [Billings 1973, pp 35-63]. Increasing the concentration of inhaled carbon dioxide increases lung ventilation much more than oxygen deficiency. Metabolically produced carbon dioxide is even more effective than inhaled carbon dioxide at stimulating respiration. This is critical for additions of external dead volume, which transforms exhaled metabolic carbon dioxide into carbon dioxide inhaled during the next breath. Once the anaerobic threshold is reached, blood buffering makes it appear that metabolic carbon dioxide increases, and respiration is stimulated so much that lung ventilation increases dramatically as work rate intensifies.

Working muscles change their efficiencies over time as they heat and tire. Additional oxygen demands of muscles that have been worked for several minutes increase the need for the respiratory system to respond. This leads to a secondary rise in lung ventilation that continues well into the exercise duration.

Moving the chest wall, lung tissue, and air in the airways requires energy. This energy is equivalent to about one to two percent of the total body oxygen consumption at rest, but increases during intense activity to 8-10 percent. For people with obstructive pulmonary disease, the percentage at rest can be

18-20 percent. These people cannot perform strenuous exercise. Adding external resistance or dead volume from a respirator (APR) or external pressure (SCBA or PAPR) increases the amount of work that must be supplied to breathe [Johnson and Masaitis 1976; Johnson and McCuen 1980, 1981]. Oxygen to supply the needs of the respiratory system cannot be used to supply the working muscles, so respiratory demands can limit the rate of work that can be expected of a responder.

The work of respiration is supplied by the respiratory muscles. These include the diaphragm, the intercostals, and the abdominals. Inhalation is caused mainly due to the straightening of the diaphragm in the chest. Exhalation at rest is passive—that is, the force to propel the air to leave the lung comes from the elasticity of the stretched lung.

Exhalation during exercise needs to happen a lot faster than during rest, so it becomes active when the abdominal muscles push air out of the lung [Johnson and Berlin 1974; Johnson and Curtis 1978]. Due to this difference, it is much easier and more comfortable to breathe against PAPR or SCBA positive pressure during exertion than during rest.

The airways are reactive, and they change during exercise. They can constrict somewhat to reduce dead volume, and thus lower wasted breathing effort, but as they constrict, they resist airflow and increase the work of breathing, so there is a dynamic level of airway tone achieved [Johnson et al. 2012b]. These same airways may constrict to protect against respiratory irritants reaching the lung and cause the same symptoms as a severe asthma attack.

Thermal Responses

The large skeletal muscles are only about 20 percent efficient. Of the energy supplied to the muscles, approximately 80 percent ends up as heat [Johnson and Berlin 1973; Johnson et al. 2012a; Scott et al. 2008]. Thus, heat loss mechanisms are necessary to maintain thermal equilibrium of the human body.

These mechanisms include vascular adjustments, sweating, and voluntary responses. Voluntary responses include moving to cooler locales, stretching out to lose more heat, drinking cool liquids, or removing heavy clothing. These responses will generally be unavailable to emergency responders.

There is a thermal mass to the body that requires some time for heat to build up and cause dangerous body temperatures. There is a normal six to ten minutes of activity that can occur before deep body temperature significantly rises. Skin temperature probably increases during this time. If sufficient heat cannot be lost to the environment, then body temperature will continue to rise until it reaches dangerous levels. Heat exhaustion can set in when core body temperatures rise above 100.4°F (38°C). It is characterized by the abnormal performance of at least one organ system and may signal impending heat stroke. A core body temperature of 104°F (40°C) is expected to result in a 50 percent casualty rate [Goldman 1975]. This condition is characterized by disorientation, convulsions, loss of body temperature control, and death. At body temperatures lower than this, performance efficiency still suffers (refer to Figure 7-2).

Heat can be lost from the body by convection (usually air movement), radiation (as to a cold clear sky), or evaporation. Convection and radiation heat loss depend on the difference in temperature between the surface losing heat and the surrounding fluid (usually air, but in a pool, for example, water). Thus, one adjustment the body makes during thermal stress is to warm the skin surface. It does this by shunting blood from deep veins into surface veins. This is why veins on the surface of the

hands seem to stand out more in hot weather than in the cold. There is also a small, but significant, amount of convective heat loss from the respiratory system as air is breathed.

Evaporating water absorbs a large amount of heat, making sweating effective as a heat loss mechanism. Sweating heat loss on the surface of the skin is nearly 100 percent effective for losing heat. Sweating through clothing cools the clothing surface where the evaporation takes place and only partially cools the skin. Sweat that drops from the skin is completely ineffective for heat removal. The amount of sweating depends on the cooling necessary, and different parts of the skin are recruited at different times to produce sweat. When fully recruited the maximum cooling that can be obtained from sweating is equivalent to nearly 12 times the body heat production at rest (or 11.4 mets).

Women have higher percentage of body fat than men. They use this body fat as insulation between their body cores and the outside environment. To lose heat, therefore, women depend more on vascular adjustments than men.

Men sweat more than women and lose a larger fraction of their heat that way. Acclimation to hot environments can improve sweating efficiency by increasing both the rate of response and amount of sweat produced.

Some responders may not need to wear protective clothing with their respirators. However, covering the entire body and moving into a hot environment eliminates nearly all possibility of heat loss natural to the human body. Other means must be provided, such as supply of cool air from an SCBA, or body temperatures must be closely monitored. An alternative is to limit heat exposure time and to provide adequate rest cycles.

Some emergencies may require response in very low temperatures. At the beginning, low temperatures may limit movement and dexterity. However, heat produced during activity and the extra insulation afforded by protective clothing and respirators soon overcome low temperature effects on the body. Surface blood vessels in the head do not constrict in the cold, as do similar blood vessels in other parts of the body. Hence, nearly half of the body's heat loss in the cold can come from the head. Covering the head and face with protective equipment helps to insulate against this large amount of heat loss.

One mistake that can be made is to cool an overheated responder by stripping protective clothing and venting remaining clothing with cool or cold air. Sweat accumulated on the skin evaporates, overcooling the skin. This elicits a reflex that shunts blood from the skin to interior blood vessels in an effort to conserve heat. The result is that deep body temperature not only does not cool very fast, but also can increase by another degree as metabolism continues at a high level for some time after physical work ceases. To cool the overheated responder faster after intense work, protective clothing should be opened only moderately to allow some of the accumulated sweat to evaporate slowly. Of course, venting protective clothing, removing gloves, and taking respirators off should only happen in a safe location.

Work and Rest

As shown in Figure 7-4, more intense work cannot be sustained as long as less intense work. If responders are expected to work very hard for a while, they must also be in a position to rest or at least slow down for some time. This can be a problem in dire emergencies, because anaerobic work continued for too long can result in the maximum oxygen debt being reached. Then the responder would not be able to work anymore until they recover sufficiently. Lives could be lost if a situation reaches this point.

The amount of time that a person can be expected to work is related to the fraction of the maximum oxygen uptake represented by the task being performed. Thus, performance time involves the size of the individual as well as age, sex, and physical conditioning. In general, men have higher maximum oxygen uptakes than women, but they have larger bodies that use more oxygen to move around. Older people have lower maximum oxygen uptakes than younger people. Responders in better physical condition have higher maximum oxygen uptakes and can perform tasks with lower oxygen use than less physically able responders. This emphasizes the need for constant physical conditioning of those who are on call to deal with emergencies. Remember, however, that emergencies such as acts of terrorism are likely to occur almost anywhere and at any time. People who are not physically conditioned or trained to respond properly may be pressed into service. Thus, it is up to the supervisor to be aware of their limitations; emergency management personnel should include this contingency in their planning process.

Work performance times can range from forever at rest, to four hours walking at three miles per hour, to 23 minutes for cross-country running, to 10 minutes climbing stairs. These are typical times for an unencumbered 40-year-old man. The addition of CBRN equipment can reduce these times to one-half or less of the values given, depending on the types of equipment worn.

Rest times are also dependent on the intensity of the task and the maximum oxygen uptake of the individual. In general, the more intense the work, the longer the recovery time, but the relationship is nonlinear. A task that can be performed for an hour requires at least a 10-minute rest period. More intense tasks (with shorter performance times) require longer rest times. One should be sure that rest can take place in a safe location, where PPE is not required, and cool liquids are available to drink.

Higher work rates are usually associated with higher lung ventilation (breathing harder). Harder breathing consumes air from the SCBA tank faster and can reduce protective capacity, or service time, of PAPR and APR filters (although this would only be important in very extreme cases). These effects could be the most important determination of task performances times.

Prolonged Activity

Some responders will be assigned support tasks that will require the use of protective gear. While the physical intensity issues described above may not apply, these responders will face different challenges and may need to be in protective gear for extended periods of time. There can be a considerable amount of discomfort associated with wearing respirators, gloves, boots, and protective suits. These pieces of equipment are worn to protect users from contaminants that can shorten or reduce the quality of their lives.

Anxieties are the most important threat to protective equipment wear, and extremely anxious people should not be asked to wear CBRN equipment if possible [Johnson et al. 1995a; Koh et al. 2006].

For those who can tolerate the discomfort and claustrophobic feelings when wearing CBRN equipment, there will nonetheless be physical effects of prolonged wear. Many respirators require a tight face seal for adequate protection. The site of the face seal may produce rashes and edema in surrounding skin areas. These will disappear with time once the equipment is removed. Vision can be important at low work rates. There may be tasks that require a broad visual field or fine discrimination among various lights, switches, or objects. Respirators interfere with vision in various ways, but visual acuity at low work rates can be compromised by lens fogging, dust or films on the lenses, or wearing of improper corrective lenses [Johnson et al. 1997a]. Sweating while wearing respirators in cold drafts can easily incur moisture condensation inside the facepiece. Dusts and precipitates that are of no respiratory consequence to the wearer can obscure vision if they cannot be wiped from the lenses.

Physiological Limits

Respirator masks may look like relatively simple devices. However, they are complex pieces of equipment. They can interfere with vision, speaking and hearing, respiration, heat loss, eating and drinking, sneezing, scratching one's face, other equipment, and a feeling of well-being. Interference with each of these functions can be the source of impaired performance when working while wearing a respirator. Both respirators and other protective clothing can be heavy, adding weight and bulk to make movements even harder than they would have been without them. Each protective component insulates not only against contaminants, but also against heat loss.

Cardiovascular

There is a maximum heart rate that can be achieved by an individual. This is age-dependent, generally predicted as 220 minus the age of the individual. Younger people therefore have higher maximum heart rates. Once this maximum heart rate is reached, cardiac output no longer increases, and oxygen delivery to the muscles becomes static. Anaerobic metabolism is incurred, terminating when the maximum oxygen debt in reached. Cardiovascular-limited exercise normally terminates in two to four minutes.

Respiratory

The most important function of the respiratory system is the removal of carbon dioxide from the body. Adjustments during exercise increase depth and rate of breathing to expel this gaseous end product of aerobic metabolism. Exercise exhalation becomes actively supported by the abdominal muscles, spewing carbon dioxide at faster rates as exercise intensifies. At some point, the rate at which air can be exhaled becomes limited by the distensible airways in the respiratory system. Any further increase in abdominal pressure cannot increase expiratory flow rate [Lausted et al. 2006]. Thus, for normal individuals, there is a limitation when exhalation time decreases to one-half second or so [Johnson and Berlin 1974; Johnson and Curtis 1978].

Carbon dioxide cannot be expelled any faster than this minimum exhalation time allows. Respiration does not usually limit work performances of healthy individuals, but respiration can limit work time when respirators are worn. Respiratory-limited work usually lasts 5-20 minutes.

For people with respiratory impairments, the maximum pressures that can be generated by the respiratory muscles can limit the rates at which they can breathe through external resistances or against external pressures. These people are not likely to be found as first responders but may volunteer from onsite spectators.

Thermal

The most important work limitation associated with heat is deep body temperature. It must be prevented from reaching 40°C. A conservative limit might be 39.2°C (102.5°F). Beyond this, thermal discomfort becomes overwhelming, and death may ensue. Muscular efficiency is reduced at high temperatures and judgment becomes impaired. Thus, the overheated individual cannot be expected to recognize his or her own dangerous situation.

Because of the thermal capacity of the body to store heat, it takes a while before body temperature rises to the point where it can become limiting. Heat-limited work usually occurs in the 10-minute to 2-hour time range.

Physiological Limits

Physiological limits to long-term exercise involve limitations on blood glucose levels and muscle glycogen stores. Dehydration or electrolyte depletion may occur. These are difficult to quantify for any individual, but frequent eating and drinking can deter them from occurring.

Psychological effects are also important and can contribute to feelings of fatigue, anxiety, and discontent.

Summary

Physical exertion involves the entire body in a coordinated fashion. The limitations of exercise or work can be modified or overcome by training and proper selection of equipment. Familiarity with the physiological adjustments that occur can lead to enhanced effectiveness and larger return on investment in relation to both staffing and equipment. As long as humans are involved in emergency responses, accommodation must be made for the adjustments that characterize their physical abilities. Training is important to improve the wearer's ability to respond in an emergency but does not eliminate the basic physiological and psychological limits to performance.

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Chapter 8: Respirator Decontamination and Disposal

Decontamination is important to avoid cross-contamination, to allow for the potential reuse of expensive and difficult to replace equipment, and to properly dispose of contaminated personal protective equipment (PPE). In every case, some level of decontamination must be performed to allow for the safe removal (doffing) of the protective ensemble. Decontamination approaches depend on many factors, including the protective ensemble used; the known or suspected chemical, biological, radiological, and nuclear (CBRN) agent; the available decontamination resources; and the urgency of the situation.

Decontamination of Level A (National Fire Protection Association [NFPA] 1991) ensemble self-contained breathing apparatus (SCBAs) is not necessary, assuming the fully encapsulating gas-tight suit is not breached and there is effective decontamination of the ensemble before taking off the SCBA. All other respiratory equipment categories and levels will need some degree of decontamination (Levels B-C, NFPA 1994 Class 2 and below, National Institute of Justice Law Enforcement Response Level [NIJ LERL] 1 and below) if exposed to a CBRN agent. Recovery and reuse will depend on the ability to demonstrate that the decontamination has been effective. Reuse is not permitted for Level B and C CBRN respirators under National Institute for Occupational Safety and Health (NIOSH)'s and manufacturers' criteria if any liquid or vapor from a chemical warfare agent (CWA) could have contacted the respirator [3M 2009; NIOSH 2006].

There are many approaches and commercially available systems (as well as military equipment and approaches) for decontamination of CBRN agents. This chapter reviews the essential aspects and issues of CBRN agent decontamination. It does not include any discussion of commercially available decontamination systems and decontamination of accessory equipment used with respirators (e.g., communications systems, drinking systems, cameras, etc.). It will include some information on United States military techniques and approaches.

What Is Contamination?

Simply defined, contamination is the addition of an unwanted agent. It follows then that decontamination is the removal (or neutralization) of the unwanted agent. The contaminating agent can be something as benign as dirt or as difficult as an extremely hazardous agent that has permeated the protective ensemble. For some substances, there may be no effective decontamination procedure available (e.g., polychlorinated biphenyls), while for others, decontamination is simply a matter of cleanliness (e.g., removal of the surface contamination). Effective decontamination of CBRN materials depends on knowing the type and physical nature of the material encountered, extent of contamination, degree of hazard presented, and access to an effective decontamination method.

For those situations beyond normal cleaning for hygienic purposes where contamination is likely or decontamination is a required precaution, the decontamination technique and efficiency should be determined before use of the respirator and protective clothing. This would include information and training supplied to the user on how to minimize the potential for contamination, the risks from contamination, and the decontamination procedures.

Types of Contamination

There are three basic categories of contamination of respirators and chemical protective clothing [Mansdorf 1992a]. The first is surface contamination. This is where the contaminant (e.g., dry particulate) does not enter the pores or molecular matrix of the protective barrier. It is simply surface adhesion taking place. The second category is pore contamination. This is where the contaminant enters the pore structure of the barrier (much like the contamination of leather by organics such as solvents, gasoline, etc.). The third and most difficult category is matrix contamination. This is where the contaminant permeates the molecular matrix of the protective barrier (e.g., goes into solution with the barrier or its ingredients). Matrix contamination is basically an artifact of permeation (diffusion of the contaminant through the barrier).

Elastomeric respirator facepiece materials are subject to surface and matrix contamination, but not pore contamination as their surfaces are essentially non-porous. Surface contamination is usually removed through physical means, such as washing or brushing. Contaminants with water solubility can be dissolved with enhanced efficiency using agents such as emulsifiers or wetting agents (e.g., soaps and detergents). Water washing should be used cautiously for water reactive chemicals and solids. The military also uses sorbents and neutralizing agents for removal of some chemical and CWA contamination (e.g., M295 Individual Decontamination Kit) [USACHPPM 2008].

A good example of matrix contamination is the diffusion of ethylene oxide from rubber medical catheters after being sterilized. That is, the gaseous ethylene oxide permeates the rubber of the catheter in the sterilizer and then continues to outgas small quantities of ethylene oxide even when removed from the gas source. Hence, aeration is required to “rinse” the ethylene oxide from the rubber matrix.

Accessory equipment for respirators such as communications systems, drinking systems, hoods, lens protectors, or camera systems also have the potential for contamination. Users should consult the manufacturer for specific instructions and limitations for decontamination.

Effects of Contamination

Surface contamination is generally not as harmful to the barrier as matrix contamination. Nevertheless, surface contamination can result in physical deterioration of the barrier, such as discoloration, pitting, cracking, or other changes. Matrix contamination can wash out additives in the barrier, such as the plasticizers, causing physical damage or loss of physical properties. For example, some rubbers may become brittle after contamination and decontamination [Coletta et al. 1988].

What is perhaps most important is the subsequent effects of re-exposure. Tests have shown that contamination of the matrix typically results in short subsequent breakthrough times and may also result in a greater flow or migration of the contaminant to the inside of the barrier [Forsberg and Faniadis 1986; Perkins 1991; Schlatter 1988].

Even where there is no visible change to the barrier and permeation is not expected, there is still the potential for cross-contamination of the wearer from removal of the protective ensemble [Mansdorf 1989]. Prevention of cross-contamination should be handled as degradation occurs, and the facepiece should be discarded after initial decontamination. Degradation of the barrier material is the primary

reason NIOSH Use and Limitation recommendations for CBRN-approved respirators (as a complete ensemble) include specific time periods for decontamination and disposal following liquid and vapor exposure to a CWA. These are generally based on a 30-minute vapor challenge test that runs for eight hours and a liquid challenge test also performed for eight hours [NIOSH 2005a,b].

The user of the protective clothing should take off (doff) that clothing in a manner that will result in the least likelihood of cross-contamination. This usually requires that the boots and outer gloves be removed first, followed by the suit (handling the inside surface for removal), followed by the respirator and inner gloves (from the cuffs, inside out).

The process for the NIOSH approval standard for CBRN respirators includes breakthrough testing using an actual representative CWA of sulfur mustard and sarin [Bartram et al. 2008]. Chapter 2 describes this testing. Research performed by NIOSH has demonstrated some permeation for certain types of facepiece elastomers. CWA permeation testing has been done on other polymers that are used in chemical protective clothing as well, but mostly on suit materials [Forsberg and Mansdorf 2007].

Degradation can occur when barrier materials are exposed to liquid or vapor challenges. Degradation is the change in the physical properties of the barrier. This can include discoloration, cracking, staining, and other visual indicators. It should be noted that not all degradation can be observed visually. When degradation occurs, the facepiece should be discarded after initial decontamination. Degradation of the barrier material is the primary reason that NIOSH Use and Limitation recommendations for CBRN-approved respirators (as a complete ensemble) include specific time periods for decontamination and disposal following liquid and vapor exposure to a CWA. These are generally based on a 30-minute vapor challenge test that runs for eight hours and a liquid challenge test also performed for eight hours [NIOSH 2005a,b].

Evaluation of Contamination

Tests for contamination can range from simple visual observation or use of a radiation detection device to relatively sophisticated chemical or biological analysis. Visual observation is appropriate if the contaminant does not permeate the barrier and can be visually observed (e.g., a dry pigment). For other materials that do not permeate the barrier, simple “swipe” testing of the surface of the barrier may be appropriate. The military uses a “swipe” test kit for determining certain types of contamination [Lillie et al. 2006]. As another example, pH paper can be used to test for contamination of the protective ensemble if the contaminant is acidic or basic [Mansdorf 1992a].

General Decontamination Approaches for Each Type of CBRN Agent

CWAs and Other Hazardous Chemicals

CWAs includes nerve agents (e.g., tabun, sarin, soman), blister agents (mustard, nitrogen mustard, lewisite), blood agents (e.g., hydrogen cyanide, cyanogen chloride, arsine) and choking agents (e.g., phosgene, diphosgene) [Czerw et al. 2009]. Terrorists could also use what have been termed toxic industrial chemicals (TICs) in an attack. For example, chlorine has been used in some attacks in Iraq

[Eckroade 2010]. There are many TICs that represent a significant hazard to responders, including cyanides, hydrogen fluoride, chlorine gas, and others. In general, materials that are gases or highly volatile are not as much of a decontamination problem as the liquid chemicals, which do not disperse with the wind or evaporate quickly, such as VX [USACHPPM 2009]. Since the range of CWAs and TICs is so broad, there is no single universal neutralizing agent available. Strong oxidizing or reducing liquids (e.g., hypochlorite, potassium permanganate, and sodium hydroxide) were originally used to decontaminate chemical agents, especially nerve agents, from equipment.

Today, there are a number of military and commercial products that work for most, but not all CBRN agents. The manufacturers can provide the test data for evaluation.

Biological Agents

The wide variety of biological agents span the spectrum of viruses (e.g., *Zaire ebolavirus,* which causes Ebola), bacteria (e.g., *Bacillus anthracis*, which causes anthrax), rickettsia (e.g., Rickettsia prowazekii, which causes typhus), and toxins (e.g., ricin). The threat is generally from aerosols (e.g., powder for anthrax spores) [Lillie et al. 2006]. If a biological agent is suspected, strong disinfecting solutions can be used for initial decontamination of equipment. This includes the use of sodium hypochlorite (household bleach) in a 1 to 10 ratio. This is effective for most, but not all, biological contamination with attention paid to contact time [Lillie et al. 2006].

Radiological Agents

Radiological agents can be removed based on their physical and chemical nature just as non-radiological agents are decontaminated; however, they cannot be truly decontaminated (neutralized). The advantage with radiological agents is the availability of monitoring equipment to detect the level of contamination. Again, it is important to know the radiological agent or agents to ensure the measurement technique will have the appropriate sensitivity to the radiological spectrum presented (alpha, beta, or gamma). Most of the radiological hazards can be physically removed (washing with soap and water) since the hazard will probably be from particulate contamination [Lillie et al. 2006].

Nuclear Agents

Response following a nuclear event would present radiological hazards from neutron-induced activity hazards and fission products contained principally in the fallout (particulate debris). As in the case of radiological agents, determination of contamination is relatively simple, provided adequate detection equipment is available. Scrubbing with soap and water is generally an effective initial decontamination technique since the majority of the contamination is from fallout [Lillie et al. 2006].

General Decontamination Approaches for CBRN Respirators

As a very brief review, there are essentially four types of NIOSH Approved® CBRN respirators: SCBAs, powered air-purifying respirators (PAPRs), air-purifying respirators (APRs), and air-purifying escape respirators (APERs). There is a detailed discussion of CBRN respirators in Chapter 7.

SCBAs can be worn inside a fully encapsulating gas-tight suit (Environmental Protection Agency [EPA]/Occupational Safety and Health Administration [OSHA] Level A). SCBAs can also be worn inside or outside of an EPA/OSHA Level B protective suit that is not gas tight. Only SCBAs worn inside a fully encapsulating gas-tight suit will not require decontamination (other than normal cleaning procedures), provided the suit remains intact and there is no cross-contamination in removal of the protective ensemble. All other respirators will require decontamination unless there is confirmation that the area entered was not contaminated.

The normal response to an unknown CBRN agent would be a level A ensemble [Mansdorf 1992b]. In the unlikely event that there is a response with less protection than this, the respirators should be sprayed or brushed with a soap and water solution (or the same solution used for cleaning the protective clothing) to hopefully dislodge any surface contamination as a first stage. The runoff from the cleaning must be collected (usually piped or held in a small pool). After the outer gloves and protective suit are removed, the canisters from APR and PAPR respirators must be removed and cannot be decontaminated. They should be removed by a protected attendant (wearing the same level of protection as the respirator wearer or one level lower if the contaminant is known) and bagged as contaminated.

Then, the same attendant should collect the respirator facepiece and bag it either in the same bag as the canisters for disposal or in a separate bag for later decontamination and testing. The military use transparent six-millimeter plastic bags to collect these respirators. For both the canisters and the respirator facepieces, the bags could then be placed into another clean transparent six-millimeter plastic bag (double bagging) and placed into a metal drum or otherwise handled for later decontamination or disposal [Lillie at al. 2006].

The military decontaminates and reuses their non-SCBA respirator facepieces, except when they cannot confirm effective decontamination. The NIOSH advice for CBRN APR respirators does not permit reuse after contact with a CWA (liquid or vapor), and the respirator manufacturers provide this warning in their instructions. Therefore, the entire respirator with canisters could be discarded after use for later disposal as hazardous waste.

Decontamination Staging

It is necessary to establish an area for decontamination either before or during the initial entry into the contaminated zone. Ideally, the decontamination area would be established before entry. The decontamination area must be sited in a “clean” location free of contamination. If this is not possible, contaminated personnel should initially be “washed” in their full response ensembles and transported to an area that is “clean.” The runoff from the initial field wash (normally soap and water) must be collected either using a temporary ditch lined with plastic or a portable pool for later treatment of the wastewater.

A decontamination station can range from a very simple field expedient arrangement (see Figure 8-1) to use of commercial or military mobile units or even the construction of semi-permanent buildings. The same basic principles apply in all cases. The established decontamination station must be in a clean zone upwind of the contaminated area; provide rinse and wash stations either by pressurized spray, shower, or hand application; include collection points for the response ensemble; and provide

a shower area for personnel after decontamination. Victims should be handled in a similar fashion, with the addition of medical triage and potentially an isolation capability for transportation to a medical facility.

The focus of this section is specific to the decontamination of the CBRN respirators. The rinse and wash solutions used will depend on the CBRN agent suspected or known to be present. The default standard is uncontaminated water and soap. Warm water is more effective than cold water if the capability for heating is present. As noted earlier, the mechanical displacement of contamination is generally effective using standard washing techniques for most CBRN agents [Lillie et al. 2006].

The general procedure is an initial rinse with water followed by an aggressive washing (using brushes) and a final rinse of the protective clothing ensemble. Boots should be removed first, followed by the outer gloves and suit, followed by the respirator, and then the inner gloves. Each should be collected by the attendant. The attendant should remove the canisters from

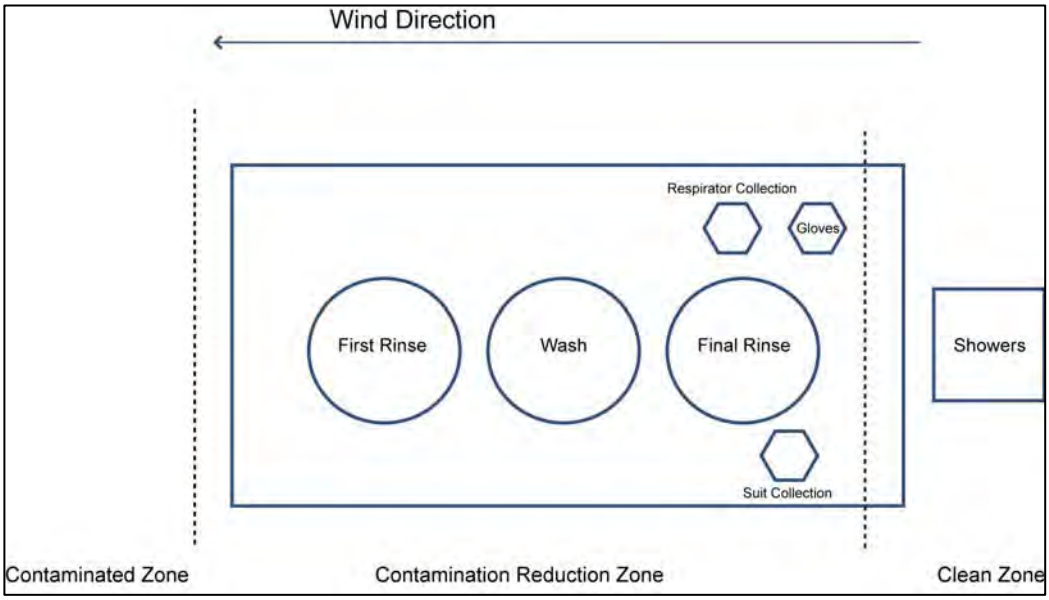

Figure 8-1. Simplified decontamination station

the respirator or PAPR and place the facepiece in a normal sanitization solution. The canisters should be bagged as hazardous waste. The blower assembly and hoses for the PAPR should be collected separately for a determination of whether they could be recovered and reused. SCBAs that have been worn in a gas-tight suit should not require decontamination other than normal handling, unless they were inadvertently contaminated during removal. Level B or NFPA Class 2 protection with an SCBA worn on the outside of the protective suit (splash suit) would require decontamination or disposal and is not recommended for this reason. This also applies to the National Institute of Justice Law Enforcement Response Level 1.

Complicating Issues in Decontamination

There are several potential complicating issues in decontamination. Soap and water washing is the general approach if the contaminant is unknown. This will likely reduce contamination to allow for removal of the protective ensemble but will not neutralize or render the contamination harmless. It is

a precautionary measure until the contaminant and decontamination technique are known. There may be an immediate need to enter the contaminated zone before the decontamination station is completed.

This scenario, while not advisable, could occur. In this case, personnel should be kept at an absolute minimum and kept in a relatively safe area upon return, until the decontamination station is completed. All wastes from the decontamination station are considered hazardous unless otherwise determined. This includes all decontamination solutions used and collected. If a method to measure the contamination is unknown, the entire protective ensemble, including respiratory protection, must be held as hazardous waste. Reuse of respirators of all types requires assurance that they are not contaminated. Therefore, the effectiveness of the decontamination procedures must be determined before the respirators are reused. In large responses, this could create equipment shortages.

Summary

All CBRN response ensembles require some level of decontamination before they can be taken off if exposed to a CBRN agent. This is necessary because of the risk of user exposure and cross-contamination. Decontamination also allows for the potential reuse of expensive and difficult to replace equipment, as well as for the proper disposal of contaminated PPE. Decontamination approaches vary widely depending on the CBRN agent encountered. A universal approach used until the actual CBRN agent is known is a soap and water wash before doffing the equipment. Decontamination of Level A or NFPA 1991 ensemble SCBAs is not necessary, assuming the fully encapsulating gas-tight suit is not breached and there is effective decontamination of the ensemble before removal of the SCBA. Recovery and reuse of the respirators will depend on the ability to demonstrate that the decontamination has been effective. Reuse is not permitted with Level B and C CBRN respirators under NIOSH recommendations and manufacturers' criteria if a CWA is present.

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Chapter 9 –CBRN Respirator User Training

Introduction

The NIOSH certification process described in Chapter 2 assures that chemical, biological, radiological, and nuclear (CBRN) respirators can protect users against a wide range of potential hazards. However, the expected level of protection cannot be achieved if the respirators are not used properly. Initial and ongoing training is necessary to ensure that each user is able to don and wear the respirator and other protective equipment while performing their assigned duties. Although information from several regulations and standards of practice must be conveyed to those trained, the ability to safely and effectively perform assigned tasks is the paramount goal of the training program. Because of the frequent use of CBRN respirators in combination with additional personal protective equipment (PPE), respiratory protection and PPE training should be conducted using an integrated, ensemble approach. The broad range of work activities performed by users of this equipment must be considered in developing an effective training program.

Regulations and Standards

The Occupational Safety and Health Administration (OSHA) Respiratory Protection regulation [Respiratory protection, 2010] has specific training requirements for respirator users. Other documents, including OSHA's Hazardous Waste regulation (HAZWOPER) [Hazardous waste, 2010] and National Fire Protection Association (NFPA) standard 470 [NFPA 2022], include respiratory protection among the competencies listed for several levels of emergency responder. The NFPA standard 1404 provides detailed information for training the fire service in the use of respiratory protection [NFPA 2006].

The OSHA Respiratory Protection regulation lists seven training topics in which respirator users must demonstrate knowledge:

1. Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator
2. Limitations and capabilities of the respirator
3. How to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions

4. How to inspect, put on, remove, use, and check the seals of the respirator
5. Procedures for maintenance and storage of the respirator
6. How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators
7. General requirements of the Respiratory Protection regulation (29 CFR 1910.134)

Training in all these areas must be completed before a worker's first respirator use in a work situation and must be repeated at least annually. Retraining is also required if changes in respirator type or usage make prior training obsolete or if a deficiency in a worker's knowledge or respirator use is apparent. OSHA does not specify a particular training method or provide assistance on how to assess workers' knowledge and understanding of the training.

In order to integrate these minimal respirator training requirements with the additional PPE and the duties of the workers undergoing training, the following additional topics should also be addressed:

8. Recognition of CBRN vs. non-CBRN respirators
9. Specific nature of the tasks/duties to be performed while using CBRN respirators
10. Concurrent donning and use of other protective equipment
11. Doffing the selected ensemble, including decontamination and disposal procedures
12. The organization's respiratory protection program and policies, including user rights and responsibilities

While not specifically required by OSHA regulations, individuals who supervise respirator use (e.g., incident commanders) should receive the same training as users, with additional emphasis on equipment selection, administrative procedures, and the recognition and resolution of problems related to respirator use. Those involved in purchasing or issuing respiratory protection or other PPE must also be familiar with the devices in use and understand why only the specified devices may be purchased. Substitution is not acceptable.

Instructors

It is implicit that those who design, deliver, and evaluate user training should have the necessary knowledge and skills to do so. This is not stated in OSHA's Respiratory Protection regulation but is mentioned in general terms for training employees covered by the HAZWOPER standard [Hazardous waste, 2010].

NFPA standard 1041 [NFPA 2007] describes in detail the qualifications and competencies necessary for fire service instructors at three levels of responsibility for preparing, delivering, and evaluating the results of instruction as well as training program administration.

Specificity

> *It is critical to recognize that for every group trained, the program presented must address the specific respirator(s) and other PPE that will be used as well as the tasks each person will be expected to perform [NFPA 2006].*

"Generic" training materials and other programs that provide broad information not relevant to the tasks to be performed are not appropriate. The 12 training topics listed earlier in this chapter must be addressed regardless of the type of CBRN respirator chosen. However, each topic must be tailored to address special characteristics, unique training or use procedures, and the limitations of the respirator to be used. In some cases, these attributes may only apply to one brand or model of respirator. As such, manufacturers' instructions must always be an integral part of user training materials. For example, different manufacturers of CBRN powered air-purifying respirators (PAPRs) may require different procedures for battery maintenance or verifying that their device's flow rate is adequate.

Only the information that applies to the specific respirator in use should be covered in training; the other manufacturers' instructions are irrelevant.

Training should be designed to impart proficiency in a desired set of skills. Attainment of these goals demands not only classroom instruction, but also opportunity for demonstrations and extensive "hands-on" practice of each skill. Skills should be introduced and developed individually and, when each is mastered, combined and practiced as they will be used during a response [NFPA 2006].

Specifically, the goals for user training are to develop proficiency in the following skills:

- *The ability to don, use, and doff (including, if appropriate, decontamination and disposal of) the chosen respirator(s) and additional protective equipment*
- *The ability to perform the intended tasks while wearing the protective ensemble*
- *The ability to respond appropriately to unanticipated equipment malfunction or other emergencies*

Evaluation

Evaluation of the adequacy of training should assess both the knowledge and the skills of the participants (i.e., their ability to perform as they were trained). The former can be accomplished using verbal or written assessments such as quizzes or discussion with each training recipient. The latter must be judged by observation of the trainees performing the procedures and tasks they were taught. This evaluation is best done with simulations of the intended response (e.g., victim rescue, containing and cleaning up a chemical release, or administering medical assistance). Of the 12 training topics listed earlier in this chapter, only numbers 1, 2, 6, 7, and 12 lend themselves to evaluation by knowledge testing alone; the remaining 7 topics must be evaluated by a combination of knowledge assessment and observation of performance.

Criteria for acceptable performance must be developed prior to the training and clearly conveyed to the participants when training starts. Procedures and policies for retraining and reevaluating unacceptable performance must also be in place before training begins. Given the potentially severe consequences of improper respirator or PPE use in highly toxic work environments, student evaluation criteria must be rigorous, but fair.

Frequency

As noted earlier in this chapter, the minimum frequency for respiratory protection training is annually for organizations regulated by OSHA. The HAZWOPER regulation also calls for annual refresher training, including use of PPE for affected workers [Hazardous waste, 2010]. While NFPA 1404 specifies at least annual retraining and recertification of respirator users, it also refers to "an ongoing training program"[NFPA 2006]. The latter should be the goal of the organization. More frequent periodic training, as resources permit, will enhance retention of the skills needed for the safe use of respirators and other PPE.

Records

While OSHA has no specific legal requirement to keep records of respiratory protection training, it is advisable to keep records that include at least the following information:

- Names of the people trained
- Dates the training was conducted
- Training materials, including handouts, outlines, manufacturer's instructions, and a description of simulations and other activities
- Evaluation criteria and performance results

As described in Chapter 5, an annual evaluation of the effectiveness of the entire respiratory protection program is strongly recommended. The training program should be a part of this evaluation. If changes to the training are needed, they should be documented in the evaluation and incorporated into the next training session.

Training Program Development Template

Because effective training programs must be "tailor made" to address the specific protective ensemble(s) and tasks to be performed by an organization, it is not possible to offer a universal training program. However, certain topics must be addressed in some way in any training program. The 12 training topics listed earlier in this chapter serve as a useful starting point in the development of a training program. This section expands on the 12 topics. The suggestions are not all inclusive, but they will assist trainers in creating site-specific programs. It is the responsibility of individual organizations to completely address the training elements necessary for safe respirator use. Further, it is assumed that organizations that use this template have written operating procedures to address each of the elements of an effective respiratory protection program.

1. *Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator:*

    a. For initial emergency response:
        i. Contaminants and concentrations will likely be unknown
        ii. Presume highly toxic/immediately dangerous to life or health (IDLH) until proven otherwise; use maximum available protective equipment

iii. Use a protective ensemble (e.g., Level A or NFPA 1991 with CBRN self-contained breathing apparatus [SCBA]) shown to resist penetration and provide inhalation protection against a wide range of chemical warfare agents and other toxins **when properly selected, fitted, maintained, and used**

b. For known hazards (e.g., initial responders have identified and quantified the toxic materials or industrial use):
   i. Identify contaminant(s), describe toxic effects, relate to exposure limits if applicable
   ii. Use a protective ensemble that offer appropriate protection (e.g., skin, inhalation) at the concentrations/conditions encountered **when properly selected, fitted, maintained, and used**
   iii. Describe measures to control/reduce/eliminate hazardous exposures

c. For all usage:
   i. All instructions and training must be carefully followed to attain protection
   ii. Greatest threats to effective protection:
      1. Removal of PPE (e.g., respirator) in contaminated atmosphere
      2. Poorly inspected/maintained PPE
      3. Improper selection/use in atmospheres or conditions other than those specified

2. *Limitations and capabilities of the respirator:*

   a. No respirator can guarantee zero exposure

   b. Describe capabilities and limitations of the specific respirator(s) to be used

      i. All respirators:
         1. Special limitations are listed in the user instructions and/or NIOSH approval label
         2. Introduce assigned protection factor (APF) concepts

      ii. CBRN SCBAs:

         1. Capabilities: supply breathable air, broadest range of inhalation protection, maximum protection (APF=10,000)

         2. Limitations: finite air supply, duration dependent on inhalation rate, weight, bulk

      iii. CBRN PAPRs

         1. Capabilities: remove specific contaminants (describe), high level of protection (APF=1,000)

         2. Limitations: atmosphere must be characterized and not IDLH, adequate oxygen must be present, battery limits use duration, canister/cartridge change schedule may limit use duration

iv. CBRN air-purifying respirators (APRs):

1. Capabilities: remove specific contaminants (describe), lesser but still high level of protection (APF=50)
2. Limitations: atmosphere must be characterized and not IDLH, adequate oxygen must be present, breathing resistance contributes to fatigue, canister/cartridge change schedule may limit use duration

v. CBRN air-purifying escape respirators (APERs):

1. Capabilities: remove specific contaminants (describe) during escape only
2. Limitations: contaminant must be one that is removed by the canister, adequate oxygen must be present, not for entry into contaminated atmosphere or "sheltering in place"

3. *How to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions:*

a. Specific to respirator(s) in use

b. Include relevant information from user instructions

c. Specific to reasonably anticipated emergency situations

d. Describe organization's written operating procedures for reacting to equipment failure

e. Develop and practice drills and simulations

4. *How to inspect, put on, remove, use, and check the seals of the respirator:*

a. Specific to respirator(s) in use

b. Include relevant information from user instructions

c. Describe organization's written operating procedures on what to do if inspection reveals defects or if a seal cannot be achieved

d. Explain and demonstrate user seal checks

e. Supervise practice of these procedures

f. Describe qualitative or quantitative fit testing procedures to be used

5. *Procedures for maintenance and storage of the respirator:*

a. Specific to respirator(s) in use

b. Include relevant information from user instructions

c. Describe organization's written operating procedures for maintenance and storage

i. Responsibilities—individual and/or centralized maintenance
ii. Location
iii. Ensure identified personnel learn and practice the procedures

6. *How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators:*

a. Respirator/PPE-related

i. Breathing resistance

ii. Unusual discomfort

iii. Symptoms of heat illness

b. Contaminant-related

i. For known contaminants: describe signs and symptoms of exposure

ii. For emergency response to potential terrorism: describe signs and symptoms of exposure to reasonably anticipated chemical warfare agents

iii. Anxiety

iv. Exhaustion

c. Describe organization's written operating procedures explaining what affected individuals and other users are to do if symptoms occur

7. *The general requirements of 1910.134*

8. *Recognition of CBRN vs. non-CBRN respirators:*

a. Describe special characteristics and capabilities of specific CBRN respirator(s) to be used

b. Describe CBRN labeling requirements and locations

c. Describe organization's written operating procedures explaining what to do if a non CBRN device is found among respirators intended for CBRN response

9. *Specific nature of the tasks/duties to be performed while using CBRN respirators:*

a. Describe specific, reasonably anticipated tasks the responder group(s) being trained will perform

i. Initial response, containment, hazard identification

ii. Remediation

iii. Decontamination

iv. Medical services

v. Site control, law enforcement

b. Describe organization's written operating procedures explaining tasks to be performed

i. What is to be done
ii. What is not to be done
iii. How to react to unexpected events/upset conditions

c. Develop and practice drills and simulations

10. *Concurrent donning and use of other protective equipment:*

a. Describe the specific PPE to be used
b. Identify capabilities and limitations of each piece of equipment
c. Include relevant information from user instructions
d. Describe organization's written operating procedures for reacting to equipment failure
e. Explain and demonstrate donning and use of each piece of equipment
f. Explain and demonstrate donning sequence for the entire protective ensemble
g. Supervise practice of these procedures
h. Integrate into drills and simulations

11. Doffing the selected ensemble, including decontamination and disposal procedures:
    a. Describe organization's written operating procedures for decontamination
    b. Explain and demonstrate doffing sequence for the protective ensemble, including disposal of used components
    c. Supervise practice of these procedures. Integrate into drills and simulations

12. *The organization's respiratory protection program and policies, including user rights and responsibilities*

Conclusion

Effective and ongoing user training is necessary for the safe use of CBRN respirators. The training should be designed specifically for the respirator(s) and other protective equipment to be used and the work to be performed. Training must ensure that workers not only learn the capabilities and limitations of their protective equipment, but also demonstrate the procedures and skills necessary to achieve the expected level of protection.

References

Hazardous waste operations and emergency response. 29 CFR 1910.120 (2010).

NFPA [2006]. NFPA 1404: Standard for fire service respiratory protection training. Quincy, MA: National Fire Protection Association.

NFPA [2007]. NFPA 1041: Standard for fire service instructor professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2022]. NFPA 70: Hazardous materials/weapons of mass destruction (WMD) standard for responders. Quincy, MA: National Fire Protection Association.

Respiratory protection. 29 CFR 1910.134 (2010).

Appendix A: CBRN Respirator Standards

Air-Purifying Respirators (APR) with CBRN Protection

Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CRBN) Full Facepiece Air Purifying Respirator (APR)

March 7, 2003
Revision 1; March 17, 2003
Revision 2; April 4, 2003
Fig. 1 Updated; January 30, 2004

1.0 Purpose:

The purpose of this standard is to specify minimum requirements to determine the effectiveness of full facepiece air purifying respirators (APR) used during entry into chemical, biological, radiological, and nuclear (CBRN) atmospheres not immediately dangerous to life or health. The respirator must meet the minimum requirements identified in the following Paragraphs:

- Paragraph 2.0, Requirements Specified in Title 42 Code of Federal Regulations (CFR), Part 84 applicable paragraphs,
- Paragraph 3.0, Requirements based on existing national and international standards,
- Paragraph 4.0, Special requirements for CBRN use.

2.0 Title 42 Code of Federal Regulations (CFR), Part 84:

The following paragraphs of 42 CFR, Part 84 are applicable:

2.1 42 CFR, Part 84, Subparts A, B, D, E, F, and G:

Subpart A: General Provisions
Subpart B: Application for Approval
Subpart D: Approval and Disapproval
Subpart E: Quality Control
Subpart F: Classification of Approved Respirators
Subpart G: General Construction and Performance

2.2 42 CFR, Part 84, Subpart I; the following paragraphs apply:

84.110 Gas Masks; description, paragraphs a(1), a(2), and (b)
84.111 Gas Masks; required components
84.112 Canisters and cartridges in parallel; resistance requirements
84.113 Canisters and cartridges; color and markings; requirements
84.114 Filters used with canisters and cartridges; location; replacement
84.115 Breathing tubes; minimum requirements
84.116 Harnesses; installation and construction; minimum requirements
84.117 Gas mask containers; minimum requirements
84.118 Half-mask facepieces, full facepieces, and mouthpieces; fit; minimum requirements, paragraphs a(1), a(2), (b), and (e)
84.119 Facepieces; eyepieces; minimum requirements
84.120 Inhalation and exhalation valves; minimum requirements
84.121 Head harnesses; minimum requirements
84.123 Exhalation valve leakage test

2.3 42 CFR, Part 84, Subpart K; the following paragraphs apply:

84.170 non-powered air purifying particulate respirators; description
84.179 non-powered air purifying particulate respirators; filter identification
84.181 non-powered air purifying particulate filter efficiency

3.0 Requirements Based on Existing National and International Standards:

3.1 Mechanical Connector:

The interface between the canister and the facepiece or respirator system shall use a standard Rd 40 X 1/7 thread in accordance with Figure 1 (NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket). The canister shall be readily replaceable without the use of special tools. For respirators where the canister is attached directly to the facepiece, i.e. respirator mounted, a single interface connector thread shall be located on the facepiece. The interface connector on the facepiece shall be the internal thread and gasket sealing gland. The canister shall use the external thread.

For respirators where the canister is not directly attached to the facepiece, i.e. not respirator mounted, an internal thread and gasket sealing gland connector complying with Figure 1 must be securely attached to a harness system to provide strain relief between the canister and the remaining respirator system. For respirator systems where the canister is not respirator mounted, multiple canister assemblies are permitted.

3.2 Gasket, Mechanical Connector:

The dimensions for the interface connector gasket shall be outside diameter 37.5 mm minimum, inside diameter 28.5 mm maximum, minimum thickness 1.55 mm as illustrated in Figure 1. The gasket material shall be ethylene propylene diene monomer (EPDM) or equivalent meeting the physical and chemical properties of Table 1 (Rubber Gasket Physical and Chemical Properties) when tested in accordance with Table 2 (Gasket Tests, Specimens and Test Methods). The manufacturer is required to provide data indicating compliance with the requirements of Table 1 and 2. Agent permeation data is not required for EPDM gasket material meeting all other properties of Table 1. For gasket material other than EPDM material samples must be tested to the agent permeation requirements.

3.3 Breathing Resistance, Canister:

In addition to the resistance to airflow determined by paragraph 3.5, Breathing Resistance, the canister resistance to inhalation airflow shall be less than or equal to 50 mm water column when tested at 85 liters per minute continuous air flow.

Table 1. Rubber Gasket Physical and Chemical Properties

Property	Units	Unaged Minimum	Unaged Maximum	Aged Minimum	Aged Maximum
Tensile Strength	Mpa (psi)	8.3 (1200)	---	6.9 (1000)	---
Ultimate elongation	Percent (%)	350	---	300	---
Tensile set at 300% elongation	Percent (%)	---	25	---	25
Tensile stress at 200% elongation	Mpa (psi)	3.4 (500)	---	3.4(500)	---
Tear resistance Either Die B or Die C (1)	kN/m (lbf/in)	21.9 (125)	---	21.9 (125)	---
Durometer hardness (Shore "A")	---	55	75	---	---
Compression set 22 hrs. at 68° C	Percent (%)	---	25	---	---
Impact resilience	Percent (%)	35	---	---	---
Agent permeation HD, Mustard & GB, Sarin (2)	Minutes Minutes	360 360	---	---	---
Low temperature brittleness at minus 51° C	---	Pass	---	---	---

(1) Test specimens shall be cut from Die B or Die C. Test specimens shall not be a mixture of Die specimens. See Table 2: Tear Resistance Method ASTM 624 D.

(2) The applicant shall submit agent permeation data on materials that are not classified as EPDM. Rubber material formulations that are 51% or greater in EPDM classifies the material as EPDM.

Table 2. Gasket Tests, Specimens and Test Methods

Property	Specimen			Total	Method
	Unaged	Heat Aged [1]	Oxygen aged [2]		
Tensile strength Ultimate elongation Tensile stress at 200% elongation	Cut one specimen from each of three slabs.	Cut one specimen from each of three slabs.	Cut one specimen from each of three slabs.	9	ASTM D 412
Tensile set at 300% elongation	Cut one specimen from each of three slabs.	Cut one specimen from each of three slabs.	Cut one specimen from each of three slabs.	9	ASTM D 412
Tear resistance, Either Die B or Die C	Cut one specimen from each of three slabs/buttons.	Cut one specimen from each of three slabs.	Cut one specimen from each of three slabs.	9	ASTM D 624
Low temperature Brittleness at –51°	Cut one specimen from each of five slabs.	None	None	5	ASTM D 746
Durometer hardness (Shore "A")	Cut one specimen from each of three slabs.	None	None	3	ASTM D 2240
Compression set [3]	Three test buttons.	None	None	3	ASTM D 395
Impact resilience (3)	Three test buttons.	None	None	3	ASTM D 2632
Agent permeation [4] [5] Sarin (GB) and Sulfur Mustard (HD)	Cut two specimens from each of six test slabs. Six specimens per agent.	None	None	12	MIL-STD-282 Method 208 Method 209

(1) Heat Aging. The specimens selected for heat aging shall be aged in an air oven at a temperature of 158° F +/-7°F (70°C -/+ 2°C) for a continuous period of 24 hours as prescribed in ASTM D 573.

(2) Oxygen Aging. Specimens shall be aged in an oxygen environment in accordance with ASTM D 572 for 72

hours. (3) Same test buttons shall be used for impact resilience and compression set in that order.

(4) If gasket material is not EPDM, applicant shall submit permeation test data for gasket material along with six test slabs for Agent Permeation Test.

(5) Test specimens shall be fabricated in accordance with ASTM D 3182 from material of the same formulation that will be used during regular production of the respirator. The test specimens shall have a cure equivalent to that of the regular production gaskets. The thickness of the test specimens shall be the minimum gasket thickness specified by the applicants' design specification. Any finish or treatment, applied to the finished gasket, shall be applied to the test specimens.

3.4 Dimensions and Weight, Respirator Mounted (Chin Style) Canister:

The maximum weight of a respirator mounted (chin style) canister shall be 500 grams. The maximum size of a respirator mounted (chin style) canister shall be such that the canister shall pass through a 5-inch diameter opening with the threaded connector perpendicular to the 5-inch diameter opening.

3.5 Breathing Resistance:

Resistance to air flow shall be measured in the facepiece of a CBRN air purifying respirator mounted on a test fixture with air flowing at
a continuous rate of 85 liters per minute both before and after each gas service life bench test. The maximum allowable air resistance to air flow is as follows:

		Chin Style	Non Facepiece Mounted
Inhalation:	**Initial**	65 mm H_2O	70 mm H_2O
	Final (1)	80 mm H_2O	85 mm H_2O
Exhalation:		20 mm H_2O	20 mm H_2O

(1) Measured at end of service life.

3.6 Field of View:

The full facepiece CBRN APR shall obtain a Visual Field Score (VFS) of 90 or greater. The VFS shall be obtained by using a medium size respirator or equivalent that is sized to fit the Head Form described in Figure 14 of EN 136, Respiratory protective devices – Full face masks – Requirements, testing, marking; January 1998 or equivalent.

The VFS is determined by using a VFS grid (Dots on visual field) as defined in the American Medical Association Guides to the Evaluation of Permanent Impairment, 5th Edition (2000) that is overlaid on the diagram of the visual field plot obtained using the spherical shell of EN 136 apertometer or equivalent. The VFS score is the average of three fittings of the same respirator on the specified head form.

3.7 Lens Material Haze, Luminous Transmittance and Abrasion Resistance:

3.7.1 Haze:

The haze value of the primary lens material shall be 3% or less when tested in accordance with ASTM D 1003-00.

3.7.2 Luminous Transmittance:

The luminous transmittance value of the primary lens material shall be 88% or greater when tested in accordance with ASTM D 1003-00.

3.7.3 Abrasion Resistance:

The haze and luminous transmittance of the primary lens material shall be determined in accordance with ASTM D 1003-00 before and after subjecting the lens material to the abrasion test. The abrasion test shall be conducted in accordance with ASTM D 1044-99 using a CS10F calibrase wheel at a minimum of 70 revolutions under a 500-gram weight. After subjecting the lens material to the abrasion test, remove the residue from the test specimens in accordance with ASTM D 1044-99 or by

using a cleaning method recommended by the applicant. After the residue is removed from the test specimens, the test specimens shall not exhibit an increase of haze greater than 4% and a decrease of luminous transmittance greater than 4%.

3.7.4

The test specimens shall be the flat four (4) inch (102mm) square version as prescribed in ASTM D 1044-99 and shall have the same nominal thickness and within the tolerance range as the primary lens of the CBRN APR. The test specimens shall be subjected to the same coating process and any other processes, as the primary lens would be under normal production conditions. A total of 6 specimens shall be furnished to NIOSH for certification testing, three pre-abrasion specimens and three specimens after being tested for abrasion in accordance with ASTM D-1044-99

3.8 Carbon Dioxide:

The maximum allowable average inhaled carbon dioxide concentration shall be less than or equal to 1 percent, measured at the mouth, while the respirator is mounted on a dummy head operated by a breathing machine. The breathing rate will be 14.5 respirations per minute with a minute volume of 10.5 liters. Tests will be conducted at ambient temperature of 25 ± 5°C. A concentration of 5 percent carbon dioxide in air will be exhaled into the facepiece. The minimum allowable oxygen concentration shall be 19.5 percent. NIOSH Test Procedure RCT-APR-STP-0064 is used for Carbon Dioxide Testing.

3.9 Hydration:

For CBRN APR respirators equipped with a hydration facility, the CBRN APR respirator shall meet all requirements of the CBRN APR standard with the hydration facility in place. Dry drinking tube valves, valve seats, or seals will be subjected to a suction of 75mm water column height while in a normal operating position. Leakage between the valve and the valve seat shall not exceed 30 milliliters per minute. NIOSH Test Procedure RCT-APR-STP-0014 is used for hydration facility leakage.

3.10 Tolerance Analysis:

The applicant will provide a tolerance analysis of the mechanical connector, canister thread and gasket identified in Paragraphs 3.1
Mechanical Connector and 3.2 Gasket, Mechanical Connector demonstrating the applicant's canister design will contact and seal on the gasket surface area defined by the 37.5mm minimum outside diameter and the 28.5 maximum inside diameter under all tolerance conditions.

3.11 Practical Performance (Modified Laboratory Protection Level Test):

A modified laboratory protection level test (LRPL) shall be performed using respirators fitted with a canister weighted to 500 grams and sized to the maximum permissible dimensions of Paragraph 3.4 Dimensions and Weight, Respirator Mounted (Chin Style) Canister. A minimum of eight respirators shall be tested to fulfill the small, medium, and large designations of facial size – 2 small, 4 medium, and 2 large. The measured laboratory respiratory protection level (LRPL) for each full facepiece, air purifying respirator shall be 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.

4.0 Special CBRN Requirements:

4.1 Canister Test Challenge and Test Breakthrough Concentrations:

The gas/vapor test challenges and breakthrough concentrations shown in Table 3: Canister Challenge, Breakthrough Concentrations, and Canister Efficiency shall be used to establish the canister service life:

Table 3. Canister Test Challenge and Test Breakthrough Concentrations

	Test Concentration (ppm)	Breakthrough Concentration (ppm)
Ammonia	2500	12.5
Cyanogen Chloride	300	2
Cyclohexane	2600	10
Formaldehyde	500	1
Hydrogen Cyanide	CBRN Handbook work	4.7(1)
Hydrogen Sulfide	1000	5.0
Nitrogen Dioxide	200	1 ppm NO_2 or 25 ppm NO(2)
Phosgene	250	1.25
Phosphine	300	0.3
Sulfur Dioxide	1500	5

(1) Sum of HCN and C2N2.

(2) Nitrogen Dioxide breakthrough is monitored for both NO2 and NO. The breakthrough is determined by which quantity, NO2 or NO, reaches breakthrough first.

4.2 Service Life:

The applicant shall specify a minimum service life as part of the application for certification. For less than a 60-minute service life, applications 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). Gas life tests are performed at room temperature, 25±5° C; 25±5 percent relative humidity; and 80 + 5 percent relative humidity. Three canisters will be tested at each specified humidity with a flow rate of 64 liters per minute, continuous flow. Tests will be conducted to the minimum specified service time. The canisters shall meet or exceed the specified service times without exceeding the identified breakthrough concentrations in Table 3. Gas testing shall be performed following environmental conditioning and rough handling.

4.3 Particulate/Aerosol Canister:

The canister shall meet the requirements of a P100 particulate filter in accordance with 42 CFR, Part 84, paragraphs 84.170, 84.179, and 84.181.

4.4 Service Life Testing, High Flow:

Each canister shall provide a minimum 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 for each of the gases/vapors identified in Paragraph 4.1, Canister Test Challenge and Test Breakthrough Concentrations.

4.5 Low Temperature/Fogging:

The respirator shall demonstrate an average Visual Acuity Score (VAS) of greater or equal to 75 points for all measurements of acuity. The respirator shall be cold soaked and tested in an environmental chamber at minus 21° C for four (4) hours. The wearer shall not experience undue discomfort because of restrictions to breathing or other physical or chemical changes to the respirator.

4.6 Communications:

Communication requirements are based upon performance using a Modified Rhyme Test (MRT). The communications requirement is met if the overall performance rating is greater than or equal to seventy (70) percent. The MRT will be performed with a steady background noise of 60 dBA consisting of a broadband "pink" noise. The distance between the listeners and speakers shall be 3 meters.

4.7 Chemical Agent Permeation and Penetration Resistance Against Distilled Sulfur Mustard (HD) and Sarin (GB) Agent Requirement:

The air purifying respirator system, including all components and accessories shall resist the permeation and penetration of Distilled Sulfur Mustard (HD) and Sarin (GB) chemical agents when tested on an upper-torso manikin connected to a breathing machine operating at an air flow rate of 40 liters per minute (L/min), 36 respirations per minute, 1.1 liters tidal volume.

Test requirements for Distilled Sulfur Mustard (HD) are shown in Table 4:

Table 4. Vapor-Liquid Sequential Challenge of APR with Distilled Sulfur Mustard (HD)

Agent	Challenge Concentration	Duration of Challenge (min)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion (mg/m^3)	Maximum Breakthrough (concentration integrated over minimum service life)(mg min/m^3)	Number of Systems Tested	Minimum Service Life (hours)
HD-Vapor	50 $mg/m^{3(1)}$	30	40	$0.30^{(3)}$	$3.0^{(4)}$	3	$8^{(6)}$
HD-Liquid	0.43 to 0.86 $ml^{(1)(2)(5)}$	120	40	$0.30^{(3)}$	$3.0^{(4)}$	3	2

(1) Vapor challenge concentration will start immediately after the test chamber has been sealed. Minimum Service Life for liquid exposure starts after the first liquid drop is applied.

(2) Liquid volume dependent on accessories used with the respirator. Minimum volume is 0.43 ml based on the respirator and single respirator mounted canister.

(3) Three consecutive sequential test data points at or exceeding 0.3 mg/m3 will collectively constitute a failure where each test value is based on a detector sample time of approximately 2 minutes.

(4) The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test. (5) Liquid agent is applied to respirator at hour 6 of the test cycle.

(6) The test period begins upon initial generation of vapor concentration and ends at 8 hours.

Test requirements for Sarin (GB) agent are shown in Table 5:

Table 5. Vapor Challenge of APR with Sarin (GB)

Challenge Concentration	Vapor Concentration (mg/m^3)	Vapor Challenge Time (minutes)	Breathing Machine Airflow Rate(L/min)	Maximum Peak Excursion mg/m^3	Maximum Breakthrough (concentration integrated over minimum service life)(mg-min/m3)	Number of Systems Tested	Minimum Service Life (hours)
GB	210(1)	30	40	0.044(3)	1.05(4)	3	8(2)

(1) The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.

(2) The test period begins upon initial generation of vapor concentration and ends at 8 hours.

(3) Three consecutive sequential test data points at or exceeding 0.044 mg/m3 will collectively constitute a failure where each test value is based on a detector sample time of approximately 2 minutes.

(4) The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.

4.8 Laboratory Respiratory Protection Level (LRPL) Test Requirement:

The measured laboratory respiratory protection level (LRPL) for each full facepiece, air purifying respirator shall be 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.

4.9 Environmental Conditioning (transportability, temperature range, survivability):

Environmental conditioning shall be performed in accordance with Table 6:

Table 6. Environmental Conditioning

Test	Test Method	Test Condition	Duration
Hot Diurnal	Mil-Std-81°F; Method 501.4; Table 501.4-II;Hot-Induced Conditions	Diurnal Cycle, 35°C (950F) -71°C (160°F);	3 Weeks
Cold Constant	Mil-Std-81°F, Method 502.4;	Basic Cold (C1), -32°C (-95°F); Constant	3 Days
Humidity	Mil-Std-810E, 507.3; Method 507.3; Table 507.3-II	Natural Cycle, Cycle 1, Diurnal Cycle, 31°C (880F) RH 88% -41°C (105°F) RH 59%	5 Days, Quick Look
Vibration	Mil-Std-810F, 514.5	US Highway Vibration, Unrestrained Figure 514.5C-1	12 Hours/Axis, 3 Axis; Total Duration =36 Hours, equivalent to 12,000 miles
Drop	3-foot drop onto bare concrete surface	Canister only; In individual canister packaging container	1 drop/filter on one of the 3 axes.

4.10 Test Sequence and Quantity:

Testing of the CBRN APR system and canisters shall follow Table 7:

Table 7. Test Sequence and Quantity

Test Order	42 CFR Testing	Human Factors	Service Life, 100 lpm	Service Life Testing, 64 lpm flow	Particulate Canister Degradation	Penetration and Permeation Testing	Efficiency Particulate Canister	LRPL Test
Qty	3 APR systems; 3 exhalation	9 APR Systems, 6 lens samples	30 canisters	54 canisters	6 canisters	6 APR systems (1)	20 canisters	25 to 38 systems
1.	Breathing Tube, 84.115 Para.2.2	Commo. Para. 4.6	Hot Diurnal Para. 4.9	Hot Diurnal Para. 4.9	Hot Diurnal Para. 4.9	Hot Diurnal Para. 4.9	Filter Efficiency 84.181	LRPL Para. 4.8
2.	Facepieces; eyepieces minimum requirement, 84.119	Low Temperature Fogging Para. 4.5	Cold Constant Para. 4.9	Cold Constant Para. 4.9	Cold Constant Para. 4.9	Cold Constant Para. 4.9	Cold Constant Para. 4.9	Practical Performance Test Para.3.11
3.	Canister in Parallel Resistance, 84.112 /.122 Para.2.2	Facepiece Resistance Para. 3.3	Humidity Para. 4.9	Humidity Para. 4.9	Humidity Para. 4.9	Humidity Para. 4.9	Humidity Para. 4.9	Humidity Para. 4.9
4.	Exhalation valve leakage test, 84.123 Para.2.2	Field of View Para. 3.6	Transportation/ Vibration Para. 4.9	Transportation/ Vibration Para. 4.9	Transportation/ Vibration Para. 4.9	Transportation/ Vibration Para. 4.9	Transportation/ Vibration Para. 4.9	
5.	Hydration 84.63(a) (c)(d) Para.3.	Haze, Transmittance, Abrasion Para. 3.7	Drop Para. 4.9(2)	Drop Para. 4.9(2)	Drop Para. 4.9(2)	Drop Para. 4.9(2)	Drop Para. 4.9(2)	
6.	Determine CO2 levels 84.63(b) (c)(d) Para.3.	Tolerance Analysis Para. 3.10	Service Life 100 lpm Para. 4.4	Initial Breathing Resistance Para. 3.5	Canister Breathing Resistance Para. 3.3	System Testing Para. 4.7	Filter Efficiency 84.181	
7.				Service Life Testing, Less Cyclohexane, 64 lpm Para. 4.2	Service Life Cyclohexane Para. 4.2			
8.				Final Breathing Resistance Para. 3.5	DOP Testing 84.181			
9.					Final Breathing Resistance Para. 3.5			

(1) A total six systems tests are performed, 3 GB and 3 HD. Two systems tests, 1 GB and 1 HD, are performed prior to Para. 4.9 Environmental Conditioning. Four systems tests, 2 GB and 2 HD, are performed after Para. 4.9 Environmental Conditioning.

(2) The Drop Test is performed on the canister only, in the minimum manufacturer's recommended packaging.

5.0 Quality Assurance Requirements:

5.1 Quality Control Plan:

Respirators submitted for CBRN air purifying respirator approval shall be accompanied by a complete quality control plan meeting the requirements of Subpart # of 42 CFR, Part 84.

5.2 Sampling/Test/Inspection Plan:

The applicant shall specify a sampling/test/inspection plan for respirator parts and materials to ensure the construction and performance requirements of this standard are established through the manufacturing process. As a minimum, specific attributes to be addressed are:

a) Materials of construction used for respirator parts that form a barrier between the user and ambient air.
b) Integrity of mechanical seals that comprise a barrier between the user and ambient air.
c) Final performance quality control tests on complete canisters demonstrating compliance with the gas life and particulate filter requirements of this standard.
d) Conformance with mechanical dimensions of respirator to canister connecting thread.
e) Conformance with mechanical dimensions of respirator to canister sealing gland including length of threads, gasket seating dimensions, and configuration.
f) Conformance with material properties, dimensional and hardness requirements of the respirator to canister gasket.

6.0 General Requirements:

In addition to the requirements of 42 CFR, Subpart G – General Construction and Performance Requirements, the following requirements apply:

Prior to making or filing any application for approval or modification of approval, the applicant shall conduct, or cause to be conducted, examinations, inspections, and tests of respirator performance, which are equal to or exceed the severity of those prescribed in the standard. Paragraph 4.7 Systems Tests are excluded from this requirement. NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket Drawing from Revision 3 (April 3, 2007) to Revision 4 (August 30, 2007).

DEPARTMENT OF HEALTH & HUMAN SERVICES Public Health Service

Centers for Disease Control and Prevention (CDC) National Institute for Occupational Safety and Health (NIOSH)
National Personal Protective Technology Laboratory (NPPTL)
P.O. Box 18070 Pittsburgh, PA 15236-0070 Phone: 412-386-5200 Fax: 412-386-4089

August 30, 2007

LETTER TO ALL MANUFACTURERS

SUBJECT: Incorporation of the NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket drawing Revision 4, Dated 09 July 2007, into the Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Full Facepiece Air-Purifying Respirator (APR), Revision 2; April 4, 2003

The purpose of this letter is to inform all manufacturers that Revision 4 of the NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket drawing, dated 09 July 2007, has been incorporated into the Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Full Facepiece Air-Purifying Respirator, Revision 2; April 4, 2003, as Figure 1. This letter serves as a notification that all previous drawing revisions used as Figure 1 are obsolete and are no longer valid. Revision 4 may be downloaded from the following webpage: http://www.cdc.gov/niosh/npptl/resources/pressrel/letters/lttr-083007.html

NIOSH CBRN APR approvals issued prior to the date of this letter remain NIOSH certified and reevaluation is not required. New or pending applications submitted for NIOSH CBRN APR certification must meet the requirements of Revision 4.

The subject drawing was updated in response to questions concerning the dimensioning of Revision 3 (Letter To All Manufacturers, NIOSH/NPPTL, April 5, 2007, Subject: Update to the NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket Drawing from Revision 2 (January 9, 2004) to Revision 3 (April 3, 2007) https://www.cdc.gov/niosh/npptl/resources/pressrel/letters/pdfs/NewUpdate_%20NIOSHCBRNRevisions2and3-508.pdf). The NIOSH/NPPTL received specific comments from manufacturers regarding Revision 3 and they were considered in the development of Revision 4.

The modifications to the drawing are as follows:

- Part A: The absolute maximum, canister air-outlet, diameter was increased from 34.0 mm to 34.5 mm. This enhances the flexibility of the design especially with thinner walled plastic canisters.
- Part A: The one-degree boundary was added so that no canister cross-sectional back face protrudes beyond the marked boundary to avoid interference with a facepiece component. For ease of measurement, a definitive location for the dimension was moved to the end of the Thread Runout feature.

- Part A: The Minimum Thread Runout was increased from 15.00 mm to 15.25 mm to enhance sealing with the internal thread component of the facepiece. Also, for the same reason, the minimum Effective Thread Length was increased from 13.72 mm to 14 mm.

- Part A: The dimension of the bend radius (2.0 Bend R) at the intersection between the thread neck and the canister back face was removed because it was design restrictive to the manufacturers.

- Part B: The connector depth will range from 7.00 mm to 14.00 mm. This allows the depth measurement to remain consistent for all connectors and eliminates the need for Option B1 and B2 (Shorter and Longer Internal Thread Connector). All measurements will now be taken from the outer edge of the connector to the gasket surface.

- Part B & C: The maximum tolerance on the gasket undercut height and gasket thickness has been removed, and it is left to the discretion of the manufacturer to produce a gasket that fits and is positively retained in the undercut. The connector depth measurement is defined from the outer edge of the connector to the gasket surface, thus controlling the thread engagement.

- Part D: The height of the thread (t1) is a reference dimension and is indicated with parenthesis.

Any questions concerning this letter, or the revised drawing should be directed to the NPPTL Policy and Standards Development Branch at 412-386-5200.

Sincerely,

Jonathan V. Szalajda
Branch Chief, Policy and Standards Development
National Personal Protective Technology Laboratory

NOTE: ALL DIMENSIONS IN MILLIMETERS

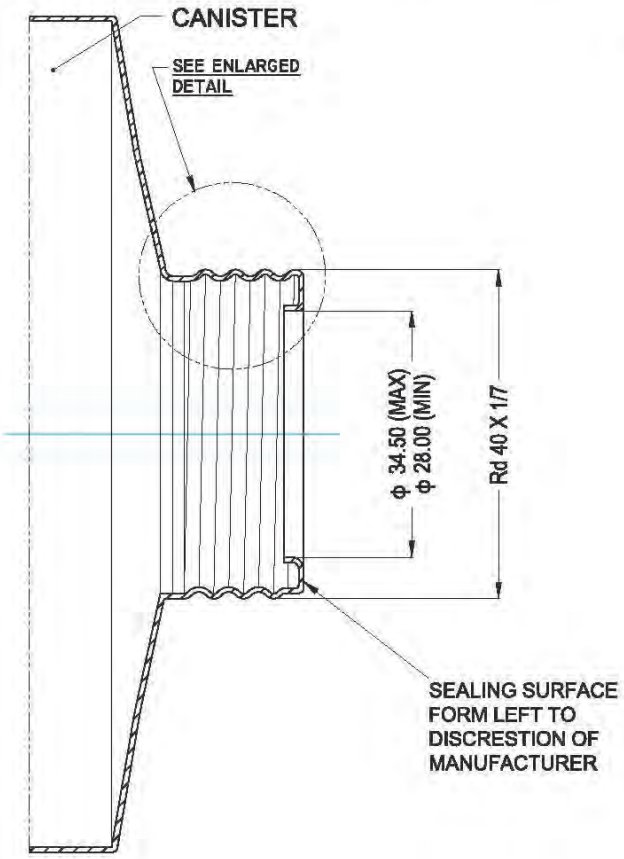
Figure 1

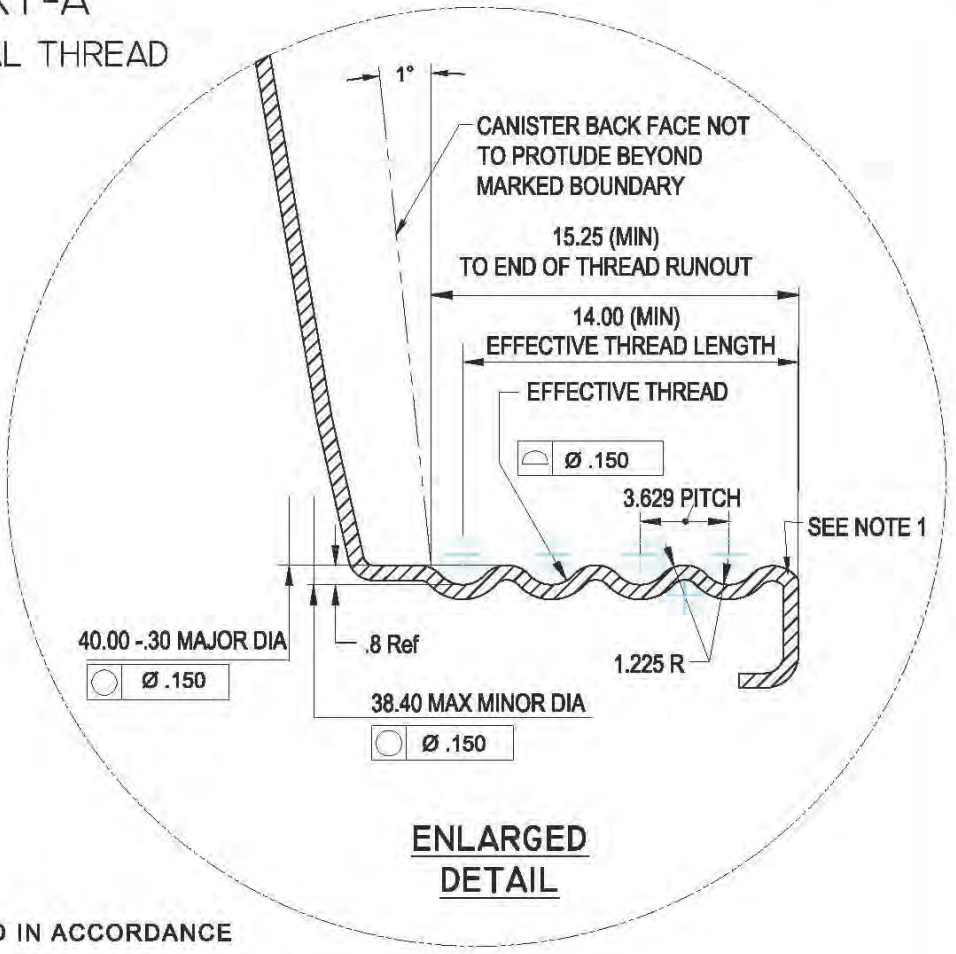
(REVISION 4) 09 JULY 2007

NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket

PART-A

EXTERNAL THREAD





NOTES:

1. FIRST AND SECOND THREAD MUST BE PROPERLY FORMED IN ACCORDANCE WITH THREAD PROFILE AND TOLERANCE.
2. NO CANISTER ADAPTERS PERMITTED (A CANISTER ADAPTER IS DEFINED AS ANY COMPONENT BETWEEN THE INTERNAL THREAD OF THE CONNECTOR AND THE EXTERNAL THREAD OF THE CANISTER).
3. *TO END OF THREAD RUNOUT*-THIS IS THAT PORTION OF THE INCOMPLETE THREAD WHICH IS NOT FULLY FORMED AT THE ROOT OR CREST.
4. *EFFECTIVE THREAD LENGTH*-THIS INCLUDES THE COMPLETE THREAD AND THOSE PORTIONS OF THE INCOMPLETE THREAD WHICH ARE FULLY FORMED AT THE ROOT BUT NOT AT THE CREST; THUS EXCLUDING THE VANISH THREAD.

NOTE: ALL DIMENSIONS IN MILLIMETERS

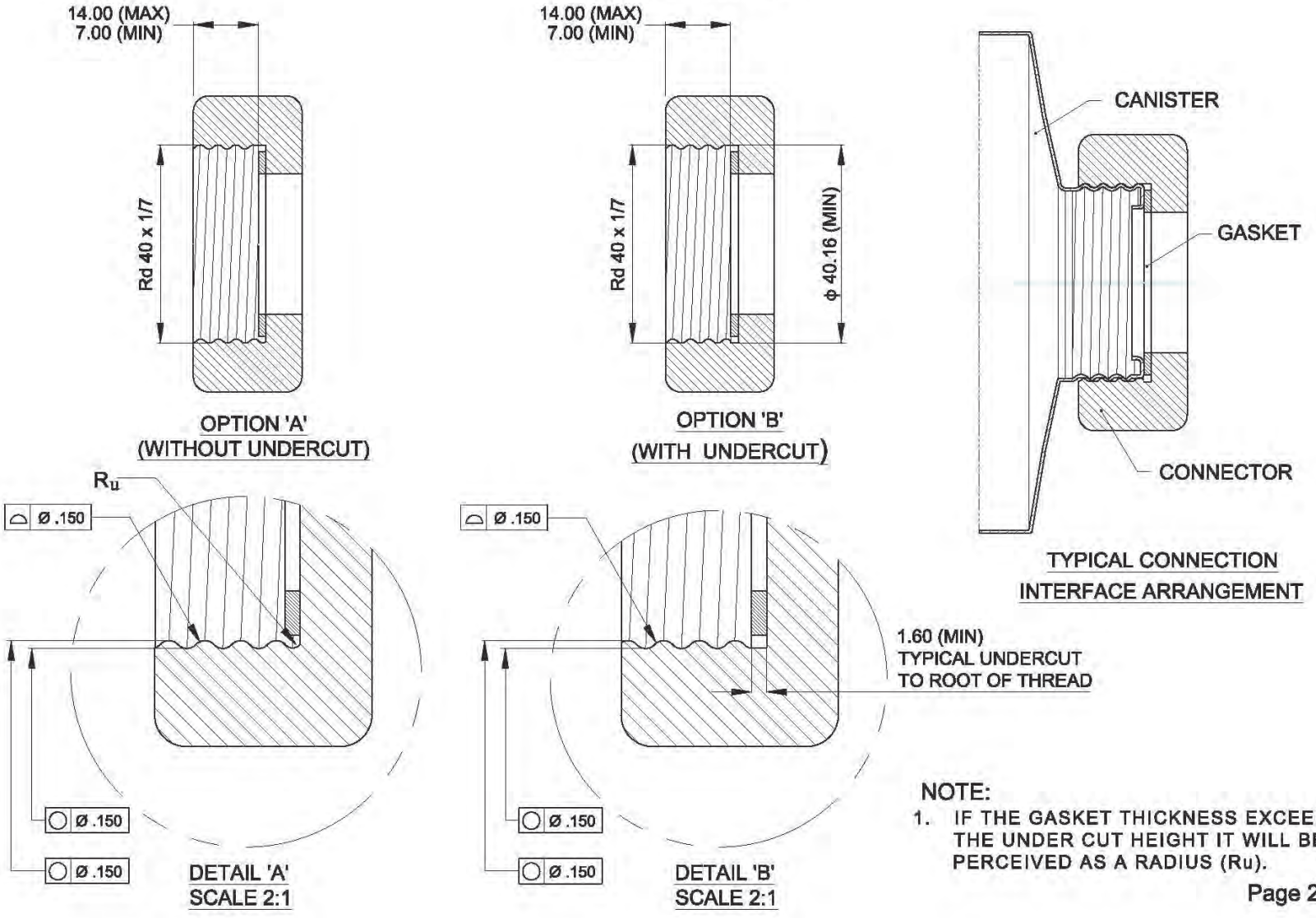
Figure 1

(REVISION 4) 09 JULY 2007

NIOSH CBRN Full Facepiece APR Mechanical Connector and Gasket

PART-B

INTERNAL THREAD



NOTE:

1. IF THE GASKET THICKNESS EXCEEDS THE UNDER CUT HEIGHT IT WILL BE PERCEIVED AS A RADIUS (Ru).

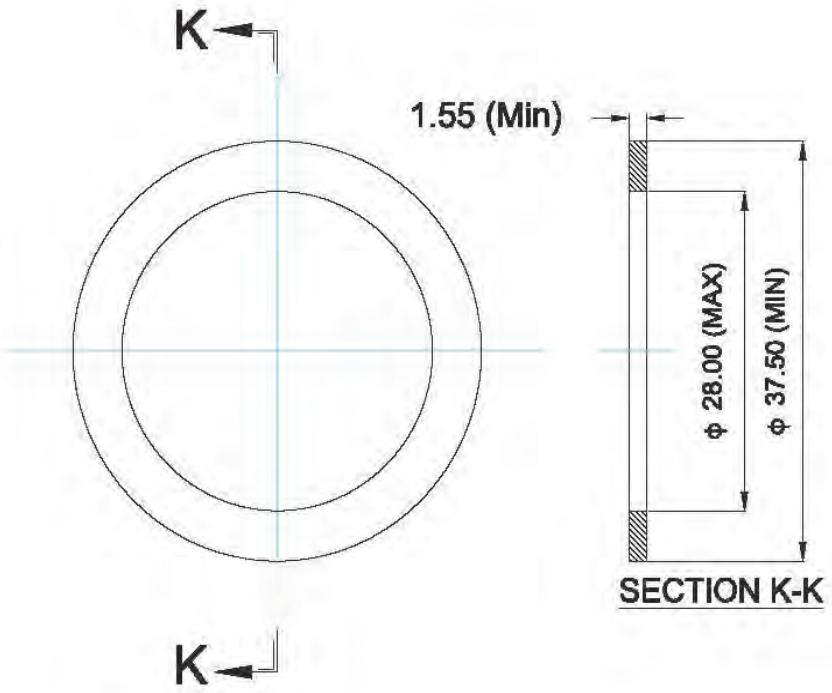
NOTE: ALL DIMENSIONS IN MILLIMETERS

Figure 1

(REVISION 4) 09 JULY 2007

NIOSH CBRN FULL FACEPIECE APR MECHANICAL CONNECTOR AND GASKET

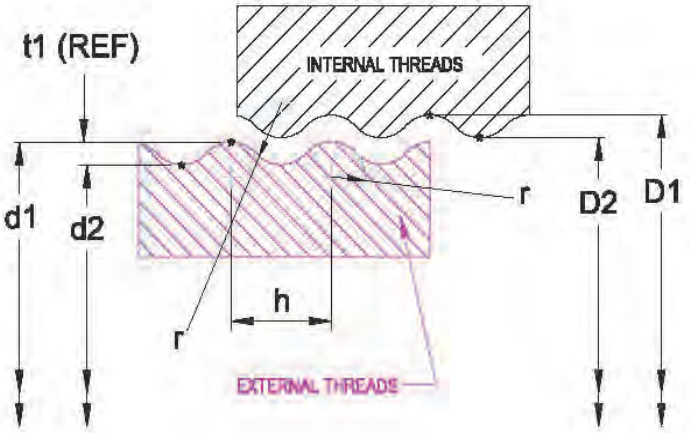
PART- C
GASKET



NOTES:

1. POSITIVE RETENTION AND CENTERING OF GASKET TO CONNECTOR RECEPTACLE REQUIRED.
2. CONNECTOR INTERFACE TO HAVE RIGHT HAND THREAD.

PART- D
THREAD DIMENSIONS



MECHANICAL CONNECTION INTERFACE
THREAD DIMENSIONS

THREAD	THREAD LIMITS						PITCH	THREADS PER 25.4 mm	HEIGHT	RADIUS
	EXTERNAL			INTERNAL						
	MAJOR DIAMETER d1		MINOR DIAMETER d2	MAJOR DIAMETER D1	MINOR DIAMETER D2					
	Max.	Min.	Max.	Min.	Min.	Max.	h		t1	r
Rd 40 x 1/7	40.00	39.70	38.40	40.16	38.56	38.86	3.629	7	(0.8)	1.225

Powered Air-Purifying Respirators (PAPR) with CBRN Protection

Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Powered Air-Purifying Respirators (PAPR)

October 6, 2006

The Chemical, Biological, Radiological, and Nuclear (CBRN) Powered Air-Purifying Respirator (PAPR) must meet the following minimum performance requirements:

(a) PAPR performance criteria from NIOSH 42 CFR Part 84, to include as applicable: Test #

	Title
1	Initial DOP - HE protection (if applicable)
3	Exhalation resistance with blower off (tight fitting)
4	Exhalation valve leakage (if applicable)
5/5A/6	IAA fit test
7	Inhalation resistance with blower off (tight fitting)
12	PAPR Airflow*
25	Silica Dust+
30	Sound Level (if applicable)
33-48 or 62	Gas and Vapor (as applicable)
60	ESLI visibility (if applicable)
61	ESLI damage resistance (if applicable)

***** 115 liters per min (Lpm) for tight-fitting, 170 Lpm for loose-fitting
+ CBRN Canister/Cartridge evaluated in Silica Dust test

(b) Special tests under NIOSH 42 CFR Part 84.63(c)

1) Durability conditioning
2) Chemical agent permeation and penetration resistance against Distilled Sulfur Mustard (HD) and Sarin (GB)
3) Laboratory Respirator Protection Level (LRPL)
4) Canister test challenge and test breakthrough concentrations

1.0 Durability conditioning (CBRN tight-fitting PAPR only) (Reference STP CBRN-0311)

1.1
Respirator containers; minimum requirements

1.1.1
Required packaging configuration (minimum packaging configuration): The CBRN tight-fitting PAPR and the required components will be subjected to the environmental and transportation portions of the durability conditioning in the manufacturer specified minimum packaging configuration. The canisters will also be subjected to an additional rough handling drop test in its designated minimum packaging configuration

1.1.2
The minimum packaging configuration is the protective packaging configuration that the end user* will store or maintain the CBRN tight-fitting PAPR and the required components inside after it has been issued for immediate use. The user instructions (UI) will identify the minimum packaging configuration and will direct the end user how to store or maintain the CBRN tight-fitting PAPR and the required components inside the manufacturer specified minimum packaging configuration while in the possession of the end user. The same minimum packaging configuration identified in the UI will encase the CBRN tight-fitting PAPR and the components when NIOSH performs the durability conditioning. The type of the minimum packaging configuration, if any, is left to the discretion of the manufacturer. Examples of common minimum packaging configurations are mask carriers, clamshell containers, draw string plastic bags, hermetically sealed canister bags, or nothing at all.

If over cases, packaging, or shipping containers are provided by the applicant over and above the minimum packaging configuration, these additional packaging levels may not be a substitute for the minimum packaging configuration and will not be used by NIOSH in the durability conditioning of the application.

* End user: The definition of the end user is the person who will derive protection from the respirator by wearing it. It is assumed that the end user will store the respirator in a location where it will be available for immediate access and use during an emergency.

1.2
Durability conditioning will be performed in accordance with Table 1

Table 1. Durability conditioning

Test	Test Method	Test Condition	Duration
Hot Diurnal	Mil-Std-810F; Method 501.4; Table 501.4-II; Hot-Induced Conditions	Diurnal Cycle, 35° C (95° F) to 71° C (160° F)	3 Weeks
Cold Constant	Mil-Std-801F, Method 502.4	Basic Cold (C1), -32° C -25.6° F); Constant	72 Hours
Humidity	Mil-Std-810E, 507.3; Method 507.3; Table 507.3-II	Natural Cycle, Cycle 1, Diurnal Cycle, 31° C (88°F) RH 88% to 41° C (105° F) RH 59%	5 Days, Quick Look
Vibration	Mil-Std-810F, 514.5	U.S. Highway Vibration, Unrestrained Figure 514.5C-1	12 Hours/Axis, 3 Axis; Total Duration = 36 Hours, equivalent to 12,000 miles
Drop	3-foot drop onto bare concrete surface	Canister only; In individual canister packaging container	1 drop/filter on one of the 3 axes

1.3

Extra batteries (not subjected to the durability conditioning) are required for certification testing

2.0 Chemical Agent Permeation and Penetration Resistance against Distilled Sulfur Mustard (HD) and Sarin (GB) Agent Requirement - (Reference STPs CBRN - 0550 and 0551)

2.1

The PAPR, while the blower is running and including all components and accessories except for the battery (or batteries), will resist the permeation and penetration of distilled sulfur mustard (HD) and Sarin (GB) chemical agents when tested on an upper-torso manikin connected to a breathing machine operating at an airflow rate of 40 L/min, 36 respirations per minute, and 1.1 liters tidal volume. Test requirements for distilled sulfur mustard (HD) are shown in Table 2. Test requirements for Sarin (GB) agent are shown in Table 3. For tight-fitting PAPRS, two systems will be used for preliminary screening. Chemical agent permeation and penetration resistance testing will be performed on four tight-fitting PAPRS (two for HD and two for GB) following the durability conditioning of Paragraph 1.0.

Table 2. Vapor-liquid sequential challenge with distilled sulfur mustard (HD)

Agent	Challenge Concentration	Duration Of Challenge (min)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion (mg/m^3)	Maximum Breakthrough (concentration integrated over minimum test time) ($mg\text{-}min/m^3$)	Number Of Systems Tested	Minimum Test Time (hours)
HD-Vapor	50 mg/m^{3*}	30*	40	0.30‡	3.0§	3	8††
HD-Liquid	0.43 to 0.86 ml*,†,**	120*	40	0.30‡	3.0‡	3	2

* Vapor challenge concentration will start immediately after the test chamber has been sealed. Minimum test time for liquid exposure starts after the first liquid drop is applied.

† Liquid Volume is dependent on accessories used with the respirator. Minimum volume is 0.43 ml based on the respirator only. Liquid challenge required on CBRN tight-fitting PAPRs only.

‡ Three consecutive sequential test data points at or exceeding 0.3 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two (2) minutes.

[§] The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.
[**] Liquid agent is applied to respirator at hour six (6) of the vapor test cycle.
[††] The test period begins upon the initial generation of vapor concentration and ends at eight (8) hours. Supplemental electrical power to the PAPR is permissible to allow the system to run for the purpose of this test.

Table 3. Vapor challenge with Sarin (GB)

Agent	Challenge Concentration	Duration Of Challenge (min)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion (mg/m^3)	Maximum Breakthrough (concentration integrated over minimum test time) ($mg\text{-}min/m^3$)	Number Of Systems Tested	Minimum Test Time (hours)
GB	210[*]	30[*]	40	0.044[‡]	1.05[§]	3	8[††]

[*]The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.
[†] The test period begins upon initial generation of vapor concentration and ends at eight (8) hours. Supplemental electrical power to the PAPR is permissible to allow the system to run for the purpose of this test.
[‡] Three consecutive sequential test data points at or exceeding 0.044 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two (2) minutes.
[§] The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.

3.0 Laboratory Respiratory Protection Level (LRPL) Test Requirement – (all Respirators, Reference STP CBRN 0552)

3.1
The measured laboratory respiratory protection level (LRPL) for each powered, air-purifying respirator will be 10,000 for $\geq$ 95% trials with the blower operating (Blower On mode). The respirator is tested in an atmosphere containing 20–40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4–0.6 µm.

3.2
The measured laboratory respiratory protection level (LRPL) for each tight-fitting powered air-purifying respirator will be 2,000 for $\geq$ 95% trials with the blower not operating (Blower Off mode). A modified LRPL using a sample size of eight subjects will be used for evaluation. The respirator is tested in an atmosphere containing 20–40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4–0.6 µm.

3.3
This test will be performed with the PAPR fully accessorized with any components identified in the assembly matrix and submitted for certification.

4.0 Canister and Cartridge Test Challenge and Test Breakthrough Concentrations– Reference STPs CBRN – 0501, 0502, 0503, 0504, 0505, 0506, 0507, 0508, 0509, 0510

4.1
Canisters (tight-fitting PAPR)

4.1.1
The gas/vapor test challenges and breakthrough concentrations are shown in Table 4. Canister capacity tests will be performed at room temperature, 25 ºC ± 2.5 °C; and at 25% ± 2.5% relative humidity and 80% ± 2.5% relative humidity. Three canisters will be tested at each specified humidity. Canister test time will be identified in 15-minute intervals (15 minutes, 30 minutes, 45 minutes). For a service life of 60 minutes or greater, applications will be identified in 30-minute intervals (60 minutes, 90 minutes, 120 minutes). Canister capacity testing for the system will be tested at a flow rate of 115 Lpm divided by the least number of canisters used on any configuration of the system for which approval is sought. Canister capacity testing will be performed following the durability conditioning.

Table 4. 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.

4.2
Cartridges (loose-fitting PAPR)

4.2.1

The gas/vapor test challenges and breakthrough concentrations are shown in Table 5. Cartridge capacity tests will be performed at room temperature, 25 ºC ± 2.5 °C; and at 25% ± 2.5% relative humidity and 80% ± 2.5% relative humidity. Three cartridges will be tested at each specified humidity. Cartridge test time will be identified in 15-minute intervals (15 minutes, 30 minutes, 45 minutes). For a service life of 60 minutes or greater, applications will be identified in 30-minute intervals (60 minutes, 90 minutes, 120 minutes). Cartridge capacity testing for the system will be tested at a flow rate of 170 Lpm divided by the least number of canisters used on the system for which approval is sought.

Table 5. 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.

4.3

Particulate/aerosol testing

4.3.1

The canister/cartridge will meet the requirements of 99.97% particulate filter efficiency in accordance with the following criteria. Particulate filter efficiency testing will be performed following the durability conditioning.

4.3.2

Twenty (20) canisters/cartridges will be tested for filter efficiency against a dioctyl phthalate or equivalent liquid particulate aerosol.

4.3.2.1

Additionally, six canisters/cartridges from the cyclohexane gas life test of paragraphs 4.1 and 4.2 will be tested for filter efficiency against dioctyl phthalate or equivalent liquid particulate aerosol.

4.3.3

The canister/cartridge including holders and gaskets, when separable, will be tested for filter efficiency level, as mounted on a test fixture in the manner as used on the respirator.

4.3.4

When the canister/cartridge does not have separable holders and gaskets, the exhalation valves will be blocked to ensure that leakage, if present, is not included in the filter efficiency level evaluation.

4.3.5

Cartridge particulate testing for loose-fitting PAPR systems will be tested at a flow rate of 170 Lpm divided by the least number of cartridges used on the system for which approval is sought. Canister particulate testing for the tight-fitting system will be tested at a flow rate of 115 Lpm divided by the least number of canisters used on the system for which approval is sought.

4.3.6

A neat cold-nebulized dioctyl phthalate (DOP) or equivalent aerosol at 25ºC ± 5°C that has been neutralized to the Boltzmann equilibrium state will be used. Each canister/cartridge will be challenged with a concentration not exceeding 200 mg/m^3.

4.3.7

The test will continue until minimum efficiency is achieved or until an aerosol mass of at least 200 mg ± 5 mg challenge point is reached. The test will be continued until there is no further decrease in efficiency

4.3.8

The DOP aerosol will have a particle size distribution with count median diameter of 0.185 µm ± 0.020 µm and a standard geometric deviation not exceeding 1.60 at the specified test conditions as determined with a scanning mobility particle sizer or equivalent.

4.3.9

The efficiency of the canister/cartridge will be monitored throughout the test period by a suitable forward-light-scattering photometer or equivalent instrumentation and recorded.

4.3.10

Current test technology limits flow rate testing to 95 Lpm. When test equipment has been validated to test at higher flows, single filter elements will be able to be evaluated.

5.0 CBRN PAPR Upgrade Retrofit

Once the system(s) has(have) met the requirements for 42 CFR Part 84 and subsequent CBRN PAPR approval, manufacturers may apply for approval of CBRN PAPR retrofit kits to upgrade existing 42 CFR Part 84 PAPR to CBRN PAPR standards. In doing so, the following applies:

5.1
PAPR units must be 42 CFR Part 84 and CBRN PAPR approved prior to applying submitting an application for upgrading to CBRN capability

5.2
Retrofit of previously approved 42 CFR Part 84 and CBRN tight-fitting PAPR must be performed in accordance with manufacturer instructions, to ensure the retrofit complies with the approved CBRN PAPR configuration, quality assurance, and performance requirements

5.3
The CBRN PAPR retrofit kit must, as a minimum, contain the following:

- CBRN PAPR retrofit kit instructions
- Replacement packaging, components, parts, materials, CBRN canisters or cartridges (as applicable), and operation instructions required to retrofit the PAPR to the identical configuration as the approved CBRN configuration level (including minimum packaging configuration)
- CBRN PAPR retrofit approval label(s) for the respirator retrofit kit
- Respirators which are to be retrofitted must be in "fully operational and protective condition"

5.4
Manufacturers will need to submit a Standard Application Form and associated documents which clearly define the respirators eligibility for retrofit and explain the configuration changes achieved with the retrofit kit

5.5
The manufacturer must provide four PAPRs which have been in service for one to five years. As a minimum, submitted respirators are to be from two different conditions of use: Two from a light condition of use category. Light use is defined as a PAPR primarily in a storage configuration; used intermittently throughout the service life. Two from a heavy condition of use category. Heavy use is defined as PAPR used routinely for respiratory protection as part of an OSHA-compliant respirator program.

5.6
The units should be supplied with the retrofit kit installed

5.7
NIOSH testing performed on the respirators will be evaluated to the special tests for chemical agent permeation and penetration resistance against Distilled Mustard (HD) and Sarin (GB) for each respirator use condition provided plus any other tests described above or as deemed necessary by NIOSH

Air-Purifying Escape Respirators (APER) with CBRN Protection

September 30, 2003

Attachment A

Statement of Standard For Chemical, Biological, Radiological, and Nuclear (CBRN) Air-Purifying Escape Respirator

1.0 Purpose:

The purpose of this standard is to specify minimum requirements to determine the effectiveness of air-purifying escape respirators that address CBRN materials identified as inhalation hazards from possible terrorist events for use by the general working population. The air-purifying escape respirator must meet the minimum requirements identified in the following Paragraphs:

x Paragraph 2.0, Requirements Specified in Title 42, Code of Federal Regulations (CFR), Part 84 applicable paragraphs,
x Paragraph 3.0, Requirements based on existing national and international standards,
x Paragraph 4.0, Special requirements for CBRN use.

2.0 Title 42 Code of Federal Regulations (CFR), Part 84:

The following paragraphs of 42 CFR, Part 84 are applicable:

2.1 42 CFR, Part 84, Subparts A, B, D, E, F, and G:

Subpart A: General Provisions
Subpart B: Application for Approval
Subpart D: Approval and Disapproval
Subpart E: Quality Control
Subpart F: Classification of Approved Respirators
Subpart G: General Construction and Performance

3.0 Requirements Based on Existing National and International Standards:

3.1 Breathing Resistance:

The resistance of airflow will be measured at the breathing zone (nose cup or mouthpiece) of an air-purifying escape respirator mounted on a head form test apparatus operated at a continuous airflow rate of 85 Liters per minute (Lpm). The inhalation resistance will not exceed 70 mm H_2O and the exhalation resistance will not exceed 20 mm H_2O.

3.2 Field of View:

The air-purifying escape respirator will obtain a Visual Field Score (VFS) of 70 or greater when tested in accordance with NIOSH Standard Test Procedure CET-APRS- STP-CBRN-0314. The VFS will be obtained by using a medium size respirator or equivalent that is sized to fit the Head Form described in Figure 14 of EN 136, Respiratory protective devices – Full face masks – Requirements, testing, marking; January 1998 or equivalent.

The VFS is determined by using a VFS grid (Dots on visual field) as defined in the American Medical Association Guides to the Evaluation of Permanent Impairment, 5^{th} Edition (2000) that is overlaid on the diagram of the visual field plot obtained using the spherical shell of EN 136 apertometer or equivalent. The VFS score is the average of three fittings of the same respirator on the specified head form.

3.3 Fogging:

The air-purifying escape respirator will demonstrate an average Visual Acuity Score (VAS) of greater or equal to 70 points for all measurements for each individual. A minimum of two respirators shall be evaluated.

The respirator will be donned by the test subject in an indoor ambient temperature of approximately 72 ± 2^0 F at 40 ± 5% Relative Humidity (RH) and then will enter into a simulated outdoor extreme temperature chamber where the visual acuity tests will be administered. The air-purifying escape respirator will be tested for fogging in the hot/humid condition of 90 ± 2^0F and 60 ± 5% RH, and the cold condition of 13 ± 2^0F.

3.4 Breathing Gas:

Breathing gas criteria will be evaluated as a two-part requirement: 1) a dead-space carbon dioxide test performed with a breathing machine and 2) carbon dioxide and oxygen concentrations during human test subject exercises. The wearer will not experience undue discomfort because of restrictions to breathing or other physical or chemical changes to the respirator. All trials will be considered as part of the Practical Performance criteria of paragraph 4.8.

3.4.1 Breathing Machine

The maximum allowable average inhaled carbon dioxide concentration will be less than or equal to one percent, measured at the mouth, while the air-purifying escape respirator is mounted on a dummy head operated by a breathing machine. The breathing rate will be 14.5 respirations per minute with a minute volume of 10.5 Liters. Tests will be conducted at ambient temperature of 25 ± 5°C. A concentration of five percent carbon dioxide in air will be exhaled into the facepiece. The minimum allowable oxygen concentration will be that of the ambient room oxygen concentration. NIOSH Test Procedure RCT-APR-STP-0064 is used for carbon dioxide testing.

3.4.2 Human Subject Testing

During the testing required by this section, the concentration of inspired carbon dioxide gas at the mouth will be continuously recorded, and the calculated maximum range concentration during the inhalation portion of the breathing cycle will not exceed the limits as stated in Table 1.

Table 1. Inspired carbon dioxide limits

Where the service time is	Maximum time-weighted fractional concentration of inspired carbon dioxide
15 min or 30 min	0.025 (or 2.5%)
45 min or 60 min	0.020 (or 2.0%)

The inhaled carbon dioxide concentration will be as indicated in the above table. The inhaled fractional oxygen concentration will be no less than 0.195 (or19.5%) when tested with human subjects at the following work rates: standing and walking at 3.5 miles per hour. Two tests (standing and walking at 3.5 miles per hour) will be performed, each using 12 test subjects. Table 2 gives face length and width criteria, which the subjects will be required to fill. Table 2 is applicable for 'one size fits all air-purifying escape respirator' or an air-purifying escape respirator with small, medium, and large sizes. For other variations in air-purifying escape respirator size, test subjects will be determined to provide for panel range of Table 2.

Table 2. Test design criteria

*LANL Boxes – 'Small'	*LANL Boxes – 'Medium'	*LANL Boxes – 'Large
1, 2, 3, 4	3, 4, 5, 6, 7, 8	7, 8, 9, 10
Four subjects in 'Small' boxes. More than one subject possible in any box.	Four subjects in 'Medium' boxes. More than one subject possible in any box.	Four subjects in 'Large' boxes. More than one subject possible in any box

*Adapted from the Los Alamos National Laboratory report respirator test panel

Each exercise will be performed for 10 minutes. Carbon dioxide and oxygen data will be considered for the last five minutes of each exercise. For each of these last five minutes, the last five breaths will be considered.

For each group of 12 subjects, 95% of the total number of trials must meet the stated criteria. Should a group of test trials not pass the 95% of trials, one addition run of test trials consisting of 12 test subjects may be performed to increase the total number of trials; the total number of trials (total of 48) will be the sum of trials from the first and second run of subjects. All trials will be considered in the Practical Performance requirement criteria of paragraph 4.8.

3.5 Flammability and Heat Resistance (applicable ONLY to respirators approved for carbon monoxide protection):

Air-purifying escape respirators submitted for approval for carbon monoxide protection will be tested for Flammability and Heat Resistance using the test equipment specified in EN 136, Respiratory Protective Devices, Full Face Masks, Requirements, Testing, Marking, 1998 Edition, Class 1 facepiece. No component of the respirator will have an after flame after five seconds. No component of the escape respirator will drip, melt, or develop a visible hole.

The distance between the outer surface of the escape respirator and the burner will be adjusted to 20 ± 2 mm. The pressure reducer will be adjusted to 2.1 ± .05 psi. The temperature of the flame positioned above the burner tip shall be 800 ± 50^0 C at a point 20±2 mm above the tip. The respirator will be rotated once through the flame at a velocity of 6 ± 0.5 cm/s. Where components of the respirator such as valves, filters, etc. are arranged on the respirator, the test will be repeated with these components at the appropriate height of 250 mm ± 6.4 mm.

3.6 Design Considerations:

3.6.1 Function:

The air-purifying escape respirator will provide a barrier from ambient conditions for the wearer's entire head, eyes, and respiratory system. The air-purifying escape respirator will not require the use of hands to maintain the respirator position to ensure proper function of the respirator when fully donned.

3.6.2 Hood Type Device:

The air-purifying escape respirator will be designed as a hooded device. The hood will include an area for field of vision. A hood is a respirator component which covers the wearer's head and neck, or head, neck, and shoulders, and is supplied with incoming respirable air for the wearer to breathe.

3.6.3 Respiratory Protection System:

The respiratory protection system may consist of an oral/nasal cup or mouthpiece. If a mouthpiece is employed, a method of preventing nasal breathing must be provided. An oral/nasal cup or a mouthpiece is not required provided all requirements of this standard are fulfilled by the air-purifying escape respirator.

4.0 Special CBRN Requirements:

4.1 Duration Rating:

Escape respirators will be rated for 15, 30, 45, or 60-minute duration as specified by the manufacturer. Only one duration rating can apply to any respirator.

4.2 Canister Test Challenge and Test Breakthrough Concentrations.

4.2.1 General Category

Escape respirators will meet the gas/vapor test challenge concentrations in Table 3, when tested in accordance with 4.3 Gas Life requirements.

Table 3. Gas/vapor test challenge concentrations

Agent	Test Challenge(ppm)	Breakthrough (ppm)
Ammonia	1250	25
Cyanogen Chloride	150	2
Cyclohexane	1300	10
Formaldehyde	250	10
Hydrogen Cyanide	470	10*
Hydrogen Sulfide	500	30
Nitrogen Dioxide	100	1 ppm NO2
Phosgene	125	1.25
Phosphine	150	0.5
Sulfur Dioxide	750	5

* Sum of HCN and C2N2.

4.2.1.1 General Category Escape Respirator Multi Gas/Vapor/Particulate with Carbon Monoxide Requirements:

Escape respirators intended for use at the General category with carbon monoxide protection will meet the requirements of paragraph 4.2.1 plus carbon monoxide.

For the general category, the test challenge concentration will be 3600 ppm. The maximum allowable carbon monoxide penetration will not exceed the values identified in the Table 4. The penetration of carbon monoxide will not exceed a maximum peak excursion of 500 ppm at any point of the test.

Table 4. Carbon monoxide penetration limits

Identified Service Life (Minutes)	Concentration-time (Ct) (ppm-minutes)
15	6037
30	
12075	
45	
18111	
60	24150

The respirators will be evaluated under the following test conditions:

a) Three respirators tested at 64+10 Lpm continuous airflow at 89 to 95% relative humidity, $25\pm3^{0}C$
b) Three respirators tested at 64+10 Lpm continuous airflow at 89 to 95% relative humidity, $0\pm2.5^{0}C$

4.2.1.1.1 Service Life Testing, High Flow, Carbon Monoxide:

The escape respirator will provide a minimum duration of five minutes when tested at a flow rate of 100+10 Lpm, 89 to 95% relative humidity, 25$\pm$3^{0}C, when tested at a challenge concentration of 3600 ppm. The penetration of carbon monoxide will not exceed a maximum peak excursion of 500 ppm at any point of the test. The maximum allowable carbon monoxide penetration shall not exceed an overall Ct of 2013 ppm- minutes. Three respirators will be tested.

4.2.1.1.2 Inspired Air Temperature, Carbon Monoxide:

Three escape respirators mounted to a head form and connected to a breathing machine, cycling at 40Lpm, 36 respirations per minutes, 1.1 Liters tidal volume, will be tested with a challenge concentration of 1200 ppm (IDLH), at 89 to 95% relative humidity and 25$\pm$2.5^{o}C. The inspired air temperature measured at the facepiece must always be less than or equal to 46°C (dry bulb) with less than or equal to 10 ppm CO for the entire test if the inspired air humidity is less than or equal to 50%. The inspired air temperature must be less than or equal to 41°C (dry bulb) with less than or equal to 10 ppm CO for the entire test if the inspired air relative humidity is greater than 50%. NIOSH test procedure RCT-APR-STP-0034 will be used.

4.2.2 Specific Category:

Escape respirators intended for use at the specific hazard threat category conditions will meet the gas/vapor testing of paragraph 4.2.1. In addition to the test requirements of paragraph 4.2.1, test concentrations for additional specific test agent protections will be as specified in Table 5.

Table 5. Agent challenge concentrations

Agent	Test Challenge (ppm)
Ammonia	2500
Cyanogen Chloride	300
Cyclohexane	2600
Formaldehyde	500
Hydrogen Cyanide	940
Hydrogen Sulfide	1000
Nitrogen Dioxide	200
Phosgene	250
Phosphine	300
Sulfur Dioxide	1500

Additional specific test agent protections can be added to the minimum as specified by the applicant for any combination of the listed test agents. Test breakthrough concentrations for the specific category will be the breakthrough concentrations identified in paragraph 4.2.1.

4.2.2.1 Specific Category Escape Respirator Multi Gas with Carbon Monoxide Requirements:

Escape respirators intended for use at the Specific category with carbon monoxide protection will meet the requirements of paragraph 4.2.2 for the requested test agent protection, plus carbon monoxide.

For the specific category, the carbon monoxide test challenge concentration will be 6000 ppm. The maximum allowable carbon monoxide penetration will not exceed the values identified in paragraph 4.2.1.1 and Table 4.

4.2.2.1.1 Service Life Testing, High Flow, Carbon Monoxide:

The escape respirator will provide a minimum duration of five minutes when tested at a flow rate of 100+10 Lpm, 89 to 95% relative humidity, 25$\pm$3^{0}C, when tested at a challenge concentration of 6000 ppm. The penetration of carbon monoxide will not exceed a maximum peak excursion of 500 ppm at any point of the test. The maximum allowable carbon monoxide penetration will not exceed a Ct of 2013 ppm-minutes. Three respirators will be tested.

4.2.2.1.2 Inspired Air Temperature, Carbon Monoxide:

Three systems mounted to a head form and connected to a breathing machine, cycling at 40 Lpm, 36 respirations per minute, 1.1 Liters tidal volume, will be tested with a challenge concentration of 1200 ppm IDLH (IDLH) at 89 to 95% relative humidity and 25$\pm$2.5^{o}C. The inspired air temperature measured at the facepiece must always be less than or equal to 46°C (dry bulb) and less than or equal to 10 ppm CO for the entire test if the inspired air humidity is less than or equal to 50%. The inspired air temperature must be less than or equal to 41°C (dry bulb) and less than or equal to 10 ppm CO for the entire test if the inspired air relative humidity is greater than 50%. NIOSH test procedure RCT-APR-STP-0034 will be used.

4.3 Gas Life:

Gas life tests are performed at room temperature, 25±5^{0}C; 25±5 percent relative humidity, and 80±5 percent relative humidity. Three filters will be tested at each specified humidity with a flow rate of 64+10 Lpm, continuous flow. Tests will be conducted to minimum specified service time. Gas testing will be performed following environmental conditioning and rough handling. The breakthrough concentration must be no greater than the specified breakthrough for each tested gas in Table 3. Testing is terminated after the applicant's specified service time is achieved.

4.4 Particulate/Aerosol Canister:

The canister will meet the requirements of a P100 particulate filter in accordance with the following criteria of 42 CFR, Part 84.

1) Twenty filters for the air-purifying respirator will be tested for filter efficiency against a dioctyl phthalate or equivalent liquid particulate aerosol.

2) Filters including holders and gaskets; when separable will be tested for filter efficiency level, as mounted on a test fixture in the manner as used on the respirator.

3) When the filters do not have separable holders and gaskets, the exhalation valves will be blocked to ensure that leakage, if present, is not included in the filter efficiency level evaluation.

4) For air-purifying particulate respirators with a single filter, filters will be tested at a continuous airflow rate of 85 $\pm$ 4 liters per minute. Where filters are to be used in pairs, the test-aerosol airflow rate will be 42.5 $\pm$ 2 liters per minute through each filter.

5) A neat cold-nebulized dioctyl phthalate (DOP) or equivalent aerosol at 25 $\pm$ 5^{o}C that has been neutralized to the Boltzmann equilibrium state will be used. Each filter will be challenged with a concentration not exceeding 200 mg/m^{3}.

6) The test will continue until minimum efficiency is achieved or until an aerosol mass of at least 200 $\pm$ 5 mg has contacted the filter. If the filter efficiency is decreasing when the 200 $\pm$ 5 mg challenge point is reached, the test will be continued until there is no further decrease in efficiency.

7) The DOP aerosol will have a particle size distribution with count median diameter of 0.185 $\pm$ 0.020 micrometer and a standard geometric deviation not exceeding 1.60 at the specified test conditions as determined with a scanning mobility particle sizer or equivalent.

8) The efficiency of the filter will be monitored and recorded throughout the test period by a suitable forward-light-scattering photometer or equivalent instrumentation.

9) The minimum efficiency for each of the 20 filters will be determined and recorded and be equal to or greater than the filter efficiency criterion listed for the P100 filter: $\geq$99.97%.

4.5 Service Life Testing, High Flow:

Each escape respirator will provide a minimum duration of five minutes when tested at a flow rate of 100$\pm$10 Lpm, 50$\pm$5 percent relative humidity and 25+5^{0}C for each of the gases/vapors identified in paragraphs 4.2.1 and 4.2.2.

4.6 Chemical Agent Permeation and Penetration Resistance Against Distilled Sulfur Mustard (HD) and Sarin (GB) Agent Requirement:

The air-purifying escape respirator system, including all components and accessories will resist the permeation and penetration of Distilled Sulfur Mustard (HD) and Sarin (GB) chemical agents when tested on an upper-torso manikin connected to a breathing machine operating at an air flow rate of 40 liters per minute (L/min), 36 respirations per minute, 1.1 liters tidal volume.

- Test requirements for Distilled Sulfur Mustard (HD) are shown in Table 6.
- Test requirements for Sarin (GB) agent are shown in Table 7.

Table 6. Vapor-Liquid Sequential Challenge of Air-Purifying Escape Respirator with Distilled Sulfur Mustard (HD)

Agent	Challenge Concentration	Duration of Challenge (min)	Breathing Machine Airflow Rate (Lpm)	Maximum Peak Excursion mg/m	Maximum Breakthrough (concentration integrated over minimum service life)(mg-min/m3)	Number of Systems Tested	Minimum Test Time (hours)
HD Vapor	**50 mg/m³***	**15/30/45/60*,****					
HD Liquid	**0.43 to 0.86 ml†**	**15/30/45/60*,****	40	0.60‡	6.0 §,‡‡	3	30/60/90/120 ††

* Vapor challenge concentration will start immediately after the liquid drops have been applied and the test chamber has been sealed.

†. Minimum volume is 0.43 ml based on the respirator and single canister. Liquid volume is applied as 25 drops of equal size.

‡ Three consecutive sequential test data points at or exceeding 0.6 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.

§ The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.

** Duration of challenge is 15, 30, 45, or 60 minutes, equal to applicant's identified rated duration (para 4.1)

†† Minimum Test Life is 30, 60, 90, or 120 minutes, equal to twice the applicant's rated duration (para 4.1)

‡‡ Respirators will be monitored in the oral/nasal and ocular regions

Table 7. Vapor Challenge of Air-Purifying Escape Respirator with Sarin (GB)

Challenge Concentration	Vapor Concentration (mg/m^3)	Vapor Challenge Time (minutes)	Breathing Machine Airflow Rate (Lpm)	Maximum Peak Excursion mg/m	Maximum Breakthrough (concentration integrated over minimum service life)(mg-min/m3)	Number of Systems Tested	Minimum Test Time (hours)
GB	**210**	**15/30/45/60**	40	0.08‡	0.9 for 15- and 30-minute devices 2.1 for 45 and 3 30/60/90/120 60-minute devices§,‡‡	3	30/60/90/120

* The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.

† The test period begins upon initial generation of vapor concentration.

‡ Three consecutive sequential test data points at or exceeding 0.087 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.

§ The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test. The breakthrough duration is based upon the applicant's identified duration.

** Duration of challenge is 15, 30, 45, or 60 minutes, equal to applicant's identified rated duration (para 4.1).

†† Minimum Test Life is 30, 60, 90, or 120 minutes, equal to twice the applicant's identified rated duration (para 4.1).

‡‡ Respirators will be monitored in the oral/nasal and ocular regions

4.7 Laboratory Respiratory Protection Level (LRPL) Test Requirement:

The measured laboratory respiratory protection level (LRPL) for each air-purifying escape respirator will be 2000 or greater, for 95% of trials, sampled in the breathing zone of the respirator, and will be 150, or greater, for 95% of trials, sampled outside the breathing zone (under the hood). Each trial must meet the breathing zone criteria and 'under the hood' criteria simultaneously for the trial to be considered passing. Test subject and replication numbers are outlined in Table 8.

Table 8. Anthropometric test criteria

	Small	Medium	Large
Face Length and Face Width	Cell A *Use LANL boxes 1, 2, 3, 4 (2 or 3 subjects each box, 2 trials per subject) Subjects= 10 Trials= 20	Cell D *Use LANL boxes 3, 4, 5, 6, 7, 8; panel size 17 (2 or 3 subjects each box, 2 trials per subject) Subjects= 17 Trials= 34	Cell G *Use LANL boxes 7, 8, 9, 10; panel size 11 (2 or 3 subjects each box, 2 trials per subject) Subjects= 11 Trials= 22
Head Circumference	Cell B N/A Subjects= 0 Trials= 0	Cell E N/A Subjects= 0 Trials= 0	Cell H 570-603 mm Subjects= 10 Trials= 20
Neck Circumference	Cell C 306-378 mm Subjects= 10 Trials= 20	Cell F 355-403 mm Subjects= 10 Trials= 20	Cell I 378-451 mm Subjects= 10 Trials= 20

*Adapted from the Los Alamos National Laboratory report respirator test panel

The respirator is tested in an atmosphere containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers. Should a group of test subjects result in LRPL trials where less than 95% of trials have passing results, one additional run of test subjects that fills the entire anthropometric panel requirements may be performed to increase the total number of trials; the total number of trials will be the sum of trials from the first and second run of subjects. All trials will be considered in the Practical Performance criteria of paragraph 4.8. The LRPL will be calculated using nine exercises: Normal Breathing, Deep Breathing, Turn Head Side to Side, Move Head Up and Down, Reach for the Floor and Ceiling, On Hands and Knees - Look Side to Side, Facial Grimace, Climb Stairs at a Regular Pace, and Normal Breathing.

For each size category (Small, Medium, and Large), each cell corresponding to the anthropometric parameter will be tested. Cells can be either consecutively tested (if the test subjects only meet the requirements of a specific cell) or simultaneously tested (if the test subjects meet the requirements of more than one cell) for each size category.

4.8 Practical Performance:

The Practical Performance of the air-purifying escape respirator will be evaluated as part of the test procedures of paragraphs 3.4, Breathing Gas, and 4.7, Laboratory Respirator Protection Level. The Practical Performance of the respirator will evaluate human

interface issues associated with the use of the escape respirator. As a minimum, contributing factors (if applicable based upon the respirator design) are: the use of mouth bits and nose clips; seal of the hood around the respirator wearer's neck; seating of inner masks; position of the hood on the respirator wearer's head; and strength required to don the respirator. Test subjects will be trained on proper use of the escape respirator in accordance with the applicant's instructions identified in paragraph 8.0, Training. Inability of any test subject participating in the test procedures of paragraphs 3.4, Breathing Gas, and 4.8, Laboratory Respirator Protection Level, to complete the test procedures will constitute a failure of the Practical Performance requirement for that trial.

Practical Performance trials will be accumulated from the test procedures of paragraphs 3.4, Breathing Gas, and 4.7, Laboratory Respirator Protection Level. For the total of these accumulated trials, 95% of these trials will exhibit acceptable Practical Performance. Should 95% of the Practical Performance test trials not be acceptable, one additional run of test trials consisting of either, or both, paragraph 3.4, Breathing Gas, or paragraph 4.8, Laboratory Respirator Protection Level, may be performed to increase the total number of trials. The total number of trials will be the sum of trials from the first and second run of subjects.

4.9 Donning:

The time to don the respirator from the ready-to-use configuration will be no greater than 30 seconds. The ready to use configuration is the operational packaging state prior to use such that immediately upon opening allows the user to don the respirator.

4.10 Environmental Conditioning Requirements:

Environmental, vibration, and drop conditioning will be performed on escape respirators in the ready-to-use configuration. The ready-to-use configuration is the operational packaging state prior to use, such that immediately upon opening allows the user to don the respirator. Respirators will be visually inspected following environmental conditioning to ensure no damage or deterioration has occurred that could negatively affect the intended use of the respirator.

Environmental conditioning will be performed in accordance with Table 9.

Table 9. Environmental Conditioning

Test	Test Method	Test Condition	Duration
Hot Constant	Mil-Std-810F, Method 501.4	71°C (160°F), Constant	5 Weeks
Cold Constant	Mil-Std-810F, Method 502.4	Basic Cold, -32° C (-24 ° F); Constant	3 Days
Humidity	Mil-Std-810E, 507.3;	Realistic, Natural Cycle Humidity Profiles in the U.S.	5 Days, "Quick Look" Mil-Std-810E Table 507.3-II
Transportation/Vibration	Mil-Std-810F, 514.5	US Roadway Vibration, Unrestrained	12 Hours/Axis, 3 Axis; Total Duration =36 Hours, equivalent to 12,000 miles
Drop	Standard Drop Test	Height of 3 feet	1 drop on each of the 3 Axes per Unit.

4.11 Test Sequence and Quantity:

Testing of the Escape Respirator shall follow Table 10.

Table 10. Test Sequence and Quantity

Test Order	Resistance and Breathing Gas	Human Factors	Service Life, 100Lpm	Service Life Testing, 64 Lpm flow	Penetration and Permeation Testing	Efficiency Particulate	LRPL Test†
Qty	24*	3-9	30	60	6*	20	30-65
1.	Inhalation Resistance Para 3.1	Donning Para 4.9	Hot Constant Para 4.10	Hot Constant Para 4.10	Hot Constant Para 4.10	Hot Constant Para 4.10	LRPL Para 4.7
2.	Exhalation Resistance Para 3.1 CO2 Machine Testing	Fogging Para 3.3	Cold Constant Para 4.10	Cold Constant Para 4.10	Cold Constant Para 4.10	Cold Constant Para 4.10	Practical Performance
3.	84.63 (a)(b)(c)(d) Para 3.4.1 Breathing	Field of View Para 3.2	Humidity Para 4.10	Humidity Para 4.10	Humidity Para 4.10	Humidity Para 4.10	
4.	Gas (Human Subjects) Para 3.4.2	Flammability and Heat Resistance Para 3.5	Transportation/Vibration Para 4.10	Transportation/Vibration Para 4.10	Transportation/Vibration Para 4.10	Transportation/Vibration Para 4.10	
5.	Practical Performance Para 4.8		Drop Para 4.10	Drop Para 4.10	Drop Para 4.10	Drop Para 4.10	
6.			Service Life 100 Lpm Para 4.3	Service Life 100 Lpm Para 4.3	System testing Para 4.6	Filter Efficiency Para 4.4	

* A total six systems tests are performed, 3 GB and 3 HD. Two systems tests, 1 GB and 1 HD, are performed prior to Para. 4.10 Environmental Conditioning. Four systems tests, 2 GB and 2 HD, are performed after Para. 4.10 Environmental Conditioning.

† All tests in the Resistance and Breathing Gas and LRPL column are performed prior to Paragraph 4.10, Environmental Conditioning.

5.0 Quality Assurance Requirements:

5.1 Quality Control Plan:

Respirators submitted for CBRN approval will be accompanied by a complete quality control plan meeting the requirements of Subpart E of 42 CFR, Part 84.

5.2 Sampling/Test/Inspection Plan:

The applicant will specify a sampling/test/inspection plan for respirator parts and materials to ensure the construction and performance requirements of this standard are established through the manufacturing process. As a minimum, specific attributes to be addressed are:

a) Materials of construction used for respirator parts that form a barrier between the user and ambient air.
b) Integrity of mechanical seals that comprise a barrier between the user and ambient air.
c) Final performance quality control tests on complete air-purifying escape respirators demonstrating compliance with the gas life and particulate filter requirements of this standard.

6.0 General Requirements:

In addition to the requirements of 42 CFR, Subpart G – General Construction and Performance Requirements, the following requirements apply:

Prior to making or filing any application for approval or modification of approval, the applicant will conduct, or cause to be conducted, examinations, inspections, and tests of respirator performance, which are equal to or exceed the severity of those prescribed in the standard. Chemical Agent Penetration and Permeation Resistance against Distilled Sulfur Mustard (HD) and Sarin (GB) tests, Paragraph 4.6, are excluded from this requirement.

7.0 Useful Life and Maintenance:

The applicant will identify an initial useful life, not to exceed five (5) years of the escape respirator. The "useful life" is defined as the length of time a unit can remain deployed in the 'ready to use' stowed condition. All applications for certification must specify useful service life with supporting data and rationale. Further, a rationale must be included for any sampling plan set forth in the user instructions which would extend the useful life of the escape respirator beyond any initial useful life. However, extensions of useful life will be determined during the last year of the initial useful life.

The following guidelines should be included in the useful service life plans:

a. Useful life plans should be based upon reliability engineering methodology and describe the conditions for use for the unit. Each plan will be individually evaluated.

b. All respirator service actions are the responsibility of the applicant, or their authorized representative. The user/owner of the respirators should perform basic inspections as described in the instruction manual and/or as required by federal regulations.

c. In order for an escape respirator to receive an incremental useful life extension, some service action must be performed on each unit.

d. After the service action has been performed, the applicant, or their authorized representative, should collect a random sample of the serviced units and performance test these respirators to verify that they function as approved. The purpose of post-service sampling and performance testing is to identify unexpected problems caused by uncontrolled or unpredicted factors.

e. The applicant may define "performance testing" by specifying the following: test procedures, pass/fail standards, performance tolerances, sample size, etc.

f. An acceptable useful life plan is exemplified in Table 11.

Table 11. Useful life plan timeline

Start	1st Service Date	2nd Service Date	3rd -- etc.	Stop
[--------I----------	---------I----------	---------I----------	---------I----------	-------I >
1st Service expiration date permanently visible on the unit	After a completed action on each unit stamp 2nd service	After a completed action on each unit stamp 3rd service	After a completed action, etc.	Terminal End of useful life
	date or terminal date	date or terminal date		

Note: The date on which the unit must be removed from service is to be permanently marked and clearly visible on the unit at the time of manufacture. If an incremental service life is granted, the applicant, or their authorized representative, must stamp the unit with a new date, as described by the timeline model. The terminal date represents the final expiration date of the unit with no further extensions.

8.0 Training:

The applicant will identify training requirements associated with its air-purifying escape respirator. As a minimum, the applicant will include an instruction manual, which will address donning procedures, respirator use, maintenance (care and useful life), and cautions and limitations. The applicant will also provide for training aid systems, to include a training respirator that mimics the performance of the approved respirator, such as inhalation and exhalation breathing resistance that will develop user proficiency in operation of the equipment, as well as identification of periodic refresher training requirements to maintain user proficiency. The applicants' training materials will be used as the basis for preparing the human test subjects

in the test procedures of paragraph 3.4, Breathing Gas, paragraph 4.7, Laboratory Respirator Protection Level, and paragraph 4.9, Donning.

9.0 Markings and Labels:

In accordance with the requirements of paragraph 84.33 of 42 CFR, Subpart D, approval labels will be marked with a CBRN Rating as determined by paragraph 4.1 Duration Rating, of the Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Air-Purifying Escape Respirator dated September 30, 2003. For example:

(a) Respirators receiving approval 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 protections are marked:

ESCAPE ONLY NIOSH CBRN 30 with Carbon Monoxide

(c) Respirators receiving approval for a 30-minute duration rating with a specific category 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 September 30, 2003

Attachment B

Statement of Standard
Chemical, Biological, Radiological, and Nuclear (CBRN) Self-Contained Escape Respirator

1.0 Purpose:

The purpose of this standard is to specify minimum requirements to determine the effectiveness of self-contained escape respirators that address CBRN materials identified as inhalation hazards from possible terrorist events for use by the general working population. The respirator must meet the minimum requirements identified in the following paragraphs:

X Paragraph 2.0, Requirements Specified in Title 42, Code of Federal Regulations (CFR), Part 84 applicable paragraphs
X Paragraph 3.0, Requirements based on existing national and international standards
X Paragraph 4.0, Special requirements for CBRN use

2.0 Title 42, Code of Federal Regulations (CFR), Part 84:

The following paragraphs of 42 CFR, Part 84 are applicable:

2.1 42 CFR, Part 84, Subparts A, B, D, E, F, and G:

Subpart A: General Provisions
Subpart B: Application for Approval
Subpart D: Approval and Disapproval
Subpart E: Quality Control
Subpart F: Classification of Approved Respirators
Subpart G: General Construction and Performance

2.2 42 CFR, Part 84, Subpart H:

Approval under Title 42, CFR, Part 84, Subpart H, for escape only, with a minimum service time of 15 minutes.

3.0 Requirements Based on Existing National and International Standards:

3.1 Field of View:

The CBRN self-contained escape respirator will obtain a Visual Field Score (VFS) of 70 or greater when tested in accordance with NIOSH Standard Test Procedure CET-APRS-STP-CBRN-0314.

The VFS will be obtained by using a medium size respirator or equivalent that is sized to fit the Head Form described in Figure 14 of EN 136, Respiratory protective devices – Full face masks – Requirements, testing, marking; January 1998 or equivalent.

The VFS is determined by using a VFS grid (Dots on visual field) as defined in the American Medical Association Guides to the Evaluation of Permanent Impairment, 5th Edition (2000) that is overlaid on the diagram of the visual field plot obtained using the spherical shell of EN 136 apertometer or equivalent. The VFS score is the average of three fittings of the same respirator on the specified head form.

3.2 Fogging:

The CBRN self-contained escape respirator will demonstrate an average Visual Acuity Score (VAS) of greater or equal to 70 points for all measurements for each individual. A minimum of two respirators will be evaluated.

The respirator will be donned by the test subject in an indoor ambient temperature of approximately 72 ± 2^0F at 40 ± 5% Relative Humidity (RH) and then will enter a simulated outdoor extreme temperature chamber where the visual acuity tests will be administered. The self-contained escape respirator will be tested for fogging in the hot/humid condition of 90 ± 2^0F and 60 ± 5% RH and the cold condition of 13 ± 2^oF.

3.3 Breathing Gas:

Breathing gas criteria will be evaluated as a two-part requirement: 1) a dead-space CO_2 test performed with a breathing machine and 2) carbon dioxide and oxygen concentrations during human test subject exercises. The wearer will not experience undue discomfort because of restrictions to breathing or other physical or chemical changes to the respirator. All trials will be considered as part of the Practical Performance criteria of paragraph 4.4.

3.3.1 Breathing Machine

The maximum allowable average inhaled carbon dioxide concentration will be less than or equal to one percent, measured at the mouth, while the respirator is mounted on a dummy head operated by a breathing machine. The breathing rate will be 14.5 respirations per minute with a minute volume of 10.5 Liters. Tests will be conducted at ambient temperature of 25 ± 5°C. A concentration of five percent carbon dioxide in air will be exhaled into the facepiece. The minimum allowable oxygen concentration will be that of the ambient room oxygen concentration. NIOSH Test Procedure RCT-APR-STP-0064 is used for carbon dioxide testing

3.3.2 Human Subject Testing

During the testing required by this section, the concentration of inspired carbon dioxide gas at the mouth will be continuously recorded, and the calculated maximum range concentration during the inhalation portion of the breathing cycle will not exceed the limits as stated in Table 1.

Table 1. Inspired carbon dioxide limits

Where the service time is	Maximum time-weighted fractional concentration of inspired carbon dioxide
15 min or 30 min	0.025 (or 2.5%)
45 min or 60 min	0.020 (or 2.0%)

The inhaled carbon dioxide concentration will be as indicated in the above table. The inhaled fractional oxygen concentration will be no less than 0.195 (or19.5%) when tested with human subjects at the following work rates: standing and walking at 3.5 miles per hour. Two tests (standing and walking at 3.5 miles per hour) will be performed, each using 12 test subjects. Table 2 gives face length and width criteria, which the subjects will be required to fill. Table 2 is applicable for 'one size fits all air-purifying escape respirator' or an air-purifying escape respirator with small, medium, and large sizes. For other variations in air-purifying escape respirator size, test subjects will be determined to provide for panel range of Table 2.

Table 2. Test design criteria

*LANL Boxes –'Small'	*LANL Boxes – 'Medium'	*LANL Boxes – 'Large'
1,2,3,4	3,4,5,6,7,8	7,8,9,10
Four subjects in 'Small' boxes. More than one subject possible in any box	Four subjects in 'Medium' boxes. More than one subject possible in any box	Four subjects in 'Large' boxes. More than one subject possible in any box

*Adapted from the Los Alamos National Laboratory report respirator test panel

Each exercise will be performed for 10 minutes. Carbon dioxide and oxygen data will be considered for the last five minutes of each exercise. For each of these last five minutes, the last five breaths will be considered.

For each group of 12 subjects, 95% of the total number of trials must meet the stated criteria. Should a group of test trials not pass the 95% of trials, one addition run of test trials consisting of 12 test subjects may be performed to increase the total number of trials; the total number of trials (total of 48) will be the sum of trials from the first and second run of subjects. All trials will be considered in the Practical Performance requirement criteria of paragraph 4.4.

3.4 Flammability and Heat Resistance:

Self-contained escape respirators submitted for approval will be tested for Flammability and Heat Resistance using the test equipment specified in EN 136, Respiratory Protective Devices, Full Face

Masks, Requirements, testing, Marking, 1998 Edition, Class 1 facepiece. No component of the respirator will have an after flame after five seconds. No component of the escape respirator shall drip, melt, or develop a visible hole.

The distance between the outer surface of the escape respirator and the burner will be adjusted to 20 ± 2 mm. The pressure reducer will be adjusted to 2.1 ± .05 psi. The temperature of the flame positioned above the burner tip will be 800±500 C at a point 20+2 mm above the tip. The respirator will be rotated once through the flame at a velocity of 6 ± 0.5 cm/s. Where components of the respirator such as valves, filters, etc. are arranged on the respirator, the test will be repeated with these components at the appropriate height of 250 mm ± 6.4 mm.

3.5 Design Considerations:

3.5.1 Function:

The self-contained escape respirator will provide a barrier from ambient conditions for the wearer's entire head, eyes, and respiratory system. The self-contained escape respirator will not require the use of hands to maintain the respirator position to ensure proper function of the respirator when fully donned.

3.5.2 Hood Type Devices:

The self-contained escape respirator will be designed as a hooded device. The hood will include an area for field of vision. A hood is a respirator component which covers the wearer's head and neck, or head, neck and shoulders, and is supplied with incoming respirable air for the wearer to breathe.

3.5.3 Respiratory Protection System:

The respiratory protection system may consist of an oral/nasal cup or mouthpiece. If a mouthpiece is employed, a method of preventing nasal breathing must be provided. An oral/nasal cup or a mouthpiece is not required provided all requirements of this standard are fulfilled by the self-contained escape respirator.

4.0 Special CBRN Requirements:

4.1 Duration/Service Life:

The self-contained escape respirator will have a minimum service life of 15 minutes.

4.2 Chemical Agent Permeation and Penetration Resistance Against Distilled Sulfur Mustard (HD) and Sarin (GB) Agent Requirement:

The self-contained escape respirator system, including all components and accessories, will resist the permeation and penetration of Distilled Sulfur Mustard (HD) and Sarin (GB) chemical agents when

tested on an upper-torso manikin. Closed-circuit devices will be connected to a metabolic breathing simulator, using the following protocol:

For a mean VO2 = 1.67 L/min for 30 minutes (aggregate VO2 = 50 L/minTime)

	VO2	VCO2	Minute Ventilation	Resp. Rate
Min	L/min, STPD	L/min, STPD	L/min, STPD	b/min
0-5	3.0	3.2	65	25
6-20	2.0	1.8	44	20
21-30	0.5	0.4	20	12

For open-circuit devices, a breathing machine will be used, operating at an airflow rate of 19.5 Lpm,18 respirations per minute, 1.1 Liters tidal volume.

Test requirements for Distilled Sulfur Mustard (HD) are shown in Table 3.

Table 3. Vapor-Liquid Sequential Challenge of Self-contained Escape Respirator with Distilled Sulfur Mustard (HD)

Agent	Challenge Concentration	Duration of Challenge (min)	Breathing Machine Airflow Rate (Lpm)	Maximum Peak Excursion (mg/m^3)	Maximum Breakthrough (concentration integrated over minimum service life)($mg\text{-}min/m^3$)	Number of Systems Tested	Minimum Service Life (hours)
HD Vapor	300 mg/m	Stated Duration					
HD Liquid	.50 ml	Stated Duration	19.5	0.60	6.0	3	Stated Duration

* Vapor challenge concentration will start immediately after the liquid drops have been applied and the test chamber has been sealed.

†Liquid volume is applied as 25 drops of equal size.

‡ Three consecutive sequential test data points at or exceeding 0.6 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.

§ The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.

** Duration of challenge is equal to applicant's identified duration.

†† Minimum Service Life is equal to twice the applicant's identified duration.

‡‡ Respirators will be monitored in the oral/nasal and ocular regions

Test requirements for Sarin (GB) agent are shown in Table 4.

Table 4. Vapor Challenge of Self-Contained Escape Respirator with Sarin (GB)

Challenge Concentration	Vapor Concentration (mg/m^3)	Vapor Challenge Time (min)	Breathing Machine Airflow Rate (Lpm)	Maximum Peak Excursion mg/m^3	Maximum Breakthrough (concentration integrated over minimum service life)(mg-min/m3) 0.9 for durations less than 30 minutes	Number of Systems Tested	Minimum Service Life (hours)
GB	Total CT of 10,000 $mg\text{-}m^{3\$}$	Stated Duration *,**	19.5	0.087‡	0.9 for durations less than 30 minutes 2.1 for durations greater than 30 minutes§,‡‡	3	Stated Duration †, ††

* The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.

† The test period begins upon initial generation of vapor concentration.

‡ Three consecutive sequential test data points at or exceeding 0.087 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.

§ The cumulative Ct including all maximum peak excursion data points must not be exceeded for the duration of the test.

** Duration of challenge is equal to applicant's identified duration

†† Minimum Service Life is equal to the applicant's identified duration.

‡‡ Respirators will be monitored in the oral/nasal and ocular regions

$ Exposure will include at least two minutes at a concentration of 2000 $mg\text{-}m^3$

4.3 Laboratory Respiratory Protection Level (LRPL) Test Requirement:

The measured laboratory respiratory protection level (LRPL) for each air-purifying escape respirator will be 3000 or greater, for 95% of trials, sampled in the breathing zone of the respirator, and will be 150, or greater, for 95% of trials, sampled outside the breathing zone (under the hood). Each trial must meet the breathing zone criteria and 'under the hood' criteria simultaneously for the trial to be considered passing. Test subject and replication numbers are outlined in Table 5.

Table 5. Anthropometric test criteria

	Small	Medium	Large
Face Length and Face Width	Cell A Use LANL boxes 1, 2, 3, 4 (2 or 3 subjects each box, 2 trials per subject) Subjects= 10 Trials= 20	Cell D Use LANL boxes 3, 4, 5, 6, 7, 8; panel size 17 (2 or 3 subjects each box, 2 trials per subject) Subjects= 17 Trials= 34	Cell G Use LANL boxes 7, 8, 9, 10; panel size 11 (2 or 3 subjects each box, 2 trials per subject) Subjects= 11 Trials= 22
Head Circumference	Cell B N/A Subjects= 0 Trials= 0	Cell E N/A Subjects= 0 Trials= 0	Cell H 570-603 mm Subjects= 10 Trials= 20
Neck Circumference	Cell C 306-378 mm Subjects= 10 Trials= 20	Cell F 355-403 mm Subjects= 10 Trials= 20	Cell I 378-451 mm Subjects= 10 Trials= 20

The respirator is tested in an atmosphere containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers. Should a group of test subjects result in LRPL trials where less than 95% of trials have passing results, one additional run of test subjects that fills the entire anthropometric panel requirements may be performed to increase the total number of trials; the total number of trials will be the sum of trials from the first and second run of subjects. All trials will be considered in the Practical Performance requirement criteria of paragraph 4.4. The LRPL will be calculated using nine exercises: Normal Breathing, Deep Breathing, Turn Head Side to Side, Move Head Up and Down, Reach for the Floor and Ceiling, On Hands and Knees - Look Side to Side, Facial Grimace, Climb Stairs at a Regular Pace, and Normal Breathing.

For each size category (Small, Medium, and Large), each cell corresponding to the anthropometric parameter will be tested. Cells can be either consecutively (if the test subjects only meet the requirements of a specific cell) or concurrently (if the test subjects meet the requirements of more than one cell) tested for each size category.

4.4 Practical Performance:

The Practical Performance of the air-purifying escape respirator will be evaluated as part of the test procedures of paragraphs 3.4, Breathing Gas, and 4.7, Laboratory Respirator Protection

Level. The Practical Performance of the respirator will evaluate human interface issues associated with the use of the escape respirator. As a minimum, contributing factors (if applicable based upon the respirator design) are: the use of mouth bits and nose clips; seal of the hood around the respirator wearer's neck; seating of inner masks; position of the hood on the respirator wearer's head; and strength required to don the respirator. Test subjects will be trained on proper use of the escape respirator in accordance with the applicant's instructions identified in paragraph 8.0, Training. Inability of any test subject participating in the test procedures of paragraphs 3.3, Breathing Gas, and 4.3, Laboratory Respirator Protection Level, to complete the test procedures will constitute a failure of the Practical Performance requirement for that trial.

Practical Performance trials will be accumulated from the test procedures of paragraphs 3.3, Breathing Gas, and 4.3, Laboratory Respirator Protection Level. For the total of these accumulated trials, 95% of these trials will exhibit acceptable Practical Performance. Should 95% of the Practical Performance test trials not be acceptable, one additional run of test trials consisting of either, or both, paragraph 3.3, Breathing Gas, or paragraph 4.3, Laboratory Respirator Protection Level, may be performed to increase the total number of trials. The total number of trials will be the sum of trials from the first and second run of subjects.

4.5 Donning:

The time to don the self-contained escape respirator from the ready-to-use configuration will be no greater than 30 seconds. The ready to use configuration is the operational packaging state prior to use such that immediately upon opening allows the user to don the respirator.

4.6 Environmental Conditioning Requirements:

Environmental, vibration, and drop conditioning will be performed on the self-contained escape respirators in the ready-to-use configuration. The ready-to-use configuration is the operational packaging state prior to use, such that immediately upon opening allows the user to don the respirator. Respirators will be visually inspected following environmental conditioning to ensure no damage or deterioration has occurred that could negatively affect the intended use of the respirator.

Environmental conditioning will be performed in accordance with Table 6.

Table 6. Environmental Conditioning

Test	Test Method	Test Condition	Duration
Hot Constant	Mil-Std-810F, Method 501.4	71°C (160°F), Constant	5 Weeks
Cold Constant	Mil-Std-810F, Method 502.4	Basic Cold, -32° C (-24 ° F); Constant	3 Days
Humidity	Mil-Std-810E, 507.3;	Realistic, Natural Cycle Humidity Profiles in the U.S.	5 Days, "Quick Look" Mil-Std-810E Table 507.3-II
Transportation/Vibration	Mil-Std-810F, 514.5	US Roadway Vibration, Unrestrained	12 Hours/Axis, 3 Axis; Total Duration =36 Hours, equivalent to 12,000 miles
Drop	Standard Drop Test	Height of 3 feet	1 drop on each of the 3 Axes per Unit.

4.7 Test Sequence and Quantity:

Testing of the self-contained escape respirator shall follow Table 7.

Table 7. Test Sequence and Quantity

Test Order	Breathing Gas †	Human Factors	Penetration and Permeation Testing	LRPL Test †
Qty	24.	5-11	6 systems *	30-65
1.	Breathing Gas Para 3.3	Donning Para 4.5	Hot Constant Para 4.6	LRPL Para 4.3
2	Practical Performance Para 4.4	Fogging Para 3.2	Cold Constant Para 4.6	Practical Performance Para 4.4
3		Field of View Para 3.1	Humidity Para 4.6	
4		Flammability and Heat Resistance Para 3.4	Transportation/ Vibration Para 4.6	

5			Drop Para 4.6	
6			System Testing Para 4.2	

* A total six systems tests are performed, 3 GB and 3 HD. Two systems tests, 1 GB and 1 HD, are performed prior to Para. 4.6 Environmental Conditioning. Four systems tests, 2 GB and 2 HD, are performed after Para. 4.6 Environmental Conditioning.

† Breathing Gas and LRPL are performed prior to Paragraph 4.6, Environmental Conditioning.

5.0 Quality Assurance Requirements:

5.1 Quality Control Plan:

Respirators submitted for CBRN approval will be accompanied by a complete quality control plan meeting the requirements of Subpart E of Title 42, CFR, Part 84.

5.2 Sampling/Test/Inspection Plan:

The applicant will specify a sampling/test/inspection plan for respirator parts and materials to ensure the construction and performance requirements of this standard are established through the manufacturing process. As a minimum, specific attributes to be addressed are:

a) Materials of construction used for respirator parts that form a barrier between the user and ambient air.

b) Integrity of mechanical seals that comprise a barrier between the user and ambient air.

6.0 General Requirements:

In addition to the requirements of Title 42, CFR, Subpart G – General Construction and Performance Requirements, the following requirements apply:

Prior to making or filing any application for approval or modification of approval, the applicant will conduct, or cause to be conducted, examinations, inspections, and tests of respirator performance, which are equal to or exceed the severity of those prescribed in the standard. Chemical Agent Penetration and Permeation Resistance Against Distilled Sulfur Mustard (HD) and Sarin (GB) tests, Paragraph 4.2, are excluded from this requirement.

7.0 Useful Life and Maintenance:

The applicant will identify an initial useful life, not to exceed five (5) years, of the escape respirator. The "useful life" is defined as the length of time a unit can remain deployed in the 'ready to use' stowed condition. All applications for certification must specify useful service life with supporting data and rationale. Further, a rationale must be included for any sampling plan set forth in the user instructions which would extend the useful life of the escape respirator beyond any initial useful life. However, extensions of useful life will be determined during the last year of the initial useful life.

The following guidelines should be included in the useful service life plans:

a. Useful life plans should be based upon reliability engineering methodology and describe the conditions for use for the unit. Each plan will be individually evaluated.

b. All respirator service actions are the responsibility of the applicant, or their authorized representative. The user/owner of the respirators should perform basic inspections as described in the instruction manual and/or as required by federal regulations.

c. In order for an escape respirator to receive an incremental useful life extension, some service action must be performed on each unit.

d. After the service action has been performed, the applicant, or their authorized representative, should collect a random sample of the serviced units and performance test these respirators to verify that they function as approved. The purpose of post-service sampling and performance testing is to identify unexpected problems caused by uncontrolled or unpredicted factors.

e. The applicant may define "performance testing" by specifying the following: test procedures, pass/fail standards, performance tolerances, sample size, etc.

f. An acceptable useful life plan is exemplified in Table 8

Table 8. Useful life plan timeline

Start	1st Service Date	2nd Service Date	3rd -- etc.	Stop
[--------I----------	---------I----------	---------I----------	---------I----------	-------I — >
1st Service expiration date permanently visible on the unit	After a completed action on each unit stamp 2nd service date or terminal date	After a completed action on each unit stamp 3rd service date or terminal date	After a completed action, etc.	Terminal End of service life

Note: The date on which the unit must be removed from service is to be permanently marked and clearly visible on the unit at the time of manufacture. If an incremental service life is granted, the applicant, or their authorized representative, must stamp the unit with a new date, as described by the time line model. The terminal date represents the final expiration date of the unit with no further extensions.

8.0 Training:

The applicant will identify training requirements associated with its air-purifying escape respirator. As a minimum, the applicant will include an instruction manual, which will address donning procedures, respirator use, maintenance (care and useful life), and cautions and limitations. The applicant will also provide for training aid systems, include a training respirator that mimics the performance of the approved respirator, such as inhalation and exhalation breathing resistance that will develop user proficiency in operation of the equipment, as well as

identification of periodic refresher training requirements to maintain user proficiency. The applicants' training materials will be used as the basis for preparing the human test subjects in the test procedures of paragraph 3.3, Breathing Gas, paragraph 4.3, Laboratory Respirator Protection Level, and paragraph 4.5, Donning.

9.0 Markings and Labels:

NIOSH will authorize the use of an additional approval label on the self-contained escape respirator that demonstrates compliance to the CBRN criteria. This label is to be placed in a visible location. The addition of this label will provide visible and easy identification of equipment for its appropriate use. In accordance with the requirements of paragraph 84.33 of 42 CFR, Subpart D, approval labels will be marked with a CBRN Rating as determined by paragraph 4.1 Duration/Service Life Rating. For example, respirators tested for 15 minutes are marked ESCAPE ONLY NIOSH CBRN 15.

Self-Contained Breathing Apparatus (SCBA) with CBRN Protection

Attachment A

Statement of Standard

The SCBAs must meet the following minimum requirements:

- Approval under NIOSH 42 CFR Part 84, Subpart H
- Compliance with National Fire Protection Association (NFPA) Standard 1981 for Open-Circuit Self-Contained Breathing Apparatus for Fire Fighters
- Special Tests under NIOSH 42 CFR 84.63(c)
  (1) Chemical Agent Permeation and Penetration Resistance Against Distilled Sulfur Mustard (HD) and Sarin (GB)
  (2) Laboratory Respirator Protection Level (LRPL)

(1). Chemical Agent Permeation and Penetration Resistance Against Distilled Mustard (HD) and Sarin (GB) Agent Test Requirement

Open-circuit, positive-pressure SCBAs, including all components and accessories except the air cylinder (shell), will resist the permeation and penetration of distilled sulfur mustard (HD) and sarin (GB) chemical agents when tested on an upper-torso manikin connected to a breathing machine operating at an airflow rate of 40 liters per minute (L/min), 36 respirations per minute, 1.1 liters tidal volume.

Test requirements for distilled sulfur mustard (HD) are shown in Table 1.

Table 1. Simultaneous Liquid and Vapor Challenge of SCBA with Distilled Sulfur Mustard (HD)

Agent	Challenge Concentration	Duration of Challenge (min)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion (mg/m^3)	Maximum Breakthrough (concentration integrated over Minimum Service Life) ($mg\text{-}min/m^3$)	Number of System s Tested	Minimum Service Life (hours)
HD-Vapor	300 mg/m^3	30 [1]	40	0.60 [3]	6.0 [4]	3	6 [2]
HD-Liquid	0.86 ml	360					

[1] Vapor challenge concentration will start immediately after the liquid drops have been applied and the test chamber has been sealed.
[2] The test period begins upon start of initial vapor generation.
[3] Three consecutive sequential test data points at or exceeding 0.6 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.
[4] The cumulative Ct including all peak data points must not be exceeded for the duration of the six-hour test.

Test requirements for sarin (GB) agent are shown in Table 2.

Table 2. Vapor Challenge of SCBA with Sarin (GB)

Challenge Agent	Vapor Concentration (mg/m^3)	Vapor Challenge Time (minutes)	Breathing Machine Airflow Rate (L/min)	Maximum Peak Excursion mg/m^3	Maximum Breakthrough (concentration integrated over Minimum Service Life)	Number of Systems Tested	Minimum Service Life (hours)
GB	2,000 mg/m^3	30 [1]	40	0.087 [3]	2.1 [4]	3	6 [2]

[1] The vapor challenge concentration generation will be initiated immediately after test chamber has been sealed.
[2] The test period begins upon initial generation of vapor concentration.
[3] Three consecutive sequential test data points at or exceeding 0.087 mg/m^3 will collectively constitute a failure where each test value is based on a detector sample time of approximately two minutes.
[4] The cumulative Ct including all peak data points must not be exceeded for the duration of the six-hour test.

(2). Laboratory Respiratory Protection Level (LRPL) Test Requirement

The measured laboratory respiratory protection level (LRPL) for each open-circuit positive- pressure self-contained breathing apparatus will be $\geq$500, when the SCBA facepiece is tested in a negative pressure mode in an atmosphere containing 20-40 mg/m^3 corn oil aerosol of a mass median aerodynamic diameter of 0.4 to 0.6 micrometers.

Appendix B: OSHA CBRN Fit Testing Interpretation Letter

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

DEC 27, 2011

Reply to the attention of:

James S. Johnson, PhD JSJ and
Associates
7867 Cypress Creek Court
Pleasanton, CA 94588

Dear Dr. Johnson:

Thank you for your July 6, 2011, letter to the Occupational Safety and Health Administration's (OSHA) Directorate of Enforcement Programs. You requested an interpretation of the fit testing requirements in the Respiratory Protection Standard, 29 CFR 1910.134. Your paraphrased question and our response are below. This response constitutes OSHA's interpretation only of the requirements discussed and may not be applicable to other scenarios and questions.

Scenario: There is some confusion about the fit-testing requirements that apply to NIOSH- certified respirators for chemical, biological, radiological, and nuclear (CBRN) protection. Many respirator manufacturers include requirements in their user instructions for users to achieve a fit factor up to 2500 using a quantitative fit test (QNFT), if the respirator is to be used for a CBRN application. The types of CBRN respirators currently available are self-contained breathing apparatus (SCBAs), powered air-purifying respirators (PAPRs), and air-purifying respirators (APRs) with canisters. All respirators that require fit testing are equipped with a full facepiece. The Respiratory Protection Standard 's requirements for fit testing, as summarized in Table 1 of OSHA Directive CPL 02-00-120, Inspection Procedures for the Respiratory Protection Standard, permits either qualitative or quantitative fit testing methods to be used for some full facepiece respirators.

Question: Which protocol does OSHA require for fit testing CBRN respirators?

Response: Workers wearing full facepiece air-purifying respirators must achieve a fit factor of at least 500 when using an OSHA-accepted quantitative fit test protocol. OSHA's Respiratory Protection Standard, 29 CFR 1910.134, does not treat CBRN full facepiece respirators differently from other full facepiece respirators. The standard designates an assigned protection factor (APF) of 50 for full facepiece air-purifying respirators. The standard requires all workers who are required to wear them to be fit tested using an OSHA-accepted QNFT protocol and receive a fit factor of 500 or greater to pass. While a manufacturer's recommendation for a pass level of 2000 or 2500 would provide an added safety factor when fit-testing their respirators, obtaining such a fit factor does not increase the assigned protection factor for that respirator, nor does it allow the use of the respirator in a more toxic atmosphere. When enforcing this standard, OSHA would still require that these tight-fitting full facepiece respirators achieve the minimum pass level of 500 when using QNFT as provided in paragraph 1910.134(f)(7). OSHA also would allow a manufacturer's higher pass level to be used.

For fit testing tight-fitting atmosphere-supplying respirators and tight-filling PAPRs, paragraph (f)(8) allows employers to use either quantitative or qualitative fit testing (QLFT) methods with the respirator in a negative pressure mode. As previously mentioned, if the QNFT protocol is used, OSHA requires the minimum pass level of 500 for QNFTs provided for in paragraph 191 0.134(f)(7) for these tight-fitting full facepiece respirators, but also would allow a manufacturer's higher pass level to be used.

OSHA allows the use of QLFT for testing tight-fitting atmosphere-supplying respirators and tight-fitting PAPRs with the respirator tested in the negative pressure mode. These respirators will be used in a positive pressure or pressure demand mode in the workplace, and QLFT will determine whether the worker can get a reasonably good fit with the facepiece. This testing procedure ensures the mask is capable of maintaining a positive pressure inside the facepiece during work activities and any leakage would be from inside the mask to the outside.

As you are located in California, you should be aware that the California Department of Industrial Relations, Division of Occupational Safety and Health (Cal/OSHA), operates an OSHA-approved State Plan that is responsible for the adoption and enforcement of standards throughout the State. State Plans are required to set workplace safety and health standards that are at least as effective as the comparable Federal standards. Information on the Cal/OSHA program is available at http://vvww.osha.gov dcsp/osp/stateprogs/california.html. Please contact Cal/OSHA directly for further information and to discuss your specific compliance situation:

Ellen Widess, Chief
Division of Occupational Safety and Health
1515 Clay Street Suite 1901
Oakland, CA 94612
PH: (510) 286-7000
FAX: (510) 286-7037

Thank you for your interest in occupational safety and health. We hope you find this information helpful. OSHA requirements are set by statute, standards, and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at www.osha.gov. If you have any further questions, please feel free to contact the Office of Health Enforcement at (202) 693-2190.

Sincerely,

Thomas Galassi

Thomas Galassi, Director
Directorate of Enforcement Programs cc: cc:
Region IX, Cat/OSHA, DCSP

Appendix C: Respiratory Protection Program Samples

Sonoma County
Fire and Emergency Services Department
Sonoma County, CA

PROCEDURE MANUAL
Safety Program
Respiratory Protection Program

Code: 2-8-2

Original Date:2005 Revised Date:2/20/11

2.01 PURPOSE

To establish rules, procedures, and guidelines relative to respiratory protection that reflects the Sonoma County Fire and Emergency Services Department (County Fire) commitment to the safety and well being of our members and compliance with CAL/OSHA Title 8, Section 5144.

2.02 SCOPE

All County Fire paid and volunteer staff

2.03 POLICY

County Fire is committed to maintaining an injury free workplace, and making every effort to protect our members from harmful airborne substances. We accomplish this through engineering controls such as air monitoring and ventilation and through administrative controls limiting the duration of exposure. When these methods are not adequate, we provide respirators to allow members to breathe safely in potentially hazardous environments.

We recognize that respirators have limitations and their successful use is dependant upon an effective respiratory protection program. This Respiratory Protection Program is designed to: identify, evaluate, and control exposure to respiratory hazards; select and provide the appropriate respirators; and coordinate all aspects required for proper use, care, and maintenance of the equipment.

2.04 PROCEDURES

1. **Program Administration:**

County Fire will provide leadership by example and ensure that adequate resources are available for effective implementation of our Respiratory Protection Program. We expect and require all members to work conscientiously to carry out our Respiratory Protection Program, which is an element of our Injury and Illness Prevention Program. The County Fire Safety Officer is the program administrator who has the authority and responsibility for overall management and administration of our Respiratory Protection Program, which consists of the following:

a. Preparing, evaluating, and modifying the written respiratory protection program
b. Identifying, locating, and maintaining ongoing surveillance and evaluation of airborne exposures
c. Selecting respirators
d. Conducting medical screening for potential respirator users e.
Conducting respirator fit testing and assignment
f. Training
g. Record keeping

To assist the program administrator, certain aspects of the program will be delegated to others

within County Fire. All supervisors are responsible for members under their supervision.

2. **Program Implementation and Evaluation**

Our Respiratory Protection Program begins with this written plan describing the procedures that we practice. Suggestions and comments from employees and volunteers about exposure conditions, respirators, personal health changes, and training issues will be addressed promptly.

3. **Workplace Exposure Assessment and Ongoing Surveillance**

Our first task in the workplace is an exposure assessment to identify harmful airborne contaminants and document their extent and magnitude, and how to control them. We must ensure that employee exposure does not exceed the permissible concentrations specified in the *California Code of Regulations* Title 8, Section 5155. This requires the department's Safety Officer to evaluate the policies and procedures and conduct exposure monitoring. We conduct air monitoring at Hazardous Materials incidents and at fires to ensure that contaminants are identified and that concentrations do not exceed the published PELs. Additional evaluations are necessary if exposures change due to new materials, operational changes, or other conditions increasing the degree of exposure or stress.

4. **Respirator Selection**

In those instances where engineering and administrative means do not achieve the desired control, or in the case of an emergency, respirators **MUST** be worn. Different types of respirators are available for a variety of applications and we must ensure that the proper NIOSH/MSHA approved respirator is selected and used for the kind of work being performed and hazards involved.

Given the type of environment, operations, and response our personnel participate in, the following types of respiratory protection are available:

a. Self-contained positive pressure breathing apparatus b.
Air-Purifying Respirators
c. HEPA filter respirator (N95) and (P100)

All unknown products will be considered an IDLH environment requiring Positive Pressure Self- Contained Breathing Apparatus (SCBA).

5. **Evaluating Respirator Wearer Health Status**

Even with the appropriate equipment and adequate training provided, health status must be considered before allowing respirator use. The wearer's physical condition, duration and difficulty of the task, toxicity of the contaminant, and type of respirator all affect the employee's ability to wear a respirator while working. Also, respirators are uncomfortable and may reduce the wearer's field of vision. Therefore, there is a medical evaluation to assess the employee or volunteer's ability to work while wearing a respirator.

Each member will be provided with the physical status questionnaire packet consisting of the following:

a. OSHA Respirator Medical Questionnaire
b. An envelope addressed to the Department's Designated Physician marked *Confidential* and affixed with the appropriate postage
c. A referral for medical evaluation

This packet is to be completed and forwarded to the Occupational Health Physician. Members will not wear respirators of any type during emergency activities until the Department has received the appropriate clearance from the Occupational Health Physician. These forms will be updated annually.

6. **Respirator Fit Testing & Assignment**

Following completion of the mandatory medical questionnaire and selection of the appropriate type of respirator, each member will participate in a qualitative fit test; the purpose of which is to determine the best fitting facepiece, model, and size for the member.

Hazardous Materials Emergency Response Team members will participate in a quantitative fit testing procedure due to the type of response they are assigned to.

Fit testing and respirator selection will be conducted consistent with CAL/OSHA Title 8, Section 5144, Appendix A, and will be conducted upon appointment and annually thereafter.

The form "Respirator Fit Testing and Assignments" (Appendix 2) will be used to document fit test results and respirator assignment. This form will be maintained in the member's personnel and training records.

Members who have facial hair that comes between the sealing surface of the facepiece and the face, or that interferes with the valve function; or any condition that interferes with the face-to-face piece seal or valve function, shall not be fit tested. In addition, it will be the responsibility of the responder and the Chief to ensure that at no time will a member with facial hair be allowed to don a respirator and therefore will be excluded from any response requiring respiratory protection.

Any member that is not fit tested and subsequently medically cleared for respirator use, will not participate in any activity requiring respiratory protection or activities with the potential for requiring respirator use. This shall include any structure fire interior attack, vehicle fire attack, structure fire back up team and/or Rapid Intervention Crew (RIC), hazardous materials response, medical response, etc. Members will be defined as any County Fire paid or volunteer personnel, who may have to don and place in operation any type of respiratory protective devise.

7. **Training**

Once the member is fitted with the correct respirator for the task, the County Fire Training Officer will ensure he/she is thoroughly trained in the need, use, limitations, inspection, fit checks, maintenance, and storage of the equipment. Ordinarily this training is initiated during the fit test and will be completed in accordance with Appendix E of the CAL/OSHA "*Guide to Respiratory Protection."*

The manufacturer provides detailed instructions for the use and care of the respirator with the equipment. This information is to be used in the training. Each employee required to wear a Self-Contained Breathing Apparatus will meet or exceed the training as outlined in the State of California Fire Fighter I program for Self-Contained Breathing Apparatus. At a minimum, annually each employee will demonstrate their competency by manipulative skills and written testing. The manufactures *Training Guidelines for M.S.A. Self-Contained Breathing Apparatus* will be used as reference for all training standards pertinent to SCBA use/maintenance.

8. **Air Manufacturing Program**

County Fire will meet the standards set forth in the OSHA "A Guide to Respiratory Protection at Work," (Air Quality). Also see compressed Air Quality Program below.

9. **Record Keeping**

The County Fire Safety Officer will document each major component of our program to:

a. Verify that each activity has occurred b.

Evaluate the success of the program

c. Satisfy regulatory requirements

These records include the written program, exposure determination, respirator selection, physical status evaluation, a fit testing and respirator assignment, training form, and program assessments.

10. **Compressed Air Quality Program**

County Fire is committed to maintaining its compressed air quality program and meeting all codes and requirements.

a. County Fire cooperates with the Windsor Fire Protection District in the operation of a high-pressure air compressor and maintains a compressor with a cascade system on the Rehabilitation unit to refill compressed air cylinders. Any other compressors used via cooperative agreements with other fire departments must be maintained and operated per OSHA requirements. The member refilling the cylinder is responsible to ensure the compressor is in compliance with subsection d.

b. All members assigned to fill SCBA bottles are trained in the safe and proper operation of the compressor.

c. County Fire has an agreement with TRI Environmental as our maintenance contractor. TRI Environmental will conduct, on a semi-annual basis, all scheduled preventative maintenance. When non-scheduled repairs are needed the County Fire Materials Handler will notify TRI Environmental as soon as possible to conduct the repair.

d. Air compressors will, at a minimum, be tested for air quality on a quarterly basis. The test will be done in accordance with the testing lab's requirements. The air samples weill be sent to TRI Environmental where staff will notify the FESD Safety Officer if test deficiencies are found. The lab will notify the tester on record immediately. If no problems are found with the sample, the lab will mail a certification of the test taken, which will be kept on file at the Windsor Fire Protection District. A copy of the verification will be sent to the County Fire Safety Officer. All air tests, at a minimum, will meet the criteria set forth in CGA G7.1 and NFPA Std, 5-34.1 for grade E air.

e. Scheduled preventative maintenance will be done on a six month cycle and will include at a minimum; filter changes, oil change if needed (100 hrs), and check control system valves. as outlined in the maintenance contract.

f. All maintenance will be logged on the form Semi-Annual Compressed Air Quality Report, (Appendix 9).

2.05 REFERENCES

Cal/OSHA Title 8, Section 5144

County of Sonoma
FIRE & EMERGENCY SERVICES DEPARTMENT

FIRE SERVICES * EMERGENCY MANAGEMENT "' HAZARDOUS MATERIALS

MARK ASTON, DIRECTOR/FIRE CHIEF

March 19, 2012

James S. Johnson, Ph.D., CIH, QEP JSJ and
Associates
7867 Cypress Creek Court
Pleasanton, CA 94588

Dear Jim,

Thank you for requesting permission to use our "Procedure Manual Safety Program, Respiratory Protection Program, Code 2-8-2, Respiratory Protection Program," Original Date:
2005, Revised Date: 2/20/11 in the CDC/NPPTL publication entitled: "CBRN Handbook." With appropriate citation we are happy to extend our permission to use this information.

Please contact us if you have any questions or concerns.

Sincerely,

Mark Aston, County Fire Chief
Department Director

MA/slt

2300 County Center Drive, #221-A, Santa Rosa, CA 95403 * *Phone* (707) 565-1152 * *Fax* (707) 565-1172 * www.sonoma-county.org/des

Fort Collins Police Services
Office of Chief of Police, Directive No. D-6
Fort Collins, CO

FORT COLLINS POLICE SERVICES Office of the
Chief of Police
General Directive

Date Issued: March 24, 2009

Subject: **Respiratory Protection Policy**

I. INTRODUCTION

Because of their unique law enforcement and emergency services roles, many Police Services employees are potentially exposed to respiratory hazards during routine operations. These hazards include lack of oxygen, harmful concentrations of dusts, mists, fumes, smoke, gases, vapors, and, in some cases, represent conditions Immediately Dangerous to Life or Health (IDLH). The primary objectives of this policy are to preserve the respiratory health of employees and to allow employees to safely function in adverse atmospheric environments so that they can provide emergency services to citizens and co-workers. While the frequency of the need to operate in such adverse environments may be low, the need to be able to safely and effectively operate in those environments when they do exist is very high from a health and safety standpoint. Fort Collins Police Services shall provide appropriate respiratory protection to employees when such equipment is necessary to protect the health and safety of the employee and the public.

II. SCOPE

A. This policy:

1. Is consistent with the OSHA Respiratory Protection Standard, 29 CFR 1910.134.

2. Applies to: All Police Officers regardless of rank or assignment, all Community Service Officers, Criminalists, Forensic Lab Manager, and Evidence Technicians. This broad application is necessary because at any time, such employees could be required to respond to and provide emergency or other crucial services in hostile and dangerous

environments, regardless of the employees' current rank or assignment.

B. The provisions of this policy are mandatory. Failure to follow the provisions of this policy may result in the imposition of discipline up to and including termination of employment.

III. MANDATORY ABILITY TO USE RESPIRATORY EQUIPMENT

A. Employees in the following positions, regardless of rank or assignment except as specifically noted, must be qualified in the use of City-designated respiratory equipment for the following levels of protection:

1. Police Officer - Level C
2. SWAT assigned Police Officer other than Negotiator- Level B
3. LCDTF assigned Police Officer - Level B
4. HZMAT assigned Police Officer - Level B
5. Community Service Officer - Level C
6. Forensic Lab Manager - Level C
7. Bomb Squad assigned Police Officer - Level B
8. Weapons of Mass Destruction Resource Group - Level B or Level C as determined by the Program Administrator depending on the duties of the Group member
9. Criminalist, and Evidence Technician - Level C

B. The following terms shall have the following meanings:

1. "Qualified" means to be capable of effectively providing emergency and other crucial services consistent with their positions using designated respiratory equipment for the specified levels of protection in adverse environments for not less than a 30-minute continuous period of time. An employee will be considered qualified if the employee is deemed medically qualified and has achieved an acceptable fit factor for the designated respiratory equipment in the

specified protection Level. Being qualified is considered an essential function of the above positions.

2. Protection "Level A" means a respiratory equipment system with a totally encapsulating protective suit and includes a self-contained breathing apparatus (SCBA).

3. Protection "Level B" means a respiratory equipment system which includes a self-contained breathing apparatus (SCBA) but not a totally encapsulating protective suit.

4. Protection "Level C" means a respiratory equipment system which includes a full face respirator with an air filter cartridge (air-purifying).

C. The designated respiratory equipment issued to an employee may be modified or adjusted within a protection Level if:

1. It is necessary based on the need of the employee; and

2. The cost (both in dollars and administratively) of the alternative equipment is not unduly burdensome to Police Services; and

3. The employee is able to meet the above use standard with the alternative equipment.

D. Depending upon the needs of Police Services and the availability of respiratory equipment, employees may voluntarily become qualified in the use of different types of respiratory equipment.

IV. DETERMINATION OF ABILITY TO USE RESPIRATORY EQUIPMENT

A. Medical Evaluation

1. Using respiratory equipment may place a physiological burden on an employee that varies with the type of respirator worn, the job, workplace conditions, and the medical status
of the employee. A physician or other licensed health care professional (PLHCP) designated by Police Services shall determine whether or not an employee has any medical conditions that would preclude the use of a respirator in the specified protection Level. The PLHCP will consider the guidance presented in the American National Standards

Institute document ANSI Z88.6 in performing medical evaluations.

2. To become qualified in the use of designated respiratory equipment within a protection Level, an employee must complete a medical history questionnaire approved by the Policy Administrator. The Policy Administrator will forward the completed questionnaire to the PLHCP for review.

   a. Employees will be permitted to fill out the questionnaire during work hours.

   b. Employees who have difficulty interpreting the questionnaire may seek clarification from the Policy Administrator or his/her designees.

   c. The Policy Administrator will gather the completed questionnaire and forward it to the PLHCP in such a manner so that the employee's answers are only available to the PLHCP.

3. The PLHCP will review the completed questionnaire to determine whether or not the employee appears to be medically qualified for the use of the designated respiratory equipment within the specified protection Level. The PLHCP may request additional information from the employee in making this determination. For protection Level A or B, the PLHCP will also gather and consider the employee's work history information.

   a. If the PLHCP determines that the employee is medically qualified, the PLHC will notify the employee and the Policy Administrator.

   b. If the PLHCP is unable to determine that the employee is medically qualified, the PLHCP will refer the employee for a follow-up medical exam.

4. The PLHCP conducting the follow-up medical exam will review the medical questionnaire and information provided by the Policy Administrator concerning respiratory equipment availability, workplace needs, and circumstances under which the equipment will be needed. The PLHCP will complete a Respirator Certification form providing a written determination regarding the employee's ability to be qualified in the use of the designated respiratory equipment within the specified protection Level and, if applicable, providing any recommendations regarding optional ways for

the employee to become qualified. The Respirator Certification form will be provided to the employee and the Policy Administrator.

a. The follow-up medical examination may include any medical tests, consultations, or diagnostic procedures that the PLHCP deems necessary to make a final determination.

b. The employee will be given the opportunity to discuss the medical questionnaire and the examination with the PLHCP prior to the issuance of a Respirator Certification form that does not determine that the employee is medically qualified in the use of the designated respiratory equipment within the specified protection Level.

c. The follow-up medical examination shall be conducted by a PLHCP chosen by Police Services and at no cost to the employee. The examination time will be considered compensable time.

d. The results of the medical examination will be kept confidential, except that those management employees who have a need to know the results because of their responsibility to supervise the employee will have access to the results.

B. Fit Testing

1. To become qualified in the use of the designated respiratory equipment within the specified protection Level, an employee must be fit tested before being assigned a respirator and achieve an acceptable fit factor for each respirator that will be worn. Respirators must fit properly to provide adequate protection from hazardous contaminants.

2. Police Services will make a number of models and sizes of the respiratory equipment available within a protection Level in order to provide correct fit and to increase the likelihood of employees being able to meet the above use standard.

3. The results of the fit test will be recorded on the Respirator Fit Test Record form and will be maintained by the Policy Administrator.

C. Remedial Program

1. An employee who is determined to be unqualified for medical reasons or for a failure to achieve an adequate fit will be placed on modified duty.

2. The Policy Administrator and the employee's supervisor will meet with the employee to determine whether or not a remedial program can be implemented that is likely to result in achievement of the qualification status within six months. The goal is to establish a realistic plan that is likely to result in the employee becoming qualified as soon as reasonably possible. The employee may be re-evaluated for qualification at the request of the employee or the Policy Administrator.

3. If it is determined that the employee is not likely to become qualified within six months, has not made a good faith effort to follow a remedial program, or has not become qualified within six months, the employee's employment may be terminated based on the employee's inability to perform an essential function of the job.

4. Under exceptional circumstances, an employee may apply to the Director of Human Resources to extend modified duty for up to a total of twelve months from the date of being determined to be unqualified. The decision whether to grant or deny the request is completely within the discretion of the City.

D. Follow-Up Examination and Testing After Initial Qualification

1. A fit test will be administered not less than annually and will be administered whenever an employee: changes makes, models, or sizes of respirators; perceives that the respirator does not seal properly; or experiences any condition which alters the configuration of the face, e.g., weight change of ten pounds or more, broken nose, loss of teeth, or facial surgery.

2. An employee may also be required to complete a new medical history questionnaire, undergo a new medical examination, and/or undergo a new fit test if:

   a. The employee reports signs and symptoms related to the employee's use of a respirator, such as shortness of breath, dizziness, chest pains, or wheezing; or

   b. The Policy Administrator or the employee's supervisor reasonably suspects that the employee may no longer be qualified. For

example, this could be based on observations of the employee's fit test, respiratory equipment use, or performance; or

c. There is a change in the type, model or size of the respiratory equipment to be used by the employee; or

d. Conditions under which the respiratory equipment may be used change, thereby increasing substantially the physiological burden placed on the employee.

e. The employee has been exposed to hazardous substances at concentrations above the permissible exposure limits without the necessary personal protective equipment being used.

V. RESPONSIBILITIES

A. Policy Administrator: A Police Services lieutenant assigned to the Patrol Division is responsible for the administration of this Respiratory Protection Policy. This Policy Administrator has the following duties:

1. Evaluate potential respiratory hazards and recommend appropriate respiratory protection and other personal protective equipment where necessary.

2. Assist in providing respiratory medical exams, fit tests, and selection of appropriate respiratory equipment.

3. Coordinate with service providers to ensure that employees are properly protected from workplace contaminants, including advising the service providers of other personal protective equipment the employee will be wearing.

4. Provide the PLHCP with the information required for them to conduct respiratory equipment users' medical evaluations.

5. Review this Respiratory Protection Policy not less than annually and recommend revisions to it as necessary to ensure that employees are protected from respiratory hazards and employees are able to safely and effectively provide emergency services in hazardous environments.

6. Provide employee respiratory protection training and administer recordkeeping.

7. Maintain knowledge of current standard of care with regard to respiratory protection and make recommendations for changes in equipment and procedures as needed.

B. Managers and Supervisors: Managers and Supervisors have the following duties:

1. Identify conditions that may require the use of respiratory equipment and consult with the Policy Administrator for assistance in assessing respiratory hazards.

2. Ensure that employees receive respiratory medical exams, fit tests, and appropriate respiratory equipment before their initial use of the respiratory equipment.

3. Coordinate with Policy Administrator in the medical evaluation, fit testing, and selection of respiratory equipment.

4. Ensure that employees are properly trained and comply with all elements of this program, including respiratory equipment inspection and maintenance.

C. Employees: Employees within the scope of this Policy have the following duties:

1. Become qualified to use the specified respiratory equipment and maintain such qualification.

2. Contact their supervisor and the Policy Administrator for assistance in evaluating potential hazards that may require respiratory protection.

3. Use the provided respiratory equipment in accordance with manufacturer's instructions and provisions of this policy.

4. Report any malfunction of equipment, concerns with respirator fit, or other problems to their supervisor and the Policy Administrator.

5. Clean, inspect, and maintain respiratory equipment in a serviceable condition.

6. Notify his/her supervisor and the Program Administrator of changes in their medical status that may impact his/her ability to safely use and be qualified to use the specified respiratory equipment.

7. Complete and file with the Program Administrator and the City's Risk Management Office a hazardous exposure report any time that an employee believes he/she may have been exposed to a hazardous substance.

VI. USE OF RESPIRATORY EQUIPMENT

A. Only respiratory equipment identified for use in an area or for a particular task by the Policy Administrator shall be used. The Policy Administrator shall publish a list of such areas/tasks and the appropriate respiratory equipment.

B. Employees who are required to be qualified to wear a tight fitting respirator must be clean-shaven where the respirator seal touches the face when the respirator is used. Facial hair will also be prohibited when it interferes with the function of the valves or the respirator seal.

C. Employees may use corrective or protective eyewear in a manner that does not interfere with the seal of the faceplate of a respirator. Eyewear with straps or temple bars that pass through the sealing surface of the respirator facepiece shall not be used. The Policy Administrator will coordinate acquiring proper eyewear for the employee at the City's expense.

D. Hats, headphones, jewelry, or other articles that may interfere with a respirator facepiece seal are not permitted.

E. To ensure proper sealing, an employee must perform a fit check each time the employee wears his/her respirator.

VII. TRAINING

A. Prior to use, employees shall be trained in the use and care of respiratory equipment. Employees must also receive annual refresher training.

B. Training shall also be conducted whenever:

1. Changes in the workplace or the type of respiratory equipment require new or additional training;

2. Employees demonstrate that they have not retained the requisite understanding or skill; or

3. Any other situation in which retraining appears necessary to ensure safe respiratory equipment use

C. At a minimum, training shall include:

1. The importance of respiratory protection

2. Factors that impair respiratory equipment effectiveness, such as poor fit, maintenance, and improper use

3. Capabilities and limitations of respiratory equipment

4. Use of respiratory equipment in emergency situations

5. Inspection

6. Procedures for donning, doffing, and using respiratory equipment

7. Procedures for checking the seals of the respiratory equipment

8. Maintenance and storage

9. Recognizing the medical signs and symptoms that may limit or prevent the effective use of respiratory equipment

D. Employees must demonstrate knowledge and skills to satisfy training requirements.

VIII. RECORDKEEPING

A. The Policy Administrator must maintain the following records:

1. Respiratory equipment certification from the PLHCP
2. Selection and fit test records
3. Copy of written respiratory protection policy
4. Employee training
5. Hazardous exposure reports

B. Employees may receive copies of the required records.

Approved: _____ Date: 3.24.09

Dennis V. Harrison
Chief of Police

This program has not been reviewed in detail by the author or NIOSH and represents each organization's current respiratory protection program. NIOSH takes no responsibility for the content of this respiratory protection program.

Fort Collins Police Services
Criminal Investigations Division
2221 S. Timberline Rd.
PO Box 580
Fort Collins, CO 80522-0580
(970) 416-2185

April 19, 2012

James S. Johnson Ph.D., CIH, QEP
JSJ and Associates
7867 Cypress Creek Court
Pleasanton, CA 94588

Re: Policy Release for CBRN Handbook

Dr. Johnson:

Thank your for your request to cite the Fort Collins Police Services Directive No. D-6 Respiratory Protection Policy, dated March 24, 2009 for use in the CDC/NPPTL publication entitled: "CBRN Handbook." I recently revised this policy for a new Policy and Procedure Manual format. However, that version has not yet been adopted and the pertinent information remains the same.

With appropriate citation, Chief John Hutto and Fort Collins Police Services are glad to extend permission to use the information under FCPS GD D-6.

If you have any questions, please feel free to contact me.

Respectfully,

Lieutenant Greg Yeager
Fort Collins Police Services
Criminal Investigations Division
2221 S. Timberline Road
P.O. Box 580
Fort Collins, Colorado 80522-0580
(970) 416-2185

National Institute for Occupational Safety and Health

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