CDC 4B051

Bioenvironmental Engineering Journeyman

Volume 5. OER Risk Assessment: Special Programs

Air Force Career Development Academy
Air University
Air Education and Training Command

4B051 05 2007, Edit Code 04
AFSC 4B051

Author: Mr. Mark H. Hanson
United States Air Force School of Aerospace Medicine (USAFSAM)
Bioenvironmental Education and Training Branch
2510 Fifth Street, Building 840
Wright-Patterson Air Force Base, Ohio 45433
DSN: 798-3010
E-mail address: mark.hanson.12@us.af.mil

Instructional Systems Specialist: Linda Matthews

Editor: Maxine Baldwin

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell AFB-Gunter Annex, Alabama

THIS IS Volume 5 of Career Development Course (CDC) 4B051, *Bioenvironmental Engineering Journeyman.* This material details many guiding principles and programs that serve to assist in the management of occupational and environmental health (OEH) workplace and contingency risks.

Unit 1 provides an overview of the potable water program, including storage/distribution, assessments, reporting and inspections of recreational waters.

Unit 2 addresses general principles of ventilation as well as procedures for evaluating the adequacy of ventilation system and their performance.

Unit 3 presents basic concepts of the respiratory protection program. This discussion includes salient information regarding types of respirators, their use, maintenance and selection, instructions for conducting fit-testing/training, and guidelines for workplace evaluation.

Unit 4 addresses a short discourse on the topic of confined space.

Unit 5 follows by expressing fundamental concepts of the hazard communication program.

Unit 6 concludes with material dealing with the Air Force Emergency Management Program and serves as a primer of principles and procedures for responding to contingencies.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

The use of a name of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information provided in this volume.

NOTE: Do not use Air Force Instruction (AFI) 38-402, *Airmen Powered by Innovation and Suggestion Program,* to submit corrections for printing or typographical errors. For Air National Guard (ANG) members, do not use Air National Guard Instruction (ANGI) 38-401, *Suggestion Program.*

If you have questions that your supervisor, training manager, or education/training office cannot answer regarding course enrollment, course material, or administrative issues, please contact Air University Educational Support Services at http://www.aueducationsupport.com. Be sure your request includes your name, the last four digits of your social security number, address, and course/volume number.

For Guard and Reserve personnel, this volume is valued at 36 hours and 9 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Portable Water Program

BIOENVIRONMENTAL ENGINEERING (BE) plays a very important role in maintaining clean and safe drinking and recreational water for the base populace. Untreated or contaminated water can carry disease bearing organisms and other harmful contaminants capable of causing serious illness if ingested. The Air Force (AF) strives to protect the safety of drinking and recreational waters in order to maintain the health of AF members and their families.

1–1. Drinking Water Overview

Water is in constant motion on, above, and below the Earth's surface. The circulation of water and water vapor is powered by energy from the sun and by gravity. This natural process is called the hydrologic cycle. When precipitation infiltrates through the surface and seeps downward through the soil, it becomes groundwater.

801. Groundwater hydrology

As part of the hydrologic cycle, groundwater is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals. Most groundwater begins as precipitation that infiltrates downward from the land surface and settles below the water table. The water table is the boundary between the unsaturated and saturated zones. The layer of earth above the water table is called the *unsaturated zone*. Water and air are present in varying amounts that change over time. Therefore, saturation does not occur. Below the unsaturated zone is the *saturated zone.* In this zone, all of the pores, cracks, and spaces between rock particles are saturated with water. The water table is not flat; it often follows the topography of the land. Springs, lakes, swamps, or rivers are formed when the water table meets the ground's surface. Figure 1–1 is a graphic representation of the unsaturated and saturated zones.

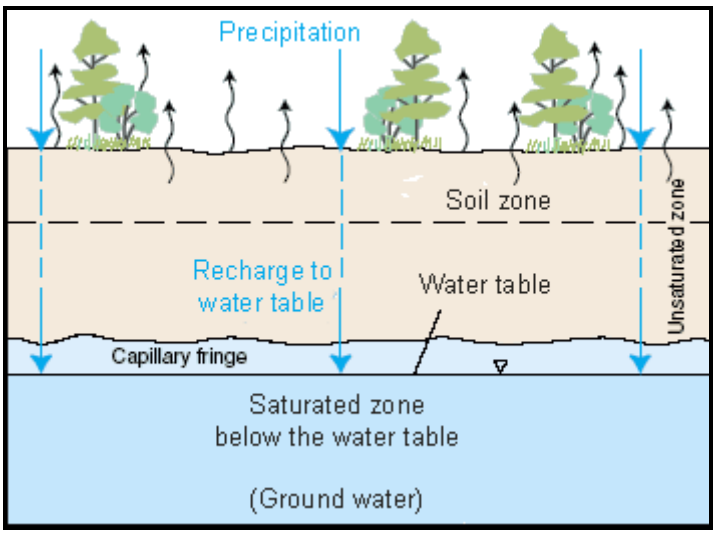

Figure 1–1. The water table is the boundary between the *unsaturated* and *saturated zones*.

The saturated zone beneath the water table is called an *aquifer*. Groundwater movement through the subsurface is dependent on the *permeability* (ease of water movement) and *porosity* (the amount of open space in the material) of the subsurface rock [1]. If the rock has characteristics that allow water to move relatively freely, groundwater can move significant distances in a short period of time. For example, sand and gravel layers provide good aquifers because of their permeability. In contrast, aquifers comprised mostly of clay or crystalline rocks are poor aquifers. Aquifers can be categorized as confined and unconfined (fig. 1–2).

- *Unconfined aquifers*: In unconfined aquifers, water has saturated the subsurface material below the water table. If a well is drilled into an unconfined aquifer, a pump may be required to push the water to the surface.
- *Confined aquifers*: Confined aquifers have layers of rock above and below them that are not very permeable to water. Natural pressure (artesian pressure) in the aquifer can exist and can sometimes be enough to push water in a well above the land surface. Confined aquifers in which the water is under pressure are called *artesian aquifers*.

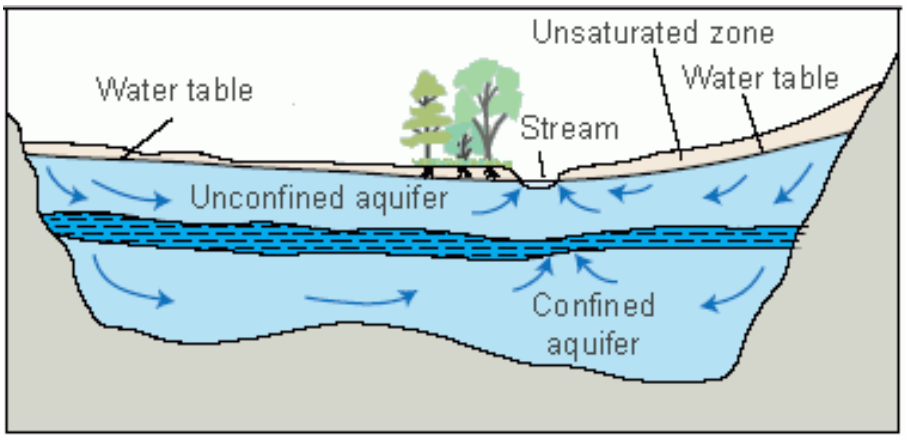

Figure 1–2. Confined versus unconfined aquifers.

Unconfined aquifers only have one layer of impermeable material beneath the saturated zone, which causes them to be more vulnerable to contamination from activities on the surface. A confined aquifer exists between confining layers of impermeable materials composed of rock, sediment, or soil that has a distinctly lower permeability than that of the aquifer. These confining layers interfere with

vertical groundwater movement between aquifers. The confining material stores groundwater but does not allow it to readily flow into or out of the aquifer. For water or contaminants to infiltrate this type of aquifer, they must enter through a *recharge zone*. A recharge zone is an area where water flows into an aquifer. It is called a recharge zone because the aquifer is being "recharged" with more water. It is important to note that these confining layers not only serve to impede the movement of water into and out of confined aquifers, they also serve as a barrier to the flow of contamination from overlying unconfined aquifers. It is important to properly characterize, assess, and monitor groundwater quality and movement in order to accurately predict the direction of groundwater flow and how and assess/refine sampling and monitoring plans.

The most common source of groundwater contamination on AF bases is from routine industrial operations. Examples include:

- Jet engine repair: degreasing operations (chlorinated solvents).
- Corrosion control: paint stripping and painting operations (chlorinated paint strippers, paint thinners, heavy metals from paint waste).
- Aircraft fuel storage and distribution systems (jet fuel).
- Leaks in industrial wastewater collection systems and all types of spills.
- Waste landfills.

Groundwater hydrology for a given area can have a strong influence on both the quantity and quality of water available for drinking and recreational use.

802. Sources and characteristics of potable water

Water supply systems on military bases must meet the demands for water quality and quantity for a variety of uses. Besides drinking, water use includes cooking, washing, bathing, sewage disposal, cleaning equipment, air conditioning, fire protection, irrigation, and recreation. In the past, many bases maintained and operated their own water supply systems. Presently, most bases purchase drinking water from a municipal supply, which typically needs little or no additional treatment. Other bases, particularly overseas, must develop their own water sources and apply treatment processes, which are dependent upon the source.

Sources of potable water

Potable water, also called drinking water, is typically supplied by a combination of surface water and groundwater sources. Where surface and groundwater are available, groundwater is generally the preferred choice.

Groundwater

Groundwater is stored in both unsaturated and saturated zones. As water filters down through underground layers of sand, clay, rock and gravel, much of the undesirable material in rainwater and runoff is effectively removed. However, water does react with these layers to extract minerals. Many minerals produce unwanted characteristics in the water such as hardness, too much fluoride, unappealing color, and taste. Excessive mineral content is a major limiting factor in the use of groundwater. Minerals such as calcium, magnesium, and iron can be removed fairly easily. High concentrations of minerals like fluoride and chloride cannot be removed easily and may require an alternative water supply. The quality of groundwater for a given area generally does not change; however, different locations can show marked differences in water quality.

The major advantages of using groundwater sources over surface water sources are:

- Less likely to be contaminated with pathogens.
- Low turbidity.
- Nearly constant temperature.

- Less affected by droughts.
- More difficult to contaminate.
- Less treatment required to make potable.

In locations where groundwater is found at varying depths, deeper aquifers offer more protection against contamination and drought. Pathogenic bacteria and nitrates are generally not found in groundwater (their presence indicates pollution of the supply). Contamination can occur through open formations in the ground, leakage from the surface (especially down the outside of an inadequately sealed well casing) or through perforations in a well's casing. Nevertheless, all groundwater usually gets some treatment because of the potential for contamination, typically chlorination for disinfection purposes.

Surface water

Runoff is the portion of rain and melting snow that becomes *surface water*. Topography and gravity control the movement of surface water. In areas where there is little fresh water, rainfall may be collected in a device. Typically, though, the runoff drains into a lake or stream. Runoff may flow through undeveloped areas, agriculture areas, industrial areas, and urban areas. Such areas form what is known as the *watershed* of a lake or stream.

Pollutants released in the *watershed* are likely to contaminate lakes or streams. Discharges from sewage plants, factories, and agricultural activities significantly contribute to the character of surface water. The quality of surface water may change drastically from one location to another and even in the same location at different times. River water may be perfectly safe one day and seriously contaminated the next because of the discharge of pollutants.

The availability of surface water also varies widely with the seasons. Therefore, the nature of a stream or lake should be investigated periodically to make sure its dependability as a year-round source. Assessments of a water source for adequacy and dependability are necessary if the source must supply a large and constant amount of water. Surface water that is used for drinking must always be treated because pollutants and toxins can potentially make their way into the water source. Therefore, securing, treating, monitoring, and protecting the water source becomes critical to the overall success of the mission.

Characteristics of potable water

As water goes through the hydrologic cycle, it gathers numerous organic and inorganic substances. Knowing what impurities are in water allows you to determine the type and extent of treatment required to make it potable and palatable. The suspended and dissolved solids, dissolved gases, and pathogens that may be found in water are its most important characteristics.

Suspended and dissolved solids

Dust, silt, minerals, and organisms are picked up by ground and surface water and dissolved or carried in suspension. Suspended solids are often easy to detect, even without testing, because the water appears cloudy or murky, giving it an apparent color. This is called *turbidity*—a physical characteristic caused by mud, sand, silt, clay and/or organic matter. True color comes from organic materials such as fuels, oils, dyes, and naturally occurring organics or from inorganic materials like iron and copper. Many chemicals, minerals, and organic materials such as algae can give water an objectionable taste and odor. These materials may be suspended—meaning they keep their structure and do not dissolve—or may dissolve forming a solution. For water to be potable as well as palatable, it must be treated to remove these impurities.

Hardness

Hard water is water that has high mineral content. It generally is not harmful to health, but is undesirable because it produces scale (a flaky coating) which builds up on equipment that handles water (e.g., boilers, cooling towers).

- Carbonate hardness results from the bicarbonates of calcium and magnesium.
- Non-carbonate hardness is caused by sulfates and chlorides of calcium and magnesium.

Minerals that cause hardness are somewhat more difficult to remove. Carbonate hardness and noncarbonated hardness together make up the total hardness of water. Water softeners reduce the concentration of hardening minerals through the process of ion exchange.

Alkalinity

Closely related to hardness, the alkalinity of water is due mainly to carbonates, bicarbonates, and hydroxide ions. Carbon dioxide (CO2) gas is absorbed by rain or surface water to form carbonic acid. The carbonic acid reacts with minerals to form bicarbonates such as calcium or magnesium bicarbonate and sometimes sodium bicarbonate. Hydroxide and carbonate ions are not found in natural water in appreciable concentrations, but appear later when the water is softened with lime and soda ash. Hydroxide alkalinity can also be found when ground or surface water is contaminated by alkaline wastewater.

Alkalinity is particularly important in operating equipment such as boilers and circulating cooling water systems. The range of alkalinity (in parts per million [ppm]) is controlled to prevent acidic corrosion. Maintaining a proper range of alkalinity also prevents the precipitation of salts that can form scale.

Acidity

The carbonic acid formed in rainwater and runoff has a direct effect on the acidity of surface and groundwater. The potential for hydrogen (pH) scale is used to express the degree of acidity; pH lower than 7 (neutral) indicates water that is acidic. Acidic water is more likely to contain elevated levels of metals, including toxic metals like lead and arsenic. Lime and other alkaline substances may be used to raise the pH. If the water is too alkaline, an acid can be added to lower the pH, or other chemicals can be added to prevent scale formation.

Dissolved gases

The gas concentration—most importantly, oxygen, hydrogen sulfide, and CO2—dissolved in water are dependent upon the concentration in the atmosphere, the atmospheric pressure, and the temperature. Adequate dissolved oxygen levels are necessary to prevent drinking water from tasting flat. Increasing water temperature causes the water to release oxygen, so generally there is higher dissolved oxygen content in cold water. A decrease in atmospheric pressure also decreases the oxygen content. Chemicals and organisms in polluted water cause it to exhaust its oxygen, while clean water has a good supply. For this reason, dissolved oxygen is used as one of the indicators of water quality.

Hydrogen sulfide is a colorless, flammable, poisonous gas with an unpleasant odor. Found in many mineral waters, it produces a disagreeable taste and a smell like rotten eggs. In groundwater, the dissolved gas is produced by the action of anaerobic bacteria in soils containing organic and inorganic sulfur compounds. Hydrogen sulfide in water forms sulfuric acid, which corrodes metals.

Along with absorption from the air, water also receives CO2 from decaying vegetation. In the water treatment process, CO2 is given off in chemical reactions and absorbed into the water. Many underground gas deposits also add to the concentration. CO2 contributes to the acidity of water, making it less suitable for many uses.

Pathogens

The ability of pathogens in water supplies to produce massive epidemics is well known. Water can be a carrier of many organisms responsible for intestinal diseases. These organisms include bacteria, viruses, protozoa, worms, and certain algae that secrete toxins. Diseases such as typhoid, cholera, dysentery, and hepatitis have occurred among Airman stationed in areas where water treatment was inadequate. The seriousness of waterborne diseases and the ease with which they can be transmitted

are reasons water supplies are chlorinated. Additional treatment is needed in areas where there are chlorine-resistant pathogens.

The majority of AF bases receive drinking water from public water systems (PWS). These public systems often rely on groundwater as the primary source of drinking water. The most important step in protecting groundwater as a source of drinking water is to prevent contamination of groundwater sources. In the United States (US), the Environmental Protection Agency (EPA) has primary responsibility for regulating and protecting groundwater; they share that responsibility with the states through various arrangements.

803. Regulatory drinking requirements of the Safe Drinking Water Act

The federal Safe Drinking Water Act (SDWA) ensures the quality of drinking water. Under SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards.

Safe Drinking Water Act

In 1974, public concern over contaminants in public drinking water supplies prompted Congress to pass the SDWA. The SDWA established a federal program to monitor and increase the safety of all publicly and commercially supplied drinking water. The law was amended in 1986 and 1986 and requires many actions to protect drinking water and its sources. This includes drinking water supplied by AF installations as well as supplies provided by other government agencies. This is accomplished by establishing national enforceable drinking water quality standards, guaranteeing water suppliers monitor to ensure national standards are met, and maintaining low levels of harmful contaminants.

The 1986 amendments to the SDWA required the EPA to establish maximum contaminant levels (MCL), maximum contaminant level goals (MCLG), and best available technology treatment techniques for organic, inorganic, radioactive, and microbiological contaminants, as well as turbidity. The MCLs represent the upper limit on the permissible concentrations of regulated contaminants in public drinking water supplies. The MCLGs are maximum concentrations below which no negative human health effects are known to exist. They are non-enforceable health goals that may not be achievable or cost effective in some areas, such as small PWSs. The federal government recognizes best available technology treatment techniques as the technologies most likely to acceptably reduce contaminant levels in drinking water at a reasonable cost.

In 1996, the SDWA was again amended. In addition to authorizing billions of dollars of expenditures for drinking water systems, the 1996 revision focused water program spending on contaminants that posed the greatest risk to human health and that are most likely to be present in a public water system. Additional revisions included more stringent controls on microbial contaminants as well as on the by-products of chlorination, requirements that water utilities notify the public of water safety violations within 24 hours, that all water system operators be certified to meet EPA's minimum certification standards, and that the EPA establish a database to monitor the presence of unregulated contaminants in water.

Compliance with the SDWA requires regular testing of water that has completed the treatment process at the treatment plant for all listed MCLs and MCLGs. Testing for microbial pathogens is also regularly conducted in the distribution system to confirm the effectiveness of filtration and disinfection practices.

Drinking water standards

The SDWA authorizes the EPA to set drinking water standards to control the level of contaminants in the nation's drinking water. The EPA has established two types of drinking water standards: primary and secondary. Primary standards are designed to protect public health (PH) by setting maximum permissible levels of potentially harmful substances in the water. Secondary standards are guidelines that apply to the cosmetic and aesthetic aspects of drinking water, which do not pose a health risk.

Primary standards are enforceable by law but secondary standards are not. Most primary standards are specified as MCLs.

Primary MCLs

National Primary Drinking Water Regulations (NPDWR) (primary standards) establish legally enforceable MCLs for particular contaminants in drinking water or required ways to treat the water to remove contaminants. The MCLs for potentially harmful or toxic substances reflect maximum levels that can be safely consumed in water, taking into consideration exposure to substances from other sources. Categories of primary contaminants include the following:

- Microorganisms.
- Disinfectants.
- Disinfection byproducts.
- Inorganic chemicals.
- Organic chemicals.
- Radionuclides.

Primary standards protect PH by limiting the levels of contaminants in drinking water. States can establish MCLs that are more stringent than those set by the EPA. Primary standards are part of the SDWA's multi-barrier approach to drinking water protection (fig. 1–3).

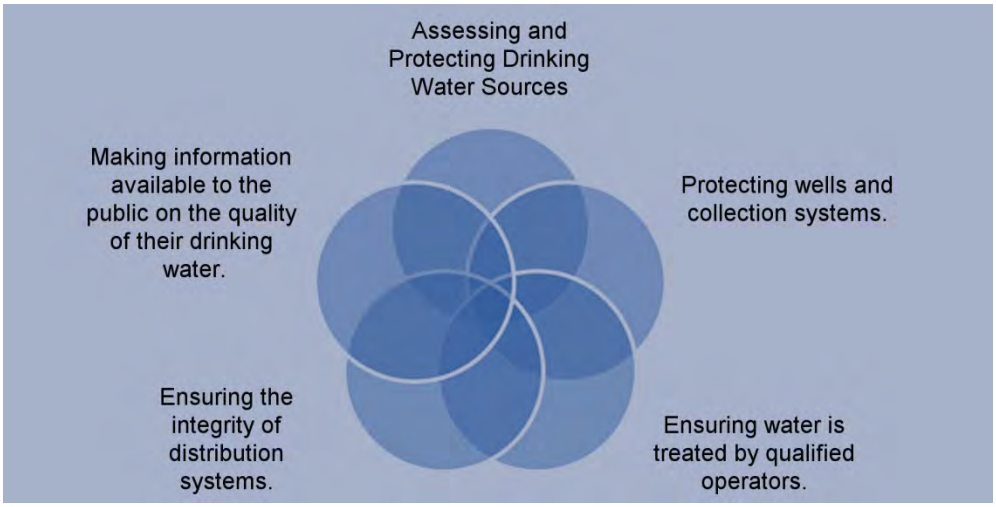

Figure 1–3. Illustration of the SDWA's multi-barrier approach.

Secondary MCLs (SMCL)

In addition to the primary standards, the EPA has established National Secondary Drinking Water Regulations (NSDWR) (secondary standards) that set non-mandatory water quality standards for 15 contaminants. The EPA does not enforce "SMCLs." They are established only as guidelines to assist PWSs in managing their drinking water for cosmetic effects, such as skin or tooth discoloration or aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL. Even though these contaminants are not health threatening at the SMCL, and PWSs only need test for them on a *voluntary* basis, secondary standards give PWSs some guidance on removing these chemicals to levels that are below what most people will find to be noticeable.

The EPA believes that if these contaminants are present in water at levels above SMCLs, the contaminants may cause the water to appear cloudy or colored, or to taste or smell bad. This may

cause a great number of people to stop using water from the public water system even though the water is actually safe to drink.

Besides establishing SMCLs, the EPA also provides guidance, assistance, and public information about drinking water, conducts studies, and oversees state drinking water programs. The implementing regulations for the requirements of the SDWA are established by the EPA and are found in Title 40 Code of Federal Regulations (CFR) parts 141 through 143.

- Title 40 CFR Part 141, *National Primary Drinking Water Regulations*: This regulation codifies the specific requirements of the SDWA including MCLs, monitoring and analytical requirements, reporting and record keeping, MCLGs, filtration and disinfection, control of lead and copper, treatment techniques, and information collection requirements for PWSs.
- Title 40 CFR Part 142, *National Primary Drinking Water Regulations Implementation*: This part sets forth regulations for implementing and enforcing the NPDWR contained in Title 40 CFR Part 141. It establishes the roles and responsibilities of various implementing agencies in monitoring and enforcing the requirements of the NPDWR and provides the implementing structure under which states participate in the monitoring and enforcement of the NPDWR. It outlines requirements for Indian tribes to participate in monitoring and enforcing the NPDWR. Waiver and exemption procedures are described in this part, as are rulings by the EPA Administrator applicable to compliance with the NPDWR. Finally, this part provides the administrator's findings regarding best available technology.
- Title 40 CFR Part 143, *National Secondary Drinking Water Regulations:* This part establishes MCLs for secondary contaminants that typically effect aesthetic qualities and public acceptance of drinking water. Examples of secondary contaminants include iron and total dissolved solids (TDS) that affect the color of water and odor. These secondary standards are not federally enforceable, but many states hold SMCLs as enforceable standards. For every MCL that has been established, the EPA also lists a MCLG. The MCLGs are not enforceable by law and represent the lowest desired contaminant level in drinking water that should be achievable if PWSs use best available technology to remove contaminants from their system.

Most states have primacy to enforce their own SDWA programs. Under the SDWA, *primacy* is the responsibility for ensuring that a law is implemented and authority to enforce a law and related regulations (Title 40 CFR Part 142). Primacy is granted to state agencies if they can demonstrate regulatory limits at least as stringent as federal regulatory limits. Some states have adopted limits that are more stringent than federal limits. It is important for bioenvironmental engineers (BEE) to know which agency has primacy at the installation because it determines which regulations and limits apply to the base.

Installations outside the US and its territories must comply with the Department of Defense (DOD), final governing standards (FGS) or environmental governing standards (EGS). Where these documents do not exist, installations must comply with DOD Instruction (DODI) 4715.5–G, the *Overseas Environmental Baseline Guidance Document* (OEBGD). In these situations, the major command surgeon general (MAJCOM/SG) serves as the primacy agent and is responsible for establishing a program that is consistent with the direction outlined in Air Force Instruction (AFI) 48–144, *Drinking Water Surveillance Program*.

BE is involved in a number of programs designed to protect the integrity of drinking water supply and distribution. These programs include the Well Head Protection Program (WHPP), sanitary surveys, water vulnerability assessments (WVA), backflow prevention, cross-connection, main break responses and sampling, analysis, and monitoring. These programs all are explained in the sections that follow.

Well Head Protection Program

The SDWA includes the groundwater rule. The groundwater rule addresses the safety of groundwater supplied PWSs. At the center of the groundwater rule is the WHPP. In this context, a well head is the top of a drinking water supply well. As the name suggests, the WHPP is a program designed to ensure protection of groundwater supplied by PWSs by protecting the area around the well head from all types of contamination. Geologic features naturally protect most groundwater; however, wells and other man-made or natural features (fissures, sink holes, etc.) can be conduits for contamination.

The WHPP is not a prescribed set of procedures; rather, it is a set of best management practices. Collectively these practices, when followed, ensure water quality is maintained by the proper management of land surface around a well or well field. Although there are still instances where PWSs are contaminated from various agricultural, recreational, and/or industrial activities, the incidence of these events has dramatically reduced since the groundwater rule and associated adoption of the WHPP. Components of a WHPP include the following:

- Delineate the well head area. Using known or measured properties of the aquifer and the surrounding area define the area needing protection.
- Inventory potential sources of contamination of the well or well field. Identify potential point sources of pollution: industrial shops/processes, flightline operations, and potential non-point sources of pollution, pesticides, fertilizers, fuels, and oils form runoff.
- Develop a management plan to protect the well or well field. This is a plan that addresses all actions necessary to protect the well head area given current and proposed base uses.
- Monitor groundwater. Strategically place groundwater-monitoring wells between sources and the well. If a known area of contamination exists, place monitoring wells between the source and the contamination to observe migration.
- Implement water conservation programs. Effective conservation plans, such as limited residential watering during nighttime hours, can reduce the amount of water pulled from an aquifer.
- Create a contingency plan to provide drinking water should the groundwater source become contaminated. For the short term this can be as simple as providing bottled water and for long term it could mean connecting to a local community or drilling new wells.

Base level responsibilities

The AF operates and maintains numerous groundwater wells on bases nationwide. At these locations the installation is responsible for obtaining a state-issued license as a utility and must comply with all aspects of the groundwater rule including the WHPP. Each installation's WHPP should address typical areas of concern such as runoff from the flight line, all operations within the entomology shop, potential surface discharges from any base industrial operations, and golf course maintenance operations. The program is implemented by members of the commander's staff (BE, civil engineering (CE), environmental management, judge advocate (JA), and public affairs [PA]) in organization with federal, state, and local regulatory agencies, public and private suppliers of water, and the surrounding community. Responsibilities related to drinking water are located in AFI 32–1067, *Water and Fuel Systems*, and AFI 48–144.

Having a safe water source helps to ensure the mission is accomplished—in both garrison and deployed environments.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

801. Groundwater hydrology

1. Why is permeability of the subsurface rock important to the flow of groundwater?

2. Why are materials such as sand and gravel considered to be good aquifers for groundwater?

3. If a well is drilled into a confined aquifer, why is a pump not normally necessary for the water to get to the surface?

4. Why are unconfined aquifers more vulnerable to contamination from surface activities?

802. Sources and characteristics of potable water

1. What is the benefit to an AF base buying drinking water from an adjacent city?

2. Even though much of the undesirable material in groundwater is filtered out during the passage through underground layers of sand, clay, rock, and gravel, what is a major limiting factor in using groundwater a source of drinking water?

3. Why is groundwater considered to be more advantageous than surface water as a source of drinking water?

4. River water may be safe one day, but significantly contaminated the next. Why is this?

5. Why should the nature of a stream or lake be investigated to ensure its dependability as a water source?

6. When are complete studies of a water source for adequacy and dependability necessary?

7. What can cause objectionable taste or odor in drinking water?

8. Why must the range of alkalinity in water be controlled?

9. Why is it important to have adequate dissolved oxygen levels in drinking water?

10. What effect do chemicals and organisms have in polluted water?

11. When might drinking water require additional treatment other than chlorine?

803. Regulatory drinking requirements of the Safe Drinking Water Act

1. Why is it important to regularly test for microbial pathogens in the water distribution system?

2. How do primary drinking water standards protect PH?

3. Why is it important to know which regulatory agency has *primacy* for drinking water criteria at the base?

4. What base drinking water standard(s) must be complied with for installations outside the continental United States?

5. List four typical areas of concern that a base's WHPP should address.

1–2. Storage and Distribution of Drinking Water

Drinking water, also known as potable water, is water that meets specific standards and considered safe to consume by humans. Water that is not properly treated and disinfected can spread diseases such as cholera, shigellosis, typhoid, and paratyphoid fever. Poor water quality or the limited availability of water is not only debilitating to individuals, but can also have a major impact on AF operational readiness. It is important to properly treat, distribute, and maintain drinking water and the systems that support it.

804. Potable water system classification

The EPA classifies water systems to establish who is required to comply with 40 CFR Part 141 (NPDWR) and other regulations. System classification generally depends on the following:

- The number of people served.

- Whether the system serves the same customers year-round or only on an occasional basis.

Since the NPDWRs only apply to systems that are considered PWSs, the first step is to determine if the water system is classified as a PWS. To be classified a PWS, a water system must (1) have at least 15 service connections, and (2) serve an average of 25 or more individuals daily for 60 or more days per year. [2]

A system that is considered a PWS must be further classified as either a community water system (CWS) or a non-community water system (NCWS), and NCWSs are further classified as transient systems (for short-term users) or non-transient systems (for long-term users). [3] The requirements for each of these PWS classification types are described in the following table.

Public Water System Classification	Requirements
Community Water System (CWS)	• Serving at least 15 service connections used by year-round residents. • Regularly serving at least 25 year-round residents.
Non-Transient Non-community Water System (NTNCWS)	• Is not a CWS. • Regularly serving at least 25 of the same persons over 6 months per year.
Transient Non-community Water System (TNCWS)	• Is not a CWS. • Does NOT regularly serve at least 25 of the same persons over 6 months per year.

System classification has a significant impact on BE sampling and monitoring requirements. For example, a TNCWS will typically have less stringent monitoring requirements since customers only drink the water occasionally. In this case, customers may be exposed to low levels of contaminants on an infrequent basis. In comparison, a CWS or NTNCWS requires more extensive monitoring due to a customer's potential exposure to the same contaminants, but over a longer, continuous period. [3]

Figure 1–4 is a flowchart that will assist you in determining system classification; however, the primacy agency—the agency of the state or Federal Government that has primary enforcement responsibility according to the SDWA—may have additional requirements or more inclusive definitions, and state regulations should be checked when determining classification.

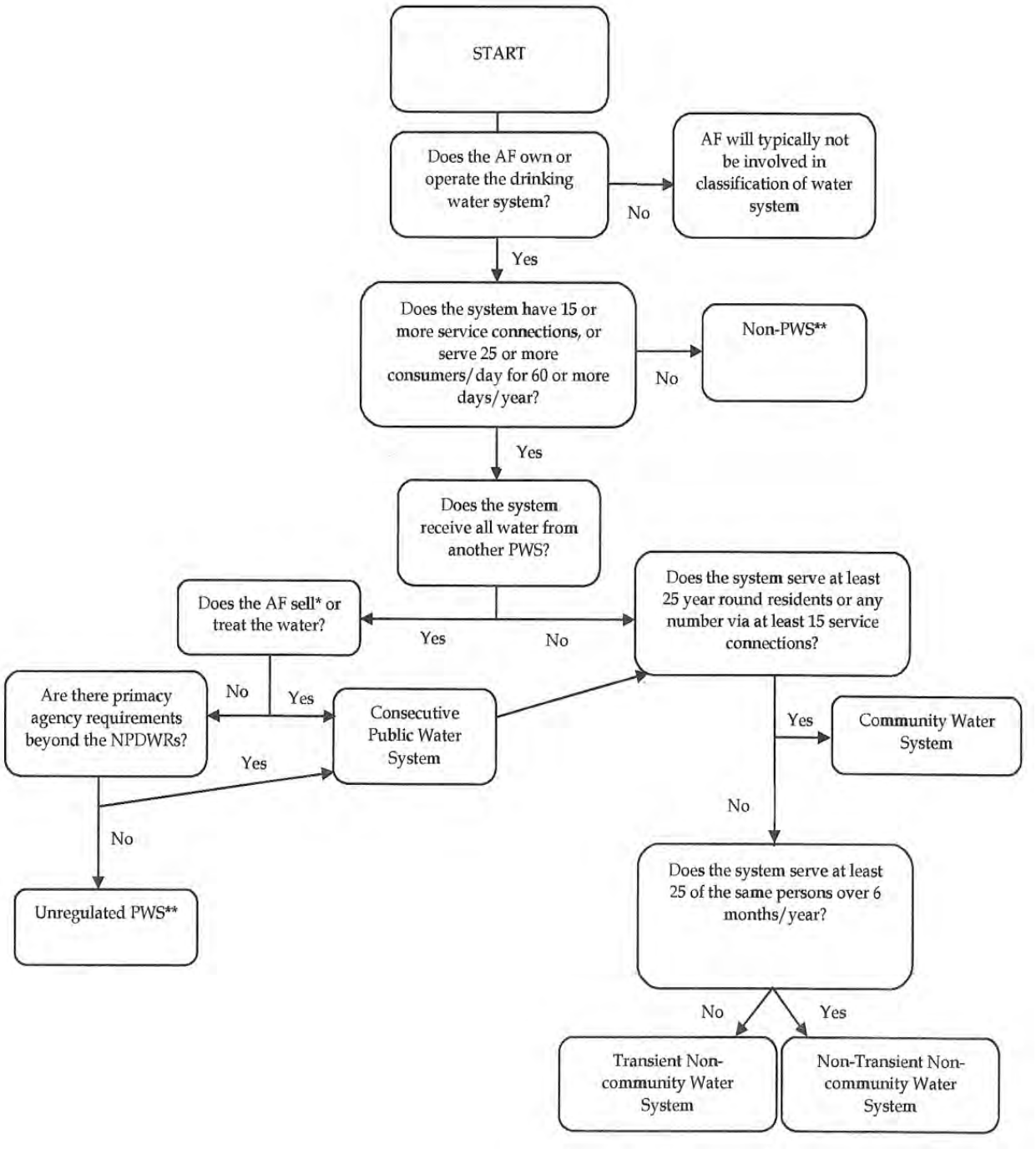

Figure 1–4. Water System Classification Decision Tree. [3]

805. Drinking water treatment

Water treatment consists of adding or removing substances in order to produce a desired change in quality. The amount and type of treatment applied varies with the source type and quality. Many groundwater systems can satisfy all federal requirements without applying any treatment, while others need to add chlorine or additional treatment. Because surface water systems are exposed to direct wet weather runoff and to the atmosphere and are therefore more easily contaminated, federal and state regulations require that surface water treatment, whereas groundwater often requires little or no

treatment. A variety of treatment processes is used but the most common are filtration, disinfection, and fluoridation.

Filtration

Conventional filtration is the most widely used technology to treat surface water to remove both turbidity and microbial contamination, but may also meet or help meet other treatment objectives such as color, taste, odor removal, and reduced byproduct formation. Major steps in conventional filtration include:

- Coagulation.
- Flocculation.
- Sedimentation.[3]

Coagulation/flocculation

Coagulation and flocculation are discussed together because flocculation refers to combining or coagulating small particles into larger particles. Alum and iron salts or synthetic organic polymers (used alone or in combination with metal salts) are generally used to promote coagulation. The end product is water in which the majority of the turbidity has been collected into floc, clumps of bacteria and particulate impurities. The floc will then settle out in the sedimentation basin.

Sedimentation

After flocculation, the water and floc moves slowly through large basins known as sedimentation or settling basins. This allows the floc to settle to the bottom of the basin. The floc that falls to the bottom of the basins is mechanically removed, and any remaining floc that didn't settle will flow out of the sedimentation basin and be captured by the filters.

Disinfection

Disinfection is a chemical or physical process (e.g., chlorine, heat) that inactivates microorganisms in the water, thereby preventing them from affecting the host, in this case, humans. Disinfection can include the use of a primary and/or a secondary disinfectant as described in the table below.[3]

Disinfectant Type	Description
Primary Disinfectant	• The objective is to achieve the desired inactivation of target microorganisms. • Applied at a point that allows for the required contact time to achieve the desired inactivation of microorganisms.
Secondary Disinfectant	• Provides longer-lasting protection against pathogens as water moves through the storage and distribution systems to consumers. • Sometimes referred to as residual or secondary residual disinfection. • Typically applied at the clear well (above ground treatment reservoir) or as drinking water leaves the water treatment plant.

Disinfection is a common type of water treatment system used at AF installations; however, other treatment processes may include, but are not limited to corrosion and scale control, lime softening, aeration, and carbon adsorption.[2]

Disinfectants can react with naturally occurring materials in the water to form unintended byproducts such as total trihalomethane (TTHM), which may pose health risks. [3] General disinfection methods are defined in the following table.

Disinfection Method	Description	Provides a disinfectant residual	No disinfectant residual (i.e., not suitable for secondary disinfection)	Not commonly used for large-scale disinfection of drinking water
Free Chlorine	Addition of gaseous chlorine, sodium hypochlorite (bleach), or calcium hypochlorite resulting in free chlorine (hypochlorous acid and hypochlorite ion)	X		
Chloramines	The addition of chlorine and ammonia rapidly react to form the chloramines.	X		
Chlorine Dioxide	Has low persistence and concentrations are limited by chlorite ion production; used by only a few utilities with small distribution systems.		X	
Ozone	Used in water treatment for disinfection and oxidation. Ozone is a powerful oxidant, but only used for primary disinfection, as a residual cannot be maintained. The use of ozone as the primary disinfectant can reduce chlorinated disinfectant by-product formation.		X	
Ultraviolet (UV)	The photochemical reaction produced by the UV damages the DNA and RNA organisms, rendering them incapable of replication. Advantages include no taste or odor and no byproducts; however, the disadvantage is there are no measurable residuals to protect the water system after the initial ultraviolet light treatment. UV is used for final disinfection of water in many water-bottling plants.		X	
Potassium Permanganate	Not used for primary or secondary disinfection; is used to oxidize iron and manganese for control of taste and odor compounds, and for control of nuisance organisms.			X
Iodine	Use as a drinking water disinfectant is generally limited to the individual level in the field and during emergencies.			X
Bromine	Sometimes used as the disinfectant in swimming pools.			X

Chlorine disinfection

Chlorine is a strong oxidizer and inactivates a wide range of pathogens found in water; therefore, is used for both primary and secondary drinking water disinfection. Chlorine leaves a residual in water, is easily measured and controlled, and is economical to use. However, chlorine use tends to result in high levels of disinfection byproducts, and maintaining a disinfectant residual throughout the distribution system can be problematic.[3]

Free residual chlorination

When chlorine is added to water, it proceeds through a series of reactions as described in figure 1–5 below. The chlorine reacts first with inorganic and organic materials and metals in the water and is not available for disinfection, also known as the *chlorine demand*. After the chlorine demand is met, the remaining chlorine, called total chlorine, is divided into one of the following:

- *Combined chlorine*: the amount of chlorine that has reacted with inorganic (nitrates, etc.) and organic nitrogen-containing molecules (urea, etc.) to make weak disinfectants that are unavailable for disinfection.
- *Free chlorine* (sometimes known as chlorine residual, free chlorine residual, residual chlorine): the chlorine that is left over and is available to for disinfection.

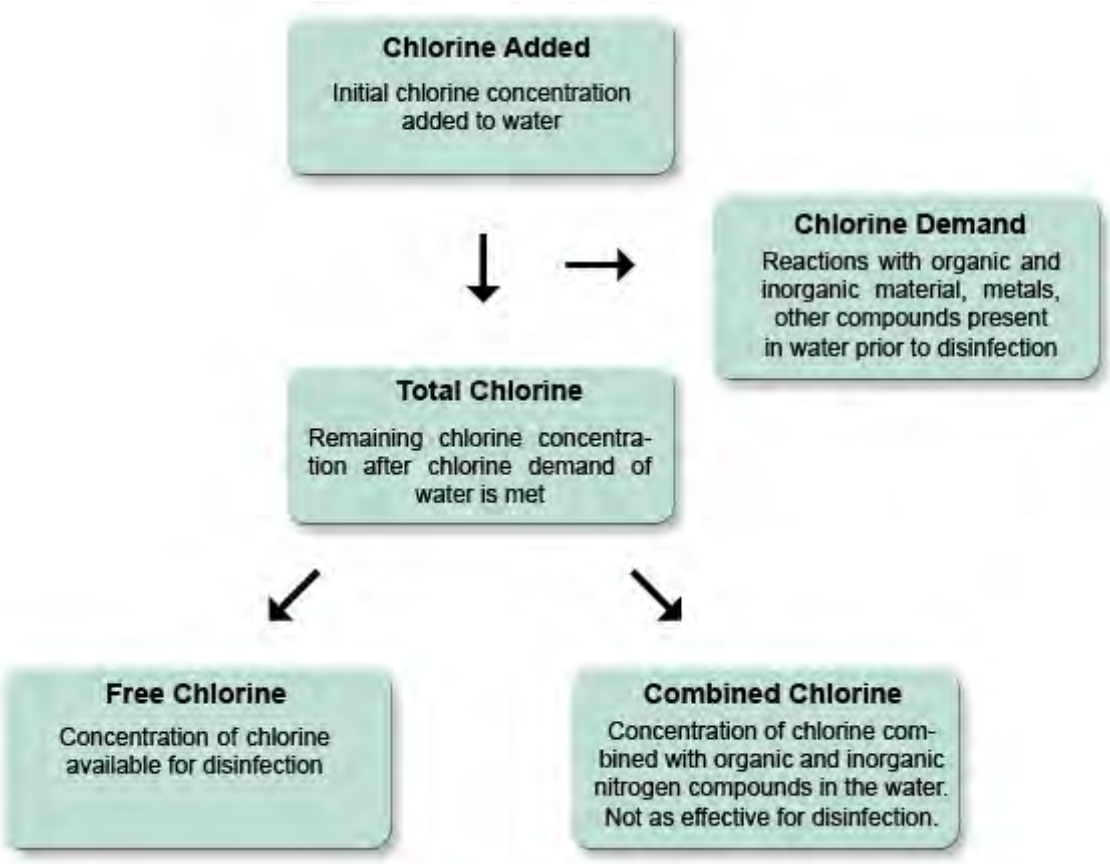

Figure 1–5. Chlorine Addition Flow Chart. [4]

It's the presence of *free chlorine* in the drinking water indicates that:

1. A sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease.
2. The water is protected from recontamination during storage.

Breakpoint chlorination

Breakpoint chlorination is the addition of chlorine to water containing ammonia to form and then destroy chloramines. Chlorinating water-containing ammonia initially results in the formation of chloramines. Continued addition of chlorine results in the destruction of chloramines (breakpoint chlorination), followed by the presence of free chlorine.[3]

Fluoridation

Fluoride is added to drinking water to prevent dental decay. The target population is children; however, evidence has shown that fluoridation helps other age groups as well. The EPA has established an MCL and MCLG of 4.0 milligram/liter (mg/L) to prevent adverse health effects and an SMCL of 2.0 mg/L to control the risk of dental fluorosis (teeth staining). This is because excessive consumption of fluoride over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel, along with a range of cosmetic effects (e.g., stains) to teeth.[5] Optimal concentrations and limits of fluoride in drinking water, recommended by the United States Public Health Service (USPHS) and American Water Works Association (AWWA), have been correlated to the annual average of maximum daily air temperature and are shown in the table below. Check primacy agency and state PH regulations for local requirements or recommendations. Overseas installations should comply with respective final governing standards (FGS) or the OEBGD.[3]

Annual Average of Maximum Daily Air Temperature, °F	Recommended Limits for Fluoridation of Drinking Water, mg/L		
	Lower	Optimum	Upper
53.7 and below	0.9	11.2	1.7
53.8–58.3	0.8	1.1	1.5
58.4–63.8	0.8	1.0	1.3
63.9–70.7	0.7	0.9	1.2
70.8–79.2	0.7	0.8	1.0
79.3–90.5	0.6	0.7	0.8

Installations that produce their own water in whole or part shall add fluoride when children under age 10 are included in the service population. Primacy agency requirements take precedence over AF-recommended fluoride levels. Where fluoride is added to drinking water, CE water operators sample for fluoride as required by the primacy agency (typically sampling product water at the treatment plant), and BE performs fluoride sampling in the distribution system using a primacy-approved method. Further information on fluoride in drinking water can be found in AFI 48–144 and the *United States Air Force School of Aerospace Medicine (USAFSAM) Drinking Water Surveillance Technical Guide*.

806. Disinfection of new water mains, water main breaks, and repairs

Installation and repair of water mains provides the potential for direct contamination of the distribution system. AFI 48–144, mandates that new or repaired potable water systems be disinfected according to requirements established by the agency with regulatory primacy. BE's responsibility in this process is to make sure potable water lines are properly disinfected and the water is safe to drink by performing all analytical tests to verify that the system meets the minimum bacteriological standards. They also are responsible for determining if a health alert (e.g., a "boil water" advisory) is needed.[3]

The main resource available for disinfection of water mains is the AWWA Standard C651–05, *Disinfecting Water Mains*, the primary reference used for this lesson. The AWWA standard addresses disinfection requirements for:

- Newly installed water mains.
- Mains that have been removed from service for repairs and maintenance.

- Mains that continually show the presence of total coliforms (TC) (i.e., microbial contamination). Mains that have undergone emergency repairs following pipe failure.

Other AWWA standards covering procedures for disinfection of system components include C652, *Disinfection of Water-Storage Facilities*, C653–13, *Disinfection of Water Treatment Plants*, and C654–13, *Disinfection of Wells*. Information on how to access AWWA standards is provided in Appendix A of the *USAFSAM Drinking Water Surveillance Technical Guide*.

The forms of chlorine that may be used in disinfection operations, according to AWWA Standard C651–05, *Disinfecting Water Mains* are:

- Liquid chlorine (contains 100 percent available chlorine).
- Sodium hypochlorite solution (5–15 percent available chlorine).
- Calcium hypochlorite granules or tablets (approximately 65 percent available chlorine by weight).

New Line Installation

You must meet some general requirements when you install new water lines. The following is a list of those requirements.

- A newly installed line must be isolated until bacteriological tests are satisfactorily completed.
- Protect the interiors of pipes, fittings, and valves from contamination.
- Close the openings in the pipeline with watertight plugs when you stop laying pipe at the close of the day's work or for other reasons, such as rest breaks or meal periods.
- Never use contaminated material or any material capable of supporting growth of microorganisms to seal joints.
- Sealing material or gaskets shall be handled in a manner that avoids contamination.
- If dirt enters the pipe, it must be removed and the interior pipe surface swabbed with a 1 to 5 percent hypochlorite disinfecting solution.
- If it is not possible to keep the pipe and fittings dry during installation, the water that may enter the pipe-joint spaces should have an available chlorine concentration of approximately 25 mg/L.
- If the main is flooded during construction, clear the floodwater and the section exposed to the floodwater should be filled with chlorinated potable water that, at the end of a 24-hour (hr) holding period, has a free chlorine residual of not less than 25 mg/L. The chlorinated water may then be drained or flushed from the main.

Methods of chlorination

Three methods of chlorination are (tablet, continuous feed, and slug) are used to disinfect water lines, resulting in an absence of coliforms. The three methods attempt to provide flexibility in responding to specific situations.

Tablet method

The tablet method consists of placing calcium hypochlorite granules or tablets in the water main as it is being installed and then filling the main with potable water when installation is completed. This method may be used only if the pipes and components are kept clean and dry during construction. This method requires an initial chlorine concentration of 25 mg/L, a minimum contact time of 24 hours and free chlorine residual must be detectable after the holding period. If the water temperature is less than 41°F (degrees Fahrenheit) (5°C [degrees Celsius]), the water must remain in the pipe for at least 48 hours.

During construction, calcium hypochlorite granules are placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500- feet (ft) intervals. The tablet method cannot be used unless the main can be kept clean and dry. It cannot be used in large-diameter mains if it is necessary for a worker to enter the main to grout joints or perform inspection, because the tablets may release toxic fumes when exposed to moist air. When using the tablet method, the chlorine concentration is not uniform throughout the main because the hypochlorite solution is dense and tends to concentrate at the bottom of the pipe. The tablet method is convenient to use in mains having diameters up to 24 inches and requires no special equipment. [6]

Continuous-feed method

The continuous-feed method consists of placing calcium hypochlorite granules in the main during construction (optional), completely filling the main to remove air pockets, flushing the completed main to remove particulates, and filling the main with potable water. Because the continuous-feed method can be used to flush particles and pre-chlorinate with calcium hypochlorite granules, this method requires an initial chlorine concentration of 25 mg/L, a minimum contact time of 24 hours, and a free chlorine residual of 10 mg/L after the 24-hour holding period. [6]

The continuous-feed method is suitable for general application. Preliminary flushing removes light particulates from the main but not from the pipe-joint spaces. The chlorine concentration is uniform throughout the main.

Slug method

The slug method is suitable for use in large-diameter mains where the volume of water makes the continuous-feed method impractical and difficult to achieve for short attachments. This method allows only a three-hour contact time, but requires a 100-mg/L initial chlorine dosage. This method results in appreciable savings of chemicals used to disinfect long, large-diameter mains and reduces the volume of heavily chlorinated water to be flushed to waste.

The slug method consists of the following:

- Placing calcium hypochlorite granules in the main during construction.
- Completely filling the main to eliminate air pockets.
- Flushing the main to remove particulates.
- Slowly flowing through the main a slug of water dosed with chlorine to a concentration of 100 mg/L. [6]

Where practical, the section of the main in which the break is located shall be isolated and all service connections shut off. The chlorinated water should remain in the pipe long enough to ensure a proper contact time, typically 100 mg/L for three hours mentioned earlier. The dose may be increased to as much as 300 mg/L and the contact time reduced to as little as 15 minutes. CE is responsible for ensuring proper chlorine levels are maintained. After the proper chlorine level and wait time has been achieved, the system goes through a final flushing to lower the chlorine concentration to levels generally no higher than the level prevailing in the distribution system.

Sampling new water mains

- After final flushing and before the new water main is connected to the distribution system, *two consecutive sets* of acceptable samples, taken at least 24 hours apart, shall be collected from the new main.
- At least one set of samples should be collected from every 1,200 ft (366 meters) of the new water main, plus one set from the end of the line and at least one set from each branch.
- If trench water has entered the new main during construction, or if excessive quantities of dirt or debris have entered the new main, take your samples at intervals of approximately 200 ft

(61 meters). In such cases, the samples should be taken from water that has stood in the new main for at least 16 hours after the final flushing is complete.

- Samples are tested for bacteriological quality according to *Standard Methods for the Examination of Water and Wastewater*.
- Samples should show the absence of coliform organisms; and, if required, the presence of a chlorine residual. Turbidity, pH, and a standard heterotrophic plate count (HPC) test may be required.
- If the sample results from the lab indicate a measured HPC greater than 500 colony-forming units (CFU) per milliliter (mL), flushing is resumed and another coliform and HPC set of samples is taken until no coliforms are present and the HPC is less than 500 CFUs per mL. [6]

Disinfection of existing lines

Many of the water systems serving AF installations have aged and experience a numbers of line breaks over the course of a year. Additionally, accidental breaks associated with construction and maintenance activities may occur. Regardless of the cause, line breaks are a potential contamination source of the distribution system and need to be dealt with swiftly and properly. As stated previously, BEEs collect bacteriological samples and determine if a health alert is needed.

CE typically provides personnel equipment and materials necessary to perform the repair and disinfect the lines. CE is required to notify BE of any unusual events affecting the water distribution system that could result in changes to water quality and potability including line breaks, new connections, distribution system maintenance (e.g., cleaning reservoirs, storage tanks, hydrant flushing), cross-connections, water treatment plant repairs, and chlorine and fluoride application problems. However, it is a local decision as to whether BE should be notified following breaks repaired under pressure (greater than or equal to (≥) 20 pounds per square inch [psi]). [3] However, if the water pressure falls below 20 psi, the water main must be disinfected and tested for coliform bacteria before being placed back into service.

The following procedures, as described in AWWA Standard C651–05, apply primarily when existing water mains are partially or completely dewatered. After the appropriate procedures have been completed, the existing water main may be returned to service.

Trench treatment

When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from this pollution. Tablet chlorination has the advantage in this situation, because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation.

Swabbing with hypochlorite solution

The interior of pipe and fittings (particularly couplings and sleeves) used in making the repair is swabbed or sprayed with a 1 percent hypochlorite solution before being installed.

Flushing

Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. After repairs are completed, but before the main is chlorinated, the main is filled to eliminate air pockets and flushed to remove particulates. Water mains are flushed at a velocity no less than 2.5 ft per second (ft/sec). The AWWA Standard C651–05 provides information on the rates of flow required to produce a velocity of 2.5 ft/sec for commonly used sizes of pipe.

Final flushing is done to remove heavily chlorinated water after the chlorination steps (discussed below) have been taken. The final flush lowers the chlorine concentration in the water to no higher than the level generally prevailing in the distribution system.

Slug chlorination

The slug chlorination method described previously is an *option* for chlorinating *new* water lines is the method used in disinfecting existing mains.

Bacteriological sampling

Take samples after repairs are completed (to include the final flush) to confirm the effectiveness of the repair procedures and to verify the water in the distribution system is safe to drink.

- The sampling pipe is dedicated, clean, disinfected, and flushed prior to sampling.
- Samples for bacteriological analysis are collected in sterile bottles treated with sodium thiosulfate, as required by *Standard Methods for the Examination of Water and Wastewater—9060 A. Collection.*
- If *positive* bacteriological samples are recorded, evaluate the situation to determine corrective actions to be taken.
- Daily sampling is continued until *two* consecutive negative samples are recorded.
- To minimize the impact on the customers, if a "boil water" advisory is *not* issued, testing results do not have to be received before the line is placed back into service.
- If a "boil water" advisory has been issued, the bacteriological samples must be confirmed negative before the "boil water" advisory can be lifted; however, the water still can be released to customers to be used for everything except drinking.
- No hose or fire hydrant is used in the collection of samples; however, for pipe repairs, if no other sampling port is available, well-flushed fire hydrants are used with the understanding that they do not represent optimum sampling conditions.
- There should be no water in the trench up to the connection for sampling.

807. Health risk ratings for backflow and cross-connection areas

There are risk ratings related to backflow and cross-connection areas. In this lesson, we will discuss backflow prevention and cross-connection control.

Backflow prevention program information

Water system designers and regulators have developed a number of safeguards to reduce the likelihood of contamination, and the AF manages them through the *Backflow Prevention and Cross-Connection Control Program*. [7] In order to understand the concept of backflow prevention, there are a couple of terms that need to be understood.

- Cross-connection is any connection between a potable water supply system and any system, fixture, or other device through which it may be possible for non-potable, polluted or contaminated water, or other substances to enter the potable water system under any condition.
- Backflow is the undesired reversal of water flow in the drinking water distribution system. There are two types of backflow: *backpressure* and *backsiphonage*.
- Backpressure causes the backward flow of water in the distribution system due to an increased pressure from a non-potable system. When systems containing non-potable water (e.g., boilers or air conditioners) generate pressure that exceeds the supply pressure in the distribution system, backpressure backflow occurs. For example, if a boiler containing chemically treated water is connected to the potable water system and the pressure from the

boiler exceeds the pressure in the potable system, then the chemically treated water will be forced into the potable water system resulting in contamination.

- Backsiphonage is the backward flow of water in the distribution system due to decreased pressure in the potable distribution system. The lower pressure is usually caused by a break in a line, use of fire hydrants, or heavy water demand.

CE, through the base backflow program manager (BPM), has primary responsibility for this proactive program. The BPM identifies, investigates, and documents all cross-connections on each installation, and when possible, eliminates cross-connection hazards. If the BPM cannot eliminate the cross-connection, appropriate backflow devices are used to mitigate the hazard.

The responsibilities of the base BPM and BEE, as defined in AFI 32–1067 are listed below. [7]

Backflow Prevention and Cross-Connection Control Program Responsibilities	
Base Backflow Program Manager	**Bioenvironmental Engineering**
• Manages backflow prevention program. • Identifies, investigates, and documents all cross-connections. • Manages cross-connections by eliminating them when possible. • Has responsibility for the backflow survey. • Follows up on corrective actions identified. • Reviews all plans and drawings of new and modified water systems and facilities to identify potential cross-connections.	• Provides technical assistance to support the Backflow Prevention and Cross-Connection Control Program. • Assigns the hazard classification to each cross-connection. • Recommends appropriate protection for each cross-connection. • Reviews all plans and drawings of new and modified water systems and facilities to identify potential cross-connections.

There have been numerous documented cases of cross-connection problems, which have resulted in compromised water quality and PH. One such example took place in a high school in New Mexico. A home economics teacher noticed that water in the potable system was yellow. Fortunately, the teacher noticed the discolored water before school started that day and immediately covered all the water fountains so that faculty and students wouldn't drink the water. The school closed for several days as an investigation was conducted. The chemical was identified as sodium dichromate, which is a toxic form of chromium. Samples taken from the drinking fountains contained levels of chromium as high as 700 ppm, significantly higher than the accepted levels of 0.05 ppm. The investigation disclosed that chromium used in the heating system boilers to inhibit corrosion of metal parts entered the potable water supply as a result of backflow through leaking check valves on the boiler feed lines. [8]

Water system backflow prevention/cross-connection surveys

CE personnel, under the supervision of the base BPM and with the assistance from BE personnel, survey all facilities and water-using equipment and systems. Surveys are conducted on new facilities before accepting the facility from the builder, and surveys of existing facilities are conducted according to the following schedule:

- A complete survey is conducted every five years.
- An annual survey of 20 percent of the facilities and devices.

NOTE: The annual survey program must ensure that no facility, system, or device goes longer than five years without being surveyed.

BE personnel assign a hazard classification to each cross-connection using *Uniform Plumbing Code* criteria and AFI 32–1067 and recommend appropriate protection for each cross-connection to ensure

that potable water quality is maintained. The hazard classification will be either high hazard or low hazard.

- *High hazard*: A high hazard, also defined as contamination, is an impairment of the quality of the potable water that creates an actual hazard to PH through poisoning or through the spread of disease by sewage, industrial fluids, chemicals, or wastewaters.
- *Low hazard*: A low hazard, also defined as pollution, is an impairment of the quality of the potable water to a degree that does not create a significant hazard to the PH, but that does adversely and unreasonably affect the aesthetic quality of potable water for potable use.

808. Base sanitary surveys

Large quantities of potable water are required on a continuous basis for drinking, firefighting, decontamination, personal hygiene, sanitation, industrial operations and other base functions, and these requirements can only be met if the water systems are properly designed, operated, maintained, and monitored. Sanitary surveys are carried out to evaluate the following:

- The capability of a drinking water system to consistently and reliably deliver an adequate quality and quantity of safe drinking water to the consumer.
- The system's compliance with federal drinking water regulations. [9]

The EPA defines a sanitary survey as:

> *"An onsite review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water."* [10]

Sanitary survey results show current and potential threats to water quality and system reliability. They are used to examine and evaluate eight specific critical elements associated with water systems, as identified by the EPA:

- Source (protection, physical components, and condition).
- Treatment.
- Distribution.
- Finished Water Storage.
- Pumps/Pump Facilities and Controls.
- Monitoring/Reporting/Data Verification.
- Water System Management/Operations.
- Operator Compliance with State Requirements. [3]

Although there are some similarities between sanitary surveys and WVA, there are some significant differences as shown in the table below. [3]

Sanitary Survey vs. Water Vulnerability Assessment	
Similarities	Differences
• Seek to ensure safe drinking water is provided. • Similar technical approach. • Involves many of the same stakeholders and subject matter experts. • Involves evaluation of common areas (system design, integrity, etc.).	• The WVA incorporates assessment criteria specifically designed to safeguard the system from malicious acts, involves interactions with the base antiterrorism officer (ATO) and Force Protection Working Group. • The WVA requires information to be documented in a format consistent with the AF antiterrorism (AT)/Force Protection Program.

Sanitary Survey vs. Water Vulnerability Assessment	
Similarities	Differences
• Requires physical inspection of the entire system.	• The WVA report is, in most cases, a classified document. • The sanitary survey involves a more in-depth review of the water system operations & maintenance and water monitoring programs, as well as recordkeeping and reporting, certifications, and other compliance-related requirements.

Bioenvironmental Engineering role

AFI 48–144 states that BE will make sure a sanitary survey is performed to satisfy the requirements of applicable regulations and standards. Also, BE is responsible for recommending measures to maintain the sanitary quality of the base drinking water system. In most cases, the state has primacy and will conduct the sanitary survey; however, in those instances where the state is not conducting a sanitary survey, BE is responsible for completing it.

Requirements for overseas locations

Installations outside the US and its territories must follow country-specific EGSs/FGSs and/or the OEBGD as applicable, and implement AFI 48–144 in compliance with the OEBGD or EGSs/FGSs. Installations located in areas where no EGSs/FGSs exist must follow the OEBGD. Completing sanitary surveys at AF overseas installations is, in most cases, a BE responsibility. [3]

The deployed environment presents unique challenges regarding PH concerns about drinking water. Air Force Manual (AFMAN) 48–138_IP, *Sanitary Control and Surveillance of Field Water Supplies*, provides detailed information on conducting water source sanitary surveys in a deployed environment.

Frequency

Federal (EPA), OEBGD, or EGS/FGS timelines must be followed when conducting a sanitary survey.

Sanitary Survey Frequency within the United States and at Overseas Locations			
Water Source	**United States**		**Overseas Locations**
	Community System	Non-Community System	
Surface water	3 years*	5 years	3 years
Groundwater under the direct influence of surface water	3 years*	5 years	3 years
Groundwater	3 years**	5 years	5 years

** Community systems that have outstanding performance (as determined by the state) may have sanitary surveys conducted every five years.*

***Community systems that have outstanding performance (as determined by the state) or treat to 4-log (99.99 percent) inactivation of viruses may have sanitary surveys conducted every five years.*

809. Performing base sanitary survey

According to the *USAFSAM Drinking Water Surveillance Technical Guide*, a sanitary survey is conducted in three phases—planning, conducting, and reporting. However, it's important to note that once a survey is complete, follow-up actions, actions to correct identified deficiencies.

Planning pre-survey

A properly conducted and thorough survey includes a review of eight essential areas. The order of the eight elements is not meant to dictate the sequence of survey activities, but to offer a rational division of the essential elements. The eight elements are:

1. Source (protection, physical components, and condition).
2. Treatment.
3. Distribution system.
4. Finished water storage.
5. Pump/pump facility and control.
6. Monitoring, reporting and data verification.
7. Water system operation and management.
8. Operator compliance with state requirements. [3]

Before conducting the onsite portion of a sanitary survey, actions should be taken to help determine focus areas and timeline execution. The following is a list of items that should be reviewed:

- Previous sanitary survey report findings.
- Information about the physical facility.
- Compliance history of the facility.
- Treatment processes in place.
- Monitoring requirements.
- Water quality data.
- Other relevant data. [3]

Following the pre-survey file review, generate a list of items to check in the field, and a list of questions about the system. Establish the format of the survey and estimate how much time it may take to execute.

Conducting onsite surveys

The onsite portion of the base sanitary survey includes visiting the water supply source and source facilities, pump stations, storage facilities, distribution system, sampling locations, and reviewing the treatment process. One of the most important functions of the onsite portion of the survey is to determine whether the existing facilities are adequate. Onsite visits should include a review and verification of the capability, capacity, construction, operation, and physical condition of the system's facilities. [9]

Each of the eight elements that comprise the onsite survey is discussed below based on information presented by the EPA; however, be sure to refer to the *USAFSAM Drinking Water Surveillance Technical Guide* and other local requirements for additional considerations when conducting sanitary surveys.

Element 1–Sources

The water supply source is the beginning of the drinking water system and can be a source of contaminants, pathogens, and particles. Preventing source water contamination is an effective way to prevent contaminants from reaching consumers. Source water protection also helps prevent additional, potentially more costly, treatment to remove contaminants. The objectives of surveying the raw water source are to:

- Review the major components of the source to determine reliability, quality, quantity, and vulnerability.
- Determine and evaluate data that define the degradation potential of the source water quality.

Element 2–Treatment

The types of treatment processes and facilities used to achieve safe drinking water are dictated primarily by the quality of the source water and the regulatory requirements that must be met. Typical groundwater treatment processes often contrast sharply with treatment for surface water sources because all surface water and groundwater under the direct influence of surface water is assumed to be contaminated by harmful microorganisms and will usually require additional treatment methods that will physically remove the pathogens.

The treatment facilities and processes should be capable of removing, sequestering, or inactivating physical, chemical, and biological impurities and meet the necessary requirements. The sanitary survey should be used to:

- Analyze all the distinct parts of the treatment process.
- Review source water quality data that may impact the treatment process.
- Identify features that may pose a sanitary risk (e.g., cross connections in the plant).
- Review the criteria, procedures, and documentation used to comply with regulatory requirements.

Element 3–Distribution system

A thorough inspection of the water distribution system is needed to determine whether it can provide a safe, reliable, and adequate supply of drinking water. The objectives of surveying the water distribution system are to:

- Determine the potential for degradation of the water quality in the distribution system.
- Determine the reliability, quality, quantity, and vulnerability of the distribution system.
- Ensure that the sampling and monitoring plan(s) for the system conform to requirements and adequately assess the quality of water in the distribution system.

Element 4–Finished water storage

Finished or treated water storage facilities provide several benefits to distribution system operations. First, they allow treatment facilities to operate at or near uniform rates, even though the demands of the system may greatly fluctuate. Secondly, they supply the peak and emergency needs of the system. Finally, they maintain an adequate pressure in the system, when designed for that purpose. Finished water storage facilities also serve an important function in maintaining the quality of drinking water ultimately received by the consumer. Proper design, operation, and maintenance of storage facilities are critical to protecting stored water from loss of chlorine residual, bacteria regrowth, contaminant entry, and other water quality problems.

Field surveys should be performed to verify the file information as well as to determine that the water storage facilities are adequate and in acceptable condition. The objectives of surveying the finished water storage facilities are to:

- Review the design and major components of storage to determine reliability, adequacy, quantity, and vulnerability;
- Evaluate the operation and maintenance and safety practices to determine that storage facilities are reliable; and
- Recognize any sanitary risks attributable to storage facilities.

Element 5–Pump/pump facility and control

In a water system, there are many applications that require pumps to move fluids (water, chemicals, etc.) from one point to another. The objectives of surveying the pumps/pump facilities and controls are to:

- Review the design, uses, and major components of water supply pumps.
- Evaluate the operation and maintenance as well as safety practices to determine that water supply pumping facilities are reliable.
- Recognize any sanitary risks attributable to water supply pumping facilities.

Element 6–Monitoring, reporting and data verification

An important part of any process that produces a product for the customer is quality control. For the water industry, quality control consists of monitoring water from the source to the tap with in-house as well as outside laboratory testing for confirmation. For most water systems, federal and/or state regulations dictate the minimum scope of a water quality monitoring plan. The objectives of surveying the water quality monitoring, reporting, and data verification are to:

- Review the water quality monitoring plan for conformance with regulatory requirements;
- Verify that the water quality-monitoring plan is being followed.
- Verify that all in-house testing, equipment and reagents conform to accepted test procedures.
- Consider whether any changes in monitoring frequency or location should be recommended.
- Verify the accuracy of the data submitted to the regulatory agency.
- Evaluate the procedures an operator follows to identify any problems with the process, determine the changes needed to correct the problem, and identify how adjustments to the process are approved and performed as needed.

Element 7–Water system operation and management

Management is a major factor that affects the performance of a water system. Management provides the direction, funding, and support needed for a public water system to continually supply safe drinking water. The objectives of surveying the water system management/operation are to:

- Review the water quality goals and evaluate plan(s) to accomplish or maintain the goals.
- Identify and evaluate the basic information on the system, management, staffing, operations, and maintenance.
- Review/evaluate the plan(s) for safety, emergencies, maintenance, and security.
- Evaluate the water system revenue and budget to meet water quality goals.

Element 8–Operator compliance with state requirements

The overall goal of a water system is to provide an adequate supply, at an acceptable pressure, of safe drinking water to the consumer. The system operators who make the operational, maintenance, and administrative decisions are an essential part of this process. To meet this goal and the associated challenges, water systems operators must be trained, certified (if required by the state agency), and display a high level of competency. Suggested questions that aid in determining the competency of operators and the criteria for operator certification include:

- Do operators know how to operate and maintain the system components?
- Does the system appear to be well operated and maintained?
- Are system personnel appropriately trained?
- Does the system employ an operator(s) of the appropriate certification level?
- Are operator certifications current for all system personnel?
- Are all personnel meeting the minimum renewal requirements for operator certification?

USAFSAM survey support

As mentioned previously, refer to the *USAFSAM Drinking Water Surveillance Technical Guide* and other local requirements for additional considerations when conducting sanitary surveys.

Additionally, USAFSAM has developed 15 separate checklists to assist in completing a sanitary survey. The checklists are available on the Environment, Safety, and Occupational Health Service Center Website and are designed to support in-depth sanitary surveys. The checklists fall into the following categories:

- Water system overview.
- Source water.
- Water treatment.
- Potable water storage.
- Water distribution system.
- Water system pumps and pumps facilities.
- Water contingency response.
- Water monitoring and reporting.
- Water purveyor questionnaire.
- Water system management and operation.

Reporting post survey

Conducting a sanitary survey of the drinking water system is a very comprehensive and potentially time-consuming process and must include documenting and reporting survey findings and recommendations. The sanitary survey report officially communicates the results of the survey to the owners and operators of the water system. The purposes of the survey report are to:

- Notify the water system owners and operators of system deficiencies.
- Request corrective action under a specified schedule.
- Provide a written record for future inspections.
- Provide important information that may be useful in emergencies.

The report should be completed promptly and reflect the information provided to the water utility personnel at the end of the onsite evaluation. The survey report should include:

- The date the survey took place, and the name(s) of the individuals conducting the survey.
- The name(s) of those present during the survey.
- A drawing of the system and, where appropriate, photographs of key system components.
- A statement of system capacity, including source, treatment, and distribution.
- The findings of the survey, along with the signatures of the team members.
- A listing of deficiencies.
- A summary of all analyses and measurements done during the survey.
- The recommended improvements to identified problems, in order of priority, with a timeline for compliance.
- A copy of the survey form.
- A recommendation on whether a system has outstanding performance.

The following table provides examples of significant deficiencies organized by each of the eight essential sanitary elements. **NOTE:** *These examples are intended for illustrative purposes only and are not intended to be a complete list.*

Minimum Sanitary Elements	Examples of Sanitary Survey Deficiencies
Source	• Activities or pollution sources in the immediate wellhead area that will cause sanitary risks. • Cross-connections to storm drains, sanitary sewers, non-potable water supplies, or a pump bearing cooling water. • Unapproved water sources being used.
Treatment	• System is not in compliance with applicable treatment technique requirements. • Unapproved treatment chemicals used. • Cross-connections at chemical tanks, filter backwash, membrane cleaning processes.
Distribution and transmission	• Repeated or frequent total coliform rule (TCR) violations or detections of fecal indicators. • The TCR sampling plan is not representative of the distribution system. • Required disinfection residual levels are not met.
Finished water storage	• The tank's vents or overflows are not screened or protected. • In ground tanks subject to flooding. • The tank's entry hatch or access ladders are not secured.
Pumps/pump facilities and controls	• The air/water relief valves provide a cross-connection to the floor drains. • Auxiliary power needed to keep the system under positive pressure during commonly experienced power outages is not available. • Cross-connections to non-potable supplies, pump or generator cooling water lines.
Monitoring, reporting and data verification	• Operators are using improper procedures and/or methods when conducting onsite laboratory analyses. • The system does not have a compliance or microbial monitoring plan. • The system is not using a certified laboratory.
System management and operation	• System security is inadequate. • Failure to notify the state of MCL violations or groundwater source fecal contamination. • Failure to comply with enforcement actions and compliance agreements.
Operator compliance with state requirements	• The operator is not certified at the level/grade required by the state. • Expired certification. • Inadequate number of operators.

810. Field drinking water

A major role for preventive medicine (PM) personnel from all Military Services during deployment is to ensure that local drinking water sources are potable and palatable. AF PM personnel (i.e., BE) must make sure water sources are safe from any event that would cause a major disruption in supply such as deployment activities, natural disasters, or sabotage.

BE personnel should consult AFMAN 48–138_IP, a multiservice publication to document policy, standards, guidelines, and procedures, to ensure that water used by military and supporting civilian personnel for drinking, showers and personal sanitation, and sanitation in the operational environment (i.e., deployments/field operations) is of the highest quality possible, and that it is not harmful to human health either in the short or long term. Refer to AFMAN 48–138_IP for additional guidance on managing field water systems. [11]

AF roles and responsibilities

Although all military services have the same objectives, some policies and procedures may vary because other services predominantly rely on field water assets common to forward operating bases, whereas the AF is more often deployed to locations that are supported by more robust semi-fixed water assets. In these situations, the AF approach will not differ significantly from those implemented on most AF installations that use fixed water systems. In addition to using AFMAN 48–138_IP, AF PM personnel (i.e., BE personnel) should also refer to AFI 48–144 to make sure all other applicable surveillance requirements are met, to include conducting WVAs using USAFSAM WVA deployment checklists and protocols outlined in the WVA guide.

The following are BE-specific roles outlined in AFMAN 48–138_IP to meet PM field-water objectives:

- Perform drinking water quality surveillance.
- Support investigations of potential drinking water-related illnesses.
- Maintain records of drinking water quality surveillance.
- Ensure laboratories perform analyses using required analytical methods.
- Ensure sanitary surveys are performed and recommend measures to maintain quality.
- Ensure special surveys are conducted as warranted in the event of contamination.
- Ensure WVAs are completed using USAFSAM references.
- Monitor and approve aircraft watering points.
- Interpret results of water analyses and reports.
- Implement public notification procedures when results indicate a potential health threat.
- Conduct engineering reviews of repairs and modifications.
- Review construction/modification plans and drawings to assess potential health hazards.
- Support cross connection and backflow prevention program by classifying health hazards.
- Advise commanders on source water protection opportunities.
- Maintain drinking water analytical data records.

It is also important to understand base CE roles outlined in AFMAN 48–138_IP, which are as follows:

- Design, construct, operate, and maintain drinking water systems.
- Coordinate all modifications/repairs to the drinking water systems with BE.
- Maintain an adequate supply of safe drinking water for the base populace.
- Protect supplies from unintentional contamination.
- Conduct drinking water treatment process control monitoring.
- Make sure a detectable disinfectant residual level is maintained in all parts of the system.
- Develop local operating instructions to include operational monitoring for process control, sampling and testing procedures, emergency operations, maintenance, and OEBGD requirements.
- Conduct a backflow prevention and cross-connection control program.
- Correct distribution system deficiencies identified through assessment or monitoring.
- Notify BE of any unusual events affecting the distribution system that could result in changes to water quality.
- Coordinate contingency support plans and base recovery actions with BE.

- Assist BE in developing and maintaining a sampling, analysis, and monitoring plan.

In the event a BEE or BE technician deploys in support of, or is co-located with, another military service, refer to Part IV (Army Specific Guidance) and Part V (Navy and Marine Corps Specific Guidance) of AFMAN 48–138_IP for applicable service-specific information and guidance.

Standards and guidelines

A PM role includes reviewing the results of water quality tests that are performed in the field as well as at approved remote laboratories, and comparing those results to the appropriate military field water standards (MFWS). If the water meets the standards, it may be declared potable and approved for distribution to personnel for drinking and all other water uses.

There are two sets of MFWS, short-term potability (STP) standards and long-term potability (LTP) standards. The standards are found in AFMAN 48–138_IP, a joint service technical manual. Standards are set with no reference to the amount of water ingested each day, and are set at levels at which some sensitive individuals might experience adverse short-term health reactions, but overall unit performance and mission accomplishment should not be jeopardized.

In addition to the contaminants addressed by the MFWS, there are military exposure guidelines (MEG) identified in the United States Army Public Health Command (USAPHC) Technical Guide 230, *Environmental Health Risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel,* to help you assess exposures to toxic industrial chemicals (TIC) that may be present in treated water.

Short-term potability standards

For water points producing bulk water during the first 30 days of field operations, treated water considered potable can be approved by PM personnel for distribution if it meets STP standards. The STP standards are designed to prevent acute illness and support mission readiness, and most of the STP standard parameters can be measured using field water test equipment.

Long-term potability standards

After 30 days of water production point operation, all shortfalls in equipment and operational monitoring should have been addressed; therefore, water produced after the first 30 days may only be approved as drinking water if it meets the more stringent LTP MFWS. These standards are based on the current US EPA NPDWR/NSDWR established in Title 40 CFR Parts 141 and 143. The LTP standards apply to treated drinking water whether it is in storage; distributed by pipes, vehicles, or trailers; or packaged and distributed by military or contractor systems and personnel.

Microbiological field water standards (short and long term)

The military standards for microbiological water quality standards apply to drinking water systems regardless of the length of time they have been in operation. They include TC as a monitor of operating system integrity and possible environmental and sample handling contamination. It does not necessarily represent potential pathogen contamination to the extent that the presence of Escherichia coli (E. coli) does. The presence of E. coli is a very strong indicator of fecal contamination and, therefore, warrants more concern.

Military exposure guidelines

USAPHC Technical Guide 230 contains water MEGs that may be used to assess potential acute and chronic adverse health risks for personnel who drink water that contains TIC contaminants that either exceed or do not have LTP standards. The water MEGs are, with few exceptions, equal to or less conservative than corresponding LTP standards; however, the MEGs include many chemicals that do not have LTP standards. The MEGs also address different drinking durations (7-day, 14-day, and up to 1 year) and drinking rates (5 and 15 liters per day) than the MFWS.

PM personnel identify the presence of these contaminants in field water by collecting and submitting samples, usually to a remote laboratory, for advanced water testing (AWT). The analytical results from AWT or special testing are then compared to the USAPHC TG 230 water MEGs to assess the potential health risk from any chemicals identified, and used as a basis for making risk-mitigating recommendations to commanders.

Bottled water standards

The STP and LTP standards apply to military- and contractor-produced field drinking water that is used to fill onsite, remote, or mobile water storage units; water that is pumped through tactical water distribution systems; and water that is bottled or packaged by contractor and military systems and personnel. The USAPHC is responsible for inspecting and approving bottled water facilities and operations for all Military Services. Information about approved water sources can be found by visiting the USAPHC drinking water Website. [12]

- *Storage*: Bottled and packaged field water should not be stored in direct sunlight because the light and warmth support bacterial growth. Bottles and packages of water should be stored in shaded, well-ventilated areas and in boxes which keep the caps elevated. Stored bottled/packaged field water should be used on a first in, first out basis, to keep the holding time as short as possible.
- *Commercially Bottled Water*: Commercially bottled water usually has a labeled shelf life of 1 year or more. It may continue to be stored and issued indefinitely beyond its expiration date, if necessary, as long as preventative medicine or veterinary service personnel test representative samples of lots as described below, and approve the expiration date/shelf life extensions.
- *Packaged Field Water*: The initial approved shelf life or expiration date for these packages/bottles, unless prescribed otherwise by PM or veterinary service (VS) personnel, is 30 days from the date of production. Shelf life or expiration dates may not be printed on packaged field water containers or labels. However, at least the production date should be on the bottle, package, or label. Expiration dates may be extended indefinitely in 30-day increments by PM or VS inspectors.

Non-potable water

Water from any untreated or treated source (including bottled water) that has not been tested and determined by the appropriate medical authority to be safe for deployed personnel to drink is considered non-potable. The water may or may not be truly safe to drink. The PM personnel can recommend authorizing the use of non-potable water for showers and personal sanitation after the associated risks have been assessed and found to be acceptable; however, non-potable water storage tanks, taps, and spigots that have been approved for showering and personal sanitation must be labeled to warn personnel not to drink the water.

Palatable water

Palatable water is water that is pleasing to the senses. Palatability is evaluated in terms of temperature, color, taste, and odor, and acceptable levels for these parameters are included in the STP and LTP MFWS. Water may be palatable and yet not be potable—it may look and taste good, but still have the potential to cause sickness. On the other hand, potable water may not taste, look, or smell good. The goal of military water systems is to provide adequate quantities of drinking water that it is both potable and palatable.

Emergency drinking water

- Drinking water standards do not apply when personnel are cut off from supply lines and military-approved water is not available. In such cases, each individual should select the clearest, cleanest water with the least odor available, and treat the water by one of the following:
- *Iodine*: Iodine water purification tablets (National Stock Number (NSN) 6850–00–985–7166) are intended to disinfect water in small containers such as canteens or water jugs. The tablets are composed of an iodine compound and are available through the Federal Supply System in bottles of 50 tablets. The tablets are subject to deterioration in storage. They must be inspected for signs of physical change before they are used; otherwise, they may not disinfect the water.
- *Boiling*: Boiling is an expedient means of disinfecting small quantities of water when no other means is available. To be effective in killing most disease-producing organisms, the water must be held at a rolling boil for 5 minutes at sea level. At sea level, water boils at 212 °F or 100 °C. To achieve the same microbiological kill at higher elevations, the water must be boiled for longer periods.
- *Chlor-Floc*: Chlor-Floc is an emergency disinfectant mixed with a settling aid that helps remove dirt and other suspended particles from water by flocculation and sedimentation. If it is available, it should be used when the water to be treated is cloudy or discolored and the operational situation is such that the treatment bag can remain motionless for the required settling period and can then be filtered.
- *Household bleach*: When calcium hypochlorite is not available to disinfect bulk supplies, commercial household chlorine bleach (unscented sodium hypochlorite) can be used in its place. Household bleach is normally a 5 percent or 50,000 mg/L chlorine solution. In general, add two drops of bleach per quart of water to be disinfected and let it stand for 30 min before drinking.
- *Marine Corps-approved individual water purification system (IWPS)*: Marine Corps System Command has fielded the IWPS to be used for emergency disinfection of an unapproved water source. The IWPS includes a 3-liter hydration bag and Mountain Safety Research, Inc. (MSR®)/CamelBak® in-line hollow fiber and charcoal filters to be used in conjunction with the MSR MIOX Purifier, also known as the MSR MIOX Pen. The manufacturer's operating instructions must be followed exactly to ensure adequate disinfection.

Potable and non-potable water uses

Potable water should be used for nearly all military water-requiring activities if it is available. From a military health perspective, potable water must be used for all activities in which there is a significant risk to a Military Service members' well-being from doing otherwise. These include drinking, cooking, brushing teeth, shaving, and making ice that contacts food. Potable water should also be used for showering because of exposure to cuts and scratches, incidental ingestion, and breathing of volatile or aerosolized material, all of which may allow contaminant entrance into the body. However, disinfected water of less than drinking water quality may be used for showering, personal sanitation, personnel decontamination, and heat casualty cooling, after an appropriate health risk assessment of the proposed water supply is performed by PM personnel and the action is approved by the commander, as shown in figure 1–6 below.

Water Class/Quality	Acceptable Activities
Class I – Potable **a. ROWPU Treated Water** **b. Bottled Water** **c. Packaged Field Water** **d. Approved Municipal Water** **e. Approved Ground Water**	a. Drinking water b. Brushing teeth c. Showers and personal sanitation[1] d. Dining facility operations e. Ice production for food preservation and cooling f. Medical treatment g. Potable water hose and pipeline testing and flushing
Class II[2] **a. Disinfected[3] Filtered[4] Fresh Water** **b. Disinfected[3] Fresh Water** **c. Treated Shower and Laundry Water[5]**	a. Decontamination of personnel[1] b. Heat casualty body cooling[1] c. Well development d. Graves registration personnel sanitation e. Retrograde cargo washing
Class III – Not Potable **a. Untreated Fresh Water**	a. Vehicle coolant b. Aircraft washing c. Pest control d. Field laundry e. Concrete construction f. Well drilling
Class IV[6] – Not Potable **a. Brackish Water** **b. Seawater**	a. Vehicle washing b. Electrical grounding c. Fire fighting d. Chemical, biological, radiological, and nuclear (CBRN) decontamination of materiel e. Dust control[7]

Notes:
[1]Permission to use other than potable water for these activities requires a risk assessment by PM assets and approval by the commander.
[2]For some surface and ground water sources, class II a and II b waters may meet short- and/or long-term potability standards, and may be used for drinking water, with PM and command approval. Such use would require a 2 mg/L FAC residual after a 30- min contact time prior to distribution.
[3]For nonpotable water, disinfected means having at least a 1 mg/L FAC residual after a 30-min contact time and at the time of use.
[4]Fresh water that has been filtered through multimedia filters, microfilters, or ultrafilters, and possibly RO concentrate water from fresh water treatment operations, depending on its quality, may be disinfected and used in lieu of or in preference to disinfected fresh water, with PM and command approval.
[5]Applies to Force Provider operations only, and has specific treatment and operational monitoring requirements specified in a 2004 Office of The Surgeon General memorandum and USACHPPM Information Paper (IP) 31-027.
[6]Brackish and seawater are minimally acceptable and may lead to significant corrosion if used; therefore, fresh water should be used if possible. ROWPU brine from seawater desalination operations may not be used.
[7]Use of nondisinfected water or any kind of wastewater, treated or not, for dust suppression requires the approval of the area medical authority, and is dependent on the quality of the water and on the potential it poses for human contact with pathogenic microorganisms.

Figure 1–6. Typical Uses of Different Classes/Qualities of Water in the Field. [11]

Water source selection

The PM personnel perform a number of important missions during deployment operations, one of which is selecting a viable source of water. There are two kinds of water sources that may be found in the field:

- Raw water sources that must be treated and/or disinfected before use.
- Water that has already been treated and is approved for use.

Raw water may be available from many different sources in the field including surface water (rivers, streams, ponds, lakes, rain, ice, snow, seas, and oceans), groundwater (wells or springs), and in some cases, from municipal water treatment systems located in the deployment area. Given a choice, it is

important to select the raw water with the best quality available as a source for any water treatment system. Military doctrine dictates that water from all raw water sources and host nation municipal drinking water systems, regardless of how clean they may appear, is non-potable until it is shown to meet the appropriate MFWS, and/or is approved by PM personnel for drinking. In many modern military operations, locally produced bottled water may be readily available. It likewise must be approved by VS to be sure it is safe to drink.

Source selection guidelines

Source selection initially involves reviewing medical intelligence information to help identify and select the best water sources to use for field water production. However, since the accuracy of the intelligence concerning those sources needs to be physically confirmed, final selection of a raw water source requires:

- An onsite source water reconnaissance survey.
- Raw water characterization.

A raw water source sanitary survey involves examining the proposed water source and the surrounding area for existing and potential sources of pollution and evidence of contamination. If visible evidence of contamination such as dead fish, rotting vegetation, oil film or sheen, floating or submerged garbage, or discharges from industrial areas is observed, a different source should be considered. If that is not possible, control measures must be implemented to minimize existing or potential exposure to contamination. There are a number of items that should be considered when surveying and comparing water sources.

Raw Water Source Parameter	Reconnaissance Considerations
Water quantity	Is the source permanent or intermittent, depending on season, temperature, or other factors (human controls such as dams)? The greater the source flow and volume, the lesser the impact from added toxic substances (intentional or accidental).
Pollution sources nearby or geographically located so that runoff/discharge may reach the source by surface runoff or subsurface movement	Landfills; agricultural and livestock wastes; industrial discharges; petroleum refineries, distribution, or storage systems; domestic sewage discharges.
Visible evidence of contamination	Dead fish or vegetation, excessive algae growth, oil slicks/sludge, or strange-colored soil or surface residues.
Potential for contamination from accidents or hostile action	Upstream industrial facilities with significant quantities of toxic industrial chemicals; toxic industrial chemical transportation routes in upstream watershed area; upstream area controlled by hostile forces.
Information from local populations	Smells, tastes, health effects and/or endemic water-borne diseases.

It is important to select the least-contaminated source water available for treatment because of the uncertainty in efficiency of rejection of industrial organics in military treatment systems. Surface waters immediately downstream from municipal or industrial outfalls should be avoided, and outfalls from petrochemical complexes are of particular concern. Also, although an undamaged and properly operated reverse osmosis (RO) membrane removes a significant percentage of all microbiological organisms, it is important to avoid source water that may contain human or other animal wastes since, for the most part, RO membranes have not been specifically tested for removal of bacteria, viruses, and parasites such as Giardia or Cryptosporidium cysts.

Using host nation municipal water systems

Where a host nation municipal water system is identified as a potential water source for deployed personnel, it must be considered a raw water source until it is approved by PM personnel for drinking or other uses that would normally require the water to be treated. If trying to use a host nation

municipal water system, assess the performance and overall condition of the municipal treatment and distribution system that will serve as the water source, to include assessing the potential for accidental or intentional contamination of the water system. It's important to conduct as thorough an analysis and assessment as the tactical mission allows.

To be considered for use as drinking water without additional treatment, the water must meet the STP standards for the first 30 days of use, after which the water must meet the LTP standards. The list of STP and LTP requirements is available in AFMAN 48–138_IP.

For a host nation municipal water system to be considered for use as non-potable shower and personal sanitation water, the water must meet the criteria in the table at the end of this lesson. The presumption is that the exposure to the water and any contained impurities are almost exclusively through contact, and that little or none of the water is ingested. When samples of these waters are submitted for AWT, PM personnel perform a health risk assessment for each parameter that exceeds an MFWS or MEG; however, a risk assessment of this should consider that the exposure primarily is contact with skin, and therefore includes minimal ingestion, inhalation, and eye contact.

Field water treatment and Disinfection

Typical field water treatment processes include straining; chemical addition; coagulation; sedimentation; various kinds of filtration including multimedia, cartridge, microfiltration, and ultrafiltration; RO; carbon adsorption; and ion exchange.

Military reverse osmosis water purification units (ROWPU)

Currently, most of the water purification systems in the US Military Services employ RO membranes to provide the ultimate barrier to chemical, microbial, organic, and radiological contaminants. When functioning properly, the membranes remove essentially all pathogens and reduce the concentrations of many dissolved chemicals of concern. Military ROWPUs employ chemical addition and filtration systems ahead of the RO cartridges to remove impurities that can rapidly clog the membranes, and also have post-RO cartridges of ion exchange and carbon filters that can be connected to remove chemicals that may pass through the RO membranes. The ROWPUs are designed to treat fresh and sea water (fig. 1–7).

There are many different kinds of RO membranes, and their abilities to remove impurities from water differ. Generally, the higher the pressure required to force water through the membrane, the "tighter" the membrane is, and the more efficient it is at removing impurities; however, it is important to note that not all contaminants are removed that well.

It is important to disinfect the ROWPU product water in order to provide measurable free available chlorine (FAC) residual for operational monitoring and PM surveillance purposes and some protection against accidental post-treatment contamination by pathogenic microorganisms. A sufficient amount of disinfectant needs to be added to ROWPU-treated water at the production site to provide a 2.0 mg/L (or ppm) FAC residual after a 30-minute contact time.

Figure 1–7. A ROWPU set up at Holloman AFB.

Commercial/contractor-operated water treatment systems

Commercial contractors frequently produce water for deployed personnel in the operational environment. Contractors may operate military ROWPUs or may set up and operate their own water treatment equipment and systems. Contractors who operate water systems must provide information that allows PM personnel to assess the capabilities and effectiveness of their water collection, treatment, storage, and distribution operations. Contractors must be able to provide documentation upon request that demonstrates the chemicals and materials they use have been appropriately tested and certified.

Chlorine disinfection

Chlorine is the preferred military water disinfectant and is normally specified for military use, and the most common chemical for bulk water disinfection is calcium hypochlorite that is approximately 68 to 70 percent FAC. No other disinfectant has been shown to be as acceptable or adaptable for field potable water treatment operations. For example, although ozone and UV radiation may be excellent disinfectants, they do not provide a measurable residual for post-treatment contamination or control microbiological regrowth like chlorine does, and so are not as desirable for use in the field. The BE personnel will determine the adequacy of other disinfectants that are encountered in the field, available locally, and/or used by contractors. The *most* important variables in the effectiveness of chlorine disinfection of drinking water are:

- *Chlorine dose*—amount added per unit volume of water.
- *Chlorine demand*—amount per liter of water that reacts with inorganic and organic matter.
- *Residual concentration*—amount left over and is available for disinfection.
- *Contact time*—the time needed for chlorine to react with and inactivate microorganisms.

The following table provides information on the recommended field water chlorine residuals, with supporting information in the paragraphs that follow.

Field Water Recommended Chlorine Residuals		
Action/Location	**Chlorine Residual**	**Comments**
Potable Water Requirements		
Point of production and initial distribution into storage or transportation containers, or into a distribution system	2 mg/L FAC	After a 30-minute contact time
Delivery to secondary storage or distribution containers and systems	1 mg/L FAC	If between 0.2 and 1 mg/L, chlorinate to 1 mg/L and deliver. If less than 0.2 mg/L, chlorinate to 2 mg/L and ensure that at least 1 mg/L FAC remains after 30 minutes
Delivery to unit level storage containers (e.g., water buffaloes, 5-gallon containers)	1 mg/L FAC	If between 0.2 and 1 mg/L, chlorinate to 1 mg/L and deliver. If less than 0.2 mg/L, chlorinate to 1 mg/L and ensure that at least 1 mg/L FAC remains after 30 minutes
Filling canteens, personal hydration systems, and other individual-use containers	0.2 mg/L FAC	If less than 0.2 mg/L (or lowest measurable value), chlorinate to 1 mg/L and ensure that at least 1 mg/L FAC remains after 30 minutes
Bottled water	No requirement	Must be from VS-approved vendor
Packaged field water – when filling package (pouch, bottle, or other container)	1 mg/L FAC	Use of a lower or no residual after disinfection may be acceptable, but only after VS and/or PM evaluation of equipment, operations, and water quality
Fresh Water Approved for Drinking		
Groundwater approved by PM for drinking after only disinfection	2 mg/L FAC	After a 30-minute contact time, prior to distribution
Emergency only – Disinfecting natural surface water, or well water under the direct influence of surface water, for drinking – no other treatment available	5 mg/L FAC	After a 30-minute contact time. Alternate emergency treatment is boiling fresh water for 5 minutes. Where *Cryptosporidium parvum* is suspected to be present in untreated water, boiling is the recommended emergency water treatment method because of the relative ineffectiveness of chlorine and iodine against that organism
Non-potable Water for Showers and Personal Sanitation		
Point of production and initial distribution into storage or transportation containers	1 mg/L FAC	After a 30-minute contact time
Delivery to intermediate storage or distribution containers and systems	1 mg/L FAC	If used
Deliver to unit level containers	1 mg/L FAC	e.g., shower point storage containers
Recycled water	1 mg/L FAC	See chapter 9 of AFMAN 48–138_IP for details

ROWPU-treated drinking water, both military and contractor-operated, must have a 2.0-mg/L FAC residual after a 30-minute contact time.

Drinking water treated by methods other than a ROWPU has the following requirements:

- If the treatment removes turbidity, cysts, and spores, and the treated water can meet STP and LTP standards, 2 mg/L FAC with a 30-minute contact time is acceptable.
- If the treatment will *not* effectively remove cysts and spores, a 5.0 mg/L FAC residual after a 30-minute contact time should be achieved.

Bulk water issue points along tactical distribution systems, at tank farms, and during bulk transport should be maintained at a chlorine residual level of 1.0 mg/L as much as possible.

Unit level storage containers (e.g., water buffalo, 5 gallon containers) must be maintained at least a 0.2 mg/L FAC residual level after meeting the 1.0 mg/L chlorine residual requirement for the *delivery* of water, as shown in the table above. The intent of this requirement is to provide water that is both potable and palatable. If the chlorine residual falls below 0.2 mg/L, the water in the container should be chlorinated to raise the residual to 1 mg/L after a 30-minute contact time before it can be issued to personnel again.

Fresh water should have a 2 mg/L FAC residual for 30 minutes before drinking when only disinfection is available as a treatment method. If *Giardia* or *Cryptosporidium* are known or expected to be present in the source water, at least 5 mg/L for 30 minutes is advisable. Individual water purifiers may be used for short periods when necessary.

Chlorine residual measurement frequencies

Military and contractor water treatment system operators, water delivery personnel, trained unit personnel, and PM personnel, as appropriate, should measure chlorine residuals at the times and frequencies shown in the table below. The measurement times and results should be recorded and reported in accordance with unit and command policy.

Chlorine Residual Measurements		
Location	**Frequency**	**Tested by**
Potable water purification points	Every 30 minutes during water production operations	ROWPU operators
Bulk potable water distribution points	At times of receipt and bulk loading	Water treatment system operators
Non-potable shower and personal sanitation water treatment/chlorination points	At least every hour during water production and at the time of bulk loading for transport	Water treatment system operators
Field shower and personal sanitation water storage points	At the time of delivery/receipt and at least two additional times daily (recommend prior to periods of high use)	Water treatment system operators
Unit potable water storage	At least twice daily	Trained unit-level personnel
Food Service water supply	Prior to beginning food preparations for each meal	Food service personnel

Chlorine dose calculations and measurements

The following tables provide volumes in drops (dp), milliliters (mL), teaspoons (tsp), tablespoons (tbls), cups (cp), quarts (qt), and gallons (gal) of liquid bleach, dry chlorine granules (high test hypochlorite [HTH]), and a concentrated calcium hypochlorite solution that, when added to the indicated volume of water, will provide the approximate chlorine dose (in mg/L) indicated. The chlorine residual achieved using these values will depend on the chlorine demand exerted by the water that is chlorinated. If there is no chlorine demand, the residual should equal the dose. The greater the chlorine demand, the lower the residual will be. Note that for all chlorine residual

concentrations in water, values in ppm are equivalent to values in mg/L (for example, 10 ppm = 10 mg/L).

Volume of 5 percent liquid bleach (typical household bleach) required to obtain a specific chlorine dose when added to the corresponding gallons of water					
Gallons of Water	**Chlorine Dose**				
	1 mg/L	**2 mg/L**	**5 mg/L**	**10 mg/L**	**100 mg/L**
5	6 dp	0.75 mL	1.9 mL	3.8 mL	8 tsp
10	0.75 mL	1.5 mL	3.8 mL	1.5 tsp	16 tsp
25	2 mL	3.8 mL	2 tsp	4 tsp	1 cp
36	3 mL	5.5 mL	2.75 tsp	2 tbls	1.25 cp
50	4 mL	1.5 tsp	4 tsp	3 tbls	1.75 cp
100	7.7 mL	3 tsp	3 tbls	5 tbls	3.25 cp
400	2 tbls	4.25 tbls	0.75 cp	1.5 cp	3 qt
500	3 tbls	0.33 cp	1 cp	1.75 cp	1 gal
1000	0.33 cp	0.67 cp	1.75 cp	3.25 cp	2 gal
2000	.66 cp	1.34 cp	3.5 cp	6.5 cp	4 gal

For example, if 50 gallons of water need to be disinfected and the required chlorine dose is 5 mg/L, use the table above to find the corresponding volume of 5 percent liquid bleach. For 50 gallons of water and chlorine dose of 5 mg/L, the required amount of 5 percent liquid bleach is 4 teaspoons.

Volume of 70 percent HTH (or solution concentrate[1]) required for to obtain a specific chlorine dose when added to the corresponding gallons of water					
Gallons of Water	**Chlorine Dose**				
	1 mg/L	**2 mg/L**	**5 mg/L**	**10 mg/L**	**100 mg/L**
5	0.9 mL	1.7 mL	4.1 mL	8.3 mL	0.25 tsp
10	1.7 mL	3.3 mL	8.3 mL	16.6 mL	0.5 tsp
25	4.1 mL	8.3 mL	20.7 mL	41.4 mL	1.25 tsp
36	6 mL	11.9 mL	29.8 mL	0.9 mL	1.75 tsp
50	8.3 mL	16.6 mL	0.6 mL	0.25 tsp	2.5 tsp
100	16.6 mL	33 mL	0.25 tsp	0.5 tsp	5 tsp
400	0.92 mL	1.9 mL	1 tsp	2 tsp	19 tsp
500	1.3 mL	0.5 tsp	1.25 tsp	2.5 tsp	0.5 cp
1000	0.5 tsp	1 tsp	2.5 tsp	5 tsp	1 cp
2000	1 tsp	2 tsp	5 tsp	10 tsp	2 cp
Note: *[1]The shaded area of the table indicates the volume of a concentrated solution made from dissolving 1 tsp of HTH in a half canteen cup (1½ cups) of water.*					

The *liquid volume conversion table*, below, is useful in converting from one unit of measurement to another. It shows equivalent values for common units of measurement. Units (e.g., mL, tsp, tbls) increase from left to right and top to bottom. All volumes on the same horizontal line (row) are equal. For example, the "ounce" row shows that 1 ounce (oz), 444 dps, 30 mL, 6 tsp, and 2 tbls are all equal volumes. Continuing to the right on the same row indicates that 1 oz. is also equal to 0.125 or 1/8th cp, 0.063 pints (pt), 0.031 quarts (qt), and so on across the table.

Liquid volume conversions										
	drop	**mL**	**tsp**	**tbls**	**ounce**	**cup**	**pint**	**quart**	**liter**	**gal**
drop	1	0.067	0.013	0.004	0.002					
mL	15	1	0.200	0.067	0.033	0.0042	0.0021	0.0011	0.0010	
tsp	74	5	1	0.333	0.167	0.021	0.010	0.005	0.005	0.001

Liquid volume conversions										
	drop	**mL**	**tsp**	**tbls**	**ounce**	**cup**	**pint**	**quart**	**liter**	**gal**
tbls	222	15	3	1	0.500	0.063	0.031	0.016	0.015	0.004
ounce	444	30	6	2	1	0.125	0.063	0.031	0.030	0.008
cup	3550	237	48	16	8	1	0.500	0.250	0.240	0.063
pint	7100	473	96	32	16	2	1	0.500	0.480	0.125
quart	14200	946	192	64	32	4	2	1	0.960	0.25
liter	15000	1000	203	68	34	4.2	2.1	1.06	1	0.26
gal	56775	3785	768	256	128	16	8	4	3.785	1

Fraction to Decimal Conversions				
Fraction	**Decimal**		**Fraction**	**Decimal**
1/16	0.0625		9/16	0.5625
1/8	0.125		5/8	0.625
3/16	0.1875		11/16	0.6875
¼	0.25		3/4	0.75
5/16	0.3125		13/16	0.8125
3/8	0.375		7/8	0.875
7/16	0.4375		15/16	0.9375
½	0.500		16/16	1.00

If the volume and/or concentration are not in the tables above, use the following equations to calculate the volume of required bleach, HTH, or concentrated calcium hypochlorite solution in mL; then use the *liquid volumes conversion table* to convert that volume in mL for use with the best measuring device available.

For HTH

Step 1

$$\text{grams HTH} = \frac{\text{desired mg/L chlorine} \times \text{gallons to be treated} \times 3.785\ \text{L/gal}}{1{,}000\ \text{mg/g} \times (\text{percent available chlorine in HTH}/100)}$$

Step 2

$$\text{mL HTH} = \frac{\text{grams HTH}}{\text{HTH density in g/mL}} \qquad \text{(use result from Step 1)}$$

(typical density is 2.35 g/mL)

For Liquid Bleach

$$\text{mL liquid bleach} = \frac{\text{desired mg/L chlorine} \times \text{gallons to be treated} \times 3.785\ \text{L/gal}}{1{,}000\ \text{mg/mL} \times (\text{percent chlorine in bleach}/100)}$$

Household bleach is normally a 5 percent (50,000 mg/L) chlorine solution. Calcium hypochlorite, commonly referred to as HTH, typically contains 68 to 70 percent by weight of available chlorine when fresh. Because of this, the above formulas can be simplified to the following formulas:

For liquid bleach (~ 5 percent available chlorine)

$$\text{mL required} = \frac{\text{desired mg/L chlorine} \times \text{number of gallons to be treated}}{13.2}$$

For HTH (~70 percent available chlorine)

$$\text{mL required} = \frac{\text{desired mg/L chlorine} \times \text{number of gallons to be treated}}{434.6}$$

For a calcium hypochlorite solution made from adding 1 level tsp HTH to half a canteen cup of water:

mL required = $\frac{\text{desired concentration in mg/L x number of gallons to be treated}}{6.04}$

For example:
Chlorinating 10 gallons of water with a dose of 5 mg/L chlorine requires the following, using the simplified formulas:

$\frac{5 \times 10}{13.2} = 3.8$ mL (**5 percent bleach)**

$\frac{5 \times 10}{434.6} = 0.115$ mL (**70 percent HTH)**, or

$\frac{5 \times 10}{6.04} = 8.3$ mL **concentrated hypochlorite solution made from 1 level tsp HTH in half a canteen cup (1 ½ cups) of water**

Field water sampling

As soon as possible after field water treatment and disinfection operations at a water production point are fully functional, PM personnel need to:

- Inspect and test the water system to ensure water meets STP standards.
- Collect and submit treated water samples for initial LTP testing.
- Collect and submit raw source water samples (if not already done) to characterize the raw water source.

STP and initial approval

The procedures involve PM onsite testing using field test kits since most of the parameters listed in the STP standards can be measured using field water test equipment organic to PM field operations. For example, use the Hach 2400 water testing kit (or equivalent) to test for the chemical parameters, follow EPA-approved testing method (i.e., membrane filter technique, Colilert® and Colisure®) to test for the presence/absence of coliforms and E. coli, and use the M272 chemical agent water testing kit to screen raw water supplies for the presence/absence of chemical agents.

If the field test results confirm that the treated water meets the STP standards shown in the appropriate table, the water can be declared potable for short-term use (up to 30 days) and approved for distribution.

LTP samples

AWT is required to confirm compliance with LTP standards for systems that operate longer than 30 days. The LTP standards are shown in the table. The procedures involve PM onsite testing and collecting and submitting water samples using water sampling kits provided by in-theater or remote laboratories that have the capabilities to test for the LTP parameters. One such laboratory is the USAPHC laboratory. Another lab with LTP parameter testing capabilities is the USAFSAM laboratory.

The following are water sampling best practices:

- Water samples should be as representative as possible of the bulk raw or treated water.
- Use appropriate chemical and environmental preservation techniques.
- Avoid contaminating the water sample or collection vessels.
- Collect water purification system product samples from a point where the disinfectant (chlorine) has had at least a 30-minutes contact time prior to sampling.

- Dechlorinate treated water samples collected for microbiological testing (typically using sodium thiosulfate or sodium bisulfite) at the time of sample collection to halt the bactericidal action of residual chlorine.

The USAPHC has developed water sampling kits for PM personnel to collect and submit water samples for analysis. The kits are specifically designed for sampling treated water and raw water sources. Each kit includes instructions that provide step-by-step procedures for collecting and shipping the water samples to the supporting laboratory:

1. Clearly identify the type of water being sampled, whether it is raw or treated surface water or groundwater, and if treated, whether by ROWPU or by some other method so the correct kit is provided.
2. All directions must be followed explicitly, including staying within the appropriate shipping times and temperatures to the extent possible.
3. Coordinate with the receiving laboratory before shipping the samples if different from the one the sampling kit came from to ensure the new lab can perform all the desired analyses using the sample containers in the kit.
4. Complete included field data sheets accurately to document critical sample information.

If no instructions accompany the sampling containers, the following general guidance should be followed:

- Label samples so test results can be accurately traced back to the time, location, and specific water that was sampled.
- Identify whether the water is raw/untreated water, treated water, wastewater, or something else.
- Give each sample a unique sample number.
- Maintain a log relating each sample to its collection location and the analytes being tested.
- Identify all preservatives added to the samples.
- Record the date, time, and location of the sampling event.
- Take photos or make a drawing of the location.
- Collect grid coordinates, if possible.
- Provide model and serial numbers of the treatment equipment components if the sample is treated water, if available.

If a water production site is approved for potable water distribution under the STP standards and samples for LTP testing have been collected and submitted, but the results are not received before the 30th day of operation, production and distribution may continue under the STP approval until the test results are received, with PM recommendation and permission from the local medical authority and unit commander.

Chemical agent testing

Use the M272 kit to conduct water tests for chemical agents if there is threat or intelligence information suggesting possible contamination. The M272 kit detection limits are not as low as the MFWS concentrations, but instead are employed as gross-level clearance indicators, and should be used on raw water first, because the concentrations in the raw water, if there are any, will be greater and easier to detect than in treated water.

If water purification operations have started, the reject/brine stream from the ROWPU can be used to test for chemical agents because the agents will be concentrated in the brine stream due to the membrane rejection capabilities and the volume reduction of the raw water stream making it easier to

detect the agents. If chemical, biological, radiological, and nuclear (CBRN) contamination is a concern, or if contaminants are identified at any stage in water source or treatment system evaluations, water purification personnel will need to immediately connect the CBRN filters.

The MFWS for chemical agents in drinking water are for exposures of seven days or less. There are no 30-day or long-term agent standards, because it is anticipated that an alternate water source would be found as soon as possible if chemical agents were discovered in the source water being used.

Frequency of Source Water Testing for Chemical Warfare Agent and Radioactivity According to Threat and MOPP Level		
Threat level	**MOPP Level[1]**	**Test frequency**
No known threat	0	Weekly
Slight threat	1	Daily
Medium threat	2	Twice daily
Severe threat	3	Four times daily
Imminent threat	4	Hourly
Known contamination	4	Hourly and before issue of each batch of water
Note: *[1]Extracted from FM 10–52–1. MOPP = mission-oriented protective posture*		

Bottled water testing

When bottled or packaged field water is a significant percentage of the total force drinking water, the procedures can be very daunting in terms of personnel, time, and in-theater travel. The following are guidelines for a conservative PM bottled water quality surveillance program and can be easily modified. The PM personnel should consider the time requirements and operational risk resulting from fully implementing these procedures, and modify them as necessary to optimize the tradeoffs among operational risk, health risk if contamination goes unobserved, and time requirements. The following procedures are guidelines for a conservative PM bottled water quality surveillance program.

- Logistics personnel may begin issuing bottled and packaged field water received from or produced at VS-approved facilities/sources upon receipt.
- PM personnel should test representative samples of bottled water (1 percent of the total number of bottles, up to a maximum of 10 bottles), randomly selected from a single lot.
- A lot number may be identified by a number on the bottles or labels, or all bottles of a brand with the same production date.
- Test representative samples in accordance with EPA-approved testing (e.g., membrane filter technique, Colilert® or Colisure®).
- Retest representative samples from the same lot if samples are positive, and suspend the lot from being issued.
- The entire lot should not be used for potable purposes if the confirmation test results indicate the presence of coliforms.
- Immediately notify the nearest veterinary detachment and suspend issue from the suspicious lot if the water in any of the bottles is cloudy, tampering is suspected, or coliform positive samples are identified.
- If no other sources of drinking water are available, bottled or packaged field water that have tested positive for coliforms may be issued for drinking, along with stern guidance that iodine, Chlor-Floc, unscented chlorine bleach or boiling must be administered to disinfect the water prior to drinking it.

Military field water standards

Short-Term Potability Military Field Water Standards [11]	
Parameter	**30-day Standard (mg/L)[1]**
Physical properties	
Color	15 CU
Odor (PM evaluation and customer response)	Acceptable
pH	5 – 9 pH units
TDS	1000
Temperature	15 – 22 °C
Turbidity	1 NTU
Chemical properties	
Arsenic	0.02
Chloride	600
Cyanide (as free cyanide)	2.0
Magnesium	30
Sulfate	250
Microbiological properties	
TC	0 CFU/100 mL
Escherichia Coli	0 CFU/100 mL
Chemical warfare agents[2]	
Hydrogen cyanide	2.0[2]
BZ (incapacitants)	2.3[2] (µg/L)
Lewisite (as arsenic)	27[2] (µg/L)
Sulfur mustard	47[2] (µg/L)
Nerve agents [3]	4[2] (µg/L)
T–2 toxins[3]	8.7[2] (µg/L)
Radiological	
Gross alpha and/or beta activity[4]	0.05 (µCi/L)

Legend*: mg/L = milligrams per liter; CU = color unit; TDS = total dissolved solids; NTU = nephelometric turbidity unit; CFU/100 mL = colony forming units per 100 milliliters; µg/L = micrograms per liter; µCi/L = microcuries per liter*

Notes*:*

[1]Units are in mg/L unless indicated otherwise.

[2]These values apply for up to 7 days exposures only. It is not anticipated that personnel would remain in an area where water is contaminated with agent longer than 7 days.

[3]See paragraph 4–11e of AFMAN 48–138_IP.

[4]Drinking water contaminated at this level has the potential to expose individuals to approximately 8 roentgen equivalent man (rem) of radiation to the gastrointestinal tract. These exposures should be documented and accounted for in individual units; radiation exposure status (RES) and operational exposure guidance (OEG).

Long-Term Potability Military Field and Bottled Water Standards [11]

Property/Contaminant	Military LTP Standards (mg/L)[1]	Food and Drug Administration (FDA) Standards for Bottled Water (mg/L)[1]
Physical Properties		
Turbidity	1 NTU	5 NTU
Odor	Acceptable	3.1 TON
Color	15 CU	15 CU
pH	6.5–8.5	-
TDS	500	500.0
Disinfectants		
Chloramines (as Cl2)	4.0	4.0
Chlorine (as Cl2)	4.0	4.0
Chlorine dioxide2 (as ClO2)	0.8	0.8
Disinfection Byproducts		
Bromate2	0.010	0.010
Chlorite2	1.0	1.0
Haloacetic acids-five (HAA5)	0.060	0.060
Total trihalomethanes (TTHM)	0.080	0.080
Inorganic Chemicals		
Aluminum	0.2	0.2
Antimony	0.006	0.006
Arsenic	0.010	0.010
Asbestos2 (fibers greater than (>) 10 micrometers)	7 MFL	-
Barium	2	2
Beryllium	0.004	0.004
Cadmium	0.005	0.005
Chloride	250	250.0
Chromium (total)	0.1	0.1
Copper	1.0	1.0
Cyanide (as free cyanide)	0.2	0.2
Fluoride	4.0	(depends on whether natural or added, and varies with temperature-(temp) see Title 21 CFR Part 165, *Beverages*)
Iron	0.3	0.3
Lead	0.015	0.005
Manganese	0.05	0.05
Mercury (inorganic)	0.002	0.002
Nickel	-	0.1
Nitrate (as nitrogen)3	10	10
Nitrite (as nitrogen)3	1	1
Selenium	0.05	0.05
Silver	0.10	0.10

Long-Term Potability Military Field and Bottled Water Standards [11]		
Property/Contaminant	**Military LTP Standards (mg/L)[1]**	**Food and Drug Administration (FDA) Standards for Bottled Water (mg/L)[1]**
Sulfate	250	250.0
Thallium	0.002	0.002
Total nitrate plus nitrite	-	10
Zinc	5	5.0
Organic Chemicals		
1,1,1-Trichloroethane	0.2	0.20
1,1,2-Trichloroethane	0.005	0.005
1,1-Dichloroethylene	0.007	0.007
1,2,4-Trichlorobenzene	0.07	0.07
1,2-Dibromo–3-chloropropane (DBCP)	0.0002	0.0002
1,2-Dichloroethane	0.005	0.005
1,2-Dichloropropane	0.005	0.005
2,4,5-TP (Silvex)	0.05	0.05
2,4-D	0.07	0.07
Alachlor	0.002	0.002
Atrazine	0.003	0.003
Benzene	0.005	0.005
Benzo(a)pyrene (polycyclic aromatic hydrocarbon [PAH])	0.0002	0.0002
Carbofuran	0.04	0.04
Carbon tetrachloride	0.005	0.005
Chlordane	0.002	0.002
Chlorobenzene (mono)	0.1	0.1
cis–1,2-Dichloroethylene	0.07	0.07
Dalapon	0.2	0.2
Di(2-ethylhexyl) adipate	0.4	0.4
Di(2-ethylhexyl) phthalate	0.006	-
Dichloromethane	0.005	0.005
Dinoseb	0.007	0.007
Dioxin2 (2,3,7,8-tetrachlorodlibenzo para dioxin [TCDD])	3x10–8	3x10–8
Diquat	0.02	0.02
Endothall	0.1	0.1
Endrin	0.002	0.002
Ethylbenzene	0.7	0.7
Ethylene dibromide	0.00005	0.00005
Glyphosate	0.7	0.7
Heptachlor	0.0004	0.0004

Long-Term Potability Military Field and Bottled Water Standards [11]		
Property/Contaminant	**Military LTP Standards (mg/L)[1]**	**Food and Drug Administration (FDA) Standards for Bottled Water (mg/L)[1]**
Heptachlor epoxide	0.0002	0.0002
Hexachlorobenzene	0.001	0.001
Hexachlorocyclopentadiene	0.05	0.05
Lindane	0.0002	0.0002
Methoxychlor	0.04	0.04
o-Dichlorobenzene	0.6	0.6
Oxamyl (Vydate)	0.2	0.2
p-Dichlorobenzene	0.075	0.075
Pentachlorophenol	0.001	0.001
Phenols2	-	0.001
Picloram	0.5	0.5
Polychlorinated biphenyls (PCB)	0.0005	0.0005
Simazine	0.004	0.004
Styrene	0.1	0.1
Tetrachloroethylene	0.005	0.005
Toluene	1	1
Toxaphene	0.003	0.003
trans–1,2-Dichloroethylene	0.1	0.1
Trichloroethylene	0.005	0.005
Vinyl chloride	0.002	0.002
Xylenes (total)	10	10
Radiological		
Gross alpha particle activity (excluding radon and uranium)	15 pCi/L	15 pCi/L
Gross beta particle and photon emitter activity	4 mrem/yr	4 mrem/yr
Tritium2,4	0.27 µCi/L	-
Combined Ra–226 and Ra–228 activity2	5 pCi/L	5 pCi/L
Uranium	30 µg/L	30 µg/L
Microorganisms		
E. coli (CFU/100 mL)	0 (P/A)	0 (MF or MPN)
Total coliforms (CFU/100 mL)	0 (P/A)	4 and 1 (MF)5
Viruses	TT	N/A
Giardia	TT	N/A
Cryptosporidium	TT	N/A

***Legend**: LTP = long-term potability; FDA = US Food and Drug Administration; mg/L = milligrams per liter; NTU = nephelometric turbidity units; TON = threshold odor number; CU = color units; MFL = million fibers per liter;*

µg/L = micrograms per liter; pCi/L = picocuries per liter; mrem/yr = millirems per year; CFU/100 mL = colony forming units per 100 milliliters; P/A = presence/absence; MF = membrane filter method;

Long-Term Potability Military Field and Bottled Water Standards [11]		
Property/Contaminant	**Military LTP Standards (mg/L)[1]**	**Food and Drug Administration (FDA) Standards for Bottled Water (mg/L)[1]**

MPN = most probable number method; TT = treatment technique (i.e., adequate filtration and disinfection); N/A = not applicable; MCL = maximum contaminant level; WHO = World Health Organization.

***Notes**:*

[1]Units are in mg/L unless noted. For analytes in water, units of mg/L are equivalent to ppm.

[2]Parameter is neither in the field test kit nor in the 40-mL AWT suite, but must be specifically requested and sampled for if contamination is suspected.

[3]Infants below the age of 6 months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.

[4]Although the current water test kits do not include a test for tritium, current procedures do call for tritium testing in special cases (such as if source water is taken downstream from a nuclear facility). The WHO standard shown has been adopted as the LTP standard.

[5]Not more than one of the analytical units in the sample shall have 4.0 or more CFU/100 mL, and the arithmetic mean shall not exceed 1 CFU/100 mL. MPN method has other requirements – see Title 21 CFR Part 165 for details.

Military microbiological field water standards (short and long term) [11]				
Total Coliform		***E. Coli***		**Interpretation and PM Action**
Absent	**Present**	**Absent**	**Present**	
X		**X**		**Green** : Water safe for drinking
	X	**X**		**Amber**: Caution; OK to drink, but repeat tests, take remedial action if results confirmed.
	X		**X**	**Red**: Water is unsafe to drink. Stop distribution. Inform operators and medical authority / commander.
X			**X**	**Gray**: Testing error: retest

***Notes**:*

***Green**—Total Coliforms Absent, and E. Coli Absent (-/-). These are the expected results. They indicate that the water treatment and disinfection systems are performing properly. Document the results, and no further action is required.*

Amber—Total Coliforms Present, but E. Coli Absent (+/-). Results indicate either a possible breakdown in the treatment and/or disinfection system or contamination of the sample during collection that has resulted in environmental contamination. Warfighters can drink it, but caution is advised. Carefully sample and retest the water, and if the results are (+) again for TC, recommend that quartermaster or engineer personnel take action immediately to confirm that the treatment system is working properly, and to fix any problems that are identified. After remedial action(s) are completed, retest the water. Continue investigating and applying remedial actions until (-) TC results are obtained.

***Red**—Total Coliforms Present, and E. Coli Present (+/+). Results indicate fecal matter contamination and possible breakdown of the treatment and/or disinfection systems. It could also be the result of contamination of the sample. The water must be considered unsafe to drink until the problem is identified and corrected. Immediately notify the water treatment system operators and the Surgeon/Commander and recommend personnel notification, increasing the chlorine dose, issuing personal water container disinfection orders, and/or discontinuing use of the water as appropriate to the situation. Perform confirmatory sampling and analysis. Report the confirmatory results to the system operators and the Surgeon/Commander. If the confirmatory results match the initial sample results (+/+), recommend continuing the previous actions until the problem is resolved. If the second test results are (-/-) or (-/+), remove the restrictions and follow the guidance for Green or Amber conditions, respectively.*

***Gray**—Total Coliforms Absent, and E. Coli Present (-/+). Results indicate that there was a problem with the*

testing, since E. Coli would be expected to show up as TC also. Examine the testing materials for expiration dates and cleanliness, and carefully repeat the sampling and testing. If the condition persists, use new testing materials.

Disinfected fresh water guidance for non-potable uses [11]	
Parameter	**Requirement**
pH	6.5 – 10 pH units
TDS	less than (<) 1500 mg/L
Turbidity	< 1 NTU if filtered; < 10 NTU if not filtered
FAC residual	1 mg/L after 30-min contact time, and maintained until the water is used

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

804. Potable water system classification

1. Water system classification by the EPA generally depends on what two factors?

2. What type of water systems do the NPDWRs apply to?

3. What is a PWS?

4. What is a primacy agency?

805. Drinking water treatment

1. What does water treatment consist of?

2. What is the purpose disinfecting water?

3. What's the difference between a primary and secondary water disinfectant?

4. What is one of the main concerns with adding disinfectants to drinking water?

5. Why is chlorine a preferred method of disinfecting water?

6. What are the concerns with adding fluoride to drinking water?

806. Disinfection of new water mains, water main breaks, and repairs

1. If a water main had a loss of positive pressure less than 20 psi within the main, what actions are required?

2. After the repair of a water main where the slug chlorination method was used, what steps must follow next?

3. What is the purpose of having three chlorination methods when installing new water lines?

4. What are the general procedures for disinfecting existing lines?

807. Health risk ratings for backflow and cross-connection areas

1. What is the responsibility of civil engineering and, specifically, the backflow program manager (BPM) for the installation backflow prevention program?

2. What is a cross-connection in regards to the installation backflow prevention and cross-connection control program?

3. Why are routine inspections of each cross-connection required?

4. What are BE's responsibilities in the backflow prevention and cross-connection control program?

808. Base sanitary surveys

1. Why is a water system sanitary survey conducted?

2. The results of a sanitary survey provide the installation with what type of valuable information?

809. Performing base sanitary surveys

1. What should be done prior to conducting the onsite portion of a sanitary survey?

2. During the onsite visit of a sanitary survey, why is it important to conduct a review of the water supply source?

3. Why is it vital that a finished water storage facility be properly designed, operated, and maintained?

4. Why does source water dictate the type of treatment processes and facilities used to achieve safe drinking water?

810. Field drinking water

1. Explain why BE personnel must refer to both AFMAN 48–138_IP and AFI 48–144 for field water?

2. Identify at least four BE-specific roles outlined in AFMAN 48–138_IP to meet PM field water objectives.

3. Explain the difference between STP standards and LTP standards.

4. Explain why LTP standards and MEGs are not the same.

5. What does a raw water source sanitary survey involve?

6. Summarize how host nation municipal water source selection should be handled.

7. If you are using liquid bleach having approximately 5 percent available chlorine, how much liquid is required to end up with a chlorine residual of 2 mg/L in a 1000 gallon tank?

8. How many bottled water samples should be tested by PM personnel?

1–3. Water Vulnerability Assessments

The importance of having a safe and reliable drinking water system is paramount to the health and welfare of all personnel on an AF installation both in garrison and in a deployed environment.

The USAFSAM *Water Vulnerability Technical Guide* states, “Large quantities of water are required on a continuous basis to meet AF mission demands for drinking, firefighting, industrial operations, decontamination, personal hygiene, food preparation, sanitation, and other needs. To ensure these demands are met, water supplies must be adequately protected from physical disruption and contamination from all hazards posed by intentional threats, accidents, and natural disasters.” [13]

811. Water vulnerability assessment

AFI 10–246, *Food and Water Protection Program*, states AF water supplies are credible targets to inflict casualties and disrupt mission-essential operations. The WVA Technical Guide suggests that in addition to terrorists and militant groups, threats are posed by insiders, criminals, vandals, or other disenfranchised individuals who have various motivations. Inherent water system design characteristics present numerous access points, increase interest in asymmetrical attack methods by operatives, and dependencies on non-AF water suppliers. [13]

Purpose and scope

The purpose of the WVA is to assist commanders, ATOs, and other risk managers in reducing water-related risks from all causes to personnel and mission-essential operations to an acceptable level. The objectives of a WVA include:

- Identifying control deficiencies that can lead to water degradation and/or supply disruption.
- Assessing corresponding levels of risk posed to personnel and mission-essential operations.
- Propose Proposing practical control recommendations and justifying corrective actions.
- Developing inputs for the Core Vulnerability Assessment Management Program (CVAMP) and secure Web-based vulnerability database.
- Assisting stakeholders in recognizing and meeting relevant regulatory requirements.
- Educating stakeholders on water vulnerability and risk-related issues.

The assessment for a water system takes into account the vulnerability of the water supply, both ground and surface water sources, transmission, treatment, and distribution systems. It also considers risks posed by the surrounding community, natural disasters, accidents, or attacks to the water system. The Air Force Vulnerability Assessment Program was not designed solely to address physical security, but also survivability aspects that include appropriate water system design and integrity, operations and maintenance, and contingency response. The CVAMP can help elevate the visibility and level of support from key decision makers for needed capital improvements, equipment and process upgrades, and other measures that improve the overall security, safety, and reliability of critical water assets. [11]

812. Performing water vulnerability assessment

The *USAFSAM Drinking Water Surveillance Technical Guide*, 2011 provides detailed guidance on conducting a comprehensive WVA. The WVA process ranges in complexity based on the design and operation of the water system, population affected, source water, treatment plant and system infrastructure. Security and safety evaluations are completed by visiting the water plant, storage tanks, and distribution lines to verify if a threat exists to the system and the base. AFI 10–246 states that BE will implement WVA Program for DOD-owned/operated and privatized water systems according to federal, state, and local regulations. In addition, under the purview of the installation threat-working group will review the WVA every year for currency and update the assessment as needed. [14] The *Drinking Water Surveillance Technical Guide* describes the WVA process in three distinct phases: *Pre-Assessment*, *Information Gathering*, and *Information Processing* (fig. 1–8).

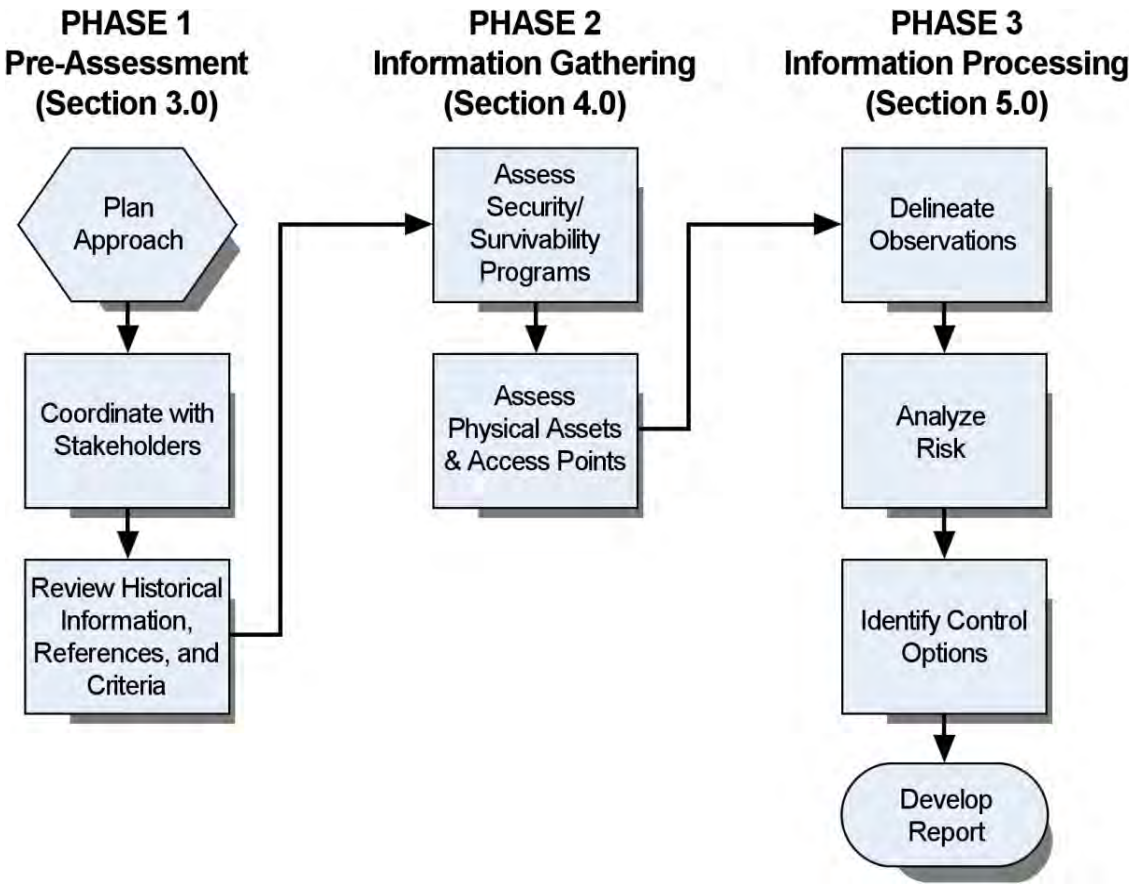

Figure 1–8. Sequence of WVA activities.

Phase I: Pre-assessment

The pre-assessment phase encompasses planning, coordinating, and reviewing historical information, references, and Air AT criteria. Pre-assessments are essentially the same at any location; the effort required is largely dependent on the size and complexity of the water system(s), and not necessarily on the type of installation or the type of water assets—fixed or field. The WVA technical steps are the same for garrison and deployed locations. In addition to AF-controlled portions of a water system, reasonable attempts should always be made to assess, identify, and report vulnerabilities and concerns associated with water systems *owned and/or operated by non-AF entities* that support AF operations.

A baseline WVA or WVA update may be conducted in conjunction with a local, multi-functional base-wide vulnerability assessment, or conducted independently. The WVAs should be done or updated annually at garrison-level installations. For deployed locations, the WVA should be done during each rotation, preferably within the first two weeks of BE personnel arriving at the location. The WVAs at all locations, whether garrison or deployed, should be accomplished whenever there are significant changes in the mission or water system.

A *baseline assessment* is comprehensive and includes systematically completing all applicable activities. A baseline assessment should be conducted in the following instances:

- For new operating locations or when new water systems are brought on line.
- When significant changes occur in the AF Vulnerability Assessment Program, water-specific criteria, or WVA guidance, or when significant changes occur to the water system.

An *update assessment* uses the same steps as the baseline process and is conducted using the following guidelines:

- Complete annual review or during each rotation, as applicable.
- Note changes to the water system(s), water source, or in the way the water is used.
- Follow-up on the status of previous observations.
- Assess program criteria (e.g., Operations and Maintenance, Water Contingency Response Plan updates, etc.) with annual or less frequent requirements.
- Complete a physical inspection of the water system/assets (using applicable physical assessment checklist) of areas where changes have taken place since the last WVA.
- Complete a WVA report: Use the previous report as a starting point for a new report and update descriptive information, add new observations in place of old ones, and re-generate as a new report.

The WVA stakeholders are responsible for the programs that impact the security and survivability of water supplies. When coordinating activities with stakeholder agencies, make sure the appropriate subject matter experts who can best answer relevant questions and provide necessary information concerning their particular functional area are identified. [13] Key documents and historical records can provide information concerning threats, responsibilities, the water system and its operations, and aid in validating the status of key programs. It is helpful to provide stakeholders with a list of required documents during coordination efforts to help ensure they are available for review or pick up during interviews. Assessors should be familiar with key documents, references, and WVA criteria to be adequately prepared when the assessment begins. Review the WVA checklists, which are categorized as general questionnaires, program review criteria, and physical assessment criteria (fig. 1–9). The most current checklists are located on the USAFSAM Website. At a minimum, review water system drawings and the most recent WVA and sanitary survey.

Number	WVA Checklist Title	Office of Primary Responsibility
General Questionnaires		
1	Antiterrorism Review for Water	ATO and CIP Manager
2	Off-base Water Supplier	Non-AF Water System Owner/Operator
3	Base Water System Overview	CEP, CEO, CEA
Program Review Criteria		
4	Water System Design and Integrity	CEP, CEO, and CEX (Fire)
5	Water System Operations & Maintenance	CEO, CEP, and CEX (Fire)
6	Water System Security Operations (owner/operator)	CEO and CEP
7	Electronic Monitoring and Control System Operations	CEO
8	Water Contingency Response	CEO, CEX (Fire)

Physical Assessment Criteria		
9	Surface Water	CEO
10	Wells	
11	Water Storage	
12	Water Treatment	
13	Water Pumps and Miscellaneous Assets/Facilities	
14	Water Supply Mains	
15	Aircraft Potable Water	Fleet Services/Operations and/or Flight Kitchen
16	Bottled Water	SVS, LRS, or CE
17	Deployment Water Assets	CEO
WVA Checklist Legend:		
ATO: Antiterrorism Officer		
CEA: Civil Engineering Asset Management		
CEO: Civil Engineering Operations		
CEP: Civil Engineering Programs		
CEX: Civil Engineering Emergency Management and Fire Emergency Services		
CIP: Critical Infrastructure Program		
LRS: Logistics Readiness Squadron		
SVS: Services		

Figure 1–9. WVA Checklists.

Phase II: Information gathering

Phase II focuses on field activities and gathering information necessary to characterize vulnerability, risk, and control options. Field activities encompass a review of programs designed to support water security and survivability, and a physical assessment of water assets and access points. Although there are no doctrinal requirements governing WVA briefings, field activities may be preceded and followed by briefings to primary stakeholders and base leadership.

An understanding of the system and related operations will enable the assessor to properly plan and accomplish an effective physical assessment. As outlined in the *USAFSAM WVA Technical Guide*, the program review consists of the following two-part investigative process:

1. *Interview subject matter experts:* Subject matter experts are the most knowledgeable individuals associated with the program area of concern, so they are the primary focal point of the interview and for providing program-related documentation. Subject matter experts are listed along with applicable program review checklists.
2. *Review Program Documentation:* Documentation may be in the form of hardcopy or electronic file reports, plans, policies, records, operating instructions, and standard operating procedures. The review of program documentation is often necessary to validate the status of the subject program. The interview and the review of the documentation can be done in conjunction with each other, or documents can be reviewed after the interview, particularly if copies are provided at that time. Applicable documentation is listed in each program criteria checklist.

Program review checklists enable a uniform and systematic assessment of programs designed to ensure water security and survivability. Checklists, which can be found on the USAFSAM Website, are designed to function as protocols common to other types of major compliance assessments.

In addition to specific program review checklists that are built around specific criteria, the following three interview questionnaires are used to gather key background information: (1) Anti-Terrorism Program Review for Water, (2) Water Purveyor questionnaire, and (3) Base Water System Overview questionnaire (fig. 1–10).

WVA Questionnaires	Description
Anti-Terrorism Program Review for Water	This questionnaire is designed for interviewing the ATO and CIP Manager to evaluate the status of previous observations, determine any known water-related threats, communicate and disseminate WVA results, and increase visibility and support for water-related observations with key stakeholders.
Off Base Water Purveyor	This questionnaire is used for interviewing non-AF water suppliers (privately-own or municipal water utility). Objectives include determining the system capabilities and limitations, identifying assets directly supporting the base and their security, projected changes to the system, and facilitating cooperation and information exchange between the utility and AF stakeholders.
Base Potable Water System Overview	This questionnaire is designed to be the initial checklist used when conducting the joint interview of the AF system owner/operator and stakeholders. This questionnaire enables assessors to gain an understanding of the system and its configuration, and is followed immediately with criteria-based checklists for CE programs.

Figure 1–10. General Questionnaires for the WVA.

After an assessor is familiar with the water system and operations, and has a perspective on what to look for and what to focus on in the field, the next objective is to conduct an “eyes on” physical assessment of water assets and access points. The goal is to identify vulnerable assets and access points and determine whether control measures designed for their security and survivability adequately meet criteria. Major assets encompass, but are not limited to:

- Groundwater wells.
- Surface water source intakes.
- Cisterns or catch basins.
- Transmission and distribution mains (i.e., the portion of the system that transmits water from the source up to the first interconnecting line that services points of use.).
- Transmission, distribution, and fire pumps.
- Treatment units/facilities.
- Tanks, bladders, and other bulk storage reservoirs.
- Supplemental support systems (e.g., power and automated control and monitoring systems.).
- Main isolation valves (particularly at major system interconnection points.).
- Centrally stored bottled water supplies.

In addition to the major assets previously mentioned, specific access points of potential concern must be assessed. These access points commonly include, but are not limited to:

- Exposed pipeline sections (e.g., aboveground, over-water crossings, and in meter/valve vaults).
- Standpipes, fire hydrants, and other major filling points.
- Other main access points (e.g., backflow prevention devices, flushing and air release valves, and water main meters).
- Water trucks/tankers.

- Water trailers/buffaloes, drums, lyster bags, and other tactical distribution containers.
- Unit-level stored bottled water supplies.
- Treatment chemical storage areas.
- Swimming pools.

An effective physical assessment largely depends on a number of factors. First, and foremost, be prepared. During the pre-assessment phase and stakeholder interviews be sure to understand the water system(s) and operations, as well as the physical assessment checklists and applicable criteria. Next, schedule the site assessments. If the assessment includes a restricted/controlled area, coordinate access with security forces (SF) or other applicable personnel. Finally, conduct a walk-through of the water system including operations plant, distribution lines, lift stations, and storage tanks.

Non-AF assets and access points

The WVA is not restricted to on-base assets and access points. During the WVA, attempt to visit all non-AF drinking water supply lines and storage assets located off base. Water mains transiting through areas accessible to the public are a security concern. Some non-AF assets may be within restricted or fenced areas, but may still be a concern if the purveyor is relying solely on a fence for security. If the water purveyor will not allow entry into certain areas or does not attend the stakeholders meeting, attempt to gain as much information as possible with base agencies and during document review. AF asset protection criteria can be considered best management practices for community drinking water utility systems. The primacy agency also mandate certain security controls, whether state, county, or city, may.

There is no prescribed order for evaluating assets and access points. One method is to begin at the source and follow the water through treatment, transmission, storage, and distribution. Convenience is often a factor, such as working from one part of the base to another. Visiting off-base assets and access points may require an escort from the purveyor.

Potable storage reservoirs/tanks

The DOD storage reservoirs or tanks are a special concern and are historically susceptible to structural problems, stagnant water, and contamination from deteriorated or missing vent covers and screens, dead animals, and other sources. A proper assessment of a storage tank requires access to the top of the tank where service hatches, vents, and other potential entry points can be inspected, and from where visual inspection of the interior can be performed. Exterior surfaces need to be inspected for corrosion and structural defects. All potential access points should be locked, hardened, or sealed to avert contaminant introduction. Inspect service hatches and air vents, and look for other structural openings, including gaps around pipes or cables that enter the reservoir.

Inspect the water for signs or indications of contamination including surface sheen, debris algae, excessive turbidity, unusual color or odor, and biofilm on structural surfaces. The interior should be inspected for corrosion, deteriorating surface coating, sediment, and other physical problems. For systems with a large number of elevated tanks, climbing all of them may not be practical. Give priority to tanks considered most critical to supporting mission-essential operations and tanks considered most at risk due to location, previous problems, age, length of time since last inspection, or other factors.

On-base transmission and distribution lines

Generally, access points (hydrants, standpipes, backflow prevention devices, etc.) located within the effectively controlled boundaries of military installations require no additional physical barriers. Contractors, vendors, and other personnel not affiliated with the base water utility or fire department who need to draw system water should always be directed to a designated filling station equipped with a permanent backflow prevention device. The device should be maintained and tested by base CE water systems operator or approved contractor. Air gaps are not considered adequate for backflow

prevention since they can be easily bypassed. Fill stations should be located in an area where activities can be easily observed. The base Security Force should be made aware of fill station locations and aid in enforcing their use.

Inspect critical valves closely to determine if they are operable, particularly where off-base transmission lines connect with the base water system and emergency supply valves. Valves should be easy to find and accessible for emergencies. Valve vaults or pits should not be flooded. Observe if the valves are heavily corroded, stuck, or frozen; ask operators to turn valves to validate their serviceability. Transmission line valves should be exercised annually and documented by CE; verify the last time the valves were tested. Verify that valves are secured (e.g., behind locked barriers or chaining of handles).

Off-base transmission and distribution lines

Drinking water lines outside a DOD-controlled perimeter which are accessible to non-DOD personnel are considered off-base lines. Water access points can be present and unsecured on lines dedicated to the AF installation. Under these circumstances, contaminants could potentially be introduced into any access point by overcoming system pressure using a water pump or by creating a backflow condition upstream of the introduction point.

Fire hydrants are of particular concern because of their widespread presence, accessibility, large port openings, and general availability of compatible connectors, hoses, and pumps. Construction and other contractors, plus municipal service agencies, are often equipped to access hydrants. Hydrants and other access points deemed highly vulnerable should be removed or taken out of service. Alternative options include turning off and securing the hydrant or flushing appurtenance valves, adding physical barriers, and/or disguising the access point and valve.

Physical disruption points such as valves and exposed pipelines present opportunities to disrupt the supply. Water main valve and meter vaults are often located directly outside the base perimeter on incoming supply lines. You, the assessor, should take into consideration:

- Systems that lack active parameter monitoring capability may incur disruptions that are not recognized until storage reservoirs are empty. It may also take time to locate the specific point of disruption.
- Valves can be manually manipulated.
- Exposed mains can be ruptured by physical force, including explosives. Explosives have been used repeatedly to rupture exposed water mains in Iraq. A main can also be ruptured by dropping an explosive into a meter or valve vault.
- Exposed lines should be buried when possible.
- Vaults and valve covers should be secured under a hardened, locked cover and when practical, disguised.
- When security outweighs convenience, remove valve hand wheels, whether behind a barrier or not.

Hazardous materials

Assess the security of water treatment chemicals and other hazardous materials stored or used within the vicinity of water access points, regardless of the owner of the materials or their intended use of materials. Concerns include the potential for introducing harmful/toxic materials into the water supply; airborne releases; and detonating munitions or combustible gases (e.g., propane). When munitions or combustible gases are located within the vicinity of water assets, check with the CE structural engineer or the base safety officer to ascertain whether calculations were performed to determine if the structure is designed to withstand the projected overpressure of a worst case detonation or a fire.

Illumination

A proper assessment of area illumination may require visiting the site during darkness. Area lighting is designed to act as a deterrent and to detect the presence of unauthorized activities. In some instances, illumination may not be beneficial such as areas where attack by mortar or other propelled munitions is credible, or when the asset is located in a remote area where illumination may actually draw attention to the asset and provide no real benefit in deterring or detecting aggressors. DOD *Unified Facilities Criteria (UFC) 4–020–02FA*, Chapter 6, provides best management practices for illumination assessments.

Fencing

Although fencing is not expected to stop aggressors, seven-foot security fencing is recommended for mission-essential water facilities and assets (e.g., wells, pumps, reservoirs, and treatment facilities), both on and off base. Proper fencing helps restrict access by vehicles used to transport contaminants, explosives, or tools. Additionally, fencing can help to deter aggressors because they will have to breech the fence and risk being seen in the act, or risk being seen within a designated controlled area.

Vandalism or unauthorized activities

Note any graffiti, damaged fencing, and other signs of unauthorized activities near the asset or access point, which may indicate a lack of sufficient deterrence and detection controls and an increased probability for malicious activity. Even the presence of trash dumped nearby can be useful information.

Photographs

Risk managers often prefer digital images of written observations. They can be useful to refer to when analyzing and processing WVA information. Avoid capturing information that can be used to identify the specific location of the asset or access point (facility numbers, street names, etc.). If the camera is equipped with a date stamp function, turn off this function. Be sure to gain permission in advance by the appropriate authority before taking photographs.

Once interviews, data collection, and site surveys have been done, the next step is processing the information.

Phase III: Information processing

This step consists of analyzing WVA information and generating results in a format familiar to CVAMP administrators. The primary steps in this process include: delineating observations, analyzing risk, determining corrective action recommendations, and developing a WVA report in a format that supports the needs of the stakeholders. [13]

This process begins by identifying deficiencies indicated on the criteria checklists. A status marking of “No” for a criterion element on a checklist indicates a deficiency. An observation represents one or more deficiencies for the subject program area or physical asset being assessed. Deficiencies noted on most program review checklists can be rolled up to support a single observation for the subject program.

The Occupational Risk Management risk analysis is used to determine the estimated risk levels for the observations found during the WVA and provide the results to stakeholders. List the observations in hierarchal order of estimated risk level (most severe to less severe).

The core product of the WVA effort is the observation table—designed with assistance from the ATO—to identify observations, provide recommendations, and suggested inputs for CVAMP, and enable the antiterrorism working group (ATWG) to effectively address mitigation of risks. An example of the observation chart is included in the *WVA Technical Guide*. Observations have to be classified as a vulnerability, concern, or neutral finding.

Self-Test Questions

811. Water vulnerability assessment

1. What is the significance (or vulnerability) of a water system that presents numerous access points?

2. The main purpose for an installation conducting a WVA is to?

3. List at least three objectives of the WVA.

812. Performing water vulnerability assessments

1. As part of the water vulnerability pre-assessment phase, why is in important to research key documents and historical records?

2. Why are subject matter experts a primary focal point for gathering water vulnerability information?

3. Why are WVA program review checklists an important part of the WVA process?

4. What is the goal of conducting an “eyes on” physical assessment of water assets and access points?

5. When are non-AF water mains that transit through areas accessible to the public of special concern?

6. Why must exterior surfaces of a portable storage reservoir/tank be inspected?

7. Who should use a designated filling station?

8. Why are fire hydrants of particular concern for water vulnerability?

1–4. Drinking Water Reporting

Due to the modern and efficient water treatment systems and methods used at most bases; ‘it’s rare to incur positive drinking water bacteriological results. However, positive bacteriological results can be an indication of a serious problem so it’s important to be familiar with drinking water reporting requirements.

813. Compliance and non-compliance reporting requirements

Public notification of drinking water results informs consumers of problems with drinking water. These notices alert consumers when problems occur and advise them of the need to take alternative measures (e.g., boil water) to ensure they have safe drinking water until the problem is fixed. Because reporting requirements can vary by state and local regulations, the EPA has established minimum notification standards for compliant and non-compliant drinking water sample results. These standards are outlined in the Public Notification Rule, 65 FR 25982.

The EPA requires all analytical results that are in compliance with the SDWA MCLs be sent to the state within 10 days of the end of the reporting period. The results typically are submitted through the CE office, but base policy may require submitting results directly to the state regulators. Notification may be done with a written letter, or based- or state-developed form. In either case, the letter, or form, is attached to a copy of the laboratory results.

Concerning non-compliance reporting, depending on the severity of the situation, water suppliers have from 24 hours to one year to notify their customers after a violation occurs. The EPA specifies three categories, or tiers, of public notification:

- Tier 1—Immediate Notice: Serious health effects under short-term exposure.
- Tier 2—Notice within 30 Days: Serious adverse health effects.
- Tier 3—Annual notice.

Water suppliers have different amounts of time (depending on violation tier) to distribute/deliver the violation notice to the customer.

Tier 1—Immediate Notice, within 24 hours

Tier 1 public notices are required for any violations/situations with significant potential for immediate short-term impact to human health. Public notice is required within 24 hours of the violation, and the base must consult with the state or federal EPA within 24 hours to receive direction on subsequent requirements. Water suppliers must use media outlets such as television, radio, and newspapers, post their notices in public places, or personally deliver a notice to their customers in these situations. Tier 1 violations include the following:

- Fecal coliform MCL violation or failure to test for fecal contamination after TC test is positive.
- Nitrate/nitrite/combined nitrite MCL violation or failure to take confirmation sample.
- Chlorine dioxide maximum residual disinfection level violation in distribution system or failure to repeat samples in distribution system.
- Exceeding maximum allowable for turbidity level resulting in an MCL or treatment technique violation, when the state or EPA determines a Tier 1 notice is warranted.
- Special public notice for NCWSs with nitrate exceedances between 10 mg/L) and 20 mg/L, when allowed to exceed MCL (10 mg/L) by the state.
- Waterborne disease outbreak or other waterborne emergency.
- Other situations as determined by the primacy agency.

Tier 2—Notice as Soon as Practical, within 30 days

Any time a water system provider detects contaminants exceeding EPA MCLs or state standards that do *not* pose an immediate risk to human health, the water supplier must notify its customers as soon as possible within 30 days of the violation. The notice may be provided via the media, posting, or through the mail. Tier 2 violations include the following:

- All other MCL or treatment technique violations not already identified as Tier 1 violations.
- Monitoring and testing procedure violations, when the primacy agency determines they require a Tier 2, rather than Tier 3, notice.
- Failure to comply with variances and exemptions approved by the primacy agency.

Tier 3—Annual Notice

When water systems violate a drinking water standard that does not have a direct impact on human health (for example, failing to take a required sample on time), the water supplier has up to one year to provide a notice of this situation to its customers. The extra time gives water suppliers the opportunity to consolidate these notices and send them with an annual consumer confidence report (discussed in the next section). Tier 3 violations include the following:

- All other monitoring or testing procedure violations not already requiring a Tier 1 or Tier 2 notice.
- Special public notices (e.g., exceeding the fluoride SMCL; announcing the availability of unregulated contaminant monitoring results).

Ten Required Elements of a Public Notice

The ten required elements of a public notice include:

1. Describing the violation, including the contaminant(s) of concern and the contaminant level(s).
2. Documenting the date the violation occurred (i.e., date the sample was collected).
3. Describing the potential adverse health effects from exposure to the contaminant(s). Health effects descriptions are provided in Appendix B of the Public Notification Rule.
4. Identifying population at risk.
5. Indicating whether alternate water supplies need to be used.
6. Describing actions consumers can take, including when to seek medical attention.
7. Documenting specific actions the water supplier is doing to correct the problem.
8. Estimating when the situation is expected to be resolved.
9. Identifying contact information for the water supplier.
10. Developing a statement encouraging distribution of the public notice to all persons served, where applicable. The statement should use standard language from the current edition of the EPA's *Public Notification Handbook.*

The public notice must be reviewed and approved by the chain of command up through the base commander, as well as the legal office, CE, PA, and any other agency determined by base policies. Depending on the violation, the base may also need to notify the major command.

The requirements just discussed are the minimum set by the EPA. Keep in mind to consult state and local regulators to find out if there are more stringent standards which must be complied with. Remember, the main goal of public notification is not only to comply with the law, but to protect the health of everyone drinking the water on base.

814. Consumer confidence reports

It is not enough to simply report results to the state. Keep consumers informed of water quality. Indicative of its commitment to PH and the public's right-to-know about local environmental information; the EPA requires CWSs to put annual drinking water quality reports into the hands of their customers. These reports are also known as *consumer confidence reports*.

The reports should not be the primary notification of potential health risks posed by drinking water; rather, they provide customers with water quality information from the previous calendar year. Each report must provide customers with the following fundamental information about their drinking water:

- The lake, river, aquifer, or other source of the drinking water.
- A brief summary of local drinking water source contamination susceptibility based on source water assessments by states.
- Way to obtain a copy of the water system's complete source water assessment.
- The level, or range of levels, of any contaminant found in local drinking water, as well as EPA's health-based standard (MCL) for comparison.
- The likely source of the contaminant in the local drinking water supply.
- The potential health effects of any contaminant detected in violation of an EPA health standard, and an accounting of the system's actions to restore safe drinking water.
- The water system's compliance with other drinking-water-related rules.
- An educational statement for vulnerable populations about avoiding cryptosporidium.
- Educational information on nitrate, arsenic, or lead in areas where these contaminants may be a concern.
- Phone numbers of additional source of information, including the water system and EPA's Safe Drinking Water Hotline (800-426-4791).

Consumer confidence reports summarize all the monitoring completed at each base. It takes all the components of the quality water program and puts them in an easy-to-understand language for consumers. Consumer confidence reports are the centerpiece of the right-to-know provisions in the 1996 amendments to the SDWA. The amendments contain several other provisions aimed at improving public information about drinking water, including the annual public water system compliance report and improved public notification in cases where a water supplier is not meeting a contaminant standard.

AF installations, including those with privatized drinking water systems that receive a consumer confidence report from a local water supplier, will provide either a copy of the original report or a modified version of the report to the base population. If an installation does not purchase its water from a municipality, then these annual reports are prepared by BE. The reports must be coordinated through the appropriate base agencies. These agencies typically include, but are not limited to, the Environmental, Safety, and Occupational Health Council, PA, CE, and the base commander. Afterwards, disseminate the reports to the base population by the means approved by the PA office. The reports are due by 1 July each calendar year.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

813. Compliance and non-compliance reporting requirements

1. What is the benefit of public notification of drinking water results?

2. Why and when is a Tier 1 public notice required?

3. If a water system violates a drinking water standard that does not have a direct impact on human health, how long does the water supplier have to notify the public?

4. What agencies must be consulted to determine if there are more stringent standards (than the EPA) that must be followed/complied with?

814. Consumer confidence reports

1. What is the importance of a consumer confidence report?

2. If a base receives a consumer confidence report from a local water supplier, what is provided to the base population?

3. What does the consumer confidence report provide?

4. If an installation does not purchase its water from a local municipality, who is responsible for preparing the annual consumer confidence report?

5. When is the consumer confidence report disseminated to the base population?

1–5. Non-potable Water

Although non-potable water is not consumed, it can be a threat to human health. Most bases have some kind of recreational waters like freshwater swimming pools, hot tubs (whirlpools, spas), and other naturally occurring fresh and marine waters. These waters can contain chemical or biological threats that can potentially lead to recreational water illnesses. They can be caused by ingesting water contaminated with pathogenic microorganisms such as *Cryptosporidium*, *Giardia*, *E. coli* or norovirus to name a few. To minimize the risk of exposure, BE conducts inspections and water monitoring at based-owned swimming pools and public bathing facilities.

815. Inspections of recreational waters

Exposure to untreated or inadequately treated human fecal waste is considered the greatest health threat. The presence of microbiological indicators in treated swimming pools or hot tubs indicate possible insufficient water exchange, disinfection, and maintenance. Bather density is a major part in determining the probability of swimmer-associated illnesses with swimming pools, particularly when there is insufficient disinfection and water circulation. The bathers themselves may also be a source

of pollution by shedding organisms associated with the mouth, nose, and skin. Diseases associated with swimming and bathing facilities are classified into the following broad categories:

- Gastrointestinal diseases.
- Respiratory diseases.
- Eye, ear, nose, and/or throat diseases.
- Skin infections.

There are currently no federal regulations governing water quality in swimming pools, hot tubs, spas, and natural bathing areas. However, AFI 48–114, *Swimming Pools, Spas and Hot Tubs, and Natural Bathing Areas*, outlines how the AF operates and maintains these environments, assigns responsibility for the healthful use and safe operation of bathing facilities, and emphasizes the PM principles of hygiene and sanitation to ensure a clean, safe swimming and bathing environment.

Swimming pools

Pool water is, for the most part, potable and treated with additional disinfectant. Modern pools have a recirculating system for filtration and disinfection. A swimming pool's water quality should be monitored for changes in chemical and physical characteristics. Water quality depends upon the efficiency of disinfection, sanitary conditions, number of bathers in the pool at any one time, and the total number of bathers per day.

BE Technicians should have a basic understanding of the types of sanitizers currently approved by the EPA to treat swimming pools. AFI 48–114 lists chlorine, bromine, polyhexamethylene biguanide (PHMB) and silver-based systems as approved EPA methods. However, chlorine and bromine are the most commonly used in the AF.

Chlorine is the most common sanitizer used in pools and spas. It can be added in a liquid, powder, tablet, or gas form to the pool water. Chlorine reacts with the pool water to form hypochlorite and hypochlorous acid, which kills pathogens. Combined chlorine, also known as chloramines, can form when free chlorine reacts with natural organics such as urea from urine. These compounds can cause eye, mucous membrane, and skin irritation and have strong objectionable odors. Chlorine also tends to degrade in sunlight. A stabilizer such as cyanuric acid may be used to counteract this degradation.

Bromine is effective over a wider pH range than chlorine, but cannot be stabilized against degradation by sunlight (cyanuric acid cannot be used with bromine). In the same way that chlorination can result in chloramines, bromination can result in byproducts called bromamines. However, bromamines are not known to be harmful at concentrations normally found in swimming pools, spas, and hot tubs. Of note, a pool disinfected with bromine cannot be converted to chlorine disinfection without draining and refilling the pool.

Advantages of PHMB as an effective pool and spa sanitizer include minimal degradation in sunlight and low eye and skin irritation. Its disadvantages are high costs, the need for additive chemicals as algaecides, and lack of understanding of compatibility with other pool chemicals (for example, chlorine degrades PHMB). Because of these disadvantages, PHMB is not recommended for AF owned or operated pools and spas and shall not be used without approval of the medical group commanders.

Silver is used as an antibacterial agent in many applications, including swimming pool sanitizers. Positively charged silver ions attach to negatively charged contaminants and destroy them. On AF installations, silver should not be used as a primary sanitizer but may be used as a supplemental sanitizer.

The table below lists water quality requirements for swimming pools as required by AFI 48–114. These water parameters for swimming pools should be maintained to avoid unnecessary continued bacteriological sampling.

Water Quality Requirements for Swimming Pools			
Parameter	**Acceptable Range**	**Monitoring Frequency**	**Responsible Organization**
FAC	1.0–4.0 ppm	Every 2 hours	Bathing facility manager or lifeguard
Bromine	1.0–8.0 ppm	Every 2 hours	Bathing facility manager or lifeguard
pH	7.2 – 7.8	Every 2 hours	Bathing facility manager or lifeguard
Total alkalinity	60 – 180 ppm	Once per week	Bathing facility manager or lifeguard
Calcium hardness	150 – 1,000 as $CaCO_3$	Every 2 weeks	CE
TDS	Not to exceed (NTE) 1500 ppm above the concentration at startup.	Every 2 weeks	CE
Clarity	An 8-inch diameter black and white Secchi disc or the main drain located on the bottom of the pool at its deepest point must be clearly visible and sharply defined from any point on the deck up to 30 ft away in a direct line of sight from the disc or main drain.	Daily	Bathing facility manager or lifeguard
Cyanuric Acid	Ideal concentration is between 25–50 ppm, but must not exceed 100 ppm.	Monthly; however if a chlorinated isocyanurate is used, monitor weekly.	CE, if used
Temperature	78° F –82° F	Every two hours	Bathing facility manager or lifeguard
	Maximum 104º F		
Algae	No visible algae when open to swimmers	Continuous	Bathing facility manager or lifeguard
Combined chlorine	0.2 ppm	Every hours	Bathing facility manager or lifeguard

If a swimming pool is inadequately disinfected, any number of common waterborne diseases may be spread. Disease transmission hazards are greatest among swimmers in the fresh water found in swimming pools because they tend to ingest more water than swimmers in brackish estuarine water and salt water of the open seas. Therefore, it is important to maintain the quality of swimming pool water. Pathogenic microorganisms that pose a threat to swimmers or bathers in pools and spas and hot tubs are shown in the table below.

Pathogenic microorganism threats in pools and hot tubs			
Diseases	**Sources**	**Characteristics**	**Symptoms**
Giardiasis	*Giardia lamblia*; infected swimmers, usually children, who contaminate the water through a bowel movement	Gastrointestinal illness	Diarrhea, cramps
Otitis externa	*Pseudomonas aeruginosa* and various species of staphylococci; swimming pools with little or no disinfection	Very common infection; also known as swimmer's ear	Itching, pain, and discharge of the ear
Swimming pool	*Mycobacterium marinum*; a skin	Associated with concrete,	Nodules on the skin that

Pathogenic microorganism threats in pools and hot tubs			
Diseases	**Sources**	**Characteristics**	**Symptoms**
granuloma or daphne sore	abrasion creates a portal of entry for the organism	gunite (spray concrete), or masonry pools; sites of infection tend to be knees and elbows from contact with the rough surface of the pool shell	may ulcerate
Genital herpes	Herpes simplex virus; is not transmitted in water but can survive on plastic surfaces of a spa or hot tube	Contact with warm, moist environmental surfaces may lead to transmission; as a preventive measure, nude persons should sit on clean, dry towels when lounging around spas or hot tubs	Genital lesions
Follicular dermatitis	*Pseudomonas aeruginonsa*; rash is related to spa and hot tube use	Common sites of lesions are buttocks, hips, and trunk	Rash, itching
Pontiac fever	*Legionella pneumophila* serotype 6; can be transmitted by aerosols of and hand hat tub water	Respiratory diseases; Self-limiting	Fever, chills, malaise, and headache

In addition to daily monitoring, pre-season and post-season inspections are also required. For facilities operated continuously, the inspection should be about 30 days before heavy seasonal use.

Pre-season inspection

A representative from CE, force support squadron (FSS), BE, PH, and wing safety conduct a joint pre-season inspection approximately 30 days before the pool opens to ensure a safe and sanitary environment, and to allow time to complete corrective actions. This inspection is generally coordinated by an FSS team member.

Post-season inspection

Within 30 days after seasonal closure, the same key players that were involved in the pre-season inspection re-group to perform joint post-season inspections, which identify the extent of off-season maintenance needs. An FSS team member will coordinate the post-season inspection. For facilities operated continuously, no special inspection is required. The bathing facility manager should conduct a survey six months after the 30-day inspection to identify any special repairs needed before the next heavy-use season.

Pre-season and post-season inspection considerations

Pre-and post-season inspections must consider, as a minimum, the following:

- Copy of pool rules openly displayed?
- Cleaning requirements being followed?
- AF Form 708, Swimming Pool Operational Log, available and properly completed?
- Water on apron draining away from pool?
- Water quality parameters (pH, temp, disinfectant level, turbidity) being met?
- Pool surface water free of scum/debris?
- Proper first-aid equipment available?
- Toilet/shower facilities cleaned/disinfected as required?
- Phone readily available with posted emergency numbers clearly displayed?

- Piping diagram of water/sewer lines posted near disinfection equipment?
- Is adequate chlorine monitoring equipment located outside the chlorination room?
- Is there a fan to exhaust any potential chlorine gas out of the room prior to entry?

Spa/hot tub

Hot tubs are designed for recreational as well as therapeutic use. Hot tubs use a close-cycle water system, a heated water supply, and generally include a hydro jet recirculation system. These types of pools are typically not cleaned, drained, and refilled after each use despite their smaller size. Hot tub-associated infections are common because of the inherent design and characteristics, which include high temperature, reduced disinfection efficiency, and increased organic material. All of these factors contribute to favorable conditions for growth of microorganisms. Because of this, facility managers are required to perform frequent testing for residual disinfectant levels and pH.

In addition to the pre-season inspection, periodically inspect spas/hot tubs to make sure water quality parameters are me—measure pH, temperature, and the disinfectant residual level. Measure frequency is determined by past performance history. Regular inspections should consider, as a minimum:

- Date of inspection and name of inspector(s) and operator.
- Copy of rules and warnings prominently displayed.
- At least one employee with documented first-aid training and cardio pulmonary resuscitation certification on duty.
- Operator enforcing rules.
- Cleaning requirements being followed.
- AF Form 708 properly completed.
- Water on apron draining away from spa/hot tub.
- Water quality parameters (pH, temp, disinfectant level, turbidity) being met.
- Scum/debris removed from surface of water periodically.
- Bottom and sides clean.
- Proper first aid equipment present.
- Toilet/shower facilities cleaned and disinfected as required.
- Phone readily available with emergency numbers clearly displayed.
- Is piping diagram of water and sewer lines posted near spa chemical equipment?

During the pre-season inspection, take pH and chlorine readings and compare those to the measurements taken by the bathing facility manager. If the readings differ significantly, work with the bathing facility manager to determine the cause of the discrepancy. The bathing facility manager takes temperature, pH, and chlorine readings daily before opening and hourly thereafter. The assessor also takes readings, but they are at a frequency based on past performance history. Because conditions in a hot tub or spa change so rapidly, research indicates there is no need to collect bacteriological samples unless an illness occurs. Spa and hot tub water must meet the water quality standards outlined in the following two tables.

Water Quality Requirements for Spas and Hot Tubs			
Parameter	**Acceptable Range**	**Monitoring Frequency**	**Responsible Organization**
Free available chlorine	2.0–5.0 ppm	Every hour	Bathing facility manager or lifeguard
Bromine	2.0–8.0 ppm	Every hour	Bathing facility manager or lifeguard

Water Quality Requirements for Spas and Hot Tubs			
Parameter	**Acceptable Range**	**Monitoring Frequency**	**Responsible Organization**
pH	7.2–7.8	Every 2 hours	Bathing facility manager or lifeguard
Total alkalinity	60–180 ppm	Daily	Bathing facility manager or lifeguard
Calcium hardness	100–800 as $CaCO_3$	Every 2 weeks	CE
Total Dissolved Solids	Not to exceed 1500 ppm above the concentration at startup.	Every 2 weeks	CE
Clarity	The bottom of the spa at its deepest point shall be clearly visible. Perform this test when water is in a non-turbulent states and bubbles have dissipated.	Daily	Bathing facility manager or lifeguard
Cyanuric Acid	Ideal concentration is between 25—50 ppm, but must not exceed 100 ppm.	Monthly; however if a chlorinated isocyanurate is used, monitor weekly.	CE, if used
Temperature	Maximum 104° F	Every two hours	Bathing facility manager or lifeguard
Algae	No visible algae when open to swimmers	Continuous	Bathing facility manager or lifeguard
Combined chlorine	0.5 ppm	Every hours	Bathing facility manager or lifeguard

Natural bathing areas

AFI 48–114 also outlines how the AF monitors natural bathing areas so that AF personnel and their families are kept as safe as possible when using these areas for recreational purposes. Natural bathing areas are any streams, lakes, oceans, or hot springs used for recreation that are under the authority of the base (fig. 1–11).

Figure 1–11. Randolph outdoor recreational area–Canyon Lake, Texas.

The medical group commander approves all areas proposed for designated natural bathing facilities. Site selection for these facilities is the most critical factor in maintaining good sanitary quality and should be based on the following considerations:

- Natural bathing areas should be free of the effects of point (a single identifiable source) and nonpoint (multiple source) pollution and sewage discharges.
- The bottom of the natural bathing area should be visible at wading depth.
- Natural bathing areas should have bottoms which slope gently and uniformly toward deep water; have no holes or sudden step-offs; be free from hidden or submerged obstructions such as rocks, stumps, snags, and sunken logs; be composed of firm sand, small-sized gravel, or shale; have no silt, quicksand, shell patches, sharp or broken rock, or debris in depths of 5 ft (1.5 meters) or less.
- Natural bathing areas should not be in an area where schistosomiasis, leptospirosis, or primary amoebic meningoencephalitis are endemic without the concurrence of the PH or PM officer.

The sanitary quality of these waters cannot be controlled nearly as easily as well-designed swimming pools. Natural bathing areas present significantly more risks in terms of pathogenic organisms because the water is not treated chemically. Scientific evidence documenting the rise of infectious diseases caused by microbial organisms in recreational waters continues to grow. For example, an epidemiological study in Santa Monica Bay, California, documented an increased risk of illness associated with swimming near storm drains. Pathogenic microorganisms that pose a threat to swimmers/bathers in natural bathing areas are shown in the table below.

Pathogenic microorganism threats in natural bathing areas			
Diseases	**Sources**	**Characteristics**	**Symptoms**
Leptospirosis	*Leptospira interrogan;* water contaminated with urine from infected animals such as rats, swine, and cattle	Generally found in fresh water	Fever, chills, and headache
Giardiasis	*Giardia Lamblia;* in the intestinal tracts of mammals such as beavers and foxes living near bathing areas	Gastrointestinal illness; generally found in fresh water	Diarrhea, cramps
Shistosome dermatitis, known as "water rash" or "swimmer's itch"	Larvae of certain trematode worms of birds and mammals penetrate the skin	Common to freshwater lakes in the north central US; can be prevented by limiting exposure to water to less than 30 minutes, followed by vigorous towel drying between fingers and toes	Dermatitis characterized by skin eruptions
Primary amoebic meningoencephalitis	*Naegleria fowleri;* a free-swimming amoeba associated with warm natural bodies of water	Common to southern US; a parasitic disease untreatable with anti-parasitic agents, antibiotics, and antimetabolites	Severe headache, fever, and death
Otitis externa	*Pseudomonas aeruginosa* and various species of *staphylococci*	Very common infection; also known as swimmer's ear	Itching, pain, and discharge from the ear
Schistosomiasis, also known as bilharziasis	*Schistosoma mansoni (blood flukes);* snails act as intermediate hosts for the cercariae, a larval form of the fluke; also found in parasite-infected drinking water, and other Schistosoma species	Serious PH disease found in fresh or mildly brackish water of tropical and semi-tropical areas– not found in marine environment	Diarrhea, abdominal pain; liver and urinary disorders
Cryptosporidiosis	*Cryptosporidium;* a pathogenic intestinal protozoa found in man and animals that forms resistant oocysts; water contaminated through direct deposit of human and animal feces into receiving waters	Oocysts associated with turbid waters; ingestion causes gastrointestinal illness	Diarrhea

Sample the water quality of a natural bathing area based on health risk. Some health risk factors to consider are proximity to the suspected pollution source, level of bathing area use, historical water quality data, and occurrence of sewage spills or other pollution events. If conducting bacteriological sampling, consult Title 40 CFR Part 131, *Water Quality Standards,* and AFI 48–114 for guidance. AFI 48–114 recommends that E. coli and enterococci be used as the indicator organisms for evaluating the microbiological suitability of the water in freshwater natural bathing areas. Enterococci shall be used as the indicator organism in marine waters. Enterolert® or any equivalent method that measures viable criteria as indicated in Title 40 CFR Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants*, shall be used. For E. coli, Colilert® or any equivalent method that measures viable criteria as indicated in Title 40 CFR Part 136 is used. All sampling shall follow guidance in Standard Methods for the Examination of Water and Wastewater, current edition.

The EPA is encouraging state governments to adopt updated water quality criteria for E. coli and/or enterococcus bacteria into their recreational water quality standards. However, many states continue to use fecal coliforms as their primary health risk indicator.

Recall the concept of primacy; state governments that have been granted primacy for recreational waters have the authority and responsibility to regulate standards. As a BE technician with the responsibility to monitor your installation's recreational waters, be aware of the state's status of primacy and adopted standards in order to know which standard is applicable to the situation.

As stated earlier, the medical group commander has overall responsibility for approving areas for natural bathing based on the following physical considerations: site location, type of bottom, physical water quality (riptides, currents), and common diseases. Services, PH, ground safety, and BE jointly establish safety and warning guidelines for hazards particular to each bathing area. In addition, these same representatives are required to conduct a sanitary survey, at least annually, for all natural bathing areas. The survey examines potential sources of pollution that could have an impact on the bathing area as well as safety hazards. Inspections of natural bathing areas should consider, as a minimum:

- Examine for potential sources of pollution such as agricultural drainage or waste water discharges.
- Evaluate the bacteriological and chemical effects of such discharges on the bathing areas.
- Evaluate water depth and bottom slope for safety.
- Evaluate area to ensure it is free of dangerous reptiles, submerged objects, drop-offs, or other physical endangerments.
- Evaluate general cleanliness to ensure it is satisfactory for safety.
- Ensure proper first aid safety equipment is present.
- Ensure safety guidelines are prominently displayed and being followed/enforced by lifeguards.

Self-Test Questions

815. Inspections of recreational waters

1. If there are microbiological indicators in treated swimming pools or hot tubs, then what does this indicate?

2. On what four factors does water quality depends?

3. Why are disease transmission hazards greatest among swimmers in fresh water swimming pools?

4. When is a pre-season swimming pool inspection done and why?

5. Describe the water quality parameters BE team members ensure are met during pre-season spa/hot tub inspections.

6. Explain the reason why you don't normally collect bacteriological samples from a spa/hot tub.

7. Cite the reason why natural bathing areas present significantly more pathogenic organism risks.

8. Cite the other agencies BE works with to jointly establish safety and warning guidelines for bathing area hazards?

Answers to Self-Test Questions

801

1. It determines how easy or difficult it is for water to move.
2. Because of their permeability.
3. Because of the natural or artesian pressure that exists in the aquifer.
4. They only have one layer of impermeable material beneath the saturated zone.

802

1. The water typically needs little or no additional treatment.
2. Excessive mineral content.
3. Because it is less likely to be contaminated with pathogens, have low turbidity, maintain nearly constant temperature, be less affected by droughts, and be more difficult to contaminate.
4. Because of the discharge of pollutants into the water.
5. The availability of surface water may vary widely with each season of the year.
6. If the water source must supply a large and constant amount of water.
7. The water probably contains chemicals, minerals, and organic matter such as algae.
8. To prevent acidic corrosion and the precipitation of salts that can form scale in boilers and circulating cooling water systems.
9. Adequate levels are necessary to prevent the drinking water from tasting flat.
10. They cause the water to exhaust its oxygen.
11. If there are areas where it's determined there are chlorine-resistant pathogens.

803

1. To confirm the effectiveness of the water filtration and disinfection practices.
2. By limiting contaminant levels in drinking water.
3. Because primacy identifies the specific agency that has the primary (main) responsibility for administering and enforcing the drinking water criteria at your installation.
4. DOD FGS or EGS.
5. (1) Runoff from the flight line, (2) all operations within the entomology shop, (3) potential surface discharges from any base industrial operations, and (4) golf course maintenance operations.

804

1. The number of people served and whether the system serves the same customers year-round or only on an occasional basis.
2. PWS.

3. A system that has at least 15 service connections, or regularly serves an average of at least 25 individuals daily at least 60 days a year.
4. The agency of the state or federal government that has primary enforcement responsibility in accordance with the SDWA.

805

1. Adding or removing substances from water in order to produce a desired change in quality.
2. To inactivate microorganisms in the water, thereby preventing them from affecting the human body.
3. A primary disinfectant is used to achieve a desired disinfection level to inactivate microorganisms and a secondary disinfectant provides longer-lasting protection as the water moves through the distribution system to the consumers.
4. Disinfectants can react with naturally occurring materials in the water to form byproducts such as TTHM which may pose a health risk.
5. Unlike many other disinfectants, chlorine leaves a residual in the water, is easily measured and controlled, and is economical to use.
6. Because an excessive consumption of fluoride over a lifetime may lead to increased likelihood of effects on bones in adults, and young children exposed to excessive amounts of fluoride have an increased chance of developing pits and staining in the teeth.

806

1. The water main must be disinfected and tested for coliform bacteria before being placed back into service.
2. The water line is flushed with potable water and samples are taken for bacteriological analysis.
3. The purpose of having three chlorination methods is to provide flexibility in responding to specific situations to disinfect new water lines while still ensuring an absence of coliforms.
4. The general procedures include the following:
   (1) Trench treatment.
   (2) Swabbing pipes and fittings with hypochlorite solution.
   (3) Flushing and chlorination of the line.
   (4) Bacteriological sampling.

807

1. To identify, investigate, and document all cross-connections on the installation, and eliminate cross-connection hazards on an installation and, when possible, eliminate cross-connection hazards.
2. A cross-connection is any temporary or permanent connection between a public water system and any source or system through which non-potable water or other substances can enter the potable water system.
3. To identify and eliminate potential risks.
4. Provides technical assistance to support the Backflow Prevention and Cross-Connection Control Program; assigns hazard classifications to each cross-connection; recommends appropriate protection for each cross-connection; and reviews water system plans and drawings to identify potential cross-connections.

808

1. To evaluate and document the capabilities of the potable water system to continually provide safe drinking water, and to evaluate the system's compliance with federal drinking water regulations.
2. An understanding of the current and potential threats to the water quality and system reliability.

809

1. A pre-survey should be accomplished to help determine what areas to focus on and how to divide up the limited time during the onsite inspection. The following items should be reviewed:
   (1) Previous sanitary survey report findings.
   (2) Information about the physical facility.
   (3) Compliance history of the facility.
   (4) Treatment processes in place.

(5) Monitoring requirements.
(6) Water quality data.
(7) Other relevant data.

2. The water supply can be a source of contaminants, pathogens, and particles.
3. To protect stored water from loss of chlorine residual, bacteria re-growth, contaminant entry, and other water quality problems.
4. Unlike groundwater treatment processes, surface water and groundwater under the direct influence of surface water is assumed to be contaminated by harmful microorganisms and will therefore require additional treatment methods to physically remove those pathogens.

810

1. AFMAN 48–138_IP documents policy, standards, guidelines, and procedures that all military services need to comply with to ensure water used by military and supporting civilian personnel for drinking, showers and personal sanitation, and sanitation in the operational environment is adequate. AFI 48–144 is used to ensure all other applicable AF surveillance requirements are met, such as WVA and sanitary surveys that are not addressed in AFMAN 48–138_IP.
2. Any four of the following are acceptable answers, as they are all BE-specific roles outlined in AFMAN 48–138_IP:
   (1) Perform drinking water quality surveillance.
   (2) Support investigations of potential drinking water-related illnesses.
   (3) Maintain records of drinking water quality surveillance.
   (4) Ensure laboratories perform analyses using required analytical methods.
   (5) Ensure sanitary surveys are performed and recommend measures to maintain quality.
   (6) Ensure special surveys are conducted as warranted in the event of contamination.
   (7) Ensure WVAs are completed using USAFSAM references.
   (8) Monitor and approves aircraft watering points.
   (9) Interpret results of water analyses and reports.
   (10) Implement public notification procedures when results indicate a potential health threat.
   (11) Conduct engineering reviews of repairs and modifications.
   (12) Review construction/modification plans and drawings to assess potential health hazards.
   (13) Support cross connection and backflow prevention program by classifying health hazards.
   (14) Advise commanders on source water protection opportunities.
   (15) Maintain drinking water analytical data records. Brief commanders, force protection officers, and other functional risk managers in reducing water-related risks from all causes to personnel and mission-essential operations to an acceptable level.
3. STP standards are water quality standards that must be met to declare a water system potable during the first 30 days of field operations, and LTP standards are water quality standards that must be met after the first 30 days of water production point operation for a water system to continue to be declared potable water.
4. Unlike LTP Standards, which must be met after the first 30 days of water production point operation for a water system to be declared potable, MEGs do not need to be met for water to be considered potable. Instead, MEGs are used to assess potential acute and chronic adverse health effects for personnel who drink water that contains TIC. The MEGs include many chemicals that do not have LTP standards.
5. A raw water source sanitary survey involves examining the proposed water source and the surrounding area for existing and potential sources of pollution and evidence of contamination.
6. Where a host nation municipal water system is identified as a potential water source for deployed personnel, it must be considered a raw water source until it is approved by PM personnel. To be considered for use as drinking water without additional treatment, the water must meet the STP standards for the first 30 days of use, after which the water must meet the LTP standards. For a host nation municipal water system to be considered for use as non-potable shower and personal sanitation water, the water must meet the criteria in AFMAN 48–138_IP, Table 3–22.

7. Using the following formula, you need approximately 152 mg/L of liquid bleach.

$$\text{mg/L liquid bleach} = \frac{\text{desired mg/L chlorine X number of gallons to be treated}}{13.2}$$

$$= \frac{2 \text{ mg/L x } 1000 \text{ gallons}}{13.2} = 151.5 \text{ or } 152 \text{ mg/L}$$

8. PM personnel should test representative samples of bottled water (1 percent of the total number of bottles, up to a maximum of 10 bottles). Bottles should be selected randomly selected from a lot.

811

1. The system is at an increased risk for an asymmetrical attack by operatives.
2. Assist commanders, force protection officers, and other functional risk managers in reducing water-related risks from all causes to personnel and mission-essential operations to an acceptable level.
3. (1) Identifying control deficiencies that can lead to water degradation and/or supply disruption.
   (2) Assessing corresponding levels of risk posed to personnel and mission-essential operations.
   (3) Propose practical control recommendations and justification for corrective actions.
   (4) Develop inputs for the CVAMP; secure Web-based vulnerability database.
   (5) Assist stakeholders in recognizing and meeting relevant regulatory requirements.
   (6) Educate stakeholders on water vulnerability and risk-related issues

812

1. These documents can provide information concerning threats, responsibilities, the water system, and its operations and aid in validating the status of key programs.
2. They are the most knowledgeable individuals associated with the program area of concern and for providing program-related documentation.
3. Checklists enable a uniform and systematic assessment of programs designed to ensure water security and survivability.
4. To identify vulnerable assets and access points and assess whether control measures designed for their security and survivability adequately meet criteria.
5. When the purveyor/supplier is relying solely on a fence for security and deficiencies exits.
6. To check for corrosion and structural defects.
7. Contractors, vendors, and others not affiliated with base.
8. Because of their widespread presence, accessibility, large port openings, and compatibility with connectors, hoses, and pumps.

813

1. It helps ensure that consumers will know if there is a problem with their drinking water.
2. When any violations/situations with significant potential for human health to be immediately impacted as a result of a short-term exposure occur; public notice is required within 24 hours.
3. Up to one year.
4. State and local regulators.

814

1. It puts the annual drinking water quality report (from the previous calendar year) into the hands of the CWS customers.
2. Either a copy of the original report or a modified version.
3. A summary of all the water monitoring your BE office conducted at the base over the past year.
4. BE.
5. By July 1st each year.

815

1. Possible insufficient water exchange, disinfection, and/or maintenance.
2. The efficiency of disinfection, sanitary conditions, number of bathers in the pool at any one time, and the total number of bathers per day.
3. Because swimmers tend to ingest more water in swimming pools than swimmers in brackish estuarine water and salt water.
4. Accomplished 30 days prior to the pool opening. To ensure that a safe and sanitary environment exists and to allow enough time to complete any required corrective actions.
5. Measuring pH, temperature, and the disinfectant residual level.
6. Because conditions change so rapidly research indicates the need to collect a sample only if an illness occurs.
7. Natural bathing area water is not chemically treated.
8. FSS, PH, and ground safety.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (801) What type of aquifer would cause water to be pushed in a well above the land surface?
   a. Perched.
   b. Pressure.
   c. Artesian.
   d. Unconfined.

2. (802) Groundwater is stored in
   a. lakes, streams, and oceans.
   b. snow, glaciers, and rivers.
   c. unconfined and confined zones.
   d. unsaturated and saturated zones.

3. (802) Which constituent is not commonly found in groundwater?
   a. Nitrate.
   b. Calcium.
   c. Fluoride.
   d. Magnesium.

4. (802) What dissolved gas needs to be at an adequate level to prevent drinking water from tasting flat?
   a. Oxygen.
   b. Carbon dioxide (CO2).
   c. Hydrogen sulfide (H2S).
   d. Carbon monoxide.

5. (803) Which Environmental Protection Agency (EPA) drinking water standard is a guideline that applies to the cosmetic effects of drinking water?
   a. Quality.
   b. Primacy.
   c. Primary.
   d. Secondary.

6. (803) What law passed by congress established a federal program to monitor and increase the safety of all publically and commercially supplied drinking water?
   a. Safe Drinking Water Act (SDWA).
   b. Well Head Protection Program (WHPP).
   c. Safe Drinking Water Surveillance Program.
   d. National Primary Drinking Water Regulation (NPDWR).

7. (803) Which installation must comply with the Department of Defense (DOD) Final Governing Standards (FGS) or Environmental Governing Standards (EGS)?
   a. Hickam AFB, Hawaii.
   b. Anderson AFB, Guam.
   c. Elmendorf AFB, Alaska.
   d. Royal Air Force (RAF) Feltwell, United Kingdom.

8. (803) What program is designed to ensure the protection of groundwater supplied by public water systems by protecting the area around the well head from all types of contamination?
   a. Well Head Protection Program (WHPP).
   b. Groundwater Protection Program.
   c. Safe Drinking Water Surveillance Program.
   d. Backflow Prevention and Cross-connection Control Program.

9. (804) What is the minimum average number of individuals served daily and the number of days per year required for a system to be classified as a public water system?
   a. 15 individuals for 30 or more days per year.
   b. 25 individuals for 30 or more days per year.
   c. 25 individuals for 60 or more days per year.
   d. 50 individuals for 60 or more days per year.

10. (805) Which is the common type of water treatment used at Air Force (AF) installations?
    a. Aeration.
    b. Disinfection.
    c. Scale Control.
    d. Carbon Adsorption.

11. (805) Which disinfection method provides a disinfectant residual?
    a. Chlorine dioxide (CO2).
    b. Free chlorine.
    c. Ozone.
    d. Iodine.

12. (806) After a water main is installed and at the end of a 24-hr holding period filled with chlorinated potable water, the free chlorine residual must not be less than
    a. 5 milligrams per liter (mg/L).
    b. 10 mg/L.
    c. 15 mg/L.
    d. 25 mg/L.

13. (806) During a water main break repair, which water pressure will not require the water main to be disinfected and tested for coliform before being place back into service?
    a. 10 pounds per square inch (psi).
    b. 15 psi.
    c. 19 psi.
    d. 25 psi.

14. (806) What is the most practical means of removing contamination introduced during water main repairs?
    a. Swabbing with hypochlorite solution.
    b. Bacteriological sampling.
    c. Slug chlorination.
    d. Flushing.

15. (806) What method of chlorination may be used if the pipes and components are kept clean and dry during the construction?
    a. Slug.
    b. Tablet.
    c. Swabbing.
    d. Continuous.

16. (807) What describes the backward flow of water in the distribution system due to decreased pressure (i.e., line break) in the potable distribution system?
    a. Air gap.
    b. Reverse flow.
    c. Backpressure.
    d. Backsiphonage.

17. (807) How often is the Water System Backflow Prevention/Cross-Connection Survey done on all facilities?
    a. Annually.
    b. Semi-annually.
    c. Every two years.
    d. Every five years.

18. (807) What hazard classification for a cross-connection is also defined as contamination?
    a. Low.
    b. High.
    c. Routine.
    d. Potential.

19. (808) Which is not a critical element examined and evaluated during a sanitary survey?
    a. Security.
    b. Treatment.
    c. Distribution.
    d. Finished water storage.

20. (808) What results does a sanitary survey provide the installation?
    a. Current and resolved risks to water quality.
    b. Current threats and potential water sources.
    c. Prioritized plan for security upgrades at well heads.
    d. Current and potential threats to water quality and system reliability.

21. (809) What sanitary survey element are you addressing when you identify a discrepancy that tank vents and overflows are not screened or protected?
    a. Treatment.
    b. Distribution system.
    c. Finished water storage.
    d. Pump/Pump facility and control.

22. (810) Which military field water standard is designed to prevent acute illness?
    a. Short-term potability (STP) standards.
    b. Long-term potability (LTP) standards.
    c. Military exposure guidelines (MEG).
    d. Environmental Protection Agency (EPA) maximum contaminant levels.

23. (811) Air Force Instruction (AFI) 10–246, Food and Water Protection Program, states Air Force (AF) water supplies are
    a. threats.
    b. security risks.
    c. credible targets.
    d. security challenges.

24. (812) Water vulnerability assessments (WVA) should be done or updated at deployed locations
    a. annually.
    b. semi-annually.
    c. every ten years.
    d. during each rotation.

25. (812) Which interview questionnaire is designed to be the initial checklist used when conducting the joint interview of the Air Force (AF) system owner/operator and stakeholders?
    a. Water Purveyor.
    b. Water Security and Survivability.
    c. Base Potable Water System Overview.
    d. Anti-Terrorism Program Review for Water.

26. (813) How long does the base have to deliver a public notice of a Tier I violation?
    a. 12 hours.
    b. 24 hours.
    c. 10 days.
    d. 30 days.

27. (813) How long does a water supplier have to provide notice of a Tier 2 violation to its customers?
    a. 1 day.
    b. 10 days.
    c. 30 days.
    d. 90 days.

28. (814) Which should not be included in the consumer confidence report?
    a. The likely source of contaminants in the local drinking water supply.
    b. The water system's compliance with other drinking water-related rules.
    c. The formulas used to reach the assessment results on local contamination.
    d. How to get a copy of the water system's complete source water assessment.

29. (815) How many days before opening is the pre-season inspection conducted at a swimming pool?
    a. 3.
    b. 10.
    c. 30.
    d. 60.

30. (815) Which is one of the organizations that perform surveys of natural bathing areas?
    a. Services (SVS).
    b. Security forces (SF).
    c. Fire department.
    d. Environmental flight.

31. (815) The swimming pool manager or lifeguard measures potential for hydrogen (pH) at least once every
    a. hour.
    b. 2 hours.
    c. 3 hours.
    d. day.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Ventilation

A SUCCESSFUL Occupational and Environmental Health Program provides organizations with documentation that health risks have been identified and evaluated, and a confirmation that proper control measures have been implemented in order to manage risks within acceptable limits. BE career field, we do our part by evaluating and recommending controls for potential occupational health and environmental hazards. You already know a considerable amount about chemical exposures. We now need to discuss one of the principal methods of controlling them—ventilation.

2–1. Principles of Ventilation

The costs associated with the installation, operation, and evaluation of the performance of ventilation systems can be staggering. Comparatively few people have an adequate grasp of the parameters that must be considered for an efficient ventilation system. Many times in the past, this has resulted in waste, insufficient protection, and a false sense of security for workers.

Your duties concerning ventilation will require you to have an understanding of the general principles of ventilation. Special emphasis is placed on understanding airflow and how system components affect it so that you can survey and recommend corrective measures effectively.

816. Characteristics of pressure within a ventilation system

There are various methods for moving air in a ventilation system; but you will probably deal primarily with fans. The fan—or *air mover*, as it is often called—is the heart of the system. It creates the pressure necessary to begin and maintain the airflow. Pressures are usually exerted within *ducting* to carry the air to where it is needed or to capture and remove contaminants from a work area. The most efficient type of ventilation, local exhaust, will also have some type of *hood* to help direct contaminants into the duct more efficiently. Local exhaust systems may also have *air cleaners* (such as filters or waterfalls) to prevent most of the contaminants from getting into the atmosphere and to protect the fan from possible damage. All of these system components affect the pressure needed to drive the system. A typical ventilation system is shown in figure 2–1.

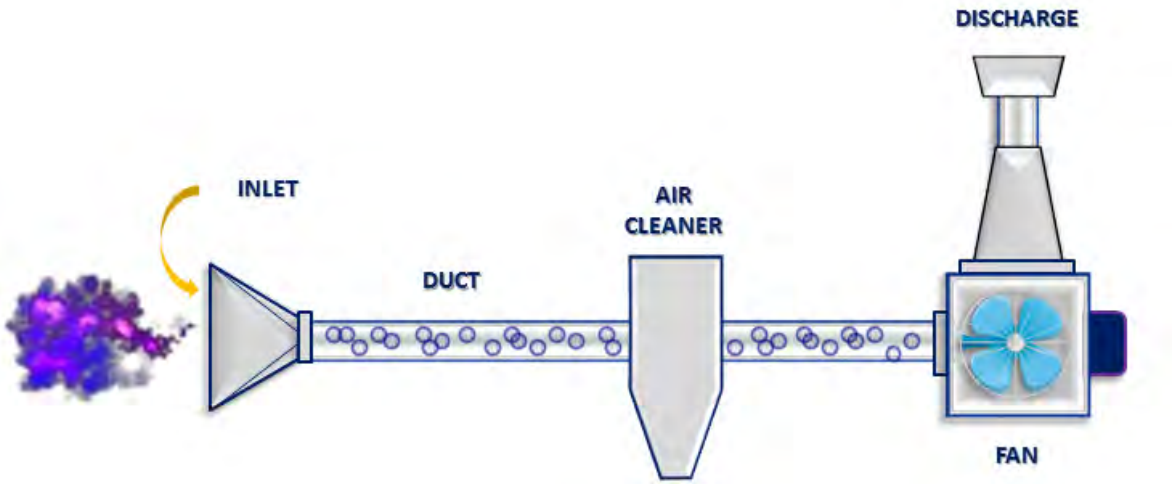

Figure 2–1. The five components of a typical ventilation system.

Static pressure

Static pressure (SP) is created when the fan is turned on and begins to suck the air from one side of the system and deliver it to the other. Separated by the fan itself, the two sides are called *upstream* of the fan (entry/inlet), and *downstream* of the fan (exhaust/outlet).

The word static means "not moving," this sounds like a strange term to use when speaking of moving air. It may also account for quite a bit of confusion in understanding just what SP is. A few examples will help. A normal electric light bulb has a partial vacuum—the pressure within it is less than normal atmospheric pressure. Figure 2–2 shows both *negative* and positive SP. It is negative in relation to atmospheric pressure, which we use as the standard in determining whether a pressure is positive or negative. Negative pressure means that the greater pressure outside of the light bulb has a tendency to squeeze or crush the bulb. The pressure is exerted from all directions around the bulb. The fan sucking the air from the duct also causes this partial vacuum, so SP upstream of the fan is negative.

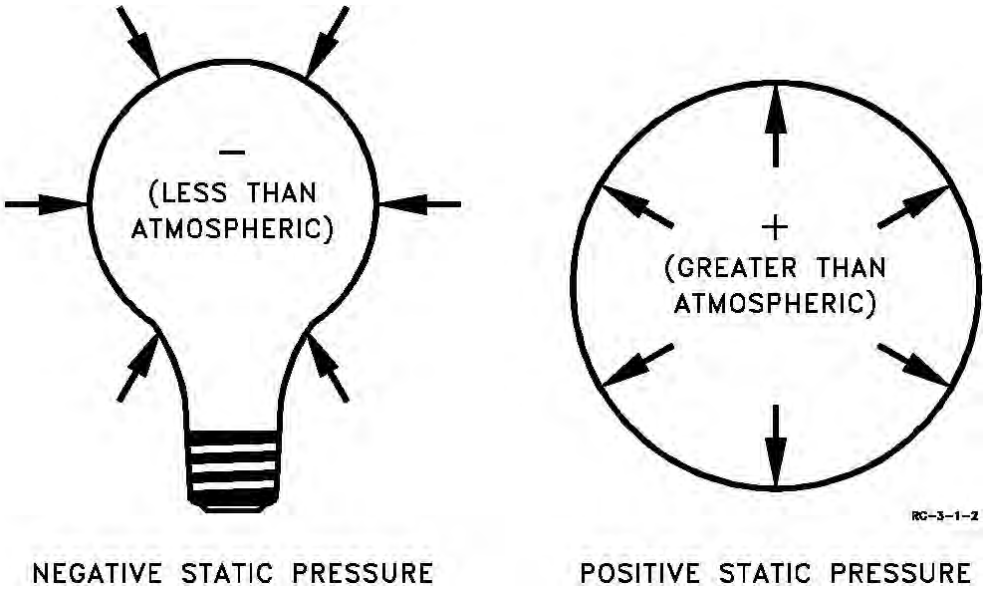

Figure 2–2. Static pressures.

SP is measured within the duct (you cannot measure it outside) to assess the performance of the system. All of the pressure measurements we make in ventilation systems are expressed in inches of water pressure. This is abbreviated *in wg* (inches water gauge).

Figure 2–3 shows a simple U-tube manometer used for pressure measurements. We will examine more sensitive manometers later, but the U-tube enables you to better visualize the behavior of different pressures. A U-tube is filled with water until the water levels on both sides (the meniscuses) are on the zero mark in the center. Pressure exerted on one side causes the water levels to change on both sides. The difference in the levels is the air pressure in inches of water.

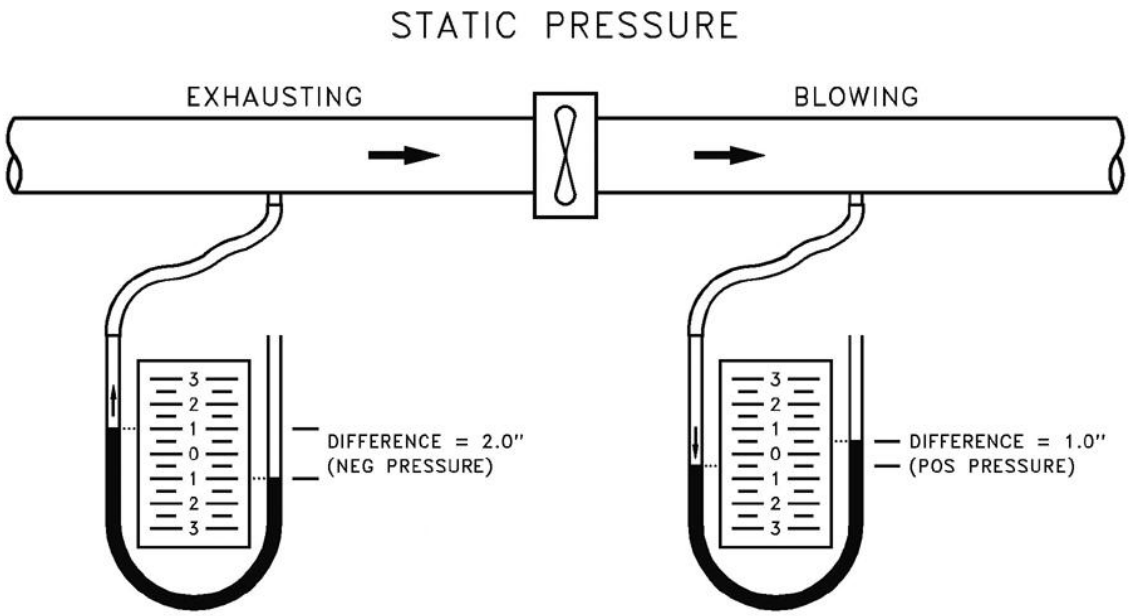

Figure 2–3. Static pressure measurement.

SP is exerted in all directions; but for reasons you will see later, it can be measured only at 90 degrees (°) to the airflow (called *normal* to the flow). We connect tubing from a small tap (pressure port) in the duct to the U-tube as shown. Upstream of the fan, the suction (negative pressure) pulls the water level upward on the left side with a corresponding drop on the right. The difference in levels is 2 inches—the SP in this part of the duct. On the blowing side, the water is pushed downward on the left of the U-tube so that there is a difference of 1 inch—the SP on this side of the fan. Remember which side of the fan you are measuring so that you can apply the proper sign (positive or negative) to the value.

Velocity pressure

When the fan sucks the air from the duct to create the negative SP, air must come in from the hood to replace it. Likewise, the positive SP on the blowing side of the fan is pushing the air through the duct, thus causing it to flow. Because of this, we say that the SP is converted to velocity pressure (VP).

VP is the pressure exerted by air in motion. Just as you can feel SP, you can feel VP. Wind is an example, as is the force of air you feel when you place your hand near a blower. SP is thought of as *potential energy*—it has the potential to do work much as does a rock on top of a hill. When the rock rolls down the hill, the potential energy is converted to *kinetic energy*—the energy of motion. In the same way, the potential energy of the SP is converted to the kinetic energy of VP. A good example is that of a balloon. Blowing up a balloon and then pinching off the air inlet causes a positive SP. When you release the inlet, the SP causes the air to rush out—VP. There is a direct relationship between VP and the velocity of moving air. A simple formula we will use later converts VP to velocity. This will help us when we begin to measure airflow in ventilation systems.

Because VP is the pressure of moving air, it is *always* measured in the direction of airflow. This also means that it must always be a positive pressure. Since VP is measured indirectly, we need to discuss total pressure (TP) to fully understand what happens in the measurement process.

Total pressure

Total pressure is simply the sum of the static and VPs at a given point in the duct-*with due regard for sign.* This means that at 5 feet upstream of the fan, for instance, be sure to note that the SP value has a negative sign and the VP is positive. You could have a SP of—2.0 in wg and a VP of 1.5 in wg, which would result in a TP of—0.5 in wg:

$$TP = SP + VP$$

$$TP = -2.0 + 1.5$$

$$TP = -0.5 \text{ in wg}$$

Note that the TP upstream of the fan is negative. When the SP is negative, the TP will be negative. On the blowing side of the fan, *all* values are positive (illustrated in the table below):

	SP	VP	TP
Upstream of fan	-	+	-
Downstream of fan	+	+	+

As shown in figure 2–4, TP can be measured with the use of an impact tube directed into the airflow. With this device you not only measure the force of air impacting against the opening of the tube—VP—but also the SP since it is exerted in all directions (hence the total pressure). Upstream of the fan, the SP is stronger than the VP (–2.0 versus 1.5). Since one is negative and one is positive, they work against each other with VP losing the battle. This offsetting of the VP prevents air from entering the impact tube. The effect is that the air is sucked out of the tube due to the negative pressure.

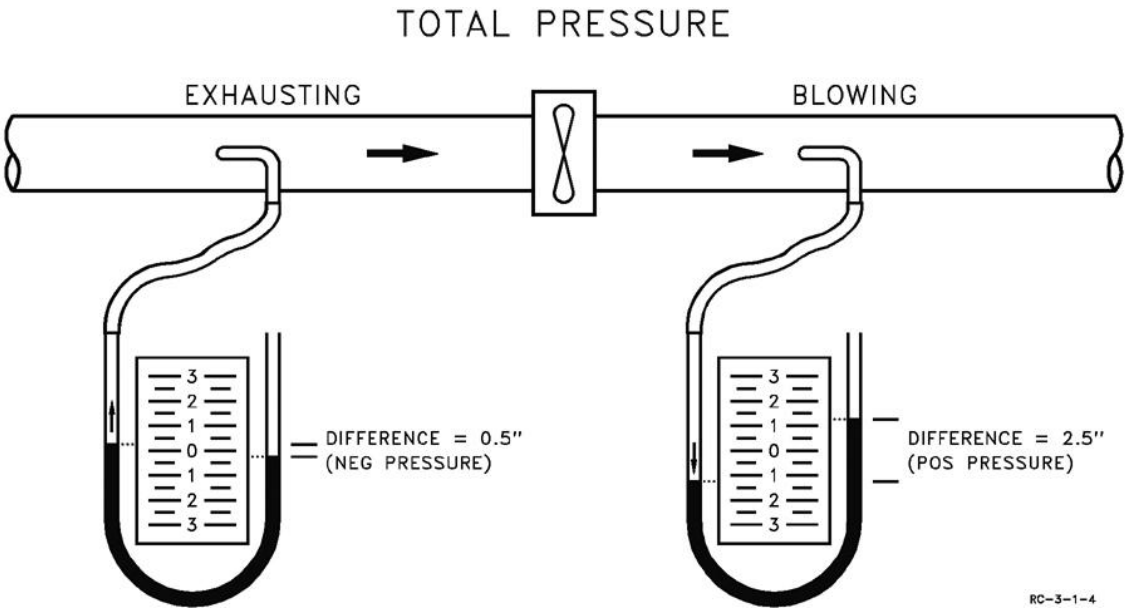

Figure 2–4. Total pressure measurement.

The impact tube also measures the combined static and VPs on the blowing side. Here the air *enters* the tube. The two positive pressures team up to push the water in the U-tube downward. Although we do measure the TP, its value alone is of little importance to us. To get a meaningful value, we must measure the SP at the same time. With the SP connection on one side of the U-tube and the TP connection on the other, we measure the VP indirectly as in figure 2–5. Looking at the exhausting side, remember that both the static and TPs have the effect of sucking the air (and thus the water) from the tube. When both sides of the U-tube are connected, the SP draws the water up on the left

while the TP draws it up on the right. The difference between the two is the *VP*. The U-tube automatically makes the subtraction for you. The pressures also counteract each other on the blowing side except that they are forcing the water downward on both sides of the U-tube (due to the positive pressures). The result is the same: the SP is subtracted from the TP to get the VP: VP = SP – TP.

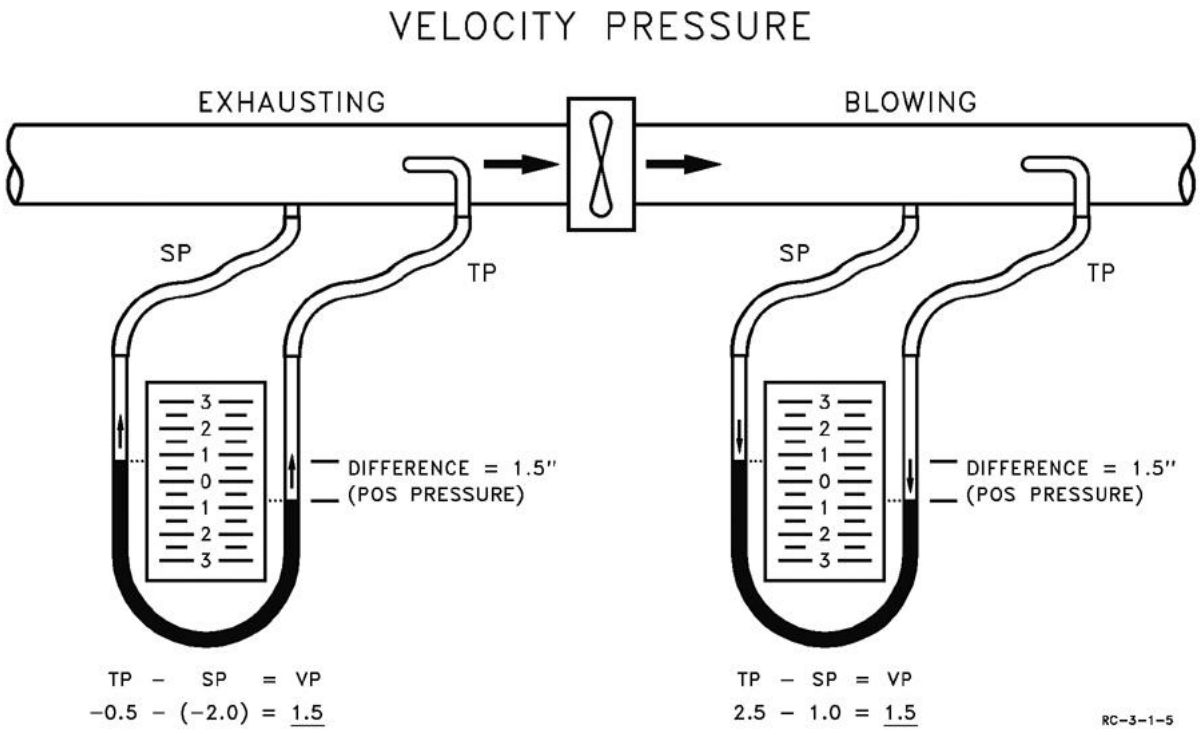

Figure 2–5. Velocity pressure measurement.

817. Pressure losses and their association with system components and performance

The conversion of SP to VP is not without sacrifice. There are pressure losses throughout the system (exactly like the pressure drop in an air sampling train) starting with the entry of the air into the hood or opening. Remember that the negative SP in the duct causes air to be drawn into the opening, thus producing a VP. If there were such a thing as a perfect hood, there would be a 100 percent conversion—the VP would equal the SP. However, there must *always* be losses in the conversion, so the SP at this point is stronger than VP. Therefore, SP = VP + losses.

Dynamic losses

Air entering a duct suffers from a great deal of turbulence. Losses due to turbulence are called dynamic losses (dynamic: moving). The relatively still air outside of the duct is drawn in from many different directions. As they are accelerated in the narrow confines of the duct, the air molecules tumble against the sides of the opening and each other and create the turbulence. The air stream is also “squeezed” just inside the duct due to the molecules from different directions trying to rush into a small area. The point of this squeezing is known as the *vena contracta* (fig. 2–6). It is important not only because of the losses incurred but also because you must avoid this unstable area when making pressure measurements. A short distance (typically 3 or 4 duct diameters) downstream of this area (toward the fan), the air fills the duct and flows more smoothly.

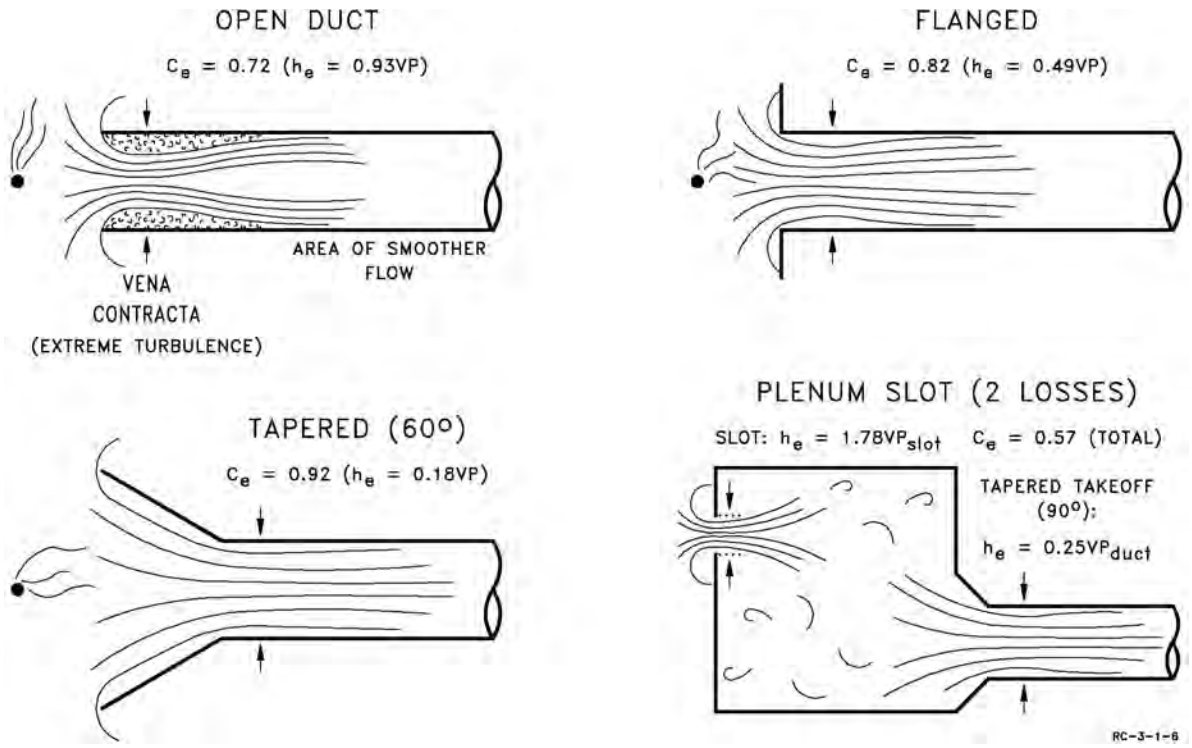

Figure 2–6. Entry losses.

The vena contracta (and thus the losses) can be reduced if the air enters the duct more gradually. This is why hoods should be tapered from their openings back to the duct whenever feasible. There will still be losses, but the static to VP conversion is more efficient.

Adding a flange also reduces the vena contracta. A flange is a flat surface that is attached to the perimeter of the opening. It reduces the amount of air that would otherwise come from behind the opening. A flange causes more air to be pulled in from the front of the opening so that there is less trouble with turbulence from air rushing in from so many directions. It also has the added benefit of better contaminant capture since more air is drawn in from the front where the contaminant is.

The losses that occur when air enters the system are called *hood entry losses (h_e)* whether there is a hood or not. H_e are important to consider when deciding upon a hood type for a certain contaminant. Losses are wasted energy since more losses mean less conversion to VP. Less VP, of course, means less airflow and ultimately less contaminant control.

An alternate method to express the efficiency of a hood is by the *coefficient of entry* (C_e). This will be of use to us later when evaluating ventilation systems. This coefficient is defined as the square root of the ratio of duct VP to hood static pressure (SP_h). The SP we must use is that found a short distance from the *hood throat* (where the hood meets the duct). It is called the *hood static pressure*. SP_h should be measured about 2–6 duct diameters downstream in a straight section of the hood duct. The measurement can be made with a pitot tube and a manometer. The VP is found anywhere along the duct where the airflow is smooth—for instance, adjacent to the hood, where there are no bends, enlargements, contractions, or other disturbing influences.

We find the C_e with the formula below. Using the example of 2.0 in wg VP and 2.5 in wg SP:

$$C_e = \sqrt{VP / SP_h}$$

$$C_e = \sqrt{2.0 / 2.5}$$

$$C_e = 0.89 \text{ (no units)}$$

This represents an efficient hood design. The Ce must always be less than one since one (100%) represents the value for the impossible perfect hood. You can find coefficients of entry for various hood types in references such as *Industrial Ventilation* published by the American Conference of Government Industrial Hygienists (ACGIH). The values give a good quick comparison of different hood designs. Most hoods have only a single value; but some, such as slot hoods, have two, one for entry into the slot and one for subsequent entry into the duct.

Dynamic losses are extremely important in the area of the hood, but turbulence is also created in a number of other sections of the system. You will have losses wherever there is a bend (elbow) in the duct, changes in the duct size, and adjustable devices in the duct to restrict flow. If there is an air cleaner on the system, it will usually cause some of the highest losses. This can have a lot to do with the choice of air cleaners for a given fan capacity or with the choice of a fan that can operate with a type of air cleaner that must be used.

Friction losses

As if dynamic losses were not enough, we must also contend with friction losses. Friction losses are due to the air molecules rubbing along the sides of the duct. This rubbing places a drag on the airflow. You can see evidence of this drag when you measure VP. You find stronger VP in the center of the duct than you do closer to the sides. If you could see the pressure in the duct, it would resemble a portion of a bubble—a bulge in the center and a drag along the sides.

Four major factors contribute to friction loss: duct material, air velocity, duct diameter, and duct length. A rough metal surface is obviously going to cause more friction loss than a smooth one; so ducting materials available on the market are generally smooth (but there are varying degrees). Faster traveling air molecules also cause more friction as well as turbulence and could result in a lot of wasted energy for a relatively small gain in velocity. A direct influence on the velocity (and friction) is the diameter of the duct. A small duct with high velocity will experience more friction losses than a large duct with the same air-flow rate. As an example, if a SP of 2 *in wg* existed within a 12-inch duct at a certain velocity, the SP would change to 4 *in wg* with a 6-inch duct, assuming you have the same velocity. Finally, friction increases as the length of the duct increases. You can find the estimated friction for a duct with charts in such references as *Industrial Ventilation*. The friction charts are based on the duct diameter and air velocity. The value you get from them will be in friction loss (in wg) *per 100 feet of duct*.

Total system resistance

Look at figure 2–7. All losses in the system, both upstream and downstream of the fan, add up to the total system resistance in the form of SP at the fan. The total resistance of the system is what the fan must work against to provide the needed flow. Thus, there is a SP for the system, such as the duct design, and a SP developed by the fan. There are two things to make note of when dealing with the system resistance. First, the SP becomes more negative as you approach the fan inlet, indicating more resistance. Second, VP should remain constant as long as the duct size does not change. As stated, the fan also develops SP and must develop enough SP to overcome the system resistance while providing the needed airflow.

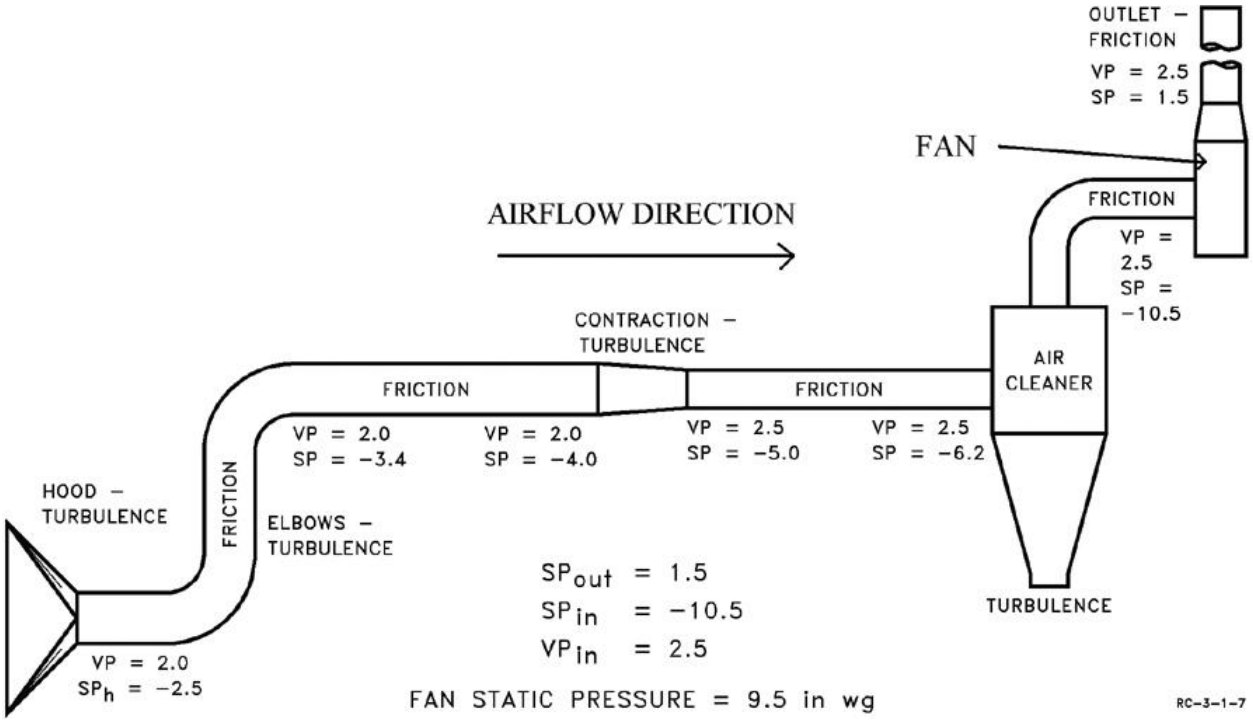

Figure 2–7. Total system resistance.

Figure 2–8 illustrates how the system resistance discussed above ultimately influences fan performance. Assuming that the fan is capable of providing an airflow volume (Q) of 4700 cubic feet per minute (cfm) when it is not connected to a system (free blowing). When the same fan is connected to a system having a resistance of four *in wg*, it can only deliver about 3000 cfm. Connected to a system having a resistance of eight *in wg*, it drops to 1200 cfm. Totally blocking the air inlet causes the fan to develop a high SP. For our example fan, this would result in a SP of about nine in wg with a VP of zero.

The discussions of pressure losses mostly affect engineers who design ventilation systems or replace a fan of an existing system; however, this information should be more than just academic interest for BE. Knowing something about the subject can help prevent you from making mistakes in evaluating various types of ventilation systems. It will also be of help when you must find out how a system can be improved. There have been numerous cases of systems with needlessly long ducts that made them less efficient. Others have had so many bends and contractions that the airflows were nowhere near what they could have been. You can see that eliminating these design flaws whenever possible can greatly enhance the control of contaminants in the workplace.

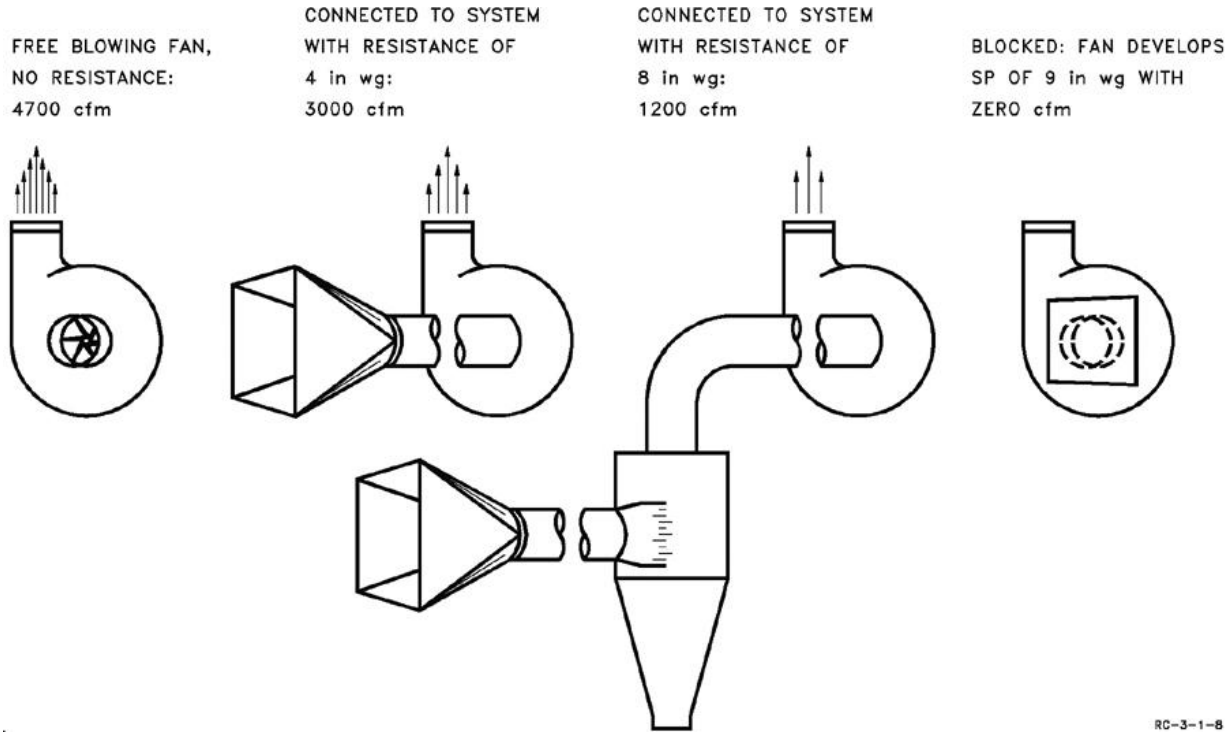

Figure 2–8. Effects of system resistance on fan performance.

818. Principles of velocity

Remember that velocity is a major cause of system resistance and is therefore *indirectly proportional* to SP. On the other hand, velocity is *directly proportional* to VP. These relationships are put to good use in calculations involving design of ventilation systems and measurements of airflow.

Pressure to velocity

Although we are speaking of measuring air pressure to find velocity, we must use units involving water pressure (*in wg*). Air is obviously less dense than water, so there is less of an affect by the force of gravity. Suppose you create a perfect vacuum in an enclosure at sea level and 70°F. In the enclosure, we have a column of water only an inch high and 1 square foot in area. It would be acted upon with the same force of gravity (would exert the same pressure) as a column of air with the same area that is more than 69 feet high. A column of water 1 foot high is acted upon the same as an air column about 831 feet high. Under the conditions mentioned, a cubic foot of water weighs about 62.3 pounds, and a cubic foot of air weighs about 0.075 pounds. Note that 62.3 divided by 0.075 equals 831 (fig. 2–9). So, air is 831 times less dense than water.

It is this force of gravity and the relationship of the densities that enables us to derive a formula for velocity from the simple equation:

$$V = \sqrt{2gh}$$

Where:

V = velocity in feet per second (fps).

g = gravitational acceleration in feet per second per second (32.2 ft/sec^2).

h = head of air in feet (831 feet—the height of a column of air exerting the same pressure as 1 foot of water).

The equation calls for VP in *feet of water*. Filling in the values and units, we have:

$$ft/sec = \sqrt{2 \text{ x} \left(\frac{32.2 \text{ ft}}{\text{sec}^2}\right) \times \left(\frac{62.3 \text{ lb}}{1 \text{ ft}^3 (water)}\right) \times \left(\frac{1 \text{ ft}^3 (air)}{0.075 \text{ lb}}\right) \times 1 \text{ ft (water, VP)}}$$

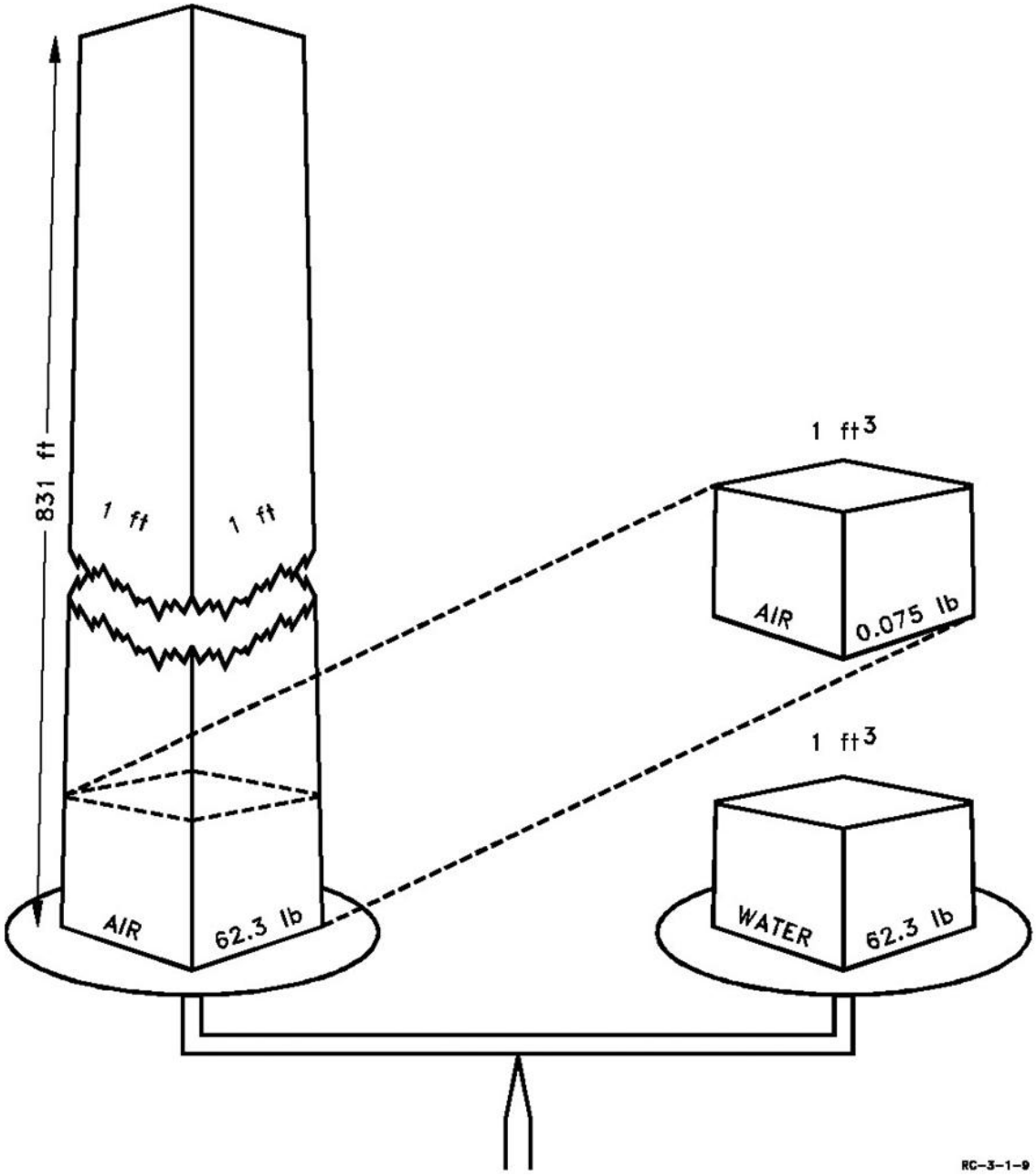

Figure 2–9. Air pressure versus water pressure.

Since we measure VP in *inches* of water, we use the conversion of 1 foot/12 inches in the formula.

$$ft/sec = \sqrt{2 \text{ x} \left(\frac{32.2 \text{ ft}}{\text{sec}^2}\right) \times \left(\frac{62.3 \text{ lb}}{1 \text{ ft}^3}\right) \times \left(\frac{1 \text{ ft}^3}{0.075 \text{ lb}}\right) \times \left(\frac{1 ft}{12 in}\right) \times 1 in (VP)}$$

It is helpful to view the formula with only the units shown for the sake of dimensional analysis. We ensure that feet per second will result by canceling units:

$$V = \sqrt{\left(\frac{ft}{sec \times sec}\right) \times \left(\frac{lb}{ft^3}\right) \times \left(\frac{ft^3}{lb}\right) \times \left(\frac{ft}{in}\right) \times in}$$

$$V = \sqrt{\frac{ft \times ft}{sec \times sec}} = \sqrt{\frac{ft^2}{sec^2}} = \frac{ft}{sec} \text{ (or fpm)}$$

We express the velocity in feet per minute (fpm) in ventilation work rather than fps, so a further conversion is used, 60 seconds/minute:

$$V = \frac{ft}{sec} \times \frac{60\,sec}{1\,min} = \frac{60\,ft}{min} \text{ (or, 60 fpm)}$$

Now, using only the numbers in the formula, including a VP of 1 *in wg* (the conversion from fps to fpm is outside of the radical sign):

$$V = 60\sqrt{\frac{2 \times 32.2 \times 62.3 \times 1(VP)}{0.075 \times 12}}$$

$$V = 60\sqrt{4458} = 60 \times 66.77 = 4005 \text{ fpm}$$

Having determined this, we can use a much shorter formula, since we know that a VP of 1 *in wg* represents 4005 fpm:

$$V \text{ (in fpm)} = 4005\sqrt{VP}$$

Understanding how this formula was derived can help prevent confusion later. It will help you to have a firmer grasp on the principles of airflow.

You should recall that the Ce is a comparison of VP to the SP_h and that velocity is therefore related to SP. When the C_e is known for a certain hood type, you can use it with the SP_h (instead of the velocity pressure) in the formula for velocity:

$$V = 4005\, C_e\sqrt{SP_h}$$

Air density

Air has a weight density of 0.075 lbs/ft^3 (pounds per cubic foot) at standard conditions while water weighs 830 times that of air, 62.4 lbs/ft^3. These conditions are 70°F at sea level, which corresponds to an atmospheric pressure of 29.92 in Hg (mercury). These are the conditions of standard temperature and pressure (STP) that are used in ventilation work. Air (and water) will not have the same weight at other conditions as it did at STP. This also means that a VP of 1 *in wg* will not be equivalent to an air velocity of 4005 fpm at other than STP.

Finding the correct velocity from a VP when air is at different conditions requires the use of a density factor (d), derived from use of the Ideal Gas Law equation (P = ρRT), where the air density (actual) = air density (standard) x d.

$$d = (\rho = lb/ft^3) = 0.075_{\text{ STD air density}} \left(\frac{530}{460 + °F}\right)$$

Or

$$d = \frac{530 \times BP}{460 + F \times 29.92}$$

Where:

Standard air density = 0.075 lb/ft^3@STP

530 = Standard temperature in Rankin (absolute: 70°F + 460) ˚R

BP = Barometric pressure (station pressure where measurements are made—uncorrected atmospheric pressure, in Hg)

°F = Temperature of the air stream

You should use a density factor in ventilation work when air stream temperatures are +/- 30°F from standard (below 40°F or above 100°F) or when the elevation differs 1000 feet or more from sea level. However, when you have some doubt about the effect air density may have, use the density factor.

A density factor of one indicates operation at STP conditions. A factor of less than one means that the air is less dense than standard air and greater than one means it is denser than standard air. The density factor is simply a ratio of the density of air you are dealing compared with to the density of air at STP. For instance, the density factor for air with a density of 0.048 lb/ft^3 compared to STP air (0.075 lb/ft^3) is:

$$D = \frac{0.048 \text{ lb/ft}^3}{0.075 \text{ lb/ft}^3} = 0.64 \text{ (no units)}$$

You would have a rarified (less dense) air with a barometric pressure of 29.27 in Hg and an air stream temperature of 350°F (which is possible):

$$d = \frac{530 \text{ x } 29.27}{(350 + 460) \text{ x } 29.92} = 0.64 \text{ (no units)}$$

To see how this would affect our calculation of 1 *in wg* VP to velocity:

$$V = 4005 \sqrt{\frac{VP}{d}} = 4005 \sqrt{\frac{1}{0.64}} = 4005 \sqrt{1.5625} = 4005 \text{ x } 1.25 = 5006 \text{ fpm}$$

The air is actually traveling through the duct faster than you would have mistakenly thought if you had omitted the density factor. One in wg of VP measured in another system moving denser air than STP would result in an actual velocity of less than 4005 fpm.

The term *actual velocity* has a very specific meaning. It means just what it says—the actual, or true, velocity of the air stream as opposed to the velocity at STP. When we use the term actual velocity, we are referring to the existing conditions, or the conditions of measurement. We add a subscript to the symbol V to show that it is the velocity at measurement conditions (V_m).

A more difficult concept is that of the velocity at standard conditions (V_s). The V_s, of course, is not the true velocity but relates more to the number of molecules (weight of the air) moving through the system each minute. It is essentially a comparison of the weight per cubic foot moved each minute at V_m to the weight per cubic foot you would have at STP. (This actually relates more to the Q, but this concept helps to clarify V_s). More molecules moved at a given speed equate to a higher V_s. Similar to what was shown earlier:

V_s = actual velocity x $\frac{\text{lb/ft}^3 \text{ of air moved at measurement}}{\text{lb/ft}^3 \text{ of air moved at STP}}$

$V_s = 5006 \text{ fpm x } \frac{0.048 \text{ lb/ft}^3}{0.075 \text{ lb/ft}^3}$

V_s = 3204 fpm

In our daily work, we would use the very same density factor that we figured earlier to find V_s:

$V_s = V_m \text{ x } d$

$V_s = 5006 \text{ x } 0.64$

V_s = 3204 fpm

We will use V_s to quite an extent in dealing with ventilation design standards (key parameters) and evaluations of performance. The concept of lb/ft^3 of air moving through a system will become very

important. You will find that the density of the air can have considerable effect on the force needed to capture contaminants and transport them through the ducts.

Velocity types

Another area that can cause confusion is the terminology used for different types of velocity. The V_m and V_s just discussed appear to be types of velocities, but we are speaking of something different here. For instance, you have a certain velocity at the hood face and you have a certain velocity in a section of duct, both of which can be in terms of V_m or V_s. The types of velocities we will cover here are those used to describe velocities in various parts of a ventilation system or those used as standards to be met (fig. 2–10).

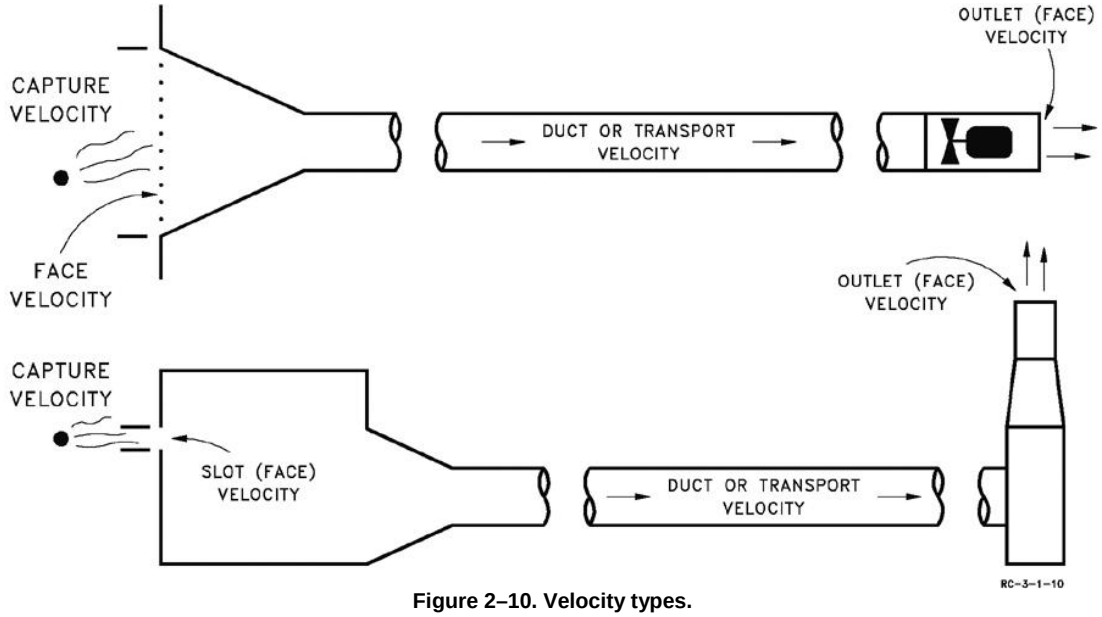

Figure 2–10. Velocity types.

Capture velocity

The most important type of velocity is capture velocity; however, not all hood types are based on it, as we will see later. It is the speed of the air at a point in front of the hood that is required to pull contaminants into the hood. As such, it is a standard to be met—not something that necessarily exists. Rather, the velocity of air that a system is pulling at the point in front of the hood where the contaminants are being released should be at least that of the capture velocity requirement.

The velocity in front of a hood cannot be accurately measured for comparison to capture velocity, but it can be estimated from the Q in the system. More important than this, we will later calculate Qs that will give us the proper capture velocity. The results of these calculations will be a certain Q at STP. For any system that is to be operated at other conditions, such as high altitude or *heated*, we need an STP conversion. The reason for this is that the capture velocity, or the velocity in front of the hood, is actually a measure of force—the force needed to pull in the contaminants. At STP, a certain capture velocity will have the required force. At other conditions, it may not. Air with a low density, for instance, has fewer molecules per cubic foot, so it has less force to move contaminants.

Face velocity

This is the velocity of air across the plane of an inlet or outlet to the system. Most face velocity measurements we make are at the face of a hood, but they can usually be made at the discharge end of the system as well. The low velocities normally found at a hood face coupled with the fact that air comes into it from many directions means that face velocity measurements are also generally inaccurate.

Slot hoods also have a face velocity, but it is usually called *slot velocity* to distinguish it from other types. Velocities at slots are much higher than at most other types of hoods. They also have higher-pressure losses because of the high velocities through narrow openings.

Duct velocity

Duct velocity actually has two meanings. The most obvious is simply the speed of air in the duct. The other is what is known as *transport or conveying velocity*. For example, you may see a design standard for a type of ventilation that says "Duct velocity=2000 fpm minimum." This is a standard to be met—a transport velocity. It is the velocity needed in the duct to keep the contaminants (such as dusts) entrained in the air stream so that they can be moved through the system without settling and causing clogging. The effect of air density on pressure is an important consideration, just as it was for capture velocity. The system is to be designed so that the velocity (at STP) in the duct will match or slightly exceed the transport velocity requirement. A certain duct velocity is achieved by installing appropriately *sized* ducts in the system.

819. Relating area, velocity, and density to the mass flow of air

The Q, or mass flow in cfm, is at the heart of any study of ventilation. It is the major key parameter concerning the ability of a ventilation system to control contaminants. You should remember its association with pressure losses and capture velocity. Note too that it represents the total quantity of air flowing through the system and thus is the measure of a fan's capacity. To begin our study of mass flow, we must return briefly to velocity.

Velocity and area

The velocity of an air stream is a one-dimensional value. However, we know that the linear feet (ft^1) per minute of air must travel through some cross-sectional *area* (A) such as a duct or hood face. Area is two-dimensional because it has length and width; and, because we use units of *fpm* for the velocity, we must use square feet (ft^2) to express the area. Therefore, when a certain velocity flows through a certain area, we come up with the three-dimensional value for volume:

Area (ft^2) x **Linear feet** (ft^1) = **Volume** (ft^3)

and

$$\text{Area } (\text{ft}^2) \text{ x Velocity} \left(\frac{\text{ft}^1}{\text{min}}\right) = \text{ Airflow Volume } \left(\frac{\text{ft}^3}{\text{min}}\right)$$

We now have the formula to find the Q of a ventilation system: ***Q = AV.*** This simple formula has been adapted for many uses, so you will see many variations of it. Some variations are difficult to recognize; others are straightforward. For example, you should recognize the following formula:

$$\left[Q = A(4005\sqrt{vp})\right] \text{ or } \left[Q = A(V)\right]$$

In another example, you may see a design for a type of ventilation system that requires the Q below:

$$Q = V\,(W \times H)$$

$$Q = V \times A$$

The *V* represents the velocity of air that is to flow through an opening with certain dimensions of width and height (W x H).

It is important to realize that the velocity and area you use in the formula must be at the same exact point in the system to find Q correctly. If you measure the average velocity at the hood face, for example, you must use the area of the hood face to find Q. If you find the velocity at the outlet, you must use the area of the outlet. Ridiculous as it sounds, there have been numerous cases of people

measuring velocity in the duct, for instance, and attempting to calculate Q by using the area of the hood.

By now, you know quite a bit about the airflow velocity, but it is a good idea to review how we find areas. Any careful measurements of velocity you may make are not worth much if the area is figured incorrectly. One simple problem is that, although areas of ducts and hoods must be expressed in square feet, their dimensions are almost exclusively expressed in inches. You may have a slot hood that measures 2 inches by 36 inches but the area is 0.5 square feet, not 72 square inches. You may also have an 8-inch round duct (diameter), but its area is 0.349 square feet. For rectangular areas, it is simply a matter of multiplying the length times the width *and dividing by 144*. The reason for this is that there are 144 square inches per square foot. To find the area of a round duct from its diameter, we use the following formula:

$$A(ft^2) = \frac{\pi r^2}{144}$$

Where:

r = radius in inches (one-half the duct diameter)

A calculation for the area of our 8-inch duct (4-inch radius) would be:

$$A(ft^2) = \frac{\pi r^2}{144} = 0.349\ ft^2$$

There are standards for some types of ventilation that employ a slightly different unit involving Q and A. This is cubic feet per minute per square foot (cfm/ft^2). You should understand this unit well because you are bound to run across it someday, and it means different things for different situations. A paint booth, for instance, is required to have a certain number of cfm/ft^2 of cross-sectional area. Referring to figure 2–11, you can see that the cross-sectional area is the width times the *height* of the booth. Each of the 64 square feet has its own allotment of 100 cfm flowing through it. The total Q for the system is therefore 6400 cfm (64 x 100).

You may have noticed that the 100 cfm/ft^2 flowing through the booth equals the average velocity through the booth—100 fpm. The cfm through a cross-sectional area is the same as the velocity because (to go backward) cfm divided by ft^2 equals velocity:

$$Q = AV = ft^2 \times \frac{cfm}{ft^2}$$

$$V = \frac{Q}{A} = \frac{cfm}{ft^2}$$

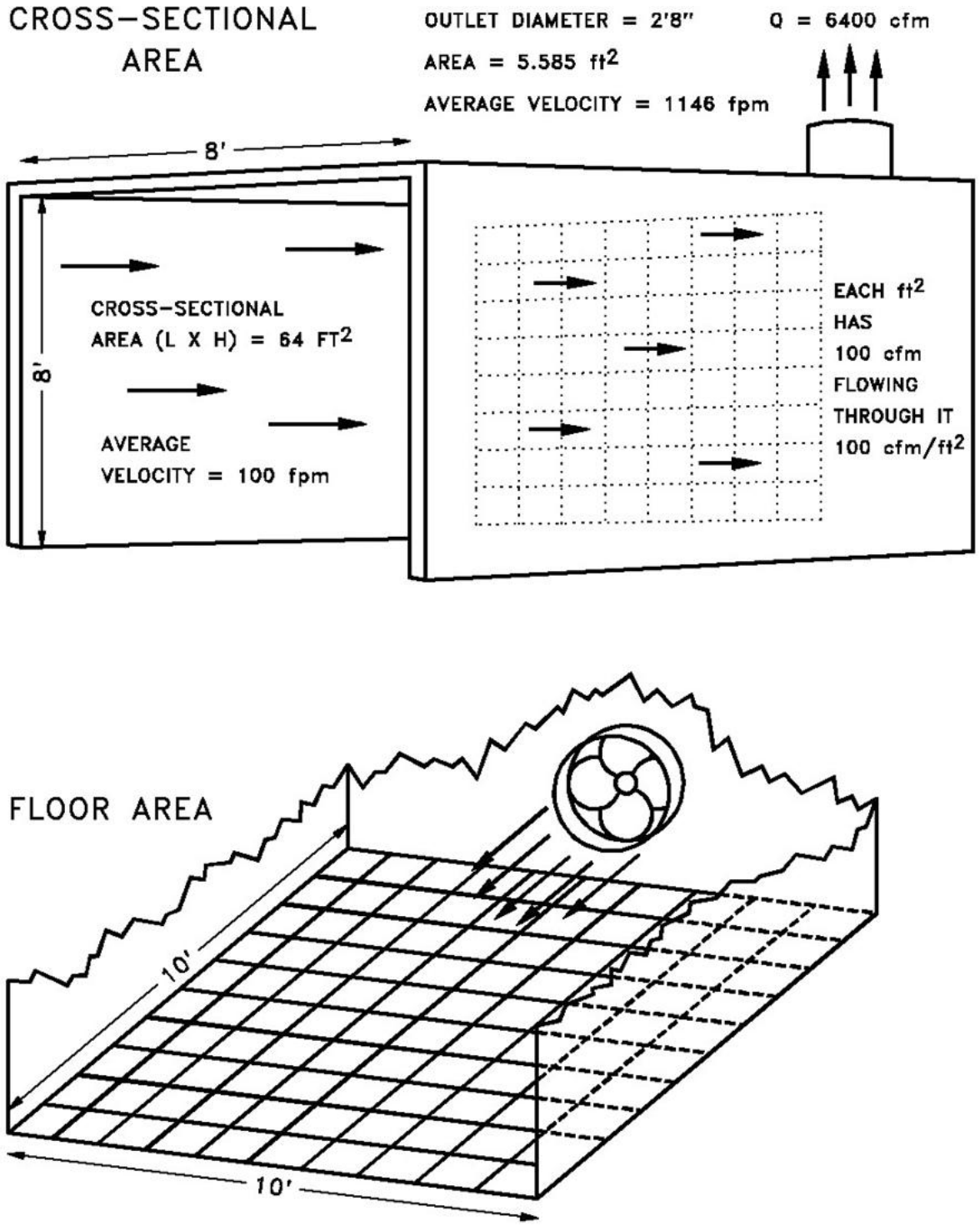

Figure 2–11. Airflow through a cross-sectional area.

When the unit is used as the number of cfm/ft^2 of floor space, for instance, the meaning is different and does *not* equal the average velocity. In this case the area in question is the width times the *length* (not height) of a room. The cfm flows over this area and not through it. Similar to a cross-sectional area, each square foot has its own number of cfm flowing across it. Again, the square foot area multiplied by the number of cfm/ft^2 gives the Q. Another example of the use of this unit is with open-surface tanks. These require a certain number of cfm/ft^2 of tank surface area.

Conservation of mass

A vitally important concept in ventilation is that the *mass flow is the same throughout the system.* What goes in must come out. You have different types and values of velocity but only one Q for the system ($Q_1 = Q_2 = Q_3$). A major reason why this concept is so valuable is that you can usually measure the airflow at the most convenient or accurate location in the system and calculate what the cfm and resulting velocity will be in another part of the system.

Returning to the paint booth briefly, the relatively low velocities within the booth tend to result in inaccurate measurements of airflow. However, we often measure the outlet velocity. The higher velocity at the outlet produces readings that are more accurate. If you had an outlet with a diameter of 2 feet, 8 inches (5.585 ft^2) and measured a velocity of 1146 fpm (more exact than you can expect), the Q would be 6400 cfm. Knowing that the 6400 cfm coming from the outlet must be flowing through the 64 ft^2 cross-sectional area of the booth, you can calculate the velocity (or cfm/ft^2) within the booth:

$$V = \frac{Q}{A} = \frac{6400\,\text{cfm}}{64\text{ft}^2} = 100\ fpm$$

Refer to figure 2–12 to expand on this idea. A hood with a face area (A_f) of 1.25 ft^2 has an air velocity of 500 fpm flowing through it. Using subscripts to denote where the values come from, we find a Q of 625 cfm:

$$Q = A_f V_f$$

$$Q = 1.25\ ft^2 \times 500\ fpm = 625\ cfm$$

If there is 625 cfm coming in the hood, there must be 625 cfm flowing through the 6-inch duct and the 8-inch duct and out the 7-inch outlet:

$$Q = A_f V_f = A_d V_d$$

Suppose you had measured the flow in a 6-inch section of duct and found 3190 fpm. You may be concerned whether the flow in the 8-inch duct was meeting the transport velocity requirement of 2000 fpm. You do not need to measure the flow in the 8-inch section. Simply calculate the flow starting with Q. In the 6-inch duct (0.196 ft^2):

$$Q = AV$$

$$Q = 0.196\ ft^2 \times 3190\ fpm = 625\ cfm$$

We know the 8-inch duct *must* have the same 625 cfm, therefore:

$$V = \frac{Q}{A} = \frac{625\,\text{cfm}}{0.349\,\text{ft}^2} = 1790\ fpm$$

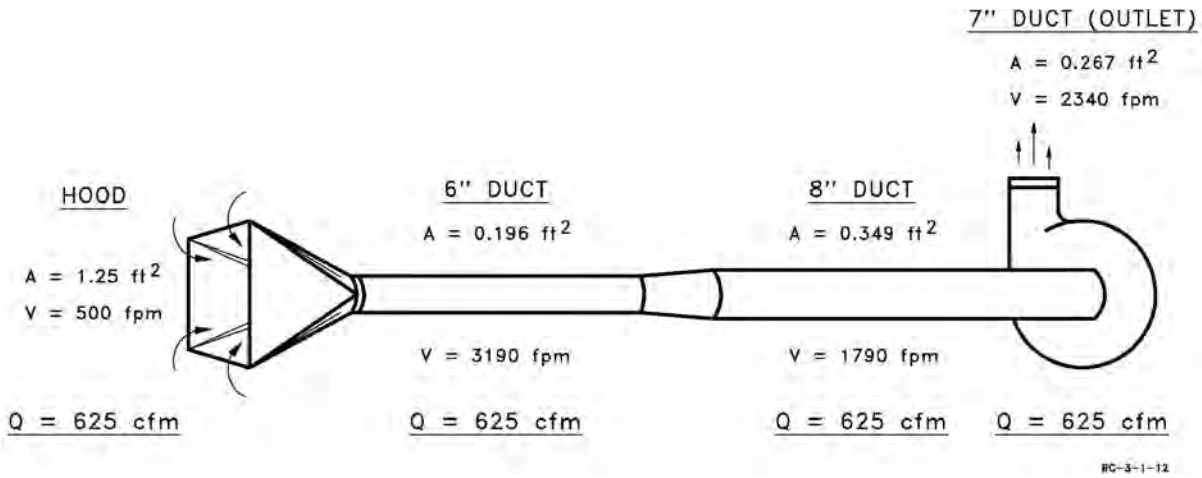

Figure 2–12. Constant air flow volume in a system.

According to our calculations, the transport velocity requirement is not met. What recommendation can we make to correct the problem? Replacing this section of duct with one of smaller diameter will increase the velocity. To find the duct size we need, we use the existing Q and the transport velocity requirement of 2000 fpm. First, find the *area needed*:

$$A = \frac{Q}{V} = \frac{625\,\text{cfm}}{2000\,\text{vfm}} = 0.31\ ft^2$$

From the area, we calculate the *diameter needed* (in inches):

$$Dia = 2\sqrt{\frac{A \times 144}{\pi}} = 2\sqrt{\frac{0.3125 \times 144}{3.14}} = 7.57\ inches$$

You will not find a duct this size. Say that a 7-inch duct is available to replace the 8-inch duct. You can then calculate the resulting velocity with the 7-inch duct (2340 fpm, shown in figure 2–12). Actually, this is only *close* to the velocity you would get. Remember that a smaller duct will cause more system resistance and therefore less cfm and fpm, so do not go too far in trying to increase velocity this way. In addition, if the system has operated for years with no trouble, it is best to leave it alone.

Similar to duct sizing, you may come across a design for a slot hood that requires a slot velocity of 2000 fpm. It may simply state that you should size the slots for this amount. It will still depend on the existing or planned Q of the system. If you planned on a Q of 1000 cfm and needed a slot along the length of a table 36 inches long, you need to know what slot width will provide 2000 fpm. Find the slot area in ft^2 and then in^2:

$$A = \frac{Q}{V} = \frac{1000\,\text{cfm}}{2000\,\text{fpm}} = 0.5\ ft^2 \times 144\ in^2/ft^2 = 72\ in^2$$

Find the slot width from the area and length:

$$W = \frac{A}{L} = \frac{72\ in^2}{36\ in} = 2\ in$$

The 2-inch slot width will provide the necessary 2000 fpm.

Comfort and dilution ventilation are used to ventilate wide or general areas rather than a specific point of contaminant release, as with local exhaust. Because of this, some references group them together under either the heading *general ventilation* or the heading *dilution ventilation* to include both types. We need to make some distinction, however. Comfort ventilation is meant to do just what its name implies—keep workers comfortable, at least comparatively. Dilution ventilation, on the other hand, is used to control some type of airborne hazard in the workplace.

820. Principles of dilution ventilation

A more important purpose for so-called general ventilation is the control of airborne contaminants that may pose a threat to health. In dilution ventilation, we are interested in providing enough clean air to a room to mix and dilute the contaminant to safe levels. It is not as efficient as local exhaust ventilation, but there are circumstances when various limitations make it more feasible to use.

By this time, we have already determined that there is a need for some form of ventilation. The choice of dilution ventilation and how well it functions depends on a number of factors. First, it can be calculated only for *vapors* (or gases), as opposed to aerosols such as mists, fibers, and fumes. There are general guidelines for welding shops, but it is not possible to dilute contaminants that settle as rapidly as sawdust. The substance(s) to be controlled must have a lower density than air.

Toxicity

The contaminant must also be *low in toxicity*. Remember that dilution ventilation does not remove contaminants from the workroom, so there will usually be some exposure. A general rule is that dilution should not be used for substances with an occupational exposure limit (OEL) of less than 100 ppm (although you may find some in operation that do not comply with this). This appears to use OELs as indexes of toxicity, but this is not intended. You might recall that one of the uses for OELs was engineering design. Also, the Q will depend on the OEL of the chemical to be controlled. Using dilution for a substance with a low OEL can require such a large volume of air as to be impractical.

Concentration and rate

The contaminant must also be generated in *low concentrations* and at a *uniform rate*. High concentrations again point to the need for excessive amounts of dilution air. Uneven “spikes” of contaminant generation during the day can tax the system’s ability to control the substance. The spikes may cause periods during which concentrations exceed short-term limits. The air volume required is based on the *average amount* of a substance used during a period.

Supply and exhaust

A combination of *supply and exhaust* (not local exhaust) is preferred for proper air distribution and dilution. Figure 2–13 shows a blower outlet and an exhaust inlet both with a diameter of 1 foot and identical face velocities of 1000 fpm. The velocity of air from the blower will be about 100 fpm at 30 feet from the outlet face. The velocity of air to the exhaust inlet will be about 100 fpm at only 1 foot from the inlet face and non-existent at 30 feet. Supply provides a far more directional airflow to mix with the contaminant better.

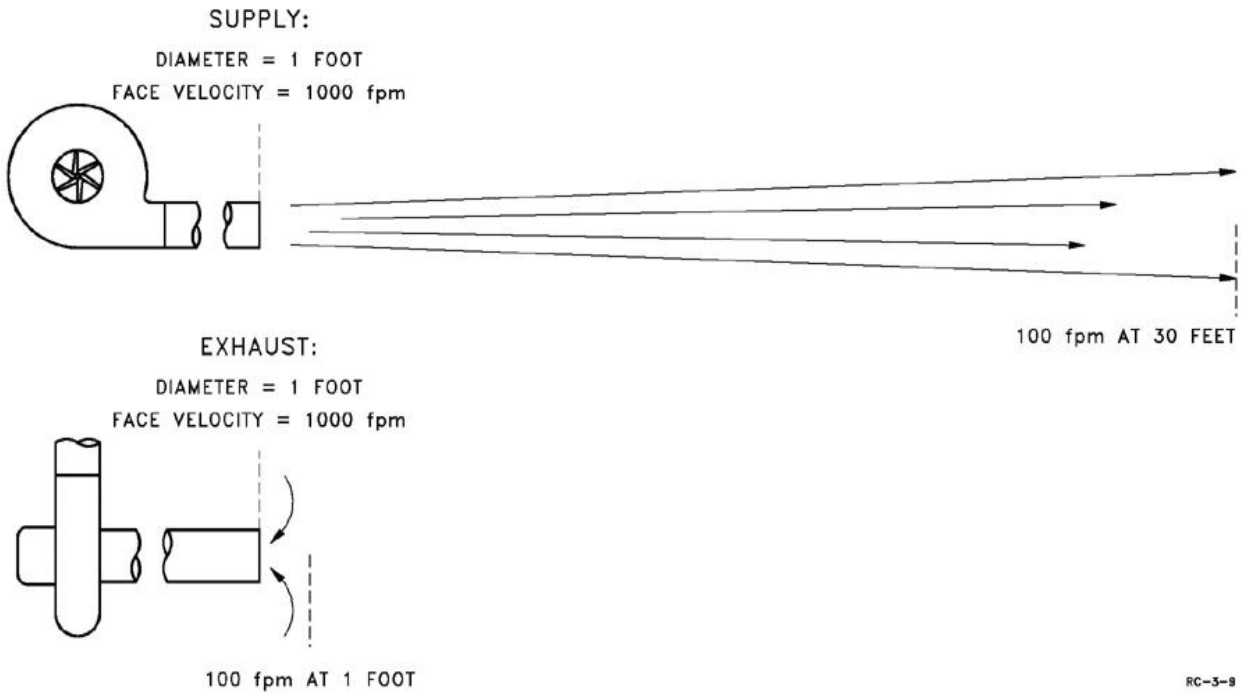

Figure 2–13. Blowing versus exhausting.

The directionality of the supply system is put to good use by ensuring that the air flows *past* the worker and through the source of contaminant generation. From there, it should empty out through doors, windows, cracks, or, ideally, an exhaust system. You certainly do not want any type of arrangement where the chemical vapors are being blown into the worker's breathing zone. Another concern is that the supply must be *tempered*—heated or cooled. The expense of treating the large air volumes that dilution systems deliver can be a major limiting factor in the use of this type of control.

Air pressure

The last goal we need to discuss involves the air pressure within the workroom. Unfortunately, this is ignored too often. A workroom in which dilution ventilation is used should have a *slight* negative pressure if an adjoining room is normally *occupied*. This means a room that is next door through the wall, not a separate building. Figure 2–14 shows an example of a workroom with offices adjoining it—the workers in the offices are supposed to be considered unexposed (something you should check), and you do not want the vapors spilling into such areas. If adjoining rooms are *not* routinely occupied (such as closets and one-room buildings), it is better that the workroom has a slight positive pressure. This helps to provide more outlets through cracks, windows, and doors for the vapors. Another way to state these pressures is that the positive pressure comes from a *slight excess of supply* and the negative pressure comes from a *slight excess of exhaust*.

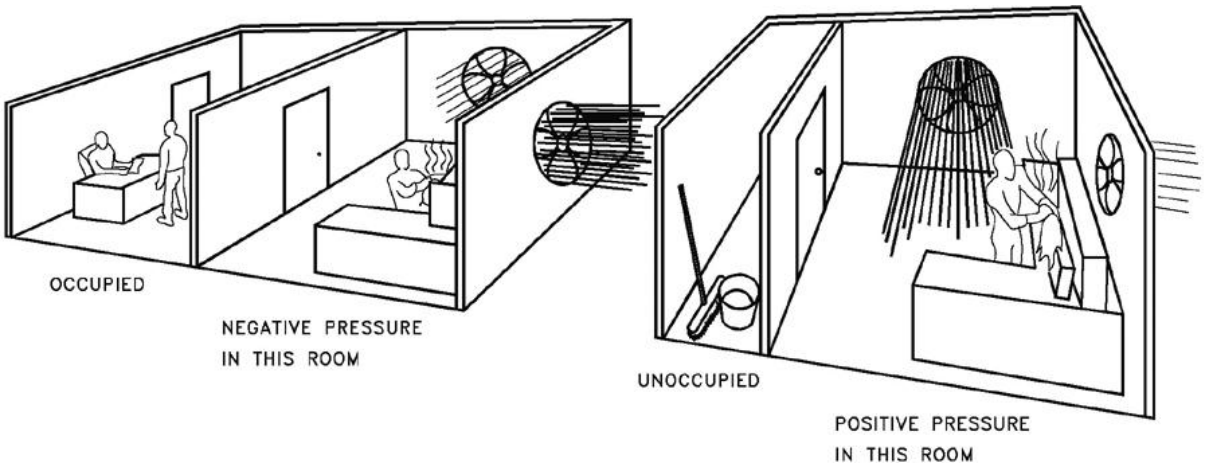

Figure 2–14. Workroom air pressures.

Key parameters

Dilution is truly a type of industrial ventilation; it is used to control chemicals with concentrations that have been found to be over their OELs. We calculate the Q that is required based on the contaminant data and conditions under which it is used. The *Q* we come up with is called a *design standard or key parameter*. We use it as a standard to be met. A new system to be installed is designed with this air volume and we test the system after installation to see if the key parameter is met. If a system already exists but has never been tested, we also calculate the key parameter to see if the existing flow meets it.

The key parameters should be documented outlining the system. This should be completed before making airflow measurements for a system. It mainly describes the contaminant to be controlled and characteristics of the system. (**NOTE:** It is not considered an industrial ventilation system if there are no contaminants to be controlled). Notice that the local exhaust section is not used since we are dealing only with dilution.

Using pounds/hour

The Q needed can be calculated using either pounds per hour (lb/hr) or gallons per hour (gal/hr) of contaminant evaporated. You will probably get this information in terms of the amount used during the operation, such as 20 lb over 4 hours (20 lb/4 hr). It will always be necessary to convert to the amount used in *1 hour*:

$$\frac{20\,\text{lb}}{4\,\text{hr}} = 5\ lb/hr$$

At standard conditions, one pound-molecular weight (lb-mole) of a material will evaporate to fill 387 ft^3 of space. We need units of cubic feet per minute (ft^3/min), so we use the conversion factor of 1-hour per 60-minutes. Note that the units of pounds and hours cancel to end up with ft^3/min.

$$\frac{387\,\text{ft}^3}{1\,\text{lb - mole}} \times \frac{1lb-mole}{hr} \times \frac{1hr}{60\,\text{min}} = 6.45\ ft^3/min$$

The K is a factor to account for three main variables. The K factor is the point at which the size of the box converges with the maximum airflow at 1" VP. The most important is the *effectiveness* of the ventilation—how well it mixes the contaminant for dilution. We determine the K factor very much as we did for vapor calculations. Examine the room for obstacles and how the ventilation system directs

the airflow throughout the room and especially through the point of contaminant generation. The other two items to consider for the K factor are the *toxicity* and *evolution rate* of the contaminant. If we use OELs only as guides in engineering control, chemicals with OELs over 500 ppm are considered only slightly toxic. Those from 100 ppm up to 500 ppm are called moderately toxic. A high OEL tends to lower the K factor, and a low OEL requires higher K factors. The consideration of evolution rate again refers to how uniform the vapor is generated, non-uniform generation requiring higher K factors. As the choice of a K factor is subjective, it is best for at least three people each to weigh all considerations, for each to estimate a K factor, and then for all three to decide on one reasonable value after discussing it. K factors usually range from one to ten but may be higher if air distribution is very poor. Also, a factor of one is usually considered too good to be attainable.

The 10^6 factor is used because we must express C (concentration) in parts per million (not mg/m^3). We are using a volume of air to dilute a volume of vapor in a room and ppm is the volume-to-volume unit needed. We are therefore determining the Q that will keep the chemical vapor concentration at the OEL level at all times. In actual practice, you will most likely find that a well-designed system will keep the concentration well below the OEL.

To see how the formula works, we will use an example situation involving ethyl acetate, a moderately toxic agent. It is generated at a steady rate of about 9.5 lbs/hr in a room with good air distribution from the ventilation system. Based on this, everyone has agreed upon a K factor of four. Ethyl acetate has an OEL of 400 ppm and a molecular weight of 88. It is always best to tabulate all your information first for better organization:

Ethyl acetate:

k = 4

lb/hr = 9.5

C = 400 ppm

MW = 88

$$Q = \frac{6.45 \text{ x K x lb/hr x } 10^6}{\text{C x MW}}$$

$$Q = \frac{6.45 \text{ft}^3 \text{ x 4 x 9.5lb/hr x } 10^6 \text{ ppm}}{400\text{ppm x 88 lb}} = \frac{245{,}100{,}000}{35{,}200} = 6963 \text{ cfm}$$

In making your recommendation for the Q, rounding to 7000 cfm is very reasonable. However, it is better to use the exact nearest whole number while you are learning this information.

The volume of 6963 cfm we found represents what is needed to dilute the 9.5 lb/hr under these conditions to the OEL of 400 ppm. The process may look familiar to you because it is a rearrangement of the method we use for vapor calculations. Note that the room volume is not needed here as it was in finding a concentration. We already have the concentration of interest, the OEL. You might be interested in using the formula for the maximum concentration possible that you learned earlier to check that 6963 cfm will hold the concentration to a maximum of 400 ppm.

Using gallons/hour

We sometimes obtain the amount of the chemical used in pounds, but far more often, it is some liquid measure. Our standard liquid measure is the gallon. We must either convert a generation rate in gal/hr to lb/hr or modify our formula. To convert:

lb/hr = gal/hr x 8.34 lb/gal x S

The factor 8.34 lb/gal is the weight of 1 gallon of *water*. Since we want the weight of the *chemical* in question, we need the specific gravity (S) of the chemical. For instance, ethyl acetate has a specific gravity of about 0.9 (lighter than water). If 1.2 gal/hr is generated, the number of lb/hr is:

$$\text{lb/hr} = 1.2 \text{ gal/hr} \times 8.34 \text{ lb/gal} \times 0.9 = 9 \text{ lb/hr}$$

You can use the 9 lb/hr in the formula we used before or simply include the conversion in the formula. The resulting formula using gal/hr for the generation rate is the more common one that we use.

$$Q = \frac{53.8 \times K \times \text{gal/hr} \times S \times 10^6}{C \times MW}$$

The 53.8 is the result of multiplying the earlier factor of 6.45 by 8.34 lb/gal.

For another example, we will use the ethyl acetate at a generation rate of 1.2 gal/hr under rather poor conditions of air distribution, so we will use a K factor of seven. Summarizing the data we have and entering it into the formula:

Ethyl acetate:

K = 7

gal/hr = 1.2

S = 0.9

C = 400 ppm

MW = 88

$$Q = \frac{53.8 \times 7 \times 1.2 \times 0.9 \times 10^6}{400 \times 88} = \frac{406{,}728{,}000}{35{,}200} = 11{,}555 \text{ cfm}$$

Multiple chemicals

Thus far, we have dealt with only one chemical in use in a room. It is not likely that you will ever find a workplace that has this situation. Shops normally use varying amounts of many different chemicals that must be considered in dilution ventilation. This could be another reason to recommend local exhaust over dilution. However, you can usually ignore less important chemicals used in minute amounts and concentrate on the major ones.

You should remember that you must consider the combined effects of chemicals that are additive to each other. These are chemicals that affect the same organ or organ system (as most chemicals within a given shop usually do—one way or another). Figuring the Q for such chemicals starts out the same way as for single chemicals. When you have two or more chemicals that are additive, you find the Q of each one and *sum the values* for the total Q required.

We found that 11,555 cfm was needed to keep ethyl acetate to 400 ppm in the last example. Suppose that sec-butyl acetate was also used in the workroom at the rate 1.2 gals/hr. We find that the Q required for this chemical under the same conditions would be:

Sec-Butyl acetate:

K = 7

gal/hr = 1.2

S = 0.865

C = 200 ppm

MW = 116

$$Q = \frac{53.8 \times 1.2 \times 0.865 \times 10^{6}}{200 \times 116} = 16{,}850 \text{ cfm}$$

If air sampling had shown the compliance factor of these two additive chemicals to be over one, then we would sum the two Qs:

$$Q = 11{,}555 \text{ cfm} + 16{,}850 \text{ cfm} = 28{,}405 \text{ cfm}$$

This is quite a volume of air for dilution, and heating costs alone could be very expensive. Local exhaust may be the better option.

If the two chemicals had *not* been additive and air sampling results showed concentrations above their OELs, we would still figure the individual Q for each, but we would choose the highest value for the total Q. In this way, the Q that takes care of one chemical also takes care of the other.

It is very possible there will be some chemicals in use that are additive and some that are not. The same rules apply. Sum the values of the additive chemicals and choose the highest Q from the sums of different groups that are not additives. You may have a group of chemicals that are additive to one another in one way and another group additive in a different way. Each group will have its own sum of values for Q, and you simply choose the highest.

A final important note on the key parameter you figure is that the value you come up with *always* represents the Q at standard conditions (Q_s). Since you are determining a standard to be met, there must be a point of reference—STP. The value will always be understood to mean standard cubic feet per minute (scfm). This will become even more critical in finding key parameters for fire/explosion dilution ventilation.

Dilution ventilation for fire and explosion control

An immediate hazard to health is the danger of a fire or explosion due to the use of solvents. You may find these potential dangers in places such as drying ovens and mixers (mullers) that combine solvents with dry products. These too require a certain Q to keep contaminants to safe levels—in this case, supply, exhaust, or a combination will work. The safe levels are expressed in terms of explosive limits.

Explosive limits

The majority of solvents used in the Air Force are flammable and each has a specific *lower explosive limit (LEL) and upper explosive limit (UEL)*. It is between the LEL and UEL concentrations that the danger lies. The LEL is the lowest concentration in percent at which a substance presents an explosion hazard. Above the UEL, the concentration becomes too rich to explode. It is standard procedure to keep all concentrations of explosive substances at or *below 25 percent of their LELs* (fig. 2–15).

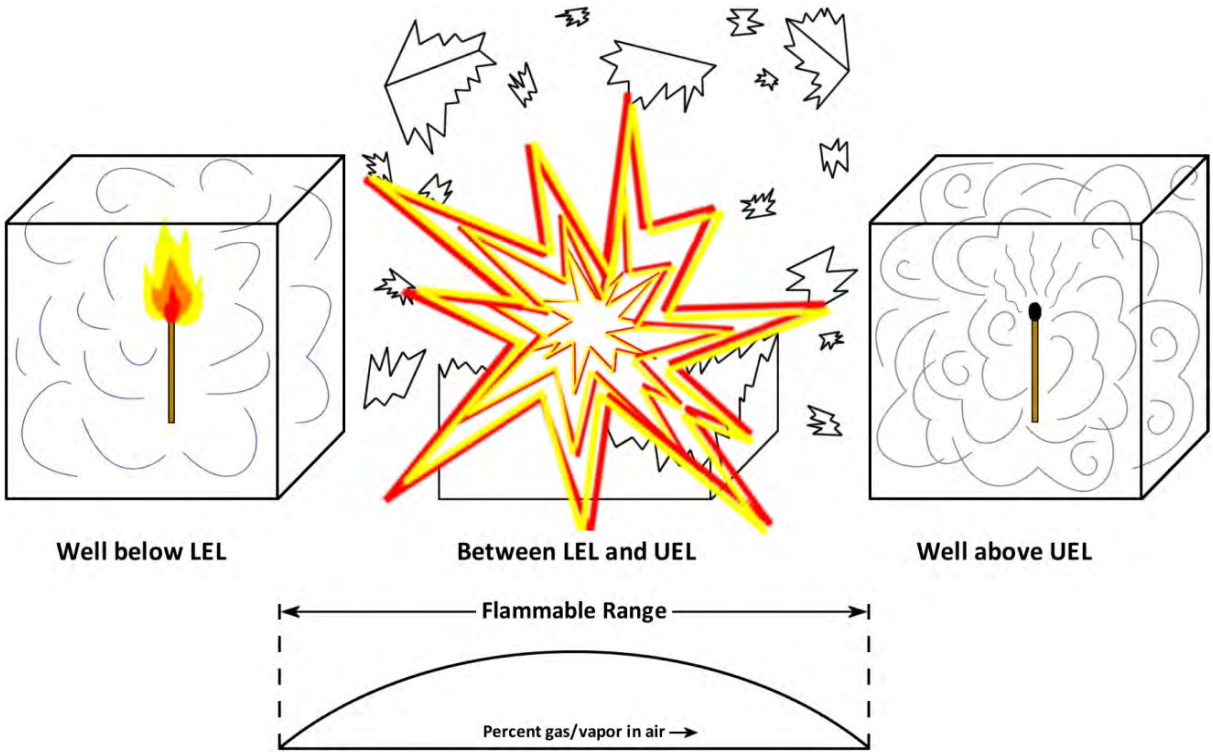

Figure 2–15. Explosive limits.

You can look up explosive limits in references such as *Industrial Ventilation* and *National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards*. You will find that there are very wide ranges for some chemicals, such as formaldehyde, which has limits of 7 to 73 percent. Typical of most chemicals we are interested in is toluene, with a narrow range of 1.27 to 6.75 percent.

Be sure that you understand that dilution for fire and explosion is very different from dilution for health. *People do not work in areas that have ventilation only for fire and explosion.* We are speaking of *enclosures* where some operation is in progress without workers inside, such as those in m figure 2–16.

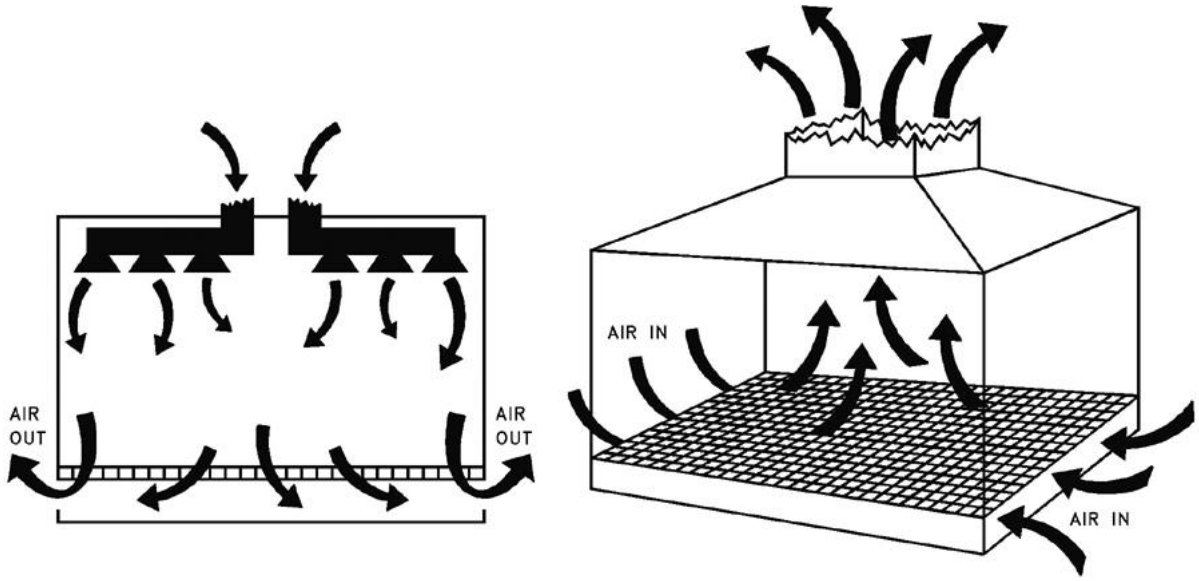

Figure 2–16. Enclosure with ventilation only for fire and explosion control.

If you have not guessed why this is true, take the example of toluene again. Its LEL of 1.27 percent (1.27 parts per 100) is equivalent to 12,700 ppm:

ppm = percent x 10,000

ppm = 1.27 x 10,000

ppm = 12,700 ppm

If we take 25 percent of the LEL in ppm, we find a concentration of 3175 ppm. For contrast, the OEL of toluene is 100 ppm, and it becomes immediately dangerous to life or health (IDLH) at 2000 ppm. It is evident that dilution to 25 percent of the LEL does not protect someone who breathes this concentration.

Saturation

Another important aspect of dilution for flammable chemicals is the degree of risk they pose. This involves the *saturation concentration*, which is the maximum amount of a certain chemical vapor that air can hold at a given temperature. It is similar to 100 percent relative humidity. We can use it to see if it is possible for the vapor to reach the LEL (or portion of the LEL) concentration at a certain temperature.

We need the vapor pressure in millimeters of mercury at the temperature of interest to find the saturation concentration. We multiply this by 100 (for percent) and divide by 760 mm (millimeters) Hg (atmospheric pressure). At high altitude, divide by the station pressure (mm Hg) at that location. Our answer will be the percentage of the chemical vapor in the air at the temperature at which no more can be evaporated (the air will hold no more). Toluene has a vapor pressure of 22 mm Hg at 68°F (close enough to our standard of 70°F). Its saturation concentration at 68°F will be:

$$\text{Saturation concentration} = \frac{\text{vapor pressure} \times 100}{760} = \frac{22\text{ mm Hg} \times 100\%}{760\text{ mm Hg}} = 2.89\%$$

Comparing this to the LEL of 1.27 %, we find that toluene can quite easily build up to explosive levels at 68°F. In fact, the temperature must get down to about 42°F before it is impossible for the concentration to build up to the LEL. At this temperature, the vapor pressure is about 9.65 mm Hg.

$$\text{Saturation concentration} = \frac{9.65\text{ mm Hg} \times 100\%}{760\text{ mm Hg}} = 1.27\%$$

To be sure, things are safe, remember that we use the criteria of 25 percent of the LEL, which in this case is 0.3175 percent (0.25 X 1.27). To make this concentration impossible for toluene vapor to attain, the temperature would have to be about 4°F for a vapor pressure of 2.4 mm Hg.

Many chemicals have vapor pressures so low that it is very unlikely that they could produce explosive concentrations at normal temperatures. Ethylene chlorohydrin is a good example. It has a vapor pressure of only 5 mm Hg at 68°F and a LEL of 4.9 percent. Refer to figure 2–17, its saturation concentration at 68°F is 0.658 percent, so it cannot even build up to 25 percent of the LEL (1.225 percent). At 86°F, however, the vapor pressure is 10 mm Hg, and the concentration can build up to 25 percent of the LEL. At 133°F (40 mm Hg), the LEL concentration itself can be attained. This points us to the importance of the operating temperature of a process when considering dilution for fire and explosion control.

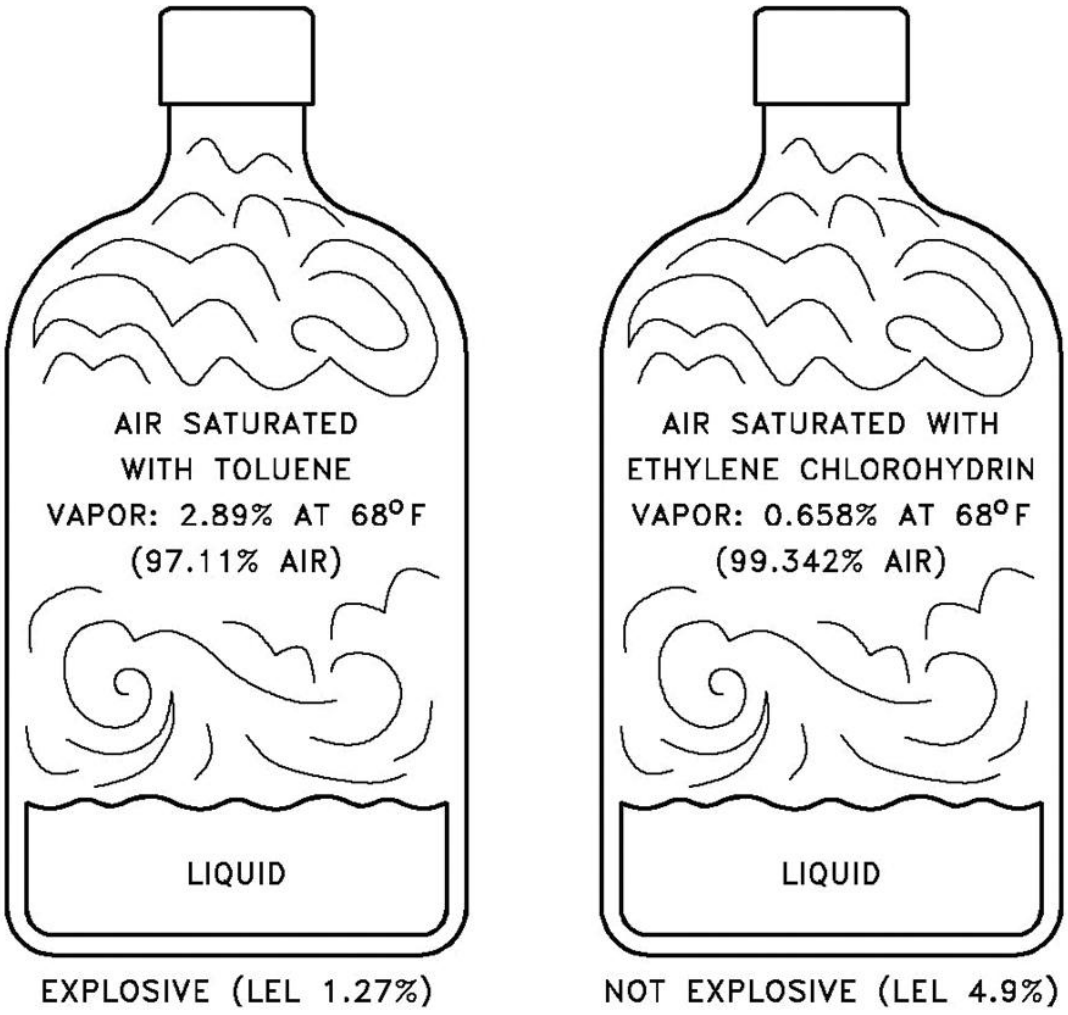

Figure 2–17. Saturation concentration versus explosive limits.

Required air-flow volume

Having determined the maximum operating temperature and the fact that some hazard exists, let's figure the Q required for 25 percent of the LEL:

$$Q = \frac{53.8 \text{ x K x gal/hr x S x } 100}{\text{LEL x MW x B}}$$

Notice that this formula requires units of gal/hr due to the factor, 53.8. You can use lb/hr as before if you use a factor of 6.45 and omit the specific gravity (you need lb/hr for gases).

The K factor is defined a bit differently here. To keep the concentration at 25 percent of the LEL or less, a minimum K factor of four is used. This would be the case for an enclosure with very good air distribution for proper mixing. Factors higher than four will be needed when air distribution is not as good. For very large enclosures with poor distribution, the K factor can be as high as 12.

Another difference in this formula is the 100 since the LEL is in percentage units, the LEL replacing the OEL, and the B. The B is a safety factor that is based on the temperature in the enclosure. You have seen the effect that rising temperature has on the danger of explosion. When the temperature is under 250°F, the B is one and can be omitted. Temperatures above 250°F require a B of 0.7 for additional protection.

Take for an example an operation using methyl isobutyl ketone (hexone) in a small enclosure with excellent air distribution at 75°F:

methyl isobutyl ketone (hexone)

K = 4

gal/hr = 9.1

S = 0.8

LEL = 1.4

MW = 100

B = 1

$$Q = \frac{53.8 \text{ x } 4 \text{ x } 9.1 \text{ x } 0.8 \text{ x } 100}{1.4 \text{ x } 100 \text{ x } 1} = 1119 \text{ cfm}$$

This type of dilution ventilation requires far less Q. Imagine the Q that would be needed for this chemical to dilute it to its OEL of 50 ppm.

The last example was not much of a problem because everything needed to solve it was provided. Finding the generation rate can sometimes be very tricky but obviously, very critical. A perfect case is that of an enclosure where a solvent is mixed with some non-flammable substance such as a resin. The operation may last all day, but the solvent usually evaporates quickly. The amount of solvent and how fast it evaporates are the important parameters. We can use a case involving n-propyl alcohol to illustrate. One gallon of this chemical is added to a mixer every 15 minutes but completely evaporates only 4 minutes after adding it. We therefore base the generation rate on 1 gallon per 4 minutes equals how many gallons per 60 minutes (gal/hr):

$$\text{gal/hr} = \frac{1 \text{ gal}}{4 \text{ minutes}} \text{ x } 60 \text{ minutes} = 15 \text{ gal/hr}$$

This is difficult for some people to accept because nowhere near 15 gallons is used in the operation. Remember that this is a *rate of usage*, not an actual amount used.

Many people would want to base the generation rate on the length of the operation or time between adding the solvent (15 minutes). This would result in an erroneous rate of only 4 gal/hr. Using the correct generation rate and example data given below, we find the true Q needed for this operation:

K = 6

gal/hr = 15

S = 0.8

LEL = 2.0

MW = 60

B = 1

$$Q = \frac{53.8 \times 6 \times 15 \times 0.8 \times 100}{2.0 \times 60 \times 1} = 3228 \, cfm$$

If we had used 4 gals/hr as the generation rate, we would figure the Q to be only 861 cfm—not enough to control the vapors at all times. The Q must control the vapors during the peak periods of concentration, no matter how short they are.

Multiple chemicals

As mentioned, it is not often that you find only one chemical used in an operation. We have a different way of handling multiple chemicals for this type of dilution. We do not have to figure a Q for each chemical, but we need to know which chemical's data to use. For this, we use the specific gravity, LEL, and molecular weight as follows:

$$\frac{S}{LEL \times MW}$$

We use this formula for each chemical in a mixture and base the Q on the chemical with the highest value. For example, using xylene and methyl ethyl ketone (MEK):

Xylene

S = 0.881

LEL = 1.0

MW = 106

MEK

S = 0.805

LEL = 12

MW = 72

$$\frac{0.881}{1 \times 106} = 0.0083 \qquad \frac{0.805}{12 \times 72} = 0.0009$$

We would figure the Q required using only the chemical data of xylene. The Q that controls xylene will also control MEK. Chemicals are not additive for fire/explosion dilution, as they often are for health dilution. However, we must use the entire amount of the mixture in the generation rate. If there had been 4 gals/hr of xylene and 12 gals/hr of MEK used, we use 16 gals/hr as the generation rate as if it is all xylene. That is, we use the entire generation rate but only the chemical data of xylene.

Another thing you may need to do is to determine the amount of active (flammable) ingredients in a product when mixed with "inert" (non-flammable) substances. This is a simple matter of adding up the percentages of the active ingredients in the product and making sure that the rest is inert. Suppose we had a 20-gallon mixture of 20 percent xylene and 60 percent MEK. The active ingredients add up to 80 percent, or 16 gallons (fig. 2–18). The other 20 percent (4 gallons) is not needed in figuring the Q. It may not be a problem to base the Q on all 20 gallons, but there may be times when it is very wasteful or when the excess could disturb the operation in some way.

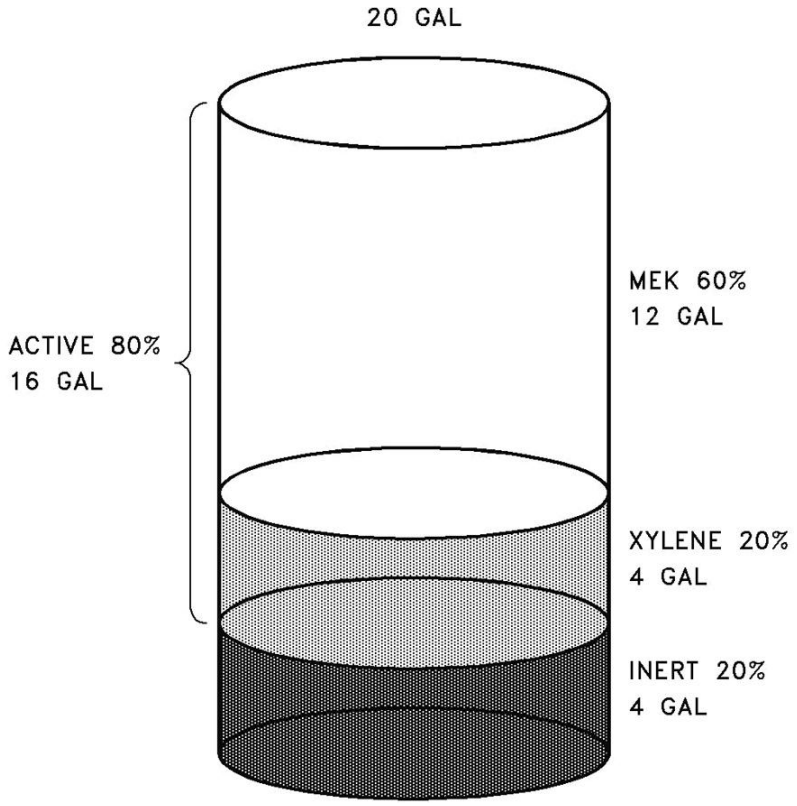

Figure 2–18. Percent active ingredients.

The last thing to do is to consider the operating conditions again. All of your careful calculations may ultimately be incorrect if you fail to do this. The key parameters you figure are for standard conditions, and many processes like those we have discussed are heated. Fresh air constantly entering from a supply system presents no problem. Trouble may arise if the system recirculates the air—the air is exhausted, contaminants removed, and sent back to the enclosure. An exhaust-only system has the same problem, but this pertains more to local exhaust ventilation.

When we say, "convert to operating conditions," we mean that the Q requirement in scfm must be converted to actual cubic feet per minute (acfm) for the proper fan capacity. For instance, a recirculating system that we know will be operating at 275°F requires an air density correction. We can label the units as $acfm_{275}$. In some areas, the barometric pressure may also be significantly different from standard and should be used in the density standard. Usually, the high operating temperature will far outweigh the difference in pressures. For our example, the density factor will be:

$$D = \frac{530}{(275+460)} = 0.72$$

Note that since the temperature exceeds 250°F, the B of 0.7 is needed in the formula. For our n-propyl alcohol example that originally required 3228 cfm, we would need 4611 cfm at 275°F. Remember that this is really 4611 scfm, so we find the $acfm_{275}$ required:

$$Acfm_{275} = \frac{Q_s}{d} = \frac{4611}{0.72} = 6404\,acfm$$

Ignoring the density of the air in a case like this can be very serious, as you can well imagine.

821. Principles of local exhaust ventilation

As with most techniques, there are some undesirable and limiting aspects of local exhaust, but the advantages of local exhaust far outweigh the disadvantages. The degree of influence that the advantages or disadvantages have will largely depend on the type of process being controlled and the type of system used to control it.

The advantages of local exhaust over dilution are many. Combining good contaminant control with generally lower air volumes, local exhaust is the most efficient and economical type of industrial ventilation. A properly designed system is usually capable of keeping exposures to zero or near-zero levels. In spite of the available knowledge, however, we see many systems that do not function as intended because they were installed without full regard for the design goals needed to make them efficient. Knowing these goals will help you make worthwhile recommendations both when in the planning stages and when a system needs correction.

With rare exceptions, such as paint booths and other large systems, there is much less air that must be handled with local exhaust than there is when dilution is used. This means that makeup air (supply) may not always be necessary; and, when it is necessary, less is required. Workers may be bothered less by drafts than they would be if the large volumes of dilution air were used. The reduced requirement for heating (and sometimes cooling) is also a big plus and has a lot to do with the cost of operating the system.

Local exhaust is cheaper in the long run mainly due to the lower operating costs. Smaller ducting and fans also help, but the initial expense is often quite high. This is one of the major reasons why these projects are delayed for years sometimes (and unwisely). Elaborate hoods are needed for some processes, expensive air cleaners for others. Just the cost of having a system competently designed in the first place can be high.

Another benefit of local exhaust is that it limits the spread of the contaminant. This can go far in protecting equipment from the wear and tear caused by the contaminant. Keeping the dust from the moving parts of saws in a carpenter shop is an example. You can see how this would also cut down costs. If a system helps protect equipment, it will likely go even further in easing housekeeping troubles since materials are not being spread all over the shop. Many shops even have a local exhaust device called a floor sweep that helps in this area. It acts as a permanently mounted vacuum cleaner where you sweep dust from the floor.

You should not forget the outside of the shop when considering advantages. Remember that cleanliness is important there, too. Besides being unsightly, contaminants dispersed into the outside air may violate pollution regulations or be sucked into air intakes of buildings. Such situations make the use of air cleaners and proper discharge very important.

Ultimately, the overriding purpose of an exhaust system is to minimize worker exposure to the contaminant. Not only is the worker at the process protected, but also controlling dispersion obviously protects those not directly involved who are considered “not exposed.” Unlike dilution, which mixes contaminants throughout a room, exhaust is designed to control a substance at its source so that it never reaches a person’s breathing zone. A worker must usually perform an operation very close to the exhaust system to ensure that exposure is minimized. This may create a noise hazard. Not only can the rush of air into the hood be quite loud and annoying, so can the fan, motor, and possible vibration in the system. These are defects that can normally be reduced or eliminated by good design procedures or modifications.

The closeness of the hood to the process can also restrict a worker’s access. It may be difficult to reach and comfortably work with the process and, in extreme cases, even see well enough to do the job. In addition to discomfort and annoyance, this could be a serious safety hazard that requires immediate correction. Such a situation is an example of a design deficiency in which the most important person involved was not properly considered. You may see such a problem mostly in connection with some hoods that enclose the process to an extent but occasionally with simpler types.

In some cases, a worker may simply think that it is “too much trouble” or annoying to get close enough to the hood. This is due more to the worker’s laziness and not being accustomed to using the hood.

Another problem that may arise is the false sense of security that a worker can develop. Although the worker’s exposures are intended to be completely controlled, this knowledge may lead to carelessness. A worker may not follow safe practices, may cause splashing or other direct contact with the substance, or may interfere with the proper operation of the system (such as causing disturbing drafts away from the hood). Use of the system may even be discontinued because “nothing ever happened before.” Attention to the design goals for local exhaust can enhance the advantages and alleviate most of the disadvantages.

An efficient system is one that is as economical to install and operate as possible. Economy must be kept in mind from the earliest stages of planning. The very first consideration is whether the contaminant can be reduced or eliminated by modifying machinery, materials, or the ways materials are processed. Whether a contaminant can be reduced or not, try the same techniques to find out if the spread of the contaminant can be restricted, such as by wetting the material. This can certainly reduce the volume of air required and, therefore, the size of the system. It would also mean that less makeup air could be used for a savings on that part of the system and its associated heating or cooling costs. One way or another, each of the design goals helps in providing an economical system.

Makeup air

Adequate makeup air is too often neglected when local exhaust is considered. It is as if some people think of it as an unnecessary luxury or something that can be cut from plans to save money. You see this serious problem continuously with larger local exhaust systems such as paint booths.

Makeup air is critical to the proper functioning of large-volume systems. Natural draft makeup through windows, doors, and cracks can be used if enough air can get in, but this method can be quite unsatisfactory. The amount of air entering a room must be the same as that exiting through all exhaust sources. Mechanical makeup is much better in providing this. It is a good idea to have a little more than needed (or a fan with a drive belt that can be adjusted for different flows) if more exhaust systems may be needed in the near future.

You see in figure 2–19, inadequate makeup causes a negative pressure in the workroom that can limit the amount of air exhausted (as we saw in pressure losses). It essentially adds to the total system resistance. The amount of air coming into the room will equal the amount exhausted, but the system capacity will be reduced. This could result in insufficient contaminant control. The installation of a makeup system would get the system’s capacity up to the air volumes for which it was designed.

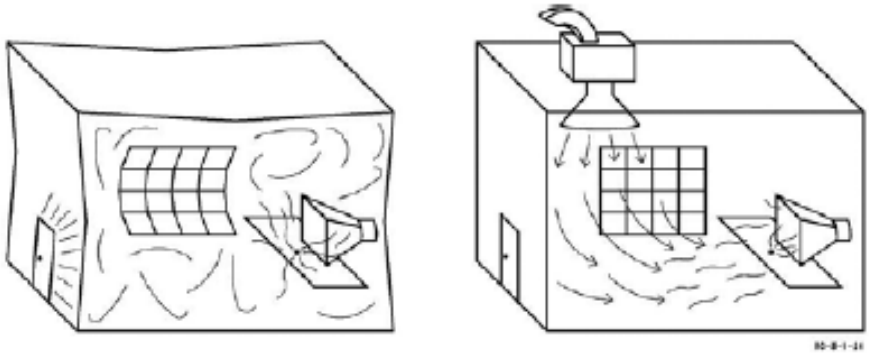

Figure 2–19. The importance of makeup air.

Inadequate makeup also may cause interfering cross drafts. Air coming in through windows, doors, and cracks can blow the contaminants away from the exhaust hood and spread them over the workroom. Misdirected makeup itself may do the same. Vapors, such as those from open tanks, are

most affected but even dusts may be easily dispersed by more extreme cross drafts. It is important to prevent this disturbing air coming from different directions by providing a smooth source of makeup air.

Unheated air being drawn into a room causes uncomfortable drafts on workers that could be eliminated with proper makeup. As with cross drafts, it is undesirable to have the air coming in from different directions instead of the smooth tempered source of makeup. This also helps to lower costs for heating by distributing the tempered air over the room to eliminate cold spots. Many workrooms in existence have some areas too warm and others too cold.

You may have come across rooms with doors that were very difficult to open because there was not enough makeup. This can be dangerous when you do get the door open and it has a strong tendency to slam on you with great force. There was even a case of one workroom with metal frame windows that were bowed inward because of intense suction without makeup to equalize the pressure.

Another potential danger to personal safety is the proper operation of devices that use natural updrafting (fig. 2–20). Think of the normal household fireplace that draws air in for combustion and sends it up the chimney with the harmful combustion products. A negative pressure in the room because of inadequate makeup would tend to suck the dangerous products out of the fireplace (backdrafting). Any similar type of process in an industrial area, such as furnaces for heating or material processing, can be affected in the same way. It is hard to believe that such important factors can be overlooked in the design of local exhaust, but they often are.

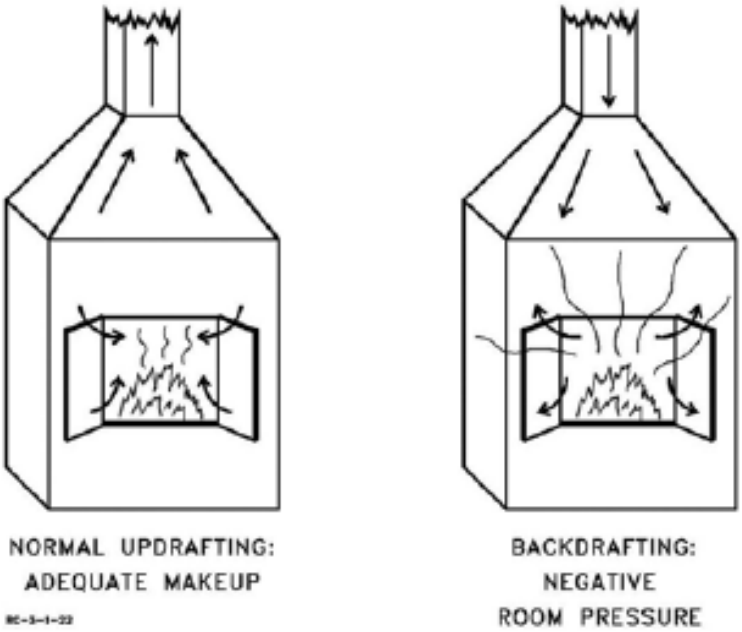

Figure 2–20. Effects of makeup air on updrafting.

Discharge

Proper discharge of contaminated air from an exhaust system is another goal that is overlooked too often. With good air cleaners, it may not be a problem. Without them, it may be serious. Have you ever seen air discharged from an outlet only to be taken back in by windows or a makeup air inlet? Maybe you have seen new buildings or processes go into operation with no regard for this problem. The discharge may have been fine until an adjacent building was put up that now takes in the exhausted air.

Route discharge outlets to the roof of a building. The stack should be high enough that contaminants cannot be blown back down into air inlets. The proper height above the roof that the stack should extend for this purpose is between about one-third of the building height and a length equal to the full building height. This helps to mix the contaminated air with higher air currents for good dilution.

Another consideration for proper discharge is the comparison of a weather cap to a stackhead. Unfortunately, the weather cap is usually used. A weather cap is a device shaped like a wide cone that is installed over the discharge outlet for rain protection. It is undesirable for two good reasons. When contaminated air blows out the stack, it hits the weather cap and is forced out sideways and down to create a possible problem at inlets. It also causes more system resistance since some of the air is bounced back down the stack and results in higher positive pressures (contributing to outlet static pressure). The preferred method, the stackhead, is simply a straight vertical discharge of the air at high velocity so that it mixes well with upper air currents and is less likely to enter inlets. Some people think that this offers no rain protection, but there are various designs that provide this. When the system is turned on, a simple plate, similar to that seen on a diesel truck that bobs up (from air pressure), could work very well. Figure 2–21 further illustrates discharge concepts.

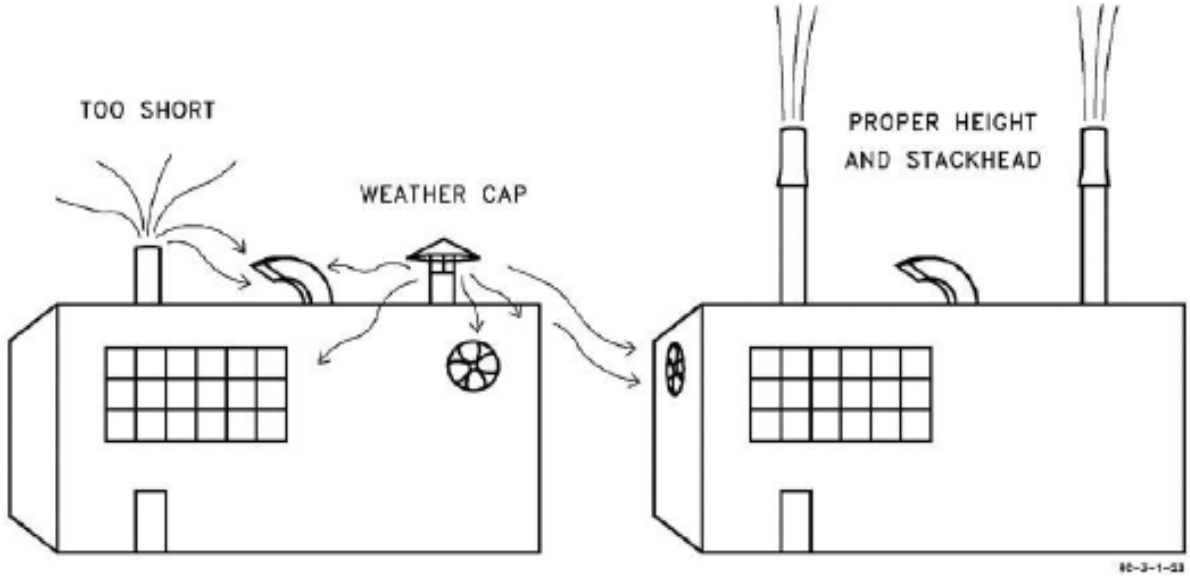

Figure 2–21. Discharge of contaminated air.

Interference

This refers to interference from and to the worker. We have seen before how workers can accidentally or deliberately frustrate attempts at protection. A worker's movements may be all that is needed to disrupt the correct functioning of an ill-designed exhaust system. Workers may also readjust blast gates (plates in ducts that regulate airflow) and so cause less exhaust at their stations or nearby branches of the system. They may simply fail to get close enough to the hood or not turn on the system at all. Educating workers on the importance of the system may help some in this area, but there are surer methods. Blast gates can be bolted or locked in place after adjusting the correct airflow. This may not stop them, but it helps to slow them down or discourage interference. (If they are persistent, maybe you should find out if there is a good reason.) A portable exhaust system or one with flexible, moving ducting may help eliminate some of the problems. The hood can also be attached to the machinery at the proper distance or a provision made to prevent the machinery from operating without the hood in place. In fact, such interlocking systems are often the best choice to make sure a system is used as it should be. Naturally, you would want the system to be interlocked with machinery so that it is automatically turned on when the machinery is started. Not only do the

workers have no choice but to use the system but there is the added benefit that they tend to forget about it altogether.

On the other side, it is very important to minimize interference to the worker. Some of the problems just discussed may be alleviated somewhat if workers do not see the exhaust system as a nuisance. If a worker must get so close to the hood while working that it is continually in the way, it may not be the right hood for the job. Enclosures and partial enclosures can also make it difficult to get at the process. Try asking the worker what type of hood might be best suited for the operation or how an existing one could be modified.

Enclosures

The best type of hood is one that encloses the source of the contaminant as much as possible but without undue interference to the worker. With an enclosure, the contaminant is already inside the hood, so capture velocity is not a problem. The airflow is needed only to prevent materials from escaping and to transport them to the ducting. Cross drafts are much less of a problem as well.

When there is an operation that needs local exhaust, always consider an enclosure first. Imagine the process completely enclosed and then what openings are needed for the worker to have comfortable access to the process. Consider hoods that do not enclose last. Many processes can get along without an enclosure if the contaminant is not very toxic and generation is low. Remember that cost always figures heavily in these considerations. However, once installed, an enclosure normally provides the best contaminant control with the lowest air volume.

Hood locations

It might seem ridiculous to talk about the location of the hood when it is obvious that it must be near the source of the contaminant. Unfortunately, too many systems that have been installed do no good because they are too far from the source. You may see welding hoods with flexible ducts that can be counterbalanced to keep them high and out of the way when not in use. Too often, they stay out of the way when they are supposed to be used.

Besides having the hood close enough, think about the direction and force of the contaminant as it is released. The inertia of dusts from a grinding wheel, for instance, can send them quite a distance at high speed. A hood should be located (and shaped) so that dusts are thrown into the hood (fig. 2–22) without pulling the contaminant through the worker's breathing zone. This works much better than attempts to use high capture velocities to control them from other directions.

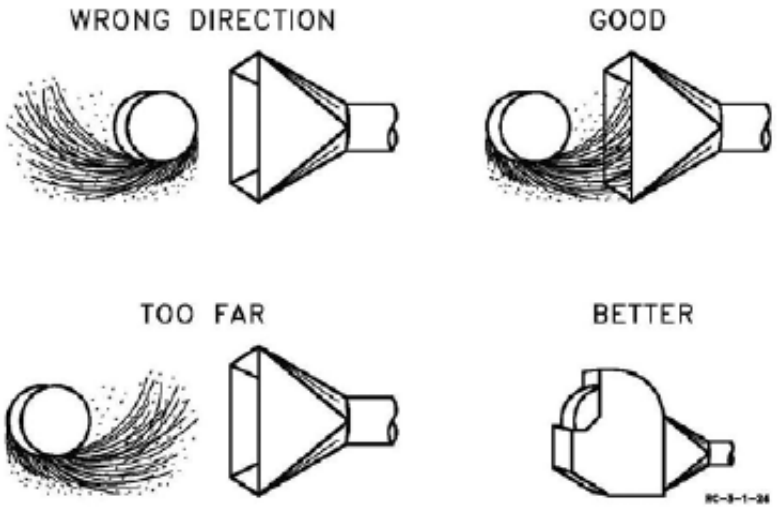

Figure 2–22. Hood locations.

Hot processes cause air and materials to rise, so it would be logical to place a hood over them. This requires less airflow to control them than if an open hood was placed at the side to try to capture them from a direction they do not naturally go. A good example is the commonly misplaced welding hood on a flexible duct. It should be angled at 45 degrees from the point directly above the operation to take advantage of naturally rising heated air and fumes.

Air movement

You have already learned that airflow should direct contaminants away from a worker's breathing zone. You can see from figure 2–23 that a hood placed over a process could require a worker to come between the process and the hood. This, of course, results in an unacceptable exposure that is controlled better by side slots to pull contaminants away from the worker.

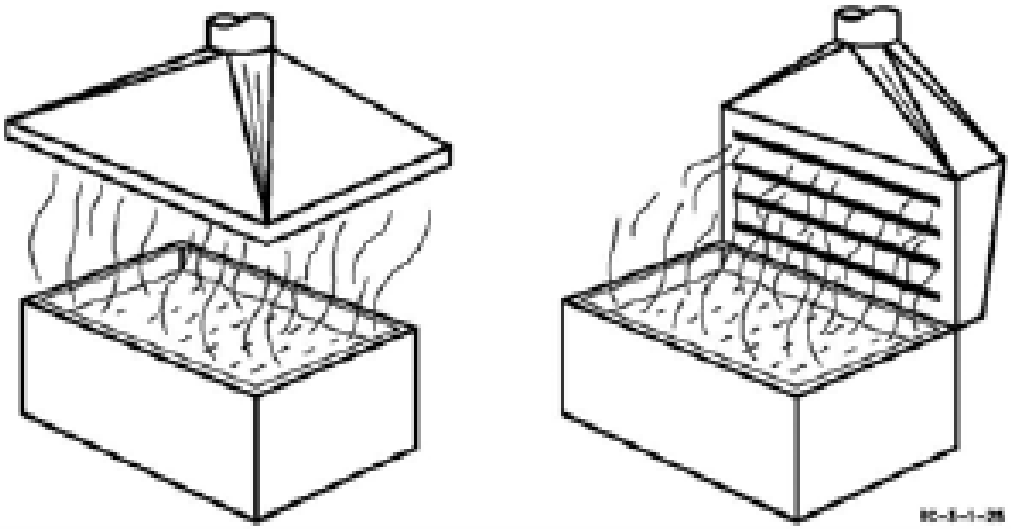

Figure 2–23. Direction of air movement.

Air movement is also important to consider in the proper flow of contaminated air into and through the exhaust system. A number of factors contribute to the disturbance of smooth flow:

- Normal currents from doors and windows.
- Currents from heating, cooling, and makeup air equipment.
- Motion of materials (such as filling barrels with bulky materials).
- Currents from machinery motion (such as from a lathe or large sander).
- Normal operator movements.
- Currents caused by hot processes.
- Fans.

Eliminating disturbances is a good argument in favor of enclosures. Using baffles (fig. 2–24) also greatly reduces interference from cross drafts so that less air volume is required. Baffles are usually metal sheets placed on both sides of a hood for this purpose (baffles approach an enclosure). The plenum (also called the manifold) for the slots also provides self-baffling. A flange acts as a baffle similarly to the plenum by eliminating air from coming behind the hood. These items baffle a hood that is placed on a floor or a bench or next to a wall.

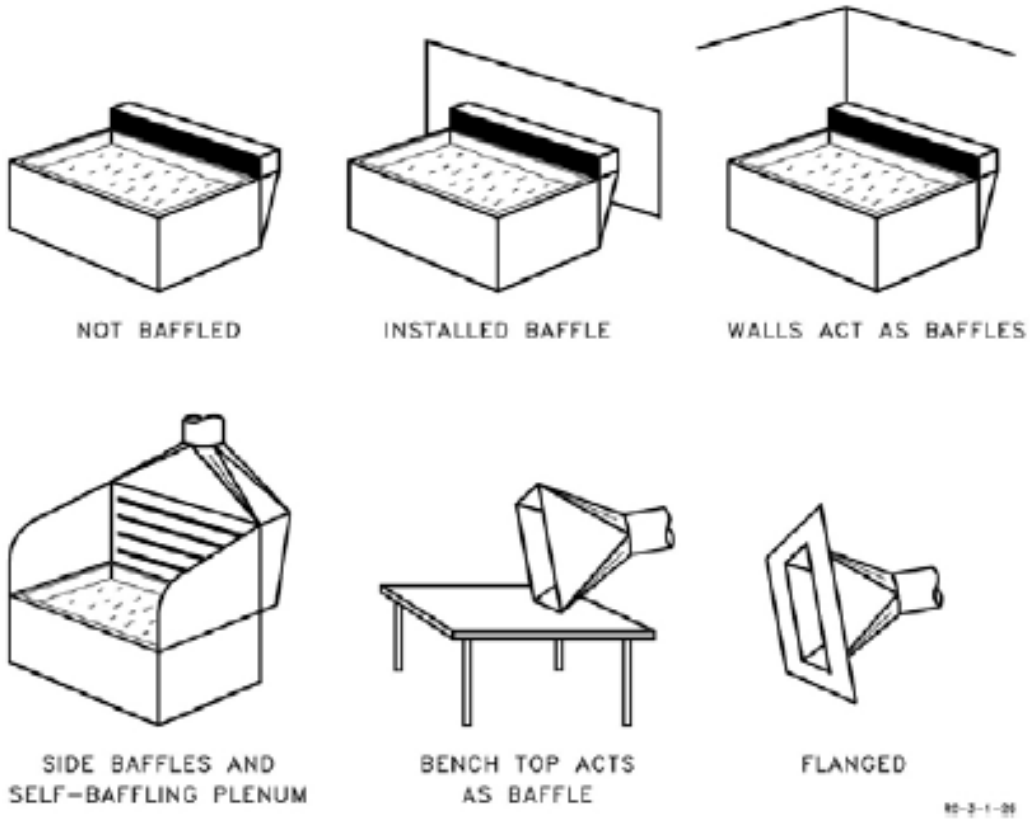

Figure 2–24. Baffling.

Air movement that is stronger on one side of the hood than the other (or stronger in the middle than the sides) may also lead to inadequate contaminant control. Proper distribution of the air across the hood face can be handled in a number of ways, as shown in figure 2–25. Baffles again, this time inside the hood, are one method. They are placed so that air is restricted more from areas where it would otherwise rush in the most. The air is rerouted to the points of less suction for a smoother flow. Splitter vanes help in a similar manner by “splitting” airflow into sections of the hood. The strongest flow has the smallest section (to restrict it) and the weakest flow has the largest section. Tapering the hood, as discussed, also helps, as does using a slot hood with a plenum or manifold. The plenum is a chamber that creates a uniform pressure (suction) across a slot for even distribution of air. For wide hoods or when other methods may not work, simply use multiple takeoffs—the section of the duct that “takes off” from the hood.

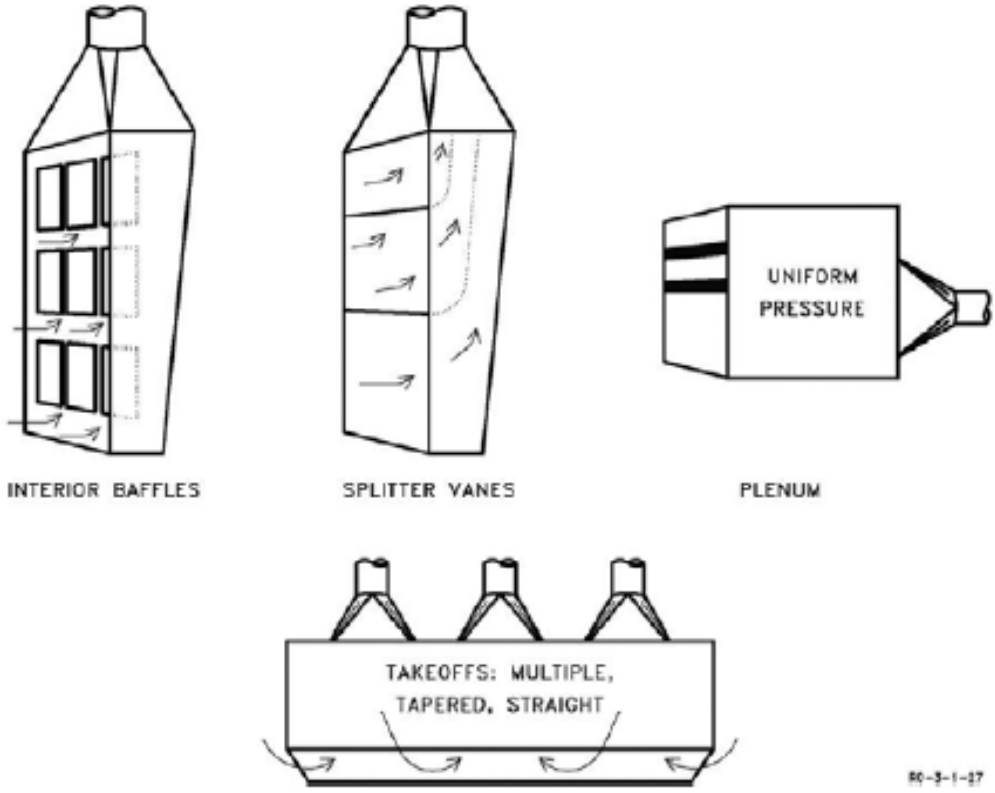

Figure 2–25. Methods of air distribution.

Takeoffs are an area where bad design can cause trouble within a system. Tapering the takeoff helps reduce turbulence and thus impacting contaminants against the sides of the hood and duct so that there is less chance for their escape. Using straight takeoffs rather than an immediate elbow also helps relieve this problem. If an elbow is absolutely needed, it should be as gradual (wide in curve) as possible. Abrupt turns just after the hood cause the air to hit the back portion of the duct and possibly bounce back out of the hood.

Air volume

The basis for adequate contaminant control always boils down to the required volume of air. To determine the correct volume, we first need to find out either what capture velocity or indraft velocity is required. The volume will be calculated from one of these based on the type of process, contaminant, and hood to be used. Capture velocity pertains to hoods that do not enclose a process. Indraft velocity is very similar but is the velocity flowing through an enclosure, such as a paint booth, needed to keep contaminants directed toward the inlet ducting or fan. Indraft is normally stated simply in terms of cfm/ft^2 of face area or cross-sectional area. Capture velocity, because it must exist outside of a hood, is somewhat more involved. Its importance and complexity require that we study it in more detail later.

822. Types of hoods

The study of local exhaust ventilation is largely a study of hood types and how to determine the Qs necessary to control contaminants. For most systems, it is necessary to calculate the required Q based on general data provided in the reference material(s) and apply it to the specific type of hood and the operation it is to control. If you are recommending that a new system be installed, you have the advantage of choosing the best hood type to handle the job.

In general, there are two types of key parameters (design standards): a transport velocity, called the minimum design duct velocity, or simply duct velocity for brevity, and a required air-flow volume, Q, to control the contaminants in a work area. As mentioned before, certain velocities are needed in ducts to keep most types of aerosol contaminants entrained in the air stream so that they will not settle out and clog the duct. The velocity required depends on the density of the contaminant. For gases, vapors, and smokes, a minimum of 1000 fpm is used since these materials are so easy to move. Fumes, being heavier, need at least 2000 fpm to keep them moving through the duct. The requirements increase further for materials such as grinding dust (3500 fpm) and wet, sticky, or very heavy dusts with small chunks (4500 fpm). Be careful, however, to keep velocities within reasonable limits. Remember that more velocity means increased system resistance as well as more wear and tear on the system.

Duct velocity requirements are listed in the ACGIH *Industrial Ventilation* manual for specific hood types and operations. The manual also lists minimum duct design velocities that can be applied to any local exhaust system that does not have a specific design requirement.

Finding the Q required for a system is not as easy. The Q will normally be based on a capture velocity or in-draft velocity. A few Qs are based on other considerations. For example, the grinder hood ventilation that is based on the speed and size of the grinding wheel. As with duct velocity, these requirements are listed for each type of hood and operation. The references also show ranges for capture velocities that must be used when specific information is lacking. Typical capture velocities can range from 50 fpm for contaminants such as vapors released into very quiet air to as high as 500 fpm or more to control heavy aerosols released at high velocity. When capture velocity requirements are quite high, it is time to consider a more efficient hood design for the process. On the other hand, very large hoods may not need as much Q as the capture velocity would indicate. The reason for this is simply that large air masses moving into the hood carry more of the contaminants and dilute them more. Capture velocity is important, but the total air volume plays a big role.

There are four general hood classifications: open, slot, canopy, and enclosing. You must then determine the specific type of hood you have within the general classification and calculate the Q required. There are a tremendous number of different hood types for which we could calculate a Q, and the instructions for many of them can be confusing. The main problem most people have is a lack of familiarity with exactly what the instructions mean. Therefore, a little practice with them on some of the more common hoods and processes can help a lot.

Open hoods

As shown in figure 2–26, an open hood can range from a plain opening duct end (an actual hood type even though there is really no hood) to tapered, flanged, rectangular (including square) or round (cone) open hoods. To be in this category, a hood must have an aspect ratio of more than 0.2 (or round). The aspect ratio is simply the figure you get by dividing the opening’s width by its length. For instance, a hood with an open area of 12 inches by 18 inches has an aspect ratio of about 0.67 (12/18), so it qualifies as an open hood.

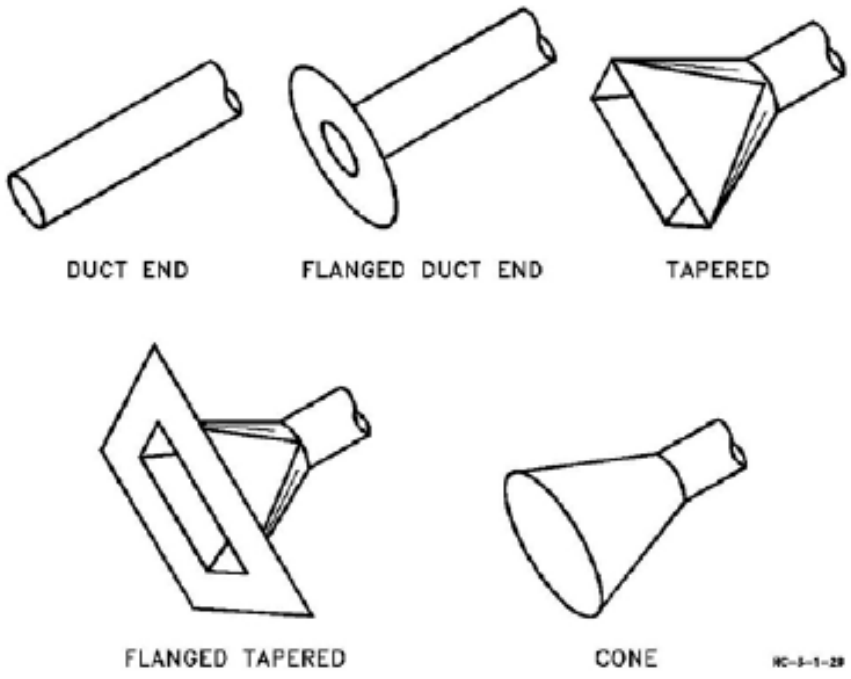

Figure 2–26. Hood opening types.

An open hood is usually placed so that air flows into it horizontally from the contaminant (sidedraft) or angled toward the contaminant. As with flanging or placing the hood on a bench, angling the hood results in more efficient control with hoods that are based on capture velocity. The contaminant should also be released as closely as possible to the centerline of the hood face. Angling helps to achieve this.

Measuring capture velocity

The distance from the contaminant release to the hood face is obviously very important whether the hood uses capture velocity or it is of the type known as a receiving hood (an open hood). The hood must be as close as practicable to the source of the contaminant. The receiving hood does not capture contaminants; rather it "receives" materials such as dusts that are thrown into it from the process. To get an idea of the difference in performance and airflow requirements between these types of hoods, we will calculate a Q for each type.

Figure 2–27 describes an exhaust system for a hypothetical welding operation. Notice that information on the process, materials, and hood is very specific so that the Q can be accurately determined. You must check the instructions in the references for the hood and process in question before going to the shop so that you will know all the information you will need. The information comes from the formula used to derive Q. Examine figure 2–27 and the formula below used for all unflanged open hoods:

$$Q = (10x^2 + A)V_c$$

Where:

x = distance in linear feet from the contaminant to the hood face.

A = area of the hood face in square feet.

V_c *= required capture velocity.*

Problems people have with this formula include incorrectly expressing the distance in inches or the area in square inches, using duct area (A_d) instead of hood face area, and confusing capture velocity

with other types, such as duct or face velocity. This again stresses the fact that you must read the instructions very carefully.

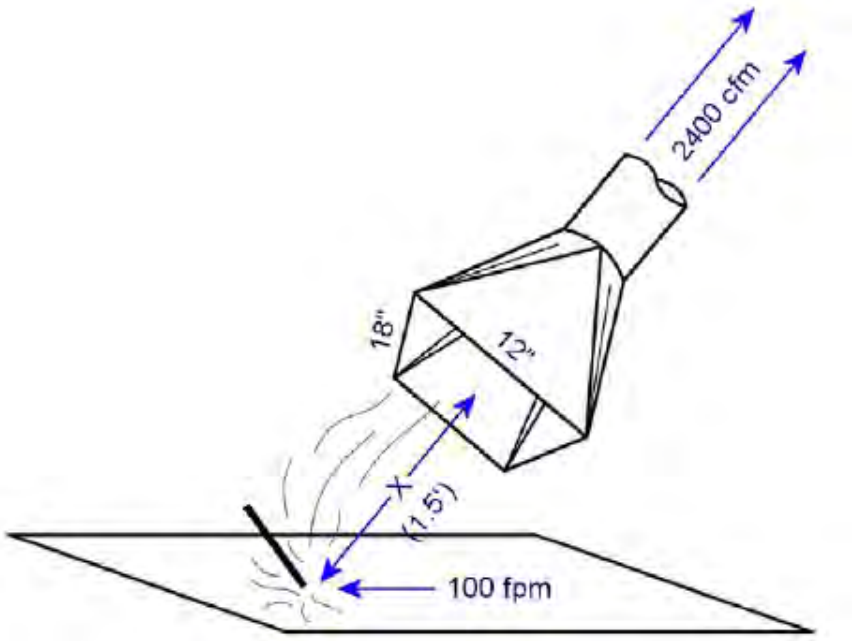

Figure 2–27. Welding hood.

The contaminant classes are used to determine the required capture velocity. Since only Class II is applicable to welding with an open hood, the capture velocity will always be 100 fpm. You should also note that some processes such as oxygen cutting/gouging and arc cutting/gouging do not allow the use of open hoods.

In addition to the capture velocity, we also need the "x" distance and face area of the hood. The x is shown to be 18 inches but must be expressed as 1.5 feet. The hood dimensions are 18 by 12 inches and correspond to an area of 1.5 ft^2 (216 square inches divided by 144 square inches per square foot). The hood dimensions also bring up an important limitation on the distance from the hood to the contaminant. The distance can be no more than that equal to the diameter of a round hood or the diagonal of a rectangular hood. For our hood, the maximum distance from it that work should be done is about 21.6 inches:

$$Max\ distance = \sqrt{\text{length}^2 + \text{width}^2} = \sqrt{18^2 + 12^2} = 21.6\ inches$$

Thus, our work distance of 18 inches falls within the criteria. Having all the information necessary, we can calculate the key parameter of Q:

$x = 1.5\ feet$

$A = 1.5\ ft^2$

$V_c = 100\ fpm$

$$Q = (10x^2 + A)V_c$$

$$Q = (10 \times (1.5ft)^2 + 1.5\ ft^2)\ 100\ fpm$$

$$Q = (22.5ft^2 + 1.5ft^2)\ 100\ fpm$$

$$Q = 24ft^2 \times 100\ fpm$$

$$Q = 2400\ scfm$$

The 2400 scfm represents a standard to meet. It is the Q that this particular system must move to provide a capture velocity of 100 fpm at 18 inches from its face. When we make actual measurements of the airflow on an initial survey, we will compare the results to the required (but not necessarily existing) 2400 scfm to see if the system is adequate. For a new system that is to be operated at nonstandard conditions, be sure to convert scfm to acfm (Q_m) (based on the expected air density factor) in your recommendation of the proper fan capacity.

Remember that simply adding a flange increases the efficiency of a hood. By flanging the hood above, we would need only 75 percent of the original Q, or 1800 scfm (2400 x 0.75). Be sure to use only the free open area of the hood face to find the area (through which the air passes)—do not include the flange dimensions in your calculations.

The formula also applies to plain opening duct ends. Suppose the process above had no tapered hood but only a 10-inch diameter (0.545 ft^2 area) duct end to capture contaminants. The Q required in this case would be:

$$Q = (10\ x(1.5ft)^2 + 0.545ft^2)\ 100fpm = 2305\ scfm\ (rounded)$$

However, you should recall that the distance x should be no more than the diameter of the hood or duct end. Thus, you must replace the distance of 1.5 feet with the maximum allowable distance of 0.833 feet (10 inches), which will result in a Q of 748 scfm. This may be too close to work comfortably, so you can see that a tapered hood is a better choice to allow greater distances. After measuring Q in the system, you should also work the above formula in reverse to find the maximum distance at which the capture velocity will be.

Receiving hoods do not need capture velocities and therefore require less Q. They only need enough flow to be able to accept and send the dusts thrown into them into the duct. Hoods for grinders, such as those often seen in a dental laboratory, are good examples of this type. The formula is similar to that we used for the welding hood, but there are very important differences:

$$Q = (10x^2 + A)\ V_s\ 0.0003$$

Where:

x = distance in ***inches*** *from hood face to nearest point on grinder wheel.*

A = area of the hood face in square ***inches****.*

V_s = speed of the wheel surface in feet per minute.

Note the confusion that can arise from the switch to inches and square inches in this formula. Finding the wheel surface speed can also cause trouble just as the symbol V_s might (it does not stand for an air velocity at standard conditions here). First, find the wheel diameter and examine the motor to find the revolutions per minute (RPM). If we had a wheel diameter of 5 inches and RPM of 3000, the speed in fpm (V_s) would be (using the symbol D for diameter):

$$V_2 = \frac{\pi \text{ x D x RPM}}{12}$$

$$V_2 = \frac{3.14 \text{ x } 5\text{in x } 3000 \text{ rpm}}{12 \text{ in}} = 3925\ fpm$$

To continue with the example, the receiving hood we have is 4 inches by 5 inches (A = 20 square inches) and is 4 inches (x) from the leading edge of the wheel. Inserting the variables into the formula:

$$Q = (10x^2 + A)\ V_s 0.0003$$

$$Q = (10 \times (4in^2 + 20in^2)\ 3925fpm \times 0.0003$$

$$Q = 180in^2 \times 3925fpm \times 0.0003$$

$$Q = 212\ scfm\ (211.95)$$

If calculations result in less than 100 scfm for this type of hood, use 100 scfm as the minimum key parameter.

Slot hoods

It was mentioned that an open hood must have an aspect ratio of more than 0.2. The reason for this is that a long narrow opening of 0.2 or less, such as one 48 inches long by 6 inches wide (aspect ratio 0.125), is a slot. The formulas for an open hood cannot be applied to such a narrow opening.

Examples of different slot hoods are shown in figure 2–28. The first two shown, somewhat like vacuum cleaner attachments, are not seen nearly as much as the plenum types. Remember that the plenum is a chamber that is to provide equal pressure and thus equal flow across a slot. To do this adequately, the air velocity across the slot must be twice or more the air velocity in the plenum. For instance, a slot with a velocity of 1000 fpm requires that the plenum have a velocity of 500 fpm or less. Slot velocities should be kept at 1000 fpm to 2000 fpm depending on the application. Increasing the slot velocity (without increasing Q) does not increase contaminant control; it just increases system resistance. Proper slot velocities are used only to maintain proper air distribution across the slot.

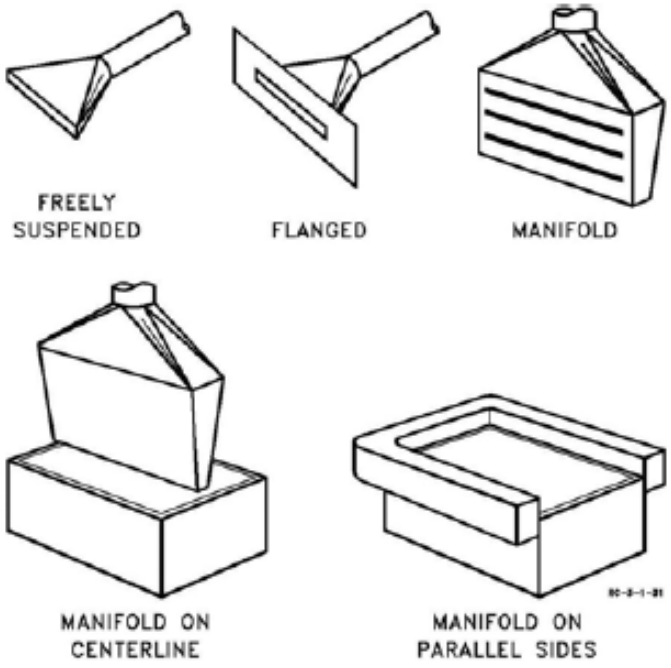

Figure 2–28. Slot hoods.

As with the open hood, it is the Q that controls the contaminants; also as before, Q is calculated from a required capture velocity. We can take the example of the welding process that we used before to illustrate the calculation of a key parameter for a typical slot hood—a cross draft table. The only

contaminant class we can use for welding on a cross draft table is Class II, which again requires the capture velocity of 100 fpm. Referring to figure 2–29, we have an example of a table 5 feet long and 2 feet wide with side baffles. To find the required Q:

$$Q = 2.4LWV_c$$

Where:

L = length of the table in feet.

W = width of the table in feet.

V_c = capture velocity required.

Using the information we have for this situation:

Q = 2.4 x 5ft x 2ft x 100fpm = 2400 scfm

Side baffles are very desirable; but, if they are not present, use a factor of 2.8 in the formula instead of 2.4.

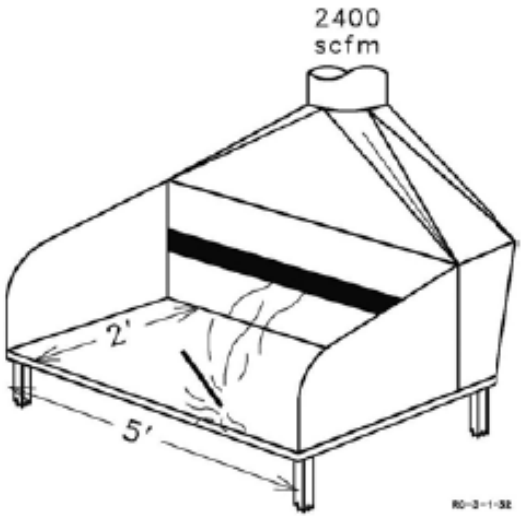

Figure 2–29. Cross draft table.

Canopy hoods

A canopy hood is an open hood placed over a process, often and unfortunately, a degreasing tank. An arrangement where potentially hazardous materials are used and a worker must bend over the tank is unsatisfactory. It can actually increase a worker's exposure. Generally, about the only substance a canopy hood should be used for is controlling steam over a hot water tank. Still, you often find them already in use and they must be evaluated. You should always seek methods to prevent workers from coming between the tank and the hood.

We use the same method of determining a capture velocity for a canopy hood over a tank as we did for a slot hood over a tank. The same tables are used to find the contaminant class and capture velocity required, but you do not need a Q value. In addition to the contaminant class, the capture velocity is based on the number of open sides of the hood. For example, most canopy hoods are placed against a wall, which means that they have three sides open. In a corner, there would be two sides open. It is recommended that side curtains be hung from a canopy hood to enclose it as much as possible. The baffling, by being against walls or equipping with side curtains, reduces the airflow required to control contaminants.

For a hypothetical situation, we will use the same tank and solvent (Class B3) as for the previous open surface tank example. The canopy hood (fig. 2–30) has three sides open and will require a capture velocity of 100 fpm. It is 3.5 feet above the tank, and here we must stop for a moment. A well-designed canopy hood should overlap the sides of the tank by a factor of 0.4 times the height above the tank to prevent "spilling out" of vapors. With a height of 3.5 feet, we need an overlap of 1.4 feet all around. For the tank dimensions of 4 feet by 2 feet, we need a canopy hood that is 5.4 feet by 3.4 feet (adding the overlap).

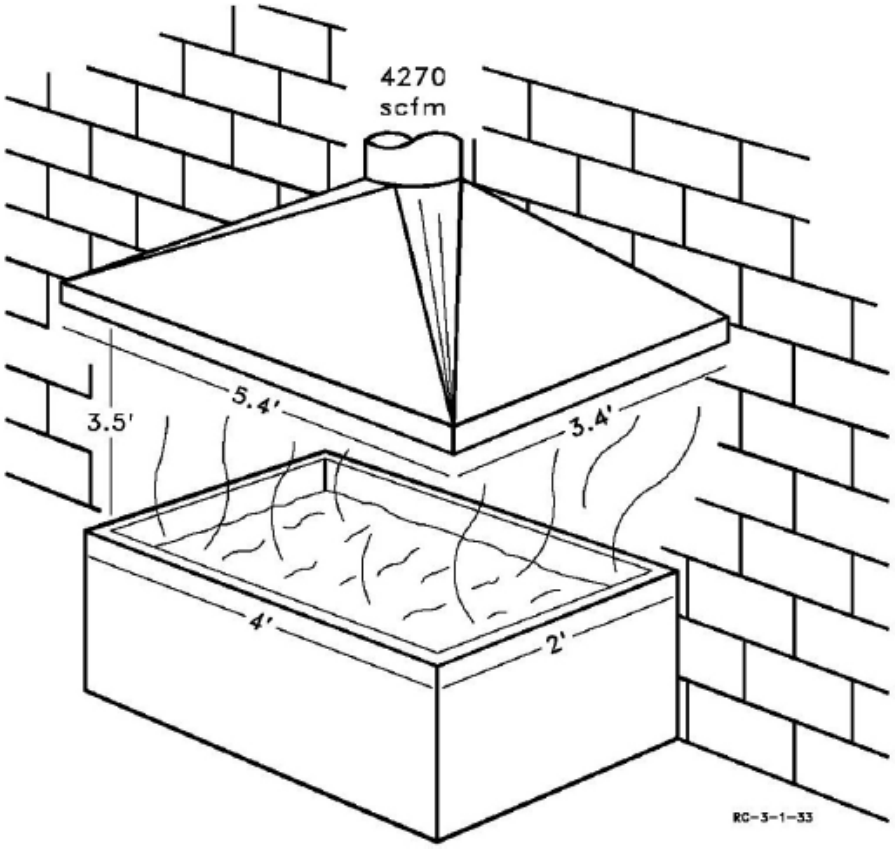

Figure 2–30. Canopy hood.

Finding the required Q is again a fairly simple matter once you have obtained the input data for the formula (for one, two, or three open sides):

$$Q = PHV_c$$

Where:

P = sum of the open sides of the hood feet.

H = height of the hood above the tank in feet.

V_c = capture velocity required.

NOTE: Do not use this formula for a canopy hood with all sides open. The method of calculation is quite different (you do not come across these often anyway).

The value for P is found by adding the two sides of 3.4 feet each to the open front, which is 5.4 feet. The total is 12.2 feet. With this data, the height of 3.5 feet, and the capture velocity of 100 fpm, we calculate the required Q:

$$Q = 12.2ft \times 3.5ft \times 100fpm = 4270\ scfm$$

You can see that it takes much more Q to control the same process with a canopy hood then it did by using a slot hood.

Enclosing hoods

We progress from generally the most undesirable type of hood to the most efficient. However, adding side curtains to three sides of a canopy hood makes it an enclosing hood. Enclosing hoods are used when the potential hazard from the contaminant does not allow other hood types. We saw this in the cases of the open and slot hoods that are not allowed for Class III welding materials. Metal spraying (also called thermal spraying) is another example of a process that requires an enclosure. People may work outside of enclosing hoods as in processes requiring a laboratory hood or glove box for toxic materials. Paint booths and welding enclosures (with tops, not open) are examples of those in which the worker is inside with the contaminants.

Along with being more efficient, it is also very easy to calculate a required Q for an enclosing hood. The Q is usually dependent only upon a required indraft velocity and the hood dimensions. We saw earlier that most walk-in paint booths require 100 cfm/ft^2 of cross-sectional area. Similarly, and typical of most enclosures, a welding or metal spraying enclosure requires a certain minimum face velocity, such as 200 fpm. You simply multiply the required cfm/ft^2 or face velocity by the area through which the air flows to determine the Q needed (Q = AV).

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

816. Characteristics of pressure within a ventilation system

1. What is the purpose of the air mover?

2. How are SP and VP described in terms of energy?

3. Why do we measure TP?

817. Pressure losses and their association with system components and performance

1. What is the vena contracta?

2. What are the principal causes of dynamic loss in a ventilation system other than in the hood?

3. What are the principal causes of friction losses?

4. At what points in a system would you expect the strongest negative SP and the strongest positive SP?

818. Principles of velocity

1. When should you use a density factor in ventilation work?

2. Describe capture velocity.

3. The velocity of air across the plane of an inlet or outlet to the system describes which type of velocity?

819. Relating area, velocity, and density to the mass flow of air

1. What are the two parameters at a given point in ventilation systems that are needed to calculate the Q?

2. What is the number of cfm reading resulting from 125 fpm flowing through a booth 15 feet wide, 8 feet high, and 20 feet deep?

3. What is important to remember when calculating the Q from your measurements?

820. Principles of dilution ventilation

1. Why can supply alone be used for dilution ventilation far more effectively than exhaust alone?

2. Under what conditions is a slight positive pressure desirable?

3. What three circumstances would result in a high K factor?

4. Explain why ventilation for dilution to a LEL or even 25 percent of a LEL would not protect the health of an exposed person.

5. What is a saturation concentration?

821. Principles of local exhaust ventilation

1. What are the benefits of the lower air volumes handled by local exhaust systems?

2. How does inadequate makeup air directly affect the performance of a local exhaust system?

3. If a new local exhaust system was to be installed in a machine shop, what provision could you recommend that would ensure the system was always used properly?

4. What are the two major advantages to local exhaust enclosures?

822. Types of hoods

1. What are the two types of key parameters for local exhaust systems?

2. What are the four general hood classifications?

3. What is the benefit of angling a hood that is based on capture velocity?

4. How does a receiving hood differ from other open hood types?

2–2. Evaluating the Performance of Ventilation Systems

After we have done the pre-survey and determined how a system should be operating to control a contaminant, it is time to measure the airflow to see if it meets the key parameters.

823. Ventilation survey requirements

BEs performs three types of ventilation system surveys: initial acceptance, baseline, and routine. Let's start by defining the different types of surveys.

Initial acceptance

Most installation BE flights have a well-established ventilation surveillance program, having initially identified and surveyed systems around the base, and continue to perform routine assessments on systems that require routine monitoring. Occasionally, ventilation systems must be replaced or a new industrial facility is constructed that houses a process that requires ventilation to control a health hazard. An initial acceptance test is performed on any new ventilation system to verify it is operating properly before putting the system into service, or in the case when a system is installed by a civilian contractor, before the base contracting officer accepts the work as being completed according to the contract. The purpose of the test is to evaluate the system's performance as compared to the key

parameters or contract specifications. If the ventilation system is performing within the appropriate specifications, it is considered acceptable.

Baseline survey

The baseline survey is done after the system has been put into service. The purpose of the survey is to ensure that the system is capable of controlling a hazard below the appropriate OEL and establish baseline parameters for future routine performance tests.

During the baseline survey, airflow measured, recorded, and compared to design criteria again. You might perform any combination of face velocity, pitot traverse, and SP measurements. The bioenvironmental engineer or senior BE technician will identify survey requirements and designate measurement points. At the time you are collecting baseline measurements, you should consider where future routine measurements, if needed, might be collected. This is preferably a SP check performed at the one point at which you will always conduct future checks. SP checks are the quickest and easiest method to perform routine assessments.

What if the ventilation system doesn't meet the key design parameters? The system may still be acceptable. The effectiveness of a ventilation system is ultimately confirmed through air sampling. During the baseline survey, you will collect air samples for the contaminant of concern and compare results to the OEL. If air sampling results are below the OEL, the system controls the hazard effectively.

Since it is known that at this particular point in time the system is working properly, BEs can use this airflow measurement as the standard that all future routine surveys must be compared. Because any differences in airflow may indicate that the system is no longer controlling below the OEL.

Routine survey

Systems that control a health hazard must be monitored routinely. Routine surveys are performed at the frequency determined by your flight leadership. The purpose for performing a routine survey is to ensure the system continues to operate properly. As mentioned, preferably, the routine checkpoint is a SP check. This is not always possible and you will probably have to revert to the time-consuming face velocity measurements. In any case, routine checks are performed at the appropriate location that was established during the baseline survey.

Performance is assessed by comparing data collected during the routine assessment to data collected during the baseline survey when air samples showed that the contaminant of concern was being controlled. The results must be within 10 percent of the *baseline* value. Never compare the results of a routine test to the key parameters.

Follow-up actions for deficient systems

If a ventilation system test shows results not within 10 percent of the baseline, you must take action to determine the cause and get it corrected. We should never recommend expensive repairs until certain it will correct the problem; begin with the simple things. Always check your technique first, make sure you performed measurements correctly, and check your math. If your technique was proper, have the workplace supervisor initiate a work order through civil engineering to have the system inspected and serviced, if necessary. If the filters of the ventilation system become clogged, this may affect the system's ability to either supply fresh air to the system or for the system to properly discharge the contaminant. Service technicians will look for clogs, check and adjust mechanics, and replace any failed parts. After any servicing has been done, do the survey again. What if the test shows results still not within 10 percent of the baseline? Remember that the ultimate test of a ventilation system's effectiveness is air sampling. It is possible for a ventilation system to exhaust air at a volume less than the design parameter, yet still control the contaminant of concern. Reaccomplish air sampling to determine if the ventilation system still controls the hazard at the lower airflow rate.

824. Face velocity ventilation survey procedures

As the name implies, the face velocity method generally involves measuring air velocities at the face of a hood or blower outlet, as shown in figure 2–31. However, this is modified in some instances such as in determining velocities in the center of a paint booth where the flow is more even. Since the face velocity method is not as accurate as measuring in a duct, it is used only when duct measurements are very difficult or impossible. Accuracy is particularly important in the careful evaluations you must do on initial tests.

Figure 2–31. Face velocity measurement.

The initial test of a ventilation system is usually the most involved, but if done carefully and properly, need only be done once. Before operating, the system should be checked to verify that it meet its design specifications. This implies that calculations indicated that contaminant levels would be over the OEL or that good industrial hygiene practice dictates the use of a system. Other systems are installed on the basis of air sampling results. There are also systems that have been in operation for some time that may need an initial test. They could have been overlooked in the past or were incorrectly evaluated.

Again, measurements of the airflow are made in each branch (subsystem) for three major reasons. The first and most important is to see if the system is operating as it was designed to. Are the existing flows within 10 percent of the key parameters? It is also necessary to have balanced flows in all branches. You do not want branches close to the fan to have extremely high flows and those further away have too little flow. The last reason is to find out how much capacity there might be for future additions to the system. A lot of trouble has been caused in the past when new branches were added to systems that could not handle the increased load. This can change a perfectly good system into one in which neither branch is adequate.

Use a locally derived form for initial tests. It is used in conjunction with the pre-survey form for a thorough description of a branch. Compare the results of this initial test to its corresponding pre-survey form. The Q is within 10 percent of the key parameter Q. Notice that the temperature and barometric pressure are shown in “location and survey conditions.” Always enter this information. The conditions on the form are not significantly different enough from STP to warrant calculating a density factor. Under more extreme conditions, it would be necessary because the Q must be in units of scfm (Q_s) before you can compare the survey results to the key parameters. In addition, the form

does not call for it, but it is a good idea to show acfm (Q_m) as well. There could be circumstances later in which it could become very helpful. They have the same value in this example since measurements were made at near enough to STP (d = 1). The measurement locations are coded on a sketch, so you know where any trouble spots are. Although not serious in this case, you can see that readings are lower at the corners of the hood than in the middle (as you should expect).

After averaging the readings, Q_m (acfm) is found first by using the formula, Q = AV, because the actual velocity (V_m) is found first. Convert Q_m to Q_s as before: $Q_s = Q_m \times d$ when the density factor is other than one. (You may want to show V_s as well). An exception is needed when you test a system that has key parameters—such as, "no readings below 75 fpm," for example. In a case like this, you need to record velocity readings in STP (velocity at standard conditions) for comparison to a standard and so note on the form. You also need to calculate the existing duct velocity so that you can compare it to the required duct velocity. This is done as shown earlier in the chapter, using $A_f V_f = A_d V_d$.

Instruments

The next question might be, "What instrument was used to measure the air flow on this survey?" There is a variety that could be used, but face velocity measurements are made most often with one of two basic types: the swinging vane anemometer (fig. 2–32) and the thermal anemometer. In a swinging vane anemometer, the pressure of moving air pushes a vane inside the instrument to one side for a reading directly in fpm. It actually converts VP to velocity readings. This direct-reading capability is very handy and useful when the velometer is properly calibrated, but there are some disadvantages. Besides dust, moisture, and corrosive materials affecting its operation, the reading does not always reflect the true actual airflow. The instrument is adjusted during calibration (at the precision measurement equipment laboratory [PMEL]) until all readings are within 10 percent of a known flow rate, but it still tends to be inaccurate at extreme ends of the scale. Low velocity readings are especially inaccurate. After the instrument has been calibrated, be sure to check for any documents that indicate it could not be calibrated to within 10 percent of any of the known values. Calibration personnel should provide this information to you when this is the case.

Figure 2–32. Velometer–swing anemometer.

Using a velometer to measure airflows at densities other than the density of the air used for calibration is also a problem. References on the subject tell you to divide readings (velocity read from the instrument, V_r) by the square root of the density factor (based on STP) to find the actual velocity (V_m) when measuring at nonstandard conditions:

$$V_m = \frac{V_r}{\sqrt{d}}$$

Since most velometers are calibrated at close to STP conditions, this usually works very well. Remember that the instrument is essentially calculating velocity from VP:

$$V = 4005\sqrt{VP}$$

At nonstandard conditions, the calculation must be done by first dividing VP by d:

$$V_m = 4005\sqrt{\frac{VP}{d}} \text{ or } V_m = 4005\frac{\sqrt{VP}}{\sqrt{d}}$$

You should be able to see now why you need to divide the velometer reading by the square root of density factor (d). However, when the velometer is calibrated at nonstandard conditions, things are different. For instance, a velometer calibrated at the Air Force Academy (about 7000 feet altitude and usual barometric pressure around 23 in Hg) can be used without correction calculations only at that location. At another location (one with different conditions), a different calculation is needed. We still divide by the square root of d, but the d we use must be based on the calibration conditions rather than STP. It is the same process we use in finding a d for use in air sampling when a rotameter is the flow rate meter.

$$D = \frac{T_{cal} \text{ x } BP_{meas}}{T_{meas} \text{ x } BP_{cal}}$$

NOTE: Be sure to add 460 to the temperatures in °F to convert to Rankin (absolute). For example, we have a velometer calibrated at 75°F (535 R) and 23 in Hg, and we use it to measure air at 65°F (518 R) and 27.31 in Hg. The instrument reads 4950 fpm (V_r). To find the actual fpm (V_m):

$$d = \frac{535 \text{ x } 27.31}{518 \text{ x } 23} = 1.21$$

$$V_m = \frac{V_r}{\sqrt{d}} = \frac{4950}{\sqrt{1.21}} = \frac{4950}{1.1} = 4500 \text{ fpm}$$

This gets you actual fpm; but, if you still need fpm at STP, you continue on with the normal calculation of d based on STP and the V_m (518 R and 27.31 in Hg). To convert the actual 4500 fpm to STP:

$$d = \frac{530 \text{ x } BP_{meas}}{T_{meas} \text{ x } 29.92} = \frac{530 \text{ x } 27.31}{518 \text{ x } 29.92} = 0.93$$

$V_s = V_m \text{ x } d$ *(No Square Root)*

$V_s = 4500 \text{ x } 0.93 = 4185$ *fpm at STP*

To obtain proper readings consistently from a velometer, you need a lot of experience and you must use the velometer carefully. You cannot just pick it up for the first time and take measurements at

random. Simply connecting the attachments and setting the controls correctly can be a problem. Connecting for the proper polarity (such as positive to negative), setting the range selector, and depressing or releasing the air vent button are among the steps often forgotten or done incorrectly. Usually, 6 to 20 readings, depending on the size of the opening, are taken in the centers of equal areas. Before you measure the airflow, you measure out or mentally form a grid over the duct opening, every 4 to 6 inches, for instance. Taping thread over an opening to form the grid can ensure that you get the right areas. Do not use anything thicker than thread because it may restrict the airflow to a degree. When you are finally ready to measure, hold the probe so that the air flows parallel to the probe's air inlet and outlet. You slightly rotate the probe until the meter shows the highest reading that stays fairly steady. You will have to observe for quite a few seconds while holding the probe perfectly still to determine the high midpoint of the needle fluctuations for a reading (it is never perfectly steady).

You can see that quite a number of errors can build up in your results. Sources of these errors include the following: the instrument is calibrated to be within 10 percent of the true airflow; there may be differing air densities to contend with; your results should be within 10 percent of the key parameters; and, the instrument operator may not be a perfect worker. As a systematic error, remembering confidence limits, operator error is the one you should be able to reduce the most—through patience and practice.

The more popular instrument and the more accurate are the electrically operated instruments—thermal anemometers. Figure 2–33. shows one type with a meter face that uses a needle for a reading similar to the velometer. It also shows a digital type that can automatically average the readings for you. They are used in much the same way as a velometer but give steadier readings. The main difference is in how they sense and measure airflow. The air to be measured flows past a heated wire in the probe, and the instrument senses the cooling effect of the air, which it translates into a velocity reading. A second unheated wire (or component with the same purpose) senses the air temperature to compensate (provide accurate readings) for a wide range of temperature variations.

Figure 2–33. Thermal anemometer.

It is important to realize that thermal anemometers sense the mass flow of the air. This means that all readings are in fpm at standard conditions. This is handy since we need our results referenced to STP for comparison to the key parameters. However, to list V_m and Q_m on your forms, you need to make a correction:

$$V_m = \frac{V_s}{d} \text{ or } Q_m = \frac{Q_s}{d}$$

Note too that some instruments (such as Kurz) are referenced to 25°C (77°F) rather than 70°F. Be careful to ensure that there are no combustible gases present when using thermal anemometers.

No matter what instrument you use to measure airflow, you should always take smoke tubes with you on initial tests. A smoke tube is invaluable for determining whether the air is going where it was meant to go. Numerous cases of systems had excellent measured airflows; but the airflows had bad distribution or went in erratic directions. A smoke tube will immediately point out any problems of this type.

Corrections

What if the key parameters are not met? Always check your technique first. Sometimes there is confusion over testing procedures. For instance, where do you need to measure a dilution system that has a combination of supply and exhaust? Some people have actually (and erroneously) measured both and added the values together. You should test both supply and exhaust, but you should use the highest value to calculate a Q and compare to the key parameters. Measurements should be made with all doors, windows, and other openings closed unless the system is always operated with something open. As a check on whether you correctly determined the higher flow rate (and whether the room has a positive or negative pressure), open one door or window, and find out which way the airflows. If it flows in the door or window, there is obviously more exhaust. If it flows out, there is more supply. This method also works very well in assessing the adequacy of makeup air for a high volume exhaust system. A very strong flow coming in a door is a good indication of inadequate makeup air (in conjunction with other factors such as the use of smoke tubes).

Quite often, it is the design or installation of the system that is the problem. It may be hard to believe, but fans have been installed backwards a number of times in the past. For some types of fans, this has caused air to blow from an exhaust hood instead of suction. For others, there was suction but it was only about 30 percent of the fan's capacity. If installed correctly, you can check the fan's specifications to see that it has the required RPM or develops enough SP to do the job. The RPM can be increased on some fans—particularly those with belt drives (which can also cause trouble when loose). The problem could be as simple as a fan requiring 220 volts and being connected to 110 volts. In other areas of the system, you should check for poor design of ducts and hoods, closed blast gates, or flow restrictions because of items left in ducts accidentally. The initial test should be made with blast gates from all branches open and then adjusted so that measurements show that branch flows are within 10 percent of their key parameters. The branches of a system without blast gates may need to be redesigned if not balanced well enough. There could be cross drafts or air movement caused by the processes that were not accounted for during design stages. A very common problem is that the hood is not close enough to the source of the contaminant.

Deficiencies in systems that have been in operation for some time are even more likely to be due to poor design. However, an older system also suffers more from the ravages of time. Always check for wear and tear on various parts of the system as well as clogs from dust accumulations that can occur almost anywhere. Check for holes in the ducts or joints that are coming loose. Damage such as bends and dents in hoods and ducts can also affect operation. The table below summarizes suggested procedures for troubleshooting ventilation systems.

Ventilation System Troubleshooting	
If air flow is low in hoods, check:	**If air flow is acceptable but contaminant control is poor, check:**
- Fan rotation (a reversed rotation delivers 30–50% of rated flow) - Fan RPM - Slipping fan belts - Clogged or corroded fan wheel/casing - Clogged ductwork - Closed dampers/blast gates - Clogged air cleaners - Poorly designed ducts — Small duct diameters (increased pressure losses) — Branches entering mains without proper angles (should enter at 45˚ or less) — Elbows bend too steeply (radius too short) - Inadequate makeup air	- Cross-drafts (such as from process air movement, floor fans, supply air, doors, and windows) - Operation too far from the hood - Poor hood enclosure (baffles, access doors, sections removed) - Wrong system for contaminant type

Frequency of testing

The baseline test is done after the system has been put into operation. It has been written that the ultimate test of a ventilation system's performance is how well it controls the contaminant. The way we find this out, of course, is by air sampling, which is an integral part of the baseline test. At the time samples are taken, some measurement is done that indicates the airflow at that time. Preferably, this SP check reflects the Q. You determine the one point at which you will always make the SP check for a given branch, and whatever that value happens to be will represent the air-flow volume in that branch. The SP value then becomes the baseline for later comparisons during routine tests. When a system does not meet its key parameters, we try to find the cause and get it corrected, but we never recommend anything expensive until the air sampling results arrive. Results that show that the contaminant is being controlled are really the final determining factor in allowing us to say the system is adequate. Thus, the system may be fine even though you must check the "no" box on the initial survey form under "system meets criteria" (lower left corner).

Systems that are controlling a contaminant are checked on a routine basis to make sure the system continues to operate adequately. A simple SP check is all that is needed unless there is no duct. Otherwise, you will probably have to revert to the time-consuming face velocity measurements. Just compare the results to the flow that existed on the baseline test when air samples showed that the contaminants were being controlled. The results must be within 10 percent of the baseline value. Never compare the results of a routine test to the key parameters. That part of the evaluation is long past by this point. You must also take some action, such as mentioned earlier, when a routine test shows results not within 10 percent of the baseline. There have been many inspector general (IG) write-ups because of people recording inadequate routine test results in a case file without any corrective action noted. Remember that this is the purpose of routinely testing the system. We will have more to say about these tests later.

825. Pitot traverse ventilation survey procedures

We have so far said nothing about comparing the existing duct velocity to the key parameter duct velocity requirement. You already know that you can calculate this after you have measured at the face of an opening and found the existing Q. You can also use the face velocity instruments to

measure airflow within ducts. This capacity not only eliminates the need for the airflow calculation but also yields better results.

Pitot tube

The pitot tube is a device used to measure VP (and static pressure) within a duct for later calculation of velocity and volume. As you will see, VP measurements are needed only for initial tests. As you can see in figure 2–34, a pitot tube consists of a tube within a tube. The inner tube runs from the very top of the device to its end at lower left and measures TP. Surrounding this is the outer tube, which has eight tiny holes and runs to the side arm connection. The holes are at 90 degrees to the airflow when the pitot tube is placed in a duct. This and the fact that the inner and outer tubes are sealed from one another should tell you that the purpose of the holes is to sense SP. When tubing is connected to both the total and SP ports, the pitot tube is ready to measure VP (TP-SP=VP).

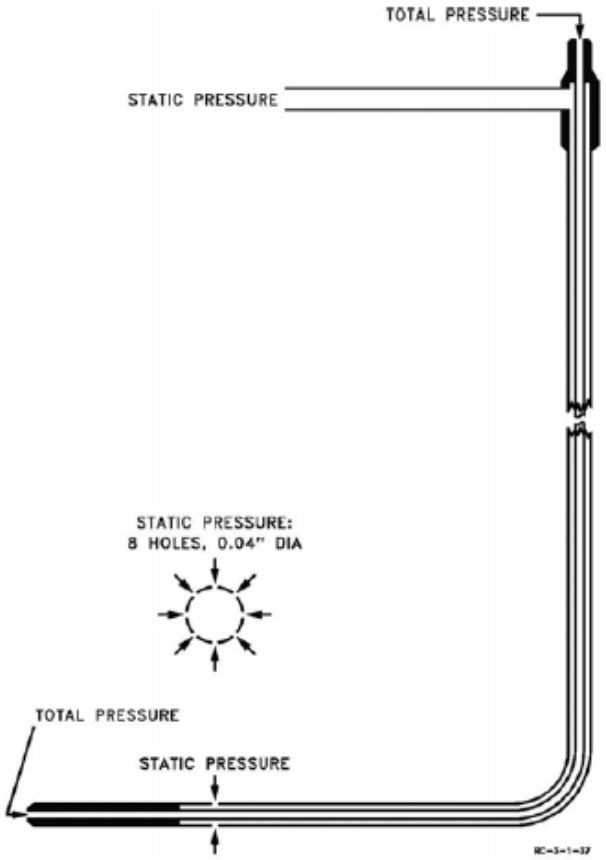

Figure 2–34. Pitot tube.

Manometer

An inclined manometer (using the same principle as the U-tube manometer) must be used with the pitot tube to make the measurements. Instead of water, the inclined manometer is filled with specific oil called red gage oil, which has a specific gravity of 0.826. You should use only red gage oil! The instrument is constructed in such a way that oil with this specific gravity accurately measures pressures in inches of water. The top of the manometer is inclined so that pressures up to 1 inch (4005 fpm) can be read more accurately. There is less error at higher pressures and velocities (less than 1 percent above 2000 fpm). It is best to use a manometer for velocities of 1000 fpm (about 0.06 in wg) and over because of the appreciable error at levels below this—15 percent error at 600 fpm. Duct velocities are required to be at least 1000 fpm to 2000 fpm anyway.

Preparations

A few preparations are needed before you can measure VP: find the appropriate measurement point(s) and ready your equipment for use. First, you must find a section of duct that is at least 7.5 duct diameters downstream and 2 diameters upstream of any disturbance such as the hood, elbows, and contractions. For a 10-inch diameter duct, this would be 75 inches (6.25 feet) downstream and 20 inches upstream. Interference from turbulence will not be so bad at these points. If you cannot find a section of duct that meets these requirements, you will have to measure at two locations evenly spaced from each other and any disturbances. You will average the velocities at these two locations if they are within 10 percent of one another. If not, you must use a third point. The two average velocities that have values closest to each other are then averaged.

Next, you ready the manometer and pitot tube for use. Neither requires calibration, but the manometer must be leveled by observing the leveling bubble built into it. You also have to use the fine adjustment knob to set the oil's meniscus to zero. Connecting the tubing from the pitot tube to the manometer can be tricky. Figure 2–35 shows that connections are made in the same way for the exhausting side of the fan as for the blowing side when you are to measure VP. The TP port of the pitot tube is connected to the left of the manometer, and the SP to the right. SP is different. On the suction side, you can simply disconnect the TP and leave the SP connection in place. On the blowing side, however, you must connect the SP port of the pitot tube to the left side of the manometer.

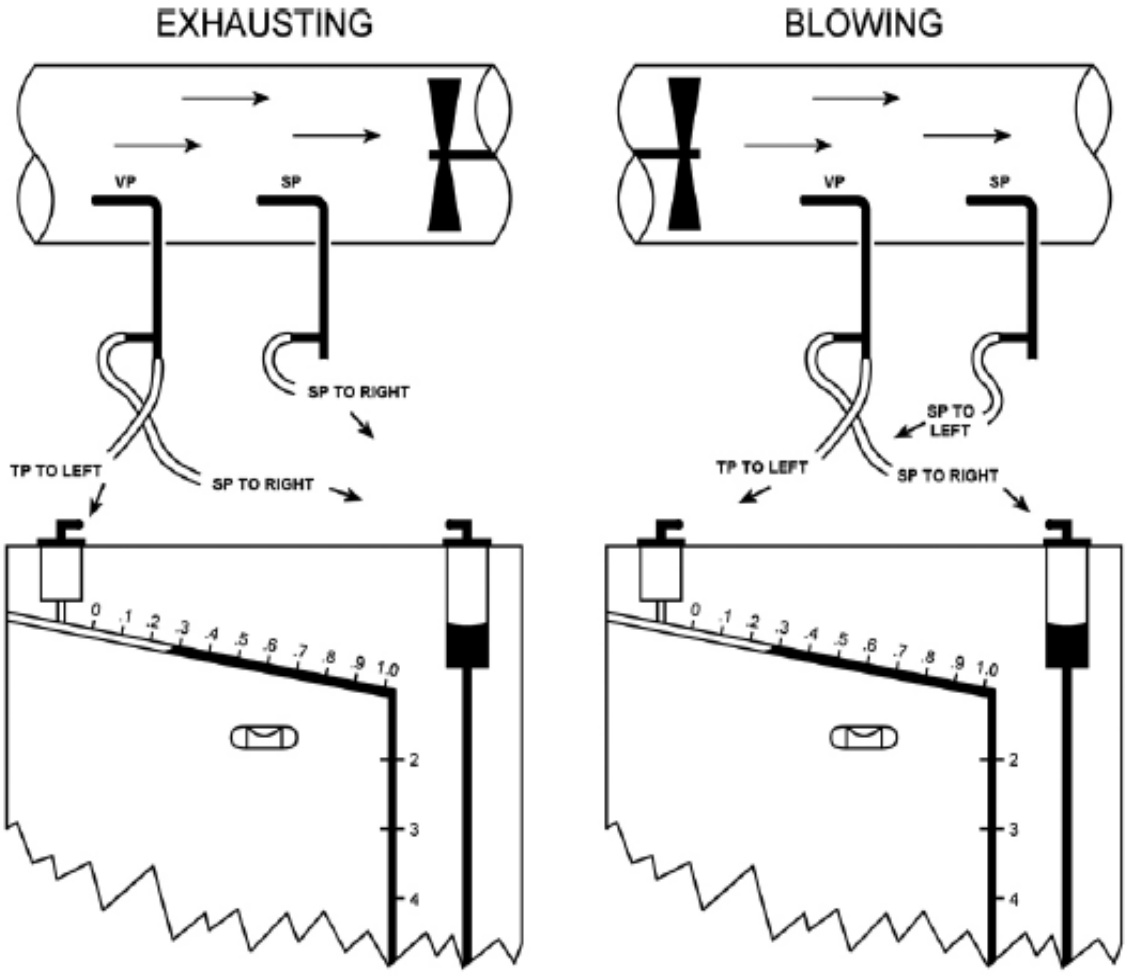

Figure 2–35. Pitot tube connection to an inclined manometer.

Although we must choose a section of duct with smooth flow for our measurements, the VP is not constant across the duct diameter. It is weaker near the duct wall and becomes stronger as you

progress toward the center of the duct. For this reason, we must take multiple measurements across the duct traverse (diameter) to calculate the average flow. We always make at least two traverses at right angles (90°) to one another, with readings at 8 to 10 points on each traverse. When traversing three diameters (60° to one another) in the same cross-section, 6- or 8-point traverses are acceptable (ACGIH, 2013, pages 14–39). In a round duct, the measurements are *not* made at equal distances. You can look-up these traverse measurement distances in Tables 3–5, 3–6, and 3–7 of the ACGIH; invalid source specified. However, traverse measurement positions can also be calculated.

To calculate the exact distance for each traverse position measurement, multiply the provided distance from duct wall in fraction of a duct diameter by the actual duct diameter for each traverse position. The fractions (provided in fig. 2–36) you will use depend on the number of measurements you plan to take along a traverse. Refer to figure 2–36 for the following example: if you are planning to take measurements at six traverse points along a 12 inch diameter traverse, the first traverse position is located at 0.032 x 12 inches=0.38 inches from the duct wall. The second traverse position is located at 0.135 x 12 inches=1.6 inches from the duct wall, and so on.

The first readings are made very close to the duct side where the friction is highest and become farther apart as you move the pitot tube toward the center. Tables in ACGIH, Chapter 3, tell you how far from the side of the duct to take each reading for round ducts from 1 inch to 50 inches diameter. For rectangular ducts, readings are made not more than 8 inches apart at 25 or more positions. This requires drilling at least five holes in the duct as opposed to two or three for round ducts. After you have determined the distances for each point, mark the pitot tube with some easily removable substance such as typing whiteout.

Number of Traverse Points	**Round duct**: **distance from duct wall in fractions of a duct diameter** **Traverse Position**									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
6	0.032	0.135	0.321	0.679	0.865	0.968				
8	0.021	0.117	0.184	0.345	0.655	0.816	0.883	0.979		
10	0.019	0.077	0.153	0.217	0.361	0.639	0.783	0.847	0.923	0.981
	Rectangular duct: **distance from duct wall in fractions of duct diameter** **Traverse Position**									
	1	*2*	*3*	*4*	*5*					
5	0.074	0.288	0.500	0.712	0.926					

Figure 2–36. Velocity pressure traverse measurement positions.

If a system has a number of branches with blast gates, you need to balance it before making the detailed initial test measurements. You can take a single measurement of the VP in the center of the duct for a rough estimate of the flow. You make this estimate by multiplying the reading by 0.81 and then calculating the velocity and volume. After finding out the barometric pressure and duct air temperature, use the formula:

$$V_s = 4005 \sqrt{\text{VP x } 0.81 \text{ x d}}$$

Multiply the velocity at standard conditions by the duct area to find Q_s. If you had a centerline reading of 0.35 in wg and a density factor of 0.77:

$$V_s = 4005 \sqrt{0.35 \text{ x } 0.81 \text{ x } 0.77} = 4005 \sqrt{0.22} = 1879 \text{ fpm}$$

For a duct diameter of 10 inches (0.545 ft^2), this results in a V_s of 1024 scfm. Compare this value to the key parameter to see if the branch has the proper flow. We calculated V_s directly followed by Qs (rather than V_m and Q_m first) so that we could make the quick check against the key parameter.

Branches nearest the fan will have the highest flows so you begin adjusting the blast gates of these branches toward the closed position. You must continue adjusting blast gates and taking readings until all branches are within 10 percent of their key parameters. Keep in mind that it will not always be possible. In the branch above where we found 1024 scfm, the blast gate may have been wide open. If the branch required a key parameter of 2400 scfm, it is deficient. Try adjusting other branches as well to see if the airflow on this one comes up but do not sacrifice the flow of one branch for another. Balancing can be time-consuming since the various branches are likely to have different key parameters. Try your best to provide balance, but do not do anything drastic until the air sampling results are available.

Measurements

After balancing, we make the careful VP traverses. It takes a lot of practice to get accurate readings—the oil level in the manometer fluctuates constantly. Using the marks you made on the pitot tube, take a reading at each point of the traverse. Hold the tube so that the mark aligns with the side of the duct and point the pitot tube directly into the air stream. It must be parallel with the airflow. Use the side arm of the SP port as a guide to keep the tube parallel to the duct. Another person a few feet away can help guide you—especially if the pitot tube can be seen in the duct by looking through the hood. Hold the pitot tube very still once it is aligned and observe the manometer oil for a number of seconds to find the highest point at which the oil stays steady. It may spike rapidly upward or plunge downward, but there will be a high point where it fluctuates much less when you hold the tube steady long enough. Do not rush. Do it carefully because you should only have to do this once for any given system. A centerline measurement of SP is sufficient since it is constant across the duct at the point where you measured VP. Hold the pitot tube and observe the manometer the same as for VP readings.

VP readings for the initial survey should be documented on locally derived forms. You can enter the corresponding velocity (do not forget the density factor if applicable) next to each reading. However, you may find it less time-consuming to calculate the average VP and then convert to the average velocity using the formula only once. You should note that VPs cannot be directly averaged. You must find the square root of each reading, sum the square roots, divide by the number of readings, and square the result:

$$V_{avg} = \left(\frac{\sqrt{VP_1} + \sqrt{VP_2} + \sqrt{VP_n}}{n} \right)^2$$

Look at the following example of four VP readings (you will have many more):

#1: 0.69

#2: 0.71

#3: 0.74

#4: 0.76

$$V_{avg} = \left(\frac{\sqrt{0.69} + \sqrt{0.71} + \sqrt{0.74} + \sqrt{0.76}}{n} \right)^2$$

$$V_{avg} = \left[\frac{0.83 + 0.84 + 0.86 + 0.87}{4} \right]^2$$

$$V_{avg} = \left(\frac{3.4}{4} \right)^2$$

$$V_{avg} = 0.72$$

There is no change in the general procedures for the baseline test from the face velocity method. We still take air samples and make some measurement that indicates the flow at that time. Since you check the SP on the initial test, a quick check of this should serve as the baseline. Hopefully, it should not have changed in the short time between the initial and baseline tests. In addition, you may have done the initial measurements at the same time as the air samples. In either case, we consider the SP as representing the existing Q.

826. Static pressure check procedures

The calculations needed to prepare for the routine tests can be confusing, so we will try a step-by-step approach, continuing the example started on the initial survey form. For our example, the system did not meet the key parameters, but the air sample results showed that the contaminant was being controlled at the existing Q_s of 1024 scfm. The SP measured that corresponds to this Q_s was 0.33 in wg at a density factor of 0.77. Since the SP is at V_m and the Q_s is at standard conditions, the SP must be converted to standard conditions. You should show your calculations. The procedures used can be applied to both the face velocity and pitot traverse methods. Start by figuring the range of acceptable values for the routine tests. Since routine test results must be within 10 percent of the baseline value, subtract 10 percent of the baseline to find the low end of the range and add 10 percent to find the high end:

Low end:

1024 - 102.4 = 922 scfm

High end:

1024 + 102.4 = 1126 scfm

The acceptable range is 922 to 1126, which must be converted to SP values. The basic relationship between Q_s and SP is:

$$\frac{Q_1}{Q_2} = \frac{\sqrt{SP_1 \times d_1}}{\sqrt{SP_2 \times d_2}}$$

This relationship is used to calculate what is called a K factor (not like the one used before) for the system. It provides a means of calculating the information needed with less confusion. Once the K factor is found, it does not change for a given system (unless damage is done that changes system characteristics). The baseline data is then used to compute the K factor. Q_1 becomes Q_{base}; SP_1 becomes SP_{base}, and so on:

$$K = \frac{Q_{base}}{\sqrt{SP_{base} \times d_{base}}}$$

$$K = \frac{1024}{\sqrt{0.33 \times 0.77}} = \frac{1024}{\sqrt{0.2541}} = 2031.4$$

For the range of acceptable values, the symbols Q_{low} and SP_{low} will be used for the lower end of the range, and Q_{hi} and SP_{hi} for the upper end. Note: the value for d will always be used with its corresponding SP under the radical sign. Now it is possible to find the SP that would correspond to the Q_{low} of 922 scfm:

$$SP_{low} = \left(\frac{Q_{low}}{K}\right)^2$$

$$SP_{low} = \left(\frac{922}{2031.4}\right)^2 = (0.454)^2$$

$$SP_{low} = 0.206$$

The SP for the high end of the range (1126) is found in the same way:

$$SP_{hi} = \left(\frac{Q_{hi}}{K}\right)^2$$

$$SP_{hi} = \left(\frac{1126}{2031.4}\right)^2 = (0.554)^2$$

$$SP_{hi} = 0.3069$$

Another method of finding the low and high values is based on the premise that a 10 percent reduction from the baseline SP is 0.9 of the baseline and that a 10 percent increase is 1.1 times the baseline. Due to the need for squares and square roots when using pressure, the acceptable range can also be found in the following manner:

$$SP_{low} = 0.9^2 \text{ x } SP_{base} \text{ x } d_{base}$$

and

$$SP_{hi} = 1.1^2 \text{ x } SP_{base} \text{ x } d_{base}$$

Thus, our range of acceptable values for routine tests is between 0.206 and 0.307. This may seem odd because we measured 0.33 during the baseline test—higher than both of these values. If the system actually had the Q_s value from either end of the range, we would not find these SP values at conditions of d = 0.77. We would find a low of about 0.27 and a high of about 0.40, which we must multiply by d to compare to the acceptable range:

0.27 x 0.77 = 0.208 (a little off from 0.206 due to rounding)

or

0.40 x 0.77 = 0.308

This leads to what must be done with the measured SP on your routine tests. The procedures for conducting SP checks are similar to conducting other types of ventilation surveys:

1. Find the first measurement point (ports drilled in the duct during the baseline survey).
2. Prepare the equipment for use.
3. Measure the pressure and record readings.
4. Move to the next measurement point.
5. Measure the pressure and record readings.
6. Correct readings for conditions.
7. Compare readings to the baseline value.

After collecting the measurements, correct them for the survey conditions before comparing them to the baseline value. All that is necessary is to multiply the measured SP from each routine test by the *d* for those conditions to make the comparison to the range. Be sure to enter the temperature, pressure, and resulting density factor on the form for each routine test.

It may seem that routine test results above the acceptable range would not be anything to be concerned about. It may even seem that the system is operating better than before, which is not likely true. An increase in SP is an indication of trouble, just as a decrease would be. To illustrate, try partially blocking the air inlet of an exhaust system and measure the SP. It will, of course, increase (more system resistance) while the airflow is decreased. In the same way, an increased SP on a routine test may indicate that a clogging somewhere in the system is causing decreased airflow. Although we calculated the SP for the high end of the range from a high value for Q_s, a high

measured SP on a routine test will probably not reflect the true Q_s (and Q_m) and there may be times when you will want to know what the Q_s is. We again use the K factor. For instance, the SP of 0.325 measured on the first routine test (d = 0.76) corresponds to a Q_s of:

$$Q_s = K\sqrt{SP_{meas} \text{ x } d_{meas}}$$

$$Q_s = 2031.4\sqrt{0.325 \text{ x } 0.76}$$

$$Q_s = 2031.4\ \sqrt{0.247}$$

$$Q_s = 2031.4 \text{ x } 0.497$$

$$Q_s = 1010 \text{ scfm (it can go as low as 922 scfm)}$$

Q_s will fluctuate with changes in air density, but Q_m (the fan capacity) does not—it slowly deteriorates with age. The baseline Q_s was 1024, the first routine Q_s was 1010, and the next routine test showed 1059. However, if Q_m is calculated from any of these (using the density factor at the time of the test), you will find that they are all very close to 1330 acfm (actually they are exact—rounding at different points caused the difference).

The calculations reviewed can appear rather involved initially but once studied and practiced, become much simpler when you understand **how** and **why** they work. Using SP checks is the simplest and fastest way to conduct a routine test. It saves a lot of time over measuring face velocities every 3 months.

827. Indoor air quality

We've spent some time discussing ventilation system applications in the industrial environment. Air quality in non-industrial environments must also be discussed. "Poor" or "inadequate" indoor air quality (IAQ) are both terms used to describe indoor spaces (non-industrial work areas) where occupants complain of health problems which seem to be correlated with building occupancy; meaning the complaints appear while inside the building and lessen when the individual leaves the building. Poor air quality can result in reduced productivity and low morale because workers suffer daily from physical symptoms such as sinus congestion, drowsiness, lack of concentration, dry itchy skin, eye irritations, intolerant temperatures, and allergies. What causes poor IAQ?

There are only two sources of indoor air contamination—interior air and exterior air. Exterior (outdoor) air contaminants make their way indoors through ventilation intakes, open doors and windows, and leaks in the building envelope. This is called infiltration and examples of outdoor contaminants include industrial emissions, automobile exhausts, bioaerosols from natural microbial growth, and so forth. Interior air may contain any of the outdoor contaminants along with contaminants that are unique to indoor environments. Typical sources of unique indoor contaminants include volatiles and particulates from building materials, furnishings, appliances, office equipment, office/residential cleaning supplies, human activities, and so forth.

It is a unique combination of physical factors, indoor air pollutant species, rate of emission, and ventilation inadequacies that cause indoor environments to provoke adverse human health effects (like those mentioned above). The table below summarizes the common IAQ issues and their potential sources.

IAQ Issues	Potential Sources
Inadequate ventilation (insufficient outside air, insufficient airflow, and/or inadequate circulation)	Energy-saving and maintenance measures, improper system design or operation, occupant tampering with HVAC system, poor office layout, unbalanced system, “tight” construction
Temperature and Humidity extremes	Improper placement of thermostats, poor humidity control, inability of the building to compensate for climate extremes, tenant-added office equipment (i.e. cubicles)
Combustion contaminants	Furnaces, boilers, generators, gas or kerosene space heaters, tobacco products, outdoor air, vehicle exhaust
Volatile Organic Compounds (VOC)	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry cleaned clothes, carpets, and furnishings
Formaldehyde	Particle board, plywood, cabinetry, furniture, fabrics
Biological contaminants	Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, re-entrained sanitary exhausts, bird droppings, cock-roaches or rodents, dust mites on upholstered furniture or carpeting
Soil gases (radon, sewer gas, VOCs, methane)	Soil and rock (radon), sewer drain leak, dry drain traps, leaking underground storage tanks, land fills
Pesticides and Biocides	Termiticides, insecticides, rodenticides, fungicides, disinfectants, herbicides
Particles and Fibers	Printing, paper handling, smoking and other combustion, outdoor sources, deterioration of materials, construction/renovation, vacuuming, insulation, carpets, housekeeping
Environmental tobacco smoke	Lighted cigarettes, cigars, pipes

Most IAQ complaints are the result of occupant health and/or health concerns. When initially responding to complaints by building occupants, it is important to respond quickly for several reasons. First, ignoring voiced concerns can lead to the development of serious illness. Secondly, early involvement and action has excellent potential for complete success in solving the problem(s) and assuring the occupants safety and health.

During the investigation process, our goal is to characterize the complaints and identify any obvious causes of the problem. Two of the most important factors to any IAQ survey are *education* and *communication*.

In most cases, the IAQ problem can be identified during the walk-through inspection. In such a case, additional testing would not be required. If you have been unable to identify an obvious cause, or the complaints associated with the building do not correlate with your findings, additional testing may be required.

If there are complaints of odor or irritation, find and remove the source. Typical sources are untrapped drain lines connected to the sewer, gas-fired heater exhaust, new furniture or carpet, off-gassing from office equipment, stagnant air, insulation fibers, paints, glues, cleaning solvents, and external emissions brought into the building by the fresh air intakes. Possible screening samples to collect are methane, hydrogen sulfide, carbon monoxide, hydrocarbons, ammonia, formaldehyde, particulates (dust and fibers), sulfur dioxide, nitrogen dioxide, VOC and ozone. You should make sure direct reading instruments are calibrated. If any samples are significantly above outdoor levels,

trace the source and remove it. If the samples are not above outdoor levels, use the data for negative documentation.

Mold or bacteria contamination can be a significant contributor to IAQ problems. Allergic responses are the most common complaint. Air sampling to confirm the presence of microbes is unnecessary in most cases (signs of contamination such as growths in the drain pans, a mold odor, or water-stained ceiling tiles is enough). The primary concern is to identify the cause of the contaminant and repair the affected areas. A moisture meter can be used to assess the amount of moisture in construction materials. It is non-destructive and an effective means of determining the scope of water damaged materials. If the decision to sample is made, refer to "microbial" sampling guidelines provided by your servicing laboratory.

Measure the carbon dioxide (CO2) concentration, relative humidity, and temperature. When these "comfort" parameters fall outside their ideal range, complaints begin. The ideal ranges are:

- 1000 ppm CO2 or less.
- Relative humidity between 40 percent and 60 percent.
- Temperature from 68 to 76˚F.

Studies conducted by the Environment, Safety, and Occupational Health Service Center at USAFSAM have shown that the three most frequent sources of unacceptable IAQ are inadequate design and maintenance of heating, ventilation, and air conditioning (HVAC) systems, insufficient fresh air, and high/low relative humidity. Assessment of ventilation systems, identification and evaluation of the sources of contaminations and correlation of the medical date should be conducted using a "team" approach (Team Aerospace). Occupancy complaints should be taken seriously. The information from each survey should be documented and filed for future references. Communication is critical for the success of a good IAQ program. Our ultimate goal should be human health and comfort.

The troubleshooting guideline provided in the following table can assist in the recognition, evaluation, and control of IAQ problems:

Troubleshooting Indoor Air Quality Problems			
Cause	**Symptom/Complaint**	**Observation**	**Recommendation**
Low relative humidity	- Dry, scratchy eyes, nose or throat - Sore throat - Can't wear contacts lenses - Headache or body aches - Sinusitis	- Relative humidity less than 40%	- Re-humidify air in air handlers
High CO2 concentration	- Sleepiness - Fatigue - Poor concentration - Restlessness - Stuffy feeling - Sensation of breathing difficulty	- CO2 levels elevated, especially in the afternoons - Fresh air dampers nearly closed - No supply air in room or supply air blocked	- Increase fresh air rate - Open dampers - Decrease density of occupants - Add supply vents - Rearrange office
Improper HVAC balance	- Hot/cold spots - Stuffy feeling	- High CO2 levels - Airflow imbalance	- Rebalance HVAC system

Troubleshooting Indoor Air Quality Problems			
Cause	**Symptom/Complaint**	**Observation**	**Recommendation**
Negative pressure building	- Hot/cold spots - Dusty	- Wide temperature variations - Doors slam shut or are hard to open - Supply flow-rate less than return - Humidity damaged paint or wallpaper	- Increase supply air fan to 5% greater than return fan - Rebalance HVAC system
Fiberglass insulation dust	- Irritative cough - Dermatitis	- Dust/fibers in room or air handler - exposed insulation in air handling unit	- Replace or remove insulation - Vacuum dusts - Clean air handling unit
Bioaerosols	- Allergy confined to building - Musty smell - Nausea/diarrhea	- Water stained ceilings - Drip pans with standing water - Mold smell - Visible mold growth - Humidity > 70%	- Clean and disinfect HVAC system - Replace filters - Eliminate source of water
Pollution source	- Smells - Headaches - Nausea/diarrhea	- Fresh air intake located near loading dock/road/water tower - Combustion source in return air - No J-traps on drains or traps are dry	- Relocate fresh air intake - Remove combustion source - Add J-traps and fill with water - Absorb offending chemical
Cigarette smoke	- Tobacco smell - Complaints about smokers	- CO more than 2 ppm - Tobacco smoke in return air	- Move smoking area - Ban smoking
Air handler neglect	- Any of the above complaints - Legionella	- No air filters - Clogged air filters - Duct work or coils oily or dirty - Standing water in air handler - Exhaust/supply air grill dirty - Less than 68˚F or more than 76˚F	- Add or replace air filters - Clean and disinfect HVAC system - Begin maintenance schedule - Calibrate controls - Balance system

Risk communication is one of the most crucial parts of addressing IAQ problems. The closing conference is a great opportunity to reassure occupants that their problems have been heard and that they are being addressed. Since occupants can contribute to or be the source of an IAQ problem, they should be educated on what they can do to help maintain good IAQ. This includes storing food properly, maintaining good housekeeping, and not blocking air vents or grills. Generally, the closing conference is concluded with a list of “action items” that each office of responsibility (BE, PH, and CE) will accomplish.

References

ACGIH. (2007). *Industrial Ventilation: A Manual of Recommended Practice for Operation and Maintenance.* American Conference of Governmental Industrial Hygienists.

ACGIH. (2013). *Industrial Ventilation, A Manual of Recommended Practice for Design, 28th Ed.* American Conference of Governmental Industrial Hygienists.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

823. Ventilation survey requirements

1. What are the three types of ventilation surveys and the purpose of each?

2. What must be done if a routine survey of a ventilation system shows results *not* within 10 percent of the baseline?

824. Face velocity ventilation survey procedures

1. What are the reasons for measuring the airflow in all branches of a system for an initial test?

2. After you connect the attachments and set the controls on your velometer, what must you do before measuring airflow across a duct face?

3. If a thermal anemometer reads 1650 fpm for air with a density factor of 0.88, what is the actual velocity (V_m) of the air?

4. A dilution ventilation system had an average of 2000 fpm measured at the supply outlet and 1700 fpm at the inlet. What value should you use to calculate a Q for comparison to the key parameter?

825. Pitot traverse ventilation survey procedures

1. What preparations are needed before you can measure VP in a duct?

2. The absence of a suitable length of duct for making VP measurements required you to measure at 3 different points. If the resulting average velocities were 1700 fpm, 2000 fpm, and 2200 fpm, what value must you record as your VP?

3. Where are VP readings taken in a round duct?

4. A test of a ventilation system resulted in an average VP of 0.48 in wg in an 8-inch diameter (0.349 ft^2) duct with an air density factor (d) of 0.75. The measured SP was 1.08 in wg. The key parameter from the pre-survey form shows a Q_s of 920 scfm. What was the velocity at V_m?

826. Static pressure check procedures

1. What is the first step to performing SP checks?

2. What must be done to SP measurements before comparing them to the baseline value?

827. Indoor air quality

1. How do exterior air contaminants make their way into a building?

2. What is our goal during the IAQ investigation process?

3. What are the ideal comfort ranges for CO2 concentration, relative humidity, and temperature?

4. According to studies conducted by the Environment, Safety, and Occupational Health Service Center at USAFSAM, what are the three most frequent sources of unacceptable IAQ?

Answers to Self-Test Questions

816

1. To create the pressure needed to begin and maintain airflow.
2. SP is potential energy. VP is kinetic energy.
3. In conjunction with SP, it indirectly gives VP.

817

1. Squeezing the air stream caused by air trying to rush into the confines of the duct from many directions, thus producing turbulence losses.
2. Bend in the duct (elbows), changes in duct size, and adjustable devices in the duct to restrict flow. If an air cleaner is on the system, it will usually cause some of highest losses; can have a lot to do with the choice of air cleaners for a given fan capacity or with choice of fan that can operate with a type of air cleaner that must be used.
3. Rough duct material, high air velocity, small duct diameter, and long ducts.
4. Strongest negative SP: at the fan inlet. Strongest positive SP: at the fan outlet.

818

1. When air stream temperatures are +/- 30° F from standard (below 40° F or above 100° F) or when the elevation differs 1000 feet or more from sea level.
2. The speed of the air at a point in front of the hood that is required to pull contaminants into the hood.
3. Face velocity.

819

1. Area and velocity.
2. 15,000 cfm.
3. Calculate using the area in square feet at the point where you measured the velocity.

820

1. Supply gives more directional air flow for proper mixing with contaminants.
2. When adjoining rooms are not occupied.
3. Inefficient ventilation (poor mixing), higher contaminant toxicities, and non-uniform evolution of contaminant.
4. The LELs for chemicals far exceed the OELs and often the IDLH levels.
5. The maximum concentration of a chemical vapor that air can hold at a certain temperature.

821

1. Combines good contaminant control with generally lower air volumes; local exhaust is most efficient and economical type of industrial ventilation. Much less air handled with local exhaust resulting in less makeup air being needed; workers bothered less by drafts; reduced requirement for heating (and sometimes cooling) reduces costs; cheaper in long run mainly due to lower operating costs.
2. It causes a negative pressure in the workroom that limits the exhaust system capacity by increasing resistance. It can also create disturbing cross drafts that hinder contaminant capture.
3. Interlock the local exhaust system with machinery so that they must be used together.
4. They provide the best contaminant control with the lowest air volumes.

822

1. Duct velocity and required Q.
2. Open, slot, canopy, enclosing.
3. Results in more efficient control.
4. It does not capture contaminants.

823

1. Initial Acceptance: purpose of the test is to evaluate the system's performance as compared to the key parameters or contract specifications; Baseline Survey: purpose to ensure the system is capable of controlling a hazard below the appropriate OEL and establish baseline parameters for future routine performance tests; Routine Survey: purpose is to ensure the system continues to operate properly.
2. You must take action to determine the cause and get it corrected.

824

1. To compare to key parameters, check balance of branches, and determine the capacity for additions.
2. Measure out or mentally form a grid over the duct opening.
3. 1875 actual fpm.
4. 2000 fpm.

825

1. Find the appropriate measurement point(s) and ready your equipment for use.
2. 2100 fpm.
3. Readings must be taken along the diameter traverse. The first readings are made very close to the duct wall where the friction is highest and become farther apart as you move the pitot tube toward the center.

4. $V_m = 4005 \frac{\sqrt{VP}}{\sqrt{d}} = 3204$ fpm.

826

1. Find the measurement points (ports drilled during the baseline survey).
2. Correct them to current conditions.

827

1. Through ventilation intakes, open doors and windows, and leaks in the building envelope.
2. To characterize the complaints and identify any obvious causes of the problem.
3. Inadequate design and maintenance of HVAC systems, insufficient fresh air, and high/low relative humidity.
4. 1000 ppm CO2 or less; relative humidity between 40 percent and 60 percent; temperature from 68 to 76˚F.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

32. (816) The pressure of moving air is always measured in the direction of airflow. What kind of pressure is this?
    a. Always positive.
    b. Always negative.
    c. Negative on the blowing side.
    d. Negative on the exhausting side.

33. (817) Less resistance and better contaminant capture in a ventilation system happens by using
    a. an air cleaner.
    b. higher velocities.
    c. elbows in the ducting.
    d. a flange or tapered hood.

34. (817) Where should you expect the static pressure (SP) to become more negative in a ventilation system?
    a. Within the hood.
    b. At the hood throat.
    c. At the inlet to the fan.
    d. At the outlet to the fan.

35. (818) Which type of velocity refers to the speed of air at a point in front of a hood that is needed to pull contaminants into the hood?
    a. Face.
    b. Duct.
    c. Capture.
    d. Transport.

36. (819) What are two parameters at a given point in ventilation systems that are needed to calculate the airflow volume (Q)?
    a. Area and pressure.
    b. Area and velocity.
    c. Velocity and pressure.
    d. Diameter and velocity.

37. (819) The cubic feet per minute (cfm) through a cross-sectional area of a ventilation booth is the same as
    a. area.
    b. density.
    c. velocity.
    d. static pressure (SP).

38. (820) In dilution ventilation, a slight negative pressure is desirable when
    a. an adjoining room is normally occupied.
    b. the contaminant is fairly high in toxicity.
    c. an adjoining room is normally not occupied.
    d. the contaminant is fairly low in toxicity.

39. (820) What circumstance would result in a high K factor?
    a. Adequate mixing of air.
    b. Higher contaminant toxicities.
    c. An even evolution of contaminant.
    d. A high occupational exposure limit.

40. (821) Other than good contaminant control, what is the biggest advantage of local exhaust over dilution ventilation?
    a. Less noise.
    b. Lower operating costs.
    c. Better protection for equipment.
    d. Easier worker access to the process.

41. (821) The purpose of using splitter vanes, multiple takeoffs, or baffles inside of a local exhaust hood is to provide
    a. a reduction in system resistance.
    b. an increase in hood static pressure (SPh).
    c. proper discharge of air away from inlets.
    d. uniform air distribution across the hood face.

42. (822) What determines the capture velocity that must be used for a properly designed canopy hood?
    a. Number of open sides.
    b. Height of the canopy hood.
    c. Location of the side curtains.
    d. Contaminant containing tank size.

43. (823) In a routine survey, ventilation system data collected during the routine assessment should be compared to
    a. key parameters.
    b. factory findings.
    c. previous routine survey data.
    d. data collected during the baseline survey.

44. (824) What instrument is used to take face velocity measurements and actually converts velocity pressure (VP) to velocity readings?
    a. U-tube monometer.
    b. Inclined manometer.
    c. Thermal anemometer.
    d. Swinging vane anemometer.

45. (824) What important procedure must you follow to obtain accurate readings with a velometer?
    a. Hold the probe parallel to the airflow.
    b. Always, make two traverses at right angles to one another.
    c. Choose a section of the duct with smooth flow for measurement.
    d. Hold tube so that the mark aligns with the side of the duct and point tube directly into the air stream.

46. (824) What may be indicated by a very strong flow coming in an open door of a room containing a local exhaust system?
    a. Adequate makeup air.
    b. Excessive cross drafts.
    c. Inadequate makeup air.
    d. Proper discharge of air away from inlets.

47. (825) What is the purpose of the eight tiny holes on the outside of a pitot tube?
    a. Detect total pressure (TP).
    b. Sense static pressure (SP).
    c. Determine the duct diameter.
    d. Determine the density factor (d).

48. (825) Velocity pressure (VP) when measured across the duct is
    a. constant across the duct.
    b. weak along the sides and becomes weaker as you near the center.
    c. weaker along the sides and becomes stronger as you near the center.
    d. stronger along the sides and becomes weaker as you near the center.

49. (826) The range of acceptable values for the airflow volume (Q) on routine tests is within what percentage of the baseline value?
    a. 25.
    b. 20.
    c. 15.
    d. 10.

50. (826) What is the first step you take when conducting a static pressure (SP) check on your routine ventilation test?
    a. Measure the pressure and record readings.
    b. Determine the temperature and pressure.
    c. Find the first measurement point.
    d. Prepare the equipment for use.

51. (827) When conducting an indoor air quality (IAQ) investigation, what would be considered an ideal range for carbon dioxide (CO2) within a building?
    a. 1250 parts per million (ppm) or less.
    b. 1000 ppm or less.
    c. 750 ppm or less.
    d. 500 ppm or less.

52. (827) During your indoor air quality (IAQ) investigation, you document several drip pans with standing water. Which recommendation would be most desirable?
    a. Eliminate source of water.
    b. Increase fresh air rate.
    c. Rebalance system.
    d. Replace filters.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Respiratory Protection Program

ADVERSE HEALTH EFFECTS occur from inhalation of hazardous materials at toxic levels. The exposures could be long-term, low level (chronic) or short-term, high-level (acute), or both. Health effects from these exposures can vary from minor irritation and temporary illness to permanent organ damage, cancer, and even death. The proper use of approved respirators will protect the wearer from toxic levels of airborne chemicals and hazardous materials.

Employees are less likely to experience illnesses from theses hazards when they wear an approved respirator correctly, and are trained in their use, care, and maintenance.

828. Roles and interactions of bioenvironmental engineering in the respiratory protection program

In any workplace where respirators are necessary to protect the health of the employee or whenever respirators are required by BE, a written respiratory protection (RP) program with workplace-specific procedures must be established and implemented. BE will oversee or appoint an individual in writing to administer the installation RP program. The program is conducted according to Occupational Safety and Health Administration's (OSHA) Standard Title 29 CFR 1910.134, *Respiratory Protection*, and AFI 48–137, *Respiratory Protection Program.*

The use of RP may be required or voluntary, depending upon the circumstances. Respirators are required when engineering and administrative controls do not reduce the exposure below the OEL. RP is required for all personnel working in areas where other controls are not feasible or, in the BE's professional opinion, exposure may an OEL, RP would be required for all personnel working in that area. Some substance-specific OSHA standards require the employer to provide workers with respirators whenever they request them, even if exposures are below applicable OELs. Voluntary use respirators will not be worn by government employees in AF industrial workplaces except for filtering face-pieces as described in AFI 48–137 and when authorized by BE. BE will authorize voluntary use after verifying the use does not create a hazard to the employee. Voluntary use of respirators must be conducted in according to Title 29 CFR 1910.134 and Appendix D.

The program elements of a RP program will be shared among workplace supervisors and other functional areas such as BE, Force Health Management, and healthcare providers. The program is updated as necessary to reflect changes in workplace conditions that affect respirator use.

BE responsibilities

Bioenvironmental engineering is the office of primary responsibility (OPR) for the installation RP and gas mask quantitative fit-testing (QNFT) program. Some of BE's responsibilities include maintaining the "master respirator inventory" in an approved occupational and environmental health—management information system (OEH-MIS), which lists all of the workplaces that use RP; being the authority for determining whether RP is required; ensuring procedures are in place for controlling ordering and issuing respirators; and conducting routine and special surveys. More BE responsibilities will be covered throughout this unit, but a definitive list can be found in AFI 48–137.

Installation respiratory protection administrator

The installation RP administrator is appointed and approved by the BE flight commander or the non-commissioned officer-in-charge. The individual selected must have attended either the 4BXXX or 43EX Air Force specialty code (AFSC) course or a RP-training course (i.e., OSHA Training Institute or equivalent). The RP administrator maintains/has immediate access to current copies of applicable OSHA standards and the NIOSH certified equipment list. If there are inconsistencies between technical orders (TO) and Air Force Occupational Safety and Health (AFOSH) standards, the administrator will research and provide a resolution for the issue. The administrator also confirms that Force Health Management or Occupational Medicine Services personnel use the appropriate respirator medical evaluation questionnaire per Title 29 CFR 1910.134. The administrator provides guidance to workplace supervisors, as necessary, in the preparation of the workplace-specific written plan and annual RP training program. The RP administrator will review workplace-specific written plans annually.

The installation RP administrator refers individuals requiring respirator-related medical evaluations to the Force Health Management, Occupational Medicine Services or equivalent. The administrator will conduct fit testing on those individuals who have been medically cleared. The administrator is the point of contact for RP concerns involving CBRN or nuclear, biological, chemical (NBC) masks. Specifically, the administrator:

- Advises on the use of respirators designed for CBRN contingency environments (e.g., MCU–2 series) for military-unique operations, to include readiness training exercises and home station defense during CBRN events.
- Ensures personnel are trained to operate the M41 Protection Assessment Test System (PATS) and the Portacount (as necessary) and to troubleshoot NBC mask problems.

If BE authorizes other organizations or contractors to conduct respirator fit testing, the RP administrator still maintains oversight and responsibility for fit testing. Additionally, the RP administrator educates and trains workplace supervisors and those individuals appointed to oversee the use, maintenance, and care of common use or escape-only respirators.

When possible, the RP administrator determines the air contaminant concentration to which the respirator wearer is exposed to effectively establish the degree of exposure, the appropriate respirator to protect the worker, and cartridge change-out schedules.

Workplace supervisors

Bioenvironmental engineering is responsible for conducting shop assessments with workplace supervisors and providing them training as specified in AFI 48–137. Supervisors should contact BE should they become a supervisor of a new workplace. To comply with the USAF Respiratory Program, workplace supervisors will require BE assistance to develop, maintain, and enforce a workplace-specific written plan for the RP program according to the guidance in Chapter 3 of AFI 48–137. Supervisors review the workplace-specific written plan and provide a copy to BE for approval annually.

Workplace supervisors are responsible for contacting BE to schedule appropriate evaluations when new hazardous materials are introduced, processes or procedures are changed, or engineering controls are modified or added. When new employees are assigned or a current employee has a change affecting wearing RP, the supervisor will notify BE to schedule fit testing.

Workers

The interactions between BE and workers will be limited but critical. Bioenvironmental engineering conducts respirator fit testing for newly assigned workers or when processes or procedures change in the workplace. During workplace assessments, BE should observe workers for compliance with the RP program. In addition to its interactions at workplaces that require the use of respirators, BE also

performs CBRN mask QNFT for each military member upon arrival at their first permanent duty station or upon assignment to a unit type code (UTC).

It is the responsibility of the workplace supervisor to ensure workers use approved respirators and that the respirators are used correctly and maintained in good condition.

829. Types and classes of respirators and how they work

The atmosphere in an occupational environment is hazardous if there is not enough oxygen to support life or if any particulate, gas, or vapor is present in excess of the established OEL. In such environments, when effective controls are not feasible or are in the process of being instituted, workers must use appropriate respiratory protective equipment. Respiratory protective equipment varies in design, specifications, application, and protective capability. This personal protective equipment (PPE) keeps occupational and environmental health (OEH) threats away from the wearer's respiratory system, thus preventing contaminants from entering the body through inhalation.

Respirators are categorized according to their protective method. (1) *Air-purifying* respirators filter chemicals out of the surrounding air; (2) *atmosphere-supplying* respirators provide air from a clean source.

Escape respirators

This type of respirator is designed to be used only in an emergency and only to escape from a dangerous area to a safe area. Many of them use a hood with a neck seal instead of a face-piece. Escape respirators are designed for one-time use for a short period.

Particulate respirators

The particulate respirator is the simplest, least expensive, and least protective of the respirator types available. These respirators are lightweight, disposable, and require no cleaning or maintenance. Particulate respirators are "air-purifying respirators" because they clean particles out of the air as the wearer breathes, but even under the best of conditions, the inhalation process will allow some contaminated air to leak into the face-piece. Particulate respirators only protect against particles; they do not protect against chemicals, gases, or vapors and are intended only for low-hazard levels. The commonly known "N–95" filtering face-piece respirator is one type of particulate respirator, often used in hospitals to protect against airborne infectious agents.

Air-purifying respirators

Air-purifying respirators remove the contaminant by way of an air-purifying element as the user inhales (fig. 3–1). No air-purifying respirator can protect from all types of hazardous atmospheres. These devices do not supply oxygen, so they must never be used in an oxygen-deficient atmosphere. A variety of air-purifying elements are available to protect against specific contaminants. Particulate-removing elements are called "filters" and gas/vapor removing elements are called "cartridges" or "canisters." Combination elements for protection against both particulates and vapors/gases are also available.

Air-purifying respirators are lightweight and do not restrict mobility. The respirator mask is durable and cleanable; only the filters/cartridges need to be replaced.

Figure 3–1. Full-face air purifying respirator.

Air-purifying canisters/cartridges are labeled and color-coded (fig. 3–2). Manufacturers are required to use the color-coding system specified by Title 29 CFR 1910.134.

Figure 3–2. Respirator canister.

Because protection is afforded by the air-purifying element, it is important that users be able to discern when the element is no longer functional. AFI 48–137, Attachment 7, provides guidance on determining when to change out cartridges. This is rather simple for particulate filters, as they become clogged and breathing becomes difficult. If an air-purifying respirator is used for protection against gas or vapor contamination, then there must be suitable warning properties of contaminant breakthrough or respirator malfunction. The following general guidelines govern the warning properties.

- When the odor, taste, or irritation effects of the substance are detectable and persistent at concentrations at or below the OEL, the warning properties are deemed to be adequate.
- When the odor or irritation threshold of a substance occurs at concentrations greater than three times the OEL, the warning properties are deemed to be poor.
- When the odor irritation threshold is somewhat above the OEL (but not in excess of three times the limit) and there is no ceiling limit, determine whether an undetected exposure in the concentration range could cause serious or irreversible health effects. If not, the substance is considered to have adequate warning properties.

- Some substances have extremely low thresholds of odor and irritation in relation to the OEL. Thus, a worker wearing an air-purifying respirator even when the respirator is functioning properly can detect these substances. These substances, therefore, are considered to have poor warning properties.

Filters and Cartridges

Particulate air-purifying respirators capture particles in the air such as dusts, mists, fibers, and fumes. They do not protect against gases or vapors. They consist essentially of a face-piece, either quarter-face (above the chin), half-face (under the chin), or full-face. Directly attached to the face-piece is one of several types of filters made up of a fibrous material that removes the particles by trapping them as air is inhaled through the filter (fig. 3–3). The "filter classes" are designed for different types of aerosols, use times, and filter efficiency levels; therefore, the proper filter selection depends on your knowledge of the material and the workplace conditions.

Figure 3–3. Pancake filter.

There are many classes of filters for respirators "specific" for airborne particulate matter of which OSHA (according to Title 42 CFR, Part 84, *Approval of Respiratory Protective Devices*) allows nine classes. These classes are further divided into three filter series: *N-Series Filters, R-Series Filters,* and the *P-Series Filters*. The selection of the type of filter depends on the presence or absence of oil particles, as follows:

- If no oil particles are present in the work environment, use a filter of any series (i.e., N-, R-, or P-series).
- If oil particles (e.g., lubricants, cutting fluids, glycerin, etc.) are present, use an R- or P-series filter.
- If oil particles are present and the filter is to be used for more than one work shift, use a P-series filter if use falls within the manufacturers time-use limitation recommendations.

NOTE: N-series filters cannot be used if oil particles are present.

Refer to the following table to select the appropriate filter series:

Filter Series	Capabilities/Limitations
N	- This series of filters are restricted to use in atmospheres free of oil aerosols - May be used for any solid or liquid airborne particulate hazard that does not contain oil - Replace filter when increased breathing resistance develops
R	- This series of filters is intended for the removal of any particle including oil-based liquid aerosols - Can be used for any solid or liquid airborne particulate hazard - Eight hour service life, or one work shift, when used with oil mist aerosols - Must be replaced after eight hours of use
P	- This series of filters is intended for the removal of any particle including oil-based liquid aerosol - Can be used for a solid or liquid airborne particulate hazard - Should be used and reused in accordance with the manufacturer's time-use limitation recommendations when oil aerosols are present

Each filter series has three levels of filter efficiency: 95 percent, 99 percent, and 99.97 percent.

Gas/vapor removing devices

These respirators use cartridges or canisters that contain granular, porous materials called sorbents (generally carbon) that interact with the gas or vapor to purify the air. These respirators are designed for protection against "specific" contaminants (such as ammonia gas) or "classes" of contaminants (such as organic vapors).

Combination devices

Combination respirators use aerosol-removing filters with a chemical cartridge or canister for exposure to multiple contaminants or more than one physical form (e.g., mist and vapor). Combination aerosol filter/gas or vapor-removing respirators are most often used for spray paint operations.

The NIOSH cartridge and/or filter labels should always be read before use to ensure that the correct one is being used. Cartridges labeled for protection against particulates only cannot be used for gases or vapors, and likewise, cartridges labeled for protection against gases and vapors only cannot be used for particulates.

Filter change-out

All filters, cartridges, and canisters must be replaced at regular intervals. The workplace must keep a schedule for changing the filters. Depending on the filter used and the hazard in the atmosphere, this schedule might be based on breathing resistance, warning indicators, or simply hours of use. Be sure that the change-out schedule is appropriate for the filter and the hazard.

Atmosphere-supplying respirators

In circumstances where an air-purifying respirator will not effectively protect the worker, an atmosphere-supplying respirator should be considered. Atmosphere- supplying respirators supply clean air (from a tested and approved source) directly to the user, independent of the ambient air. These respirators fall into three groups: (1) air-line respirators, (2) self-contained breathing apparatuses (SCBA), and (3) combination air-line and SCBAs.

Air-line respirators

Air-line respirators deliver breathable air from a compressor or compressed air cylinders through a supply hose that is connected to the wearer's face-piece or head enclosure. These respirators can provide clean air for an extended amount of time and are usually lightweight in comparison to other air-supplying respirators. The hose, however, can limit the mobility of the wearer.

These devices should only be used in atmospheres that are not IDLH or atmospheres in which the user can escape without the use of a respirator. This limitation is necessary because the respirator is entirely dependent upon an air supply that is not carried by the wearer. If the air supply fails, the wearer may have to remove the device and escape the area.

Self-contained breathing apparatus

The SCBA is composed of a wearable clean air supply and provides RP against gases, vapors, particulates, and oxygen-deficient atmospheres. The wearer carries the clean air supply (the air supply is typically back-mounted). The tank and harness can be very heavy and restrict movement. SCBAs require special training to use and highly skilled personnel must perform maintenance. A full-face respirator is most commonly used with SCBA. Half-face, hoods, and mouthpieces are available on some units. There are two major types of SCBAs: *closed circuit* and o*pen circuit.*

Closed-circuit SCBA

Within a closed-circuit SCBA, all or a percentage of the exhaled gas is scrubbed and re-breathed (fig. 3–4). Oxygen either continuously flows into a breathing bag or is controlled by a regulator governed by the pressure or degree of inflation of the bag. The user inhales from the bag and exhales into it, and the exhaled air is scrubbed of carbon dioxide. The re-breathed air can become quite warm. Closed circuit units can provide up to 4 hours of breathing air to the user.

Figure 3–4. Closed-circuit SCBA.

Open-circuit SCBA

In contrast to the closed-circuit units where the air is scrubbed and re-breathed, these devices release the exhaled air into the surrounding environment and should not be worn during clean or sterile procedures. The open-circuit SCBA is more commonly used in the AF by BE and Fire and Emergency Services (fig. 3–5). The breathing gas is generally compressed air and they are typically designed to provide 30–60 minutes of air to the user.

Figure 3–5. Open-circuit SCBA.

NOTE: Some SCBAs are designed strictly for escape. They are similar to the types described above, except that the use durations are shorter (typically 5, 7, or 10 minutes). These units are approved for escape only and cannot be used to enter hazardous atmospheres.

Combination air-purifying and atmosphere-supplying respirators

This type of respirator combines an air-line respirator and an auxiliary air-purifying attachment, which can provide protection in the event that the air supply fails. The respirators cannot be used in atmospheres that are considered to be immediately dangerous to life and health or atmospheres containing less than 19.5 percent oxygen.

830. Use, care, and maintenance of respirators

Individuals issued a respirator are responsible for its care and maintenance. When respirators are used collectively and stored by an activity, the workplace supervisor is responsible for establishing the respirator maintenance and cleaning program per Title 29 CFR 1910.134. The respirator maintenance program includes cleaning respirators, inspecting the equipment for defects, maintaining and repairing defects found, and properly storing the respirator. Each respirator must be inspected by the wearer immediately before each use to ensure it is in proper working condition. In addition, emergency and rescue use respirators must be inspected at least monthly. Emergency escape-only respirators must be inspected before being carried into the workplace for use. All respirators that do not pass the inspection must be immediately removed from service and repaired or replaced.

Inspection

Respirators should also be inspected during cleaning to determine if they are in good condition, if parts need to be replaced and/or repaired, or if the device needs to be discarded. At a minimum, inspect the items listed in the following table.

Equipment Part	Inspect respirators for the following problems
Rubber face-piece	Dirt
	Cracks, tears, and/or holes
	Distortion from improper storage
	Cracked, scratched, or loose-fitting lens
	Broken or missing mounting clips
Head straps	Breaks and/or tears
	Loss of elasticity
	Broken or malfunctioning buckles or attachments
	Excessively worn head straps which might allow the face-piece to slip
Valves	Detergent residue and dust or dirt on the valve seal
	Cracks, tears, or distortion of the valve
	Missing or defective valve cover
Filter element	Proper type of filter for the activity and contaminants involved
	Approved design
	Missing or worn gaskets
	Worn threads
	Cracks or dents in the housing
	Spent and/or dirty (possibly indicating “used” filter)

The inspection should also include a check for proper function of the regulators, alarms, and other warning systems (if applicable). Compressed gas cylinders or SCBA must be checked to ensure they are fully charged according to the manufacturer’s instructions.

Disinfection

Personally assigned respirators must be cleaned and disinfected regularly. Respirators that are worn by multiple workers (collective use) must be cleaned and disinfected before being worn by a different individual. Cleaner-disinfectants that effectively clean the respirator and contain a bactericidal agent are commercially available. For personally assigned respirators, equipment wipes containing this type of agent are available; however, they should not be the only method in place. Alternatively, respirators can be washed in a mild detergent solution (such as dishwashing liquid) and then immersed in a disinfecting solution. Individuals and supervisors should use the procedures for cleaning and disinfection respirators outlined in Title 29 CFR 1910.134, Appendix B–2.

Rinse the respirator in clean water or rinse once with a disinfectant and once with clean water. The clean water rinse is particularly important because traces of detergent or disinfectant left on the mask can cause skin irritation and/or damage the respirator’s components. The device is then allowed to air dry, with the respirator positioned so that the face-piece rubber will not become misshapen when dry (**NOTE:** Strong cleaning and disinfecting agents and many solvents can damage rubber and elastomeric respirator parts; therefore, these substances should be used with caution.). Respirators used in fit testing and training should be cleaned and disinfected after each use.

Protection

Respirators must be protected from dust, sunlight, extremes of temperature and moisture, and damaging chemicals. They should be stored to prevent deformation of the face-piece and exhalation valve. Emergency respirators must be readily accessible and they should be stored in compartments or in covers that are clearly marked as containing “emergency” respirators (and stored according to any applicable manufacturer’s instructions).

Documentation

Respirators that are maintained for emergency use only require the workplace supervisor to certify the respirator by documenting the date the inspection was performed, the name of the person who made the inspection, the findings, required remedial action, and a serial number or other means of identifying the inspected respirator. This information should be provided on a tag or label that is attached to the storage compartment of the respirator, or is included in inspection reports stored as paper or electronic files. This information is maintained until replaced following the next certification. Remember that respirators used for emergency use only are required to be inspected at least monthly.

Workplace supervisors are responsible for respirator use in their work areas. They are required to ensure respirators are cleaned and disinfected, properly stored, inspected, and repaired. Moreover, they must ensure all filters, cartridges, and canisters used in the workplace are legibly labeled and color-coded with the NIOSH approval label.

831. Procedures for selecting and approving respiratory protection equipment

Proper respirator selection depends on the contaminant involved, conditions of exposure, human capabilities, and the respirator fit. AFI 48–137 requires that respirators be selected according to OSHA Standard Title 29 CFR 1910.134 (d) and the NIOSH certified equipment list. Rationale for selection is documented, by process, in the workplace-specific written plan. Selection is based on the evaluation of respiratory hazards within the workplace, the time period that respirators must be worn, and the worker's activities. A NIOSH-approved respirator is then selected for the "situation" after the physical characteristics, functional capabilities and limitations, and the assigned protection factors (APF) have been considered. Respirator selection may be driven by compliance with OSHA Expanded Standards or AF guidance.

RP for exposure to airborne infectious diseases with high morbidity or mortality (e.g., tuberculosis (TB) or severe acute respiratory syndrome [SARS]) is based on the risk of an occupational exposure. Perform a health risk assessment (HRA) of the potential for exposure to an infectious disease prior to determining who is required to wear RP. Determine RP requirements based on the facility-specific risk assessment that considers the hierarchy of controls to address the hazard, local threat, population served, and services provided, in accordance with OSHA standards, Centers for Disease Control and Prevention (CDC) guidelines and recommendations, and AF Instructions.

Proper respirator selection for other OEH threats involves determining the hazard(s) and following a logical process to choose the correct type or class of respirator that offers the right amount of protection. Proper selection guidelines are outlined in the paragraphs that follow.

Start with identifying workcenter respiratory hazards that may be present by reviewing historical data and/or conducting surveillance. In addition, determine whether there is an OSHA substance-specific standard or other AF-approved guidance for the contaminant(s) that may have specific respirator requirements, which will influence the selection process.

Next, assemble the necessary toxicological, safety, and other relevant information for each respiratory hazard, including the following:

- Each worker's activity and location in an inhalational hazard area must be considered when selecting the proper RP. For example, consider whether the worker is in the hazardous area continuously or intermittently during the work shift and whether the work rate is light, medium, or heavy. Also, take into consideration issues affecting respirator comfort (e.g., heat stress, medical, or psychological conditions).
- The period of time a respirator must be worn is an important factor that should be taken into account when selecting a respirator. Consideration is given to the type of respirator application, such as for routine, non-routine, emergency, or rescue use.

- The location of the hazardous area with respect to a safe area, which has respirable air, should be considered when selecting a respirator. This will permit planning for the escape of workers if an emergency occurs, entry of workers to perform maintenance duties, and rescue operations.
- Environmental conditions and physical effort required of the respirator wearer may affect respirator service life. For example, extreme physical exertion can cause the user to deplete the air supply in a SCBA unit such that its service life is reduced by half or more.
- Consider other exposures (skin absorption or external radiation) when selecting RP. For example, wearing the respirator could increase worker exposure by longer stay times in a hazardous environment, such as exposures to external radiation.

Once the hazard(s) are identified and the necessary information has been gathered, perform a hazard determination of the contaminant(s) involved. More information on identifying and analyzing chemical hazards is provided in volume 2, unit 4. When selecting a respirator, evaluate all possible actions, such as increasing ventilation or isolating the source of contaminants, to attain an atmosphere that is not IDLH before authorizing personnel to enter areas known to have IDLH conditions. Refer to Title 29 CFR 1910.134 g (3) and g (4) for procedures for IDLH atmospheres. As part of the hazard determination, measure the concentration of the contaminant and determine whether it is equal to or greater than 10 percent of the LEL if the potential for an explosive atmosphere exists. Determine whether there is a potential for a sudden chemical release that could impair a worker's ability to egress the area safely. For each contaminant, calculate a hazard ratio.

$$\textit{Hazard ratio} = \frac{\textit{time-weighted average (TWA)}}{\textit{occupational exposure limit (OEL)}}$$

[**NOTE:** If the contaminant has a ceiling limit, divide the maximum exposure concentration for the contaminant by the ceiling limit. If the contaminant has a short-term exposure limit (STEL), divide the maximum 15 min time-weighted average (TWA) exposure concentration for the contaminant by the STEL.]

If a more stringent standard such as a substance-specific OSHA standard exists for a particular contaminant, follow those guidelines/requirements for respirator selection. Respirators should be selected with an APF that is greater than the value of the hazard ratio.

In addition to calculating the hazard ratio for each substance, it may be necessary to calculate the compliance factor when two or more substances are present and act on the same target organ rather than considering each substance individually. The sum of the hazard ratios for two or more substances is the same as the compliance factor.

Assigned protection factor

The APF is how well a particular respirator fits a person's face. Protection factors are assigned to different kinds of respirators as measures of how well any respirator of the group protects against airborne hazards. It is the minimum level of protection provided by a properly fit and functioning respirator.

Maximum use concentration

The maximum use concentration (MUC) is the highest contaminant concentration for which a respirator adequately protects the wearer. It is the most conservative (lowest) of the following:

- OEL multiplied by the APF.
- IDLH concentration.
- Maximum contaminant concentration for filter/cartridge (if specified).

Scenario: Munitions Maintenance

Munitions maintenance has been tasked to complete a 180-day inspection on fifty outboard pylons. As part of the inspection, workers will have to re-paint the front cowlings and paint new warning stencils on the access panels. This will be a limited operation lasting approximately two weeks. To increase productivity the shop supervisor has requested that the back portion of the workplace be used for re-painting and stenciling only. After an HRA is performed, exposure control recommendations are made.

OEH exposure assessment: The contaminants of concern are the organic compounds in the paint (methyl ethyl ketone, toluene, etc.) Based on instantaneous air samples collected with a HAPSITE, airborne concentrations of toluene vapors could exceed the OEL. The air sampling results indicate vapor concentrations could reach as high as 50 ppm.

Engineering controls: Engineering controls are not feasible due to the temporary nature of the operation.

Administrative Controls: Bay doors and windows will remain open during painting operations and at least 30 minutes afterward to allow vapors to clear from the work bay. Floor fans will be used after painting is complete to help remove vapors from the area.

PPE: Use respirators to protect against the inhalation hazard. Use coveralls, gloves, and eye protection to reduce contact hazard.

Step 1: Identify the contaminant of concern

To select the proper respiratory protection, first identify the workcenter respiratory hazards. In this situation, it is toluene vapors above the OEL.

Step 2: Assemble toxicological and other relevant information about the contaminant of concern

Next, assemble the toxicological, safety, and other relevant information about the respiratory hazard, toluene.

Operation/Task: Spray painting

Task Location: Munitions Maintenance

Contaminant Name: Tname: Toluene

Physical Form: Vform: apor

OEL: 20 ppm (2007 TLV booklet), no STEL

IDLH: 500 ppm (NIOSH revised value)

Carcinogen: No; no A4, not classified as a human carcinogen (reference 2007 TLV & Biological Exposure Indices (BEI) documentation).

Possible Skin Absorption: Nskin absorption: o

Target Organs and Organ Systems: Eorgan systems: yes, female reproductive, pregnancy loss.

Step 3: Perform hazard determination

After gathering all of the information, perform a hazard determination. Determine the concentration of the contaminant through air sampling.

Concentration: The air sampling results taken by BE were: Calculated TWA concentration Toluene = 188.5 ppm

Hazard Ratio: Concentration (calculated TWA)/OEL = 188.5 ppm/20 ppm = 9.4

Since none of the contaminants will act on the same target organ, it is not necessary to sum the hazard ratios. The physical form of this contaminant is a vapor, so next determine the Maximum Use Concentration.

Step 4: Select appropriate respiratory protection device

Limitations

Respirators of all types have common limitations, though the degree will vary, both with the respirator and with the individual wearing the device. For example, all respirators increase the

physical stress of a job; they can impede breathing, the inside of the mask may become hot, and they are generally uncomfortable. Sweat inside a tight-fitting respirator can be a problem, especially since the needed seal prevents sweat from escaping as effectively as it keeps out ambient air. This can cause the face-piece to slip out of position (compromising the integrity of the seal). Also, workers can become hypersensitive and suffer from rashes or other illnesses caused by the wear of a tight-fitting respirator and/or have an allergic reaction to the silicone. Over-tightening the straps of the face-piece can cause bruising, jaw soreness, and headaches. Wearing respirators should decrease the risk of injury or illness, not cause injury or illness; that is why it is important that workers be trained to wear their PPE properly.

Before a worker is required to use any respirator with a tight-fitting face-piece, the worker must be fit-tested with the same make, model style, and size of respirator.

832. Quantitative and qualitative respirator fit-testing procedures

Fit-testing is the only practical way to verify a respirator actually forms a barrier between harmful agents in the air and a worker's respiratory system. Although respirators are made in different sizes, faces come in varying shapes as well as sizes, and no respirator is yet made that can form an airtight seal on every face. The "fit factor" is an objective measurement of the integrity of this barrier.

So how do we determine this fit factor? By measuring the concentration of a contaminant in the atmosphere at the same time the concentration is measured inside the mask, one may determine how well the mask keeps the contaminant outside—that is, how well the respirator fits.

For example, if the air contains 120 micrograms per cubic meter ($\mu g/m^3$) particulates outside the mask and 4 $\mu g/m^3$ inside the mask, the ratio of these (the fit factor) is:

$$\frac{120 \mu g/m^3}{4 \mu g/m^3} = 30$$

The fit factor can only be calculated for a QNFT. So what is the acceptable fit factor? After calculating how well a respirator fits an individual, how does one know whether it fits well enough or whether the worker needs to try a different face-piece size or model? In most cases, 100 is the minimum acceptable fit factor for a half-mask respirator and 1,000 for one with a full face-piece. However, for negative pressure respirators, if 10 times the APF is higher, use that value as the standard. If the measured fit factor does not meet the standard, fit the worker with another respirator.

The air within a respirator needs to be sampled to determine the respirator's fit factor. Respirator manufacturers typically provide attachments for their regular respirators, or special respirators modified for fit-testing. It is better, especially when verifying the fit periodically, to attach the fitting to the worker's issued mask; this ensures the respirator worn every day fits properly.

Fit test protocol, both *qualitative* and *quantitative*, are valid only for negative pressure respirators. Positive pressure respirators must be modified to work in a negative pressure mode with the appropriate filter installed. For many powered air-purifying respirators, this is as simple as turning off the blower. For others, obtain adapters to do this from the respirator's manufacturer. Modification for fit-testing should not affect the normal fit of the device. Do not use it if it does.

Remember that the purpose of the fit test is to verify an integral face-to-face-piece seal—nothing more. A performance test is similar to a fit test, but the performance test is done with a respirator operating in a positive pressure mode. This type of test measures the performance of a respirator rather than the fit of the respirator to the face. There may be times when a worker cannot get a proper fit with any tight-fitting respirator. These workers are then provided with a positive pressure, loose-fitting face-piece or helmet (or hood device of sufficient APF for the hazard), or they are transferred to a job or workplace where respirator protection is not required. Workers who wear respirators are fit-tested and trained initially and then annually thereafter. **NOTE**: OSHA expanded standards may require more frequent fit-testing; be sure to check.

Quantitative fit-testing (QNFT)

QNFT must be done when specified by an OSHA substance-specific standard or when fit-testing a negative pressure air-purifying respirator that must achieve a fit factor greater than 100 (i.e., a full-face respirator). The quantitative method is more objective than the qualitative method, and the number assigned (the fit factor) can be interpreted as the degree to which the respirator fits the face of the wearer. It does take more specialized equipment than the qualitative method.

Portacount Plus system

The Portacount is an ambient aerosol QNFT system used to perform fit tests. The Portacount Plus fit-test system (fig. 3–6) can be used on respirators and gas masks. QNFT, using the Plus system, is generally performed on both full-face and half-face negative pressure respirators. Fit factors are determined by comparing the particle concentration outside the respirator with the concentration inside the respirator face-piece. An acceptable fit is achieved when the respirator wearer successfully completes a series of six programmed exercises (normal breathing, deep breathing, moving head up and down, moving head side to side, reading, and normal breathing) with a fit factor of 100 or more.

Figure 3–6. Portacount Plus system.

M41 Protection Assessment Test System

The M41 PATS is used to perform QNFT on gas masks only. The settings are tailored to the gas masks. The M41 PATS (fig. 3–7) is a compact lightweight device designed to check the fit and protection factor of protective masks. It is based on a Condensation Nucleus Counter that continuously samples and counts naturally occurring particles in the air. The M41 counts individual particles, compares the concentration of these particles inside and outside the mask, and derives a protection factor. The pass level is set at 2000.

Figure 3–7. M41 PATS.

CBRN mask fit-test

CBRN mask fit-testing applies to unique military respiratory protective masks designed specifically for use in a CBRN environment; it does not include the aircrew CBRN mask. This program is intended to be a training aid rather than a certification tool to ensure personnel meet or exceed the minimum target fit factor. QNFT increases personal protection by increasing personal confidence by confirming individuals' mask sizes are correct and validating training individuals received on properly donning their masks to attain an adequate fit and to know what their mask feels like when an adequate fit is attained. CBRN mask fit-testing is accomplished in accordance with TO 14P4–15–11, *Operator and Unit Maintenance Manual for Protective Assessment Test System (PATS), M41*, or other approved policy.

CBRN mask fit-testing is done for each military member upon arrival at their first permanent duty station or upon assignment to a UTC according to AFI 10–401, *Air Force Operations Planning and Execution*, and AFI 10–403, *Deployment Planning and Execution*. QNFT will be re-accomplished if a new size or type mask is issued, the wearer gains/loses 10 percent or more of body weight following completion of the initial QNFT, or the wearer experiences extensive dental work, facial surgery, scarring, or disfigurement.

The AF target fit factor for the MCU–2A/P is 2000. The fit factor of 2000 is a "division" between "adequate" and "poor" fitting CBRN masks. The fit factor indicates how well the mask fits; it is not a protection factor. A protection factor indicates the degree to which an adequately fitted mask will reduce the concentration of a contaminant. The QNFT does not measure or determine the protection factor.

The BE flight will notify the unit commander in writing if an individual is unable to achieve a minimum fit factor.

Quantitative fit-testing procedures

To prepare the Portacount or PATS for fit testing, the following steps are required:

1. Turn ON/OFF the switch and wait for 60-second warm up.
2. Ensure the system is set to the proper settings for the mask being used.

3. Press COUNT Key: Ensure the mask or filter is not attached.
4. Conduct a Zero Check: Attach the high efficiency particulate air (HEPA) filter to clear sample tube (check arrow). Particle count must be 0–0.6 particles/cm^3 (per cubic centimeter).

Before a fit test can be administered, the following steps must be taken:

1. Mask must be clean inside. Use a lint free cloth.
2. Place fit testing adapters on the mask. For gas mask attach red adapter to drinking tube.
3. Have individual don mask; ensure all hair is out of the seal.
4. Have individual perform a user seal check.

Individuals using tight-fitting respirators are to perform a user seal check to ensure that an adequate seal is achieved each time the respirator is put on.

- Positive Pressure Checks—Close off the exhalation valve with the palm of the hand and exhale gently into the face-piece. The face fit is considered satisfactory if a slight positive pressure can be built up inside face-piece without any evidence of outward leakage of air at the seal.
- Negative Pressure Checks—Close off the inlet opening of the canister or cartridge(s) covering with the palm of the hand(s) or by replacing the filter seal(s). Inhale gently so that the face-piece collapses slightly, and hold the breath for ten seconds.
- Manufacturer's Recommended User Seal Check Procedures—The respirator manufacturer's recommended procedures for performing a user seal check may be used instead of the positive and/or negative pressure check procedures, provided that the employer demonstrates that the manufacturer's procedures are equally effective.

The person conducting the fit test will determine if something can be changed to improve the fit of the mask. This may include modifying donning procedures, using a skull cap, ordering advantage 1000 spectacle inserts, or selecting a smaller or larger mask. All of this is done at the time of the fit test. Do *not* make adjustments yourself. Offer advice to the user and allow them to make adjustments. Most people who do not reach the minimum fit factor will be able to achieve it through these simple actions.

Tell the individual what to expect—test procedures, exercises to be performed and their responsibilities during the test.

Initiate the Portacount or PATS test sequence

The following steps are taken to perform a RP fit test:

1. Attach the clear tube on the tube assembly to the fit test adapter.
2. Press COUNT Key. This will indicate whether the individual has a good seal before starting the test. Particle count must be below 3. (Particles/cm^3 before starting test.)
3. Press the FIT TEST key.
4. Press the START/STOP TEST key.
5. Verify that the number of exercises is set to 5 by momentarily pressing the NUMBER OF EXERCISES key until the number 5 appears on liquid crystal display (LCD). Release the key while the number 5 is displayed to make the change take effect. Verify that the number of exercises is set to 5 by momentarily pressing the NUMBER OF EXERCISES key. Refer to Appendix A for the exercises performed for the fit test.

Interpret results

If the test is a PASS (overall fit factor of 1667 or higher for the MCU–2A/P mask), have the wearer remove the mask. If the test is a FAIL, check to ensure head harness pad is centered correctly,

re-tighten straps after adjustment of head harness pad, check for hair under face-piece sealing surfaces, make sure all connections to the Portacount/PATS are correct and then repeat mask fit test. Remove the drink tube-sampling adapter and sample tube extension from wearer's mask. Attach the HEPA filter to the twin tube marked "SAMPLE" and put the PATS into Count Mode by pressing the COUNT Key. If there will be a wait of more than 15 minutes before the next test, follow the closing procedure.

If the mask fails the test again, repeat the test on a replacement mask of the same size. If the fit test fails on the replacement mask, size down one size and repeat the fitting and fit testing procedures. A smaller size face-piece usually seals better than a larger size

The BE flight will provide individuals with three hard copies of the QNFT results: One copy will be maintained by the individual in the mask carrier, one copy will be provided to the unit deployment manager (UDM) for placement in the individual's mobility folder and one copy will be maintained by the member for obtaining a mask at future duty stations.

QNFT documentation will include, at a minimum, the individual's name, last four numbers of their SSN, date accomplished, mask size and type, and overall fit factor.

Qualitative fit-testing (QLFT)

QLFT can be accomplished whenever quantitative testing is not specifically required by regulations or fit-factor requirements. QLFT is a pass or fail test. It requires no complicated equipment and can be done easily in the field. This type of fit-testing relies on the sensory response of a worker to a contaminant put into the air. The most common challenge agents used to fit-test are reasonably non-toxic chemicals with strong, distinctive odors, such as irritant smoke or isoamyl acetate (IAA), commonly known as *banana oil*).

When dealing with qualitative test protocols, there are three steps: (1) threshold screening, (2) respirator selection, and (3) fit testing. The threshold screening is performed without wearing a respirator to determine whether the wearer can detect low levels of the test agent. This level is similar to the inside of the mask if the respirator was a face-piece-to-face seal and it had a leak.

If a qualitative fit test is accomplished using banana oil, the respirator must be equipped with organic vapor cartridges or canisters. Respirators that use a particulate filter or the filtering face-piece respirators can be fit tested with the Bitrex solution. Respirators must be equipped with class 100 or HEPA filters in order to use the irritant smoke. Typically, in the AF when qualitative fit tests are being accomplished, they are accomplished on the filtering face-piece (i.e., N–95) for the medical lab, ambulance personnel, and the TB response team.

Taste threshold screening

The Bitrex taste threshold screening is performed without wearing a respirator. During threshold screening as well as during fit testing, subjects shall wear an enclosure hood. Using an inhalation medication nebulizer, the test conductor shall spray the Threshold check solution into the enclosure. An initial ten squeezes are repeated rapidly and then the test subject is asked whether the Bitrex can be tasted. If the test subject reports tasting the bitter taste during the ten squeezes, the screening test is completed. If the response is negative, ten more squeezes are repeated rapidly and the test subject is again asked whether the Bitrex is tasted. If the test subject reports tasting the bitter taste, the screening test is completed. If the response is negative, ten more squeezes are repeated rapidly and the test subject is again asked whether the Bitrex is tasted. If the test subject reports tasting the bitter taste during the third set of ten squeezes, the screening test is completed. The test conductor will take note of the number of squeezes required to solicit a taste response. If a taste response is elicited, the test subject shall be asked to take note of the taste for reference in the fit test. If the Bitrex is not tasted after 30 squeezes, the test subject is unable to taste Bitrex and may not perform the Bitrex fit test.

Bitrex solution aerosol fit-test

The test subject may not eat, drink (except plain water), smoke, or chew gum for 15 minutes before the test. The test subject shall don the enclosure while wearing the respirator. The respirator should be properly adjusted and equipped with any type particulate filter(s). The nebulizer is inserted into the hole in the front of the enclosure and an initial concentration of the fit test solution is sprayed into the enclosure using the same number of squeezes (either 10, 20 or 30 squeezes) based on the number of squeezes required to elicit a taste response as noted during the screening test. After generating the aerosol, the test subject shall be instructed to perform a series of exercises identified in Appendix A of OSHA Standard Title 29 CFR 1910.134.

Qualitative fit-testing procedures

Fit-testing of tight-fitting atmosphere-supplying respirators and tight-fitting powered air-purifying respirators is accomplished by performing quantitative or QLFT in the negative pressure mode regardless of the mode of operation (negative or positive pressure) used for RP. Fit-testing is conducted using the following procedures:

1. The test subject is allowed to pick the most acceptable respirator from a sufficient number of respirator models and sizes so that the respirator is acceptable to and correctly fits the wearer.
2. Before the selection process, the test subject is instructed on how to put on the respirator, how it should be positioned on the face, how to set the strap tension, and how to determine an acceptable fit. A mirror should be available to assist the subject in evaluating the fit and positioning of the respirator.
3. The test subject is informed that they are to select the respirator that provides the most acceptable fit. Remember that each respirator represents a different size and shape; therefore, it must be fitted and used properly to ensure adequate protection is provided.
4. The test subject is instructed to hold each of the selected face-pieces up to their face and eliminate those that obviously do not offer an acceptable fit.
5. The more acceptable face-pieces are noted in the event that the one selected proves unacceptable; the most comfortable mask is donned and worn at least 5 minutes to assess comfort. Assistance in assessing comfort can be given by discussing the criteria involved in obtaining an adequate fit (discussed next).
6. Assessment of comfort includes a review of the position of mask on face, nose, and cheeks, room for eye protection, and for communication with the test subject and allowing the test subject adequate time to determine the comfort of the respirator.
7. The following criteria should be used to determine the adequacy of the respirator fit: Chin properly placed in the mask, adequate strap tension — not overly tightened, fit across nose bridge, respirator of proper size to span distance from nose to chin, subject's self-observation in mirror to evaluate fit and respirator position.
8. The subject is now ready to conduct a user seal check. Before conducting this pressure check, the subject is told to seat the mask on the face and to move the head from side-to-side and up and down slowly while taking a few slow deep breaths. If the test subject fails the user seal check tests, another face-piece will need to be selected.
9. The test should not be conducted if there is any hair growth between the skin and the face-piece sealing surface such as stubble beard growth, beard, mustache, or sideburns that cross the respirator sealing surface. Any type of apparel that might interfere with a satisfactory fit should be altered or removed.
10. If a test subject exhibits difficulty in breathing during the tests, they should be referred to a licensed health care professional (as appropriate) to determine whether the test subject can wear a respirator while performing their duties.

11. If the worker finds the fit of the respirator unacceptable, the test subject is given the opportunity to select a different respirator and to be retested.
12. Before the commencement of the fit test, the test subject is given a description of the fit test and their responsibilities during the procedure. The description of the process will include a description of the test exercises that the subject will be performing. The respirator to be tested is worn for a minimum of 5 minutes before the start of the fit test.
13. The fit test is performed while the test subject is wearing any applicable safety equipment that may be worn during actual respirator use, which could interfere with the respirator fit.

There are certain test exercises that are required to be performed for all fit-testing methods prescribed; the test subject will have to perform these exercises in the test environment. Appendix A outlines the exercises as they apply to both quantitative and QLFT.

833. Conducting respirator training

Fit-testing and training are usually consecutive as both are required annually and conducted by BE. As the OPR for the installation RP program, BE is responsible for providing effective training to workers who are required to use respirators. The training must be comprehensive, understandable, and re-occur annually or more often if required.

Initial and periodic training

BE will provide or arrange for the initial training of respirator wearers and supervisors who have the responsibility of overseeing work activities of one or more persons who must wear respirators. Training will include the requirements of Title 29 CFR 1910.134 (k). This training must be provided to the worker before requiring the individual to use a respirator in the workplace.

Trained workplace supervisors will provide annual instruction and retraining to respirator wearers or it will be conducted by BE during the annual fit testing. BE will provide retraining when notified by the supervisor of changes in the workplace or the type of respirator used (rendering previous training obsolete). BE will also provide retraining upon notification or observation of inadequacies in the employee's knowledge or when use of the respirator indicates that the employee has not retained the requisite understanding or skills.

Key players in respiratory protection training

Supervisors play a critical role in the training process. Supervisors are required to ensure that approved respirators in their workplace are used and maintained properly. For this reason, BE discusses RP requirements with supervisors during outline occupational health surveillance. Supervisor training is repeated when a supervisor has a permanent change of station (PCS) or becomes a supervisor of a different workplace.

Personnel issuing respirators

All personnel who issue respirators are briefed annually by their supervisor on the issue of "suitable substitutes" for respirators or respirator parts. Issue of substitutes for respirators or parts is prohibited and bench stocked respirators must be maintained per manufacturer's instructions.

Respirator maintainers

BE shall train respirator maintainers initially and as needed as determined locally, in the following areas, as a minimum:

- Inspection for defects, cleaning and sanitization, repairs, and maintenance of respirators. This training should be specific for the types of respirators the person will maintain.
- Respirator storage.
- Respirator cartridge or filter change procedures, if needed.
- Importance of maintaining NIOSH certification of respirators (e.g., replacement parts).

Emergency and Rescue Teams

Teams that are established for the purpose of responding to emergencies or rescues, such as Fire and Emergency Services personnel, shall be properly trained in the use of respirators. Each team will develop a workplace-specific written plan to address respiratory training requirements.

The Defense Automated Visual Information System/Defense Instructional Technology Information System (DAVIS/DITIS) provides information about audiovisual productions and interactive multimedia instruction (IMI) products available to support training, command information, and operational missions to enhance training for the system operators.

Documentation

Documentation of training may be made on AF Form 55, Employee Health and Safety Record, AF Form 2767, Occupational Health Training and Protective Equipment Fit Testing, AF Form 1151, Training Attendance and Rating, in the AF Enterprise, Environment, Safety, and Occupational Health – Management Information System (EESOH-MIS) or in the Core Automated Maintenance System (CAMS). If forms are used to document this training, the information shall also be included in the AF EESOH-MIS.

Documentation of initial training of supervisors who have the responsibility of overseeing work activities of one or more persons who must wear respirators will be made in the OEH-MIS.

834. Work area respiratory protection program evaluations

BE conducts an annual review/evaluation of the RP program and reports the findings in writing to the Aeromedical Council and the Combined Occupational Safety and Health Council. The findings of these evaluations may also be included in the workplace survey report. The evaluation includes investigating wearer acceptance of respirators, inspecting respirator program operation, and assessing protection provided by the respirator. Evidence of excessive exposure of respirator wearers to respiratory hazards is followed up by investigation to determine why inadequate RP was provided. The findings of the respirator program evaluation will be documented, and this documentation should list plans to correct faults in the program and set target dates for the implementation of the plans. These evaluations will be conducted at least annually. When evaluating a shop on their RP program, there are basic elements each workplace is required to maintain. The basic elements are:

- Current office instruction (OI) approved by BE.
- Adequacy of the respirator for workplace exposures.
- Adequacy of maintenance and storage practices (shared, emergency use, and individual respirators).
- Air-purifying respirators—correct filters and adequate supply based no change out schedule.
- Atmosphere-supplying respirators—adequate air supply and breathing air; review of air testing results as appropriate.
- Documentation of inspection.
- Documentation of respirator training – everyone current.
- If governed by OSHA-expanded standards, applicable standards are available.
- Cleaning procedures—adequate equipment available and following OI procedures.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

828. Roles and interactions of bioenvironmental engineering in the respiratory protection program

1. Who is the installation level authority on RP?

2. What is the master respirator inventory?

3. When will the supervisor notify BE to schedule fit testing?

829. Types and classes of respirators and how they work

1. When can adequate warning properties for a chemical be assumed?

2. Why can't you use an air-purifying respirator in an atmosphere that is immediately dangerous to life and health?

3. What are the characteristics of an open-circuit SCBA?

830. Use, care, and maintenance of respirators

1. How often must emergency and rescue use respirators be inspected?

2. During inspection, what should valves be checked for?

831. Procedures for selecting and approving respiratory protection equipment

1. Proper selection of RP begins with what?

2. During which step in the selection process is the worker's activity in relation to the inhalation hazard considered?

3. How might sweat inside a respirator cause problems?

832. Quantitative and qualitative respirator fit-testing procedures

1. What steps must be taken before a fit test can be administered?

2. What must be done for workers that cannot get a proper fit with any tight-fitting respirator?

3. What criteria should be followed to determine the adequacy of respirator fit before the actual fit-test?

4. What test exercises must the subject perform during a QNFT?

833. Conducting respirator training

1. Which supervisors are required to receive initial RP training from BE?

2. Rescue teams shall be properly trained on the use of respirators and develop what?

3. Where can respirator training be documented?

834. Work area respiratory protection program evaluations

1. To who does BE report the RP program review/evaluation findings and how often must they be reported?

2. What should be included in the RP program evaluation report?

Answers to Self-Test Questions

828

1. Bioenvironmental engineering is the OPR for the installation RP and gas mask QNFT program.
2. List all of the workplaces that use RP in an approved OEH-MIS.
3. When new employees are assigned, or a current employee has a change affecting the wear of RP.

829

1. The respirator does not supply oxygen and must never be used in an oxygen deficient atmosphere.
2. When the odor, taste, or irritation effects of the substance are detectable and persistent at concentrations at or below the OEL.
3. These devices release the exhaled air into the surrounding environment. The breathing gas is generally compressed air and they are typically designed to provide 30 – 60 minutes of air to the user.

830

1. Inspect at least monthly.
2. Check for detergent residue and dust or dirt on the valve seal; cracks, tears, or distortion of the valve; missing or defective valve cover.

831

1. Identifying workcenter respiratory hazards that may be present.
2. Assemble the necessary toxicological, safety and other relevant information.
3. Can cause the face-piece to slip out of position (compromising the integrity of the seal).

832

1. (1) Clean the mask inside, (2) place fit testing adapters on the mask, (3) have individual don mask, ensure all hair is out of the seal, and (4) have individual perform a user seal check.
2. These workers are provided with a positive pressure, loose-fitting face-piece, helmet, (or hood device of sufficient APF for the hazard) or transferred to a job or workplace where respirator protection is not required.
3. Chin properly placed, adequate strap tension—not overly tightened, fit across nose bridge, respirator of proper size to span distance from nose to chin, subject's self-observation in mirror to evaluate fit and respirator position.
4. Normal breathing, deep breathing, turning head from side-to-side, moving head up and down, talking, grimacing, bending over, normal breathing.

833

1. The supervisors that have the responsibility of overseeing work activities of one or more persons who must wear respirators.
2. A workplace-specific written plan to address respiratory training requirements.
3. If forms are used, the information shall be included in the AF EESOH-MIS. Initial training of supervisors will be made in the OEH-MIS.

834

1. Aeromedical Council and the Combined Occupational Safety and Health Council; annually.
2. Wearer acceptance of respirators, inspecting respirator program operation, and assessing protection provided by the respirator. Plans to correct faults in the program and target dates for the implementation of the plans.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

53. (828) Which agency serves as the office of primary responsibility (OPR) for the installation respiratory protection (RP) program?
    a. Civil engineering (CE).
    b. Bioenvironmental engineering (BE).
    c. United States Air Force School of Aerospace Medicine (USAFSAM).
    d. Occupational Safety and Health Administration (OSHA).

54. (828) Who will provide resolution when there are inconsistencies for respiratory protection (RP) between technical orders (TO) and Air Force Occupational Safety and Health (AFOSH) standards?
    a. Workplace supervisor.
    b. Installation safety officer.
    c. Unit respiratory protection (RP) officer.
    d. Respiratory protection administrator.

55. (828) Who is responsible for ensuring that approved respirators are used correctly and are properly maintained?
    a. Individual workers.
    b. Workplace supervisor.
    c. Bioenvironmental engineering (BE).
    d. Personnel issuing the respirators.

56. (829) What series of filter cannot be used if aerosolized oil particles are present in the work environment?
    a. N.
    b. P.
    c. R.
    d. S.

57. (829) What respirator remains dependent upon an air supply that is not carried by the wearer?
    a. Air-line.
    b. Air-purifying.
    c. Open-circuit self-contained breathing apparatuses (SCBA).
    d. Closed-circuit self-contained breathing apparatuses (SCBA).

58. (830) At least how often are respirators used for emergency use only required to be inspected?
    a. Monthly.
    b. Quarterly.
    c. Annually.
    d. Bi-annually.

59. (830) Why is it important to rinse a respirator in clean water after it has been immersed in a disinfecting solution?
    a. To remove dead pathogens.
    b. To maintain compliance with standards.
    c. Ensures the respirator can be used for emergency and rescue situations.
    d. Because traces of the disinfectant left on the mask can cause skin irritation.

60. (831) Proper respirator selection is not based on which these criteria?
    a. Worker's activities.
    b. Evaluation of respiratory hazards.
    c. Worker's respirator brand preference.
    d. Time period that respirator must be worn.

61. (831) Which respirator selection factors would be considered during the planning of emergency situations in which workers must escape?
    a. Exposure route.
    b. Worker's activity.
    c. Period of time the respirator must be worn during the work shift.
    d. Location of hazardous area with respect to area with respirable air.

62. (831) What is the highest contaminant concentration for which a respirator adequately protects the wearer?
    a. Fit factor.
    b. Hazard ratio.
    c. Maximum use concentration (MUC).
    d. Assigned protection factor (APF).

63. (832) A fit factor can be calculated for what type of fit-test?
    a. Qualitative.
    b. Quantitative.
    c. Positive pressure.
    d. Expanded standards.

64. (832) What method of fit-testing must be used when specified by an Occupational Safety and Health Act (OSHA) substance-specific standard?
    a. Qualitative.
    b. Quantitative.
    c. Positive pressure.
    d. Expanded standards.

65. (832) What method of fit-testing relies on the sensory response of the individual to the contaminant put into the air?
    a. Qualitative.
    b. Quantitative.
    c. Positive pressure.
    d. Expanded standards.

66. (833) Workers are required to be trained and fit-tested initially and every
    a. 6 months.
    b. 12 months.
    c. 18 months.
    d. 24 months.

67. (833) Supervisor training should be repeated when there is a
    a. change in worker positions.
    b. new worker in the workplace.
    c. permanent change of station (PCS).
    d. change in position in the workplace.

68. (833) Personnel who issue respirators are briefed how often and by whom concerning the issue of respirator parts?
    a. Semi-annually; by respirator manufacturer.
    b. Annually; by respirator manufacturer.
    c. Semi-annually; by supervisor.
    d. Annually; by supervisor.

69. (834) To whom does bioenvironmental engineering (BE) report the findings of a respiratory program review?
    a. Aeromedical Council and the Combined Occupational Safety and Health Council.
    b. Installation respiratory protection (RP) administrator and Aeromedical Council.
    c. Installation Base safety office and Combined Occupational health working group.
    d. Occupational health working group and installation respiratory protection administrator.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Confined Space Program

IN SOME WORKPLACES, workers must enter areas that, under normal circumstances, are not designed to be continuously occupied. These "spaces" are considered "confined" because their configurations hinder the activities of the workers who must enter, work in, and exit from. For example, fuel systems repair workers are often required to enter aircraft fuel cells (i.e., above ground storage tanks and tanker trucks) to clean and perform maintenance. The physical characteristics and hazards of confined spaces vary widely, as do the reasons why one is entered. According to the Bureau of Labor Statistics, there were over 100 confined space–related fatalities in the year 2010, due to conditions such as: 1) oxygen deficiency, 2) inhalation hazards to harmful substances, and 3) collapsing materials. [1] These statistics indicate how critical it is to conduct an organized evaluation program of all confined spaces in order to identify, evaluate, and control all (potential) hazards.

835. Roles and interactions in the Confined Space Program

Primarily, AF BE personnel use OSHA's General Industry Regulation, Title 29 CFR 1910.146, *Permit-Required Confined Spaces*, to assess and manage AF confined space operations:

Although these documents are the primary directives used when dealing with confined space(s), there are other standards that also address hazards of this nature. More than one standard may apply in any given workplace or confined space operation. For example, confined space operations may involve welding operations that are governed by Title 29 CFR Subpart Q, *Welding Cutting and Brazing*, and AFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*, Chapter 27, *Welding, Cutting and Brazing*, in addition to the confined space standards.

The OSHA confined space standard, Title 29 CFR 1910.146, is a performance-based standard, which means that it instructs what must be done but *not how to do it*.[1] In general, the OSHA standard dictates that the workplace evaluation be executed to determine if any spaces are *permit-required spaces*. A comprehensive permit program will need to be developed and implemented if workers will be entering a permit-required space. AFMAN 91–203 provides specific details on how permit-required spaces are to be managed and outlines specific organizations and functions that must be involved with implementing and managing confined space operations. This information outlines the specific roles and responsibilities of each organization/function. The following table highlights key roles of these organizations, as outlined in Chapter 23 of AFMAN 91–203. The responsibilities identified in the table are not a complete list of responsibilities. Refer to AFMAN 91–203 for the comprehensive list.

Organization/Function	Confined Space Program Responsibilities
Installation Ground Safety	Serve as the focal point for implementation of this standard. Coordinate the installation Confined Space Program. Lead the installation confined space program team (CSPT). Maintain confined space records provided by the organization. Assist with PPE selection, training, and review of permits. May act in place of the installation CSPT if no AF personnel will enter installation confined spaces.

Organization/Function	Confined Space Program Responsibilities
Fire Emergency Services	Ensures fire emergency services (FES) personnel are trained in confined space requirements. Assist in identification and selection of required equipment, including PPE. Assist with PPE selection, training, and review of permits. Evaluate confined spaces for oxygen-enriched atmosphere, flammability, and toxicity when permitting entries that are covered by a master entry plan (MEP).
Bioenvironmental Engineering	Refer to “Bioenvironmental Engineering’s role” paragraph following this table.
Confined Space Program Team	Includes representation from Ground Safety, Fire and Emergency Services, and Bioenvironmental Engineering. Assist functional managers and commanders with identification, evaluation, and classification of all confined spaces and administering Confined Space Programs. Develop and provide a CSPT train-the-trainer program. Evaluate and approve MEPs. Review installation Confined Space Program at least annually.
Commanders and/or Functional Managers	Ensure a written MEP and Confined Space Program are developed, implemented, and approved by the CSPT. Ensure all personnel assigned duties and responsibilities are properly trained, equipped, and qualified. Maintain a list of their respective confined spaces, permit-required and non-permit, and provide the list to CSPT and Environmental Management office.
Entry Supervisors	Be responsible for authorizing entry, overseeing entry operations, and terminating entry if a change in conditions warrants such action. Ensure a qualified person (trained in the operation of direct-reading oxygen, flammability, and toxicity monitoring equipment) evaluates and classifies the confined space according to AFMAN 91–203, Table 23.1. Revoke the permit and contact installation Ground Safety office when any entry condition is not consistent with the MEP. Coordinate assistance from Ground Safety office, BE, or FES Flight, as required. Ensure workers are properly trained and qualified in safe operating and emergency procedures, use of protective equipment, and how to egress.
Confined Space Attendants	Maintain an accurate accounting of all entrants. Maintain continuous communication with all authorized entrants within the permit-required space. Know the procedure and have the means to summon immediate emergency assistance, if required. Remain at the attendant’s post and do not leave for any reason (except self-preservation) unless replaced by an equally qualified individual. Keep unauthorized persons from entering the permit-required space.
Confined Space Entrants	Be provided guidance and direction on all procedures, safeguards, and emergency egress and/or rescue procedures associated with the entry. Follow all required safe work procedures. Notify the entry supervisor when hazards exist that have not been previously identified.

Organization/Function	Confined Space Program Responsibilities
Shop Supervisors	Annually assess the sections or unit's known confined space workplaces. Include specific confined spaces requirements and safety training in the Job Safety Lesson Plan and document training. Ensure personnel are trained and certified in use, calibration (user), and care of atmospheric testing and monitoring equipment, and maintain a list of the trained and qualified personnel.

Although the Confined Space Program is managed overall by the base Ground Safety office, BE plays a vital role as a member of the CSPT. Some of the BE-specific roles, as described in AFMAN 91–203, include the following:

- Receive formal permit-required confined space training (at least one BE representative).
- Evaluate potential worker exposure related to confined spaces.
- Sample the confined space atmosphere as often as required to ensure changing conditions do not result in hazardous atmospheres.
- Select appropriate respiratory protection and other PPE.
- Train on the use, calibration, and care of atmosphere testing and monitoring equipment.
- Assist in the training of personnel for confined space duties.
- Certify organizational personnel, as required, to test confined spaces.
- Conduct atmospheric testing and monitoring for permit-required confined spaces operations in isolated cases where organizational personnel are not available or certified.

Members of the CSPT will be involved in the initial confined space testing as well as when changes occur that could possibly affect space classification. The CSPT may conduct these evaluations alone or as a member of a team. Testing results are reported to the CSPT.

After the initial testing and classification of the confined space, *verification testing* must still be performed. The verification testing is done before each entry, usually by qualified members of the workplace, to ensure conditions are safe and meet entry requirements. AFMAN 91–203 defines a "qualified person" as someone who is trained and certified in the operation, calibration, and care of the specific testing equipment as well as in the interpretation of monitoring data. BE is responsible for *certifying personnel* to perform these atmospheric tests. This is discussed later in this unit.

836. Classifying confined spaces

This lesson addresses the two main types of confined spaces, permit-required and non-permit confined spaces. It is important to first understand what a confined space is. According to OSHA Standard Title 29 CFR 1910.146 and AFMAN 91–203, a confined space is a space that meets the following three criteria:

1. It is large enough and so configured that an individual can enter the space and perform his or her assigned work.
2. It has limited or restricted means of entry or exit.
3. It is not designed for continuous human occupancy.

If an area is determined to be a confined space, it must be further classified as either a permit-required or non-permit confined space. Permit-required or non-permit classification is determined by conducting atmospheric testing (oxygen content, flammability, and toxicity), identifying the material contained in the space, and determining whether the material could cause engulfment or has a configuration that could result in entrapment and/or asphyxiation. The following table obtained from AFMAN 91–203 summarizes this categorization process. [3]

Confined Space Classification by Atmospheric Testing		
Atmospheric Condition	**Permit-Required (Hazardous Atmosphere)**	**Non-Permit (Non-Hazardous Atmosphere)**
Flammability	1. Flammable gas, vapor, or mist in excess of 10 percent of LEL, or 2. Airborne combustible dust at a concentration that meets or exceeds its LEL. (*See Note 1*)	1. Flammable gas, vapor, or mist less than or equal to 10 percent of its LEL, or 2. Airborne combustible dust at a concentration less than its LEL.
Oxygen	Atmospheric oxygen concentration less than 19.5 percent (148 mm Hg) or greater than 23.5 percent (greater than 179 mm Hg). (*See Note 2*)	Atmospheric oxygen concentration range from the minimum of 19.5 percent and the maximum of 23.5 percent (148–179 mm Hg).
Toxicity	An atmospheric concentration of any chemical substance which is capable of causing death, incapacitation, impairment of ability to self-rescue, injury or acute illness due to its health effects or which could result in an exposure or dose in excess of its OEL. (*See Note 3*)	An atmospheric concentration of any chemical substance which is not capable of causing death, incapacitation, injury, impairment of ability to self-rescue, or acute illness due to its health effects.
Other Condition	Any atmospheric condition that is IDLH or local conditions that could be potentially hazardous or life threatening. (*See Note 4*)	No atmospheric IDLH condition present.

Note 1: *This concentration may be approximated as a condition in which the dust obscures vision at a distance of five (5) feet or less.*

Note 2: *Based upon a total atmospheric pressure of 760 mm Hg (sea level).*

Note 3: *Exposure at or above levels determined to be safe solely to prevent long-term adverse health effects is not considered a hazardous atmosphere on that basis alone and in itself would not constitute a permit-required confined space classification. However, other OSHA standards, TOs, etc. may apply for exposure to chemical substances at levels greater than the OEL.*

Note 4: *Immediately Dangerous to Life or Health – as referenced in NIOSH, Registry of Toxic Effects of Chemical Substances, Manufacturing Chemists data sheets or other recognized authorities. (Reference IDLH definition in Attachment 1, Terms). Local conditions could present potentially hazardous or life-threatening situations such as extreme temperatures, noise, animals (rat droppings, potentially dangerous insects, wild animals, etc.). The installation CSPT will notify units of potentially hazardous or life-threatening conditions in the local area.*

In addition, the OSHA decision flowchart (fig. 4–1) can be used to determine if spaces are permit-required confined spaces.

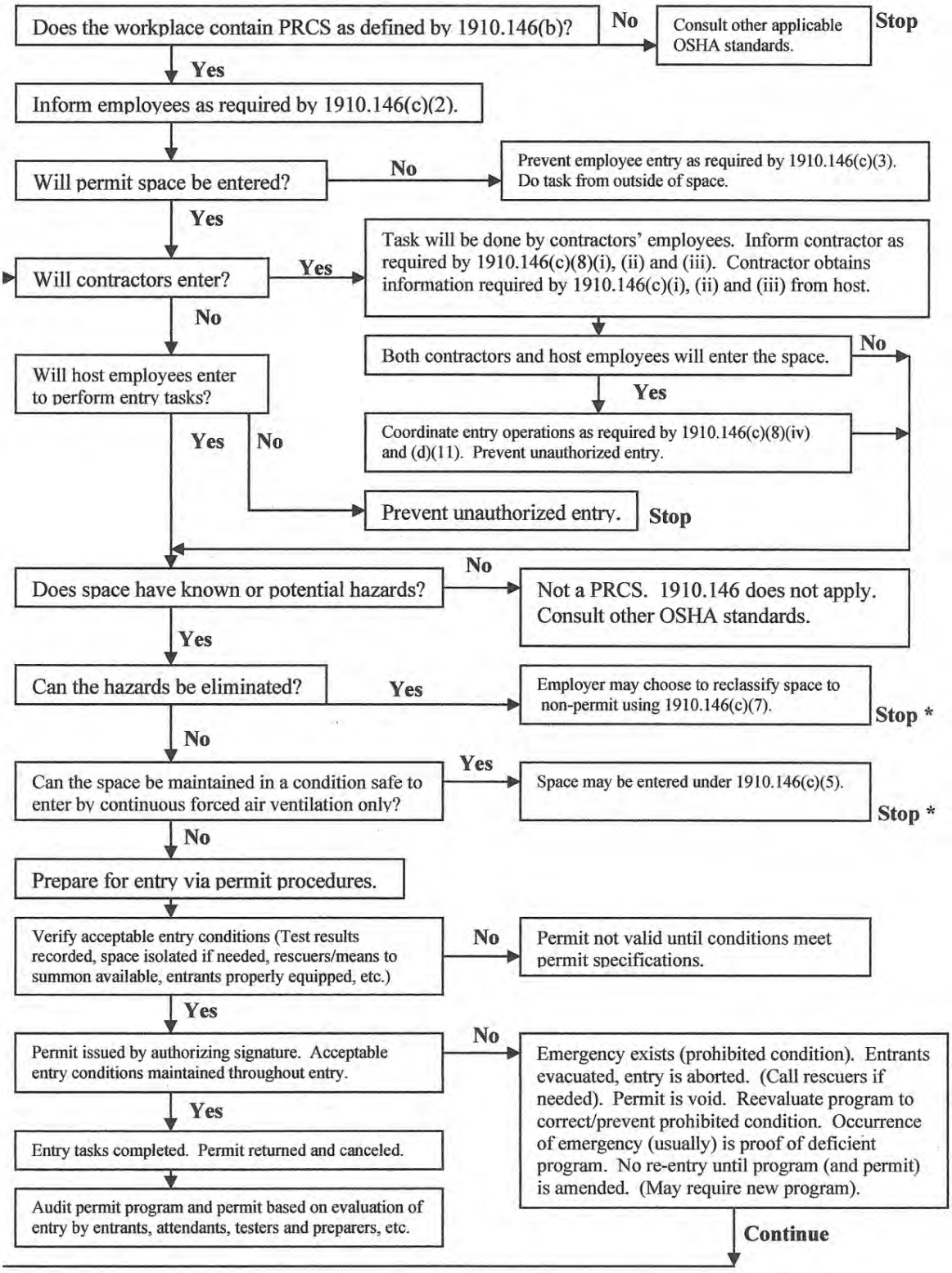

Figure 4–1. OSHA confined space decision chart. [4]

Permit-required confined spaces

Spaces that meet the definition of a confined space, as defined at the beginning of this lesson, and exhibit any of the following four characteristics are classified as *permit-required confined spaces*.

1. An IDLH atmosphere is present or there is a potential for a hazardous atmosphere to develop.
2. The oxygen content is less than 19.5 percent or greater than 23.5 percent.
3. Atmospheric testing results are greater than 10 percent of the LEL.
4. There is an atmospheric condition of any chemical substance over the exposure limit which is capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects.

Once a confined space has been identified as having any one of the above potential hazards, it must be distinguished as such. This is done through signage or other communication means. Additionally, any time a worker is required to enter a space of this distinction, a written program (i.e., permit) needs to be developed. The permit outlines and instructs workers on proper procedures for working around and in the space. Some examples of permit-required confined spaces include 1) above-ground fuel tanks, 2) aircraft fuel cells, 3) refueler pits and trucks, 4) lift stations, 5) chemical tanks, and 6) tank rail cars.

Non-permit confined spaces

The term *non-permit confined space* refers to a confined space that does not contain, or does not have the potential to contain, any hazards (atmospheric or other safety hazards) capable of causing death or serious physical harm. A confined space may be classified as a non-permit confined space for as long as hazards remain absent; however, once a hazard is present, the spaced must be reassessed and the requirements of permit-required confined spaces be followed.

Entering into non-permit confined spaces is allowed without attendants or entry permits. [3] Although the confined space is classified as a non-permit confined space (when using typical criteria to evaluate hazards such as atmospheric, engulfment, or entrapment) the space may contain other physical hazards. Hazards such as slippery surfaces or deteriorated pipe ladders may make self-rescue difficult for the entrant.

Non-permit confined spaces will be reviewed before each entry to determine if changed conditions in or around the space could have introduced a hazard that is immediately dangerous to life or health, thus changing the classification of the space to permit-required. Well-ventilated, frequently entered non-permit confined spaces such as aircraft engine inlets/intakes/exhausts and avionics bays (discussed below) can normally rely on a visual review prior to each entry, unless a changed condition in or around those spaces could have introduced an atmospheric or other non-visual hazard, in which case, instrumented testing is warranted. [3]

Confined spaces on aircraft

The Air Force confined space standard, AFMAN 91–203, Chapter 23, Table 23.2, lists spaces on military aircraft systems that are classified as permit-required or non-permit confined spaces, as defined by the major command (MAJCOM) ground safety office. However, it is important to note that this list should not be considered all-inclusive since hazard classifications can easily change, depending on the nature of the work being performed. It is important to document how the confined space is determined to contain no permit-required confined space hazards.

Figure 4–2. Entering confined space in an aircraft.

837. Confined space hazard controls

The best way to control the hazards of a confined space is to eliminate the need to enter the space (fig. 4–2). However, where entry cannot be avoided, good work practices and well-designed entry practices are critical to ensure a safe entry. Although confined spaces can vary considerably, many of them share similar hazards. Thus, similar engineering and administrative control measures can be applied in widely varying situations. Common controls include controlling unauthorized entry, protecting workers from external hazard, draining and flushing the space prior to entry to remove residue, isolating the space and controlling hazardous energy, purging and ventilating the space, and using proper protective equipment.

Engineering controls

Engineering controls include the use of purging and ventilating the space. Ventilation in relationship to confined spaces is the process of continuously moving fresh air through the space. This continuous movement of air maintains an adequate level of oxygen in the space; dilutes or removes toxic air contaminants that may be in the space; and improves comfort by controlling temperature, humidity, and nuisance odors. The decision to force air into a space, or exhaust it out, will depend on a variety of factors to include the size and configuration of the space, the nature of its contents, and the number of openings. Some situations may require that air be blown into a space as well as exhausted out.

Ventilation provides other benefits. When contaminants are removed, workers experience less irritation and work is more productive. Illnesses caused by overexposure to welding fumes or gases can be avoided, therefore, eliminating the need for respiratory protection. In hot weather, air temperature is reduced, increasing productivity and reducing heat-related illnesses.

Since an oxygen-enriched atmosphere (above 23.5 percent) will cause flammable materials, such as clothing and hair, to burn violently when ignited and may cause some nonflammable materials to ignite, *never* use pure oxygen to ventilate a confined space. Instead, ventilate with normal air.

Administrative controls

Signs and training are two of the most effective administrative controls. There should be warning signs to prevent unauthorized entry to any confined space. If there are confined spaces designated as permit-required and workers and other employees could inadvertently enter, personnel must be informed of the existence, location, and the danger(s) of the space by posting danger signs, like the one shown in figure 4–3.

Figure 4–3. Confined space warning sign.

Confined spaces where personnel cannot inadvertently enter, such as those protected by heavy manhole covers which require tools to remove, do not require a warning sign.

Training is another administrative control. The importance of training cannot be overstated. Regardless of the size and characteristics of the space, there are some universal training principles that must be applied. Each confined space-training program must address specific training requirements to all personnel entering or assisting with a confined space entry, to include entry supervisors. The training must include how to test the confined space for hazards using an atmospheric device. Personnel need to understand the safe levels of oxygen, carbon monoxide, hydrogen sulfide, and associated LELs. Personnel are also required to receive training on all equipment used for entry into a confined space along with proper rescue procedures. Proper training is critical.

Anyone working in a confined space must be constantly alert for any changing conditions within the confined space. In the event of an alarm from monitoring equipment or any other indication of danger, workers should immediately leave the confined space.

838. Confined space entry permits

The AF Form 1024, Confined Spaces Entry Permit, is an administrative tool used to document completing a hazard assessment for each confined space entry. It authorizes entry into a specific confined space for a specific purpose, by specific work crews, and for a specific work period, which normally will not exceed a single shift. If multiple shifts are necessary, either a new entry permit shall be completed or the CSPT may approve a continuation of the initial permit with a new entry supervisor and crew members. Rescue team entry is exempt from this requirement. [3] Entry permits must be approved by the installation ground safety office, BE, and fire department personnel before entry. Someone fully trained and experienced in confined space work should complete the entry permit. Entry permits should contain at least the following information, as described in AFMAN 91–203:

- The length of time the permit is valid.
- The name(s) of the worker(s) who will enter the confined space.
- The name(s) of the attendant(s) (safety watch) and/or supervisor.

- The location of the confined space.
- The work that is to be done in the confined space.
- The date and time of entry into the confined space and the anticipated time of exit.
- The details of any atmospheric testing done of the confined space—when, where, results, date monitoring equipment were last calibrated. Ideally, calibration would be done just before each use. If this is not possible, follow the equipment manufacturer's guidelines for frequency of calibration.
- The use of mechanical ventilation and other protective equipment needed and any other precautions that will be followed by every worker who is going to enter the confined space.
- The protective equipment and emergency equipment to be used by any person who takes part in a rescue or responds to other emergency situations in the confined space.
- A signature of a worker who did the confined space testing. The signature on the permit would indicate that adequate precautions are being taken to control the anticipated hazards.

The entry permit should be posted at the confined space and remain so until the work is completed. The employer should keep a copy of the completed permit on file.

References

[1] Bureau of Labor Statistics, "Fatal occupational injuries by event or exposure for all fatal injuries and major private industry 1 sector, All United States," 2010.

[2] AIHA, The Occupational Environment: Its Evaluation, Control and Management, 2nd Edition, Fairfax: AIHA Press, 2003.

[3] AFMAN 91–203, *Air Force Occupational Safety, Fire, and Health Standards,* 3 September 2019.

[4] OSHA, "Permit-Required Confined Spaces," [Online]. Available at https://www.osha.gov/Publications/osha3138.html.

[5] NFPA, "Oxygen Deficient Environments in Confined Spaces," 13 Nov 2012. [Online]. Available: www.nfpa.org.

[6] W. Popendorf, Industrial Hygiene Control of Airborne Chemical Hazards, CRC Press, 2006.

[7] J. F. Rekus, Complete Confined Space Handbook, CRC Press, 1994.

[8] ACGIH, "Guide to Occupational Exposure Values," 2012.

[9] M. Goldstein, "Carbon Monoxide Poisoning," *Journal of Emergency Nursing,* vol. 34, no. 6, pages 538–542, December 2008.

[10] EPA, Hazardous Materials Incident Response Operations.

[11] OSHA, "Confined Spaces: Construction Safety and Health Outreach Program," May 1996. [Online]. Available: https://www.osha.gov/doc/outreachtraining/htmlfiles/cspace.html.

[12] RAE Systems, "Guide to Atmospheric Testing in Confined Spaces, AP–206."

[13] OSHA, OSHA Fact Sheet — Procedures for Atmospheric Testing in Confined Spaces, OSHA, 2005.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

835. Roles and interactions in the Confined Space Program

1. List the personnel required to be members of the CSPT.

2. What are your primary roles as a member of the CSPT?

3. What type of testing is performed by a workplace member before an entry?

836. Classifying Confined Spaces

1. List the three conditions a space must meet to be considered a confined space.

2. Hazards encountered in confined spaces fall into what categories?

3. Confined spaces are separated into what two categories?

4. Confined spaces exhibit any of what four characteristics that make them permit-required spaces?

837. Confined space hazard controls

1. List the common methods for controlling confined space hazards.

2. What are the benefits of using ventilation as a confined space control?

3. Why should you *never* use pure oxygen to ventilate a confined space?

838. Confined space entry permits

1. What is a confined space entry permit?

2. List the minimal information that an entry permit should contain.

Answers to Self-Test Questions

835

1. Ground Safety, FES, BE, and various functional managers.
2. Evaluating confined spaces for hazards and training personnel.
3. Verification testing.

836

1. (a) It is large enough and configured such that an individual can bodily enter the space and perform his or her assigned work.
   (b) It has limited or restricted means of entry or exit.
   (c) It is not designated for continuous human occupancy.
2. Flammability, oxygen, toxicity and other conditions.
3. (a) Permit-required confined spaces
   (b) Non-permit confined spaces
4. (a) An IDLH atmosphere is present or there is a potential for a hazardous atmosphere to develop.
   (b) The oxygen content is less than 19.5 percent or greater than 23.5 percent.
   (c) Atmospheric testing results are greater than 10 percent of the LEL.
   (d) There is an atmospheric condition of any chemical substance over the exposure limit, which is capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects.

837

1. Controlling unauthorized entry, protecting workers from external hazard, draining and flushing the space before entry to remove residue, isolating the space and controlling hazardous energy, purging and ventilating the space, and using proper protective equipment.
2. It maintains an adequate level of oxygen in the space; dilutes or removes toxic air contaminants that may be in the space; and it improves comfort by controlling temperature, humidity, and nuisance odors.
3. An oxygen-enriched atmosphere (above 23.5 percent) will cause flammable materials, such as clothing and hair, to burn violently when ignited and may cause some nonflammable materials to ignite.

838

1. An administrative tool used to document the completion of a hazard assessment for each confined space entry that authorizes entry into the specific confined space for a specific purpose, by specific work crews, and for a work period.
2. The **length** of time the permit is valid.
   The **name(s)** of the worker(s) who will enter the confined space.
   The **name(s)** of the attendant(s) (safety watch) and/or supervisor.
   The **location** of the confined space.
   The **work** that is to be done in the confined space.
   The **date** and **time** of entry into the confined space and the anticipated time of exit.
   The **details** of any atmospheric testing done of the confined space
   The **use** of mechanical ventilation and other protective equipment needed and any other precautions.
   The **protective equipment** and **emergency equipment** to be used by any person who takes part.
   A **signature** of a worker who did the confined space testing.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the AFCDA.

70. (835) Which organization is responsible for the overall management of the Confined Space Program?
    a. Public health (PH).
    b. Ground safety.
    c. Fire and emergency services (FES).
    d. Bioenvironmental engineering (BE).

71. (835) Before a worker can perform verification testing of a confined space, they must be
    a. able to identify and evaluate hazards in the space using specific testing equipment.
    b. able to evaluate hazards in the space and perform emergency rescue procedures.
    c. be trained and certified on the specific testing equipment and emergency rescue procedures.
    d. be trained and certified on the specific testing equipment and qualified to interpret the results.

72. (836) Which atmospheric characteristics classify a confined space as permit-required?
    a. No recognized safety or health hazards.
    b. The oxygen level is between 19.5 percent and 23.5 percent.
    c. No credible potential for hazardous atmosphere engulfment or entrapment.
    d. Contains a material that has the potential for a hazardous atmosphere to develop.

73. (837) Which gas should be used to ventilate a confined space?
    a. Air with more than 23.5 percent oxygen.
    b. Pure nitrogen.
    c. Pure oxygen.
    d. Normal air.

74. (837) If workers or other people could inadvertently enter a permit-required confined space, what action must be taken?
    a. Post an observer at the entrance to redirect people.
    b. Post a danger sign at the entrance of the space.
    c. Place a barrier at the entrance of the space.
    d. Increase atmospheric testing frequency.

75. (838) Entry permits must be approved by the installation
    a. bioenvironmental engineering (BE), public health (PH), and civil engineering (CE).
    b. BE, commander, and CE.
    c. ground safety office, BE, and fire department personnel.
    d. ground safety, public health, and CE.

Please read the unit menu for unit 5 and continue ➔

Unit 5. Hazard Communication Program

PROTECTING WORKERS from occupational and environmental health hazards is facilitated by effective communication of OEH hazards and risks. During the course of your work, you will regularly interact with shop workers and supervisors and be expected to effectively communicate hazards and risks. This unit covers some of the processes you will use in order to achieve this aim.

5–1. Communication

Communication skills are vital in any environment where teamwork is important. The military environment is unique. Much of its uniqueness requires exceptional communication skills. Information and directives effectively communicated enable us to do things better than we can accomplish as individuals.

839. Fundamentals of written correspondence and public speaking

Communication is defined as **the process** of sharing ideas, information, and messages with others. In the Air Force, most communication involves speaking and writing, but this definition includes nonverbal communication such as body language, graphics, and other means. As BEEs, we operate highly technical equipment in lethal environments. We are held to very high standards by the country we serve. Miscommunication can cause expensive mistakes, embarrass our organization, and cause accidents or even death. [1]

Basic principles

Once you accept that communication is important, it is important to understand what makes communication succeed and what makes it fail. Most mistakes are caused by forgetting one of five principles of good communication, which are organized to spell out the acronym FOCUS [1]:

- **F**ocused.
- **O**rganized.
- **C**larity.
- **U**nderstanding.
- **S**upported.

Focused

Being *focused* means to have a clear idea of purpose and objective, locking on the target and staying on track. Failure to focus can really hurt staff communication. Time and time again our efforts crash and burn because we never carefully read the words or really listen to the speaker for the real message. Failure to focus comes in three forms:

1. *Answering the wrong question*. This happens when we don't understand the assignment or what the audience really wants. Have you ever written what you thought was an excellent paper, only to be told you answered the wrong question or you missed the point? Have you ever asked someone a question and received a long answer that had nothing to do with what you asked?
2. *Answering only part of the question*. If a problem or question has multiple parts, sometimes we work out the easiest or most interesting part of the solution and forget the unpleasant remainder.
3. *Adding irrelevant information*. Here the communicator answers the question, but mixes in information that is interesting but unnecessary. Though the answer is complete, it is hard to understand.

Organized

Good organization means the material is presented in a logical and systematic manner. This helps the audience understand you without reading your words over and over, trying to sort out what you're really trying to say. When writing or speaking is not well organized, audiences can become confused or impatient, and may stop reading or listening. Even if you are providing useful, relevant information, your audience may underestimate its value and your own credibility.

Clear

This principle covers the following two interrelated ideas to communicate clearly:

1. Understanding the rules of language (spelling, pronunciation, grammar, etc.).
2. Getting to the point and not obscuring the message in a jungle of words.

People are quick to judge, and mangled or incorrect language can cripple your credibility and limit acceptance of your ideas. Acceptable English is part of the job, so commit to improving any problems you may have. Developing strong language skills is a lot like developing strong muscles—steady commitment produces steady improvement. Always remember that progress, not perfection, is the goal.

Grammar scares many of us, but the good news is that many common mistakes can be corrected by understanding a few rules. Start by reviewing the AF *Tongue and Quill* and books or Internet sites that address grammar and writing. Using language correctly is only half of the battle, though—many Air Force writers and speakers cripple themselves with bureaucratic jargon, big words, and use of passive voice. These bad habits make it hard to understand the message.

Understanding

If you want to share an idea with others, it helps to understand their current knowledge, views, and level of interest in the topic. If you have been asked to write a report, it helps to understand the expected format and length of the response, the due date, the level of formality, and any staffing requirements. It is easy to see how mistakes in understanding your audience can lead to communication problems.

Supported

Most writers and speakers try to inform or persuade their audience. Part of the communicator's challenge is to assemble and organize information to help build his or her case. Support and logic are the tools used to build credibility and trust with our audience. Nothing cripples a clearly written, properly punctuated paper quicker than a fractured fact or a distorted argument. Avoiding this pitfall is most difficult, even for good writers and speakers. Logic is tough to teach and learn because it challenges the highest levels of human intellect—the ability to think in the abstract.

Basics of communicating health risk

In earlier lessons, you learned your role in the HRA process is to identify and analyze occupational and environmental health risks at both garrison and deployed locations, determine appropriate control options, and communicate this information through your chain of command. Communicating HRAs

can be done through briefings or reports, and sometimes both. Effective communication of health risks will rely on the communicator's ability to develop key messages, know the audience, be prepared, believe in the topic, and use oral and written communication fundamentals and more advanced principles of risk communication.

When the HRA identifies conditions that are immediately hazardous to life or health, you must communicate this information immediately and notify everyone within the chain of command. When HRA findings exceed the OEL, you will notify the supervisor (or counterpart), then follow local reporting procedures for your chain of command.

For routine HRAs, reports should be generated from data entered into Defense Occupational and Environmental Health Readiness System (DOEHRS). Suggested contents of the report include the following:

- A cover letter.
- Summary of health risks.
- Identified PPE linked to specific processes and similar exposure groups (SEG).
- A compliance assessment checklist.
- Recommendations requiring follow-up with a request for a written reply to findings with a firm date for completion.

At times, you may be required to brief assessment hazards and risks to personnel within the chain of command. Your briefing should be tailored to fit the situation and conditions. CBRN incidents may require interagency coordination.

For special HRAs, results will be documented in DOEHRS and a special assessment report will be generated and distributed to the affected commanders and supervisors. Local policy will determine the report format and coordination.

840. Brief chemical, biological, radiological, nuclear and physical hazards/risks to personnel and prepare health risk assessment reports

The OEH assessment process is complete when the *risks and results* or *your assessment* is properly communicated. [2] Effective risk communication provides individuals with the information they need to make informed judgments about the risk. For example, commanders have the vital information they need to make their operational risk management (ORM)-based decisions. While risk communication is applicable across the full spectrum of assessing, managing, and mitigating risk, it is most critical in situations where people are concerned about a hazard and have little or no trust in those responsible for the risk. It is also critical in situations where people have very little concern about a hazard, but the experts believe they should be very concerned. [3]

A desired outcome of effective communication is an agreement among those involved, the stakeholders, on what is considered an acceptable level of risk, resulting in the appropriate actions taking place. Achieving this can eliminate spending resources and time on actions to make people safe when it may not be necessary. Some of the overall goals of risk communication include the following:

- Establishing, maintaining and/or increasing trust and credibility.
- Allowing affected stakeholders to participate.
- Raising awareness of potential hazards.
- Educating stakeholders about the risk.
- Reaching an agreement on how to address a risk.
- Informing and improving decision-making.
- Fostering understanding and acceptance of decisions made.

- Motivating action. [4]

Steps for effective risk communication

Risk communication can range from communicating OEH risks to shop workers or organizational leadership to providing support to the incident commander (IC) during an accident or other contingency, and can therefore vary in form and approach. Regardless of the situation, a simplified process can be followed to get you to the desired outcome. The simplified process includes the following four steps:

1. Conduct your research.
2. Develop your message.
3. Share the message.
4. Evaluate communication effectiveness. [4]

Conduct your research

This step involves getting to know your stakeholder and gathering knowledge about the issue. Success begins with understanding the information associated with the risk, determining who the stakeholders are, and having an understanding of the stakeholders' perspectives. A good way to start the stakeholder identification process is to ask questions such as:

- What are the issues?
- What is at stake?
- Who is most likely to be affected by the problem or issue?
- Who is concerned, what do they care about and why?
- Who needs to be involved and kept informed?
- What are the key points and topic areas that need addressed?

Initial research to gather this information will help you understand what your objective should be. The objectives, which support the overall risk communication goals discussed earlier, generally fall into one of four areas:

1. To provide information.
2. To gather information.
3. To build trust and credibility.
4. To influence behavior.

Develop your message

Your message should be designed to address the stakeholder's needs along with the needs of your organization. It should be brief, accurate, straightforward, easy to understand, and crafted in a way that will help establish and/or maintain trust. When constructing messages, keep the following principles in mind:

- ***Be proactive***—An ongoing and continuing dialogue with stakeholders goes a long way in preventing a communication crisis.
- ***Obtain internal agreement on the message***—Be aware of what others within the chain of command are saying about an issue and realize that everyone has a part to play in reaching consensus on the Air Force message. Even slight variations in wording used to present results or conclusions can be disastrous if they highlight possible disagreements within the chain of command. In other words, before conveying messages externally, make sure the members of your team/organization understand and will consistently convey the same message.
- ***Tailor the language to the stakeholders***—Consider reading level, language barriers, concerns about the issue, experience with risks, and scientific understanding.

- ***Use simple and clear language***—Avoid acronyms, jargon, and shortcut explanations with all stakeholders. Effective messages contain a balanced amount of information. Do not overwhelm your audience with technical information. On the other hand, do no oversimplify information to the point that important information is lost. [3] Remember, keep it brief, accurate, straightforward, easy to understand.
- ***Use language that empowers or gives control to stakeholders***—If a decision regarding a planned action has not been made, keep verbs conditional. Example: *"The most important thing you can do to protect yourself and your family in this situation is…" or "Until we have final test results, we recommend…"*
- ***Avoid absolutes***—Do not present estimates as facts. Explain estimates in terms of the uncertainties. Example: *Instead of saying "There is no risk," say "In nearly all cases…" or "Most of the time…"* [3]

BE often write letters or reports to communicate OEH risk information. Whether dealing with e-mails, reports or PowerPoint presentations, messages should be short and to the point, explain how risks were estimated, provide risk comparisons (if appropriate), and define the actions or steps being taken as a result of the risk assessment findings. [4] Clearly articulate the following elements:

- Provide important summary information in the front.
- What was done and why.
- The results and what they mean (details can be provided in appendices).
- Any action or decision that is required.

It is important to note that AFMAN 48–146, *Occupational & Environmental Health Program Management*, recommends the following be included content for written routine OEH assessment reports:

- Cover letter.
- Summary of health risks and list of current processes that exceed action levels, or exposure pathways with unacceptable exposure.
- Summary of all risk assessment codes (RAC) assigned to the shop/processes.
- Recommendations and required follow-up actions, including suspense dates and request to notify BE of completion in writing.

An effective IC must be able to work with multiple agencies and response personnel in order to minimize injury or damage. This requires the IC be assertive, decisive, objective, calm, and a quick thinker. You will be under pressure to provide immediate information to leadership and stakeholders in a compressed time frame. In a crisis, stakeholders will have the following expectations for government-provided information:

- Prompt, open, and candid.
- More information and not less.
- Frequently updated.
- Reassuring but upfront about uncertainties.
- Admit any mistakes.
- Avoid spinning the truth.
- Empathetic and compassionate.

In a crisis, the IC and other responders will understand and be better motivated to take recommended actions when they receive essential information in positive, concise, memorable, and clearly explained messages. If there is no communication and information voids exist, stakeholders, and eventually the news media, will fill the gaps with speculative information or material received from

other sources. Figure 5–1 provides useful quick dos and don'ts that integrate the best practices in crisis and risk communication. [3]

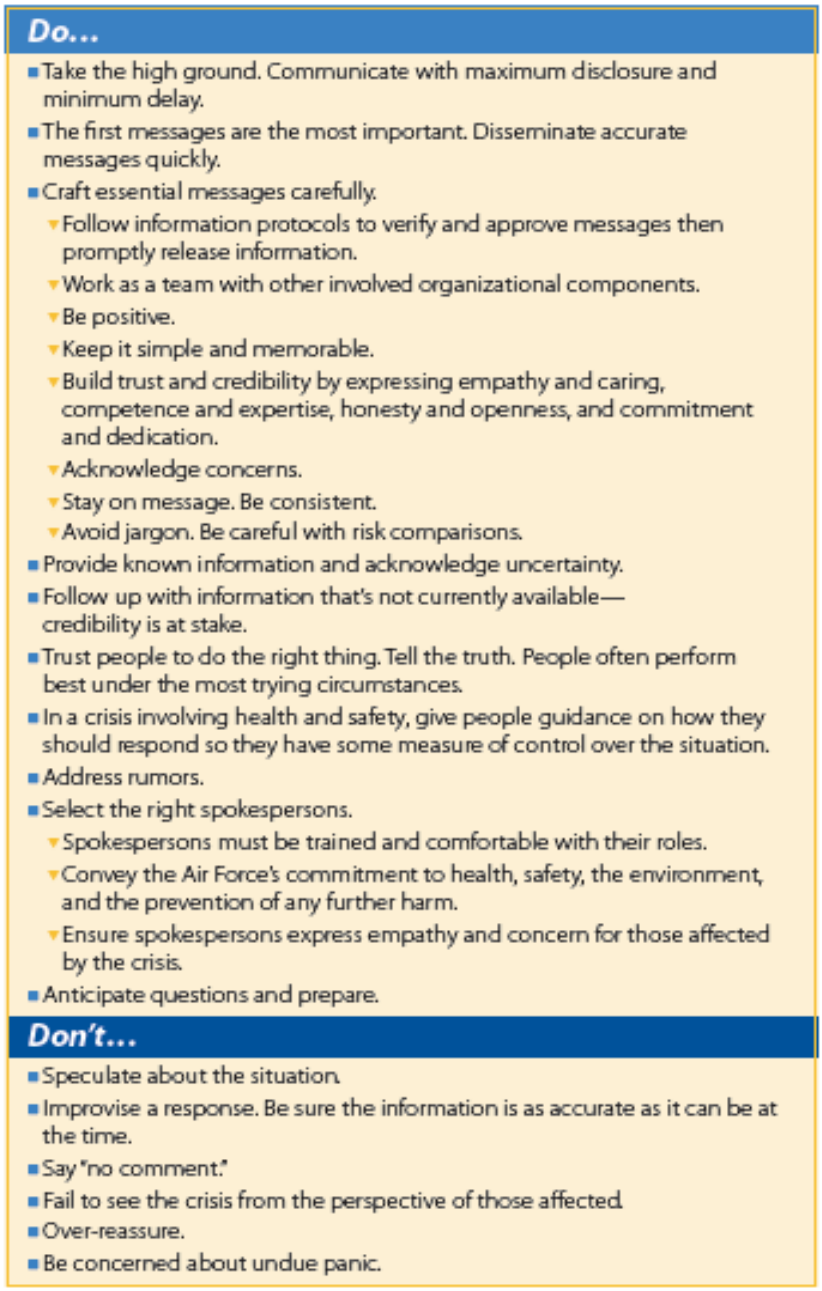

Figure 5–1. Risk Communication *DOs* and *DON'Ts* during a Crisis. [3]

Share the message

Information should be presented in a manner that is appropriate for stakeholders based on their preferred method of communication, which may include e-mails, written correspondence (e.g., routine and special surveillance HRA reports), small group meetings, town hall meetings, or a combination of the options. ICs generally receive health risk information verbally because they need to make prompt decisions to address the immediate hazard; whereas, shop supervisors generally receive OEH risk assessment information in written form. Some regulations, such as OSHA specific standards for example, specify how and when information must be presented.

Evaluate communication effectiveness

Risk communication is not about everyone coming to agreement, but it is important to evaluate the communication process to determine whether the needs of the stakeholder were met. You may not always be able to avoid a contentious situation; nevertheless, effective risk communication can increase credibility with stakeholders, leading to improved relationships and understanding that is more accurate on all sides. Evaluation criteria to consider:

- Did the risk information or message reach the targeted stakeholders?
- Did the decision makers have the information they needed?
- Did the targeted stakeholders understand the information or message?
- Is there understanding about the targeted stakeholders' perspectives of the issue?
- Has there been a change in media coverage, the types of questions asked, or the level of understanding? [3]

Effective risk communication is important to meet OEH program objectives. How well you apply the basic risk communication principles will determine your overall effectiveness at ensuring the information you provide is understood, correctly prioritized, and acted upon. Always make sure your chain of command is involved and never forget to determine if the issue requires public affairs involvement.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

839. Fundamentals of written correspondence and public speaking

1. List the five principles of good communication.

2. When you have to brief assessment hazards and risks within the chain of command. What should your briefing be tailored to fit?

840. Brief chemical, biological, radiological, nuclear and physical hazards/risks to personnel and prepare health risk assessment reports.

1. How does properly communicating risk assist commanders?

2. What is the desired outcome of effective communication?

3. List at least four of the eight overall goals of risk communication.

4. List the four steps of effective risk communication.

5–2. Hazard Communication Program

The US Occupational Safety and Health Administration (OSHA) address hazard communication (HAZCOM) as follows:

> "An effective hazard communication program depends on the credibility of management's involvement in the program; inclusion of employees in safety and health decisions; rigorous worksite analysis to identify hazards and potential hazards, including those which could result from a change in worksite conditions or practices; stringent prevention and control measures; and thorough training. It addresses hazards whether or not they are regulated." [6]

This statement lays the groundwork for our discussion of the components, concepts, and implementation of an effective HAZCOM Program that follows.

841. Hazard communication program overview and evaluation

In response to several accidents and incidents, both in the United States and overseas, involving releases of hazardous chemicals into the environment, the OSHA enacted Title 29 CFR 1910.1200, *Hazard Communication*, which went into effect in 1986. It was revised in 2012 to align with the United Nations' Globally Harmonized System (GHS) of Classification and Labeling of Chemicals. In short, OSHA's HAZCOM standard (sometime referred to as Worker Right-to-Know Legislation) requires employers to inform employees about the health hazards specific to the chemicals they handle or use at work and about the ways in which employees can protect themselves against those hazards.

Since hazardous chemicals are found on virtually every AF installation, the AF implemented AFI 90–821, *Hazard Communication (HAZCOM) Program*, which describes the AF HAZCOM program that puts into effect the requirements of Title 29 CFR 1910.1200. The AFI is intended to minimize the incidence of chemically induced occupational illnesses and injuries in AF workplaces by establishing guidance for training employees on the health and physical hazards associated with, and proper preventive measures to be taken when using or handling (during normal use or emergency) hazardous chemicals in work area/shop(s).

The AF HAZCOM program requirements apply to any chemical hazard, except as stated below, known to be present in work area(s)/shop(s) in such a manner that workers may be exposed under normal conditions of use or in a foreseeable emergency. [5]

Materials exempt from AF HAZCOM program

The OSHA and AF HAZCOM program requirements do not apply to the following items:

- Hazardous wastes regulated under the Resource Conservation and Recovery Act (RCRA).
- Hazardous substances subject to a remedial action or removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
- Tobacco or tobacco products.
- Wood or wood products that will not be processed.
- An article is a manufactured item other than fluid or particle which: (1) is formed to a specific shape or design during manufacture; (2) has end-use function(s) dependent in whole or in part upon its shape or design during end use; and (3) under normal conditions of use does not release more than very small quantities, for example, minute or trace amounts of hazardous chemicals and does not pose a physical hazard or health risk to employees.
- Food, alcoholic beverages, and cosmetics.
- Any drug in its solid, final form for direct administration to a patient or intended for personal consumption by employees while in the work area (such as first aid supplies, non-prescription and prescription medication, dry pelletized drugs, for example tablets, pills, or capsules).

- Consumer products, depending on how they are used, may or may not be exempt from HAZCOM program. For example, personnel who use window cleaner in the manner similar to that of any average consumer in terms of frequency and duration will not require HAZCOM training; however, housekeeping or maintenance personnel using the same window cleaner at a higher rate and duration than the average consumer will require HAZCOM training.
- Nuisance particulates that do not pose a physical or health hazard.
- Ionizing/non-ionizing radiation.
- Biological hazards.
- Munitions as defined in AFMAN 21-200, *Munitions and Missile Maintenance Management*.

Laboratories, as defined in the AF HAZCOM standard, are primarily governed by OSHA Standard Title 29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories*, and are not required to establish a written HAZCOM program. They do, however, need to establish a Laboratory Chemical Hygiene Program (discussed later in this unit).

In addition, the HAZCOM labeling requirements do not apply to the following:

- Any pesticide when subject to labeling requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
- Any chemical substance when subject to the labeling requirements of the Toxic Substances Control Act (TSCA).
- Any food, food additive, color additive, drug, cosmetic, or medical or veterinary device or product, including materials intended for use as ingredients in such products (e.g., flavors and fragrances) when subject to the Federal Food, Drug, and Cosmetic Act or Virus-Serum-Toxin Act labeling requirements.
- Any distilled spirits (beverage alcohols), wine, or malt beverage intended for non-industrial use when subject to the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Federal Alcohol Administration Act labeling requirements.
- Any consumer product or hazardous substance when the product is subject to a consumer product safety standards or labeling requirements.

Written HAZCOM Programs

The AF HAZCOM program requires that installations and specific work areas/shops whose employees handle, use and/or will potentially be exposed to hazardous chemicals that are not exempted (as described above) must prepare and implement a written HAZCOM program.

Work area/shop specific program

Each work area/shop whose employees may be exposed to hazardous materials (HAZMAT) (not exempted as described above) must develop a workplace specific written HAZCOM program. The written program must contain information such as how the requirements for labeling and employee training are implemented in the workplace. The written program is placed in a three-ring binder maintained in the workplace and is a good resource to train workers on the shop specific HAZCOM program. The section of the OSHA standard that outlines written program requirements is Title 29 CFR 1910.1200(e).

The written program must include the items below, each of which is discussed in more detail in the paragraphs that follow [5]:

- Inventory of hazardous chemicals.
- Obtaining and maintaining safety data sheets (SDS).
- Labeling requirements for hazardous chemicals.

- Procedures for informing/protecting employees conducting non-routine tasks/jobs involving potentially hazardous chemicals.
- Employee training.

Chemical inventory

Workplaces that use hazardous chemicals maintain a chemical inventory and provide access to SDS. The inventory is a reflection of all chemicals used in the workplace and includes information such as the specific chemical name and specific company/manufacturer name (as listed on the SDS). The inventory is a fundamental building block for the workplace specific HAZCOM program. The type of chemicals on the inventory will determine the scope of the HAZCOM program and training requirements appropriate for a workplace. It is also important to note that the inventory must be updated as chemicals are added or deleted from the workplace. Shop supervisors may use the EESOH-MIS authorization report with product data as their work area hazardous chemical inventory [5].

Safety data sheets

SDS, previously known as material safety data sheets (MSDS), communicate material specific hazard information. SDSs are uniformly formatted to include specific section numbers, headings, and associated information that align with the United Nations' GHS format. Both versions are provided by the chemical manufacturer to communicate the hazards of chemicals used in the workplace. The sheets are a critical component of a workplace specific HAZCOM program because they contain important information concerning the hazardous effects, physical and chemical characteristics, and recommendations for appropriate protective measures. The SDS/MSDS is the basic document used to inform/train worker about the hazards of the chemicals they work with. You may refer back to Career Development Course (CDC) 4B051 Volume 2 Unit 4 "Chemical Health Hazards" for a discussion about using SDSs to identify potential chemical health hazards in the workplace.

Shops may continue to use older MSDSs if new SDSs are not available. Chemical manufacturers have until June 2015 to be in full compliance with the new format requirements. After June 1, 2015, manufacturers must provide chemical safety information in the new SDS format. Sections 1 through 8 contain general information about the chemical, identification, hazards, composition, safe handling practices, and emergency control measures (e.g., firefighting). Sections 9 through 11 contain other technical and scientific information, such as physical and chemical properties, stability and reactivity information, toxicological information, exposure control information. [6] A summary of the SDS sections is provided in figure 5–2 below:

SDS Section	Description
Section 1, Identification	Includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
Section 2, Hazard(s) identification	Includes all hazards regarding the chemical; required label elements.
Section 3, Composition/information on ingredients	Includes information on chemical ingredients; trade secret claims.
Section 4, First-aid measures	Includes important symptoms/ effects, acute, delayed; required treatment.
Section 5, Firefighting measures	Lists suitable extinguishing techniques, equipment; chemical hazards from fire.
Section 6, Accidental release measures	Lists emergency procedures; protective equipment; proper methods of containment and cleanup.
Section 7, Handling and storage	Lists precautions for safe handling and storage, including

SDS Section	Description
	incompatibilities.
Section 8, Exposure controls/personal protection	Lists OSHA's permissible exposure limits (PEL); threshold limit values (TLV); appropriate engineering controls; PPE.
Section 9, Physical and chemical properties	Lists the chemical's characteristics.
Section 10, Stability and reactivity	Lists chemical stability and possibility of hazardous reactions.
Section 11, Toxicological information	Includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
Section 12, Ecological information*	*__NOTE:__ Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15 (Title 29 CFR 1910.1200 (g) (2)).
Section 13, Disposal considerations*	
Section 14, Transport information*	
Section 15, Regulatory information*	
Section 16, Other information	Includes the date of preparation or last revision.

Figure 5–2. Explanation of SDS Sections.

The SDS must be available and accessible at all times (in either paper or electronic format) for every item on the workplace specific hazardous chemical inventory. All workers on all shifts must know how to access SDSs, and have unrestricted direct access. If the primary means for SDS access is electronic, a back-up system for SDS access must be established in case primary computer access is disrupted. OSHA does not specifically prohibit any form of access as long as there are "no barriers to immediate employee access."

Labeling

According to AFI 90–821, supervisors must make sure that labels on containers of hazardous chemicals in their work area meet OSHA requirements, remain affixed to their containers, and are not obliterated or covered [5]. (fig. 5–3)

The OSHA Standard Title 29 CFR 1910.1200(f) requires that chemical manufacturers, importers, or distributors ensure that each container of hazardous chemical they produce/manufacture is labeled, tagged or marked with the information in the following table to comply with the GHS format [6]:

OSHA HAZCOM Labeling Requirements [7]	
Label Element	**Description**
Name, Address and Telephone Number	Information of the chemical manufacturer, importer or other responsible party.
Product Identifier	This is how the hazardous chemical is identified. This can be (but is not limited to) the chemical name, code number or batch number. The manufacturer, importer or distributor can decide the appropriate product identifier. The same product identifier must be both on the label and in the SDS section 1.
Signal Words	These are used to alert the chemical user to a potential hazard and indicate the relative level of severity of the hazard. There are only two words used as signal words: **"Danger"** and **"Warning."** "Danger" is used for the more severe hazards and "Warning" is used for the less severe hazards.

OSHA HAZCOM Labeling Requirements [7]	
Label Element	**Description**
Hazard Statements	Describes the nature of the hazard(s) of a chemical, including, where appropriate, the degree of hazard. For example: *"Causes damage to kidneys through prolonged or repeated exposure when absorbed through the skin."* The hazard statements are specific to the hazard classification categories, and chemical users should always see the same statement for the same hazards no matter what the chemical is or who produces it.
Precautionary Statements	Describes recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure to the hazardous chemical or improper storage or handling. There are four types of precautionary statements: **prevention** (to minimize exposure), **response** (spills, emergency response, and first aid), **storage**, and **disposa**l. For example, a chemical presenting a specific target organ toxicity (repeated exposure) hazard would include the following on the label: *"Do not breathe vapor. Get medical attention if you feel unwell. Dispose of contents/container in accordance with local/regional/national and international regulations."*
Pictograms	Pictograms are graphic symbols used to communicate specific information about the hazards of a chemical. The required pictograms consist of a red square frame with a black hazard symbol on a white background. Figure 5–3 shows several pictograms, the written name for each pictogram, and the hazards associated with each of the pictograms.

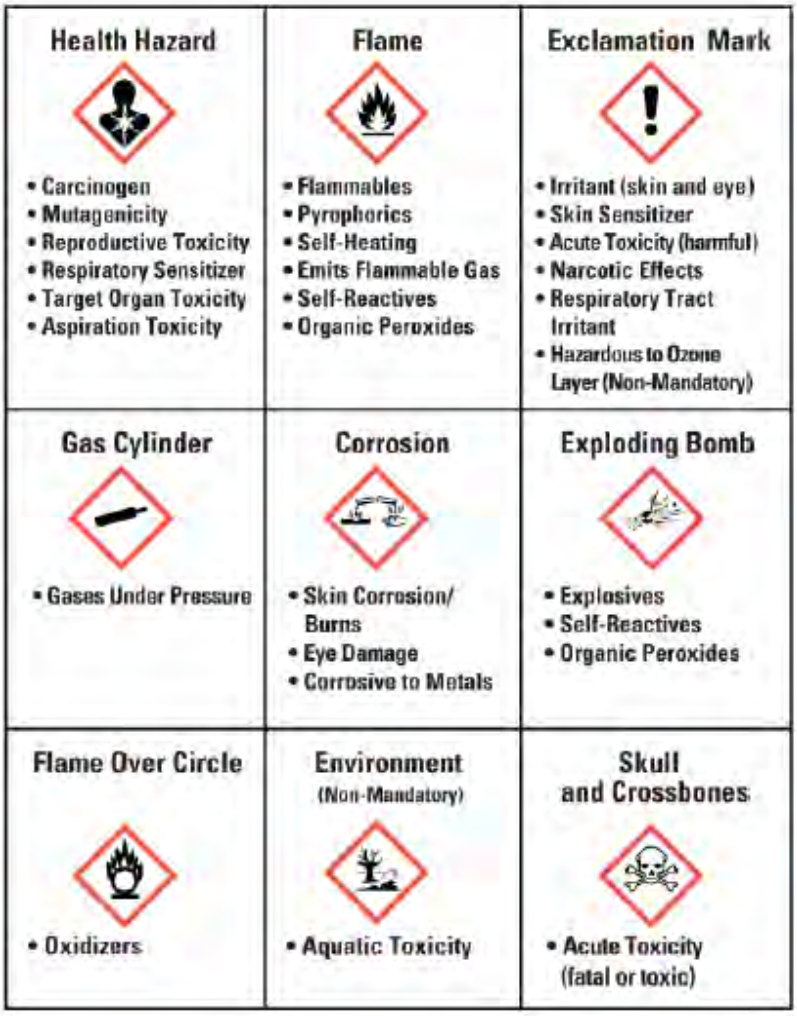

Figure 5–3. OSHA Label Pictograms and Corresponding Hazards [7]

Labels must be legible, in English, and prominently displayed. Work area supervisors are not responsible for updating labels on shipped containers, even if the shipped containers are labeled under the 1994 HAZCOM standard requirements; however, supervisors must relabel items if the labels are removed or defaced [7]. Additionally work area personnel are not required to label portable containers into which hazardous chemicals are transferred from labeled containers, and which are intended only for the "immediate use" by the employee who performs the transfer. Immediate use means that the hazardous chemical will be under the control of and used only by the person who transfers it from a labeled container and only within the work shift in which it is transferred. If chemicals are transferred from the original container into other containers that are not intended for immediate use, these containers must be also labeled.

Non-routine tasks

The AF HAZCOM program covers non-routine jobs/tasks that workers perform within their work area, for example, cleaning a solvent tank and stripping/painting hangar floor, or other duties outside an individual's normal AFSC, such as a base detail, on an infrequent basis that includes using or being exposed to potentially hazardous chemicals. [5]

Supervisors must ensure work area/shop operating instructions (OI), specific task lists, and job safety analysis (JSA) thoroughly describe non-routine tasks, associated hazards, and the controls. OIs do not need to be prepared if technical orders (TO) or other official documents adequately describe these

tasks and associated hazards and controls. Supervisors must ensure workers review these procedures before performing the non-routine tasks. [5]

When workers temporarily perform duties outside their normal AFSC, the supervisor of the gaining activity must ensure these workers receive initial HAZCOM training and work area/shop-specific training, as necessary, on work area/shop-specific chemical hazards and before beginning the activity. [5]

Training

Work area supervisors must make sure workers are provided with effective information and training on all hazardous chemicals in their work area at the time of their initial assignment, and whenever a new physical or health hazard the employees have not previously been trained about is introduced into their work area. Information and training may be designed to cover categories of hazards (e.g., flammability, carcinogenicity) or specific chemicals. Chemical-specific information must always be available through labels and SDSs/MSDSs. Training consists of the following topics [5]:

- Identification of operations or processes (including non-routine processes) in the work area where hazardous chemicals are present or used.
- Location and details of the written HAZCOM program, including the required list(s) of hazardous chemicals, and SDSs/MSDSs required by this section.
- Methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.).
- Physical and health hazards of the chemicals in the work area.
- Measures workers must take to protect themselves to minimize or eliminate exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and PPE to be used.
- Explanation of the labeling and SDS/MSDS systems, and how workers can obtain and use the appropriate chemical hazard information.
- Additional training on expanded standards (e.g., asbestos, benzene, lead, etc.) as required by OSHA.

Supervisors will ensure appropriate functional experts (i.e., public health, BE, base safety office, and fire and emergency services) review and approve the shop specific hazard training program for technical accuracy and completeness prior to implementation in the work area/shop. Additionally, all work area supervisors must review USAFSAM's supervisor HAZCOM training to maintain competency, and must review the existing work area-specific HAZCOM training plan and any required expanded standard training prior to assuming supervisory duties in a new work area. [5]

Contractors

In situations where contractors may be exposed to hazardous chemicals from AF operations, AF work area supervisors must provide the contractors information on AF operational hazards and protective measures, where and how relevant SDS/MSDS information is available, and information on the hazardous chemical labeling system. It is important to note, however, that the contractor is responsible for their own HAZCOM program and uses the information to determine the adequacy of their company's HAZCOM program or the exposures of their employees. [5]

842. Responsibilities of key players in hazard communication

As you can imagine, there are many key players with varying degrees of responsibilities in the Air Force HAZCOM program from the Secretary of the Air Force down to the unit level work area supervisors. In this section we will discuss the key players that are important for you, as a BE Journeyman, to be familiar with as defined in AFI 90–821.

Bioenvironmental engineering

The BE Flight has numerous responsibilities relating to the installation AF HAZCOM Program. These responsibilities are as follows:

- Provide technical expertise to work area/shops on potential health hazards, training requirements, and regulatory requirements (e.g., OSHA expanded standards) associated with hazardous chemicals and the AF HAZCOM program.
- Review and approve new or modified work area-specific HAZCOM training plans for technical accuracy and completeness prior to implementation by the work area supervisor.
- Assess work area HAZCOM program compliance in conjunction with routine or special assessments and when deemed necessary.
- Maintain access to SDSs/MSDSs contained in DLA's Hazardous Material Data Management System.
- Request from manufacturers, as needed, portions of a SDS/MSDS designated by the manufacturer as a trade secret, and send proprietary SDS/MSDS information to USAFSAM/OE to be incorporated into DLA's Hazardous Material Data Management System.
- Provide HAZCOM advice to the contracting office upon request to assist in ensuring all contracts include HAZMAT identification and data requirements.
- Request copies of, or contractor access to, DLA's Hazardous Material Data Management System when requested by the contracting officer for use by a contractor's health and safety representative.

Wing/installation commander

The Wing/Installation commander is ultimately responsible for all aspects of the wing/installation HAZCOM program. Specifically, he or she is responsible for the following:

- Ensure supervisors and employees who handle, use, or are potentially exposed to hazardous chemicals in the course of official AF duties are provided information and training on the AF HAZCOM Program and the specific hazards in their work areas according to AFI 90–821.
- Ensure supervisors of work areas where hazardous chemicals are used or handled, understand, prepare, and implement a written work area-specific HAZCOM program.
- Ensure all installation HAZMAT (for example, documentation of use, frequency, movement), formally known as hazardous materials pharmacy (HAZMART), meet relevant AF HAZCOM program requirements.

Squadron/unit commander

Squadron/unit commanders are responsible for the following:

- Ensure all workers in their squadron/unit are provided a safe and healthy work environment.
- Ensure all workers potentially exposed to hazardous chemicals in their work area are familiar with the hazards within the work area.
- Understand appropriate ways to manage risk associated with the hazardous chemicals.
- Provide the resources to maintain effective work area-specific HAZCOM programs within work areas under their control.

Public health

The public health flight is responsible for the following:

- Assists work area supervisors with accessing USAFSAM's training materials and tools.

- Assists BE with addressing work area supervisor inquiries regarding potential health hazards associated with hazardous chemicals, especially those related to mutagens, teratogens, carcinogens, and reproductive hazards.
- Reviews and approve new or modified work area-specific HAZCOM training plans for technical accuracy and completeness prior to implementation by the work area supervisor.

Work area/shop supervisors

Work area/shop supervisors are responsible for the HAZCOM program in their functional area, but may designate an alternate to assist in daily program execution. Work area supervisors have the following responsibilities, as outlined by the AF HAZCOM program:

- Review USAFSAM's AF supervisor HAZCOM training initially and as needed to maintain competency. Supervisors shall contact public health for assistance.
- Develop and maintain a work area-specific HAZCOM written program according to AFI 90–821, to include all individual components of the program, as described earlier.
- Develop an installation-approved HAZCOM training plan for their work area, and make sure assigned personnel receive and understand the training.
- Through formal contract pre-performance conferences or work area familiarization briefings, provide contractors information on AF operational hazards and protective measures, where and how relevant SDS information is available, and information on the hazardous chemical labeling system.
- Properly document supervisor and worker initial and supplemental HAZCOM training.

HAZMAT Tracking Activities

- Obtain SDSs/MSDSs for hazardous chemicals received unless the SDS is already available in EESOH-MIS and DLA's Hazardous Material Data Management System.
- Ensure all hazardous chemicals are properly labeled prior to issue.
- Provide new and updated SDSs to the EESOH-MIS data steward for submittal into EESOH-MIS according to AFMAN 32-7002, *Environmental Compliance and Pollution Prevention*.
- At the time of local purchase approval, ensure the procuring organization obtains the most current SDS from the identified vendor.
- For items procured through Defense Logistics Agency (DLA)/General Services Administration (GSA) that are received without a SDS/MSDS, search DLA's Hazardous Material Data Management System to determine the correct SDS/MSDS for the product.

As you can see, several people on an installation are involved in the AF HAZCOM program. For the HAZCOM program to be successful, everyone involved in the program must take their roles seriously and work as a team to accomplish the goal of HAZCOM—to inform and educate workers about the hazards of the potentially hazardous chemicals they use or are exposed to so they can protected themselves from any serious health effects.

843. Evaluating shop hazard communication programs

You are now well educated on the Air Force HAZCOM program components and the key players' responsibilities. Now you need to take what you've learned and put it into practice by evaluating specific workplace/shop compliance with the HAZCOM program when you go out and perform your routine OEH site assessments.

As mentioned earlier, one of your responsibilities is to assess work area compliance with the program in conjunction with routine or special assessments or whenever deemed necessary. Either this generally involves sitting down with the shop supervisor or the supervisor's designated HAZCOM program representative and conducting a comprehensive review/evaluation of the shop's HAZCOM

program. Your review/evaluation should include walking around the shop and talking to some of the workers. In short, your goal is to determine if the workplace/shop is understands and meets the requirements of the AF HAZCOM program. Some specific aspects of reviewing a shop's HAZCOM program are addressed in the table below.

HAZCOM Program Assessment Considerations.		
Required Element	**Summary of Requirements**	**Methods of Evaluations**
Written hazard communication program	Supervisors must develop and implement a work area-specific written program that describes how the HAZCOM criteria will be met, who is responsible for MSDSs/SDSs, labels, warning signs and training, and the location of the chemical inventory, MSDSs/SDSs, and other information and resources pertaining to hazardous chemicals. Supervisors must ensure appropriate functional review and approval of the written program for technical accuracy and completeness.	• Determine whether supervisor developed and is implementing a written HAZCOM program. • Verify appropriate functional review was completed (i.e., PH, BE, base safety office, and fire and emergency services). • Verify awareness of it and what it specifies from work area personnel. • Determine if workers can get the written program. • Does written program include, at a minimum, the following: a. Labels and other forms of warning b. Material MSDS/SDS. c. Employee information and training d. Lists of hazardous substances in use in workplace. e. Methods used to inform employees of non-routine task. f. Methods used to share information on hazardous substances in multi-employer worksites. • Determine how contractors are notified of work area hazards and how campus is notified of HAZMAT used by contractors.
Chemical inventory	Supervisors of each workplace that uses potentially hazardous chemicals, not exempt from the HAZCOM program, must develop and maintain a chemical inventory of each chemical on hand in the workplace. Supervisors may use the EESOH-MIS authorization report with product data as their work area hazardous chemical inventory.	• Find who maintains the inventory and what procedures they follow. • Determine whether workers can locate the inventory. • Spot check chemicals in various locations to see if they are on the inventory.
Safety data sheets /material safety data sheets	Supervisors must have an SDS/MSDS for each chemical used and sheets must be readily accessible in primary workplace. After June 1, 2015, information must be in the new SDS format; older MSDSs will no longer be acceptable. SDSs/MSDSs may be kept in any form	• Find who obtains, distributes, and archives SDSs/MSDSs and what procedures they follow. • Ask workers if they're aware of hazards of materials they use on spot check basis. • Ask workers if they know how to get material hazard information.

HAZCOM Program Assessment Considerations.		
Required Element	**Summary of Requirements**	**Methods of Evaluations**
	(electronic or hard copy).	• Spot check chemicals in various locations and see if local personnel can find SDSs/MSDSs for them. • Ask to see SDSs/MSDSs or how workers actually access them. • Determine mobile crew awareness and whether they know how to obtain SDSs/MSDSs. • Determine how quickly an SDS/MSDS can be obtained.
Labels and other forms of warning	According to AFI 90-821, supervisors must ensure labels on containers of hazardous chemicals used in their work area meet OSHA requirements, remain affixed to their containers, and are not obliterated or covered. OSHA requires that chemical manufacturers, importers, or distributors ensure that each container of hazardous chemical they produce/manufacture is labeled, tagged, or marked with the appropriate information; the GHS labeling format is not mandatory until June 1, 2015. Secondary containers labeled by person who transfers the chemical. Container labeled with name of chemical, concentration, date transferred, initials of person transferring. Containers that are under control of one person and used only by them in one work shift need not be labeled.	• Determine policy for primary, secondary labeling in shop, as needed. • Determine whether workers understand labeling policies and requirements. • Check primary container labels for condition (defaced, removed, etc.). • Check secondary container labels in field for legibility, readability, presence, and condition in field.
Non-routine tasks	The AF HAZCOM program covers non-routine jobs/tasks that workers perform within their work area. Supervisors must ensure work area/shop OI, specific task lists, and JSA thoroughly describe non-routine tasks, associated hazards, and the controls.	• Determine if non-routine tasks are performed in the work area. • Determine whether OIs, specific task lists, and JSAs describe non-routine tasks, associated hazards, and the controls, if applicable. • Verify that gaining supervisor provides work area-specific training to workers temporarily performing duties outside their normal job.

HAZCOM Program Assessment Considerations.		
Required Element	**Summary of Requirements**	**Methods of Evaluations**
Employee information and training	Supervisors must ensure workers are provided with effective information and training on all hazardous chemicals in their work area at the time of their initial assignment, and whenever a new hazard is introduced into the work area. Supervisors must review the USAFSAM supervisor training. Supervisors must ensure appropriate functional expert review and approval of the work area-specific training prior to implementation. Worker training must include the following: • Identification of operations or processes where chemicals are present or used. • Location and details of the written program, including the chemical inventory and SDSs/MSDSs. • Methods and observations that may be used to detect the presence or release of hazardous chemicals. • Physical and health hazards of the chemicals. • Measures workers must take to protect themselves. • Explanation of the labeling and SDS/MSDS systems, and how workers can obtain and use the hazard information. • Additional training on expanded standards as required by OSHA. In situations where contractors may be exposed to hazardous chemicals from AF operations, AF work area supervisors must provide the contractors information on AF operational hazards and protective measures, where and how relevant SDS/MSDS information is available, and information on the hazardous chemical labeling system.	• Obtain HAZCOM training policy. • Determine if contents of training meets minimum requirements. • Verify appropriate functional review of training plan was completed (i.e., PH, BE, base safety office, and fire and emergency services). • Ascertain if proof of training/awareness is obtained from trainees (e.g., testing). • Determine if/how training is documented. • Determine whether policies are in place to address contractors.

Review and evaluation of a shop's HAZCOM program components will provide a good indication of the quality of the program. However, a good way to find out if a shop has an effective HAZCOM program is to observe workers when they are doing tasks with hazardous chemicals. Additionally, asking workers HAZCOM program-related questions gives you an indication of whether they have been adequately trained, but exercise caution because if workers feel as though you are inspecting them, they might not feel comfortable answering honestly.

Once you have finished your evaluation of a work area HAZCOM program, you should provide feedback to the supervisor and/or HAZCOM program manager regarding your finding and observations. Your feedback should include areas where the shop is meeting and exceeding HAZCOM program requirements as well as specific recommendations shop personnel should implement to comply with the program. It is important for you to commend them for the good things they are doing and to be tactful when providing recommendations to correct any discrepancies found.

844. Laboratory chemical hygiene program

AFOSH Standard 48–22, *Occupational Exposure to Hazardous Chemicals in Laboratories*, contains the requirements for a chemical hygiene plan (CHP), assigns responsibilities, and provides guidance for protecting workers from the health hazards presented by hazardous chemicals used in the laboratory work environment. It applies to laboratory operations that meet the definitions of a "laboratory" as described in OSHA Standard Title 29 CFR 1910.1450.

The OSHA standard defines a laboratory as a facility where the "laboratory use of hazardous chemicals" occurs, and goes on to say that it is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis. [8] Facilities meeting this definition can include:

- Educational laboratories (chemistry labs).
- Histopathology laboratories (tissue specimen analyses).
- Clinical laboratories (medical sample analyses).
- Environmental laboratories (water, soil, hazardous waste analyses).
- Experimental laboratories (small).

This guidance specifically excludes routine tests or operations that are part of, or adjunct to, a production operation. For that reason, this standard usually will not apply to dental, pharmacy, non-destructive inspection (NDI), PMEL, and quality control labs. This standard also does not apply to laboratory operations that rely solely on prepackaged, commercially prepared kits. Most BE test procedures (e.g., drinking water) rely on these types of kits and their laboratories would not be covered by this standard. [8]

General requirements

The elements of a complete laboratory safety and health program include a written CHP, standard operating procedures, the appointment of a chemical hygiene officer (CHO), properly maintained laboratory type hoods and protective equipment, employee information and training, hazard identification through use of labels and SDSs/MSDSs, employee exposure determinations, and medical consultation/examination. These elements will be addressed for all Air Force operations, which are defined as "laboratories." [8]

Specific requirements

The specific requirements of a laboratory chemical hygiene program include chemical selection, CHO, written CHP, employee information and training, medical consultation and examination, hazard identification, use of respirators, record keeping, and employee exposure determination and notification.

Chemical selection

Consider all potential adverse impacts (health, environment, safety, etc.) when selecting a chemical. The requirements for the selection and procurement of chemicals are outlined in AFMAN 32-7002.

Chemical hygiene officer

The CHO may be an officer, noncommissioned officer (NCO), or civilian. To act as the CHO, an NCO must have attained a 7-level qualification in either a laboratory or BE specialty. All CHOs are appointed in writing. They must have a detailed working knowledge of the operating procedures and

precautions for the laboratory to which they are named CHO. The responsibilities of a CHO include developing, implementing, and maintaining the CHP; coordinating the protective measures with the base bioenvironmental engineer; monitoring procurement, use, and disposal of chemicals; routinely auditing and documenting compliance with the CHP; and reporting the status of chemical hygiene compliance to the laboratory supervisor. [8]

Written chemical hygiene plan

Each Air Force operation meeting the definition of a laboratory must develop a written CHP. The plan is usually a unit regulation or operating instruction, is tailored to the specific needs, and hazards associated with operations at the laboratory. Organizations with multiple laboratories will usually write a generic CHP with appendices specific to each functional area. Before being implemented, the plan must be approved by the unit commander, director, or functional manager following coordination with fire, safety, environmental management, and BE. The plan must be readily available and needs to include the following elements as outlined in OSHA Standard Title 29 CFR 1910.1450:

- Standard operating procedures relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals.
- Criteria that the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of PPE and hygiene practices; paying particular attention to the selection of control measures for chemicals that are known to be extremely hazardous.
- Lab hoods and other protective equipment are “required” to be functioning properly and specific measures are to be taken to ensure proper and adequate performance of such equipment.
- Provisions for employee information and training (covered later in this section).
- Circumstances where particular laboratory operation, procedure, or activity require prior approval from the employer or the employer’s designee before implementation.
- Provisions for medical consultation and medical examinations (covered later in this section).
- Designation of personnel responsible for implementation of the CHP, to include assigning a CHO and establishment of a chemical hygiene committee, if necessary.
- Provisions for additional employee protection for work with particularly hazardous substances. These will include select carcinogens, reproductive toxins, and substances that have a high degree of acute toxicity. Under these circumstances, the following specific considerations should be taken: establishment of a designated area; use of contaminant control devices (lab hoods or glove boxes); procedures for safe removal of contaminated waste; and decontamination procedures.

The employer needs to review and evaluate the effectiveness of the written CHP annually and make updates as necessary.

Employee information and training

Laboratory supervisors are required to provide information and training to familiarize workers with the hazards present in their workplace. The information and training must include the items found in the OSHA standard (Title 29 CFR 1910.1450) and must be provided at the time of an employee’s initial assignment to a work area where hazardous chemicals are present, or prior to assignments involving new exposure situations.

Information and training

Employees will be informed and trained on the following:

- Contents, location and availability of the CHP.
- Occupational and environmental exposure limits for chemical substances or recommended exposure limits for other hazardous chemicals where there is no applicable OEL.
- Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
- Location and availability of known reference material on the hazards, safe handling, storage, and disposal of hazardous chemicals found in the laboratory including, but not limited to, SDSs/MSDSs received from chemical suppliers.
- Methods and observations that may be used to detect the presence or release of hazardous chemicals (such as monitoring conducted by BE, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.).
- The physical and health hazards of chemicals in the work area.
- The measures employees can take to protect themselves from these hazards. These measures should include specific procedures implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and PPE to be used.
- The applicable details of the CHP.

Medical consultation and examination

The local aeromedical services will provide employees with medical consultations and medical examinations under the following circumstances:

- Whenever an employee develops signs or symptoms associated with exposure to a hazardous chemical, the employee will be provided an opportunity to receive an appropriate medical examination.
- Where exposure monitoring reveals an exposure level routinely above the action level or OEL for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements, medical surveillance will be established for the affected employee, as prescribed by the particular OSHA standard.
- Whenever an event takes place in the work area such as a spill, leak, explosion, or other occurrence, resulting in the likelihood of a hazardous exposure, the affected employee will be given an opportunity for a medical consultation. Such consultation will be for determining the need for a medical examination.

In such cases, the employer will provide the physician with the identity of the hazardous chemical, a description of the conditions under which the exposure occurred, and a description of the signs and symptoms that the employee may be experiencing because of the exposure.

Hazard identification

Original containers of hazardous chemicals are labeled and must not be damaged or defaced. All other chemical containers, regardless of type or size, are required to be marked with their contents. MSDSs/SDSs for each chemical are maintained in the laboratory; BE maintains a copy.

Chemical substances developed in the laboratory must adhere to the provisions of the OSHA standard. The requirements vary:

- If the composition of the chemical substance which is produced exclusively for the laboratory's use is known, it will be determined if it is a hazardous chemical. If the chemical is determined to be hazardous, appropriate training as described earlier will be provided.
- If the chemical produced is a byproduct whose composition is not known, it is assumed the substance is hazardous and managed as a hazardous laboratory chemical meeting all the requirements of the CHP.
- If the chemical substance is produced for another user outside of the laboratory, the laboratory must comply with the OSHA Hazard Communication Standard (HCS) (Title 29 CFR 1910.1200), including the requirements for preparation of SDSs/MSDSs and labeling.

Use of respirators

As a BE journeyman, you will evaluate potential inhalation hazards and determine the need for respirators and, if required, the type of respirator. Select the respirators in accordance with Title 29 CFR 1910.134, *Respiratory Protection Standard*, and AFI 48–137, *Respiratory Protection Program.*

Employee exposure determination and notification

The bioenvironmental engineer performs exposure determinations whenever there is reason to believe that exposures to a substance routinely exceed the action level or the OEL. Unless required otherwise by a substance-specific standard, BE provides the employee(s) written notification of any monitoring results within 15 days of receiving analytical data. Notification may be made either individually or by posting results in an appropriate location that is accessible to employees.

845. Hazardous material reports and requests

AF Form 3952, Chemical/Hazardous Material Request Authorization Form, provides information required to support the Air Force Hazardous Material Management Program (HMMP); it documents the HAZMAT authorization process. Supervisors submit the form for first time use of a HAZMAT in a work area, for renewal of an existing authorization that is expiring, or to revise an existing AF Form 3952 because of changes to the process. The term "3952" refers to either the actual AF Form 3952 or the standardized Air Force electronic HAZMAT tracking system known as Enterprise, Environmental, Safety, and Occupational Health-Management Information System (EESOH-MIS). The electronic data entry screens may or may not appear similar to the hard copy of the AF Form 3952.

For any requested material that is not currently loaded in EESOH-MIS (i.e., new item/first time use), the HMMP team will determine whether it meets the HAZMAT definition, as defined in AFI 32-7002, paragraph 3.1.3. If the team determines that the requested material does not meet the HAZMAT definition, the work area supervisor does not need an AF Form 3952 authorization to obtain the material. If the HMMP determines that the material does meet the HAZMAT definition, the HAZMART will load the material information into EESOH-MIS.

For a material that is loaded in EESOH-MIS and has "blanket" authorizations from all three authorizing offices (CE, SE, and BE), the supervisor only has to complete sections I, II, and VI (on AF Form 3952) and does not need to obtain separate CE, SE, and BE authorization.

For HAZMAT that requires a process-specific authorization by one or more of the authorizing offices, the work area supervisors must provide a copy of the document(s) that require the use of the requested HAZMAT. The requiring document will be a TO, owner/operator manual, work specifications, or drawing. A copy of the requiring document or pertinent page(s) must be provided with the request. In the absence of a requiring document, the authorizing offices, look for and approve the least HAZMAT available.

When an authorization is required, the authorizing offices may only approve the use of that HAZMAT if a suitable material reduction or substitution is not feasible. The HAZMART works with the authorizing offices to identify the least hazardous available materials and advises the requestor of the recommended selection, and, with the requestor's concurrence, ensure that it is properly reflected on the AF Form 3952. The HAZMART can only issue to the requestor those items specifically identified on the AF Form 3952.

Each of the authorizing offices makes an independent determination of whether to authorize the HAZMAT use as specified by the requestor, authorize with additional restrictions (specified in the "Remarks" block of the form), or not authorize the request. If any one of the authorizing offices does not authorize the request, then the request is denied.

Evaluation

BE's role in the authorization process is to determine if there are any occupational health-related concerns. Therefore, it is important for you to understand how the information provided on the AF Form 3952 assists us in the evaluation process.

So, what should you look for during our evaluation of the AF Form 3952? At a minimum, you need to evaluate the health risks to Air Force personnel as well as the exposure control options. To do this, evaluate the ingredients and characteristics of the HAZMAT being requested, and the activity it is to be used in. The bottom line is to ensure that the HAZMAT is issued *only* if a less-hazardous suitable substitute or less material is not feasible, and *only* when appropriate control measures are in place.

It is very important to review each AF Form 3952 for accuracy and completeness, to include making sure the information provided on the request matches the information reflected on the SDS/MSDS. Check to see that the NSN matches what is being requested and that the SDS/MSDS is not outdated. If these are off, the SDS/MSDS being used to complete your assessment may not reflect the chemical's actual constituents or health risks.

One system BE personnel often use to assist with the assessment is the Hazardous Materials Information Resource System (HMIRS). HMIRS is a DOD automated system developed and maintained by the DLA, and it is the central repository for SDSs/MSDSs for the United States Government military services and civil agencies. It also contains value-added information that is input by the service/agency focal points. This value-added information includes chemical name and synonyms, ingredients and percentages, HAZCOM warning labels and transportation information. HMIRS provides this data for HAZMAT purchased by the Federal Government through the DOD and civil agencies. The system assists Federal Government personnel who handle, store, transport, use, or dispose of HAZMATs. Since you should have access to HMIRS in your local BE office, you can use the information contained in HMIRS to assist you in the chemical/HAZMAT request/authorization process.

If the request is an initial request then it is likely that there won't be *previous* data available to assist in making an authorization decision. Because of this, initial requests may take a little more time to review; however, the benefits are tremendous because they provide BE with the opportunity to anticipate/recognize HAZMATs *prior* to the HAZMATs entering the workplace. Renewal requests and/or requests that involve a reported change in activity, on the other hand, may not require as much time; however, should not be taken lightly. Renewal requests offer BE an opportunity to identify and ensure that the least HAZMATs available are being used.

The AF Form 3952 is divided as follows:

- Part I, Material Request.
- Part II, Material Authorization.

Both parts are further divided into sub-sections. It is important to refer to AFMAN 32–7002 for a detailed description of the AF Form 3952 and the approval process, as it serves as a valuable reference tool on the HAZMAT authorization process. Using figure 5–4 as an example, let's apply

what you've learned to evaluate the AF Form 3952 submitted by the Structural Maintenance Shop. Begin your evaluation with a thorough review of the submitted request; again, check for accuracy and completeness. After you are satisfied with your initial review, you should apply the HRA principles taught to you in earlier volumes to the evaluation of this AF Form 3952.

CHEMICAL/HAZARDOUS MATERIAL REQUEST AUTHORIZATION FORM PART I - MATERIAL REQUEST	1. TYPE OF REQUEST	2. PROCESS CODE

SECTION I. REQUESTOR INFORMATION

3. COMMAND/INSTALLATION/ORGANIZATION/OFFICE SYMBOL:		4. WORKCENTER TITLE:
5. DODAAC and SUPPLY ACCOUNT CODE(S)	6. BUILDING NUMBER	7. LOCATION *(Be specific)*

SECTION II. MATERIAL INFORMATION (Attach copy of MSDS)

8. MATERIAL NAME	9. NSN/LSN/MSN	10. MATERIAL SPECIFICATION
11a. SOLE SOURCE MANUFACTURER NAME/CAGE	11b. SOLE SOURCE PART NUMBER/TRADE NAME	

12. MSDS REFERENCE #/DATE	13. UNIT OF ISSUE	14. DRAW AMOUNT	15. DRAW FREQUENCY

SECTION III. REQUIRING DOCUMENT(S) (Attach copies of specified pages)

16a. DOCUMENT NUMBER	16b. PARAGRAPH NUMBER	16c. PAGE NUMBER	16d. REVISION/CHANGE NUMBER	16e. REVISION/CHANGE DATE

SECTION IV. PROCESS INFORMATION

17. IS THIS REQUEST FOR A NEW WORKLOAD OR PROCESS IN THIS SHOP? (Circle one): ☐ YES ☐ NO

18.PROCESS *(Fully describe the process in which this material is used.)*

19. AMOUNT OF MATERIAL USED PER PROCESS	20. FREQUENCY OF PROCESS	21. DURATION OF PROCESS

22. DESCRIBE ANY ENGINEERING CONTROLS IN USE DURING THE PROCESS *(such as exhaust/ventilation systems, enclosures, covered tanks, cooling coils, etc.)*

23. INDICATE ANY PERSONAL PROTECTIVE EQUIPMENT *(PPE)* CURRENTLY BEING USED IN CONJUNCTION WITH THIS PROCESS

24. DESCRIBE THE METHOD OF DISPOSAL FOR THE WASTE THAT IS GENERATED

SECTION V. REMARKS

25. PROVIDE ADDITIONAL INFORMATION

SECTION VI. CERTIFICATION

26a. REQUESTER'S NAME/ORGN SYMBOL, AND PHONE	26b. SIGNATURE "I certify that material will be used as stated above."	26c. DATE
27a. CERTIFYING OFFICIAL'S NAME/ORGN SYMBOL/TELEPHONE NO.	27b. SIGNATURE "I certify that material is required as stated above."	27c. DATE

AF IMT 3952, 20060301, V1

Figure 5–4. Example, AF Form 3952, Part I.

Looking at the example AF Form 3952, are you able to identify any potential hazards? Your answer to that question should have been, yes. Based on the process information alone, you should see the potential for inhalation and/or contact hazards. You should also notice that this is a request for renewal; therefore, it would be good to look at the information already stored in EESOH-MIS and compare it to the current request to ensure that the documented activity/process data matches the current activity/process description. For example, the following table was taken directly from the requested material's MSDS (this is the type of information that is stored in the standardized Air Force HAZMAT tracking system). Note that "*inhalation"* and "*skin"* are listed as potential routes of entry. This should tell you that the potential exposure hazards may be inhalation and contact/absorption.

==========

Health Hazard Data

==========

Route of Entry - Inhalation: YES

Route of Entry - Skin: YES

Route of Entry - Ingestion: NO

Health Hazard, Acute and Chronic: INHAL: IRRIT RESP TRACT/NOSE/THROAT, ACUTE NS DEPRESSION. SKIN/EYES: IRRITATION. ABSORPTION: POS MODERATE IRRIT/ DRYING/DEFATTING/CRACKING W/PROLONGED/REPEATED EXPOSE. INGEST: IRRIT/CORROSIVE ACTION IN MOUTH/STOMACH TISSUE/DIGESTIVE TRACT, ASPIRATION OF LIQ RESULTING IN CHEM PNEUMONITIS.

Carcinogenicity - NTP: NO

Carcinogenicity - IARC: NO

Carcinogenicity - OSHA: NO

Signs/Symptoms of Overexposure: INHAL: HEADACHE, DIZZINESS, STAGGERING GATE,

TEARING, REDNESS, SWELLING W/STINGING SENSATION.

Med Cond Aggravated By Exp: ASTHMA AND ANY OTHER RESPIRATORY DISORDERS. SKIN ALLERGIES, ECZEMA, AND DERMATITIS.

Emergency/First Aid Proc: INHAL: GET FRESH AIR. RESTORE BREATHING.

ASTHMATIC TYPICAL SYMPTOMS MAY DEVELOP, MAY BE IMMED OR DELAYED BY SEVERAL HRS. GET MED AID. SKIN: REMOVE CONTAM CLOTHES. WASH THOROUGHLY W/SOAP & WATER. EYES: FLUSH W/CLEAN LUKEWARM WATER (LOW PRESSURE) AT LEAST 15 MIN, LIFTING LIDS. GET MED AID. INGEST: DON'T INDUCE VOMITING. DON'T GIVE ANYTHING BY MOUTH TO UNCONSCIOUS PERSON. GET MED AID.

There are several key questions that require answering during our evaluation process:

1. What is the material being used for and how is it used?
2. How much of the material is being used?
3. How often does the activity take place and for how long?
4. Are there existing engineering controls in place?
5. What PPE is being used?

Referring to our example in figure 5–4, let's find some answers!

- *What is the material being requested and how is it used?*
  We are able to determine that our requested material will be used to paint aircraft parts. Of interest is how the material is being used. Can you guess why? How a material is applied can affect that material's hazard potential. For example, the material being requested is applied with a high velocity, low pressure (HVLP) spray gun. We know that spraying a material increases the potential for inhalation hazards (see how easy it can be to recognize hazards). Next is to determine how much of the material is being used, how often the activity takes place, and how long it lasts.

- *How much/how often/how long?*
  We see that this activity takes place three times each week with 1 quart of material being used each time the activity is performed. The activity lasts for 35 minutes and according to our information, that includes mixing the paint prior to the spraying of the parts and the cleaning involved after the painting is completed. So, what about the controls?
- *What engineering controls are used?*
  According to the request, the activity is being performed inside a large spray paint booth (located inside the hangar). You should already know that providing adequate exhaust ventilation is an important factor in keeping airborne concentrations below the recommended OELs.
- *What PPE is being used?*
  The request indicates that personnel performing activity involving the HAZMAT wear Tyvek coveralls, latex rubber glove (inserts) with neoprene gloves, and a Bullard air-supplied respirator. Do you think this PPE is adequate? A good place to look for the answer to this question is the material's SDS/MSDS. Looking at the following table, can you make a sound decision about the adequacy of the current PPE?

Control Measures
Respiratory Protection: USE ORGANIC VAPOR RESPIRATOR (AIR PURIFYING/FRESH AIR SUPP). OBSERVE OSHA REGULATIONS (RESPIRATOR USE). PROVIDE VENT TO KEEP EXPOS LEVELS BELOW OSHA LIMITS. IF BELOW TLV, OTHER NIOSH/MSHA APPROVED RSPRTR MAY BE USED.
Ventilation: EXHAUST VENT SUFFICIENT TO KEEP AIRBORNE CONC (MIST/VAPOR)
BELOW TLV'S MUST BE USED. REMOVE ALL IGNITION SOURCE.
Protective Gloves: COTTON, NEOPRENE, RUBBER, POLYETHYLENE
Eye Protection: SPLASH GUARD/SIDE SHIELDS/CHEM GOGGLES
Other Protective Equipment: FACE SHIELDS. THE USE OF LONG SLEEVE AND LONG
LEG CLOTHING IS RECOMMENDED.
Work Hygienic Practices: REMOVE AND WASH CONTAMINATED CLOTHING BEFORE REUSE. WASH HANDS BEFORE EATING, SMOKING OR USING THE WASHROOM.
Suppl. Safety & Health Data: RESP PROTECTION: IF TLV LIMITS CAN BE
MAINTAINED & DOCUMENTED BELOW OSHA/ACGIH LIMITS, AIR-SUPPLIED RESPIRATOR
MAY NOT BE REQUIRED; HOWEVER, OTHER OSHA/NIOSH APPROVED RESPIRATORS MAY BE
USED.

The MSDS specifically outlines the use of an air-purifying or air-supplied respirator. The protective gloves and the Tyvek coveralls (long sleeve and long leg) worn by the structural maintenance workers also matches with the suggested PPE. What about eye protection? Our request doesn't indicate the workers are using any type of eye protection and the MSDS clearly lists "eye protection" as a control measure. We know that the structural maintenance workers mix the material, and then apply the material using a spray paint gun. Should eye protection be worn during this activity? Does the respirator provide adequate eye protection? What if the respirator is not work during the mixing process? The answers to the questions above should provide you with the big picture of how the material is being used and if the controls that are being used are adequate. Use sound judgment during the evaluation process because authorizing the request essentially says you are approving how the material is being used, and that the PPE identified is adequately protecting the workers. You may

choose to “approve” with conditions (such as requiring additional PPE). If a material is not approved, then you must provide the shop with the reason why the material was *not* approved.

References

[1] Air Force Handbook (AFH) 33–337, *Tongue and Quill*, 1 August 2014.

[2] AFMAN 48–146, *Occupational & Environmental Health Program Management*, 15 October 2018.

[3] Battelle, *Air Force Bioenvironmental Engineering Risk Communication Guide*, May 2011.

[4] AIHA, *The Occupational Environment: Its Evaluation, Control and Management*, 2nd Ed, 2003.

[5] AFI 90–821, *Hazard Communication (HAZCOM) Program*, 13 May 2019.

[6] OSHA, *“Hazard Communication,”* [Online]. Available: https://www.osha.gov/dsg/hazcom/.

[7] OSHA, *“Hazard Communication Standard: Labels and Pictograms (OSHA Brief),”* 2013.

[8] OSHA Standard Title 29 CFR 1910.1450, *Occupational Exposure to Hazardous Chemicals in Laboratories.*

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

841. Hazard communication program overview and evaluation

1. How does AFI 90–821, *Hazard Communication (HAZCOM) Program*, minimize the incidence of chemically induced occupational illnesses/injuries?

2. Explain why laboratories are not covered under the AF HAZCOM Program

3. When are consumer products exempt from the HAZCOM Program requirements?

4. Who provides HAZCOM training to workers when they perform duties outside of their normal AFSC?

5. What’s the difference between an SDS and an MSDS?

6. Match each hazard with the number of the corresponding pictogram.

Carcinogen _____

Skin sensitizer _____

Acute toxicity (fatal/toxic) _____

Eye damage _____

Pictogram 1

Pictogram 2

Pictogram 3

Pictogram 4

7. When is HAZCOM training required to take place?

8. Name the five items required of written HAZCOM programs by OSHA Standard Title 29 CFR 1910.1200(e).

842. Responsibilities of key players in hazard communication

1. Who is responsible for ensuring that all workers in a unit are provided a safe and healthy work environment?

2. Which office functions as the OPR for installation SDS/MSDS management?

3. What can be used to provide descriptions of all routine and non-routine work tasks to include associate hazard and controls?

843. Evaluating shop hazard communication programs

1. What is the purpose of a shop's written HAZCOM program?

2. Where must the shop's written HAZCOM program be maintained?

3. When is the only time a shop is not required to label a HAZMATs container?

4. What action should you take after you have finished your evaluation of a shop's HAZCOM program?

844. Laboratory chemical hygiene program

1. What is the requirement for an NCO to be a CHO?

2. How often must the employer review and evaluate the effectiveness of the written CHP?

3. If a chemical is stored in a non-original container, how must the container be labeled?

4. When must a laboratory comply with the OSHA HAZCOM standard?

845. Hazardous material reports and requests

1. What is one of the main reasons you review the chemical inventory during a routine workplace assessment?

2. What is the value of reviewing shop-specific EESOH-MIS data as part of your workplace assessment?

3. Why should you review the HMIRS as part of your chemical/HAZMAT request/authorization process?

4. How do supervisors obtain authorization for first time use of a HAZMAT in their work area?

5. What is your role in the HAZMAT authorization process?

6. If you approve/authorize HAZMAT for use, what are you telling the workplace?

Answers to Self-Test Questions

839

1. (1) Focused, (2) organized, (3) clear, (4) understanding and (5) supported.
2. Situation and conditions.

840

1. Communicating risks properly assists commanders in their ORM-based decisions.
2. Agreement among those involved, the stakeholders, on what is considered an acceptable level of risk, resulting in the appropriate actions taking place.
3. The eight overall goals of risk communication include:
   (1) Establishing, maintaining, and/or increasing trust and credibility.
   (2) Allowing affected stakeholders to participate.
   (3) Raising awareness of potential hazards.
   (4) Educating stakeholders about a risk.
   (5) Reaching agreement on how to address a risk.
   (6) Informing and improving decision-making.
   (7) Fostering understanding and acceptance of decisions made.
   (8) Motivating action.
4. The four steps of effective communication are:
   (1) Conduct your research.
   (2) Develop your message.
   (3) Share the message.
   (4) Evaluate communication effectiveness.

841

1. By establishing guidance for training workers on the health/physical hazards associate with using hazardous chemicals in the work area.
2. Laboratories are primarily governed by AFOSH Standard 48–22, *Occupational Exposure to Hazardous Chemicals in Laboratories*.
3. Consumer products can be exempt depending on how they are used, for example, when used in the manner similar to that of any average consumer in terms of frequency and duration.
4. The supervisor of the gaining activity.
5. SDSs are a replacement to the older MSDSs and are formatted to include specific section numbers, headings, and associated information in order to align with the United Nations' GHS format.
6. (1) Carcinogen: 2.
   (2) Skin sensitizer: 4.
   (3) Acute toxicity (fatal/toxic): 3.
   (4) Eye damage: 1.
7. At the time of a worker's initial assignment and whenever a new physical or health hazard the employees have not previously been trained about is introduced into their work area.
8. (1) Inventory of hazardous chemicals.
   (2) Obtaining and maintaining SDS.
   (3) Labeling requirements for hazardous chemicals.
   (4) Procedures for informing/protecting employees conducting non-routine tasks/jobs involving potentially hazardous chemicals.
   (5) Employee training.

842

1. Squadron/unit commanders.
2. BE Flight.
3. TO, job safety standards, BE survey letters, operating instructions or specific task lists.

843

1. It indicates/explains how the shop will meet the HAZCOM program requirements.
2. In a location that is accessible to all workers.
3. When a chemical is transported into a portable container that is intended for the immediate use by the worker who performed the chemical transfer during the same work shift.
4. Provide feedback to the workplace supervisor and/or HAZCOM program manager in your observations/findings.

844

1. Must have attained a 7-level qualification in either a laboratory or BE specialty.
2. Annually.
3. The non-original container must be marked with the chemical contents.
4. If a chemical substance is produced for another user outside of the laboratory.

845

1. To ensure the workplace actually uses the chemicals listed on the inventory.
2. It lists and identifies all of the HAZMATs used by all organizations on your base.
3. Because it contains a lot of value-added information such as chemical names and synonyms, as well as ingredients and percentages.
4. The supervisor must submit an AF Form 3952.
5. To evaluate the HAZMAT request to determine if there are any occupational health-related concerns.
6. That you approve how the HAZMAT is being used and the PPE being used to protect workers.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

76. (839) Which situation is most likely to require immediate communication?
    a. You have identified conditions that are immediately hazardous to life or health.
    b. Routine health risk assessment (HRA).
    c. Special health risk assessment.
    d. All of the above.

77. (840) All of these are goals of risk communication except for
    a. frightening workers into personal protective equipment (PPE) donning and doffing compliance.
    b. informing and improving decision making.
    c. raising awareness of potential hazards.
    d. motivating action.

78. (840) In developing your message and determining how to deliver it, what question should you ask about the audience?
    a. What is their experience with risk and scientific understanding?
    b. What questions can you anticipate from them?
    c. What is their reading level?
    d. All of the above.

79. (841) AFI 90–821, Hazard Communication (HAZCOM) Program, describes the requirements of which federal regulation?
    a. Title 29 Code of Federal Regulations (CFR) 1903.
    b. Title 30 CFR 75.1903.
    c. Title 30 CFR 75.1200.
    d. Title 29 CFR 1910.1200.

80. (841) To which of the following items do AFI 90–821, Hazard Communication (HAZCOM) Program, requirements not apply?
    a. Hazardous wastes regulated under the Resource Conservation and Recovery Act (RCRA).
    b. Tobacco or tobacco products.
    c. Biological hazards.
    d. All of the above.

81. (841) Select the best option for items to which hazard communication (HAZCOM) labeling requirements do apply.
    a. Any chemical substance when subject to the labeling requirements of the Toxic Substances Control Act (TSCA).
    b. Any Occupational Safety and Health Administration (OSHA) expanded standard.
    c. Any pesticide when subject to labeling requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
    d. Distilled spirits.

82. (842) Which individual/office has the primary responsibility of documenting worker hazard communication (HAZCOM) training completion?
    a. Bioenvironmental engineering (BE).
    b. Public health (PH).
    c. Wing/installation commander.
    d. Work area/shop supervisor.

83. (843) Upon your arrival, the hazard communication (HAZCOM) program manager for the shop provides you with the chemical inventory. Which chemicals should be listed on this inventory?
    a. Every chemical used on the base.
    b. Every chemical used in the wing.
    c. Every chemical used in the shop.
    d. Every chemical used in the unit.

84. (844) Written notification of exposures exceeding the action level or occupational exposure limit (OEL) must be provided to the worker by bioenvironmental engineering (BE) within how many days of receiving analytical data?
    a. 2.
    b. 7.
    c. 15.
    d. 30.

85. (845) How do supervisors obtain authorization for first time use of hazardous material (HAZMAT) in their area?
    a. Submit Air Force (AF) Form 3952.
    b. No authorization is required.
    c. Submit Environmental Protection Agency (EPA) Form 8700–12.
    d. None of the above.

Please read the unit menu for unit 6 and continue ➔

Unit 6. Emergency Management

AS YOU LEARNED IN Basic Military Training, the mission of the AF is to fly, fight, and win. Most AF missions require support from AF bases or other fixed installations where AF personnel operate. Unfortunately, there are many emergency events, called incidents that can prevent or disrupt the AF from completing its mission by affecting these facilities and personnel. Incidents range from natural disasters and accidents, such as earthquakes and aircraft mishaps, to intentional acts by others; including terrorist use of CBRN material, and enemy attack on an AF facility.

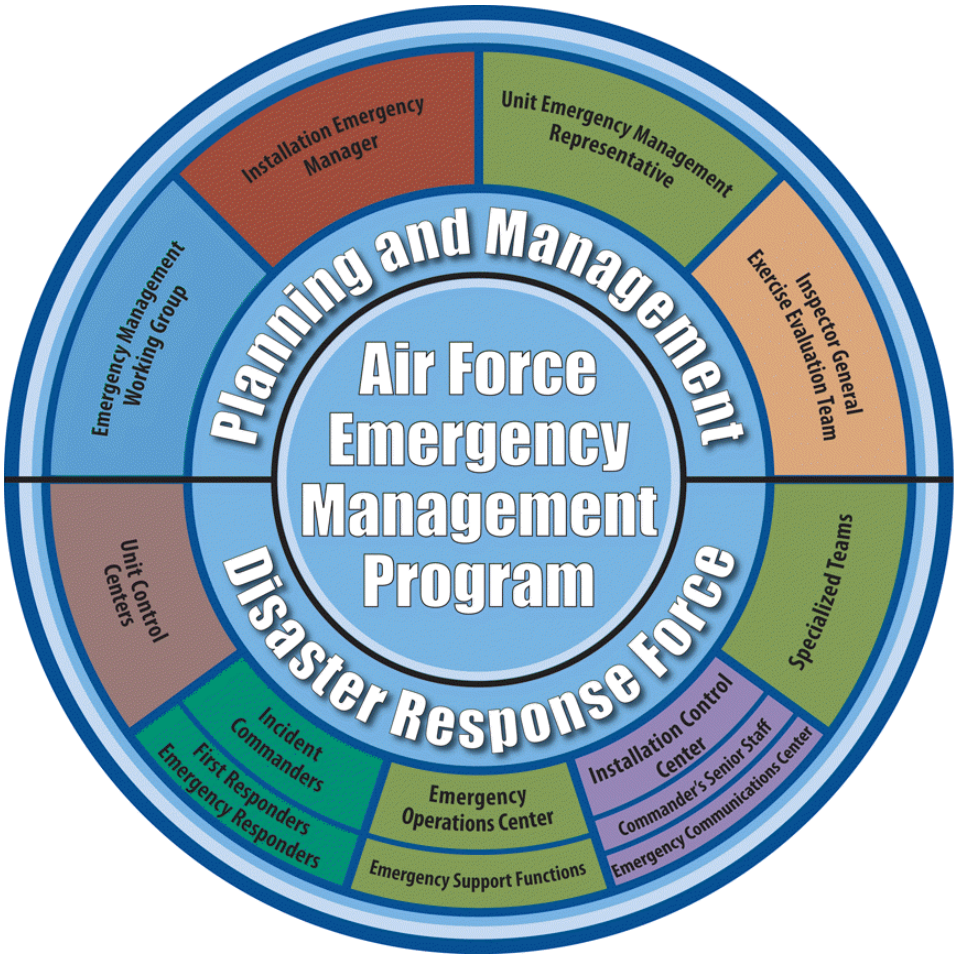

Figure 6–1. Air Force Emergency Management Program.

In addition to preventing or disrupting mission operations, emergency incidents can place AF personnel, their families, and local community members at risk of serious harm. The purpose of the Air Force Emergency Management Program, illustrated in figure 6–1, is to prevent these incidents, prepare for incidents that cannot be prevented, respond effectively when an incident occurs, and recover mission and supporting operations as quickly as possible. Because health risk assessment (HRA) and occupational and environmental health site assessment (OEHSA) are important parts of prevention, preparation, response, and recovery, as a BE team member, you play a key role in this program!

846. Chemical, biological, and radiological hazards

Chemical, biological, and radiological (CBR) agents can be used at any time, against any target, and by various delivery methods. The release of CBR agents, whether intentional or accidental, can have catastrophic consequences. CBR incidents may also result in overwhelming numbers of people seeking medical treatment, whether or not they were actually exposed. [4]

Chemical hazards

Chemical hazards are defined in Air Force Tactics, Techniques, and Procedures (AFTTP) 3-2.42_IP, *Multi-Service Doctrine for Chemical, Biological, Radiological, and Nuclear Operations*, as "any chemicals (manufactured, used, transported, or stored) that can cause death or other harm through the toxic properties of those materials." The types of chemical hazards of concern have expanded from a handful of "traditional" chemical agents specifically manufactured for warfare, to now include a broad class of toxic industrial chemicals and toxic industrial materials (TIC/TIM) and other non-traditional agents. [5] You may also refer back to CDC 4B0X1 Volume 2 for a detailed discussion of chemical health threats.

Chemical weapons are those chemical agents and its precursors that are prohibited under the *Chemical Weapons Convention.* This definition also encompasses munitions or delivery systems for prohibited substances. [5]

Chemical agents are substances intended for use in military operations to kill, injure, or incapacitate, mainly through physiological effects resulting from chemical exposure. Chemical agents are grouped into four types:

Chemical Agent Type	Example
Nerve	Sarin (GB), Soman (GD), Tabun (GA), and VX
Blood	Hydrogen Cyanide (AC), Cyanogen Chloride (CK), and Arsine (SA)
Blister	Sulfur Mustard (HS), Distilled Mustard (HD), Nitrogen Mustard (HN), Lewisite (L)
Choking agents	Chlorine (Cl), Phosgene (CG)

Riot control agents (e.g., tear gas, smoke grenades) are generally used for law enforcement actions, but they could also be in military operations to incapacitate.

TICs/TIMs are chemicals that are manufactured for use in industrial operations or research. Examples include pesticides, petrochemicals, fertilizers, corrosives, explosives, and poisons. TIC/TIM are not primarily manufactured for the purpose of producing human casualties, but many highly hazardous chemicals could be exploited for such use. For example, hydrogen cyanide, cyanogen chloride, phosgene, and chloropicrin are TICs that can also be used to inflict harm. The accidental or intentional release of large volumes of TIC/TIM can inflict harm and reduce operational effectiveness. Installation vulnerability assessments (VA) are performed to identify potential TIC/TIM hazards. TIC/TIM VA will be discussed later in this lesson.

Biological hazards

A biological hazards is an organism or substance derived from an organism (i.e., toxin) that poses a threat to human or animal health. Refer to the 4B051 CDC Volume 2 for a detailed discussion of biological health threats.

Biological weapons deliver, disperse, or disseminate a biological agent (including arthropod vectors). Weaponized biological agents may be infectious and/or have lethal and incapacitating properties. Effects from exposure to weaponized biological agents are generally delayed.

Biological agents are categorized as pathogens or toxins. Pathogens are *disease-producing* microorganisms (e.g., bacteria, viruses, fungi) that attack via biological processes. Toxins are poisonous substances derived from living organisms (but may also be produced synthetically).

There are a number of factors that make biological agents a significant threat:

- Small doses can produce lethal or incapacitating effects over an extensive area.
- They are difficult to detect in a timely manner.
- They are easy to conceal and can be covertly deployed.
- The large variety of potential biological agents significantly complicates effective prophylactic and therapeutic treatments.

Radiological hazards

Radiological hazards include any electromagnetic or ionizing radiation capable of causing damage, injury, or destruction. Radiological hazards in this context refers to radiation hazard sources other than nuclear weapons.

Radiological dispersal device (RDD) is also known as a “dirty bomb” that is intended to disperse radioactive material into the environment. RDDs are expected to likely consist of radioactive materials packed into an improvised explosive device (IED) that uses conventional explosives. RDDs do not undergo fissile or nuclear reaction.

Radiological emission device (RED) is simply a radioactive source that is hidden in a stationary location, for example under the seat on a bus. The purpose of a RED is to expose the victims to high levels of radiation.

Incident types

AFI 10–2501, *Emergency Management Program*, describes four types of incidents that affect AF operations and gives some examples of each type.

INCIDENT TYPES	EXAMPLES
Natural Disaster	Hurricane, Earthquake, Flood, Tornado, Natural disease outbreak.
Major Incident/Accident	Weapon accident, HAZMAT spill, aircraft crash, and fire.
Contingency and Wartime CBRN Attack	Enemy Missile with Chemical Warfare Agent Warhead.
Terrorist Use of CBRN/TIC/TIM	RDD, Toxic Industrial Chemical/Toxic Industrial Material (TIC/TIM) material release, RED.

Natural disasters

At one end of the incident spectrum are natural disasters that can damage facilities and put people at risk of death or serious harm. Let’s look at some examples of natural disasters and how they can create health risks which have the potential to affect an AF installation.

A hurricane is one type of natural disaster that can seriously affect AF operations and people. Hurricanes can cause significant damage to installation facilities and infrastructure, as shown by

figure 6–2 High winds can cause buildings to collapse or lose portions of their structure, which can release hazardous material, such as stored chemicals or asbestos containing material, into the environment. The installation and local electrical power grid is often damaged and electrical service disrupted during strong hurricanes, which can stop the functioning of critical systems, including pumps maintaining pressure in the drinking water system and fan motors on ventilation systems designed to control chemical hazards. Storm surges and flooding caused by hurricanes also damage facilities and infrastructure, including breaking drinking water distribution system pipes and causing wastewater treatment plants and sewer lines to overflow. Damaged building interiors can become saturated with rainwater or floodwater, creating an environment where mold can quickly grow to levels affecting occupant health and comfort. Hurricanes can create many potential hazards that need assessment by professional health risk experts to ensure appropriate actions are taken to control or mitigate the risks.

Figure 6–2. Example damage caused by hurricane winds and floodwaters.

Earthquakes, tornados, floods, mudslides, wildfires, severe snowstorms, and tsunamis are all other types of natural disasters that can affect AF operations and personnel.

Major incidents/accidents

In addition to natural disasters, another type of emergency incident addressed by the Air Force Emergency Management Program is a major accident. A major accident is an accident of such a magnitude that it warrants response by the installation disaster response force (DRF). It differs from day-to-day emergencies and incidents that are routinely handled by base agencies without the DRF assistance. Like all incidents, however, major accidents can range in complexity from a small, complexity “Type 5” incident, which is large enough to need DRF assistance, but only requires a few emergency responders for a short period of time, to a complexity “Type 1” incident, which requires many local, State, and Federal resources to effectively manage the operation for days, weeks, or longer (fig. 6–3).

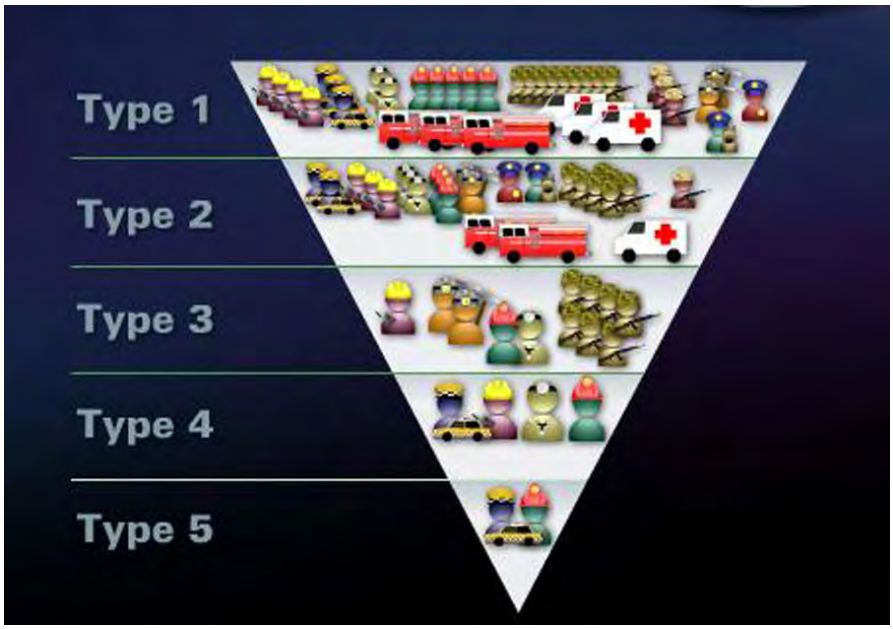

Figure 6–3. Incident complexity types.

Similar to what we learned about natural disasters, major accidents could create a number of health hazards that need to be assessed by BE personnel. As an example, let's look at some of the health hazards that can be created by an aircraft mishap, just one type of major accident where BE personnel could be called upon to provide support during incident planning, response, and recovery (fig. 6–4).

Figure 6–4. Aircraft mishap site hazards.

Both military and commercial aircraft contain hazardous materials, including fuel, hydraulic fluid, and radioactive materials. In addition, aircraft structures and components can be made from materials that present a health hazard if the material is damaged, such as composite fibers. Because of the large quantity of flammable material (fuel) on-board an aircraft, severe mishaps often result in a fire, which can create and release more hazardous material than the initial event itself. Composite material that does not normally present a significant health hazard when intact can release large quantities of microscopic fibers and hazardous gases, such as carbon monoxide, when burned. Aircraft components containing radioactive material, such as glass lenses coated with americium–241, engine ignition exciters containing cesium–137, and counterweights made from depleted uranium, can also become damaged and no longer contain the radioactive material as designed. In addition to aircraft, there can be semi-trucks that routinely transport hazardous chemicals to and through AF installations, which in an accident could release seriously harmful amounts of hazardous materials that must also be considered.

Unfortunately, not all major incidents are as obvious as an aircraft accident. One of the most serious radiological incidents to ever occur took place in Goiania, Brazil in the mid–1980s, and illustrates the possibility of dealing with an incident involving a RED. An abandoned medical therapy unit containing Cesium–137 was stolen for scrap metal, and when the unit was opened and the remnants of the unit were sold for scrap to a junkyard owner, the individuals involved exposed themselves and the surrounding population to high levels of radiation. This ultimately resulting in the contamination of 42 of the 159 houses monitored as well as the monitoring of approximately 112,000 people. Of the people monitored, 249 were contaminated either internally or externally, 20 were identified as needing hospital treatment, and 4 died within four weeks. The contamination was only identified because one of the individuals irradiated connected the illnesses with the source capsule they had contact with and went to the local public health department. [1] With all of these potential hazards, you can see why BE personnel are needed to conduct assessments at incident sites to identify potential hazards, assess the health risk, and provide appropriate control and mitigation recommendations.

While natural disasters and accidents inadvertently cause health risks to AF personnel, there are two types of emergency incidents where health risks are deliberately caused to harm AF personnel and the mission they are supporting, contingency and/or wartime CBRN attacks, and terrorism.

CBRN attack

The first type of incident caused by deliberate action is identified in AFI 10–2501, as "*CBRN attack*." CBRN attack is when an enemy military force uses CBRN weapons, such as an aircraft with chemical bombs, to attack AF personnel and facilities. CBRN attacks are different from terrorist attacks with CBRN materials because they involve the fielded military forces of an enemy state. Military forces generally have sophisticated weapon systems that are designed to cause significant damage and disruption to AF operations, often by causing life-threatening hazards to personnel. The impacts from use of CBRN weapons can vary significantly across the spectrum of conflict, potentially leading to increased levels of protective posture that may be detrimental to mission operations tempo. [2] Enemy weapon systems, their effects, and how they are likely to be used are studied by US intelligence organizations, and we are often able to plan specific defensive measures, such as a protective shelter program, to protect Airmen and AF operations.

Terrorism

Another type of incident caused by deliberate action is *terrorist use of CBRN material*. Terrorist use of chemical, biological, radiological, nuclear, or high-yield explosive (CBRNE) materials is separated from CBRN warfare because of the legal requirements for handling the terrorist incident as a crime scene and preserving evidence. All responders will be under close scrutiny and must be aware of evidence collection and preservation requirements. They must also be aware of the need to follow peacetime rules and regulations such as OSHA standards. [3] As you learned in previous volumes, chemical, biological, and radiological materials have properties that can present significant health hazards. To inflict the most damage and disruption of AF operations, terrorists use these materials to create intentionally hazardous conditions; or uncertainty of the hazards and risk which can degrade or paralyze operations. Terrorists may be able to obtain sophisticated military weapon systems with CBRN material, but often they create more crude weapons, such as an IED with CBRN material attached to the device
(fig. 6–5), such as a RDD.

Figure 6–5. Improvised explosive device with CBRN material.

As with natural disasters and major accidents, BE personnel who can identify health hazards, assess risks, and provide guidance to commanders can be critical to successful prevention, planning, response, and recovery from CBRN attacks as well as terrorist use of CBRN materials.

847. Air Force emergency management program

In this lesson, you will learn how the Air Force Emergency Management Program is organized and how BE personnel fit within the program.

National response

The events that occurred on and since September 11, 2001, exposed a need for improved prevention, preparedness, response, recovery, and mitigation capabilities, and coordination processes across the country. To improve the effectiveness of emergency response, President George W. Bush issued Homeland Security Presidential Directive–5 (HSPD–5), which directed the creation of a comprehensive national approach to incident management applicable to all jurisdictional levels and across functional disciplines. This means all emergency responders need to be on the same page.

Before looking in detail at the organization of the Air Force Emergency Management Program, it is helpful to understand how the AF fits in the National Response Framework (NRF) and follows the National Incident Management System (NIMS).

The National Response Framework

The NRF is essentially all of the emergency response organizations and capabilities of Federal, State, tribal, and local governments in addition to private sector and nongovernmental organizations that may respond to incidents. The primary functions of the NRF are a concerted national effort to:

- Reduce vulnerability to terrorism.
- Prevent terrorist attacks within the US.
- Respond to major disasters and other emergencies.
- Minimize the damage and recover from attacks, major disasters, and other emergencies.

The National Incident Management System

If the NRF is the "*who*" of domestic incident response, the NIMS is the "*how*." The NIMS establishes a standardized incident management structure—processes, protocols, and procedures—that all responders at all levels (federal, state, tribal, and local) use to coordinate and conduct response actions.

The NIMS states that the five phases of incident management are:

1. Prevention.
2. Preparedness.
3. Response.
4. Recovery.
5. Mitigation.

The incident command system

One important element of the NIMS is the incident command system (ICS). The ICS integrates key aspects of response management, such as facilities, equipment, personnel, procedures, and communications, within a common structure. The ICS provides common terminology to help define organizational structures, a unified command, key facility locations, and resource management. Collectively, these elements put all emergency responders on the same page.

Department of Defense role

Congress has passed numerous laws providing for DOD support to civil authorities. Installation commanders may assist local civil authorities under specific circumstances such as when:

- Directed by the president after declaration of a major disaster or emergency.
- A mutual aid agreement for support exists between the installation and local community.
- Serious conditions exist to immediately save lives, prevent human suffering, and mitigate great property damage.

Within the United States, support to civil authorities from the DOD would often be according to applicable Federal emergency plans and would likely require coordination and cooperation with agencies, organizations, and individuals outside the military's chain of command or direct control. In these situations, other federal agencies, such as the Federal Emergency Management Agency (FEMA), will likely have the lead role in crisis management. Sometimes, however, DRFs from an AF installation may be asked to respond immediately to local incidents to save lives, prevent human suffering, and mitigate great property damage. In these cases, AF personnel may directly support a local or State authority that is responsible for the incident response.

Air Force Emergency Management Program mission and structure

The primary missions of the Air Force Emergency Management Program are to save lives; minimize the loss or degradation of resources; and continue, sustain, and restore operational capabilities in an all-hazards physical threat environment at AF installations worldwide. The ancillary missions of the Air Force Emergency Management Program are to support homeland defense and civil support operations and to provide support to civil and host nation authorities in accordance with DOD directives and through the appropriate combatant command.

In response to changes in the national emergency management framework that created the NIMS, the AF needed to restructure its own emergency management program. The Air Force Emergency Management Program was implemented with the publication of the revised *Air Force Emergency Management (EM) Program Planning and Operations*, with its latest revision 10 March 2020. The program aligns the AF with HSPD–5, the NIMS, and the National Response Force and replaced the full spectrum threat response (FSTR) approach with the Air Force Incident Management System (AFIMS).

The Air Force Incident Management System

The AFIMS incorporated the ICS into the Air Force Emergency Management Program coordinating response procedures as directed by HSPD–5 while preserving the unique military requirements of the expeditionary AF. The AFIMS is used for peace or war, at domestic and foreign locations, and does not compromise operational missions or disrupt military command authority.

Because emergency incidents can cause a wide variety of health risks as discussed previously, BE personnel play an important role in the Air Force Emergency Management Program. BE personnel apply their HRA and OEHSA skills to provide commanders and other decision-makers critical information for selecting appropriate courses of action to recover mission operations while keeping people safe. Let's take a closer look at how the Air Force Emergency Management Program is organized and how BE personnel use their capabilities to support the program.

The Air Force Emergency Management Program is built on two elements: (1) a planning, education, training, and operational coordination component (planning and preparing for emergencies) and (2) a DRF structure (responding to and recovering from emergencies).

Planning and management

The installation emergency management planning staff consists of the force protection executive council, emergency management working group, force protection working group, threat working group, the civil engineering readiness and emergency management flight, emergency management aspects of the installation exercise evaluation program, and unit emergency management representatives. These groups assist the commander by examining potential emergencies and disasters based on the risks posed by likely hazards, developing and implementing programs aimed at reducing the impact of these events on the installation, preparing for risks that cannot be eliminated, and prescribing actions required to deal with consequences of actual events and to recover from those events.

The installation threat working group advises the commander on antiterrorism/force protection issues. The primary focus of the group is analyzing threats from deliberate actions of enemy forces or terrorists. Key functions include analyzing threats and providing recommendations to the commander concerning potential force protection condition (FPCON) changes, antiterrorism, and other measures based upon potential threats to facilities or personnel. Core membership typically includes the antiterrorism officer, Air Force Office of Special Investigations, intelligence office, chief of security forces, and other agencies as required by the installation commander. The installation threat working group generally includes BE involvement because of their expertise with understanding the risk from the various health threats they evaluate.

The installation force protection working group identifies and plans for all antiterrorism and force protection issues. The group typically includes representatives from relevant disciplines across the installation, including bioenvironmental engineering (BE) as the medical group's point-of-contact.

The installation emergency management working group, chaired by the mission support group commander, coordinates and implements the various facets of emergency management planning and managing. For example, the emergency management working group reviews emergency management program training status; schedules, design, and trends exercises; and monitors response plan updates, to name a few responsibilities. Similar to the threat working group (TWG), the emergency management working group analyzes threats but considers natural disasters and major accident threats as well as those from deliberate actions of enemy forces or terrorists. The group also determines which specialized teams are required to support the installation emergency management program and team composition. BE personnel participate in this working group as an important HAZMAT emergency planning team member.

Figure 6–6 illustrates the relationship between the installation working groups and installation leadership.

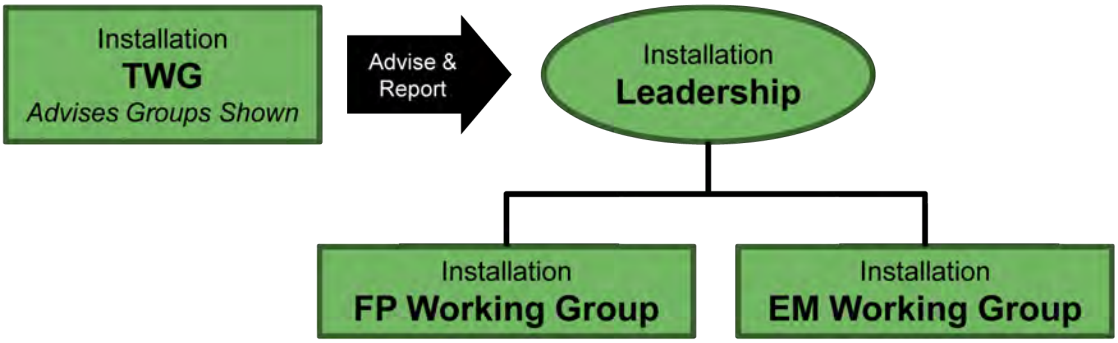

Figure 6–6. Installation Threat Working Group (TWG).

Disaster response force

In response to incidents, your installation activates the second element of the Air Force Emergency Management Program: the DRF. Under AFIMS, the DRF is composed of the installation control center, emergency operations center (EOC), the emergency communications center (ECC), IC, first responders and emergency responders, unit control centers (UCC), and specialized teams. Figure 6–7 depicts the DRF's organizational structure.

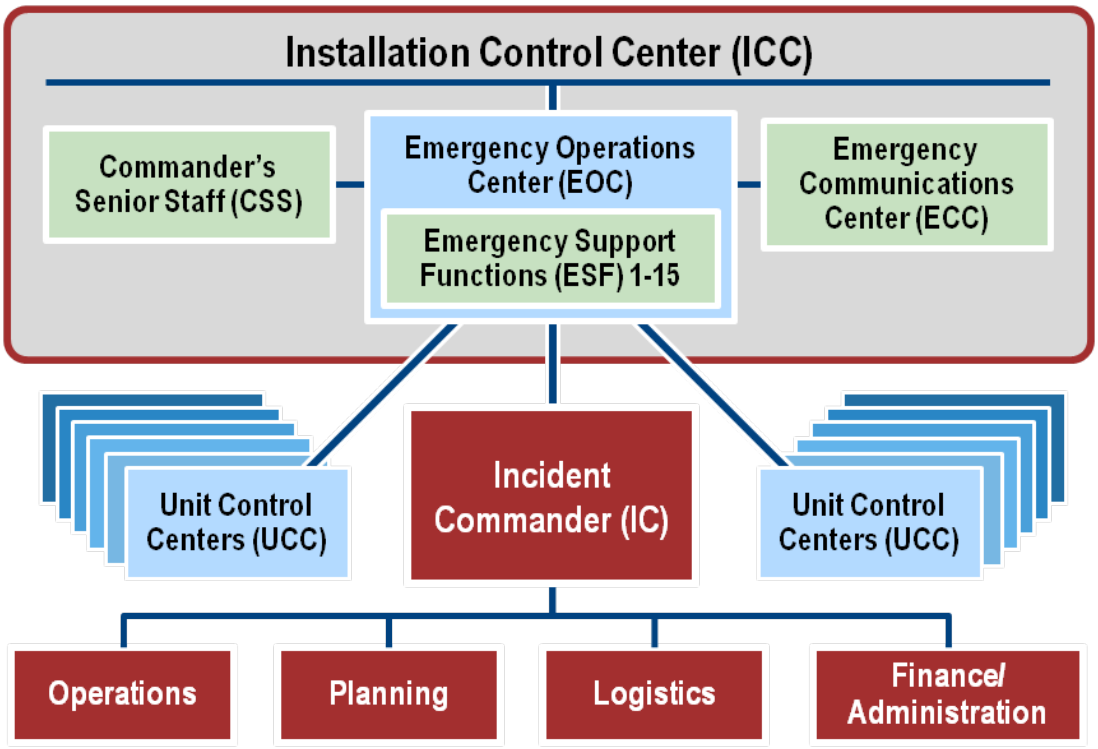

Figure 6–7. Disaster response force's organization structure.

When a situation arises that requires a response, installation commanders may choose to activate the DRF and deploy the EOC. The DRF can be configured differently depending upon the incident and may or may not involve all of the Force's elements; common elements to all incident responses are the IC, first responders, emergency responders, the EOC, and other emergency support functions (ESF).

The IC for an AF emergency response is the person in charge at the incident site and must be fully qualified to manage the response. Normally, ICs are experts from the fire, medical, or security forces

response elements that are trained to provide on-scene tactical control and leadership. The IC is very important to BE personnel who respond to the incident site because they will be under his/her tactical control and direction while at the site and provide support as part of the commander's organization. The IC establishes the command and organization under which all emergency responders will function at the incident site (fig. 6–8).

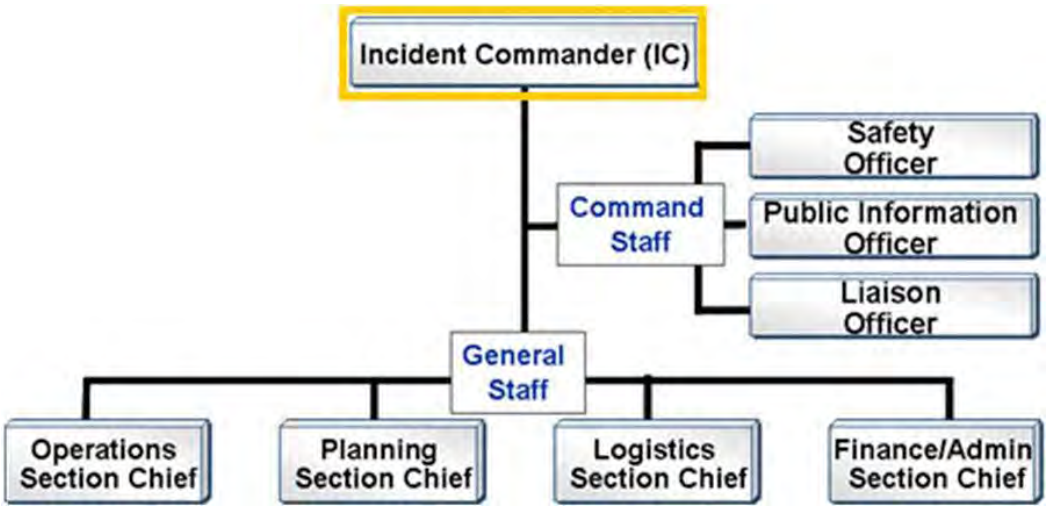

Figure 6–8. Incident command and organization.

The NIMS requires an ICS designed to enable effective and efficient domestic incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure. The ICS is used at all levels of government—Federal, State, local, and tribal—as well as by many private-sector organizations.

The AFIMS incorporates an ICS structure based upon the NIMS so that it is compatible with non-AF response organizations; thus, when AF responders work together with other organizations, all of the emergency responders are on the same page.

First responders, including firefighting, security, and emergency medical forces, are the first to deploy to an accident site (fig. 6–9). Their mission is to establish initial command and control, save lives, and control hazards. Any of the first responders can assume the role of "IC" if properly qualified for the type of incident they are facing.

Figure 6–9. Incident first responders.

Emergency responders are the response element of a DRF that deploys to the incident scene after the first responders to expand command and control and perform support functions. Emergency responders include follow-on elements such as firefighters, law enforcement personnel, security personnel, and emergency medical technicians, as well as readiness and emergency management personnel, explosive ordnance disposal personnel, medical treatment providers, public health officers, BE personnel, and several other specially qualified personnel. Emergency responders also include specialized teams such as the readiness support team or shelter management team. Not all emergency responders are first responders, but all first responders are emergency responders. We will discuss in detail how BE personnel interact as emergency responders in the next lesson.

If more support or resources are needed at the incident site than can be provided by first and emergency responders, the IC may recommend activation of the emergency operations center.

The emergency operations center is the command and control support element that directs, monitors, and supports the installation's actions before, during, and after an incident. The emergency operations center is activated and recalled as necessary by the installation commander. It updates the installation commander, support staff with ongoing incident status, and seeks support when on-scene requirements surpass the installation's inherent capability and support provided by agreements with local agencies.

The EOC is led by a director, who is typically the mission support group commander, and is organized into 15 ESFs that handle various aspects of coordinating the support required for the incident. For example, ESF–1 – Transportation, is staffed by personnel who coordinate sending transportation resources, such as busses to evacuate people from the incident site area, to the IC's staging area. We will talk more about how BE personnel may be asked to assist various ESFs at the EOC later in this unit.

The installation control center is the command and control element that directs strategic actions to execute the installation's mission. The command post is part of the installation control center, functioning as the essential command and control node for the installation commander and senior staff. The installation control center provides a communications link with higher headquarters, local civilian communities, and appropriate government or host-nation agencies. As the focal point for installation-wide warning, notification, and operations, the installation command center communicates directions, information, and recommended courses of action directly to units and agencies supporting incident activities. This communication includes courses of action to restore and continue critical missions while contending with single or multiple incidents. The installation control center directs the EOC and coordinates activities with UCCs located across the installation.

Unit control centers provide a focal point within an organization to maintain unit command and control. For the medical group, the unit control center is referred to as the medical control center. They relay information to and from unit personnel, provide expertise to the EOC or IC, and leverage unit resources to respond to and mitigate the incident. For typical installation medical groups, a single unit control center is established for the entire medical group; however, other organizations on the installation may have control centers located at the squadron level.

Responding to incidents of national significance

So far in this lesson, we've focused on the organization of an installation DRF and how it responds to on-base or local incidents. Because of their significant capabilities (OEHSA execution, OEH hazard identification, etc.), BE personnel may be tasked to support an "Incident of National Significance", when directed by the president after declaration of a major disaster or emergency. In these cases, BE personnel will be deployed to the combatant command that is responsible for that part of the United States, such as Northern Command (NORTHCOM). BE personnel are deployed as part of a UTC that you should recall from Volume 1, such as the preventive and aerospace medicine (PAM) team (FFPM1/2/3). If you are deployed to support a combatant command's support to a domestic incident, such as a NORTHCOM joint task force established to assist a major disaster, the response structure you encounter may be somewhat different and more complex than the installation DRF you are used to supporting. Figure 6–10 depicts the BE UTCs within NORTHCOM.

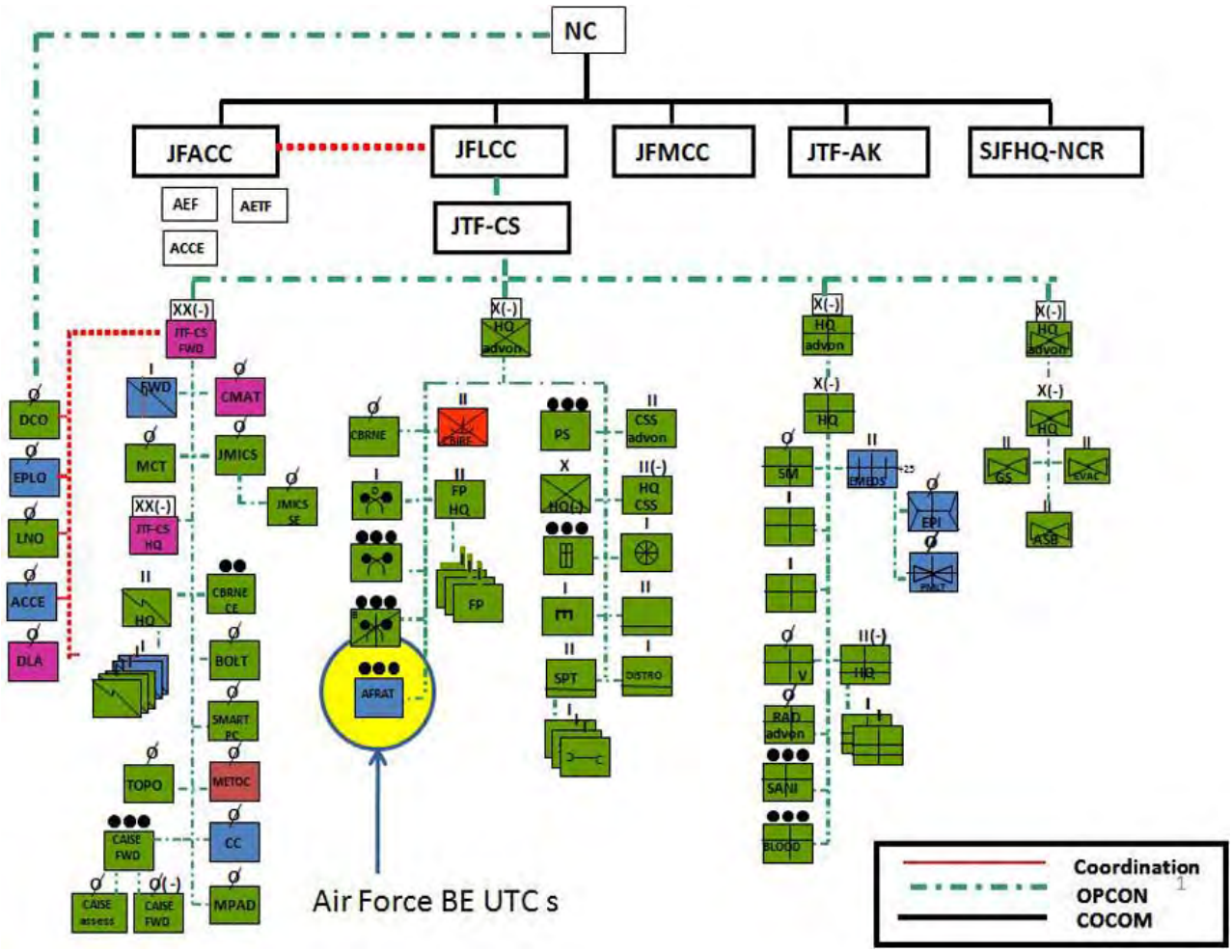

Figure 6–10. Example BE UTCs in complex NORTHCOM joint task force organization.

One of the helpful aspects of the NIMS and the AFIMS is that the basic incident site organization, with an IC and ICS, will be the same.

BE personnel can also be deployed to support expeditionary operations at locations where the base operating support, including emergency management, is the responsibility of another service or coalition partner. In these cases, the organization and terminology of the DRFs may be fairly different, but the essential capabilities that BE personnel and BE UTCs bring to the organization remain the same.

848. Roles and interaction of BE in response operations

Probably the most important emergency response organizational structure you as a BE team member will need to be familiar with is the incident command structure. Earlier in this unit, we discussed the IC and the organization that directs and conducts all of the activities at the incident site; refer back to figure 6–8.

When first responders arrive at the incident site, the senior person becomes the IC and establishes the incident command structure. As additional first and emergency responders arrive at the incident site, they report in to the IC and are given assignments to become part of the incident command structure. The incident command structure is flexible and can be arranged in any way the IC determines is necessary, but typically the incident command structure will contain an operations section, to conduct tactical incident site operations, and a planning section, where plans for the incident site operations

are developed and reviewed. As a member of the BE team, you may be assigned to either the operations or planning section when you arrive at the incident site and report in to the IC.

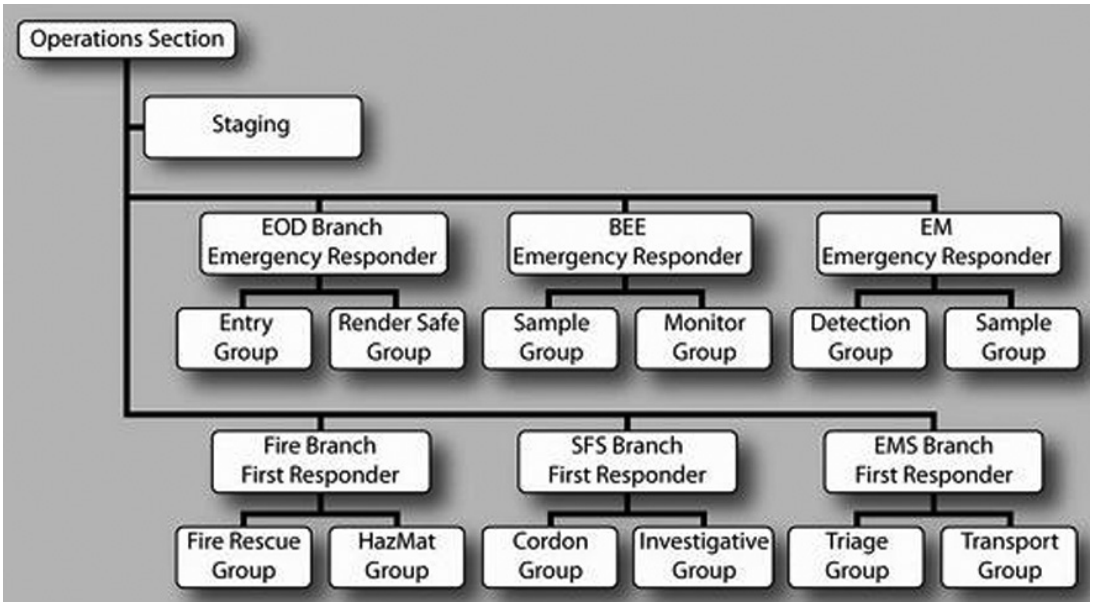

Figure 6–11. Example operation section organizational structure.

BE in the incident command structure

Figure 6–11 shows one example of how an incident command structure's operation section might be organized to support a hazardous material incident. You can see that in this example, the BE team members are part of their own sub-organization (called a branch) for conducting HRA activities at the site. Activities may include sampling material for potential hazards and monitoring the air for hazards that put responders or the public at risk. If you are donning protective equipment and preparing sampling equipment for entry into the incident site, you are probably part of the operations section. Figure 6–12 shows BE personnel entering an incident site.

Figure 6–12. BE personnel in operations section enter incident site.

Often, BE team members will be assigned as part of a multi-discipline branch that includes firefighting, readiness and emergency management, and explosive ordinance disposal personnel as an integrated team conducting combined operations to identify and evaluate hazards.

BE personnel are often assigned to the planning section, where tactical information pertaining to the incident site is gathered, evaluated, and disseminated. The planning section prepares and updates the incident action plan and information on the current and forecast incident site situation, such as the location of a hazardous material vapor plume. Figure 6–13 is an example of how an incident command structure's planning section might be organized to support a hazardous material incident.

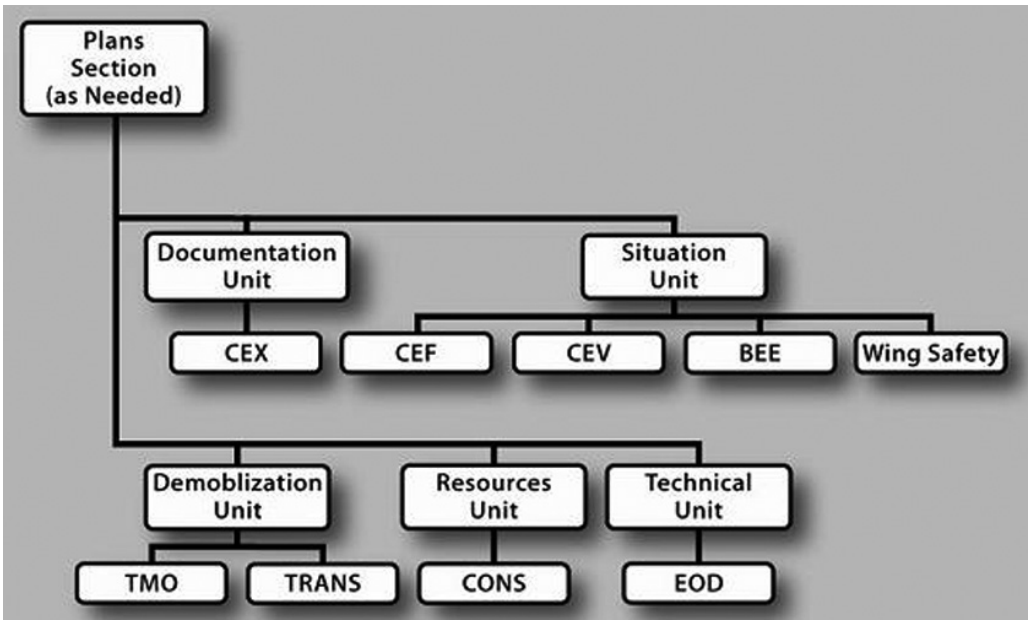

Figure 6–13. Example planning section organizational structure.

The planning section of the incident command structure usually contains the IC's technical specialists, who advise the incident and his/her staff on aspects of the incident pertinent to their area of expertise. For this reason, the BE team member assigned to the planning section is often the most senior or experienced person who can evaluate the information from site operations and provide the IC with the most accurate HRA possible. So, if you are evaluating the incident site sample data and working with a readiness and emergency management team member to assess the potential health and operational risks to personnel downwind of the site, you are probably part of the incident command's planning section.

Now that you understand how BE personnel fit within an incident command structure, it may make more sense that the AFIMS adopted the ICS as its method of organizing responders at an incident site. Once you have become familiar with responding as part of an AF incident command structure, you will also know what the local community incident command structure is like and where you fit in that structure as well, because it uses the same basic ICS structure and terminology. If you are deployed to an expeditionary AF installation, you will find the same basic ICS structure and terminology there as well. While it is true that you may be deployed to an installation operated by another service that uses a different emergency response structure, many of the other services are also in the process of adopting ICS for their emergency response operations at both garrison and expeditionary locations.

BE in the emergency operations center

Now that you understand the organizational structure at an incident site, let's take a look at another important emergency response organization, the EOC that provides support to the IC and responders. As we introduced earlier in this unit, the emergency operation center (EOC) is the command and

control support element that directs, monitors, and supports the installation's actions before, during, and after an incident. The EOC links the installation control center to ICs, specialized teams, and UCC supporting incident operations. Refer back to figure 3–7 for an illustration of this direct relationship.

While for the AFIMS, the EOC is described as more of a capability than a location, you may also hear the EOC defined as the physical location at which the coordination of information and resources to support attack response and incident management activities normally takes place. An EOC may be a temporary facility (fig. 6–14) or may be located in a more central or permanently established facility (fig. 6–15).

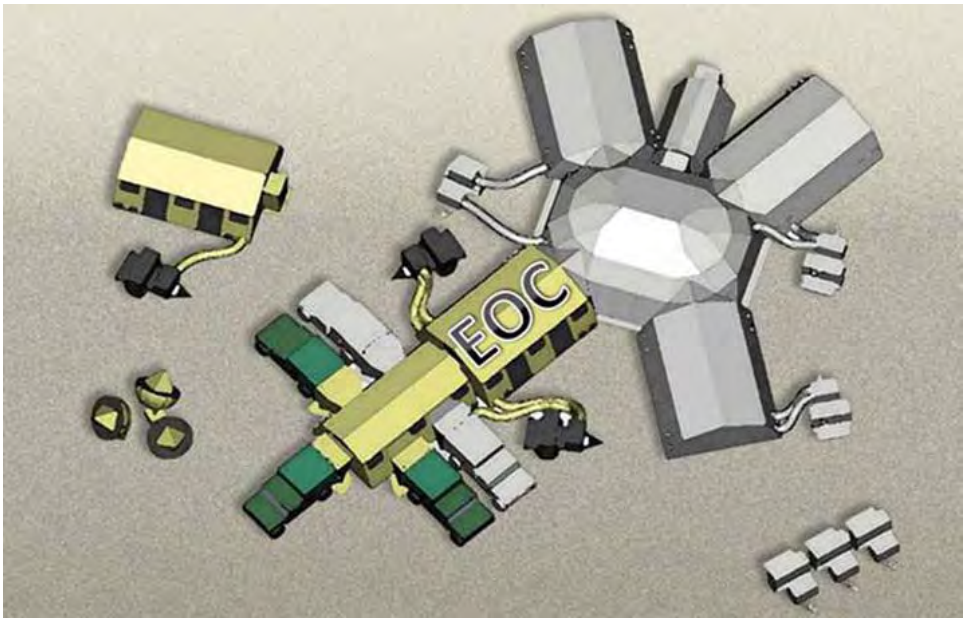

Figure 6–14. Temporary expeditionary Emergency Operation Center facility layout.

Figure 6–15. Permanent Emergency Operation Center facility.

The EOC is made up of a director (typically the mission support group commander), an EOC manager (typically the senior readiness and emergency management flight member), and expert personnel from many base organizations, including experts from the medical group. The EOC is

organized into 15 ESFs, shown in figure 6–16. In the AFIMS, the ESFs have been modified slightly from the NIMS/NRF construct to fit AF organizations, except that AFIMS specifies that all phases of incident management will be the same regardless of the type of incident; therefore, no unique wartime ESFs exist.

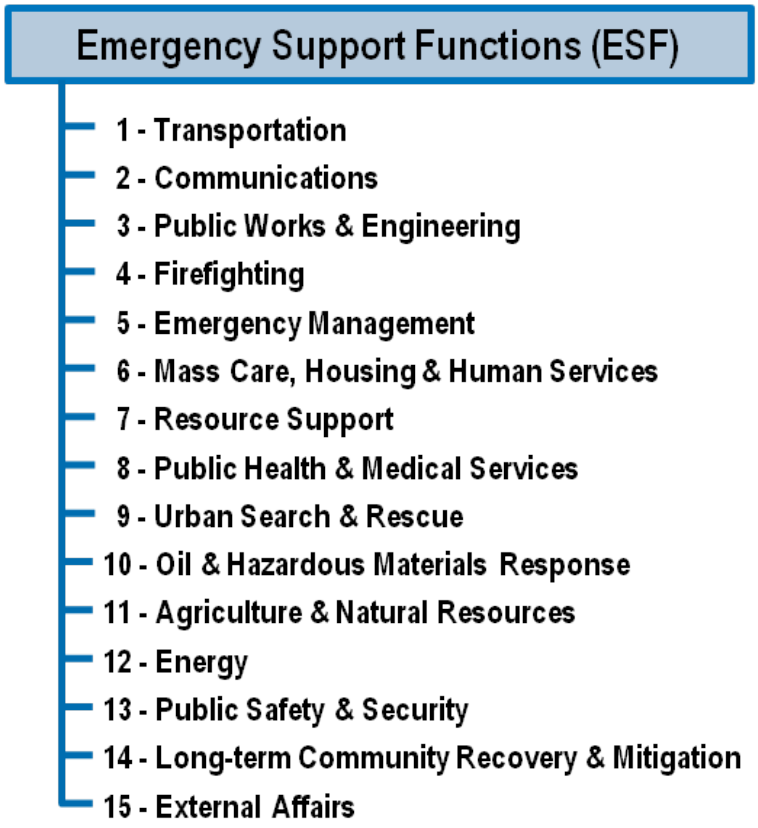

Figure 6–16. Emergency support functions.

ESFs are groupings of capabilities that provide the support, resources, program implementation, and services that are most likely to be needed during an emergency response. In other words, these support functions are responsible for anticipating the IC's needs and receiving his/her requests for support, then determining how and where to get that support, and finally providing the resources the commander requires. The resources provided by the EOC to the IC can be material (such as food, water, or heavy equipment items), personnel (such as additional emergency responders or specialized experts), or informational (such as the location, capabilities, and status of local hospital emergency rooms supporting an incident). The primary experts needed at the EOC, therefore, are people who know what type of resources may be needed by an incident, people who know where and how to get the resources, and people who have the authority to commit resources to the IC.

Each ESF has an OPR and one or more office(s) of collateral responsibility. The OPR for each support function is identified based on authorities, resources, and capabilities. The office of collateral responsibility (OCR) provides additional capabilities within each ESF. Using figure 6–17 as an example, you can see the OPR for ESF–1-Transportation is the Logistics Readiness Squadron representative, which makes sense because the squadron owns or controls most of the transportation resources on an installation. The squadron is also the most knowledgeable about transportation resources in the local community and agreements or contracts that might be available to get those resources in an emergency. The OCRs, however, augment the OPR with additional expertise, such as the Aerial Port Squadron ESF representative, who can provide aircraft scheduling and airborne transportation support expertise. You may have noticed that the bioenvironmental engineer (BEE) is

listed as an OCR to ESF–1 as well, which often confuses people at first glance because the BE team does not own or control many transportation resources. When you look at the scope of ESF–1 responsibilities, however, and see that movement restrictions and impact assessment are part of the ESF–1 scope, you can see how BE's understanding of hazardous material releases, liquid and vapor plume movement across transportation routes, and when a route may be unsafe or safe for movement to and from an incident site provides an important additional expertise to ESF–1. Similarly, the civil engineer squadron ESF representative may be needed to coordinate clearing or rebuilding of transportation routes to and from an incident site, not just for any vehicles that they own.

ESF	SCOPE	OPR	OCR
- Transportation	- Federal and civil transportation support - Transportation safety - Restoration or recovery of transportation infrastructure - Movement restrictions - Damage and impact assessment - Convoy operations	- Logistics Readiness Squadron	- Aerial Port Squadron - Bioenvironmental Engineer - Civil Engineer Squadron - Contracting - Judge Advocate - Security Forces

Figure 6–17. Example ESF OPR, OCRs, and scope.

You may wonder how big an EOC is and how many people are involved. The size and makeup of an EOC vary with each incident, depending on the needs of the IC. Based on the magnitude of the incident, the EOC director decides to recall the full Operations Center or to tailor the recall to include only those staff members and ESFs required to handle the incident. For a small incident, where very few resources are needed, the EOC may be only partially activated, with only a few of the ESFs actively staffed and functioning. For a large, complex incident, the entire set of support functions may be staffed with many experts from multiple disciplines. So, for BE personnel, not every incident will require a BE team member to be sent to the Operation Center. In fact, for most incidents, the BE team may be primarily involved with direct support to the IC and communication of resource information.

The chemical, biological, radiological, nuclear control center

The CBRN control center, illustrated in figure 6–18, is a unique capability within an AF EOC that directs CBRN reconnaissance activities to shape the hazards and advises the commander on hazards, countermeasures, and protective actions. The CBRN control center is managed under ESF–5, Emergency Management, and serves as an advisory element to the EOC and the installation commander. As we just discussed, for incidents where the CBRN control center is activated, the EOC is generally operating as an area command with its director assuming the role of area command commander.

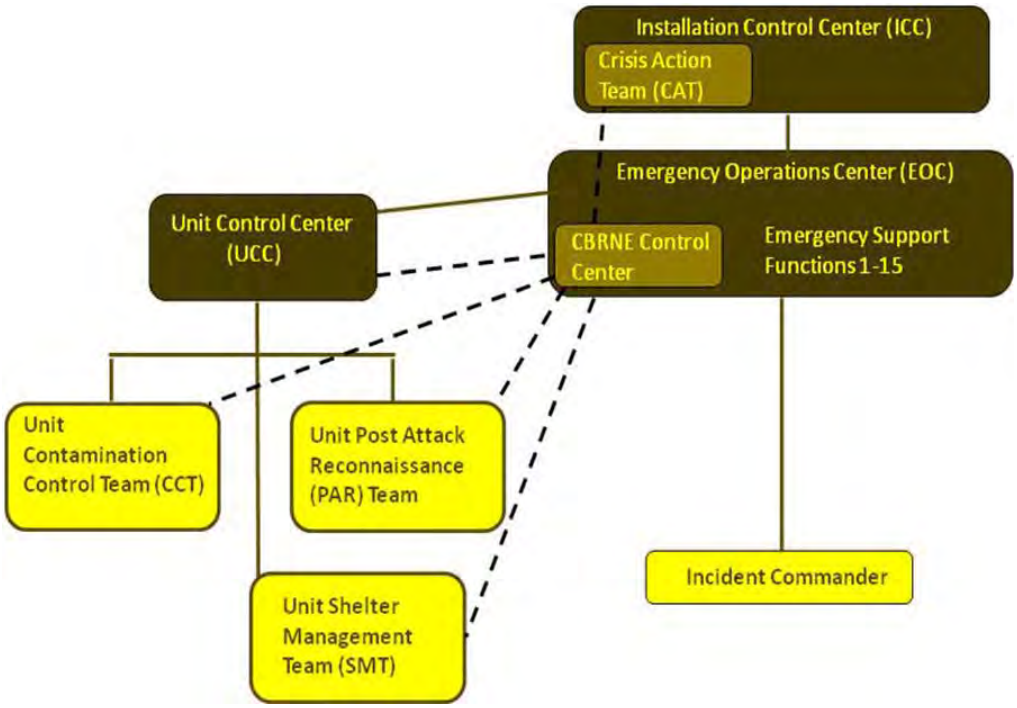

Figure 6–18. CBRNE Control Center.

The control center plots and maintains CBRN hazards status on the installation, in off-base areas of operational concern, and at potential recovery installations. The CBRN control center also conducts CBRN and release-other-than-attack (ROTA) plotting and reporting activities. These activities facilitate force survivability and mission continuation for forces on and off the installation, both in the hazard area and in the downwind hazard area. The CBRN control center manages the readiness support team, shelter management teams, contamination control area, and contamination control team operations and supports installation warning/reporting and operations with United States, joint service, coalition, and host nation forces.

As the medical group's CBRN hazard and HRA experts, BE personnel work as OCR within ESF–5 and the CBRN control center to provide health risk advice to the commander in coordination with readiness and emergency management flight personnel advising the commander on operational risks.

849. Emergency Planning and Community Right-to-Know Act

Back on December 3, 1984, there was an accidental release of approximately 27 tons of methyl isocyanate gas at the Union Carbine plant located in Bhopal, India. Methyl isocyanate is a toxic chemical used by the plant in making pesticides. The release exposed more than 500,000 people to methyl isocyanate. It's estimated that the immediate death toll was over 2,000 people and that over 25,000 people have since died from methyl isocyanate-related diseases. In response to the Bhopal disaster and concerns regarding the environmental and safety hazards posed by the storage and handling of toxic chemicals, Congress enacted the Emergency Planning and Community Right-to-Know Act (EPCRA).

Authorized by Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986, EPCRA established requirements for federal, state and local governments, Indian tribes, and industry regarding EPCRA reporting of hazardous and toxic chemicals. The Community Right-to-Know provisions help increase the public's knowledge and access to information on chemicals stored at facilities, their uses, and releases into the environment. States and communities, working with facilities, can use the information to improve chemical safety and protect public health and the environment.

To implement EPCRA, Congress requires each state to appoint a State Emergency Response Commission (SERC). The commissions are required to divide their states into Emergency Planning Districts and to name a local emergency planning committee (LEPC) for each district. Broad representation by fire fighters, health officials, government and media representatives, community groups, industrial facilities, and emergency managers ensures that all necessary elements of the planning process are represented.

Key provisions of EPCRA

EPCRA includes four key provisions to help communities plan for emergencies involving hazardous substances and to comply with the chemical reporting requirements.

Sections 301, 302, and 303, Emergency Planning

Local governments are required to prepare chemical emergency response plans, and to review plans at least annually. State governments are required to oversee and coordinate local planning efforts. Facilities that maintain extremely hazardous substances on-site in quantities greater than corresponding threshold planning quantities (TPQ) must cooperate in emergency plan preparation. The extremely hazardous substances list contains over 300 chemicals. Basically any facility with any extremely hazardous substances on-site greater than the relevant TPQ are subject to the emergency planning requirements.

Section 304, Emergency Release Notification

Facilities must immediately report accidental releases and/or spills of extremely hazardous substances chemicals and “hazardous substances” in quantities greater than corresponding reportable quantities defined under the CERCLA to state and local officials.

Sections 311 and 312, Community Right-to-Know Requirements

This section applies to any facility required under OSHA regulations to maintain SDSs for hazardous chemicals stored or used in the workplace. Facilities that manufacture, process, or store hazardous chemicals must make SDSs available to state and local officials and local fire departments. Facilities must also report, to state and local officials and local fire departments, inventories of all on-site chemicals for which SDSs exist. Information about chemical inventories at facilities and SDSs must be made available to the public.

Section 313, Toxics Release Inventory

This section requires that facilities in certain industries that manufacture, process, or use any of the more than 600 Toxic Release Inventory chemicals above the applicable threshold quantities to report annually on the disposal or other releases and other waste management activities related to these chemicals. If a facility meets this criterion, it must complete and submit a Toxic Chemical Release Inventory Form R to the EPA on or before July 1 of the year following the reporting year. The EPA maintains a Toxics Release Inventory national database that is available to the public.

The release reporting requirements set out in the CERCLA and EPCRA enable federal, state, and local authorities to effectively prepare for and respond to chemical accidents. The primary purpose of the CERCLA and EPCRA release reporting requirements is to notify various government levels of potential hazards so the necessary response actions can be taken (to ensure maximum protection of human health and the environment) in a timely fashion.

The agencies notified in the event of a reportable release operate as an emergency response network to deploy appropriate emergency assistance in the event of a chemical release. The National Response Center (NRC), located at the United States Coast Guard (USCG) Headquarters, is the national communications center, which is continuously manned for handling activities related to response actions. The NRC acts as the single federal point of contact for all pollution incident reporting. SERCs and LEPCs, established under the EPCRA, are dedicated to emergency response on the state and local levels.

So what is the connection between BE and EPCRA? The EPCRA plays a vital role when conducting TIC/TIM VAs. Because of the requirements of EPCRA, each base should have a thorough list of all of the chemicals used and stored on the installation. This makes gathering information for VAs much easier and aids in formulating and executing response actions during contingencies. Additionally, your knowledge and expertise of hazardous chemicals, SDSs/MSDSs, emergency response, and chemical hazard control measures plays a major role in assisting your installation in complying with EPCRA requirements and dealing with major releases of hazardous chemicals.

850. Toxic industrial chemical/toxic industrial material vulnerability assessments

As you know, there are a variety of potentially hazardous chemicals/materials, also known as TICs/TIMs, which are stored and used on a typical AF base. These substances could harm the base population if there was an accidental or intentional release into the environment (air, soil, water). An intentional release refers to the discharge of TICs/TIMs by enemies of the United States (terrorists) with the intent of causing significant harm. TICs/TIMs in the vicinity of installations also present a threat. The proper definitions of TICs/TIMs are:

Toxic industrial chemicals: Any chemicals manufactured, used, transported, or stored by industrial, medical, or commercial processes. For example: pesticides, petrochemicals, fertilizers, corrosives, or poisons. Some common TICs include ammonia, chlorine, and hydrogen cyanide.

Toxic industrial materials: All toxic industrial materials manufactured, stored, transported, and used in industrial or commercial processes. It includes toxic industrial chemicals (TIC), toxic industrial radiologicals (TIR), and toxic industrial biologicals (TIB). TIMs produce toxic impacts to personnel, material, and infrastructure.

TICs/TIMs are readily accessible, easy to obtain, and even in some instances already on-site right where the enemy can access them (if not adequately safeguarded). Nearly every country in the world produces some form of TIC/TIM. Production in very large quantities, modes of transportation, large storage facilities, universal distribution and potential to cause illness/injury make TICs/TIMs an attractive improvised weapon.

The good news is that most, if not all, of the TICs/TIMs on a base have been evaluated for their hazard potential as well as the adequacy of where they are used and stored. However, something you might not know is that it’s common for a base to be located in an area where there are off-base facilities that manufacture, use, and/or store potentially hazardous TICs/TIMs. If these facilities are located close enough or up wind from the installation, they also could harm-base personnel-if TICs/TIMs were released. The base could also be located adjacent to roads and railroads that transport potential hazardous TICs/TIMs that could also be released. Given these factors, a significant threat from TICs/TIMs to US forces exists.

Commanders have responsibility for protecting their forces against threats and, therefore, must become aware of and plan for defense against the potential release of any TICs/TIMs that could affect their installation. The main purpose of a TIC/TIM VA is to provide a general indication as to the types of events that could occur at your installation. It also evaluates/estimates the relative severity and risk of potential consequences from TIC/TIM releases and provides rough estimates of the potential magnitude of consequences. The assessment allows individual bases to prioritize their risks and plan accordingly.

The final assessment report will outline vulnerabilities and if your base is prepared to handle a potential attack/release and will also provide recommendations, if needed, such as providing better security measures for TIC/TIM storage facilities. According to Department of Defense Instruction (DODI) 2000.16, *DoD Antiterrorism (AT) Program Implementation: DoD AT Standards*, AT/FP vulnerabilities will be classified in accordance with the Defense Threat Reduction Agency (DTRA) *Force Protection Security Classification Guide (SCG)*. A document identifying vulnerabilities or a concern associated with a specific US military site will be classified as CONFIDENTIAL (C) or

SECRET (S). Using the latest guidance, it is recommended that assessments be marked SECRET. Portions of documents identifying a vulnerability, but is not associated with a specific US military site in the same report, will be marked FOR OFFICIAL USE ONLY (FOUO). Portions of documents not identifying specific AT/FP vulnerabilities, but containing information that if released to the public could be exploited (e.g., firefighting or redundancy deficiencies, etc.) will be marked FOUO. Sections or paragraphs containing solely unclassified information should be marked UNCLASSIFIED. Follow the same procedures for briefings. When compensatory/interim corrective measures are put into place to reduce the risk, the vulnerability finding remains classified. Once the deficiency has permanently been corrected, the finding may be declassified.

There are a several publications that reference TIC/TIM VA but the one that specifically references BE responsibilities is AFI 41–106, *Medical Readiness Program Management.* This AFI states that a bioenvironmental engineer or a BE craftsman will:

- Conduct an annual assessment of local industrial facilities (on and off base) that may be of consequence to base operations if TICs/TIMs are released and report results to the medical readiness staff function and wing force protection working group.
- Provide the public health emergency officer threat assessment information necessary for planning the clinical response to chemical, biological, radiological and nuclear (CBRN) events, including TIC/TIM events.
- Ensure classification of appropriate data where required and utilize appropriate procedures for briefing and controlling classified information.

Your BE experience will assist you greatly with the task of recognizing TIC/TIM threats and assessing and managing the associated risks. You will rely to a great extent on much of the same knowledge and skills used to perform routine assessments in the occupational environment. The next lesson discusses the phases and steps of performing a TIC/TIM VA.

851. Collecting data required for a toxic industrial chemical/toxic industrial materials (TIC/TIM) vulnerability assessment

A key document that you can use to guide you through a TIC/TIM VA is the *USAFSAM Assessment Methodology for Toxic Industrial Chemicals/Toxic Industrial Materials Guidance Manual*. Much of what we'll discuss throughout the rest of this section is taken from this manual.

The TIC/TIM assessment methodology is consistent with AFI 90–802, *Risk Management*. The major elements of risk estimate are shown in figure 6–19. These are the same elements used to determine/assign risk level of each worst-case and alternative TIC/TIM scenario (analysis step).

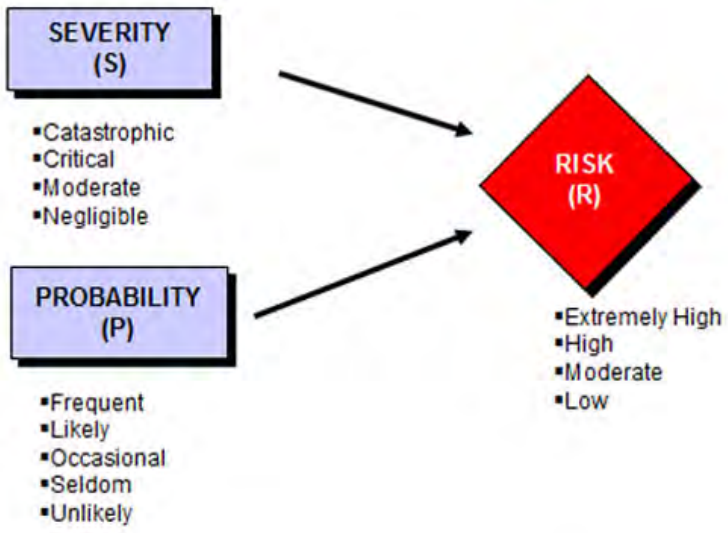

Figure 6–19. Elements of risk estimate.

The assessment process outlined in the USAFSAM guidance manual involves collection and evaluation of accurate and detailed information regarding the following major components:

- Preparation of an inventory of TIC/TIM on or near the AF base.
- Characterization of worst-case and alternative scenarios.
- Determination of potential severity of toxic releases and radioactive exposures.
- Determination of probability of toxic releases and radioactive exposures.
- Determination of risk and ranking of scenarios.

Keep in mind that due to the nature of risks associated with TIC/TIM, sensitive information will be collected and reported during the development of the assessments. Such information would need to be managed in a manner consistent with its sensitivity.

The TIC/TIM VA methodology process consists of the following phases: planning and coordination, data collection, analysis, and assessment report.

Planning and coordination

Planning and coordination activities are keys to ensuring that the assessment is carried out efficiently and according to schedule. The following are the major steps involved in the planning and coordination of the VA: identify the lead assessor, identify team members and assign roles and responsibilities, and develop list of stakeholders (organizations/personnel/points of contact that can provide the required data for the assessment.)

Data collection

This step involves identifying all TIC/TIM that may exist on and around an AF base. AFI 48–145, *Occupational and Environmental Health Program*, recommends considering potential hazardous facilities within a 20-mile radius of the installation in the vulnerability assessment. There are three types of TIC/TIM that should be inventoried and/or evaluated in this methodology:

Toxic industrial chemicals

TICs that are evaluated in this methodology include toxic gases and highly volatile toxic liquids. Based on the definition of a TIC, chemical compounds that are flammable/explosive but have little or no acute toxicity (e.g., propane, butane, natural gas, isopropyl alcohol, ethyl alcohol, petroleum distillates, diesel, gasoline, and jet fuel) are not inventoried or evaluated in this methodology. At a

minimum, it is recommended that TICs of concern include toxic substances regulated under the EPA Risk Management Plan program and toxic chemicals for which the NIOSH has established Immediately Dangerous to Life and Health concentration values.

Toxic industrial biologicals

TIBs (bacteria, viruses, and toxins) are found in medical research, pharmaceutical, or other manufacturing processes that are toxic to humans and animals. For this methodology, TIBs are inventoried but not evaluated, due to their imprecise nature. It is recommended that TIBs of concern include, at a minimum, those substances regulated by the Department of Health and Human Services (HHS) as "HHS Select Agents and Toxins" and "Overlap Select Agents and Toxins."

Toxic industrial radiologicals

TIRs are used in research, power generation, medical treatment, and other non-weapon developmental activities that are harmful to humans and animals if released outside their controlled environment. This methodology will inventory alpha-emitting and beta-emitting TIRs, and inventory and evaluate gamma-emitting TIRs. Alpha-emitting and beta-emitting TIRs require additional evaluation. It is recommended that TIRs of concern include, at a minimum, those radiological materials that are regulated by the Nuclear Regulatory Commission as "Nationally Tracked Sources" that equal or exceed Category 2 quantity (activity) thresholds.

Numerous sources are available for collecting the data needed to accomplish a TIC/TIM VA. The specific data collection sources used will depend on whether the TIC/TIM of concern is off base, transportation-related, on base, or a combination. Assessors should obtain information with respect to the potential for a TIC/TIM to cause any of three health effects: deaths, severe injuries/illnesses, or minor injuries/illnesses. To identify this potential for each TIC/TIM, the chemical concentrations or radiological dosage that can cause these varied effects should be identified. Refer to the USAFSAM guidance manual for sources for collecting TIC/TIM data and for examples of what types of TIC/TIM data to collect.

Once all of the data has been collected, the data should be verified for accuracy and completeness. To ensure the information is accurate and complete, assessors can contact/visit the agencies storing the TIC/TIM for data verification. After data verification, all of the TIC/TIM data should be compiled into a combined inventory so it is readily available for the Analysis Phase of the TIC/TIM process.

Analysis

In the Analysis Phase, the identified TIC/TIMs are evaluated to determine their potential impact to the base. From this point on, the data and analyses may need to be treated as classified information. All due caution should be taken to protect this information, to include working on a computer designed to handle SECRET documents (i.e., a Secret Internet Protocol Router Network (SIPRNet) computer). The table below summarizes the Analysis Phase steps:

Analysis Step	Description
Screen toxic substances to determine potential impact to the base	Assess TIC/TIM inventory to determine which ones may impact the base and require further analysis. Assessors use worst-case scenario conditions to model potential impact of the particular TIC/TIM. TIC/TIM that displays an impact to the base should be further analyzed in this phase.
Develop location maps	Develop maps that assist in locating TIC/TIM that pose greatest potential risk to base (maps should include: TIC/TIM identifiers/location, base facilities and critical assets, transportation assets). Identify locations of any distribution lines of interest (i.e., chemical feed lines that supply the base with toxic chemicals).
Develop worst-case and alternative scenarios—using meteorological conditions; quantities released; type, duration, height	Scenarios are developed for all TIC/TIM that display potential to impact the base during the screening process. Location where a scenario takes place should be the TIC/TIM's normal use location or storage as identified in the inventory. Major distinctions between two scenario types—meteorological conditions used and quantity of substance released/radioactive material. Two release options for plume model—instantaneous and continuous.
Determine/assign risk level of each worst-case and alternative TIC/TIM scenario	Relative risks for each scenario are evaluated to provide a mechanism through which planning and response measures can be prioritized using three steps: Determine severity rating (catastrophic, critical, moderate, negligible). Determine probability (frequent/likely, occasional, seldom, unlikely). Assign risk level (extremely high, high, moderate, low).

Assessment report

Once data collection and analysis have been accomplished, the assessment team should document and consolidate the results and develop an assessment report. Since risk assessment is not an exact science, it is important to maintain records of expert opinions and judgments made during each step of the process. The assessment team should document and maintain data for further analysis and to support proposed recommendations and alternatives. This documentation can be provided to decision-makers for review and can be used as a baseline for follow-on or future analyses and assessments. The report should include the following: executive summary; introduction; scope and imitations; methodology; TIC/TIM inventory; risk assessment; conclusion; references; and appendices (workbooks, maps).

Information gathered during the baseline assessment is unlikely to change significantly after one year, therefore annual updates will not take as much time or resources. Keeping this in mind, it is suggested that an initial TIC/TIM VA be accomplished as outlined in the USAFSAM TIC/TIM assessment guidance manual, and that it be updated annually.

Annual assessment updates include a verification of the information in the comprehensive TIC/TIM inventory. This verification should include a review of the most current data found in TIC/TIM data sources and comparing these data to the information in the comprehensive TIC/TIM inventory.

The TIC/TIM report is a living document designed to reflect the most current information within the body of the report; and provide a historical record of changes that have occurred over time since the initial TIC/TIM VA. The following actions should be implemented, each time a TIC/TIM VA is updated:

- Update the report where applicable. Examples include adding or deleting rows from tables, adding or deleting plumes, and modifying text with updated observations or conclusions.
- Summarize any changes made to the report since the last TIC/TIM VA. An example "Record of TIC/TIM Updates" form is included in the USAFSAM TIC/TIM guidance manual can be used to document changes. Also include the date of the change and the individual(s) responsible for making the change.
- Change the dates on the report cover and the declassification dates in the page headers and footers and, if necessary, change the report classification to reflect the latest TIC/TIM VA.

852. Shelter operations

Often, an important way to protect personnel, equipment, and mission operations before, during, and after an incident is to use shelters against the incident hazards. Because incidents and their hazards span a wide range of conditions from high winds to high concentration of chemical vapors, shelters needed to protect against these hazards also come in a wide variety of types and purposes. The objective of the AF shelter program is to provide the best available physical protection of personnel from the effects of war or disaster. Key elements to a successful personnel shelter program include adequate shelters, a base population familiar with shelter procedures, a competent staff trained in shelter management, an ability to activate and close shelters at the appropriate times, an ability to stock shelters with required supplies and equipment, and an ability to occupy shelters for extended periods.

In the Air Force Emergency Management Program, there are generally two primary types of shelters: those that are deliberately planned for a particular incident and its hazards, and "sheltering in-place" within a facility not necessarily designed to protect against specific hazards but used as an expedient shelter during incidents. BE personnel play an important role in planning and operations for both types of shelters. Let's look at deliberately planned shelter operations first.

Deliberately planned shelters

AFI 10–2501 requires AF installation commanders to establish an installation shelter program that addresses shelter requirements after reviewing the threat. For example, installations located in an area prone to hurricanes must develop a shelter program and evacuation plans to protect personnel and mission-critical assets from the effects of a hurricane. Installation commanders ensure that units have threat-based contamination control and shelter management capabilities, including the ability to identify contamination, decontaminate essential resources, and mark contaminated areas. They also ensure that transportation, munitions, civil engineering, maintenance, and medical group units establish contamination control teams based upon the threat and that all units have the ability to implement expedient contamination control and shelter-in-place procedures if an incident occurs with little or no warning (fig. 6–20). Because some incident hazards remain for an extended duration, part of shelter planning is to ensure all units have the ability to sustain operations in a contaminated environment.

You recall how the installation's Comprehensive Emergency Management Plan (CEMP) 10–2 contains the mission, threat, and response actions, grouped into four annexes for each of the four types of emergency incident. Each annex of the installation's CEMP 10–2 may have an appendix that

outlines the necessary shelter-related steps to take in case of an emergency incident created by the threats addressed by the annex.

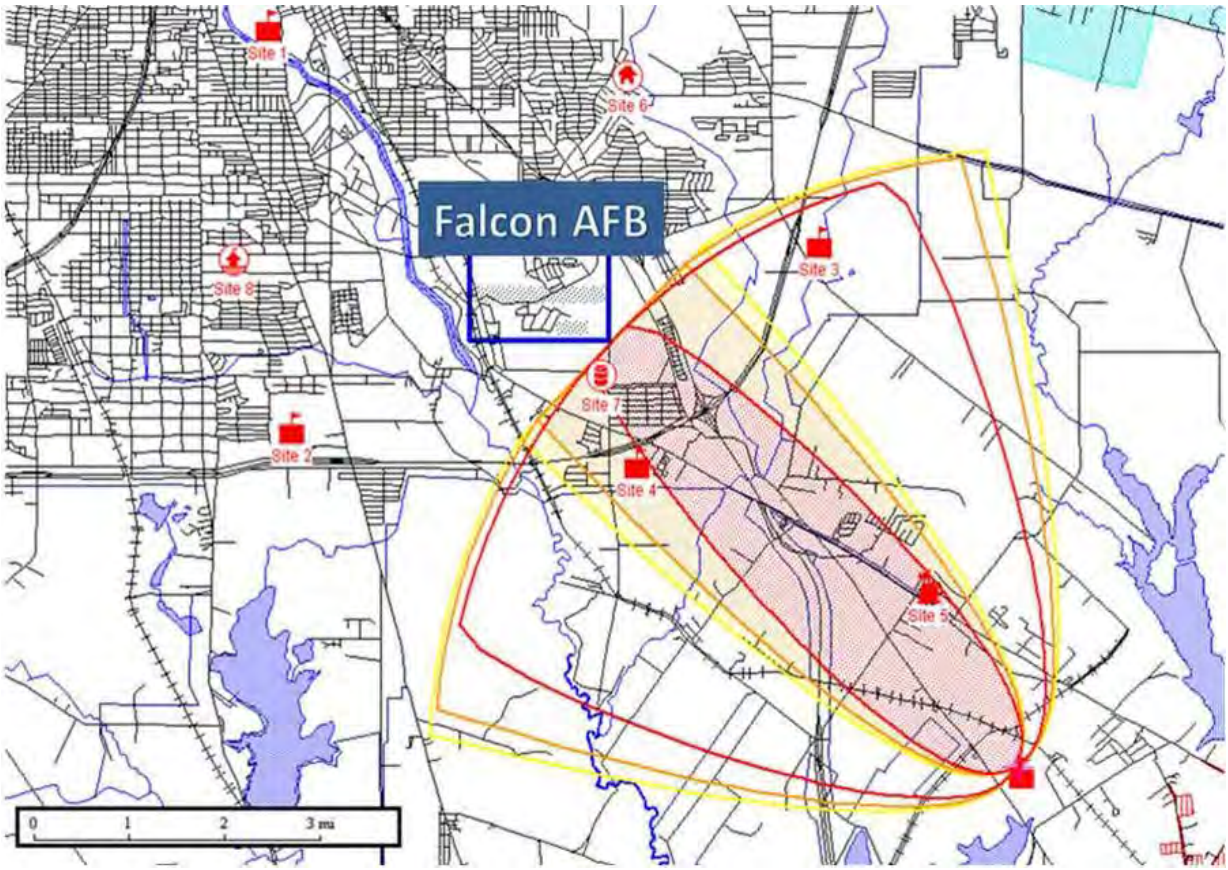

Figure 6–20. Evaluating major accident shelter requirements.

Major accident shelters

Historically, AF emergency response planners did not develop detailed major accident threat, vulnerability, and risk assessments, so deliberate shelter planning was not often found in the CEMP 10–2, Annex A, *Major Accidents*. With improved threat, vulnerability, and risk assessments performed by BE and readiness and emergency management flight personnel, however, installations often have the ability to consider deliberate shelter planning for major accident hazards during force protection and emergency management working group meetings. For example, if your installation is near a large chemical storage facility that has the potential to be damaged and release hazardous vapor, threat analysis including assessment of prevailing winds that may carry the hazardous vapor plume over the installation can be considered along with critical missions that the installation must accomplish. In many cases, the installation's senior leadership will decide that evacuation in the event of a major accident is the preferred option, but there may be some critical missions, such as the protection of nuclear weapons, where protective shelters offer an improved capability to respond during an incident.

It is the base civil engineer's responsibility to identify and evaluate installation facilities that may be used for shelters; however, as the installation's health risk experts, BE personnel assist in identifying and evaluating potential shelters for their ability to protect personnel against the incident health hazards. Air Force Pamphlet (AFPAM) 10–219, V2, *Civil Engineer Contingency Response and Recovery Preparations*, outlines detailed shelter planning considerations BE personnel can review along with their civil engineering counterparts.

Most major accidents are not expected to create conditions that require sheltering for extended periods of time (days, weeks), and planners will typically look to transfer critical missions to an alternate location as soon as possible, so often only minimal support services need to be planned for these shelters, and BE personnel may not have to consider many of the associated long-term health and hygiene issues. We will see, however, that BE involvement in long-term occupancy considerations become very important for sheltering from other types of hazards.

Natural disaster shelters

As with major accident shelters, natural disaster shelters are also planned based on expected emergency events; in other words, installations in hurricane/typhoon-prone areas should designate buildings that are built to withstand hurricane/typhoon-force winds, installations in flood-prone areas should designate buildings that sit above the flood plain, and so forth.

On-base agencies that provide a service to the population will normally be required to provide that service to shelter occupants, but depending on the type of incident, the service may no longer be available for a period of time. Services typically provide food and bedding; CE provides power, water, sanitary facilities, and trash removal; medical provides medical care; and security forces (SF) provide security for the shelters. Some of these requirements, for example, food and bedding; may require staging in the shelter prior to the event. Others, for example, water and power, may be readily available through the normal infrastructure, if it is not damaged. If it is damaged, then bottled water and generator power may be needed. Sources for both should be located before the need arises, so BE personnel are integral to identifying alternate water sources prior to an incident and then ensuring they are potable after the incident has occurred to maintain shelter health and sanitation.

Since there may be more people crowded into a shelter than normal work and living environments, proper ventilation is needed to maintain a minimum oxygen level, prevent an excessive buildup of CO_2, and control shelter temperature. Temperature and humidity control competes against the desire to provide fresh air, particularly when electrical power is limited, so BE evaluation of indoor air quality concerns, both before and during shelter operations, is important to balance risks.

Enemy CBRN attack shelters

When people discuss shelter operations, they are often referring to classic “wartime” shelter operations that are really shelters planned and designed for enemy CBRN attack. During the Cold War, where a significant chemical and nuclear weapon attack threat existed for many of our installations, a robust enemy CBRN attack shelter program was developed to protect personnel and equipment while providing for continued operations during and after an attack.

Enemy CBRN attack shelters need to be designed to simultaneously protect against a variety of hazards that can be created by enemy attacks, such as blast, shrapnel, chemical vapors/aerosols, biological aerosols, and radiological fields and contamination.

An important concept for enemy CBRN attack shelter operations is collective protection (COLPRO), which includes systems that protect those inside a building, room, shelter, or tent against contamination through the combination of impermeable structural materials, air filtration equipment, air-locks, and over-pressurization (fig. 6–21). Ideally, it provides a temperature-controlled, contamination-free environment to allow personnel relief from continuous wear of IPE. The inside of a COLPRO shelter is a *toxic free area*, and in order to get to the this area from the contaminated environment outdoors, COLPRO shelters will have a *contamination control area* where contamination is removed from personnel prior to entering the shelter.

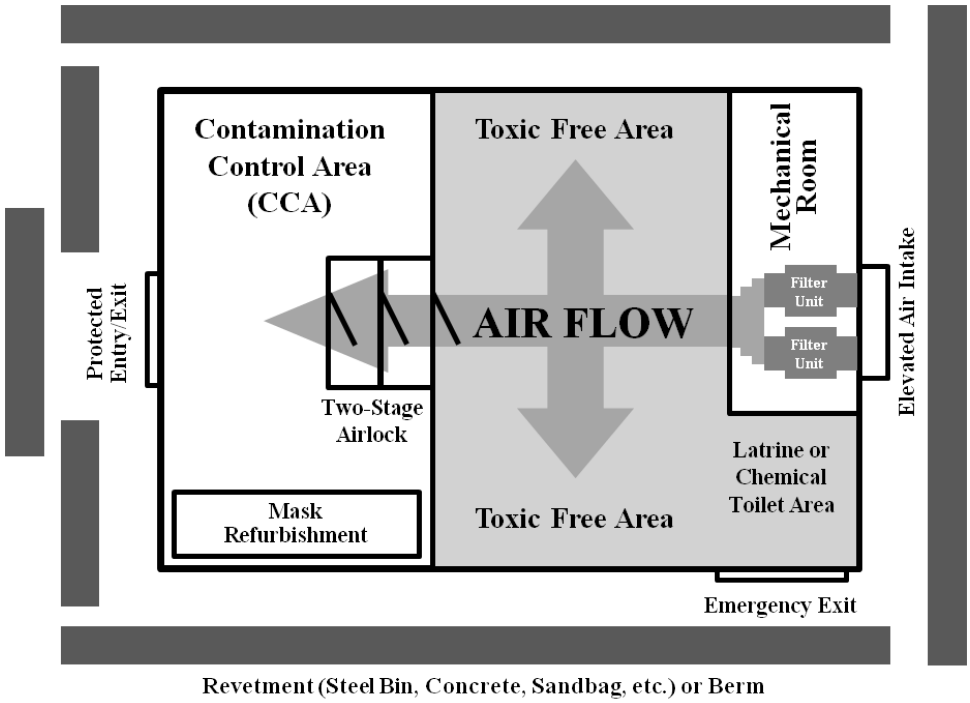

Figure 6–21. CBRN attack shelter.

While enemy CBRN attack shelters also include shelters to protect equipment from multiple types of attack hazards, in this lesson we will focus on personnel shelters, starting with categorization of these shelters by their designated function: *emergency operations shelters*, where personnel perform essential functions; and *rest and relief shelters*, where personnel obtain rest and relief between work shifts. Emergency operations shelters are designated work centers where personnel perform essential wartime or emergency tasks. These facilities house control centers and other work centers that must remain operational during any phase of hostilities. The command post and aircraft control tower are examples of emergency operations shelters. Rest and relief shelters are used by personnel to rest and eat. A protected dormitory is an example of a rest and relief shelter.

Enemy CBRN attack shelters are also further classified by the level of COLPRO integration in the shelter facility:

- Class I, Full Integration.
- Class II, Partial Integration.
- Class III, Expedient.
- Class IV, Secondary Enclosure.
- Class V, Shelter in Place.

Class I, full integration

Permanent modifications are made to the building(s), and CBRN filter units are fully integrated with existing heating, ventilating, and air conditioning (HVAC) system(s). Dampers controlling ventilation openings automatically activate when filter units turn on. There are permanent accommodations for an airlock and contamination control area. The Collectively Protected — Emergency Medical System (CP-EMEDS) is an example of a Class I, fully integrated collectively protected system.

Class II, partial integration

Permanent modifications and sealing measures are made to the building or a portion of it, and partial integration of HVAC filter units or alternate COLPRO systems allows heating/cooling. Manual

dampers control outside air and exhaust. Airlock integration is permanent or partial. The contamination control area can be permanent or temporary (e.g., a tent).

Class III, expedient

Selected portions of the building are sealed by temporary measures such as plastic sheeting and tape. Transportable filter units are temporarily mounted to the building. Heating/cooling systems may or may not be employed. A temporary airlock and contamination control area are established.

Class IV, secondary enclosure

The building is not tight enough to economically maintain pressurization, but it is suitable for using portable internal enclosures or liner systems such as the M28 or M20 COLPRO equipment previously mentioned. The system allows use of the existing HVAC or alternate system. A temporary airlock and contamination control area are established. Examples include warehouses, hangars, and deployable medical-systems-equipped hospitals and maintenance bays.

Class V, shelter in-place

Sheltering in-place is simply remaining within the facility that you're in when an incident occurs; not typically part of deliberate shelter planning for enemy CBRN attack.

While COLPRO is effective for many vapor and aerosol hazards, including chemical and biological warfare agents, the radiation hazards created by radioactive fallout or gamma-emitting RDDs are only partially mitigated by COLPRO keeping the radioactive material out of the shelter. As you learned in earlier lessons, gamma radiation can travel long distances and penetrate building materials. The type and thickness of the building material will determine how much of the gamma radiation can penetrate the facility walls to create a hazard inside the shelter. The amount of protection against outdoor gamma hazards provided by a facility depends upon the building's protection factor, which is the ratio of outdoor to indoor dose rates. The larger the protection factor, the more protection provided. For example, people inside a building with a protection factor of two will receive one-half of the dose received by unprotected personnel outside the shelter. People inside a building with a protection factor of 100 will only receive 1/100th of the dose received by personnel outside. Where radiological or nuclear attacks are a significant threat to an installation, pre-calculating or measuring the protection factor of enemy attack shelters is essential to effective BE HRA activities in the CBRN control center.

The protection factor of a shelter can be calculated by dividing the outside intensity reading by the inside intensity reading. Let's say you wanted to determine the protection factor of a shelter. You will need to take two readings: one outside the shelter and one inside the shelter. In this case, let's say the outside reading is 150 Roentgens per hour (R/hr) and the inside reading is 5 R/hr. The protection factor for your shelter is 30.

Going a step further, let's say that the installation operations center is requesting a current outside dose rate from your shelter. What would you tell them? You can use the formula below to calculate the outside dose rate without leaving the shelter.

outside reading = inside reading x protection factor

For example, let's say that your ADM–300 is reading 7.5 R/hr inside your shelter. Simply multiply the inside reading (7.5 R/hr) by the protection factor of 30 to calculate the outside reading.

7.5 R/hr x 30 = 225 R/hr

Now you can inform the operations center that the outside reading is 225 R/hr. Calculating the outside reading in this manner protects shelterees from unnecessary exposures. For example, let's say it takes 5 minutes to exit a shelter, take a reading, and return. Using the outside reading you just calculated (225 R/hr), this 5-minute excursion would have resulted in an exposure of 18.75 radiation absorbed dose (rad).

Because few shelters provide complete protection from radiological hazards, and calculated protection factors are just estimates of the true protection offered by attack shelter structure, specialized reconnaissance and shelter management team personnel provide measured dose rate and accumulated dose information to the CBRN control center so BE personnel can conduct more reliable HRA and provide advice to commanders on the risks to personnel in attack shelters.

With external dose rate estimates from readiness and emergency management flight personnel modeling an approaching nuclear fallout plume and protection factor for the installation attack shelters, BE personnel can use tools like the CBRN Health Assessment and Risk Tool to calculate expected stay times and health risk to personnel in the shelters.

Shelters for terrorist use of CBRN

Similar to major accidents, AF emergency response planners have not often developed deliberate shelter plans for terrorist attacks, including terrorist use of CBRN materials. With the increased understanding of terrorist threats and critical mission operations that must continue after a terrorist attack, however, many installations have now considered shelters as part of the overall vulnerability reduction or risk mitigation strategy for an installation. While the range of CBRN material that terrorists might employ is generally larger than those from an enemy attack threat, deliberate shelter planning for terrorist attacks, including COLPRO, shelter classes, etc., is not very different from enemy attack. One major difference, however, for garrison locations that there is a general desire to evacuate all non-essential personnel away from the installation and only shelter those critical persons performing critical missions that must continue through the hazard period. At deployed locations, particularly in hostile or non-permissive environments, evacuation away from an installation may be less feasible or safe, so the entire installation population may need shelter facilities.

Shelter management team

A very important component of any deliberately planned shelter is the shelter management team which plans, prepares, trains, and executes duties needed to ensure healthy and safe operations of the shelter. The shelter management team obtains and checks shelter equipment and supplies, including items for the shelter's contamination control area. They also preparing the shelters for occupancy and pre-position personal gear, equipment, food, clothing, first aid supplies, and hygiene kits for occupants. When the shelter is activated and occupied, the shelter management team conducts damage assessment and post attack reconnaissance, including using basic chemical warfare agent and radiological detection equipment. The shelter management team operates and maintains COLPRO equipment and the shelter's contamination control area. For radiological or nuclear hazards, the shelter management team will operate dosimeters, record accumulated doses, and report status to BE personnel at the CBRN control center.

While BE has no formal role outlined in shelter management regulations, as the installations HRA experts, they assist readiness and emergency management flight personnel with training shelter management team members on specialized equipment (e.g., electronic personal dosimeters) that BE personnel are proficient at operating. After an incident has occurred and shelters are operating, BE performs a central HRA role for the installation; this may include assisting or verifying shelter management team hazard measurements that are important for HRA and commander decisions. For example, in the event of a radiological or nuclear incident, BE may be called upon to assist shelter management teams in maintaining radiological shelter logs and personal logs. Standard HRA responsibilities, such as drinking water source evaluation, indoor air quality/HVAC assessment, and protection factor calculation for facilities, involve BE personnel.

Shelter-in-place

Shelter-in-place is an emergency management action where people are directed to go or stay indoors when a hazardous condition exists, essentially making a shelter out of their current location. Any fully enclosed, unpressurized structure that prevents the entry of liquid contamination is suitable for this purpose. Most permanent airbase structures and some temporary structures with low air leakage rates

will suffice for this type of protection. Sheltering in-place is used by ICs when it is more advantageous for personnel to remain indoors rather than evacuate and become exposed to the full CBRN effects. Sheltering in-place can provide short-term protection to the occupants before the hazard has passed or before they can be evacuated to a safe area. Sheltering in-place can be used with no prior deliberate planning, evaluation of the facility, or training of personnel, but it is most effective when building occupants plan and practice their actions in advance. Speed is essential for this plan of action to work, since the quicker actions are taken, the less airborne contaminants will enter the facility.

Because sheltering in-place operations often rely on creating a temporary indoor atmosphere that is separated from the outdoor environment, installation shelter-in-place planning must include identifying procedures for each facility to turn off its HVAC systems. Just as with attack shelters, for radiological hazards that create significant gamma or x-ray fields, the amount of protection provided by sheltering in-place depends upon the building's protection factor. Where radiological accidents or terrorist use of radiological materials is a significant threat to an installation, pre-calculating the protection factor of installation facilities can assist quick shelter-in-place decisions after an incident has occurred.

853. Response materials and sources

When conducting or supporting vulnerability and risk assessment activities, there are a number of references and resources available for BE personnel to use. For the purpose of this discussion, the materials have between separated into three categories:

1. Threat, vulnerability, and risk assessment materials and sources.
2. Planning materials and sources.
3. Response materials and sources.

Threat, vulnerability, and risk assessment materials and sources

Air Force Tactics, Techniques, and Procedures (AFTTP) 3–2.82_IP, *Occupational and Environmental Health Site Assessment*, contains a section on "pre-deployment and baseline activities" for OEHSA that lists and describes a wealth of hazard and threat information resources, from home station documentation, such as Environmental Restoration Program documents, to formal intelligence products, such as the DOD National Center for Medical Intelligence (NCMI).

The *Bioenvironmental Engineering Field Manual* has information on health threats throughout its sections and contains an appendix with addresses of Secret Internet Protocol Router (SIPR) sites where BE personnel can access classified health threat information.

For VA, US Air Force School of Aerospace Medicine (USAFSAM) has developed two guidance documents for BE personnel:

- *Water Vulnerability Assessment Technical Guide.*
- *TIC/TIM Vulnerability Assessment Technical Guide*.

These guides, along with many additional OEHSA information resources, can be found at the USAFSAM Environmental Safety, and Occupational Health (ESOH) Service Center Website.

While not directly a BE responsibility, the installation should determine where and how sortie generation and other maintenance processes would be accomplished and how they would be vulnerable to degradation in a CBRN environment. Air Force Tactics, Techniques, and Procedures (AFTTP) 3–2.54, *Multiservice Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical Vulnerability Assessment*, provides detailed guidelines installations should use during this process.

Planning materials and sources

When beginning to plan emergency response actions, BE personnel should become members of and use the excellent materials and information at the AF Emergency Management Community of Practice (EM CoP), which can be found on the AF Portal.

Linked to the AF EM CoP and a great source of BE specific emergency response planning material is the BE CoP, which has many BE members.

Most BE personnel are aware of the USAFSAM ESOH Service Center website for non-emergency response guidance and information, but the website also contains a significant amount of information relevant to planning emergency response actions.

The following AFPAM/AFMANs are a great resource for BE personnel to understand the Air Force Emergency Management Program details and help with planning BE response actions to support the program.

- AFPAM 10–219, Volumes 1–3 are guidance documents with broad application to commanders and emergency response professionals.
- AFMAN 10–2502, *Air Force Incident Management System (AFIMS) Standards and Procedures.*
- AFMAN 10-2503, *Operations in a Chemical, Biological, Radiological, and Nuclear (CBRN) Environment.*

In addition to AF specific guidance, there are many references that are used by all of the joint services, called multi-service tactics, techniques, and procedures (MTTP) that contain additional useful response information and are particularly relevant when assigned or deployed in a joint environment. The table that follows summarizes MTTPs relevant to BE emergency response planning.

MTTPs Relevant to BE Emergency Response Planning	
Number	**Title**
AFTTP 3–2.37_IP	*Multi-service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Consequence Management Operations.*
AFTTP 3–2.42	*Multi-service Doctrine for Chemical, Biological, Radiological, and Nuclear Operations.*
AFTTP 3–2.44	*Multi-service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Reconnaissance and Surveillance.*
AFTTP 3–2.46	*Multi-service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Passive Defense..*
AFTTP 3–2.55	*Chemical, Biological, Radiological, and Nuclear Threats and Hazards*.
AFTTP 3–2.56	*Multi-service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Contamination Avoidance.*
AFTTP 3–2.60	*Multi-service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Decontamination.*
AFTTP 3–42.32	*Home Station Medical Response to Chemical, Biological, Radiological, and Nuclear (CBRN) Incidents.*

AFTTPs can be can be found on the AF publications website by searching for “AFTTP” or copies can be requested from the Air Force Civil Engineer Support Agency (AFCESA).

The US Army Public Health Command (USAPHC) produces several technical documents that help BE personnel plan emergency response actions. USAPHC Technical Guide 230, *Environmental HRA and Chemical Exposure Guidelines for Deployed Military Personnel*, contains short term military exposure guidelines that can be used for HRA in military unique emergency response situations. Also, USAPHC Report No. 47–EM–5863–04, *Acute Toxicity Estimation and Operational Risk*

Management of Chemical Warfare Agent Exposure, explains the basis for much of the chemical warfare agent HRA that BE personnel employ after a CBRN attack and can help BE personnel apply judgment in planning for this difficult and dangerous response.

As discussed earlier, the *BE Field Manual* Appendixes A and B contain excellent sources of information that can be used for planning as well as threat, vulnerability, and risk assessment.

Response materials and sources

Good planning can provide BE personnel with the information they need to handle most emergency responses they will support, but there are also many materials and sources BE personnel will bring with them or use during an incident response.

Recall from earlier lessons that in major accidents and terrorist use of CBRN materials, initial information will usually come from witnesses, victims, and first responders, such as fire department personnel. BE personnel may also be able to glean initial information themselves by examining Safety Data Sheets, vehicle placards, shipping documents, chemical inventories, containers, etc., as well as interviewing people familiar with the incident site.

Of course the installation's CEMP 10–2, the medical contingency response plan, and other supporting BE checklists are critical for any response to ensure that during the confusion and stress of an incident response, critical equipment, procedures, and information needed to accomplish incident response missions are not forgotten.

A great resource for all emergency responders, including BE personnel, is the Department of Transportation's (DOT) *Emergency Response Guidebook*. During Hazardous Material Operations and Specialist training, BE personnel learn how to effectively use the guide.

For chemical exposures in an emergency response situation, BE personnel will often refer to the American Industrial Hygiene Association's (AIHA) *Emergency Response Planning Guidelines (ERPG) and Workplace Environmental Exposure Levels (WEEL) Handbook.* The handbook contains tables of ERPGs and explains their definition and use. Figure 6–24 provides an example of information that might be found in the handbook.

Chemical (CAS Number)	**ERPG–1**	**ERPG–2**	**ERPG–3**
Acetaldehyde (75–07–0)	10 ppm	200 ppm	1000 ppm
ERPG Definitions			
ERPG–1:	*"The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than* ***mild, transient adverse health effects or without perceiving a clearly defined objectionable odor****."*		
ERPG–2:	*"The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing* ***irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action****."*		
ERPG–3:	*"The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing* ***life-threatening health effects****."*		

Figure 6–24. Example AIHA ERPG table.

Many BE personnel use the NIOSH *Pocket Guide to Chemical Hazards* as part of their day-to-day HRA and OEHSA operations, but the guide is also a wealth of information for emergency responders, including IDLH values, physical and chemical properties, links to DOT guides, and other critical information.

As you have learned in earlier parts of this unit, the CHART program and its companion, the Chemical Hazard Estimation Method and Risk Assessment Tool (CHEMRAT), are very useful references for assessing hazards and estimating hazard duration during CBRN incidents, particularly chemical warfare agent attacks. These tools are available at the USAFSAM ESOH Service Center website.

An important reference for aircraft mishaps is TO 00–105E–9, *Aerospace Emergency Rescue and Mishap Response Information*, which contains detailed information on potential mishap site hazards including the location and type of composite material, radioactive materials, pyrotechnic devices, and many other important items (fig. 6–25). BE personnel can get a copy of the TO from their local fire and emergency services flight or by contacting AFCESA's Fire and Emergency Services branch.

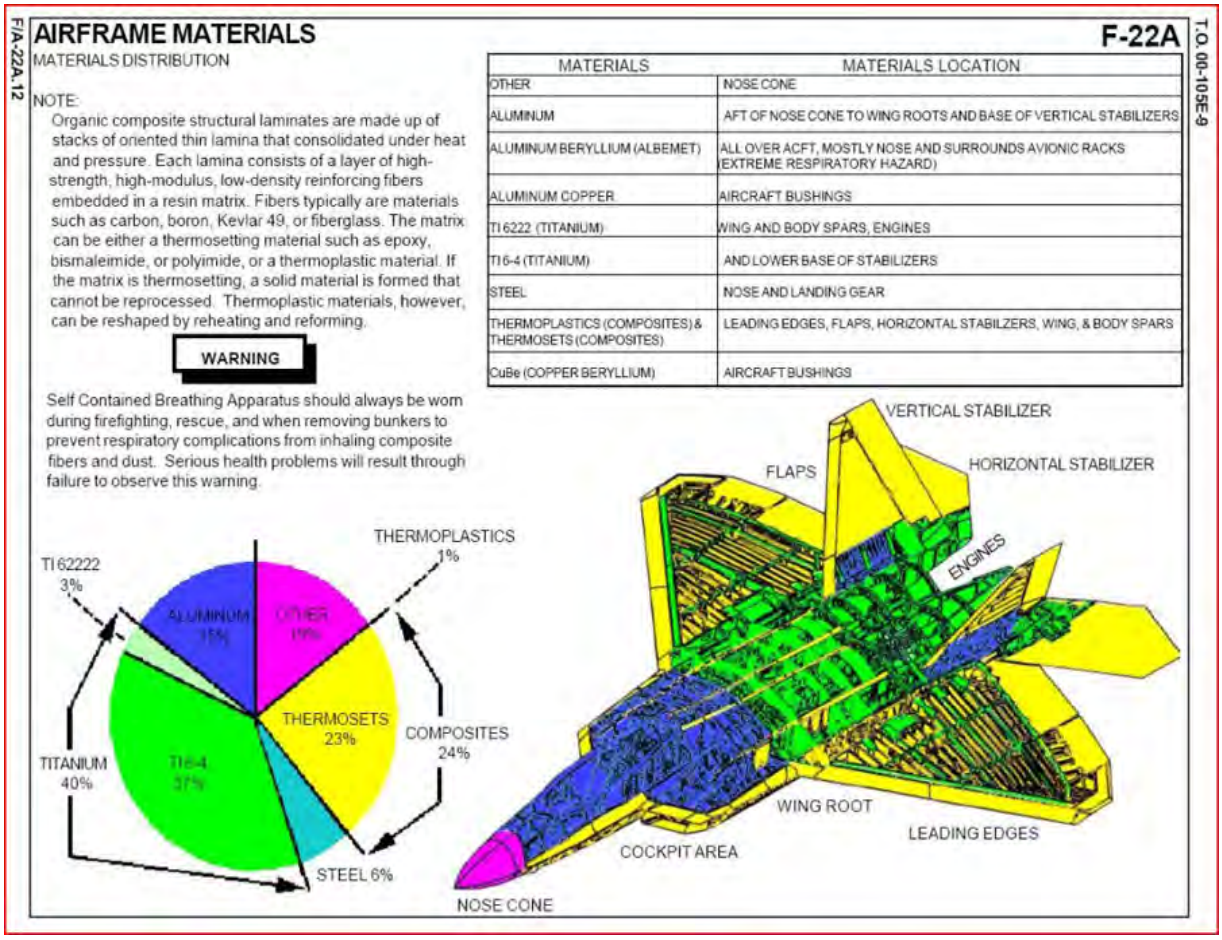

Figure 6–25. Example page taken from TO 00–105E–9.

The BE Field Manual is certainly a good reference for vulnerability assessment and planning, but you will also find it has several appendixes that can be used as quick reference during an incident response. Similarly, your Airman's Manual (AFTTP 3-4) contains many quick reference guides (radio communications, heat stress, MOPP levels, etc.) that are very useful during emergency response operations and give you simple tools to explain to other Airmen actions they can take to reduce health risks.

Webster's Dictionary defines "ready" simply as the state of being prepared to act. Planning greatly increases the likelihood of our success in this endeavor. Because of the magnitude of the BE's responsibilities, an extensive and elaborate planning process is required to maintain an effective posture of readiness. Following the framework outline by the Air Force Emergency Management

Program heightens our ability to help in preventing incidents, prepare for those incidents that cannot be prevented, and respond effectively when an incident occurs.

References

[1] International Atomic Energy Agency (IAEA), The Radiological Accident in Goiania, Austria: IAEA, September 1988.

[2] AFDD 3–40, *Counter-Chemical, Biological, Radiological and Nuclear Operations,* 26 January 2007, Last Review 1 November 2011.

[3] AFI 10–2501, *Emergency Management Program Planning,* 10 March 2020.

[4] AFTTP 3–42.32, *Home Station Medical Response to Chemical, Biological, Radiological, and Nuclear Incidents,* 2013.

[5] AFTTP 3–2.42_IP, *Multi-Service Doctrine for Chemical, Biological, Radiological, and Nuclear Operations,* 2011.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

846. Chemical, biological, and radiological hazards

1. What are the factors that make biological agents a significant threat?

2. List the four types of incidents that affect AF operations as outlined in AFI 10–2501.

847. Air Force Emergency Management Program

1. The AF fits into the NRF by following what management system?

2. What are the primary missions of the Air Force Emergency Management Program?

3. What role does BE personnel play in the Air Force Emergency Management Program?

4. Why are BE personnel included in the installation threat working group?

5. Under the emergency management construct, what is the mission of the first responders?

6. What response element does BE personnel fall under?

7. What is the role of the Emergency Operations Center during response operations?

8. What is the function of the command post within the installation control center?

848. Roles and interaction of BE in response operations

1. What two common sections make up an incident command structure and what are their functions?

2. After responding to an incident, you are tasked with entering the incident site to collect a sample. What section of the incident command structure are you aligned under?

3. If you are evaluating the incident site sample data and working with a readiness and emergency management team member to assess the potential health and operation risk to personnel downwind of the site, then you are likely assigned to what section of the incident command structure?

4. The EOC is organized into 15 ESFs. What role do they serve?

5. Describe the role of the CBRN control center within an AF EOC.

6. Describe the role of BE personnel within the CBRN control center.

849. Emergency Planning and Community Right-to-Know Act

1. What prompted Congress to enact EPCRA?

2. Congress required each state to take what action in order to implement EPCRA?

3. When must a facility comply with the EPCRA emergency planning requirements?

4. What is the role of the NRC in the event of a reportable release?

850. Toxic industrial chemical/toxic industrial material vulnerability assessments

1. What makes TICs/TIMs an attractive improvised weapon?

2. What is are the functions of the TIC/TIM VA?

3. Match the vulnerability examples in column A to the classification requirements in column B. Choices in column B can be used once, more than once, or not at all

Column A	*Column B*
____ (1) Portions of a document where a vulnerability has been identified and associated with a specific US military site.	a. CONFIDENTIAL or SECRET.
____ (2) Portions of a document where a vulnerability has been identified but is not associated with a specific US military site identified in the same report.	b. FOR OFFICIAL USE ONLY.
____ (3) Portions of a document not identifying specific vulnerabilities, but containing information that if released to the public could be exploited.	c. UNCLASSIFIED.

851. Collecting data required for a toxic industrial chemical/toxic industrial materials (TIC/TIM) vulnerability assessment

1. What document will guide you through performing a TIC/TIM VA?

2. The assessment process involves collection and evaluation of information regarding what major components?

3. Match the phase of a TIC/TIM VA in column B to the description of what occurs during the phase in column A.

Column A	*Column B*
____ (1) Identify the lead assessor.	a. Planning and Coordination
____ (2) Identify all TICs/TIMs that may exist on and around the base within a 20 mile radius.	b. Data Collection
____ (3) Identify team members and assign roles and responsibilities.	c. Analysis
____ (4) Develop worst-case and alternative scenarios that display potential to impact the base.	
____ (5) Contact or visit facilities using or storing TICs/TIMs.	
____ (6) Determine the risk associated with scenarios.	

4. What type of TICs do you not include when collecting your TIC/TIM data?

5. How often is the TIC/TIM VA updated?

852. Shelter operations

1. What key elements are needed to ensure a successful shelter program?

2. What are the two primary shelter types within the Air Force Emergency Management Program?

3. Who is responsible for inspecting a facility to determine if it can be used as a shelter?

4. What type of shelter are you working from if you were assigned to the command post during a CBRN attack?

5. When gamma radiation is of concern, what considerations must be given when choosing a building for sheltering in-place?

6. What is the major difference in shelter planning for terrorist attacks in garrison versus a deployed location?

7. When are ICs most likely to implement shelter-in-place to provide protection to AF personnel?

853. Response materials and sources

1. Cite the three categories that response materials can be separated into?

2. What resource could help BE personnel apply judgment in planning for a chemical warfare agent risk assessment following a CBRN attack?

3. What two references are extremely useful tools particularly in response operations where chemical warfare agents are involved?

4. What reference material contains detailed information on potential mishap site hazards associated with aircraft mishaps?

5. What reference material contains quick reference guides for radio communications and heat stress?

Answers to Self-Test Questions

846

1. (1) Small doses can produce lethal or incapacitating effects over an extensive area
   (2) They are difficult to detect in a timely manner.
   (3) They are easy to conceal and can be covertly deployed.
   (4) The large variety of potential biological agents significantly complicates effective prophylactic and therapeutic treatments.
2. (1) Natural disaster.
   (2) Major accident.
   (3) CBRN attack.
   (4) Terrorist use of CBRN.

847

1. The NIMS.
2. To save lives; minimize the loss or degradation of resources; and continue, sustain, and restore operational capability in an all-hazards physical threat environment at AF installations worldwide.
3. BE personnel apply their HRA and OEHSA skills to provide commanders and other decision-makers critical information for selecting appropriate courses of action.
4. Because of their expertise with understanding the risk from the various health threats they evaluate during VAs.
5. To establish initial command and control, save lives, and control hazards at the accident site.
6. Emergency responders.
7. To direct, monitor, and support the installation’s actions before, during, and after an incident.
8. It functions as the essential command and control node for the installation commander and senior staff.

848

1. An operations section to conduct tactical incident site operations, and a plans section, where plans for the incident site operations are developed and reviewed.
2. Operations section.
3. Plans section.
4. Provide support, resources, program implementation, and services that are most likely needed during an emergency response.
5. Directs CBRN reconnaissance activities to shape the hazards and advises the commander on hazards, countermeasures, and protective actions.
6. Provide health risk advice to the commander.

849

1. Concerns regarding the environmental and safety hazards posed by the storage and handling of toxic chemicals.
2. Appoint a State Emergency Response Commission.
3. If a facility has any extremely hazardous substances on-site greater than the relevant TPQ.
4. The NRC acts as the single federal point of contact for all pollution incident reporting.

850

1. Chemical production in very large quantities, modes of transportation, large storage facilities, universal distribution, and potential to cause illness/injury.
2. (1) Provide a general indication as to the types of events that could occur at your installation, (2) evaluate/estimate the relative severity and risk of potential consequences from TIC/TIM releases, (3) provide rough estimates of the potential magnitude of consequences.
3. (1) a.
   (2) b.
   (3) b.

851

1. The US Air Force School of Aerospace Medicine Assessment Methodology for Toxic Industrial Chemicals/Toxic Industrial Materials Guidance Manual.
2. (1) Preparation of an inventory of TIC/TIM on or near the AF base.
   (2) Characterization of worst-case and alternative scenarios.
   (3) Determination of potential severity of toxic releases and radioactive exposures.
   (4) Determination of probability of toxic releases and radioactive exposures.
   (5) Determination of risk and ranking of scenarios.
3. (1) a.
   (2) b.
   (3) a.
   (4) c.
   (5) b.
   (6) c.
4. Chemical compounds that are flammable/explosive but have little or no acute toxicity.
5. Annually.

852

1. Adequate shelters, a base population familiar with shelter procedures, a competent staff trained in shelter management, an ability to activate and close shelters at the appropriate times, an ability to stock shelters with required supplies and equipment, and an ability to occupy shelters for extended periods.
2. Shelters that are deliberately planned for a particular incident and its hazards and sheltering in-place.
3. The base CE.

4. CBRN attack shelter.
5. Type and thickness of the building material.
6. For garrison locations, there is a general desire to evacuate all non-essential personnel away from the installation and only shelter those critical persons performing critical missions that must continue through the hazard period. For locations, particularly those in hostile or non-permissive environments, evacuation away from an installation may be less feasible or safe, so the entire installation may need shelter facilities.
7. When it is more advantageous for personnel to remain indoors rather than evacuate and become exposed to the full CBRN effects.

853

1. (1) Threat, vulnerability, and risk assessment materials and sources.
   (2) Planning materials and sources.
   (3) Response materials and sources.
2. USAPHC Report No. 47–EM–5863–04.
3. CHART and CHEMRAT.
4. TO 00–105E–9.
5. Airman's Manual (AFTTP 3-4).

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

86. (846) Air Force Instruction (AFI) 10–2501, Emergency Management Program, describes four types of incidents that affect Air Force (AF) operations. An enemy missile with a chemical warfare agent warhead would be an example of what type of incident?
    a. Terrorist use of chemical, biological, radiological, and nuclear (CBRN).
    b. Natural disaster.
    c. Major accident.
    d. CBRN attack.

87. (847) The role of the National Incident Management System (NIMS) in incident response is to
    a. provide the framework of emergency response organizations and capabilities.
    b. establish a standardized incident management structure used by responders.
    c. integrate key aspects of response management within a common structure.
    d. respond to disasters and other emergencies.

88. (847) What working group focuses primarily on analyzing threats and providing recommendations to the commander?
    a. Installation threat working group (TWG).
    b. Installation force protection working group.
    c. Emergency management working group.
    d. Disaster response force (DRF) working group.

89. (848) During response operations, if you are donning protective equipment to enter a site to perform sampling, to what section of the response structure are you assigned?
    a. Plans.
    b. Resources.
    c. Technical.
    d. Operations.

90. (849) What did Congress enact in response to concerns regarding the environmental and safety hazards posed by the storing and handling of toxic chemicals?
    a. State Emergency Response Commission.
    b. Superfund Amendments and Reauthorization Act (SARA).
    c. Emergency Planning and Community Right-to-Know Act (EPCRA).
    d. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

91. (849) Which is a key provision of the Emergency Planning and Community Right-to-Know Act (EPCRA)?
    a. Emergency planning.
    b. Toxic release inventory.
    c. Emergency release notification.
    d. All of the above are key provisions of EPCRA.

92. (849) Which agency acts as the single federal point of contact for all pollution incident reporting?
    a. National Response Center (NRC).
    b. United States Coast Guard (USCG).
    c. Environmental Protection Agency (EPA).
    d. Occupational Safety and Health Administration (OSHA).

93. (850) All these characteristics make toxic industrial chemicals (TIC) and toxic industrial materials (TIM) attractive improvised weapons except
    a. very large quantities.
    b. modes of transportation.
    c. inability to safeguard against.
    d. potential to cause illness/injury.

94. (850) The main purpose of a toxic industrial chemical/toxic industrial materials (TIC/TIM) vulnerability assessment (VA) is it
    a. assesses health risk for the surrounding community within 20 miles radius.
    b. indicates areas where security cameras should be installed on the installation.
    c. provides information to set force protection condition levels.
    d. provides an indication of the types of incidents that could occur at your installation.

95. (850) If a toxic industrial chemicals (TIC) and toxic industrial materials (TIM) vulnerability assessment (VA) final report identifies and associates a vulnerability to a specific United States (US) military site, it must receive what classification?
    a. TOP SECRET.
    b. CONFIDENTIAL or SECRET.
    c. FOR OFFICIAL USE ONLY.
    d. UNCLASSIFIED.

96. (851) When identifying toxic industrial chemicals (TIC) and toxic industrial materials (TIM) in the vicinity of an installation, you should collect data on and evaluate facilities within how many miles of the installation?
    a. 5.
    b. 10.
    c. 15.
    d. 20.

97. (852) What are the two primary types of shelters portrayed in the Air Force Emergency Management Program?
    a. Emergency operations and shelter-in-place.
    b. Deliberately planned and shelter-in-place.
    c. Emergency operations and contamination control.
    d. Deliberately planned and contamination control.

98. (852) Under shelter operations, who spearheads identifying and evaluating installation facilities that can be used as shelters?
    a. Incident commander (IC).
    b. Base civil engineer (CE).
    c. Bioenvironmental engineer (BEE).
    d. Installation safety officer.

99. (853) Which of the source materials provides short-term military exposure guidelines (MEG) for HRA in military unique situations?
    a. AFTTP 3–2.82, Occupational and Environmental Health Site Assessment.
    b. USAPHC Technical Guide 230, Chemical Exposure Guidelines for Deployed Military Personnel.
    c. AFMAN 10–2502, Air Force Incident Management System (AFMIS) Standards and Procedures.
    d. USAPHC Report No. 47–EM–5863–04, Acute Toxicity Estimation and Operational Risk Management of Chemical Warfare Agent Exposure.

100. (853) Which of the source materials are useful for assessing hazards and estimating hazard duration during chemical, biological, radiological, and nuclear (CBRN) incidents?
    a. Workplace Environmental Exposure Levels (WEEL).
    b. Emergency Response Planning Guidelines (ERPG).
    c. Chemical Hazard Estimation Method and Risk Assessment Tool (CHEMRAT).
    d. MEDIC CD.

Glossary of Abbreviations and Acronyms

µCi/L	microcuries per liter
µg/L	micrograms per liter
°	degree
°C	degrees Celsius
°F	degrees Fahrenheit
>	greater than
≥	greater than or equal to
<	less than
A	area
acfm	actual cubic feet per minute
ACGIH	American Conference of Government Industrial Hygienists
A_d	duct area
A_f	face area
AF	Air Force
AFCESA	Air Force Civil Engineer Support Agency
AFH	Air Force handbook
AFI	Air Force instruction
AFIMS	Air Force Incident Management System
AFMAN	Air Force manual
AFOSH	Air Force Occupational Safety and Health
AFPAM	Air Force pamphlet
AFSC	Air Force specialty code
AFTTP	Air Force tactics, techniques, and procedures
AIHA	American Industrial Hygiene Association
APF	assigned protection factor
AT	antiterrorism
ATF	Bureau of Alcohol, Tobacco, Firearms and Explosives
ATO	antiterrorism officer
ATWG	antiterrorism working group
AV	actual velocity; airflow volume
AWT	advanced water testing
AWWA	American Water Works Association
BE	bioenvironmental engineering
BEE	bioenvironmental engineer
BEI	biological exposure index

BP	barometric pressure
BPM	backflow program manager
C	CONFIDENTIAL; concentration
CAMS	Core Automated Maintenance System
CBRN	chemical, biological, and radiological
CBRN	chemical, biological, radiological, and nuclear
CBRNE	chemical, biological, radiological, nuclear, or high-yield explosive
CDC	career development course; Centers for Disease Control and Prevention
C_e	coefficient of entry
CE	civil engineering
CEA	civil engineering asset management
CEMP	comprehensive emergency management plan
CEO	civil engineering operations
CEP	civil engineering programs
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEX	civil engineering emergency management and fire emergency services
cfm	cubic feet per minute
cfm/ft^2	cubic feet per minute per square foot
CFR	Code of Federal Regulations
CFU	colony-forming unit
CGI	combustible gas instrument; combustible gas indicators
CHEMRAT	Chemical Hazard Estimation Method and Risk Assessment Tool
CHO	chemical hygiene officer
CHP	chemical hygiene plan
CIP	Critical Infrastructure Program
cl2	chloramine; chlorine
cm^3	cubic centimeter
CO2	carbon dioxide
COLPRO	collective protection
cop	community of practice
cp	cup
CP-EMEDS	Collectively Protected — Emergency Medical System
CSPT	confined space program team
CU	color unit
CVAMP	Core Vulnerability Assessment Management Program
CWS	community water system
D	diameter
d	density factor

DAVIS/DITIS	Defense Automated Visual Information System/Defense Instructional Technology Information System
DBCP	dibromochloropropane
DLA	Defense Logistics Agency
DNA	deoxyribonucleic acid
DOD	Department of Defense
DODI	Department of Defense instruction
DOEHRS	Defense Occupational and Environmental Health Readiness System
DOT	Department of Transportation
dp	drop
DRF	disaster response force
DTRA	Defense Threat Reduction Agency
E. coli	Escherichia coli
ECC	emergency communications center
EESOH-MIS	Enterprise Environment Safety and Occupational Health–Management Information System
EGS	environmental governing standard
EM	emergency management
EM CoP	Emergency Management Community of Practice
EMIS	Environmental Management Information System
EOC	emergency operations center
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERPG	Emergency Response Planning Guidelines
ESF	emergency support functions
ESOH	Environmental Safety and Occupational Health
FAC	free available chlorine
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FES	fire emergency services
FGS	final governing standard
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOCUS	focused, organized, clarity, understanding, supported
FOUO	FOR OFFICIAL USE ONLY
FPCON	force protection condition
fpm	feet per minute
fps	feet per second
FSS	force support squadron

FSTR	full spectrum threat response
ft	feet/foot
ft/sec	feet per second
ft/sec^2	feet per second per second
ft^1	linear feet/foot
ft^2	square feet/foot
ft^3	cubic feet/foot
ft^3/min	cubic feet per minute
gal	Gallon
gal/hr	gallon per hour
GHS	Globally Harmonized System
GSA	General Services Administration
H2S	Hydrogen sulfide
HAA5	Haloacetic acids-five
HAZCOM	hazard communication
HAZMART	hazardous materials pharmacy
HAZMAT	hazardous material
HCS	hazard communication standard
h_e	hood entry losses
HEPA	high efficiency particulate air
Hg	mercury
HHS	Department of Health and Human Services
HMIRS	Hazardous Materials Information Resource System
HMMP	Hazardous Material Management Program
HPC	heterotrophic plate count
hr	hour
HRA	health risk assessment
HSPD–5	Homeland Security Presidential Directive–5
HTH	high test hypochlorite (dry chlorine granules)
HVAC	heating, ventilation, and air conditioning
HVLP	high velocity, low pressure
IAA	isoamyl acetate (banana oil)
IAEA	International Atomic Energy Agency
IAQ	indoor air quality
IC	incident commander
ICC	installation control center
ICS	incident command system
IDLH	immediately dangerous to life or health

IED	improvised explosive device
IG	inspector general
IMI	interactive multimedia instruction
in wg	inches water gauge
IWPS	individual water purification system
JA	judge advocate
JSA	job safety analysis
L	liter
lb/hr	pound(s) per hour
lb-mole	pound-molecular weight
lbs	pound(s)
lbs/ft^3	pounds per cubic foot
LCD	liquid crystal display
LEL	lower explosive limit
LEPC	local emergency planning committee
LFL	lower flammable limit
LRS	Logistics Readiness Squadron
LTP	long-term potability
MAJCOM	major command
MAJCOM/SG	major command/surgeon general
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MEG	military exposure guideline
MEK	methyl ethyl ketone
MEP	master entry plan
MF	membrane filter
MFL	million fibers per liter
MFWS	military field water standard
mg	milligram
mg/L	milligram/liter
mL	milliliter
mm	millimeter
MOPP	mission oriented protective posture
MPN	most probable number
mrem/yr	millirems per year
MSDS	material safety data sheet
MSR	Mountain Safety Research
MTTP	multi-service tactics, techniques, and procedures

MUC	maximum use concentration
N/A	not applicable
NBC	nuclear, biological, chemical
NCMI	National Center for Medical Intelligence
NCO	noncommissioned officer
NCWS	non-community water system
NDI	non-destructive inspection
NIMS	National Incident Management System
NIOSH	National Institute for Occupational Safety and Health
NORTHCOM	Northern Command
NPDWR	National Primary Drinking Water Regulations
NRC	National Response Center
NRF	National Response Framework
NSDWR	National Secondary Drinking Water Regulations
NSN	national stock number
NTE	not to exceed
NTNCWS	non-transient non-community water system
NTU	nephelometric turbidity unit
OCR	office of collateral responsibility
OEBGD	Overseas Environmental Baseline Guidance Document
OEG	operational exposure guidance
OEH	occupational and environmental health
OEH-MIS	occupational and environmental health management information system
OEHSA	occupational and environmental health site assessment
OEL	occupational exposure limit
OI	operating instructions; office instruction
OPR	office of primary responsibility
ORM	operational risk management
OSHA	Occupational Safety and Health Administration; Occupational Safety and Health Act
P/A	presence/absence
PA	public affairs
PAH	polycyclic aromatic hydrocarbon
PAM	preventive and aerospace medicine
PATS	Protective Assessment Test System
PCB	polychlorinated biphenyls
pCi/L	picocuries per liter
PCS	permanent change of station

PEL	permissible exposure limits
pH	potential for hydrogen
PH	public health
PHMB	polyhexamethylene biguanide
PM	preventive medicine
PMEL	precision measurement equipment laboratory
PPE	personal protective equipment
ppm	parts per million
psi	pounds per square inch
pt	pint
PWS	public water system
Q	airflow volume
$\mathbf{Q_{base}}$	baseline data for airflow volume
$\mathbf{Q_{hi}}$	upper end of the range for airflow volume
QLFT	qualitative fit-testing
$\mathbf{Q_{low}}$	lower end of the range for airflow volume
$\mathbf{Q_m}$	airflow volume at nonstandard conditions
QNFT	quantitative fit-testing
$\mathbf{Q_s}$	airflow volume at standard conditions
qt	quart
R/hr	Roentgens per hour
RAC	risk assessment code
rad	radiation absorbed dose
RCRA	Resource Conservation and Recovery Act
RDD	radiological dispersal device
RED	radiological emission device
rem	roentgen equivalent man
RES	radiation exposure status
RO	reverse osmosis
ROTA	release-other-than-attack
ROWPU	reverse osmosis water purification unit
RP	respiratory protection
RPM	revolutions per minute
S	SECRET; specific gravity
SARA	Superfund Amendments and Reauthorization Act
SARS	severe acute respiratory syndrome
SCBA	self-contained breathing apparatuses
scfm	standard cubic feet per minute

SCG	security classification guide
SDS	safety data sheets
SDWA	Safe Drinking Water Act
SEG	similar exposure groups
SERC	State Emergency Response Commission
SF	security forces
SIPR	Secret Internet Protocol Router
SIPRNet	Secret Internet Protocol Router Network
SMCL	secondary maximum contaminant level
SP	static pressure
SP_{base}	baseline data for SP
SP_h	hood static pressure
SP_{hi}	upper end of the range for SP
SP_{low}	lower end of the range for
STEL	short-term exposure limit
STP	short-term potability; standard temperature and pressure
SVS	services
TB	tuberculosis
tbls	tablespoon
TC	total coliform
TCDD	tetrachlorodlibenzo para dioxin
TCR	total coliform rule
TDS	total dissolved solids
temp	temperature
TIB	toxic industrial biological
TIC	toxic industrial chemical
TIC/TIM	toxic industrial chemical/toxic industrial materials
TIR	toxic industrial radiological
TLV	threshold limit value
TNCWS	transient non-community water system
TO	technical order
TON	threshold odor number
TP	total pressure
TPQ	threshold planning quantity
TSCA	Toxic Substances Control Act
tsp	teaspoon
TT	treatment technique
TTHM	total trihalomethane

TWA	time-weighted average
TWG	threat working group
UCC	unit control center
UDM	unit deployment manager
UEL	upper explosive limit
UFC	*Unified Facilities Criteria*
US	United States
USAFSAM	United States Air Force School of Aerospace Medicine
USAPHC	United States Army Public Health Command
USPHS	United States Public Health Service
USCG	United States Coast Guard
UTC	unit type code
UV	ultraviolet
UXO	unexploded ordinance
VA	vulnerability assessments
$\mathbf{V_{avg}}$	average velocity
$\mathbf{V_c}$	required capture velocity
$\mathbf{V_d}$	duct volume
$\mathbf{V_f}$	face volume
$\mathbf{V_m}$	actual velocity; velocity at measurement conditions
VOC	volatile organic compound
VP	velocity pressure
V_r	velocity read from the instrument
VS	veterinary service
$\mathbf{V_s}$	velocity at standard conditions
WEEL	workplace environmental exposure level
WHO	World Health Organization
WHPP	Well Head Protection Program
WVA	water vulnerability assessment
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter

Student Notes

Student Notes

AFSC 4B051
4B051 05 2007
Edit Code 4