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Respiratory Protection for Emergency Responders

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19.1 History of National Institute for Occupational Safety and Health Respiratory Protection Approval for First Responders

The National Institute for Occupational Safety and Health (NIOSH) is a federally mandated agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH houses the Respirator Approval Program (originating in the U.S. Bureau of Mines). The program's key functions include developing and implementing performance standards for respirators used in an occupational setting in accordance with Title 42 Code of Federal Regulations Part 84 (42 CFR 84) and certifying respirators that meet performance standards (herein referred to as "NIOSH-approved") (Department of Health and Human Services, 1995). This authority is derived from the federal Occupational Safety and Health Act of 1970 and the Mine Safety and Health Act of 1977. The Occupational Safety and Health Administration (OSHA) regulates occupational safety and health in private sector workplaces. Since 1970, OSHA has required that civilian respirators be NIOSH-approved for occupational use (Occupational Safety and Health Administration, 2011).

Emergency responders, consensus standards associations, and the U.S. federal government play critical roles in collaborating to identify next-generation needs. These groups also define personal protective technology and equipment standards that help protect workers against perceived and known threats that include chemical, biological, radiological, and nuclear (CBRN) terrorism agents. An example of this collaborative relationship is the one between NIOSH and the National Fire Protection Association (NFPA). NIOSH and the NFPA forged an alliance 10 years ago to conduct important research on firefighter health and safety. The first NFPA document to address firefighter respiratory protection was NFPA number 19B, *Standard on Respiratory Protective Equipment for Fire Fighters,* 1971. This standard prohibited the use of air-purifying canister filtration media in masks for firefighters and permitted the first time use of self-contained breathing apparatus respirators (SCBAs) (National Fire Protection Agency, 1971). In 1974, NIOSH and the U.S. Bureau of Mines issued the first open circuit, pressure-demand SCBA approval in accordance with the requirements of 30 CFR Part 11. The first open circuit, demand SCBA approval was issued in October 1973. Demand SCBAs allow the air to flow into the facepiece only on "demand" by the wearer (i.e., demand SCBA or negative-pressure SCBA). Pressure-demand SCBAs have a pressure-demand valve that is held slightly open allowing a continual air flow into the facepiece to maintain positive pressure (Bollinger and Schutz, 1987). The NFPA 19B standard was replaced in 1981 by the consensus standard, *Standard on Self-Contained Breathing Apparatus for Fire Fighters.* This standard specifies that NFPA SCBAs be approved by NIOSH and the Mine Safety and Health

Administration (MSHA), have a minimum rated service life of 30 minutes, and requires all fire service open-circuit SCBAs to be positive pressure (National Fire Protection Association, 2007). The NFPA 1981 standard—updated and republished every five years—was the first public standard that advocated the NIOSH-approved CBRN protection requirement for fire service SCBAs. NIOSH continues to issue SCBA approvals for the mining industry (jointly with MSHA) as well as non-mining, non-CBRN, and CBRN SCBA approvals under 42 CFR Part 84 and in accordance with the CBRN SCBA standard.

19.2 Need for CBRN Respiratory Protection

In addition to occupational use, emergency responders are required to use NIOSH-approved respirators for expected hazards (Occupational Safety and Health Administration, 2004, 2009a, b). Prior to 2001, there were no U.S. standards for emergency response personnel using respiratory protective devices (RPDs) for expected CBRN terrorist threats (e.g., chemical, biological). Neither industrial nor military respirators provided protection from all potential CBRN respiratory hazards; therefore, standards were needed to protect responders against CBRN threats. In 1999, NIOSH, the Department of Defense (DOD), and OSHA sponsored a Chemical and Biological Respiratory Protection Workshop to explore potential hazards, respiratory protection needs, RPD standards, and public health and medical community concerns associated with chemical and biological terrorism. This workshop marked the beginning of NIOSH standards development activities to add CBRN protection to several respirator classes. Attendees expressed the need for NIOSH-approved respirators that provide adequate protection against chemicals potentially released in a terrorist attack (National Institute for Occupational Safety and Health, 2000). Attendees revealed both chemical warfare agents (CWAs) and toxic industrial chemicals (TICs) were of concern to first responders. Guidelines and standards were needed to assess chemical and/or biological concentration levels of response scenarios.

In addition, the certification of respirators for use against these threats was noted as a requirement. Respiratory protection standards and certifications for SCBAs, air-purifying respirators (APRs), and powered air-purifying respirators (PAPRs) were listed as immediate responder needs. NIOSH was urged to provide leadership to bring appropriate military, safety, and health experts together to develop the necessary standards and protect the nation's emergency responders. Several federal agencies collaborated to address gaps in knowledge, technology, standards, and training. Agencies involved included the Department of Justice (DOJ), Office of Justice Programs, Office of Domestic Preparedness, Department of Commerce, National Institute of Standards and Technology (NIST), DOD, Department of Labor, OSHA,

International Association of Fire Chiefs, International Association of Fire Fighters, International Safety Equipment Association, Memorial Institute for the Prevention of Terrorism, and NFPA.

Before NIOSH could develop performance standards to protect against CBRN respiratory hazards, various agents that have the potential to be used in acts of terrorism needed to be identified. The toxicity and chemical/physical properties of identified CBRN agents were essential for NIOSH to further identify test challenge agents, their chemical concentrations to challenge the CBRN respiratory equipment, and breakthrough concentrations for development of performance standards. In collaboration with other federal agencies, NIOSH developed national CBRN respirator certification standards to evaluate candidate respirators designed to protect fire service, law enforcement, and other public safety emergency response personnel from the effects of CBRN agents.

19.3 Description of CBRN Respiratory Hazards

19.3.1 CBRN Threat Assessment

The NIOSH, DOD, and NIST evaluation of potential CBRN and TIC hazards, as well as the NIOSH evaluation of the materials constructing the respirator, indicated that the characteristics of the respirator (including facepiece-to-user interfaces) needed to be verified and evaluated for each commercially available respirator that was submitted for NIOSH certification. The interagency members also recognized that the research priority would be the toxic chemical agents because toxic chemical agent gases and vapors were known to have greater permeation and penetration characteristics through facepiece material than radiological or biological particulates. The interagency members concluded the chemical agent challenge concentration and each agent's unique permeation and penetration effects on respirator samples must be determined.

The selection of test agents to challenge CBRN RPDs was based on a comprehensive review of available technical data and through consultations with various government agencies (e.g., DOD, DOJ, Department of Energy, Environmental Protection Agency (EPA), Agency for Toxic Substances and Disease Registry, NFPA 1994 standard, U.S. Army Center for Health Promotion and Preventative Medicine [USACHPPM] Technical Guide 244, and other classified sources). A total of 151 toxic industrial TICs/CWAs were identified as potential candidates for challenge agents. NIOSH and the U.S. Army Soldier and Biological Chemical Command (SBCCOM) evaluated the candidate agents based on various characteristics, including physical properties and interaction with activated carbon (e.g., for permeation [molecularly diffusing through material] and penetration [seeping through interfacing components]).

19.3.2 Chemical Threats

NIOSH held a public meeting in 2001 to discuss the development of CBRN standards (CBRN Standards Public Meeting, 2001). One of the recommendations was to use the CWA challenge chemicals identified in the NFPA 1994 standard as part of the NIOSH standard. NFPA 1994 is a standard to determine the permeation of CBRN agents into chemical personal protective clothing (NFPA, 2012). The NFPA Technical Committee provided recommendations and rationale for the selection of nine chemicals, which included four CWAs. The CWAs identified in NFPA 1994 were HD (or distilled mustard), Lewisite ("L"), Sarin (or GB), and VX as well as permeation resistance to liquid TICs (dimethyl sulfate [DMS]) and gaseous TICs (ammonia, chlorine, hydrogen cyanide, and cyanogen chloride).

19.3.2.1 Chemical Penetration/Permeation Test

NIOSH evaluated the physical characteristics of the CWAs listed in USACHPPM TG 244, the 151 CWAs/TICs identified as part of the NIOSH/SBCCOM review, and the CWAs/TICs listed in NFPA 1994 standard to select representative test agents for chemical penetration/permeation tests. Many of the TICs identified as part of the 151 materials did not have well-defined chemical characteristics or physical properties. When considering the effects of these agents on respirators and the likelihood of use in a terrorist incident, GB and HD best represented the list of potential agents and were selected for the penetration/permeation test due to the chemicals' physical properties and molecular structure. However, it is important to note that this is not a stagnant analysis—as physical data is incorporated into the TICs list, additional chemicals may be identified that could be added to the test procedure. Future developments in the form of new agents, methods of deployment and dissemination, and availability require constant overview to ensure certification testing matches the identified threats. At the time of the standard development, both GB and HD were considered to be reasonable challenge agents given their permeation and penetration characteristics, relative ease to produce, and worldwide availability in thousands of metric tons. The GB and HD CWA challenge concentration requirements were derived by averaging multiple indoor concentration–time profiles from the most likely dispersal scenarios.

NIOSH with consultation with SBCCOM selected GB as the representative for nerve agents because it is the most volatile of the nerve agents, having a volatility of 22,000 mg/m^3 (National Institute for Occupational Safety and Health, 2011a). The low molecular weight and molecular structure of GB enables the permeation through respirator materials more readily than other G-series (e.g., soman) and V-series agents (e.g., VX). A liquid GB test is not performed since GB is so volatile—the liquid would evaporate shortly after the test started. Therefore, GB vapor adsorbed on the surface of the respirator was the only challenge source for permeation.

NIOSH and SBCCOM also selected HD as a test agent because of its permeation characteristics. HD is a linear molecule (as compared with GB which has a branched configuration), and is expected to permeate most materials at a faster rate than GB. Thus, HD was a choice agent to evaluate permeation through the respirator facepiece material. A combination liquid–vapor test was used for the HD tests, where liquid droplets of HD were placed on selected areas of the respirator and a vapor challenge of HD was introduced into the test chamber. Liquid HD tested the permeation, but also indicated if the integrity of the respirator polymeric materials were able to withstand the persistent chemical effects of HD. Adding a vapor challenge to the chamber tested for penetration leaks. Other CWAs and TICs, including VX, Lewisite, hydrogen cyanide, phosgene, chlorine, DMS, and ammonia, were not selected mainly due to their low volatility and large molecular size (which cause low permeation).

19.3.2.2 Air-Purifying Filtration Performance

A list of chemicals, biological agents, and radiological agents identified in the original hazard assessment that should be considered in developing standard requirements were outlined in the presentation, "*CBRN Canister Requirements*" delivered at the 2003 NIOSH public meeting (National Institute for Occupational Safety and Health, 2003). In an effort to reduce the number of certification tests necessary as part of a CBRN APR standard, NIOSH and SBCCOM categorized the potential respiratory hazards into chemical classes and selected test representative agent(s) (TRAs) for each class based on the interaction with the cartridge/canister sorbent. The gas filter component (i.e., sorbent) of canisters and cartridges generally consists of activated carbon where challenge agents are primarily removed through physical adsorption to the carbon. Often, the activated carbon is impregnated with chemicals that assist in removing the challenge agents through chemical reaction. Other materials, such as synthetic polymers and zeolite, have been tested for filtration, but no other sorbent has proven to be as widely applicable as activated carbon.

A NIOSH-approved CBRN APR canister provides protection against a minimum of 139 identified CBRN agents, which are classified into the following seven families: organic vapors (61), acid gases (32), base gases (4), hydrides (4), nitrogen oxides (5), particulates (32) (composed of three chemical, 13 biological, and 16 radiological and nuclear particulate threats), and formaldehyde (1). The TRAs NIOSH uses for certification testing to represent each agent family are listed in Table 19.1.

There is a diverse ability for chemicals within the organic vapor/hydrocarbon class to be adsorbed into activated carbon. Therefore, a method defining the relative adsorption affinity of carbon for particular agents was devised. A number of physical properties were considered, including molecular weight, boiling point, vapor pressure, relative toxicity, and polar/

TABLE 19.1

CBRN APR Canister Terrorist Threat Protections

Acid Gas Family (32 agents)	
5-TRA chemicals are used for NIOSH certification testing to represent the Acid Gas Family	*They are cyanogen chloride, hydrogen cyanide, hydrogen sulfide, phosgene, and sulfur dioxide*
Boron tribromide	Hydrogen chloride
Boron trichloride	Hydrogen cyanide (AC)
Boron trifluoride	Hydrogen fluoride
Bromine	Hydrogen iodide
Bromine chloride	Hydrogen sulfide
Bromine trifluoride	Phosgene (CG)
Carbonyl fluoride	Phosphorus trichloride
Chlorine	Silicon tetrafluoride
Chlorine pentafluoride	Sulfur dioxide
Chlorine trifluoride	Sulfur trioxide
Chlorosulfonic acid	Sulfuric acid
Cyanogen chloride (CK)	Sulfuryl chloride
Dichlorosilane	Titanium tetrachloride
Ethyl phosphonous dichloride	Tungsten hexafluoride
Fluorine	Bromine pentafluoride
Hydrogen bromide	Hydrogen selenide
Nitrogen Oxide Family (5 Agents)	
1 TRA chemical (nitrogen dioxide) is used for NIOSH certification testing to represent the nitrogen oxide family	
Nitric acid	Nitrogen tetraoxide
Nitric acid, fuming	Nitrogen trioxide
Nitrogen dioxide	
Base Gas Family (4 Agents)	
1 TRA chemical (ammonia) is used for NIOSH certification testing to represent the base gas family	
Allyl amine	Dimethyl hydrazine, 1,2
Ammonia	Methyl hydrazine
Hydride Family (4 Agents)	
1 TRA chemical (phosphine) is used for certification testing to represent the hydride family	
Arsine	Phosphine
Germane	Stibine
Formaldehyde Family (1 Agent)	
1 TRA chemical (formaldehyde) is used for certification testing to represent the formaldehyde family	
Formaldehyde	

(*Continued*)

TABLE 19.1 ***(Continued)***

CBRN APR Canister Terrorist Threat Protections

Organic Vapor Family (61 Agents) *1 TRA chemical (cyclohexane) is used for certification testing to represent the organic vapor family*	NOTE: CWAs are in this TRA OV family
Acetone cyanohydrin	Methanesulfonyl chloride
Acrylonitrile	Methyl orthosilicate
Allyl alcohol	Methyl parathion
Allyl chlorocarbonate	Methyl phosphonic dichloride
Bromoacetone	Mustard, lewisite mixture
Bromobenzylcyanide (CA)	Nitrogen mustard HN-1
Chloroacetone	Nitrogen mustard HN-2
Chloroacetonitrile	Nitrogen mustard HN-3
Chloroacetophenone (CN)	N-propyl chloroformate
Chloroacetyl chloride	O-chlorobenzylidene malononitrile (CS)
Chloropicrin (PS)	O-ethyl-s-(2isopropyaminoethyl)methyl phosphonthiolate
Chloropivaloyl chloride	Parathion
Crotonaldehyde	Perchloromethyl mercaptan
Cyclohexyl methyphosphonate	Phenyl mercapatan
Dibenz-(b,f)-1,4-oxazepine (CR)	Phenylcarbylamine chloride
Diketene	Phenyldichloroarsine
Dimethyl sulfate	Phosgene oximedichloroforoxime
Diphenylchloroarsine	Phosphorus oxychloride
Diphenylcyanoarsine	Sarin (GB)
Diphosgene (DP)	Sec-butyl chloroformate
Distilled mustard (HD)	Soman (GD)
Ethyl chloroformate	Tabun (GA)
Ethyl chlorothioformate	Tert-octyl mercapatan
Ethyl phosphonothioicdichloride	Tetraethyl dithiopyrophosphate
Ethyl phosphorodichloridate	Tetraethyl lead
Ethylene dibromide	Tetramethyl lead
Hexachlorocyclopentadiene	Tetranitromethane
Hexaethyl tetraphosphate	Trimethoxysilane
Iso-butyl chloroformate	Trimethylacetyl chloride
Iso-propyl chloroformate	VX
Lewisite (L, L-1, L-2, L-3)	
Particulate Family Canister Protections (32 Agents) *1-TRA chemical (dioctyl phthalate [DOP]) is used for certification testing to represent the particulate family.*	
Particulate—Chemicals (3)	
Sodium azide	
Adamsite	
Sodium fluoroacetate	

(*Continued*)

TABLE 19.1 ***(Continued)***

CBRN APR Canister Terrorist Threat Protections

Particulate—Biological (13)	
Anthrax	Venezuelan equine encephalitis
Glanders	Brucellosis
Tularemia	Pneumonic plague
Smallpox	Query (Q) fever
T-2 Mycotoxins	Viral hemorrhagic fevers
Ricin	Botulism
Staphylococcus enterotoxin B	
Particulate—Radiological/Nuclear (16)	
Carbon 14	Hydrogen 3
Cobalt 60	Phosphorous 32
Strontium 90	Nickel 63
Iodine 131	Technetium 99 m
Promethium 147	Cesium 137
Radium 226	Thallium 204
Uranium 235 and 238	Thorium 232
Americium 241	Plutonium 239

nonpolar characteristics. During the standards development process, the best indicator of the ability to be adsorbed on activated carbon was vapor pressure. Chemicals with a lower vapor pressure have greater affinity for activated carbon. Cyclohexane was chosen to be the representative chemical for organic vapors. Cyclohexane has been accepted as an organic vapor TRA by other standard generating organizations, including the Europeans and the Japanese (Furuse et al., 2001; HSE, 2013). A canister or cartridge that passes the organic vapor test provides protection for all organic vapors having vapor pressures less than that of cyclohexane. Sixty-one organic chemicals from the CWAs/TICs are covered by this.

19.3.3 Biological Threats

NIOSH considered 13 high-threat biological agents when developing the standards which were either identified in the Centers for Disease Control and Prevention (CDC) list of biological threat agents or from the U.S. Army Medical Research Institute of Infectious Diseases (USAMRID) list. The following NIOSH list consisting of bacterial agents, viral agents, and toxins was adapted from those sources and are currently still considered high-threat biological agents: anthrax, brucellosis, glanders, pneumonic plague, tularemia, Q fever, Venezuelan equine encephalitis, viral hemorrhagic fevers, T-2 mycotoxins, botulism, ricin, *Staphylococcus*, enterotoxin B, and smallpox. NIOSH concluded these identified biological agents are either a particulate or vapor

droplet hazard; thus if NIOSH-approved CBRN respirators could provide a minimum level of respiratory protection against a chemical particulate, aerosol, vapor, or gas, the respirators would provide minimal protection against particulate or aerosol biological agents. Figure 19.1 is an illustration of the filter efficiency of high efficiency particulate air (HEPA) and P-100 filters demonstrating various particle sizes and the size range of common biological agents.

19.3.4 Radiological/Nuclear Threats

Another task of the hazard assessment was to determine the most likely radiological particulate agents to be encountered in a domestic radiological particulate or nuclear detonation terrorist act. The 16 radiological/nuclear agents considered when developing the NIOSH CBRN respirator standards were: hydrogen-3, carbon-14, phosphorous-32, cobalt-60, nickel-63, strontium-90, technetium-99m, iodine-131, cesium-137, promethium-147, thallium-204, radium-226, thorium-232, uranium-235 and 238, plutonium-239, and americium-241. Dispersion of radiological agents can produce an internal or external radiological hazard or both at the scene of a terrorist attack. External radiation exposure is defined as the dose equivalent received from radiation sources outside the body. Alpha radiation is not normally regarded as an external radiation hazard because it cannot penetrate the outer layers of the skin. The external radiation hazard may be due to beta, gamma, or neutron sources, all of which can penetrate the sensitive organs of the body. Figure 19.2 illustrates the penetration potential for alpha, beta, gamma, or neutron radiation.

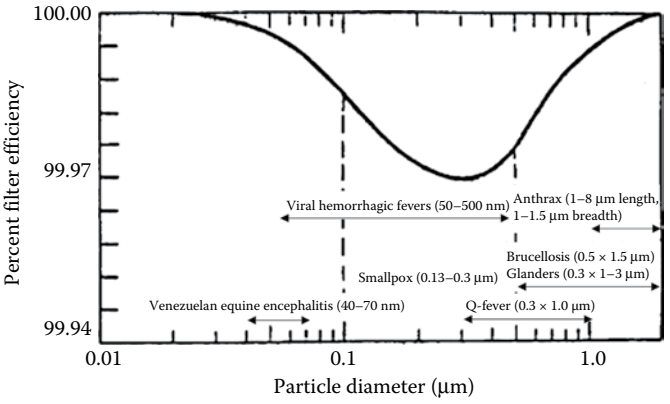

FIGURE 19.1
Illustration of the filter efficiency science of HEPA/P-100 Filters for the various particle diameter sizes with emphasis on the size of the most penetrating particle, and the size range of common biological agents. (Courtesy of HEPA/P-100 Filters for Biologicals; Presentation NBC Hazards-Implications for respiratory protection by Scott Deitchman and Frank Palya; Joint NIST/NIOSH/SBCCOM Stakeholder Meeting, April 17–18, 2001, Richland Ball Room, Edgewood, MD.)

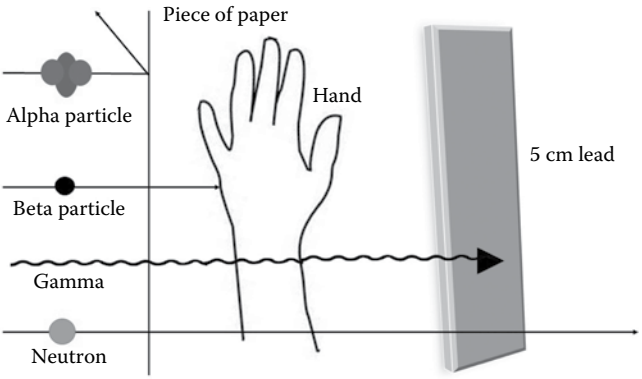

FIGURE 19.2
Illustration of the penetration potential of alpha and beta particles, a gamma ray, and a neutron emitted from an external radiation source. (Courtesy of Radiation Penetration from an External Source; Adapted from Presentation NBC Hazards-Implications for respiratory protection by Scott Deitchman and Frank Palya; Joint NIST/NIOSH/SBCCOM Stakeholder Meeting, April 17–18, 2001, Richland Ball Room, Edgewood, MD.)

Internal radiation exposure is the dose equivalent received from radioactive material taken into the body by ingestion, contamination of wounds, or inhalation (U.S. Nuclear Regulatory Commission, 1995). Full facepiece, tight-fitting respirators cannot provide the wearer protection against external radiation exposure. However, when worn and used correctly, these respirators can provide a minimum level of protection against internal radiation exposure by capturing radioactive particles on a P-100 filter bed and reduce contact with the dermal surfaces of the face by the full facepiece (Department of Energy, 2008). NIOSH used the same approach to protect against radiological particles as it did for biological agents. If a NIOSH-approved CBRN respirator could provide protection against a chemical particulate, aerosol, vapor, or gas, it would provide protection against radiological particulates or nuclear detonation radioactive particulate fallout. NIOSH requires that CBRN nonpowered APRs meet filtration performance requirements of a P-100 filter to provide a minimum known level of protection against particulate material contaminated with radioactive material.

19.3.5 Additional Standards Considerations

19.3.5.1 Tiers of Requirements

Based upon the review of threats and standards, the CBRN interagency group determined that numerous performance requirements addressing breathing flow rates, flame and heat resistance, rough handling, communications, vision, and other human factors including facepiece fit were essential to ensuring that CBRN respirators would safely protect users. In addition to

the tests that evaluate penetration and permeation resistance, and performance in gas and vapor chemical and particulate testing, NIOSH incorporated requirements from national and international consensus standards as part of the CBRN respirator performance requirements (National Personal Protective Technology Laboratory, 2016a).

19.3.5.2 Laboratory Respirator Protection Level

A major concern for development of the NIOSH CBRN respirator standards was the potential exposure of CBRN agents through the respirator–human interface that may be due to an inadequate face seal or a poorly fitted respirator. Also, the respirators needed to be able to fit a wide range of the population. NIOSH addressed the facepiece fit concern by adding a new quantitative fit test method identified as the Laboratory Respiratory Protection Level (LRPL). The LRPL test is required in all NIOSH CBRN respirator standards and assesses how well the respirator facepiece fits to a wearer's face through a series of 11 standard exercises (National Personal Protective Technology Laboratory (NPPTL), 2008). 42 CFR Part 84 and NIOSH CBRN SCBA respirator Statement of Standard requires evaluation of the entire individual respirator assemblies configured in the most accessorized configuration or in a special configuration, as determined by NIOSH (National Institute for Occupational Safety and Health, 2011b), However, it is still necessary for the employer to develop—and the respirator wearer to follow—a written respiratory protection program in accordance with OSHA regulations to ensure a conformity assessment and validation of the intended CBRN respirator design and its capacity to minimize or eliminate the total amount of interface inward leakage.

19.4 Development of the CBRN Respiratory Conformity Assessment Process

19.4.1 CBRN SCBA Respirator Standards

Prior to September 11, 2001 (9/11), NIOSH standards and NFPA consensus standards addressed certain requirements that were unique to residential, industrial, or structural firefighting and rescue operations regarding SCBAs as complete systems. SCBAs were not evaluated under laboratory conditions against any form of TICs, or special CWAs. NIOSH and its federal partners created interagency agreements and looked for scientific and engineering information that could help protect against the penetration and permeation of CWAs that had the potential to contaminate air pressure boundaries and degrade materials of the SCBA. After the 9/11 terrorist attacks,

the occupational safety and health needs of civilian emergency responders became a top priority for NIOSH, OSHA, and the DOD. The NIOSH CBRN SCBA standards development process consisted of nine phases. This process was also adopted as a standards development template for the creation of the subsequent air-purifying and escape respirator standards offering CBRN protection (National Institute for Occupational Safety and Health, 2010a,b). The nine steps of the process from 2001 to 2003 are as follows:

1. Identify threats and conduct hazard analysis
2. Determine needed protections, dosage, and system test values
3. Conduct literature search to include environmental and durability conditioning standards and human factors requirements
4. Benchmark and formulate laboratory test requirements, procedures, and equipment resources for each test plan
5. Write and publish standards concept paper
6. Write, validate, and verify standard test procedure
7. Adopt applicable quality assurance provisions
8. Conduct public meetings for vetting the draft and final standard. Reconcile public comment. Generate administrative application procedures and specific CBRN caution and limitation statements to support certification functions
9. Implement by policy, via published NIOSH Letters to All Manufacturers

The NIOSH standards development and respirator certification programs led to an increase in the national inventory of CBRN protection for emergency response personnel (National Personal Protective Technology Laboratory, 2016b). In 2002, and in conjunction with the NFPA, new approval applications requesting CBRN protection were processed by NIOSH in three tiers: the first tier was 42 CFR 84 evaluation, the second tier was NFPA 1981 evaluation, and the third tier was special NIOSH CBRN live agent testing and corn-oil LRPL fit evaluation. Each evaluated configuration consists of an extensive quantity of part-numbered subcomponent assemblies that are produced by the manufacturer and assembled into a complete respirator. All the required subcomponent parts for a complete respirator are listed on the respirator manufacturer's assembly matrix. Components and materials of a NIOSH-approved CBRN SCBA and other NIOSH-approved SCBAs are different and must not be intermixed. Only components with exact part numbers shown on the full NIOSH CBRN SCBA approval label are considered a subcomponent of a fully assembled CBRN respirator approval (National Institute for Occupational Safety and Health, 2011a,b,c). More information regarding the CBRN SCBA can be found on the NIOSH Fact Sheet (National Institute for Occupational Safety and Health (NIOSH), 2011c).

From 2001 to 2006, emergency responders operated in the field with a mixture of CBRN and industrial approved SCBAs. To address the SCBAs already deployed in the field, NIOSH introduced retrofit kits to upgrade the devices to NIOSH CBRN protections. NIOSH still issues approvals that allow the retrofit of field-deployed NFPA non-CBRN SCBAs to be upgraded to NFPA-compliant NIOSH-approved CBRN SCBA. The 2007 edition of the 1981 standard informs the fire service community that NIOSH CBRN protection offers levels of protection that did not exist prior to the creation of the NIOSH CBRN SCBA standard. NFPA 1981–2007 edition, further clarifies this perspective and reads:

> CBRN certification offers verification of enhanced protection for emergency responders that is not otherwise available. Without (NIOSH) CBRN protection, SCBA subcomponents are not tested for permeation, penetration, corrosion resistance, or other detrimental effects from exposure to toxic industrial chemicals during hazardous materials incidents and hazardous chemical warfare atmospheres. NIOSH benchmark testing of non-CBRN hardened SCBA against CBRN agents demonstrated that chemical warfare agents (CWAs) could cause catastrophic failures within minutes of exposure (National Fire Protection Association, 2007).

19.4.2 APR and Air-Purifying Escape Respirator

In 2003, NIOSH implemented a voluntary program to accept applications to test and evaluate full-facepiece APRs and air-purifying escape respirators (APERs) for use against CBRN agents. These respirators are tested to ensure protection against specified levels of CBRN agents. Care must be taken to identify the components of an APR with CBRN protection because the NIOSH approval label issued with the respirator may contain both CBRN APR gas mask and non-CBRN APR gas mask subcomponents. The respiratory protection program administrator should ensure the CBRN APR is assembled with the correct components for the required protection in accordance with the manufacturer's user instructions and NIOSH CBRN labels. Industrial APR canisters are not tested against CWAs; the components of industrial APR and CBRN APR are not interchangeable. Some NIOSH-approved CBRN APRs require special subcomponents to be in place for the respirator to provide rated NIOSH CBRN protection (National Institute for Occupational Safety and Health, 2013).

NIOSH CBRN APRs have unique performance, use limitations, and storage requirements specific to CBRN APRs and not NIOSH-approved industrial APRs. NIOSH CBRN APRs are not evaluated at the same toxic agent concentration levels as CBRN SCBAs. Therefore, CBRN APRs are not to be used as entry devices into unknown or potential CBRN agent atmospheres. The respirators are intended to be used by emergency responders that are enrolled in a written respiratory protection program that establishes

change-out schedules and performs hazard analysis and concentration characterization steps in the respirator selection process. Because of the single-canister requirement, NIOSH CBRN APRs are frequently not assigned for use in military activities by active or reserve military personnel which may require military-specified gas masks or other unique military designs. NIOSH CBRN APRs can be specified for use by U.S. government civilian military workers in accordance with written installation respiratory protection program requirements and within the scope of the NIOSH approval. Approved CBRN APRs may only be used to escape an immediately dangerous to life or health (IDLH) atmosphere, and are not to be used in oxygen-deficient atmospheres or used to enter any IDLH atmosphere. More information on NIOSH-approved CBRN APR can be found on the NIOSH Fact Sheet (National Institute for Occupational Safety and Health, 2016a).

19.4.3 Powered Air-Purifying Respirators

PAPRs are generally connected to a tight-fitting full facepiece via a breathing hose which is connected to a blower device affixed with canisters and mounted on a waist belt, back pack, or single hose-canister device mounted directly to the facepiece. In 2006, NIOSH issued the CBRN PAPR standard addressing tight-fitting and loose-fitting PAPRs. NIOSH-approved CBRN APRs, APERs, and PAPRs are subjected to environmental and durability conditioning procedures while the test samples are stored in manufacturer-specified minimum packaging configurations (MPCs). MPCs are the protective packaging in which the end user must store or maintain the CBRN air-purifying device and its required components. The manufacturer's user instructions and the full NIOSH approval label will identify the components of the MPCs. More information on NIOSH-approved CBRN PAPRs can be found on the NIOSH Fact Sheet (National Institute for Occupational Safety and Health (NIOSH), 2013).

19.5 User Recognition and the NIOSH Certified Equipment List

Users should first inspect the respirator for labels indicating conformity and ensure the complete respirator is checked per the user instructions. Wearers can locate the NIOSH Testing and Certification (TC) number on the respirator and then contact NIOSH or the approval holder to assist in defining the full or partially identified NIOSH TC number. NIOSH has developed a fact sheet to help users identify important aspects of the approval label (Metzler and Szalajda, 2011).

Manufacturer-generated labels attached directly to the CBRN APR canister are most often adhesive labels. The printed labels appearing on the canister shipping container provide more condensed information. This guidance will help respiratory protection program administrators, managers, and respirator users in understanding the special features of NIOSH-approved CBRN APRs, PAPRs, and APERs. The most notable label required by NIOSH to be on a CBRN SCBA is the black and white label that reads "CBRN Agent Approved" in large font letters. This label can be anywhere on the SCBA backframe but is usually on the area around the first stage regulator/reducer or on respirator backframe and harness assembly. Figure 19.3 is a field photograph of what a first generation CBRN SCBA would carry as the *CBRN Agent Approved* adhesive label. Current generation CBRN SCBAs carry the same label, but without the CDC logo. SCBAs upgraded to CBRN protections will have the same NIOSH logo label and text, but with the word "Retrofit" added under the *CBRN Agent Approved* title.

Since 1994, NIOSH has maintained an online version of all respirator approvals (not just CBRN) (National Institute for Occupational Safety and Health, 2016b). CBRN respirator approval dates and descriptions are documented with the NIOSH Certified Equipment List (CEL). The NIOSH CEL allows a respiratory protection program administrator or respirator user to conduct both quick and advanced database searches. The search results confirm the existence of a NIOSH-approved respirator, validate field information concerning user recognition data of a deployed respirator, or identify what subcomponents (if listed) constitute a completely assembled CBRN respirator, as described in 42 CFR Part 84 and NIOSH CBRN respirator statements of standard.

Certificates of approval listed on the CEL are issued for RPDs that meet the applicable NIOSH requirements. These certificates of approval are not issued

FIGURE 19.3
CDC/NIOSH *CBRN Agent Approved* Label example for SCBAs. Used between May 1, 2002 and December 5, 2005.

for any individual respirator components (e.g., CBRN Cap 1 canister, individual facepiece), but for the entire respirator assembly (National Institute for Occupational Safety and Health, 2011a, b, c). The CEL provides the user with seven sets of information per each listed SCBA respirator approval: the schedule of approval (13F), the approval number (which coupled with the schedule number makes up the NIOSH TC number), the respirator manufacturer/brand name, the model name of the SCBA, the rated time duration of the breathing air cylinder evaluated, the rated pressure value, the actual NIOSH approval issuance date, and the components icon hyperlink which lists the subcomponents that make up the individual respirator assembly per the NIOSH approval. Users are directed to a single fact sheet that details the selected respirator's approval specifics when they click on the approval number icon. CEL software enhancements to the 2016 edition will expand the Quick Search capability to search by TC number or by other single information factors such as brand name, model name, or listed protection (National Personal Protective Technology Laboratory, 2016b). The CEL is regularly updated as respirators are approved, made obsolete, or change status. As of 2016, a "Quick Search" on the CEL resulted in 246 approvals related to NIOSH-approved CBRN respirators (National Personal Protective Technology Laboratory (NPPTL), 2016c).

19.6 CBRN Respiratory Selection Criteria for Emergency Responders

NIOSH assists in identifying existing and evolving industrial hazards by listing the physical science properties in a reference guide, commonly known as the NIOSH "Pocket Guide" (National Institute for Occupational Safety and Health, 2016c). The 2016 release of the mobile application for the NIOSH Pocket Guide provides responders access to 634 chemical entries and links to recommended exposure level (REL) limits and IDLH values—information that aids respirator selection. For a CBRN respirator selection sequence, adapted and condensed from the NIOSH 2004 published selection, the user must answer queries regarding:

1. The intended use of the CBRN respirator (e.g., firefighting)
2. If the CBRN respirator is to be worn in an oxygen-deficient or other IDLH atmospheres
3. Anticipated concentration of single or multiple toxic agents in relation to the NIOSH REL or OSHA permissible exposure limit (PEL) or other recognized exposure limit applicable for that single agent or the most toxic agent of the multiple agents

4. If the CBRN contaminant is an eye irritant or can cause eye damage (which determines the fitting of the respirator)
5. The CBRN agent maximum hazard ratio value
6. Evaluation of assigned protection factor (APF) in relation to the maximum hazard ratio
7. Use in escape environments

Where the NIOSH Pocket Guide recommends the use of a SCBA, any suitable supplied air respirator (SAR) with integrated escape SCBA may be relied upon for protection; both respirators have an OSHA APF of 10,000. While providing this APF, CBRN SCBAs are significantly enhanced and improved from other NIOSH-approved SCBAs due to the live agent testing (LAT) (i.e., live agent chemist permeation/penetration) and LRPL (i.e., corn-oil aerosol particulate tests). In summary, NIOSH-approved CBRN respirators rely on traditional respirator selection factors because the CBRN respirators are essentially enhanced versions of industrial respirators awarded NIOSH approval.

19.7 Emerging Hazards

The United States must remain vigilant for new imminent threats that can appear and make sure the protection provided to responders and medical personnel is effective. Government agencies continue to monitor emerging CBRN threats so the performance of NIOSH-approved CBRN RPDs and other non-CBRN RPDs can be evaluated against newly discovered threats. Some biological threats that have recently emerged or became more prevalent include: Severe acute respiratory syndrome (SARS), Ebola, and the Zika virus. These emerging biological threats (and previously identified biological threats) are either a particulate or vapor droplet hazard. Therefore, NIOSH CBRN air-purifying devices (APRs and PAPRs) and filtering facepiece respirators (FFRs) with N-, R-, and P-series particulate filters are expected to provide protection against new biological threats.

NIOSH is continually working to develop and improve testing methods to enhance the respirator/human interface fit and provide better protection to respirator users from existing and emerging CBRN threats. When emerging threats are identified for which current NIOSH-approved RPDs are not adequate to provide user protection, NIOSH and its partners will develop new performance requirements and test procedures to determine appropriate respirators to use against these threats. NIOSH will publicly disseminate the requirements and procedures so that manufacturers can develop new respirator products to provide protection against emerging threats.

Disclaimer

Mention of commercial product or trade name does not constitute endorsement by the National Institute for Occupational Safety and Health. The findings and conclusions of this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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