

UNIFIED FACILITIES CRITERIA (UFC)

SECURITY ENGINEERING: PROCEDURES FOR DESIGNING AIRBORNE CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL PROTECTION FOR BUILDINGS



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CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL PROTECTION FOR BUILDINGS**

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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with [USD \(AT&L\) Memorandum](#) dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate.

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- NAVFAC Engineering Innovation and Criteria Office Internet site <http://criteria.navfac.navy.mil>.
- Construction Criteria Base (CCB) system maintained by the National Institute of Building Sciences at Internet site <http://www.ccb.org/>.

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CHAPTER 1

INTRODUCTION

1-1 BACKGROUND

Assets may require protection against airborne contamination by chemical, biological, or radiological (CBR) agents. The assets typically targeted by aggressors using CBR agents are personnel, mission-essential equipment, and facilities. Airborne delivery tactics involve the introduction of a CBR agent into an occupied building by an aggressor directly inserting the agent into the building's outside air intake for the ventilation system, releasing the agent at a standoff distance upwind of the building, or releasing an agent inside the building. Threats can come from a wartime or terrorist attack or from CBR agents released either accidentally or by sabotage. An airborne release involving a CBR agent and caused by an attack or release, either external or internal to the facility, is called a CBR event. The consequences of a CBR event can be of short duration (a few hours) or long duration (a number of days).

Protection can be achieved by evacuating the affected area, by providing a passive shelter or collective protection (CP) area of the building where personnel can work or shelter during release of a CBR agent, or by employing individual protective equipment (IPE). Response to a CBR event is dictated by the facility's emergency operation procedures. When evacuation is logistically impracticable, nonpressurized shelters can provide limited protection for a short period. Increased protection and longer durations require either a pre-placed system to provide CP capability or IPE. In some cases, advance warning of a suspected CBR event will enable building occupants to increase survivability significantly and reduce injury or incapacitation by implementing basic contamination avoidance actions.

1-2 PURPOSE

This document contains Unified Facilities Criteria (UFC) that provide guidance to protect assets against airborne delivery tactics using CBR agents. The intended audience consists of:

- Engineers who design new facilities or retrofit existing facilities
- Building managers
- Security personnel
- Personnel who are deploying to field or theater areas and are tasked with providing the commander with recommendations for immediate protection

The purpose is to protect assets with a minimum facility design and procurement cost based on the design basis threat, defined as "the threat (aggressors, delivery tactics, and associated weapons, tools, or explosives) against which assets within the building must be protected and upon which the security engineering design of the building is based" (UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings).

1-3 **SCOPE**

The scope of this document is limited to the threat of a CBR terrorist attack and the accidental or intentional release of CBR agents. The intent is not to supersede or duplicate design guidance for fully hardened wartime facilities.

1-3.1 **Body**

The body of this document provides design criteria to protect assets based on the design basis threat. The level of protection ranges from very low to high, depending on the anticipated threat. The design criteria apply to CBR protection of personnel and mission-essential equipment located in new facilities, in existing facilities either expediently or permanently retrofitted with CBR protection capabilities, and in temporary and mobile CP shelters. CP for CBR threats is intended to prevent personnel who are not using IPE from coming into direct contact with the agents or inhaling or ingesting them. Specifically, the guidance herein pertains to the following:

- Designing new facilities that are designated to have CP capability or are required to incorporate design features facilitating future installation of CP capability
- Modifying existing facilities designated to have CP capability

1-3.2 **Appendices**

The appendices include additional design guidance and other information, as follows:

- Appendix A – References (refer to Paragraph 1-4, below)
- Appendix B – Glossary, which provides definitions of the abbreviations and acronyms well as specialized terminology used in this document
- Appendix C – Airlocks and Entry or Exit Processing
- Appendix D – Sheltering in Place
- Appendix E – Protective Action Plan: Operational Procedures to Protect Existing Buildings and Their Occupants from Airborne Hazards
- Appendix F – Determining the Building Protection Factor
- Appendix G – CP Filtration System Equipment
- Appendix H – CP Filtration System Testing Requirements

1-4 REFERENCES

As noted in the preceding paragraph, Appendix A contains the references cited in this document. These are grouped into governmental and nongovernmental sources.

1-5 SECURITY ENGINEERING UFC

This document is one in a series of security engineering UFC manuals that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate the development of projects throughout the design cycle. These manuals include the following.

1-5.1 DoD Minimum Antiterrorism Standards for Buildings

UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings, and UFC 4-010-02, Design (FOUO): DoD Minimum Standoff Distances for Buildings, establish standards that provide minimum protection against terrorist attacks for the occupants of all inhabited DoD buildings. These UFC are intended for use by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. These UFC also include recommendations that should be, but are not required to be, incorporated into all such buildings.

1-5.2 Security Engineering Planning Manual

UFC 4-020-01, Security Engineering Planning Manual, presents processes for (1) determining the applicability of a threat of airborne CBR contamination, the design basis threat, and the default level of protection; (2) developing the design criteria that are necessary to incorporate security and antiterrorism into DoD facilities; and (3) identifying the cost implications of applying those design criteria. The design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction associated with those cost increases are tabulated for reference but are only representative of construction that will meet the design criteria. UFC 4-020-01 also includes a means to assess the tradeoffs between cost and risk. The intended audience consists of planners as well as security and antiterrorism personnel with support from planning team members.

The commander or authority having jurisdiction may determine whether facilities are susceptible to a CBR threat and may choose to incorporate CBR protection whether or not it is required based on UFC 4-020-01.

1-5.3 Security Engineering Design Manual

UFC 4-020-02, Security Engineering Design Manual, provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include the building and site elements, equipment, and supporting manpower and procedures necessary to make them all work as a system. The information is sufficiently detailed to

support concept-level project development and, as such, can provide a good basis for a more detailed design. This manual also describes how forced or covert entry might be used to deliver a CBR weapon and includes a process for assessing how protective measures impact risk. The primary audience is the design team, but security and antiterrorism personnel may also use this manual.

1-5.4 Security Engineering Support Manuals

In addition to the aforementioned UFC manuals regarding standards, planning, and design, there are UFC manuals that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These security engineering support manuals contain specialized, discipline-specific design guidance. Some address tactics, such as direct fire weapons, forced entry, or airborne delivery. Others address limited aspects of design, such as resistance to progressive collapse or design of portions of buildings such as mailrooms. Still others address details of designs for specific protective measures, such as vehicle barriers or fences. These support manuals are intended for use by the design team during the development of final design packages.

1-5.5 Design Examples for Airborne CBR Protection for Buildings

UFC 4-024-02, Security Engineering: Design Examples for Airborne Chemical, Biological, and Radiological Protection for Buildings, provides two examples for designing facilities to protect assets against airborne delivery tactics: a two-story administration building with a crisis management center requiring a medium level of protection and an existing command center requiring retrofitting to provide a medium level of protection.

1-5.6 Manual for CBR Protection of Wartime Facilities

UFC 3-340-01, Design and Analysis of Hardened Structures to Conventional Weapons Effects, contains design criteria for CBR protection of wartime facilities that incorporate contamination control areas (CCAs). This manual addresses many issues relating to wartime and long-duration events.

1-6 ADDITIONAL GUIDANCE

The following multiservice document also applies to the use of temporary and mobile shelters for protecting personnel against CBR threats: Multiservice Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical (NBC) Protection (Army Publication FM 3-11.4 [FM 3-4], Marine Corps Publication MCWP 3-37.2, Navy Publication NTTP 3-11.27, and Air Force Publication AFTTP(I) 3-2.46).

CHAPTER 2

ASSUMPTIONS AND DESIGN CONSTRAINTS

2-1 ASSUMPTIONS

The design criteria presented herein are based on the following assumptions:

1. A CBR event can occur without warning. It is possible, however, for an initiating event, a credible warning, or a warning under elevated threat conditions to occur. Advance warning allows operational actions to be taken to enhance protection.
2. Airborne delivery tactics include an external release of an agent (from an upwind standoff distance or into a fresh air intake) and an internal release (through the ventilation system or into a building area).
3. Actions such as heightened security measures taken as a result of increased levels of Force Protection Conditions are appropriate for protection against CBR events. Force Protection Conditions are a set of specific security measures promulgated by the commander after considering a variety of factors including the design basis threat, current events that might increase the risk of a terrorist attack, and observed suspicious activities.
4. This document does not address the use of explosives or other weapons in conjunction with a CBR event.

2-2 CONSTRAINTS

Certain physical features that cannot be changed or altered by facility personnel are constraints to protection against CBR events. Examples are as follows:

- Facility location adjacent to an area where public access is uncontrolled – The facility may be located near roads and railroad tracks where trucks and trains carry toxic industrial chemicals (TICs) or toxic industrial materials (TIMs).
- Facility with neighboring businesses or airport – A business adjacent to the facility may manufacture or store TICs or TIMs, making the facility vulnerable to accidental leaks or sabotage of the chemical storage facility. Aircraft may frequently fly near the facility because of a neighboring general aviation airport, rendering the facility vulnerable to an aerial release.

CHAPTER 3

TECHNICAL REQUIREMENTS AND GUIDANCE

3-1 CBR PROTECTION DESIGN PROCESS

The CBR protection design process consists of two major phases: (1) assessment and (2) planning and design.

3-1.1 Assessment Phase

To successfully provide CP capability and counter CBR threats, it is essential to understand the agent types and their physical states, potential delivery tactics, and the effects of the agents. The different types and physical states of contamination cause different hazards and may require different CP methods. Therefore, the assessment phase includes the following tasks:

- Identify the assets and rank their value. The assets addressed in this document generally are personnel in a facility or group of facilities and mission-essential equipment that may become unusable as a result of contamination.
- Determine the probable aggressor(s), agent type(s), and delivery tactic(s). The agent type and quantity, delivery tactic, release location, and duration of the event are difficult to estimate. Nevertheless, the user must define these in order for the designer to determine the design basis threat and the level of protection for the facility.
- Determine the design basis threat (refer to Paragraph 3-3.3).
- Determine the appropriate level of protection (refer to Paragraph 3-5, Design Requirements).
- Determine the appropriate overpressure class (refer to Paragraph 3-6, Duration of an Event and Classes of Overpressure).

The design basis threat, along with the corresponding level of protection and overpressure class, should be part of the design criteria. Refer to UFC 4-020-01 for information on determining the design basis threat, default level of protection, and overpressure class.

3-1.2 Planning and Design Phase

Following the assessment phase, the design process moves into the planning and design phase, which includes determining the following:

- Constraints
- Resources
- Costs

Using this information, the designer can determine the optimal design solution, which then allows either construction or the procurement or acquisition process to begin.

3-2 FACILITY CONSTRUCTION TYPES

3-2.1 General

CBR protection is required in accordance with UFC 4-010-01 for all new inhabited facilities and all existing facilities that are undergoing major renovation. The design of all facilities should incorporate protective system features consistent with the design criteria established during the planning phase. CBR protection may also be provided if required by the commander or authority having jurisdiction over the facility.

Paragraphs 3-2.2 through 3-2.4, below, explain how CBR protection can be designed into new construction, retrofit to existing buildings, or provided as an integral part of an expeditionary CP shelter.

3-2.2 New Facilities

New facilities should be designed to provide a well-sealed perimeter around the CP area. Depending on the actual ventilation system design, new facilities may require increased heating, ventilating, and air-conditioning (HVAC) system capacity and larger mechanical rooms to fully integrate a CP system. The CP system includes the CP filtration system, sealing measures, dampers, ductwork, and controls. The CP filtration system consists of the filters, fan, and filter housing.

3-2.3 Retrofits

All inhabited facilities undergoing a major retrofit to include new mechanical ventilation systems should be modified to meet the very low level of protection requirements in Paragraph 3-5.1, Very Low Level of Protection (Passive Sheltering in Place). In addition, the retrofits should provide the protective features of the level of protection determined in the assessment phase.

Existing facilities should be evaluated in terms of their tightness, the degree to which protection equipment can be integrated with existing HVAC systems, and the extent of modifications needed to meet the required level of protection. Major retrofits, like new facilities, may not be capable of fully integrating a CP system without increased HVAC system capacity.

3-2.3.1 Temporary and Permanent Modification of Existing Facilities

Expedient sealing measures, such as plastic sheeting and tape, can provide a temporary CP shelter. These measures, together with the use of portable fan and filtration equipment or recirculation filters with particulate or particulate and organic removal capability, can increase the level of protection during an emergency. The temporary measures must be in place prior to the release of an agent or before the agent reaches the building. Such sealing can temporarily enhance the protection afforded by a shelter until permanent measures can be provided.

The entire building or selected portions of the building can also be sealed by permanent measures, including architectural construction materials, weather sealing,

insulating foam, caulking, and other measures that provide a sealed, protected area envelope. Sealing the shelter and shutting down the ventilation system may result in carbon dioxide build-up above safe levels when the shelter is fully occupied. Carbon dioxide levels should be measured to ensure that the concentration does not exceed 0.5 percent. Temporary supplemental heating and cooling systems may be necessary if design temperatures are to be maintained in the pressurized mode. Ingress and egress from the shelter facility should be limited during a CBR event. If ingress and egress are required, however, they must occur through a CCA, where personnel can safely remove contaminated IPE, put on clean IPE, and bring items in or out.

3-2.3.2 **Secondary Enclosure**

If a facility cannot be sealed economically to maintain a CP overpressure but is suitable as a shell, a secondary enclosure for portable CP systems can be installed within the facility. The secondary enclosure must be in place and activated before a CBR event or an agent reaches the facility. With this type of arrangement, the existing HVAC system can partially or fully maintain the facility design temperature outside the enclosure. An example of this type of secondary enclosure is the M20/M20A1 simplified CP equipment. Secondary enclosures may be installed in a variety of facilities, including warehouses, gymnasiums, hangars, hardened aircraft shelters, and maintenance bays.

3-2.4 **Expeditionary Shelters and Equipment**

In expeditionary situations where existing facilities are unavailable or inadequate for incorporating CBR protection features, a transportable CP system or a military system such as M28 CP equipment can be used. For additional information on these systems, refer to Army Publication FM 3-11.4 (FM 3-4), Marine Corps Publication MCWP 3-37.2, Navy Publication NTTP 3-11.27, or Air Force Publication AFTTP(I) 3-2.46.

3-3 **THREAT TYPE**

The threat type is a combination of the agent type and the delivery tactic. Paragraphs 3-3.1 through 3-3.2, below, discuss agent types, the physical state of agents, the effects of agents, and airborne delivery tactics.

3-3.1 **Agent Types**

CBR agents can be TICs and TIMs, biological or radiological agents, or military chemical agents. They can be categorized by their physical state as liquids, solids (or particulates), and gases (or vapors).

3-3.1.1 **Toxic Industrial Chemicals and Materials**

TICs and TIMs are liquids, particulates, and gases produced for commercial and industrial applications. They are generally of lower toxicity than military chemical agents but are available throughout the world. An international task force listed 98 of these chemicals, in *Final Report of Task Force 25: Hazard from Industrial Chemicals*, as presenting a particular threat because of their toxicity and availability. Facilities may be vulnerable to an accidental or terrorist-caused release of TICs and TIMs from nearby manufacturing or storage facilities. Accidents or sabotage involving trucks, train cars, or ships carrying TICs or TIMs traveling near the facility can also cause releases.

3-3.1.2 **Biological Agents**

Biological agents (pathogens and toxins) are small particles. Effective delivery of these agents as aerosols generally requires a particle size ranging from 1 to 5 microns. Pathogens are some of the smallest agents, with a particle size of 0.005 to 0.5 microns, and therefore will affect filter requirements. Pathogens act more like a gas than a particle and travel in droplet nuclei or in clumps, whereas toxins may be in liquid or crystalline form. For a description of biological agents, refer to Army Publication FM 3-6, Marine Corps Publication FMFM 7-11-H, or Air Force Publication AFM 105-7.

3-3.1.3 **Radiological Agents**

Although it is possible for a terrorist to acquire and use a functioning nuclear weapon, creating large amounts of radioactive fallout, the intentional spread of radioactive isotopes or radioactive waste is much more likely. The most probable terrorist method is the use of a radiological dispersion device, known as a "dirty bomb." This device couples conventional explosives with a source of radioactive material. The physical form of a radioactive threat could be liquid, particulate, or vapor. For a description of radiological agents, refer to Army Publication FM 3-6, Marine Corps Publication FMFM 7-11-H, or Air Force Publication AFM 105-7.

3-3.1.4 **Military Chemical Agents**

Military chemical agents can be liquid, gas, or aerosol at standard conditions. Most of the toxic military chemical agents are liquids, which evaporate at differing rates to produce vapor. Chemical agents produce casualties through inhalation or contact with the skin or eyes. For a description of military chemical agents, refer to Army Publication FM 3-9, Navy Publication P-467, or Air Force Publication AFM 355-7.

3-3.2 **Airborne Delivery Tactics**

There are two principal tactics for delivering agents to facilities:

- External release from a point or line source, such as an aircraft (aerial release) or aerosol upwind of a facility (standoff release), or by direct insertion into an outside air intake
- Internal release via a direct release within the building, insertion into the internal ventilation system, or mail or supplies delivery

Paragraphs 3-3.2.1 and 3-3.2.2, below, address tactics that are considered to pose the greatest potential threat for delivery of a CBR agent.

3-3.2.1 **External Release**

External releases may result from accidents involving industrial transport or storage, fires, or malicious acts. This delivery tactic does not require introducing a device or container into a building or passing it through a secured perimeter. In the case of a building, the plume of the agent is directed by the wind to an outside air intake or open windows and doors. Atmospheric conditions and wind speed influence the effective range of a directed-plume attack.

3-3.2.2 **Internal Release**

The internal release delivery tactic involves transporting a device containing a CBR agent into a building and initiating the release manually, automatically, or remotely. An internal release can rely simply on the natural air currents or forced air movement and occupant movement to circulate the agents throughout the building. An agent can be delivered by personnel with unrestricted access to the protected area of the building (that is, the CP area, where personnel are able to work or shelter without wearing IPE during release of a CBR agent), inserted into the building's mechanical room ventilation system, or delivered by mail or supplies. The goal is to prevent an internal release by implementing security measures that will keep CBR agents out of the facility.

3-3.3 **Design Basis Threat**

As outlined in Paragraph 3-1.1, Assessment Phase, the design basis threat is established by evaluating the aggressor likelihood and objectives with respect to the assets (refer to UFC 4-020-02, Chapter 3). The following descriptions of the design basis threat levels for airborne contamination are based on the sophistication of the agents and delivery methods likely to be employed. **Note that each design basis threat level includes all of the lower levels.** Refer to UFC 4-020-01 for guidance on establishing the asset value, threat likelihood, vulnerability, risk level, and design basis threat.

The CP system design should protect the facility against agents identified at the appropriate threat level. Designing to protect against a lower threat level equates to a higher risk of exposure and greater likelihood of defeat but entails lower costs. Designing to meet a higher threat level equates to a low likelihood that the building will be compromised if attacked but entails high initial and operating costs.

3-3.3.1 **Very Low Design Basis Threat**

The very low design basis threat pertains to normal day-to-day operations where a CBR threat is considered very low to nonexistent. At this level, there is a general hazard threat, which is the threat of an external or internal release of TICs and TIMs, against all facility types.

3-3.3.2 **Low Design Basis Threat**

A low design basis threat is the very low threat (a general hazard threat) plus the threat of external release of biological or radiological particulates. No toxic military chemical threat is expected.

3-3.3.3 **Medium Design Basis Threat**

A medium design basis threat is the low threat (a general hazard threat as well as the threat of external release of biological or radiological particulates) plus the threat of external release of toxic military chemical agents.

3-3.3.4 **High Design Basis Threat**

A high design basis threat is the threat of external as well as internal release of all agent types.

3-3.3.5 **Summary of Airborne Contamination Threats**

Table 3-1 summarizes the design basis threat, agent type, and delivery tactic for the various airborne threats.

Table 3-1. Airborne Contamination Threats

Design Basis Threat	Agent Type	Delivery Tactic
Very Low	General hazard	External or Internal
Low	General hazard	External or Internal
	Biological and radiological particulates	External
Medium	General hazard	External or Internal
	Biological and radiological particulates	External
	Toxic military chemical agents	External
High	All agent types	External or Internal

3-4 **FACILITY DESIGN STRATEGY FOR CBR PROTECTION**

3-4.1 **General**

A CBR airborne threat can come from an industrial accident or an intentional release either external or internal to the facility. During these events, the first means of protecting personnel is by evacuation from the affected area. If evacuation is logistically impractical (for example, if the event or mission requirements prevent evacuation), then sheltering in place, CP sheltering, or IPE is required.

3-4.2 **Protection from External Release**

The simplest way to protect against an external release is to shut down the HVAC system and shelter in place as described below and in Appendix D, Sheltering in Place. In addition, CP filtration systems can be placed on the outside air intakes or in the central air-handling unit (AHU) to remove CBR agents and enable pressurization of the building with clean air. Filtration systems are described in Paragraphs 3-5.3, Low Level of Protection; 3-5.4, Medium Level of Protection; and 3-5.5, High Level of Protection. Classes of overpressure are addressed in Paragraph 3-6.2, Overpressure Classification.

3-4.2.1 **Procedures to Provide Passive Sheltering in Place**

Before the protective measures can be applied, the release must be detected and adequate warning must be issued. Upon receipt of a credible warning or event, protection is achieved by quickly closing building openings such as windows and doors, turning off ventilation systems, and closing the outside air intake, relief, and exhaust dampers. Note that protection diminishes over time.

3-4.2.2 Effectiveness of Sheltering in Place

Passive sheltering in place is time dependent, based on the sheltering time, infiltration leakage rate, external wind conditions, and building stack effect (defined as thermally driven air density differences between the building indoor and outdoor ambient conditions). To provide shelter-in-place capability for a facility that requires continuous operation, the outside air intakes must be closed during the release and the protected area envelope must be reasonably tightly sealed. The protection factor achieved can be estimated by the procedures in Appendix F, Determining the Building Protection Factor.

3-4.3 Protection from Internal Release

The simplest way to protect against an internal release is to shut down the HVAC system to limit the dispersion of CBR agents. Central air-handling filtration systems that are designed to remove the appropriate CBR agent help limit distribution of the CBR agent within the building through the HVAC system. However, such filtration systems do not protect the immediate area where the internal release occurred or possibly even the adjacent area, and contaminated air in return air ducts may be spread to other parts of the facility if clean areas are at a lower static pressure than the duct pressure. The most effective method to protect building personnel against an internal release is to prevent containers of hazardous materials from being brought into the building in the routine flow of people, mail, supplies, and other deliveries.

An integrated building protection approach is required to provide maximum protection. This approach includes access control, filtration of HVAC return air, and isolation of high-risk areas such as mailrooms, lobby areas, and supply delivery areas with separate ventilation systems as well as unscreened public access areas and any other general-access areas.

3-4.3.1 Access Control

All secured doors should have an electronic entry or manual lock system that only authorized personnel can activate. All maintenance personnel and their equipment should be checked for hazardous materials. Screening personnel should be provided with specific operational procedures to detect the presence of hazardous material containers.

3-4.3.2 Security Screening

Entry screening is a two-step process: (1) detecting a closed container and (2) determining whether the contents of the container are hazardous or likely to be hazardous. The first step involves the use of x-ray equipment; the use of a metal detector; or a manual search of briefcases, handbags, packages, letters, boxes of supplies, and deliveries of food and bottled beverages. The following are items to exclude or examine further:

- Aerosol cans or other pressurized containers
- Manual or electric spray devices
- Containers of liquids or powders

- Bottled gases typically used for repair or maintenance within the building
- Pressurized dispensers containing irritating agents, including pepper spray, mace, and tear-producing agents

The second step involves examining the container, its contents, and labels and then determining whether the contents agree with the label. Liquid or powder in an unlabeled container is reason for prohibiting it from entering the building. This step also involves checking for alterations to the label.

3-4.3.3 **Ventilation System Isolation**

To limit the spread of agents after an internal release, areas having a higher risk of a release should have a separate HVAC system, exhaust fan, sealed full-height boundary walls, and low-leakage doors and dampers. These areas also should be kept at a slight negative pressure relative to the other areas of the building.

3-4.3.4 **Smoke Purge System**

Depending on the ventilation and smoke control system design, it may be possible to contain an internal release and purge an area of the building by energizing the smoke control system. The smoke purge system can also be used to purge the building of any built-up contaminants following an external release after the external concentrations have been confirmed to have dissipated to below internal concentrations. However, contaminated air in return air ducts may be spread to other parts of the facility if clean areas are at a lower static pressure than the duct pressure.

3-4.3.5 **Windows**

Fixed and forced-entry-resistant exterior window designs can prevent a container with a CBR agent from being thrown through a window. Refer to UFC 4-010-01 for minimum window requirements; UFC 4-026-01, Security Engineering: Design of Buildings to Resist Forced Entry, for window requirements to resist forced entry; and UFC 4-023-04, Security Engineering: Design of Windows to Resist Explosives Effects, for the design of windows to resist explosive effects where resistance to explosives is required.

3-5 **DESIGN REQUIREMENTS**

The facility design requirements for each level of protection against varying CBR threats are discussed in Paragraphs 3-5.1 through 3-5.5, below. This discussion includes the following topics:

- Design requirements for the very low level of protection against a very low design basis threat (Paragraph 3-5.1)
- Recommended measures to protect facilities regardless of the level of protection and design basis threat (Paragraph 3-5.2)
- Design considerations for the low level through the high level of protection against the corresponding design basis threat (Paragraphs 3-5.3 through 3-5.5)

For a table summarizing the levels of protection and the corresponding overpressure, design basis threat, and filtration system for each level, refer to Paragraph 3-7, Building Protection Summary.

3-5.1 **Very Low Level of Protection (Passive Sheltering in Place)**

The very low level of protection is used to protect against a very low design basis threat. It incorporates passive building component features at little or no additional cost when included in new facility designs and major retrofits. A public address system; emergency air distribution shutoff; sealed mailrooms with separate, dedicated ventilation systems and exhaust fans; elevated outside air intakes; and restricted roof access are recommended for all buildings and are **required** protection measures for new facility designs and major retrofits. Refer to Paragraphs 3-5.1.1 through 3-5.1.3, below, and to UFC 4-010-01 for additional information on these requirements.

3-5.1.1 **Public Address or Alarm System**

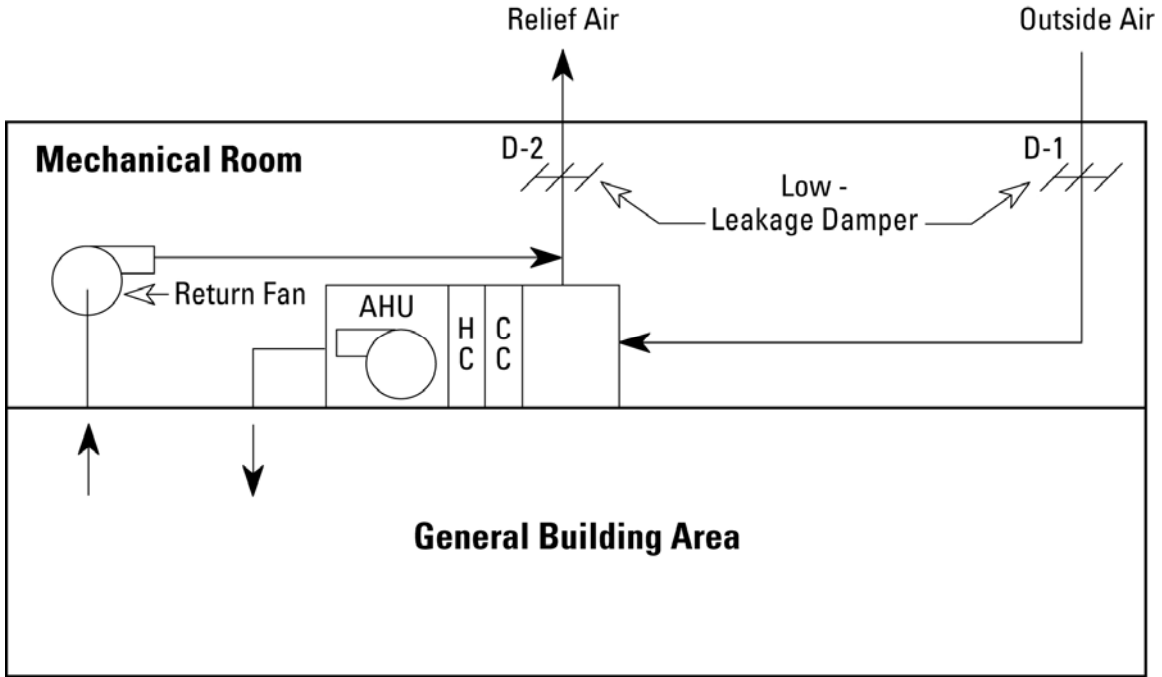
A public address or alarm system is critical to the CBR protection system. It is necessary to alert building occupants of a CBR release by indicating when to initiate evacuation procedures, provide direction for evacuation, put on protective masks, or employ CP. The public address or alarm system must be separate from the fire alarm or integrated with the fire alarm but easily distinguishable from it.

3-5.1.2 **Emergency Air Distribution Shutoff**

All new and existing inhabited buildings must be provided with at least one emergency air distribution shutoff switch. When the switch is activated, air distribution equipment throughout the building will be de-energized and motorized dampers will close to prevent the flow of airborne contaminants within the building and between the building and outdoors. It is also recommended that the emergency deactivation cause elevators, if in motion, to go to the next floor and stop (the doors may open and close, but the elevator is not to move).

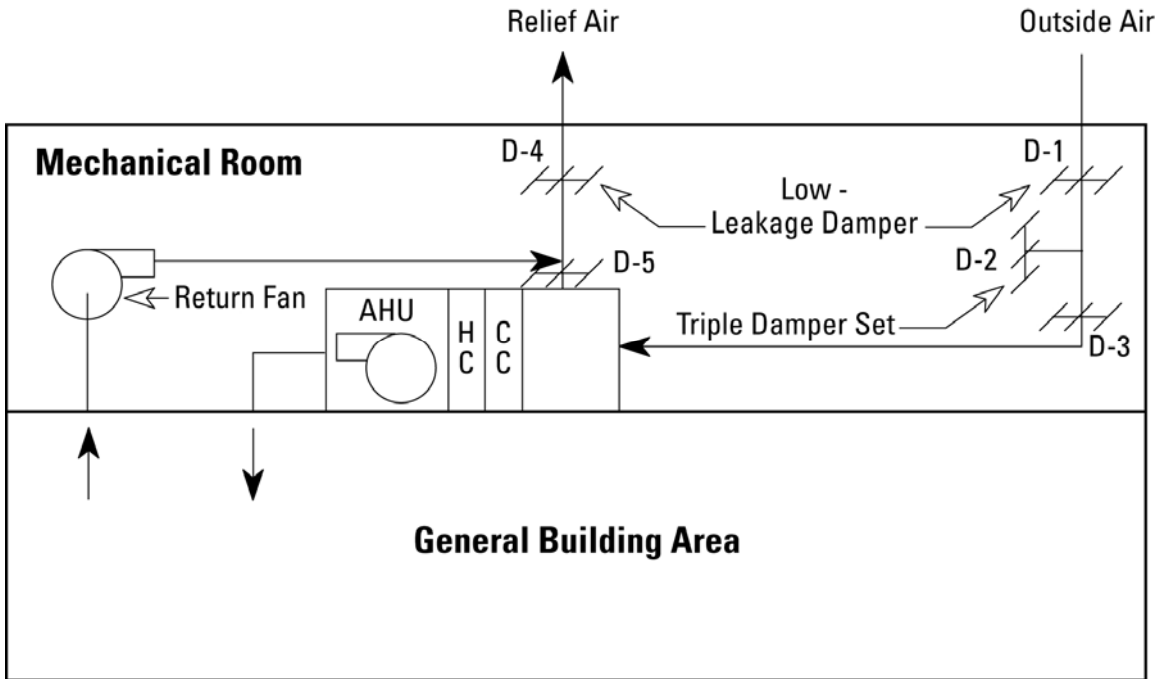
Figures 3-1, 3-2, and 3-3 illustrate the emergency air distribution shutoff for the very low level of protection for some typical air-handling systems. Figure 3-1 represents a central air-handling system that can be shut down during a CBR event. If the central air-handling system cannot be shut down due to critical heating or cooling needs, a triple damper arrangement, as shown in Figure 3-2, is recommended. The AHU is placed in a recirculation mode, and the triple damper arrangement reduces the possibility of contaminated outside air leakage through the outside air damper. Figure 3-3 illustrates a typical fan coil system with a central outside air intake that is ducted to the fan coil units. For more details on shelter-in-place protection, refer to Appendix D, Sheltering in Place.

Figure 3-1. Very Low Level of Protection – Central Air-Handling System



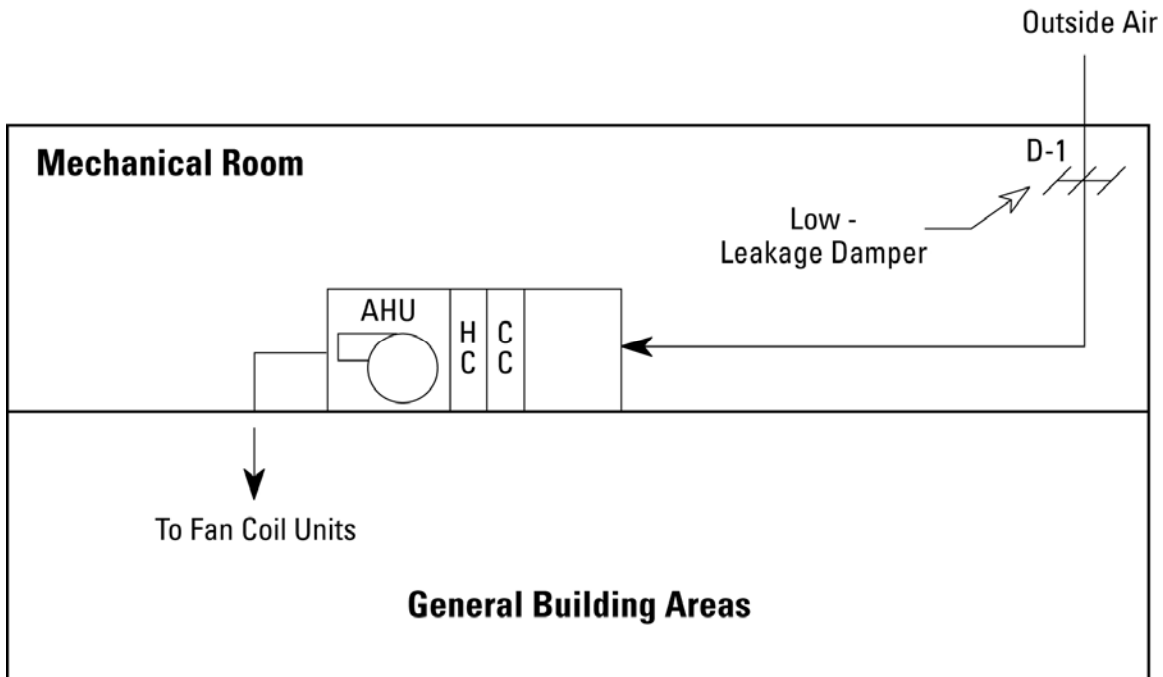
Damper No. or Equipment	Normal Mode	Protection Mode
D-1	Open	Closed
D-2	Open	Closed
AHU	On	Off
Return Fan	On	Off

Figure 3-2. Very Low Level of Protection – Central Air-Handling System Requiring Continuous Operation



Damper No. or Equipment	Normal Mode	Protection Mode
D-1	Open (or modulating)	Closed
D-2	Closed	Open
D-3	Open	Closed
D-4	Open (or modulating)	Closed
D-5	Open (or modulating)	Open
AHU	On	On
Return Fan	On	On

Figure 3-3. Very Low Level of Protection – Fan Coil System



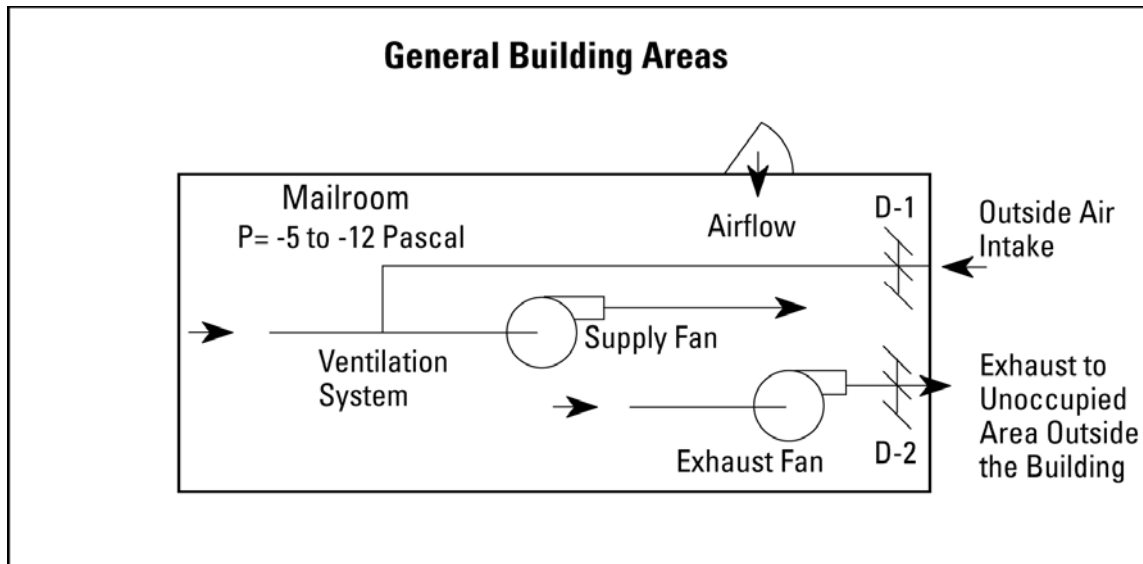
Damper No. or Equipment	Normal Mode	Protection Mode
D-1	Open	Closed
AHU	On	Off
Fan Coil Blowers	On	Off

3-5.1.3 Mailroom Ventilation

The design and installation of mailroom ventilation must conform to the design basis threat level for the building. The basic threat for all facilities corresponds to the very low design basis threat, which requires that mailrooms be constructed and sealed in accordance with the minimum antiterrorism standards provided in UFC 4-010-01.

Figure 3-4 illustrates a typical dedicated air-handling system for mailrooms to meet the basic threat at all levels of protection. If possible, mailroom ductwork should not be run in the plenum space in a protected area as contaminated air could leak from the ductwork into the protected area. The table under Figure 3-4 indicates the recommended damper positions and fan operating status for the normal operating mode, for the protection mode when a release has occurred outside of the mailroom, and for the protection mode when a release has occurred inside of the mailroom. As a first response to a release, it is recommended that the facility operate in the protection mode for a release outside of the mailroom, with all dampers closed and all fans de-energized. If the release is determined to be inside the mailroom, the exhaust fan can be energized and the exhaust damper opened.

Figure 3-4. All Levels of Protection – Dedicated Air-Handling System for Mailrooms



Damper No. or Equipment	Normal Mode	Protection Mode – Release Outside of Mailroom	Protection Mode – Release Inside of Mailroom
D-1	Open	Closed	Closed
D-2	Open	Closed	Open
Supply Fan	On	Off	Off
Exhaust Fan	On	Off	On

3-5.2 Recommended Protection Measures for All Levels of Protection

Recommended measures to protect facilities regardless of the level of protection and design basis threat are provided in Paragraphs 3-5.2.1 through 3-5.2.9, below. These measures exceed the minimum standards presented in UFC 4-010-01.

3-5.2.1 Building Sealing Measures

Particular attention should be paid to ensure adequate sealing of the building or protected area envelope as well as all utility penetrations and building interface joints (for example, the wall and roof interface). Reducing the rate of air exchange with the outside air greatly improves the effectiveness of a passive shelter and reduces the cost of installing and operating a CP system to provide overpressure to a protected area. Measures to reduce the air exchange rate and ensure proper sealing are as follows:

- Incorporate typical weatherizing sealing measures and continuous vapor barriers in the building or protected area envelope.
- Include sealing of the window and wall interfaces as well as weather stripping of exterior doorways and doorways between the protected area and potentially contaminated areas of the building.

- Perform a seal integrity pressure test, with an internal pressure applied to the seals, and perform a smoke test.
- In multistory buildings, seal gaps in stairwells, elevator shafts, mechanical chases, and other openings between floors to reduce the stack effect within the building.

Refer to Paragraph 3-8.2.1, Leakage Prevention in Existing Facilities, for more information on sealing measures.

3-5.2.2 **Outside Air Intakes**

To prevent the direct insertion of agents into the outside air intakes and to reduce the potential for an agent released at ground level to reach the outside air intakes, the following measures are recommended:

- Elevate outside air intakes and secure roof access in accordance with UFC 4-010-01.
- Place screens over the outside air intakes to prevent objects from being inserted into the intakes. Note that the slope of the screens should allow objects placed or thrown onto them to roll or slide off.
- Do not place equipment under wall-mounted outside air intakes that an aggressor could climb to reach the intakes.
- For existing buildings with outside air intakes that are below grade, at ground level, or wall mounted outside secure areas, use physical security measures such as fencing around the intakes and surveillance cameras and motion detectors monitored by security personnel.

Although physical security measures can minimize susceptibility to malicious acts, they are less effective than elevating the outside air intakes because, under certain conditions, ground-level releases can enter the intakes from points outside the fenced or monitored area. However, the effectiveness of elevating intakes has practical limits. A plume or cloud of hazardous materials can reach the intakes, particularly if the source is large and distant. In low-rise buildings (those having a width more than twice the height), a plume originating at ground level near the building travels over the building rather than around it. The wind conveys contaminants to the top of the building, with some dilution occurring.

3-5.2.3 **Vestibules and Revolving Doors**

Designing or retrofitting main building entrances with integral vestibule areas or revolving doors minimizes infiltration caused by wind and stack effect. Vestibules, airlocks, and revolving doors provide a means of controlling infiltration at main building entrances as people enter and exit the building. These are most beneficial in multistory buildings with large temperature-driven stack effect pressure differences between indoor and outdoor conditions. At the building entrances, the airflow is inward in the winter and outward in the summer.

3-5.2.4 **Control Systems**

Regardless of the level of protection, incorporating shelter-in-place and containment protection modes into the HVAC or fire alarm control system maximizes the building's passive protection capability against an external threat with forewarning and limits the dispersion of an internal release. The shelter-in-place protection mode consists of de-energizing the ventilation system and closing the outside air intakes and exhaust dampers using a master control capability. The containment protection mode consists of compartmentalizing the fire zones by closing the fire doors and, if the building is so equipped, the smoke dampers.

Measures to incorporate shelter-in-place and containment protection modes into the HVAC or fire alarm control system are as follows:

- Locate the master control switch or CP control system so that it is easily accessible but operable by authorized personnel only.
- Incorporate low-leakage dampers and assemblies into the outside air intakes, HVAC system, and exhaust system, as shown in Figures 3-1, 3-2, and 3-3, above.

3-5.2.5 **Mechanical Rooms**

Mechanical room doors should be constructed of metal with no windows and should be properly locked. Building or shelter managers should control access to the mechanical rooms to prevent access by unauthorized or unescorted personnel and to prevent direct insertion of an agent into the building ductwork system. Mechanical rooms should be large enough to accommodate filtration equipment and perform maintenance.

3-5.2.6 **Measures to Accommodate Retrofits to a Higher Level of Protection**

Building retrofits can be accommodated to a higher level of protection as follows:

- Incorporate space within the facility or directly next to its exterior for the future addition of equipment to increase the level of protection.
- As in typical building HVAC design practice, design the main building ventilation system to achieve a slight overpressure of 5 to 12 Pascal (Pa) (0.02 to 0.05 inches of water gage [in wg]). For HVAC system retrofits, provide additional outside air as necessary to maintain the slight overpressure and additional heating and cooling capacity if required by the increase in outside air and fan energy.

3-5.2.7 **Zoned Isolation of High-Risk Areas**

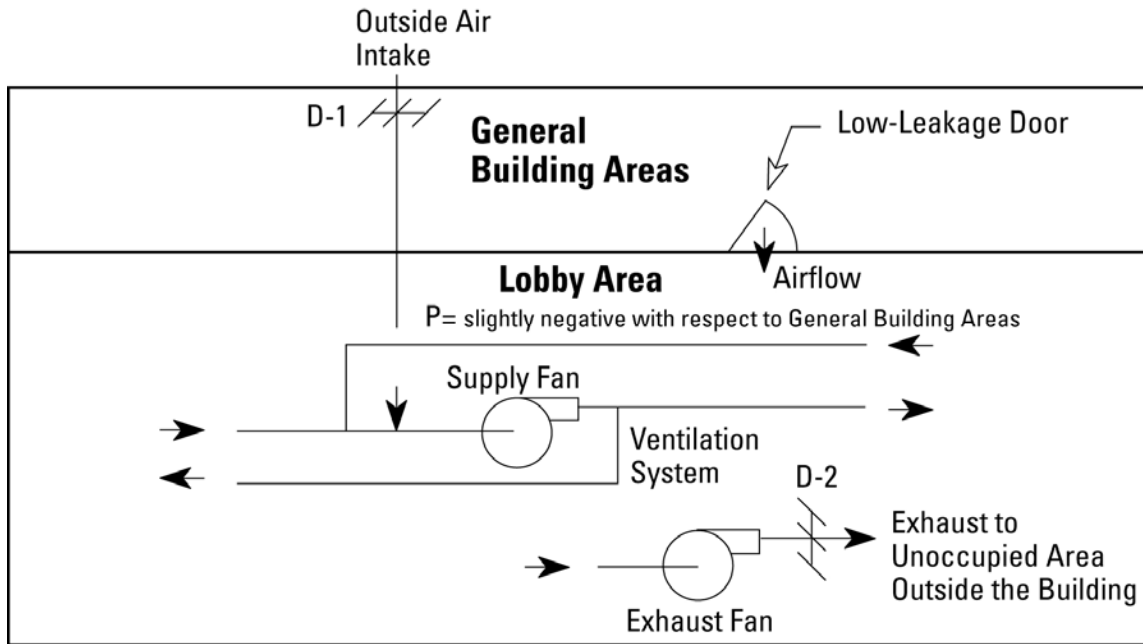
Measures to limit the spread of agents released inside a high-risk area such as a lobby, receiving dock, or any other publicly accessible building area are as follows:

- Design the facility to provide zoned isolation for areas having a greater potential for an internal release, as shown in Figure 3-5.

- Provide a separate, dedicated air-handling system to prevent airborne CBR agents from migrating from the high-risk area to other areas of the building through the ventilation system.
- Provide an exhaust fan, and maintain the high-risk area at a negative pressure relative to the rest of the building.
- To limit the migration of airborne CBR agents from the high-risk area into other portions of the building, ensure that the envelope of the high-risk area is well sealed. Ensure that the walls are full-height construction and that they fully extend and are sealed to the undersides of the roof, to the undersides of the floor above them, or to hard ceilings (that is, gypsum wallboard ceiling). When sealing, include visible cracks; the interface joints between the walls and the ceiling, roof, or floor above; and all wall and roof penetrations.
- Provide low-leakage doors between the high-risk area and the rest of the building.
- Provide a separate method of control to isolate the high-risk area. Note that independent control of the air-handling and exhaust systems is required in the event of a suspected or actual CBR release within the high-risk area.
- Consider the use of recirculating-type filtration units to remove contaminants after a release.

Figure 3-5 illustrates the ventilation system of a lobby as a typical high-risk area. The table under Figure 3-5 indicates the recommended damper positions and fan operating status for the normal operating mode, for the protection mode when a release has occurred outside of the lobby, and for the protection mode when a release has occurred inside of the lobby. As a first response to a release, it is recommended that the facility operate in the protection mode for a release outside of the lobby, with all dampers closed and all fans de-energized. If the release is determined to be inside the lobby, the exhaust fan can be energized and the exhaust damper opened.

Figure 3-5. Very Low Level of Protection – Lobby Area Ventilation Containment System



Damper No. or Equipment	Normal Mode	Protection Mode – Release Outside of Lobby	Protection Mode – Release Inside of Lobby
D-1	Open	Closed	Closed
D-2	Open	Closed	Open
Supply Fan	On	Off	Off
Exhaust Fan	On	Off	On

3-5.2.8 Protected Area Floor Space Requirements

The total required protected area floor space is determined based on the sheltering period, the number of people sheltered, and the required floor area per person. Generally, large open areas such as common areas, multipurpose areas, and gymnasiums provide the most efficient floor area for protecting a large number of personnel. In addition, areas containing people who cannot be evacuated, such as hospital patient rooms, must be considered when establishing the protected area boundaries. The protected area envelope should include bathroom facilities and, if possible, kitchen facilities.

The command or authority having jurisdiction determines the sheltering area per person and the CP button-up period, which can range from a few hours to several days. The button-up period influences the floor area per person and the amount of storage for consumables and waste but generally does not significantly affect the design of the CP system. The following are guidelines for the minimum floor area for shelter occupants. The minimum floor area does not include mission-critical functional areas that operate continuously.

3-5.2.8.1 Suggested Personnel Floor Area – Less than 24 Hours

A button-up period less than 24 hours does not require sleeping areas. The occupant loading generally follows the guidelines in Table 3-2. A short duration requires a net area of 1 m²/person (10 ft²/person), depending on the classification of occupancy, as stated in the National Fire Protection Association’s NFPA 101 *Life Safety Code*®. The classification of occupancy may require a higher or lower occupant loading, depending on the building classification. The occupant loading must be coordinated with the authority having jurisdiction.

**Table 3-2. FEMA Tornado and Hurricane
and NFPA 101 *Life Safety Code*® Requirements**

Type of Emergency	Anticipated Shelter Time	Floor Area per Person
Tornado	Less than 1 hour	0.46 m ² (5 ft ²)
Hurricane	Less than 12 hours	0.93 m ² (10 ft ²)
Hurricane	A few days	1.86 m ² (20 ft ²)
Hurricane	Days to weeks	3.72 m ² (40 ft ²)

Sources:

Federal Emergency Management Agency (FEMA), Design and Construction Guidance for Community Shelters, July 2000.

FEMA, Taking Shelter from the Storm: Building a Safe Room Inside Your House, August 1999.

NFPA, NFPA 101, *Life Safety Code*®, 1997.

3-5.2.8.2 Suggested Personnel Floor Area – More than 24 Hours

A button-up period greater than 24 hours requires sleeping areas. The minimum floor area, with single-size beds, is approximately 1.86 to 5.6 m²/person (20 to 60.3 ft²/person). With bunk beds, the minimum floor area is approximately 0.93 to 2.8 m²/person (10 to 30 ft²/person). Button-up periods longer than 24 hours are generally restricted to wartime.

3-5.2.9 Airlock Requirements

Airlocks are required only for facilities where people or supplies must enter the protected area during a CBR event, during which conditions outside the facility may contaminate people or supplies entering the facility. Personnel who enter and exit the protected area during CP operations must process through an airlock. The airlock maintains an overpressure in the protected area, prevents migration of airborne contaminants into the protected area, and purges contaminants from personnel before they enter the protected area. The number of airlocks required depends on the number of personnel who enter and exit during a given time period. At least one airlock or similar air control passageway is required for the resupply of food, bottled water, and emergency evacuation items or for bringing in mission-critical material. Design guidance for airlocks is provided in Appendix C, Airlocks and Entry or Exit Processing.

3-5.2.10 CBR Detectors

Theoretically, automatic detectors can be used to initiate protective actions such as shutting down ventilation systems, closing outside air intakes, or turning on filtration systems. However, automated responses to an attack or accidental release are not feasible due to limitations in detector technology. The following should be noted:

- The practical application of chemical detection is limited by shortcomings in response time and broad-spectrum capability, false alarms, maintenance requirements, cost, and the quantity of sensors needed for the various chemical agents at outside air intake locations.
- Current biological detection is limited to a few biological agents, and the technology requires a minimum delay of approximately 15 minutes to detect the presence of biological agents.
- Radiological agents can be detected with off-the-shelf equipment.
- In the case of terrorist threats, there may not be audible and visual indications of the attack other than the incapacitation of people. For such threats, therefore, detectors should be applied only for the following purposes:
 - To detect radiological agents.
 - To allow first responders to determine the appropriate entry procedure (if the actual chemical agent type is known).
 - To monitor casualties before medical treatment.
 - To determine the extent of the hazard.
 - To determine when protective measures are no longer required.
 - To monitor the outside air intakes but not provide an active response.
 - To collect samples and forensic evidence.

3-5.3 Low Level of Protection

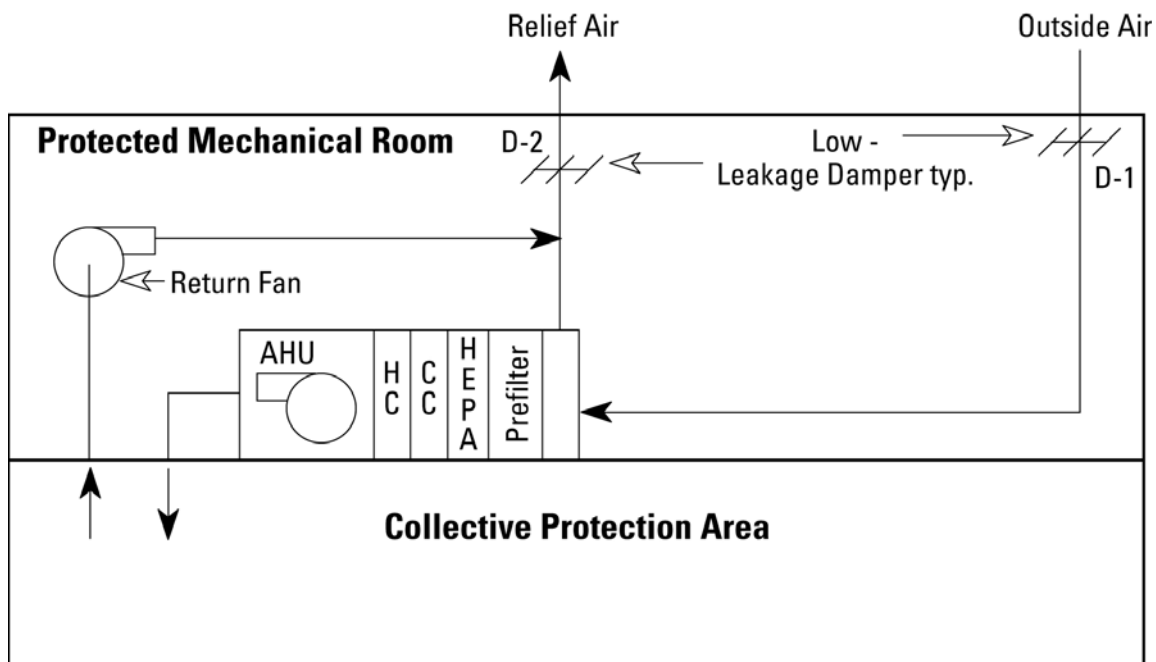
3-5.3.1 Features of Low Level of Protection

The low level of protection is used to protect against a low design basis threat. In addition to the features of the very low level of protection, the strategy at this level of protection incorporates high-efficiency particulate air (HEPA) filters to filter particulates in the outside air stream. However, as a practical matter, the HEPA filters are generally installed in the central AHU and filter both outside air and recirculated air. Although not necessary for this level of protection, this arrangement has the added benefit of limiting the spread of the agent through the building and purges the agent more rapidly if there

is an internal release. HEPA filtration removes biological and radiological agents and should be run continuously.

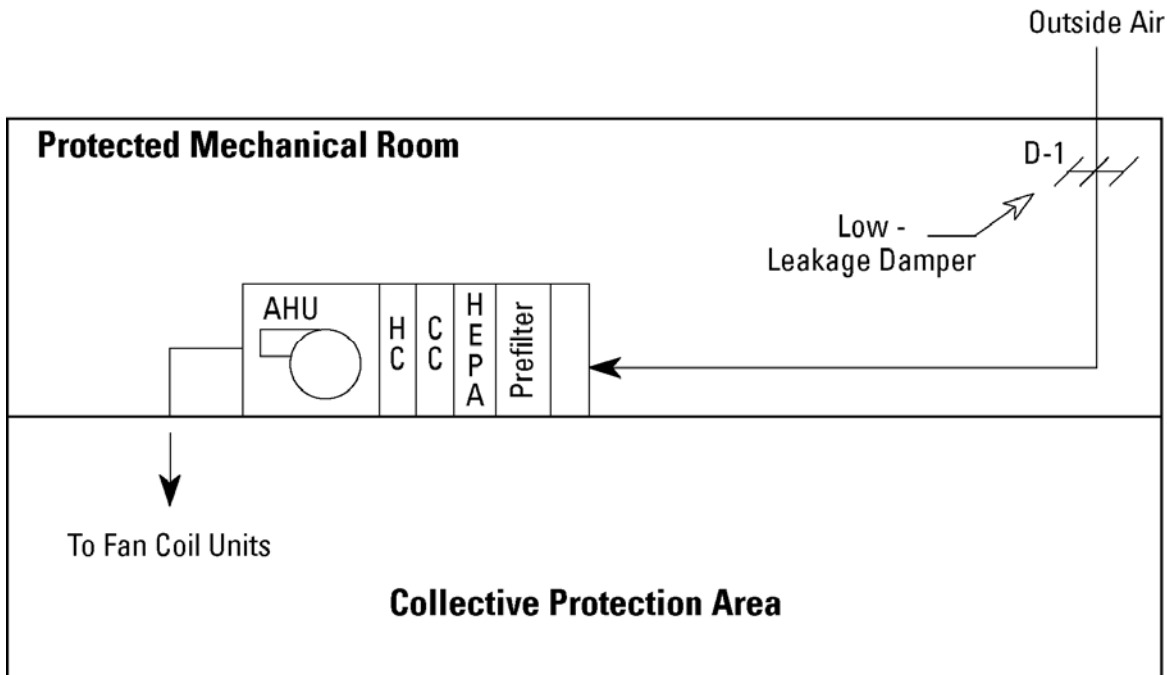
Figure 3-6 illustrates the arrangement of a typical central air-handling system for the low level of protection. Figure 3-7 illustrates the low level of protection provided by filtration applied only to the outside air of a system using fan coil units. The table under each figure indicates the recommended damper positions and fan operating status for the normal operating mode, for the protection mode when a chemical release has occurred, and for the protection mode when a particulate release has occurred. For the low level of protection, it is recommended that the facility operate in the chemical protection mode, with all dampers closed and all fans shut off until it can be determined what type of release has occurred. If the release is determined to be a particulate, the system can be switched to the particulate protection mode.

Figure 3-6. Low Level of Protection – Central Air-Handling System



Damper No. or Equipment	Normal Mode	Protection Mode – Chemical Release (Default Mode)	Protection Mode – Particulate Release
D-1	Open	Closed	Open
D-2	Open	Closed	Open
AHU	On	Off	On
Return Fan	On	Off	On

Figure 3-7. Low Level of Protection – Fan Coil System



Damper No. or Equipment	Normal Mode	Protection Mode – Chemical Release (Default Mode)	Protection Mode – Particulate Release
D-1	Open	Closed	Open
AHU	On	Off	On
Fan Coil Blowers	On	Off	Off

3-5.3.2 Retrofits

Retrofitting existing facilities to meet the low level of protection requires incorporating HEPA filtration into the central air-handling systems. The existing AHUs may need modification to allow room for installing the HEPA filters and the required prefilters. The existing AHU fans may require upgrading to compensate for the increased static pressure drop through the additional filters.

3-5.3.3 Mailroom Ventilation

The design and installation of mailroom ventilation for the low level of protection must meet the requirements for the very low level of protection. Figure 3-4, above, illustrates a typical dedicated air-handling system for mailrooms.

3-5.4 Medium Level of Protection

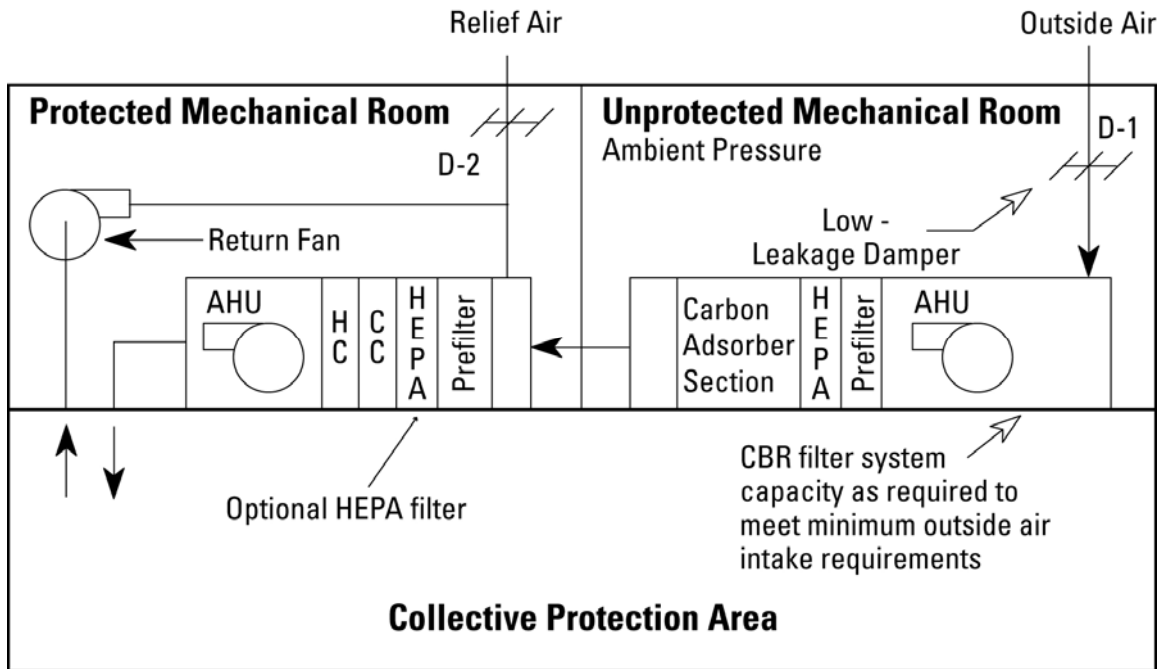
3-5.4.1 Features of Medium Level of Protection

The medium level of protection is used to protect against a medium design basis threat. This level of protection has the following features in addition to those of the low level of protection:

- A vapor adsorber system with carbon-activated, impregnated, copper-silver-zinc-molybdenum-triethylenediamine (ASZM-TEDA) carbon on the outside air intakes of the ventilation system either in continuous operation or in standby mode
- Commercially available limited-life carbon adsorbers for short-duration protection while the building is evacuated
- For the standby mode, activation of the CP filtration system during a heightened threat condition, initiating event, or credible warning

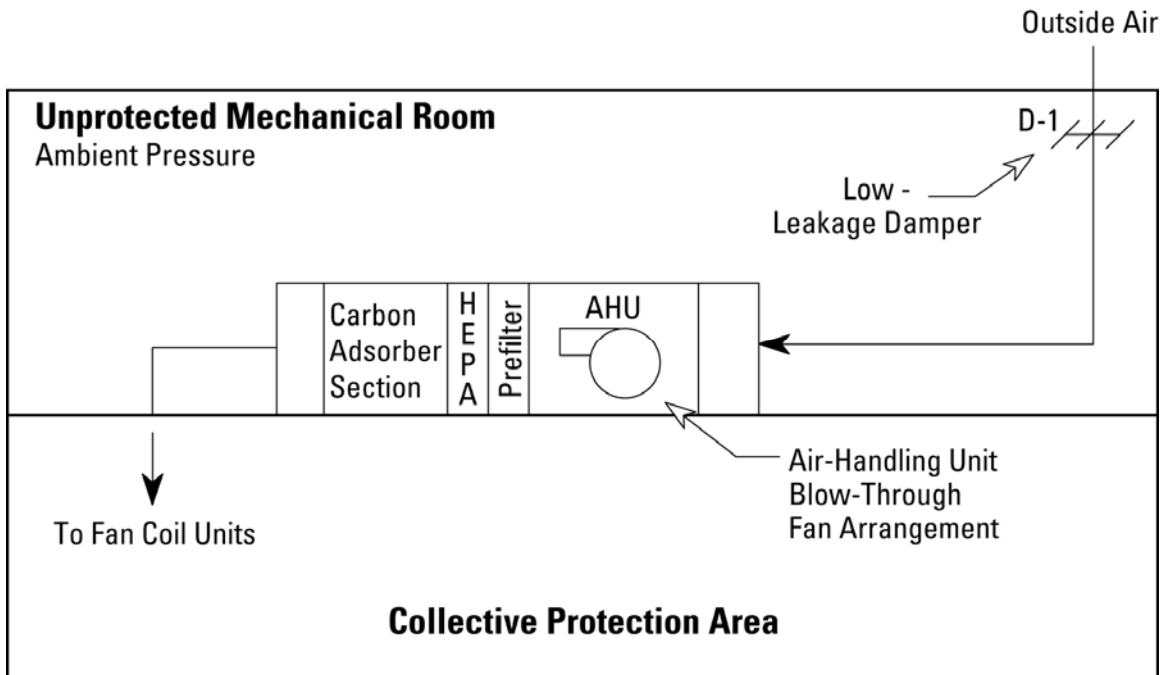
Figures 3-8 and 3-9 show the general arrangement of the air-handling systems for the medium level of protection. The table under each figure indicates the recommended damper positions and fan operating status for the normal operating mode, for the protection mode when an internal release has occurred, and for the protection mode when an external release has occurred. For the medium level of protection, it is recommended that the facility operate in the external protection mode, with all dampers open and all fans operating. If agents are present in the building, the emergency air distribution shutoff should be activated; fans should be de-energized, and dampers should be closed as indicated for the internal release protection mode.

Figure 3-8. Medium Level of Protection – Central Air-Handling System



Damper No. or Equipment	Normal Mode	Protection Mode – Internal Release	Protection Mode – External Release
D-1	Open	Closed	Open
D-2	Open	Closed	Open
AHU	On	Off	On
Filter Unit Blower	On or Standby	Off	On
Return Fan	On	Off	On

Figure 3-9. Medium Level of Protection – Fan Coil System



Damper No. or Equipment	Normal Mode	Protection Mode – Internal Release	Protection Mode – External Release
D-1	Open	Closed	Open
AHU	On	Off	On
Fan Coil Blowers	On	Off	On

3-5.4.2 Mailroom Ventilation

The medium design basis threat exists when the building has an elevated profile, the function of the building is likely to produce attacks, or resources within the building are unique and justify additional protection. For the medium design basis threat, mailrooms must meet the requirements for the very low and low levels of protection. In addition, it is recommended that they have airlocks or vestibules at the entrances to prevent free flow of air from exiting the mailroom. Figure 3-4, above, illustrates a typical dedicated air-handling system for mailrooms.

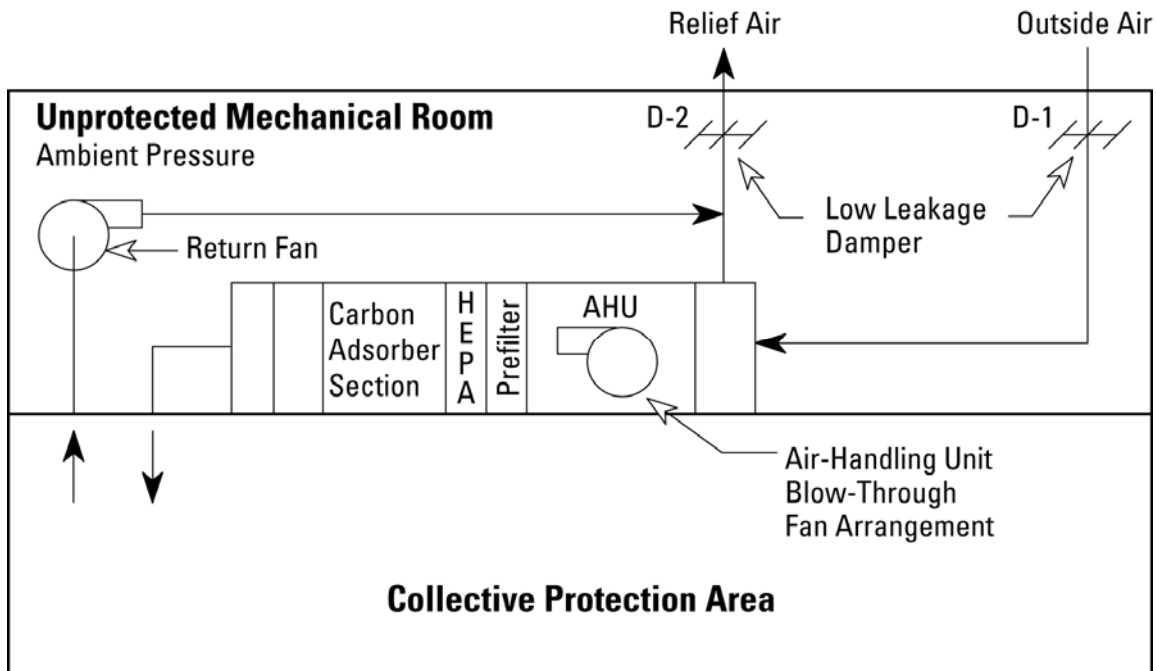
3-5.5 High Level of Protection

3-5.5.1 Features of High Level of Protection

A high level of protection is used to protect against a high design basis threat. In addition to the features of the medium level of protection, the high level of protection has a continuous HEPA filter and a vapor adsorber system for the outside air intake and return air.

The high level of protection limits the effects of an internal release by removing the CBR agent at the central AHU and CP filtration system before the air is distributed to other areas of the building. Although high level of protection does not eliminate an internal release from migrating through doorways, walls, and ceilings, it scavenges and purges the area where the internal release occurred and other portions of the building through repeated air exchange. Figure 3-10 shows the general arrangement of the air-handling system for the high level of protection.

Figure 3-10. High Level of Protection – Air-Handling System with Integral Filtration



Damper No. or Equipment	Normal Mode	Protection Mode
D-1	Open	Open
D-2	Open	Open
AHU	On	On
Return Fan	On	On

3-5.5.2 Mailroom Ventilation

A high design basis threat exists when the building has a high profile, the function of the building is likely to produce attacks, or resources within the building are unique and justify additional protection. For the high design basis threat, mailrooms must meet the requirements for the very low, low, and medium levels of protection. In addition, it is recommended that there be containment control hoods for opening mail. Figure 3-4, above, illustrates a typical dedicated air-handling system for mailrooms.

3-6 DURATION OF AN EVENT AND CLASSES OF OVERPRESSURE

The duration of an event and the need for a building to remain operational during an event, as dictated by the value of the asset to its user and the facility’s emergency operation procedures, determine the overpressure required to provide CP capability. An overpressure is established within a building, or portion of a building, by supplying more filtered air to the building than is exhausted from the building by the building’s ventilation system. The overpressure prevents external CBR agents from infiltrating through the building shell into the protected area. For existing and new facilities designated to provide CP capability, there are three overpressure classes:

- Class I – Filtration with pressurization
- Class II – Filtration with slight pressurization
- Class III – Passive protection

3-6.1 Duration of an Event

3-6.1.1 Short Duration

Short-duration external releases last for a few minutes to a few hours, depending on the event. There is little or no warning, but it is possible to identify the source quickly and provide mitigation. Facilities that are used as shelters or must be operated continuously may be designed as passive shelters with no filtration or overpressure or with a minimal overpressure with continual filtration of the ventilation air intakes.

3-6.1.2 Long Duration

Large-scale, long-duration external releases that last a number of days or weeks are very unlikely as a result of a terrorist attack or an industrial accident. However, existing circumstances may result in contamination that persists for a long period of time.

3-6.2 Overpressure Classification

The three classes of overpressure for existing and new facilities relate to the duration that an asset must be protected against the threat depending on its value to its user and emergency operation procedures. Table 3-3, Overpressure, by Class, summarizes the CP capability provided by each class of overpressure based on the event duration and wind speed. In the table and the following paragraphs, the overpressure classes are presented in order of increasing protection.

Table 3-3. Overpressure, by Class

Class	Event Duration	Internal Overpressure	Wind Speed
III – Passive Protection	Minutes to hours (depending on event)	0 Pa	NA
II – Filtration with Slight Pressurization	Minutes to hours (depending on event)	5-12 Pa (0.02-0.05 in wg)	8-13 km/hr (5-8 mph)
I – Filtration with Pressurization	Weeks	75 Pa (0.30 in wg)	40 km/hr (25 mph)

3-6.2.1 Class III – Passive Protection

Class III, passive sheltering in place, provides limited protection to building occupants during a short-duration CBR event from an external release and limits the dispersion of agents from an internal release. It does not provide overpressure for CP capability. Although Class III protection has a low cost, there is a higher likelihood of defeat or risk of exposure and a higher vulnerability for the assets. For more information, refer to Paragraph 3-4.2.1, Procedures to Provide Passive Sheltering in Place, and to Appendix D, Sheltering in Place.

3-6.2.2 Class II – Filtration with Slight Pressurization

Class II corresponds to a lower likelihood of defeat than Class III. Class II provides a minimal overpressure capability of 5 to 12 Pa (0.02 to 0.05 in wg) to resist a short-duration event with little or no warning. A continuous CP filtration system designed to remove CBR agents continuously protects outside air intakes, and the overpressure prevents agents from penetrating the protected area envelope of low-profile (one- to two-story) buildings at wind speeds of 8 to 13 km/hr (5 to 8 mph). The filtration system is sized for the normal outside air intake requirement.

Existing and new facilities designated as Class II do not require an airlock for personnel ingress or egress, but it is desirable to have a double-entry door such as a vestibule entrance or revolving door that acts as an airlock to maintain the slight overpressure of the protected area and the integrity of the envelope.

3-6.2.2.1 Class II – Existing Facilities

Existing facilities should be pressure-tested to identify and seal leakage paths. The indoor air quality and exhaust airflow rates must meet building mechanical codes. The ventilation design must be analyzed to determine whether an overpressure can be achieved by supplying additional outside air through the existing ventilation system or by restricting exhaust airflow rates such as from an economizer air exhaust or from other building exhaust systems. In some cases, both means may be necessary. To analyze the ventilation system design overpressure capability, an air leakage measurement test using a blower door assembly or the existing air-handling system can be performed in accordance with American Society for Testing and Materials (ASTM) E779. If the existing ventilation system cannot achieve an overpressure, filtering the outside air intakes still provides protection, though at a lower factor.

3-6.2.2.2 Class II – New Facilities

New facility design should incorporate sealing measures. An overpressure can be achieved by supplying a higher rate of conditioned outside air to the protected area than is exhausted. To obtain a minimum overpressure of 5 to 12 Pa (0.02 to 0.05 in wg) in the protected area, the additional air required can be approximated by the unit leakage values presented in Table 3-4, or the additional air intake requirement can be determined using calculation procedures in the American Society of Heating, Refrigerating and Air-Conditioning Engineers' 2001 *ASHRAE Handbook Fundamentals* (refer to Appendix F, Determining the Building Protection Factor).

Table 3-4. Building Overpressure Unit Leakage Rates*

Building Leakage Category	Construction Type	Unit Leakage Rate L/s per m ² (cfm per ft ²) of floor area			
		Level of Overpressure			
		5 Pa (0.02 in wg)	12 Pa (0.05 in wg)	75 Pa (0.30 in wg)	100 Pa (0.40 in wg)
Very Tight	72-inch-thick walls and roof, no windows	0.08 (0.02)	0.13 (0.03)	0.36 (0.07)	0.40 (0.08)
Tight	12-inch-thick poured concrete walls, windows with supplemental sealing, concrete roof	0.10-0.36 (0.02-0.07)	0.20-0.61 (0.04-0.12)	0.56-1.83 (0.11-0.36)	0.66-2.18 (0.13-0.43)
Typical	12-inch-thick concrete/block walls, windows with weather seals, metal deck roof	0.76-1.27 (0.15-0.25)	1.27-2.29 (0.25-0.45)	3.81-5.84 (0.75-1.15)	4.57-7.11 (0.90-1.40)
Loose	Poorly constructed building, framed walls, evident leakage paths	2.54 (0.50)	4.57 (0.90)	15.2 (3.0)	18.5 (3.65)

* Building leakage rates are a general estimate derived from limited fan pressurization tests of the construction types listed.

3-6.2.3 Class I – Filtration with Pressurization

The protected areas of facilities that cannot be evacuated but may experience a large-scale release of agents over an extended period of time must be designed for a Class I overpressure. Class I provides an overpressure capability to resist a long-duration event and corresponds to a low likelihood that an event will compromise an asset. Typically, this level of protection is limited to wartime events, which are not covered in this document. For information on designing wartime facilities, refer to UFC 3-340-01, Design and Analysis of Hardened Structures to Conventional Weapons Effects.

Extended protection requires a CP system that provides an overpressure to resist a continual large-scale threat in a 40 km/hr (25 mph) wind. Therefore, the minimum protected area overpressure is 75 Pa (0.30 in wg), which corresponds to a wind speed impact pressure normal to a wall of 40 km/hr (25 mph). Areas requiring ingress and egress must have an internally or externally located CCA with ingress and/or separate egress airlocks. The CCA should be located outside of the facility or under an open-air overhang, roofed shelter, or tent. The CP system may be operated continuously or maintained in a standby mode (that is, energized only when there is a known threat of attack). It is advisable, however, to operate the filtration system continuously to protect the building occupants.

3-6.2.3.1 Class I – Existing Facilities

It is possible to reclassify buildings with a Class II overpressure as Class I by de-energizing the building's exhaust systems and thereby increasing the internal overpressure. Modification of existing facilities for Class I overpressure requires an engineering analysis to determine whether the existing HVAC system is capable of fully

or partially integrating the CP system. If the existing system is not capable, or only partially capable, a supplemental heating and cooling system can be provided.

If the facility cannot be sealed economically to maintain an overpressure but is suitable for a secondary enclosure, then the secondary enclosure allows the facility's existing HVAC system to partially or fully maintain the design temperature outside the shelter. Examples of potentially suitable facilities are warehouses, hangers, and maintenance bays. For more information, refer to Army Publication FM 3-11.4 (FM 3-4), Marine Corps Publication MCWP 3-37.2, Navy Publication NTTP 3-11.27, or Air Force Publication AFTTP(I) 3-2.46.

3-6.2.3.2 Class I – New Facilities

New facilities with Class I overpressure must be capable of maintaining the facility temperature during CP operations. Refer to the above discussion of Class II overpressure in new facilities for methods of determining the airflow rates required to obtain the necessary overpressure.

3-7 BUILDING PROTECTION SUMMARY

Table 3-5, Building Protection Summary, provides an overview of the overpressure classes and the corresponding design basis threat, level of protection, and filtration system.

Table 3-5. Building Protection Summary

Overpressure	Design Basis Threat	Level of Protection	Filtration System
None	Very Low	Very Low	None
Class III None	Low	Low	HEPA filters on outside air or supply air if more practical
	Medium	Medium	HEPA filters and carbon adsorbers on outside air
	High	High	HEPA filters and carbon adsorbers on all supply air
Class II 5 to 12 Pa	Low	Low	HEPA filters on outside air or supply air if more practical
	Medium	Medium	HEPA filters and carbon adsorbers on outside air
	High	High	HEPA filters and carbon adsorbers on all supply air
Class I 50 to 75 Pa	Low	Low	HEPA filters on outside air or supply air if more practical
	Medium	Medium	HEPA filters and carbon adsorbers on outside air
	High	High	HEPA filters and carbon adsorbers on all supply air

3-8 DESIGN OF THE COLLECTIVE PROTECTION SYSTEM

3-8.1 Design Approach

For CP systems, the airflow capacity required for the air filtration units is determined by the greater of two components: (1) the sum of the air leakage rate at design overpressure and the ventilation rate for exhaust requirements or (2) the amount of outdoor air to satisfy indoor air quality requirements. All penetrations in the protected area envelope require proper sealing, and the air leakage control barriers must be continuous. Weather sealing measures can reduce leakage by 5 to 50 percent, depending on the type and quality of facility construction. Sealing the protected area envelope reduces the air leakage rate and thus the required amount of filtered air and the cost of heating and cooling. Simple weather stripping on doors can reduce the leakage rate over that of a standard interior door installation. For most applications, the use of weather-strip-grade door seals is sufficient. The cost of sealing measures should be balanced against the cost of filtration and HVAC equipment; sealing measures must be economical compared to the cost of the filtration and HVAC equipment.

In most cases, the installation of a CP system will increase the facility's energy usage due to higher fan static pressures, increased outside air requirements to pressurize a building, and the possible elimination of economizer cycles. In addition, operation and maintenance (O&M) costs will increase due to filter replacement and system testing. Designers, facility managers, and commanding officers should evaluate these costs to ensure that sufficient O&M funds will be available.

3-8.2 Envelope Leakage Rate

For buildings designed for the medium and high levels of protection, the air leakage rate of the protected area envelope can be estimated using Table 3-4, Building Overpressure Unit Leakage Rates, above. The building leakage characteristics in the table are a general estimate derived from limited fan pressurization tests of the construction types indicated. Therefore, specific air leakage testing should be performed for the construction type used. The leakage test of the protected area envelope should occur after construction or renovation to verify the leakage rate and ensure that the CP filtration system has sufficient capacity.

3-8.2.1 Leakage Prevention in Existing Facilities

Steps to determine leakage rates and provide recommendations for preventing leakage of the protected area envelope in existing facilities are as follows:

- Perform a pressurization test using a blower door assembly or the facility AHUs in accordance with ASTM E779.
- Plot test data on a log-log graph for ease of data tabulation, extrapolation, and review.
- During testing, identify air leakage locations when the blower door assembly is operated in the negative pressure mode and draws outside air into the proposed protected area.

- Identify leakage locations by physical inspection or smoke testing.
- Seal leakage areas with a good-quality sealant or, if necessary, reconstruct the areas.
- After sealing, conduct a second pressure test to determine the final protected area envelope air leakage rate.

3-8.2.2 **Leakage Prevention in New Facilities**

Steps to determine leakage rates and provide recommendations for preventing leakage of the protected area envelope in new facilities are as follows:

- Calculate the leakage rate using the effective leakage area procedures in the 2001 *ASHRAE Handbook Fundamentals* (refer to Appendix F, Determining the Building Protection Factor). Include the walls, roofs, floors, doors, windows, sole plates, mechanical and electrical penetrations, ceiling-wall joints, and isolation dampers.
- Use the overpressure of the protected area as the differential pressure in determining the leakage rate.
- Using Table 3-4, Building Overpressure Unit Leakage Rates, confirm the unit leakage rate determined by the calculations.
- During construction, properly seal penetrations and use continuous air leakage control barriers in the protected area envelope.
- After construction, perform a blower door or pressure test of the protected area envelope to verify the leakage rate and ensure that the CP filtration system has sufficient capacity.

3-8.3 **HVAC Requirements**

3-8.3.1 **HVAC for Existing Facilities**

HVAC requirements for existing facilities are as follows:

- Perform an engineering evaluation to determine whether the existing HVAC equipment can be used for CP operations to maintain the designed indoor air temperatures for both the summer and winter design conditions.
- Coordinate the final indoor temperature for the summer and winter design conditions with the user.

- When providing an overpressure, increase the existing outside air intake if needed. Modify mechanical equipment or add heating and cooling equipment as necessary to meet the new outside air intake requirement and account for additional fan heat.
- For facilities that do not require the HVAC system to maintain above-freezing indoor conditions during low outdoor ambient conditions, incorporate provisions for protecting water utilities from freezing during CP operations.

3-8.3.2 HVAC for New Facilities

HVAC requirements for the design of new facilities are as follows:

- Design the HVAC equipment to incorporate the requirements of the CP system and maintain indoor design conditions.
- Locate the outside air intakes in an inaccessible location or secure the intakes by means of a standoff distance that inhibits the direct insertion of contaminants.
- Provide ventilation isolation zones by separating HVAC systems.

3-8.3.3 Indoor and Outdoor Design Temperatures

Indoor dry and wet bulb design temperatures and outdoor design temperatures must be determined in accordance with UFC 3-400-02, Design: Engineering Weather Data, and associated references as well as mission requirements.

3-8.3.4 Outside Air Ventilation Rate per Occupant

The target outside air intake rate per occupant must conform to ASHRAE Standard 62 for normal operations. For facilities that function as a CP shelter where the outside air intake rates required in ASHRAE Standard 62 cannot be maintained, lower air intake rates are allowable for temporary CP operations. Different levels of indoor air quality can be used depending on user requirements and facility restrictions. To maintain indoor air quality based on the ASHRAE Standard 62 acceptable indoor carbon dioxide level of 0.1 percent, the minimum air intake rate is 7 L/s (15 cfm) per building occupant.

3-8.4 Ductwork

Ductwork that serves the protected area during normal operations but is not required during CP operations must be closed off and isolated by means of low-leakage dampers at the protected area envelope. During CP operations, the CP system must maintain pressure on the isolation dampers under all conditions and thereby prohibit contaminated air from entering the protected area. Isolation damper position indicators must be included to visually identify the open and closed positions or failure to move to the appropriate CP position. The isolation damper position must also be visually annunciated at the CP system control panel. The leakage rating of the isolation dampers must be selected based on an economic comparison of damper leakage and additional filtration capacity.

Ductwork must have the proper configuration or construction to prevent unfiltered air from leaking from the ductwork into the protected area and from an unprotected area into return air ductwork that is under a negative pressure. The designer should avoid locating ductwork carrying clean filtered air in a contaminated environment (that is, outside the protected area envelope), and locating ductwork carrying unfiltered air in a clean environment (that is, inside the protected area envelope). If these situations cannot be avoided, ductwork carrying filtered air must be under a positive pressure when located in a contaminated environment, and ductwork carrying unfiltered air must be under a negative pressure when located in a clean environment. If these duct pressures cannot be met or if differential pressures are uncertain, then the ductwork should be sealed by welding seams or other methods and leak tested.

3-8.5 **Doors**

Doors at the protected area envelope must be weather sealed to reduce the air leakage rate. Door positions can be monitored and visually annunciated at the CP system control panel. The 2001 *ASHRAE Handbook Fundamentals* provides air leakage calculation procedures to determine the additional air intake requirement (refer to Appendix F, Determining the Building Protection Factor).

3-8.6 **CP Filtration System Design**

The CP filtration system is the most critical part of the CP system.

3-8.6.1 **CP Filtration System Configuration**

The CP filtration system must have the proper configuration to prevent unfiltered air from leaking from the housing and ductwork into the protected area, as follows:

- If located in a contaminated environment (that is, outside the protected area envelope), it must be designed as a blow-through system with the blower located before the CP filtration system.
- If located in a clean environment (that is, inside the protected area envelope) and draws in the contaminated air through a ductwork system, it must be designed as a draw-through system with the blower located after the CP filtration system.

The protected mechanical rooms should meet the same overpressure requirements as the protected area. The total static pressure of the CP filtration system blower must be designed to allow for a filtration system with dirty filters, ductwork system pressure losses, and the overpressure requirement of the protected area. The CP filtration system fans can be equipped with a variable frequency drive of inlet vanes to adjust the airflow rate to maintain the desired overpressure in the protected area. The variable airflow will allow the system to adjust for clean or dirty filters and changes in air density from winter to summer conditions. The CP filtration system must be designed for zero bypass around the HEPA filters and carbon adsorbers.

3-8.6.2 Filtration Equipment

A number of CP filtration systems are available from both the military and commercial suppliers (refer to Appendix G, CP Filtration System Equipment, for more information). If commercial filtration systems are used, the mechanical system designer should have the technical expertise to prepare specifications that meet military filtration system requirements. For continuously operated filtration systems, accessory equipment such as moisture eliminators or baffles to prevent the filters from being exposed to water droplets and large particulate prefilters must be considered to protect the filtration system.

3-8.6.2.1 Filter Sections

A CP filtration system unit requires a HEPA filter (99.97 percent efficiency at 0.3 microns) and a carbon adsorber in series. In addition, a roughing filter (30 percent efficiency per ASHRAE), followed by a prefilter (85 percent efficiency per ASHRAE), is typically used upstream of the HEPA filters to collect large dust particles and extend the life of the HEPA filters. HEPA filters without a prefilter can be fully loaded after 9 months of continuous use. A prefilter extends the life of the HEPA filter to about 2 to 4 years of continuous use. A postfilter (95 percent efficiency per ASHRAE), which collects carbon that has separated from the adsorber and prevents it from being distributed in the HVAC system, is optional. The postfilter is most commonly used with non-military carbon adsorbers. The entire filter train described above is as follows:

- Roughing filter (30 percent efficiency per ASHRAE)
- Prefilter (85 percent efficiency per ASHRAE)
- HEPA filtration (99.97 percent efficiency at 0.3 microns)
- Carbon adsorber
- Postfilter (for non-military applications, 95 percent efficiency per ASHRAE)

3-8.6.2.2 Filter Housings

Housings must be off-the-shelf units that are developed by the military, meet Naval Sea Systems Command (NAVSEA) Navy Drawings 6573690-04 and 6573690-05, or are designed and constructed to meet the basic requirements identified in American Society of Mechanical Engineers (ASME) AG-1, Code on Nuclear Air and Gas Treatment, and applicable sections of ASME N509, Nuclear Power Plant Air-Cleaning Units and Components. Housings must be designed for the pressure that will be encountered. Challenge test ports for in-place testing must be incorporated into the system housing or elsewhere in the system ductwork. Pressure test ports for measuring differential pressures across the roughing filter, prefilter, HEPA filter, and carbon adsorber must be incorporated into the filter housing. Refer to Appendix G, CP Filtration System Equipment, for additional information.

3-8.6.2.3 HEPA Filters

HEPA filters and frames must meet the materials, design, inspection, fabrication, and quality assurance requirements and be marked with the nameplate data specified in ASME AG-1, Code on Nuclear Air and Gas Treatment. HEPA filters must have 99.97 percent efficiency with a 0.3-micron-diameter particle size, as determined by the dioctyl phthalate (DOP) test method. The pressure drop across clean HEPA filters is in the 245 to 380 Pa (1.0 to 1.5 in wg) range; the pressure drop across dirty HEPA filters ranges from 490 to 850 Pa (2.0 to 3.5 in wg).

3-8.6.2.4 Chemical Adsorber Capabilities

A CP filtration system for building protection requires the capability to remove a broad spectrum of chemical vapors and gases from an air stream with a very high efficiency. Although there are several methods of filtration, the current standard for filtering chemicals is the carbon adsorber, which is a packed bed of impregnated, activated carbon granules. Some industrial chemicals, such as chlorine gas, cannot be adsorbed but must be neutralized through chemical reaction. The carbon adsorber employs two different processes to remove the chemical agents: physical adsorption and chemical reaction. To remove warfare agents, military carbon adsorbers use ASZM-TEDA impregnated carbon, which also removes many TICs.

The Edgewood Chemical Biological Center has evaluated and performed limited testing on the effectiveness of ASZM-TEDA carbon in removing TICs. Of the 98 TICs identified, 34 are effectively removed, 33 are marginally removed, and 31 are poorly removed. To determine the effectiveness of the CP filtration system equipment, it is helpful to conduct a survey of available sources of TICs and TIMs within proximity of the facility. Possible sources include nearby chemical plants, chemical storage facilities, swimming pools with large chlorine tanks, streets or highways with heavy truck traffic, and rail lines with freight traffic. Some information on chemicals stored in buildings near the site may be available from the local fire department. After sources of TICs and TIMs in the proximity of a facility have been identified, the installation manager or designer should contact the Joint Program for Collective Protection (JPM ColPro) to verify that the chemicals of concern will be removed by ASZM-TEDA carbon. To ensure adequate protection, it may be necessary to add a filtration element to the filter train to remove TICs or TIMs that are stored in or near the facility. Selection of filtration element materials or coatings that are chemically resistant to the TIC or TIM of concern may also be necessary.

3-8.6.2.5 Carbon Adsorber Units

Several types of large-volume chemical vapor carbon adsorber units and systems that are available from both the military and commercial suppliers apply to CBR building protection. Military-procured adsorbers conforming to MIL-PRF-51527A(EA) have the advantage of being pre-approved for use on military installations, while commercially available equipment requires additional government quality testing and must be government approved.

3-8.6.2.6 **Military Carbon Adsorber Media**

The standard carbon for military applications is impregnated with triethylenediamine (TEDA) in accordance with U.S. Army Edgewood Research, Development and Engineering Center (ERDEC) specification EA-C-1704. The ERDEC specification for carbon adsorber design is MIL-PRF-32016(EA). The carbon adsorber must have an efficiency of 99.999 percent. After installation, the CP filtration system must be subjected to a mechanical leak test.

Deep bed adsorber charcoal media must be designed to adsorb chemical vapors and must meet the requirements of MIL-PRF-32016(EA). The minimum residence time must be 0.25 seconds when TICs are a potential agent. If the threat is a known military chemical agent, the residence time may be reduced to 0.19 seconds. For unknown threats and adsorption of volatile agents, ASZM-TEDA carbon conforming to EA-C-1704 will be used. If the threat is known, the use of ASZM-TEDA may not be required; if agents of higher volatility, such as hydrogen cyanide and cyanogen chloride, are not a threat, activated carbon (not impregnated carbon) will suffice.

3-8.6.3 **Leak Testing**

The design must provide adequate filter access for CP filtration system testing. The CP filtration system must be subjected to in-place leak tests to ensure that critical filter-to-housing seals do not allow leakage around the filters. For information on CP filtration system testing during startup and operation of the CP system, refer to Chapter 4, Startup, Operation, and Maintenance of the CP System; Appendix G, CP Filtration System Equipment; and Appendix H, CP Filtration System Testing Requirements.

3-8.7 **Standby Collective Protection Control System and Operational Requirements**

The CP control system must be located in the protected area. The preferable location is a security check point that (1) is manned during all work hours and (2) has indicators of a security breach signifying an unauthorized opening of a door. In addition, the CP control system must have the following capabilities and features:

- Be energized by one control panel switch that de-energizes other facility systems not required during CP control system operations. Examples of these other systems are normal outside air fans, exhaust fans, and recirculation fans that are in the building but outside the protected area envelope.
- Monitor the position of all isolation dampers and doors by an indicator light at the CP control panel. The CP control panel must indicate all device positions (open or closed) or failure to operate.
- For large systems, include an indicator to show whether the dampers or doors are in the correct position during CP control system operation. For small systems, consisting of three doors or less and five dampers or less, individual indicator lights are not required; a single light indicating failure is acceptable.

- Monitor and display, on the control panel, the protected area overpressure with reference to the atmosphere.
- Include interlocking of the airlock doors, if the CP system includes an airlock, to ensure that the doors are not opened simultaneously.

3-9 DESIGN CONSIDERATIONS FOR BUILDING DECONTAMINATION

3-9.1 Retention of CBR Agents Released into a Building

If CBR agents are released into a building, the normal exchange of the indoor air with the outdoor air purges a portion of the contaminants released. However, the following processes retain a portion of the agents in the building over time:

- Chemical agents in the liquid phase are absorbed by building materials and furnishings and by contents of the building. The agents desorb slowly over time.
- Chemical agents in the gas phase are absorbed or adsorbed by building materials. The agents desorb slowly over time.
- Biological and radiological aerosols and other solid aerosols settle onto surfaces or are forced into small openings, such as those on computers, at a rate dependent on aerodynamic particle size and air movement. They may be re-aerosolized with the movement of people, air, and equipment in the building or with changes in temperature and humidity.

3-9.2 Decontamination Measures

Immediately after release, measures must be taken to purge, disinfect, decontaminate, or contain agents. Otherwise, the agents can be transported to and deposited onto inaccessible surfaces in the building, greatly complicating the decontamination process. Decontamination and disinfection range from simply removing the agent with soap and water to using complex procedures for neutralization, cleaning, or accelerated desorption.

3-9.3 Design Objectives

There are three objectives in designing a building to minimize agent retention and to facilitate decontamination:

1. To make surfaces and materials in the building less adsorbent. This can be done by minimizing pores, using materials or coatings that can resist agent penetration and absorption, using the smallest openings necessary for their purpose, and using rounded corners instead of square joints.
2. To make accessible for decontamination all surfaces on which agents are likely to deposit.
3. To design certain areas to accommodate the use of water in large volumes for decontamination.

3-9.3.1 Making Surfaces and Materials Less Adsorbent

Chemical agent resistance is defined by the rate at which a material absorbs chemical agents, with minimal change in its physical and chemical properties and minimal impact by standard CBR liquid decontamination solutions. Many plastics and elastomers readily absorb chemical agents such as mustard and nerve agents, which are strong solvents. Measures to make surfaces and materials less adsorbent are as follows:

- Minimize the use of curtains and fabric wall coverings.
- Avoid open-face insulation in ducts and plenums.
- Select plastics, polymers, paints, sealants, and other construction materials for the building for their resistance to chemical agents, regardless of whether the material is likely to be exposed to an agent in the form of liquid or vapor. Note, however, that the practicality of doing so is limited because agent-resistant materials may not have acceptable physical properties, availability, cost, and aesthetic qualities.

There is no standard criterion for the rate of chemical absorption. Chemical agent tests have shown that after exposure to a liquid agent at a concentration of 10.0 g/m^2 (0.3 oz/ft^2), the most-resistant materials desorb the agent at very low rates, such as $3 \text{ } \mu\text{g/cm}^2$ (98 noz/ft^2). Results of tests on various plastics, elastomers, and sealants are available in reports from the Chemical Biological Information Analysis Center (CBIAC) at Aberdeen Proving Ground, Maryland.

3-9.3.2 Making Surfaces Accessible for Decontamination

The principal consideration with regard to accessibility for decontamination is access to ducts and plenums. Access ports should be located to facilitate cleaning of ducts and plenums.

3-9.3.3 Designing for Ease of Decontamination with Water

Decontamination with large volumes of water applies primarily to areas with a high likelihood of becoming contaminated, such as shipping and receiving areas, mailrooms, lobbies, and airlocks. Design considerations are similar to those for a medical operating room:

- Minimize sharp corners and sharp edges that could allow cracks to propagate to inaccessible areas.
- Slope the floor slightly to facilitate collection of water and decontaminants.
- Construct floor drains for the containment of run-off.
- Select materials and coatings for ease of cleaning and resistance to aggressive decontaminants and biocides.

CHAPTER 4

STARTUP, OPERATION, AND MAINTENANCE OF THE CP SYSTEM

4-1 STARTUP OF CP SYSTEM

After installation of a CP system, adherence to the startup procedures is important to ensure that the system is operating properly.

4-1.1 Airflow Balancing

The ventilation system should be balanced to ensure that the design airflow rates are being provided under the normal and CP operation modes. At a minimum, outside, return, and supply air flows should be balanced. It may also be necessary to balance other parts of the air supply, return, or exhaust system.

4-1.2 CP Filtration System Testing

It is recommended that an independent testing agency field test the CP filtration system after installation. Refer to Appendix H, CP Filtration System Testing Requirements.

4-1.3 Performance Testing

After testing, adjusting, and balancing are complete, each system must be tested as a whole to determine that all items perform as integral parts of the system and that pressures, temperatures, and conditions are met and evenly controlled throughout the building. Corrections and adjustments must be made as necessary to produce the conditions indicated or specified. An experienced engineer should conduct capacity tests and general operating tests to demonstrate that the entire system is functioning according to specifications.

4-2 CP SYSTEM OPERATIONAL TESTING

Standby CP systems should be tested once each month to ensure that they are in good operating condition. Continuously operated systems should be monitored periodically to ensure that they are operating properly.

4-3 CP FILTRATION SYSTEM

In addition to the manufacturer's recommended maintenance requirements, there are the following filter replacement and testing requirements.

4-3.1 Airflow Testing

The CP filtration system airflow rate should be periodically tested and re-balanced as necessary to maintain the design airflow rate. The filtration system should also be airflow tested after prolonged use.

4-3.2 CP Filtration System Testing

In addition to field testing following the startup of the CP filtration system, it is recommended, but not required, that the system be subjected to a mechanical leak test every 12 months. The system should also be tested after replacement of the HEPA filter or carbon adsorber.

4-3.3 **Testing Cost**

The facility operating budget must include the periodic testing.

4-4 **IDENTIFICATION OF PROTECTED AREA**

A floor plan should identify the protected area for the facility occupants. The floor plan should be included in the facility protective action plan and posted at a central location in the building. For additional information, refer to Appendix E, Protective Action Plan: Operational Procedures to Protect Existing Buildings and Their Occupants from Airborne Hazards.

4-5 **TRAINING**

All facility personnel (for example, security, maintenance, and occupational health and safety staff) potentially required to operate the CP system must receive training. Additional training of the facility occupants should be performed in a manner similar to fire evacuation drills. The protective action coordinator (PAC) or someone familiar with the CP system, such as the design engineer or the construction contractor, should provide the training.

4-6 **OPERATING INSTRUCTIONS**

Operating instructions and system diagrams for standby CP systems must be provided to the building tenant and displayed at eye level next to the CP system control panel. The operating instructions must describe, in short and concise language, the steps required to operate the CP system. All CP system control switches and indicators must be clearly marked and identified.

4-7 **OPERATION AND MAINTENANCE MANUAL**

An O&M manual must be provided for the CP system and located together with the protective action plan for the installation. The O&M manual must contain system operating instructions; emergency operation procedures; preventive maintenance, troubleshooting, and corrective maintenance information; periodic maintenance recommendations; critical instructions; and a spare parts list.

4-8 **FILTER REPLACEMENT**

4-8.1 **Carbon Adsorber Replacement**

4-8.1.1 **Service Life**

The service life of an impregnated carbon adsorber is defined by the reactive gas life and the physical adsorber life. The adsorber life against reactive gases is generally the shorter of the two; therefore, the replacement cycle is usually based on the degradation in reactive gas capacity. Adsorber life is site specific, although the environmental air quality affects both capacities. The adsorption of organics (air pollutants) reduces the physical adsorption life. Adsorber capacity for reactive gases such as chlorine, hydrogen cyanide, and cyanogen chloride diminishes gradually over time and, with ASZM-TEDA carbon, is typically lost within 2 to 4 years of exposure to humidity in ambient air. The rate at which the impregnant degrades varies with the temperature and the amount of water reacting with the carbon bed. Degradation begins once an adsorber is opened to the atmosphere. The degradation is more rapid when air is being

drawn through the adsorber because atmospheric pollutants contribute to the degradation. Adsorber life can also be affected by loosening of the carbon as air is drawn through the adsorber, a condition that can be determined by conducting an in-place leak test at certain intervals.

Surveillance testing has shown that substantial physical adsorption capacity can remain after air is drawn through an adsorber continuously for periods as long as 10 years. Studies have shown that adsorbers in service for long periods show very little degradation in adsorber life against nerve or mustard gas when an adsorber is operated in a low-pollution environment away from heavy industry and vehicular traffic. Adsorbers used where there are high levels of air pollution, however, showed substantial degradation in capacity. Adsorbers continuously operated for 1 year in Washington, DC, were found to have lost about one-third of their adsorption capacity.

4-8.1.2 **Replacement Considerations**

Carbon adsorbers must be replaced on a regular basis. Depending on the local atmospheric pollutants, adsorber change-out can be expected to be required every 2 to 4 years.

The carbon adsorber should be replaced as indicated by adsorbent life testing conducted on samples removed from the adsorption system. The adsorber design must include a means to obtain samples of the adsorbent, either by removing a carbon adsorber from the CP filtration system or by incorporating into the filtration system a set of sample pilot canisters that represents the total carbon adsorber bed thickness. Adsorbers not contaminated by chemical surety materials or by other hazardous materials can be refilled by the manufacturer, but the owner must dispose of any contaminated carbon in accordance with local, state, and federal regulations. Carbon adsorbers that have been contaminated by CBR agents may have to be changed by personnel wearing IPE and must be disposed of in accordance with local, state, and federal hazardous waste regulations.

4-8.2 **HEPA Filter Replacement**

Depending on its structural capability, a HEPA filter can have a dust buildup static pressure drop of up to 2,488 Pa (10 in wg). However, HEPA filters are typically changed when the dust buildup is approximately 746 to 995 Pa (3 to 4 in wg), thereby limiting the system static pressure requirements. An economic analysis should be performed for the site-specific location to determine at what static pressure drop the filters should be changed. The economic analysis should include the cost of HEPA filter replacement, the energy cost for the fan static pressure, and the initial cost of the system for the static pressure required.

APPENDIX A

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APPENDIX B

GLOSSARY

This glossary includes acronyms, abbreviations, and specialized terms used in the foreword, the body, and the appendices of this document.

B-1 ACRONYMS AND ABBREVIATIONS

ACH	air changes per hour
AFCESA	Air Force Civil Engineer Support Agency
AFM	Air Force Manual
AFTTP(I)	Air Force Tactics, Techniques, and Procedures (Interservice)
AHU	air-handling unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASZM-TEDA	carbon-activated, impregnated, copper-silver-zinc-molybdenum-triethylenediamine
CAM	chemical agent monitor
CBIAC	Chemical Biological Information Analysis Center
CBR	chemical, biological, or radiological
CC	cooling coil
CCA	contamination control area
CCB	Construction Criteria Base
CCR	Criteria Change Request
cfm	cubic feet per minute
cm	centimeter(s)
cmh	centimeters per hour

CONUS	continental U.S.
CP	collective protection
DCS	Deputy Chief of Staff
DMMP	dimethylmethylphosphonate
DoD	Department of Defense
DOP	dioctyl phthalate
DWG	drawing
ELA	effective leakage area
eq.	equation
ERDA	Energy Research and Development Administration
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
FEMA	Federal Emergency Management Agency
FFA	fan filter assembly
FM	Field Manual
FMFM	Fleet Marine Force Manual
ft	foot or feet
FOUO	for official use only
g	gram(s)
GFE	government-furnished equipment
HAZMAT	hazardous materials
HC	heating coil
HEPA	high-efficiency particulate air
HFC-4310	decafluoropentane
HQUSACE	Headquarters, U.S. Army Corps of Engineers
hr	hour(s)

HVAC	heating, ventilating, and air-conditioning
IEEE	Institute of Electrical and Electronics Engineers
IEST	Institute of Environmental Sciences and Technology
in.	inch(es)
in wg	inches of water gage
IPE	individual protective equipment
JPM ColPro	Joint Program for Collective Protection
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
m	meter(s)
µg	microgram(s)
µm	micrometer
MCRF	multi-cell radial-flow
MCWP	Marine Corps Warfighting Publication
MIL-PRF	Military Performance Specification
MIL-STD	Military Standard
min	minute(s)
mm	millimeter(s)
mph	mile(s) per hour
NA	not applicable
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NBC	nuclear, biological, and chemical

NFPA	National Fire Protection Association
noz	nano-ounce(s)
NSN	National Stock Number
NTTP	Navy Tactics, Techniques, and Procedures
O&M	operation and maintenance
OPNAV	Office of the Chief of Naval Operations
oz	ounce(s)
Pa	Pascal
PAC	protective action coordinator
s	second(s)
TEDA	triethylenediamine
TIC	toxic industrial chemical
TIM	toxic industrial material
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
USACE	U.S. Army Corps of Engineers
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

B-2 TERMS

agent	a substance in the form of a TIC or TIM, biological or radiological agent, or military chemical, which together with the delivery tactic is a type of threat
airborne delivery tactics	methods that include external release of an agent (from an upwind standoff distance or into a fresh air intake) and internal release (through the ventilation system or into a building area)
areas of rescue assistance or areas of refuge	spaces where persons unable to use stairs can call for and await evacuation assistance from emergency personnel

assets	personnel, mission-essential equipment, and facilities
blower door assembly	a calibrated device that measures the airflow rate into the facility during pressurization and out of the facility during depressurization
carbon adsorber	a packed bed of impregnated, activated carbon granules
CBR event	an airborne release involving a CBR agent and caused by an industrial accident or an intentional release either external or internal to the facility
collective protection	provision of a contaminant-free area where personnel can function without individual protective equipment such as a mask and protective garments
containment protection mode	mode that consists of compartmentalizing the fire zones by closing the fire doors and, if the building is so equipped, the smoke dampers
contamination control area	an area where personnel can safely remove contaminated IPE, put on clean IPE, and bring items into or out of a protected area in a proper air flow environment using the appropriate contamination control procedures
CP filtration system	the filter unit, consisting of the filters, fan, and filter housing
CP system	the system that includes the CP filtration system, sealing measures, dampers, ductwork, and controls to provide CP
credible warning	a believable but nonspecific message informing of danger from an imminent attack that has yet to be confirmed and lacks sufficient information for effective prevention
delivery tactic	the method of delivering a CBR agent (external or internal release)
design basis threat	“the threat (aggressors, delivery tactics, and associated weapons, tools, or explosives) against which assets within the building must be protected and upon which the security engineering design of the building is based” (UFC 4-010-01)
dwelt time or dwell cycle	the period of time to purge an airlock compartment after protective garments are removed and personnel enter the inner airlock compartment

envelope	everything that separates the interior of a building, or portion of a building, from the exterior environment, including the windows, walls, foundation, basement, slab, floor, ceiling, roof, and insulation
expedient	temporary
expeditionary situations	situations in which existing facilities are unavailable or inadequate for incorporating CBR protection features and transportable or mobile facilities are used for field applications
Force Protection Conditions	a set of specific security measures promulgated by the commander after considering a variety of factors including the design basis threat, current events that might increase the risk of a terrorist attack, and observed suspicious activities
general hazard threat	an external or internal release of TICs and TIMs
high-risk areas	portions of a building that are at a high risk of an internal release, such as mailrooms, lobby areas, and supply delivery areas with separate ventilation systems as well as unscreened public access areas and any other general-access areas
independent testing agency	a contractor or government agency that is financially and corporately independent of the mechanical subcontractor and reports to and is paid by the government or the prime contractor
infiltration	the uncontrolled exchange of the building's interior air with outside air
Level A	a military level of packing that provides protection required to meet the most severe worldwide shipment, handling, and storage conditions
Level B	a military level of packing that provides protection required to meet moderate worldwide shipment, handling, and storage conditions
level of protection	the degree to which an asset is protected against injury or damage from a CBR event
natural filtration	filtering that occurs when an agent is deposited in the building shell or on interior surfaces as air passes into and out of the building; generally, the tighter the building, the greater the effect of natural filtration

natural ventilation	the exchange of the building's internal air with outside air by means of intentional openings in the building envelope such as open doors and windows
overpressure	the difference in static pressure between the inside of a building and the ambient pressure outside of the building
pathogens	living disease-producing agents of biological origin, including bacteria, viruses, and fungi
prefilter	a low- to medium-efficiency filter that precedes the HEPA filter to remove large particulates
progressive collapse	the spread of an initial local failure from element to element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it
protected area of a building	the CP area, where personnel are able to work or shelter without wearing IPE during release of a CBR agent
protective action plan	security measures and operational procedures to protect existing buildings and their occupants from airborne hazards by reducing vulnerability, preventing a release, reducing the likelihood that releases will affect building occupants, and mitigating the hazard once a release has occurred
secondary enclosure	a portable enclosure system that can be installed within a facility if the facility cannot be sealed economically to maintain an overpressure but is suitable as a shell
shelter-in-place protection mode	mode that consists of de-energizing the ventilation system and closing the outside air intake and exhaust dampers using a master control capability
stack effect	thermally driven air density differences between the building indoor and outdoor ambient conditions
standby mode	mode in which the CP system is energized only when there is a known threat of attack
standoff distance	a distance maintained between a building or portion thereof and the potential location for a release
threat	aggressors, delivery tactics, and associated weapons, tools, or explosives against which a facility is protected; established by evaluating aggressor likelihood and objectives with respect to the assets

threat type	a combination of the agent type (chemical, biological, or radiological) and the delivery tactic (external or internal)
toxins	metabolic byproducts of living organisms that are classified as biological agents even though they are nonliving substances

APPENDIX C

AIRLOCKS AND ENTRY OR EXIT PROCESSING

C-1 PURPOSE AND GENERAL FUNCTION OF AN AIRLOCK

Airlocks are used in facilities with a high level of protection, where an overpressure must be maintained during CP operations. Airlocks serve the purpose of allowing entry and exit without a substantial exchange of air through open doorways. To allow entry or exit processing, an airlock maintains a pressure differential continuously in the room or building that is protected (for example, the protected area), isolated, or environmentally controlled. The pressure differential is produced by fans, wind, or buoyancy effect. If ventilated with filtered air, an airlock allows entry or exit to occur while contamination is present outside the airlock without introducing airborne contaminants into the protected space. In the case of chemical agents, an airlock can also be used effectively as a safe place to perform monitoring.

To prevent the direct transport of airborne contaminants through the airlock, people must pause in the airlock for a specified purging period during entry or exit. However, this purging alone does not prevent the transport of contamination through the airlock. Entering from a contaminated area also requires removing or neutralizing contaminants deposited on the entering person's clothing, mask, skin, or hair. This is normally achieved by removing outer clothing immediately before entering the airlock or while in the airlock and by washing or showering.

C-2 AIRLOCK DESCRIPTION

Airlocks can be single stage or two stage, as described below.

C-2.1 Integral Single-Stage Airlock

The integral single-stage airlock is provided with filtered air from the protected area as shown in Figure C-1 or from a dedicated filter blower. The overpressure in the protected area cascades through the airlock, thereby continuously purging contaminants from the airlock. Airflow from the top of the chamber to the bottom enhances protection by reducing contaminated air in the breathing zone (refer to Paragraph C-4, Regulation of Airlock Flow).

C-2.2 Stand-Alone Two-Stage Airlock

A two-stage airlock consists of two airlocks in series. As shown in Figure C-2, the stand-alone two-stage airlock has an outer first-stage and an inner second-stage compartment. Clean airflow is provided by a dedicated filter blower unit connected to the inner compartment at the filtered air inlet (refer to Paragraph C-4, Regulation of Airlock Flow). The stand-alone airlock is designed for a 94 L/s (200 cfm) filter blower unit and is intended for retrofitting to existing facilities.

The outer compartment is used for personnel to remove protective garments while the airlock is being continuously purged by the flow of filtered air. After protective garments are removed, personnel enter the inner compartment, which is then purged of vapors for a set period of time, called the "dwell time" or "dwell cycle." After the dwell cycle, personnel enter the protected area.

Figure C-1. Integral Single-Stage Airlock

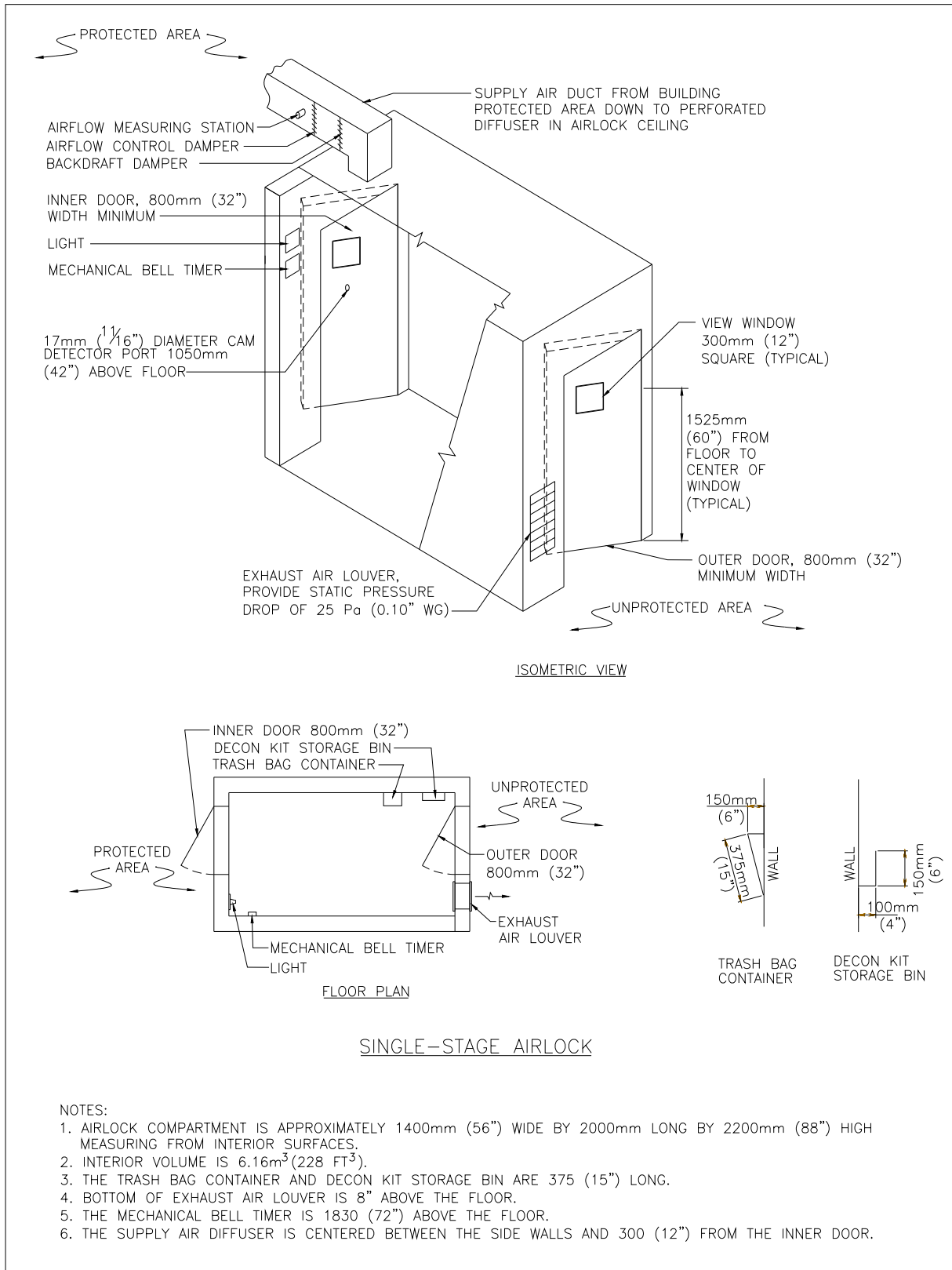
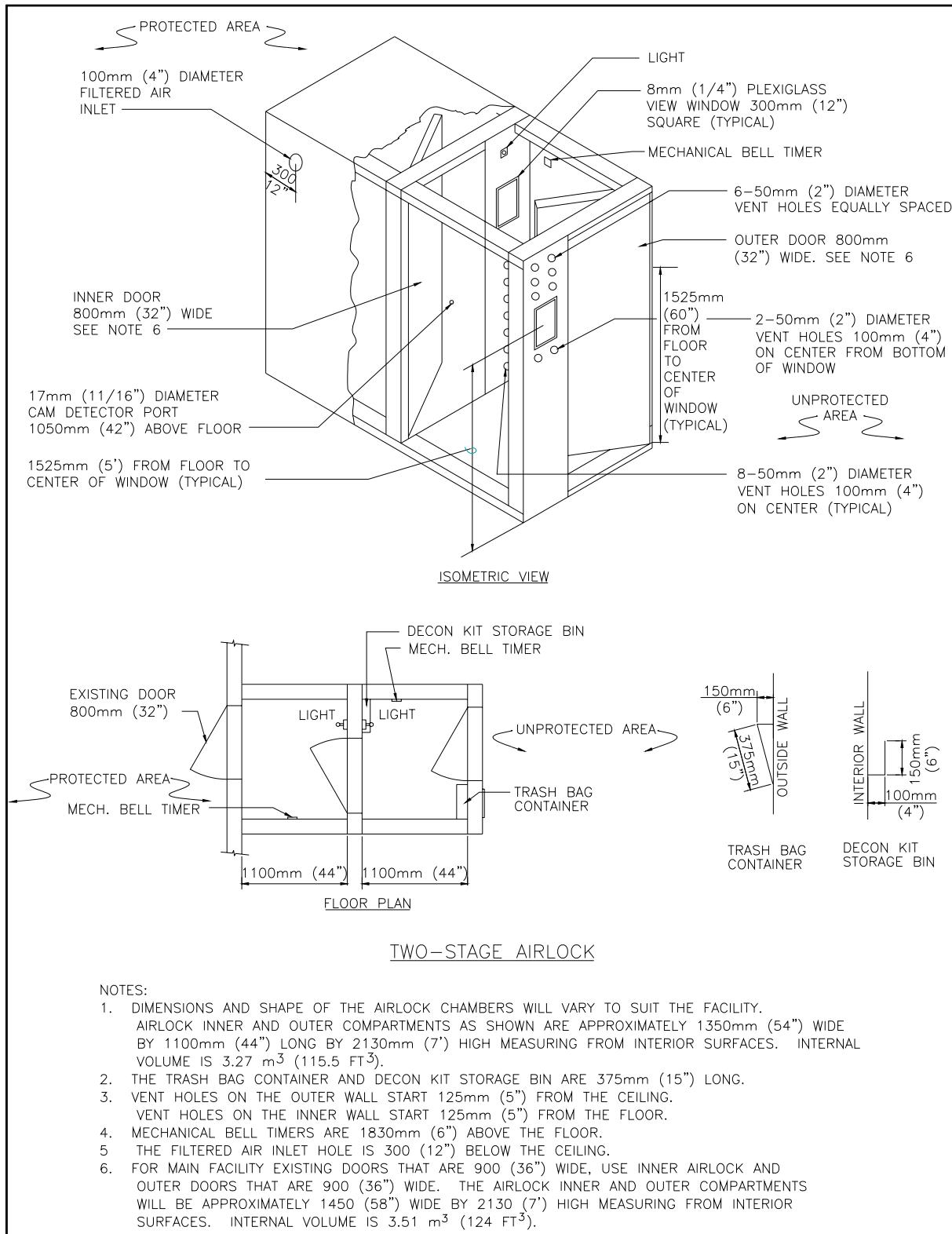


Figure C-2. Stand-Alone Two-Stage Airlock



C-2.3 Airlock Features

Airlocks have the following common features:

1. Timers – Each compartment requires a mechanical bell timer for the personnel processing dwell times. Personnel should check the process time to purge before entering the protected area.
2. Windows – Each compartment requires a window for determining whether the compartment is occupied.
3. Lights – Artificial lights compensate for the lack of adequate natural lighting in the airlock.
4. Purge vents – Airlocks without a dedicated filter blower unit require a variable area purge vent or flow control valve to adjust the airflow rate and maintain the required purge rate. The two-stage airlock with a dedicated filter blower unit can have fixed rather than adjustable purge vents because the dedicated filter blower unit provides a constant volume of airflow.
5. Monitoring port – The monitoring port allows a chemical agent monitor (CAM) operator located in the inner compartment to insert the CAM detector inlet into the outer compartment. This allows the CAM operator to determine whether there is agent vapor in the outer compartment. With a negative reading of about 10 seconds each for the G and H agents (nerve and mustard agents), the operator may determine that a shorter or longer dwell period is required. A second CAM check for sorbed vapor can then be performed in the inner or second-stage compartment.
6. Caulking – All joints should be caulked or otherwise sealed to limit uncontrolled air leakage.
7. Paint – The interior and exterior surfaces must be painted with epoxy paint to minimize the sorption of liquid and vapor agent.
8. Clothing chute or trash bag container – A clothing chute allows contaminated clothing to be removed from the airlock and discarded outdoors without re-exposure of personnel to the contaminated atmosphere. As an alternative, plastic trash bags can be placed in the airlock so that personnel can seal clothing in the bag after removal. If there is no clothing chute, a trash bag container should be provided (refer to Paragraph C-7, Processing Procedure Recommendations).
9. Instructional signs – Basic personnel processing instructions should be stenciled on the outer and inner doors of the airlock, as shown in Tables C-1 and C-2.

Table C-1. Integral Single-Stage Airlock Signs

Sign Text	Location
1. Airlock	1. Above the outer door
2. Do Not Open if Airlock Is Occupied	2. On the outer door
3. After Removal of IPE, Set Timer for 3 Minutes*	3. On the outer door below the other sign
4. Remove Mask Only After 3-Minute Purge and CAM Check**	4. On the second door; read from inside the airlock compartment
5. CAM Check Port	5. On the second door above the CAM port

* Actual time required is determined by equation C-1, below.

** Actual purge time is determined by equation C-1, below.

Table C-2. Stand-Alone Two-Stage Airlock Signs

Sign Text	Location
1. Two-Stage Airlock	1. Above the outer door
2. Do Not Open if Airlock Is Occupied	2. On the outer door
3. Upon Entering, Set Timer for 4 Minutes*	3. On the outer door below the other sign
4. Filtered Air Input	4. Near the filtered air inlet
5. CAM Check Port	5. On the second door above the CAM port
6. Remove Outer Garments before Processing to Next Compartment if Exposed to Chemical Agent	6. On the second door below the other sign; to be read from the outer compartment
7. Set Timer for 4 Minutes	7. On the second door; to be read from the inner compartment
8. Remove Mask Only After 4-Minute Purge and CAM Check**	8. On the protected area door; to be read from the inner compartment

* Actual time required is determined by equation C-1, below.

** Actual purge time is determined by equation C-1, below.

C-3 PURGE RATE

C-3.1 Estimating the Airflow Rate

The performance of an airlock is measured by its purge rate, which is determined by the flow rate of clean air through it, the volume of the airlock, the mixing efficiency, and the rates at which contaminants are sorbed or deposited on inner surfaces of the airlock. The airflow rate needed for purging an airlock in a specified time can be estimated by the following equation C-1:

$$C/C_o = e^{-QT/V} \quad (\text{eq. C-1})$$

where

- C = concentration at time T
- C_o = initial concentration
- Q = airflow rate in cfm
- T = time in minutes
- V = volume of the airlock in ft³

Airlocks are usually designed to achieve a three-log (99.9 percent) reduction in 5 minutes or less. For a three-log reduction, the equation simplifies to $Q = 6.9 V/T$. This equation does not account for sorption or deposition of agent on interior surfaces of the airlock. Therefore, airlocks are normally tested using aerosols or nondepositing tracer gases.

C-3.2 Benefit of a Two-Stage Airlock

Dividing an airlock into stages is a means of improving the purge rate with a given volume of purge flow. The benefit of using a two-stage airlock is that it will achieve a two-log, rather than a three-log, concentration reduction in each of the two sequential stages.

The following example illustrates the benefit of a two-stage airlock. An airlock that is 3.0 m (10.0 ft) long, 1.2 m (4.0 ft) wide, and 2.1 m (7.0 ft) high and is ventilated with 283 L/s (600 cfm) of filtered air achieves a three-log concentration reduction in 3.2 minutes according to equation C-1, shown above. If a center door is added to divide the airlock into two equal 1.5-m- (5.0-ft-) long stages, the purge period for each stage is 1.1 minutes for two logs. As people enter, they remain in the first stage 1.1 minutes and proceed to the second stage for a 1.1 minute purge to achieve a four-log purge in 2.2 minutes.

C-4 REGULATION OF AIRLOCK FLOW

There are multiple approaches for regulating airlock flow.

C-4.1 Vents

The most common approach is to vent clean air from the protected area through the airlock. This controlled leakage is driven by the overpressure in the protected area and is regulated by vents that are adjustable, weighted, or fixed at each end of the airlock. The disadvantage of this approach is that the purge rate can vary, and even decrease to zero, if the uncontrolled leakage rate of the protected area envelope increases and the user adjusts the vents to maintain the prescribed overpressure.

C-4.2 Exhaust Fan

An alternative is to use an exhaust fan drawing air from the airlock to achieve a relatively constant purge flow. The exhaust fan minimizes variations in the airlock flow rate but increases the variability in overpressure if the leakage varies over time in the protected area.

C-4.3 **Dedicated Filter Unit**

An approach that minimizes variability in both the purge flow and overpressure is to employ a dedicated filter unit for the airlock. With this approach, there is no vent between the protected area and the airlock. A dedicated filter unit can be employed in either a once-through mode or a recirculating mode, as follows:

- In the once-through mode, filtered air is introduced to the airlock at a point near the innermost door. It exits the airlock through vents in or around the outermost door. These vents are sized to produce an airlock pressure lower than the overpressure of the protected area.
- In the recirculating mode, a return duct connects the filter unit to the airlock at a point near the outermost door. The recirculating mode requires that a relatively small volume of air be vented from the protected area through the airlock for pressurization of the airlock. The level of pressure for the airlock should be 25 to 50 Pa (0.1 to 0.2 in wg) if the protected area is pressurized to 75 Pa (0.3 in wg). At this airlock pressure, the outer vents of the airlock must be shielded from the wind to prevent backflow through the airlock vents in windy conditions.

C-5 **MONITORING**

To use an airlock for monitoring chemical agents, a 17.0-mm- (0.7-in-) diameter port for the military standard CAM is placed in the inner door of the airlock or in the middle door of a two-stage airlock. A CAM operator stands in the protected area or in the second stage of a two-stage airlock and places the inlet of the CAM in the port to draw air from the airlock. The operator can also instruct a person in the airlock to stand close to the port to determine whether chemical agent is desorbing from garments that have been exposed to agent vapor outside the airlock.

Use of the CAM for monitoring purposes can ensure that the airlock has purged properly. It can also shorten the airlock dwell time if no contamination is likely to be present outside and the CAM indicates that none is present in the airlock. The CAM detects only G and H agents, so monitoring in the airlock applies only for these agents.

C-6 **AIRLOCK CAPACITY**

The following are design considerations:

- For a building having a high surge rate of entry and exit, consider multiple airlocks to accommodate the required traffic.
- For dormitories, provide a minimum of two airlocks, with either to be used for ingress or egress.
- If decontamination or showering is necessary, consider providing separate airlocks for male and female personnel.

- To calculate airlock capacity, multiply the required entry and exit rate (people per hour) by the purge period (in minutes) and divide by 60. For example, if an airlock must accommodate 120 entries and exits per hour, and the purge period for three-log reduction is 3 minutes, the airlock must accommodate six people at one time (capacity = $120 \times 3/60 = 6$ people).
- To calculate the size of an airlock in floor area needed to support an expected entry and exit rate, size the airlock based on a per-person area allocation. Use a space allocation of 2 m² (21.5 ft²) for the first person and 0.5 m² (5.4 ft²) for each additional person, as recommended by UFC 3-340-01, Design and Analysis of Hardened Structures to Conventional Weapons Effects. For the example above, the airlock should have a floor area of 4.5 m² (48.4 ft²) to accommodate six people at one time.

C-7 PROCESSING PROCEDURE RECOMMENDATIONS

C-7.1 Doffing Procedure and Dwell Cycle

In most military applications, the outer clothing is removed outdoors immediately before entering the airlock, and the mask is left on. If an airlock is large enough, however, protective garments can be removed in the airlock while it is being continuously purged by the flow of filtered air. Doing so substantially reduces the potential for deposition of agent on the clothing in the interval between removing the outer clothing and entering the airlock. In the case of chemical agents, a thorough check with detector paper is necessary before a person enters the airlock to ensure there is no liquid contamination on boots or garments that would be transferred to interior airlock surfaces. Doffing in the airlock also requires a means of removing the doffed clothing from the airlock to the more contaminated area. This can be done by means of a chute or by placing the clothing into a plastic bag for removal by the next person entering as soon as that person opens the outer door. It is recommended that surgical scrubs or other inexpensive clothing be provided as contaminated clothing will be discarded.

After the protective garments are removed, the airlock is purged of vapors during the dwell cycle. After the dwell cycle, personnel enter the protected area.

C-7.2 Ingress In-Processing Procedures

Processing procedures are the responsibility of the local command authority. Tables C-3 and C-4 list basic and commonly used ingress in-processing procedures for single-stage and two-stage airlocks. If detector paper indicates liquid contamination on outer garments, open-air decontamination may be required before entering the airlock.

Table C-3. Single-Stage Airlock Processing Procedures

Item	Description
1	Before entering the airlock, ensure that air is being discharged from the purge vents.
2	Look through the view window to ensure that the airlock is not occupied. If unoccupied, enter the airlock.
3	After entering the airlock, remove any items left from the previous in-processing group. Remove outer garments and put them in the trash bag or clothing chute provided. Keep mask on. Set the timer for a 3-minute dwell time (or as determined by equation C-1).
4	When the dwell time is complete, personnel in the protected area should check the airlock with a CAM to ensure that the contaminants have been sufficiently removed. After the airlock has been checked and no contaminants have been detected, hold your breath, remove your mask, and enter the protected area. Depending on user requirements, either place the mask in a mask bag, seal the bag, and take it into the shelter for use during an emergency or leave the mask in the airlock for the next processing group to remove for decontamination. Proceed to the protected area.

Table C-4. Two-Stage Airlock Processing Procedures

Item	Description
1	Before entering the first stage of the airlock, ensure that the airlock filter blower unit is operating and the air is being discharged from the purge vents.
2	Look through the view window to ensure that the first stage of the airlock is not occupied. If unoccupied, enter the first stage.
3	After entering the first stage of the airlock, remove any items left from the previous in-processing group. Set the timer to 4 minutes (or as determined by equation C-1). During the dwell time, remove outer garments and put them in the trash bag or clothing chute provided.
4	When the dwell time is complete, wait until personnel in the second stage of the airlock have checked the first stage with a CAM to ensure that the contaminants have been sufficiently removed. If no contaminants have been detected, proceed to the second stage. If contaminants have been detected, reset the time to 4 minutes (or as determined by equation C-1).
5	After entering the second stage, set the timer for a 4-minute purge time (or as determined by equation C-1). After this time has elapsed, hold your breath, remove your mask, and enter the protected area. Depending on user requirements, either place the mask in a mask bag, seal the bag, and take it into the shelter for use during an emergency or leave the mask in the airlock for the next processing group to remove for decontamination.

APPENDIX D

SHELTERING IN PLACE

D-1 LIMITATIONS OF SHELTERING IN PLACE

The very low level of protection, passive sheltering in place, employs barriers between people and airborne hazards. The barriers consist of a building envelope or a portion of a building envelope that forms a tight enclosure to protect the occupants from hazards originating outdoors. Sheltering in place normally does not involve substantial filtration and is therefore effective for only limited periods of time. This limitation exists because even a tightly constructed building does not prevent the exchange of indoor air and outdoor air. As air is exchanged, even at a small rate, the protection provided diminishes over time. Any personnel entry or exit during a CBR event could contaminate the interior of the building.

D-2 ALTERING AIR EXCHANGE

In normal operation, a building and its mechanical system are designed to exchange indoor and outdoor air. Unless the rate of this air exchange is altered before and after the hazardous condition exists, the dose of agent indoors is not substantially less than the dose of agent outdoors. To provide shelter-in-place protection, three distinct actions must be taken to alter the air exchange rate of a building:

1. Reduce the indoor-outdoor air exchange rate before the airborne hazard reaches the building. To do so, close all windows and exterior doors and turn off air conditioners, combustion heaters, and supply and exhaust fans that induce indoor-outdoor air exchange.
2. Increase the indoor-outdoor air exchange rate as soon as the hazard has passed. To do so, open all windows and doors and turn on all supply and exhaust fans to ventilate the building. This step is necessary to purge the airborne contaminants that have entered the building while the external hazard was present.
3. Permit no ingress or egress until the hazard has passed.

Taking actions to alter the air exchange rate requires knowledge about the presence of an airborne hazard. There must be a warning that a hazardous cloud is approaching and, afterwards, a signal that the hazardous cloud has passed or dissipated to a safe level or that IPE has been issued to personnel for egress. In view of this requirement for detecting airborne hazards, sheltering in place is not practical for protection against any hazard unless there is some type of warning accompanying the release of the agent. Sheltering in place can, however, be used as a short-term precautionary measure if a likely, immediate threat is known.

D-3 **MAXIMIZING PASSIVE PROTECTION**

The protection provided by passive shelter-in-place measures varies with the following:

- Air exchange rate of the building. A tighter building allows for a lower air-exchange rate, therefore providing greater protection for a longer duration. In most cases, air conditioners and combustion heaters cannot be operated while sheltering in place because their operation increases the indoor-outdoor exchange of air. Generally, operating forced-air ventilation systems can increase the air exchange rate to the outside by inducing negative pressure areas within the building.
- Duration of exposure. Protection varies with time, diminishing as the time of exposure increases. Sheltering in place is therefore suitable only for exposures of short duration (a few hours or less) depending on conditions.
- Purging and period of occupancy. The length of time occupants remain in the building after the hazardous condition has passed affects the level of protection. Because the building slowly releases contaminants that have entered, at some point during cloud passage, the hazardous concentration inside will exceed the concentration outside. Maximum protection is attained by increasing the air exchange rate after cloud passage or by exiting the building into clean air.
- Natural filtration. Some filtering occurs when the agent is deposited in the building shell or on interior surfaces as air passes into and out of the building. Generally, the tighter the building, the greater is the effect of this natural filtration.

D-4 **SELECTING AND PREPARING A SAFE ROOM**

A single room in a building can be selected as a safe shelter-in-place room if it is readily accessible to all people who are to be sheltered, is more tightly constructed than other rooms in the building, and can be tightly sealed very rapidly. There is no substantial advantage in a room on the higher floors of a low-rise building. A location should not be selected based on height above ground level if it would increase the time it takes people to reach the shelter in an emergency. Although an interior room is preferable, one with windows can be used if the windows seal well when closed. A safe room should have protected access to drinking water, toilets, and a means to communicate with the authorities to determine when it is safe to exit the facility.

Architectural, mechanical, and electrical modifications can be made to prepare a safe room, as well as an entire building, to provide greater and more reliable protection when used for sheltering in place. Generally, these modifications have four objectives:

- To seal unintentional openings, thereby reducing the air exchange rate of the protected area envelope.
- To facilitate rapid closing of the protected area envelope and deactivation of fans.
- To allow the possible use of recirculated air-conditioned air while sheltering without reducing the level of protection.
- To add internal (recirculating) filtration.

D-4.1 **Sealing**

Measures for tightening the protected area envelope include sealing all penetrations for pipes, conduit, ducts, and cables using caulk, foam sealants, duct seal, or weather stripping. Typically, most leakage occurs through the top of the protected area envelope, particularly where suspended lay-in ceilings are used without a hard ceiling or without a well-sealed roof-wall juncture above the lay-in ceiling. In such cases, the ceiling should be replaced with gypsum wallboard.

D-4.2 **Facilitating Rapid Sheltering**

Particularly in large buildings, building personnel need the capability to rapidly turn off all fans and shut all exterior doors and, if possible, all interior fire doors. Relays or digital control systems can be used to provide easy control of fans. To close all doors quickly in a large building, there must be a notification system such as a public address system and a protective action plan on which building occupants have been trained.

D-4.3 **Allowing Use of Air Conditioning**

Standard air-conditioning and heating systems cannot be operated while sheltering in place because fans either directly or indirectly introduce outside air. If many people are confined in a room or building without air conditioning or air movement in hot weather, conditions can become unbearable and cause people to leave the shelter or safe room before authorities determine it is safe to leave the shelter.

To provide an air-conditioning and heating system that can operate safely in sheltering mode, the AHU must serve the safe room exclusively. In addition, both the AHU and the return ducts must be located within the safe room, with the AHU in an interior mechanical closet and the return ducts beneath a hard ceiling. The system must also have a reliable damper system to shut off outside air to the AHU. This normally requires a triple-damper set in which two dampers are in line with a relief damper, which is between the other two dampers and opens when they close. An alternative is to install a split system, which does not introduce outside air in either the normal or protection mode.

D-4.4 Adding Internal Recirculation Filtration

Internal filtration involves the use of indoor air purifiers or indoor air quality units, which are commercially available. These can be ceiling-mounted, wall-mounted, or free-standing floor or table units having both a HEPA filter and carbon adsorber. The HEPA filter increases the protection that sheltering provides against aerosols, and the adsorber increases the protection against chemical vapors. Several of the common industrial chemicals (such as ammonia) are not removed. Therefore, filtration is not effective for all chemicals. A maintenance program to replace filters and adsorbers is required to ensure that particulate filters are not clogged and carbon adsorbers are not depleted when needed for sheltering.

APPENDIX E

PROTECTIVE ACTION PLAN: OPERATIONAL PROCEDURES TO PROTECT EXISTING BUILDINGS AND THEIR OCCUPANTS FROM AIRBORNE HAZARDS

E-1 INTRODUCTION

This appendix presents a variety of ways to protect existing buildings and their occupants from a short-duration CBR event. The guidance is intended to help building managers, designers, and security planners minimize the potential effects of hazardous materials accidentally or intentionally released.

Protective measures can be as simple as defining a protective action plan that includes security measures and operational procedures to reduce vulnerability, prevent a release, reduce the likelihood that releases will affect building occupants, and mitigate the hazard once a release has occurred. Protective measures include the following:

- Determining the protective capability of a building (refer to Paragraph E-3)
- Identifying protective actions for perceptible hazards (refer to Paragraph E-4)
- Developing building-specific protective action plans (refer to Paragraph E-5)

E-2 PERTINENT FACTS ABOUT AIRBORNE HAZARDS

The basis of a protective action plan is awareness of warning properties, symptoms in other people, and other signs that can initiate protective measures.

E-2.1 Warning Properties

Most industrial chemicals and chemical warfare agents are readily detectable by smell. Soldiers in World War I and World War II were taught to identify by smell such agents as mustard, phosgene, and chlorine. This detection method proved effective for determining when to put on and take off gas masks.

Some agents, however, are imperceptible. The chemical warfare agent sarin is odorless and colorless in its pure form. Carbon monoxide, among the most common imperceptible TICs, causes many deaths in buildings each year because it is odorless and colorless. Biological agents are also imperceptible; there are currently no detection devices that can determine their presence in the air in real time.

E-2.2 Warning Symptoms and Signs

In the absence of a warning property, observations of symptoms or effects in others can alert people to some airborne hazards. This provides a practical means for initiating protective actions because the susceptibility to hazardous materials varies from person to person. The concentrations of airborne materials may also vary substantially within a given building or room, producing a hazard that may be greater to some occupants than to others.

Other warning signs of a hazard involve seeing and hearing something out of the ordinary, such as the hiss of a rapid release from a pressurized cylinder.

E-2.3 Protective Measures

For protection against imperceptible agents, the only practical protective measures are those that are always in place, such as filtering outside air on a continuous basis and using automatic, real-time sensors that are capable of detecting the imperceptible agents.

To define operational protective measures for buildings, releases are divided into two general types:

- *External releases*, which may result from accidents involving industrial storage or transport, fires, or malicious acts. An important consideration is that the source of the hazard is most likely to be at or near ground level. When gases or aerosols are released at ground level, they tend to remain at ground level under neutral or inversion conditions. If they do not remain at ground level, they are diluted as they rise under lapse condition, which occurs typically on sunny days. However, plumes originating at ground level will be diverted upward. In general, a plume will take the shortest path past a building. If the width of a building is more than twice its height, the shortest path will be over the building, and the plume will travel upward to openings on upper floors.
- *Internal releases*, which may occur through the ventilation system or into a building area. The response to an internal release is as follows:
 - Isolate the hazard to a particular building location.
 - Initiate either evacuation of the building or shelter-in-place procedures, as appropriate.
 - If the hazard is a biological agent, maintain shelter-in-place procedures and use expedient sealing measures to contain the agent.
 - After the hazard has passed, initiate an orderly evacuation away from the source.

E-3 PROTECTIVE CAPABILITY OF A BUILDING

E-3.1 Protection by Barriers

A building is a system of barriers that protects the occupants from the environment. The barrier system is incomplete, however, in that it contains openings upon which winds, fans, and natural infiltration act to exchange indoor air with outdoor air. These openings are both intentional, such as windows, doors, vents, and outside air intakes, and unintentional, such as cracks, joints, seams, and pores in construction materials. In general, the protection that a building provides against an external release is

determined by these openings, their locations, the forces that drive the exchange of air through them, and the presence of any air filters.

In normal operations, a building does little to protect occupants from airborne hazards outside the building because outdoor air must be continuously introduced through these intentional openings to provide a comfortable, healthy indoor environment. A building can provide substantial protection against agents released outdoors only if the flow of outside air is filtered or temporarily interrupted or reduced. Interrupting the flow of outside air is the principle applied in sheltering in place.

E-3.2 Protection by Mechanical Ventilation

Buildings with mechanical ventilation are designed to introduce outdoor air at a rate of about 7 to 9 L/s (15 to 20 cfm) per person. In normal operations, there is a constant potential for contaminants released outside a building to be transported indoors. In buildings with mechanical ventilation, the outside air predominantly enters through the outside air intakes. A smaller portion enters by infiltration through cracks, seams, joints, and pores in the building shell. To limit very small particulate agents from being distributed through the building by the central ventilation system, only HEPA filters with sealed holding frames are necessary. Less efficient filters and poorly sealed holding frames will filter the air stream to a certain degree. Very small particulate agents, however, will distribute and contaminate the building served by the ventilation system.

Once contaminated air enters a building, the ventilation system can transport it rapidly to various parts of the building. Within each ventilation zone, contaminated air can be drawn through return ducts and distributed through supply ducts at high rates of flow. Contaminated air can also be driven by stack effect via stairwells or elevator shafts, particularly in winter when inside and outside temperatures differ greatly. At ground level, the airflow is inward in winter and outward in summer because of stack effect. Therefore, a building's vulnerability to a ground-level release is greatest in winter. In spring and fall, buildings that use economizer systems typically introduce much greater volumes of outside air. Contaminated air can also be transported between zones of a building by flow through hallways and occupied spaces of a building.

E-3.3 Protection by Natural Ventilation and Infiltration

Buildings that do not have mechanical ventilation meet outside air requirements by natural ventilation (the exchange of the building's internal air with outside air by means of intentional openings in the building envelope, such as open doors and windows) and by infiltration (the uncontrolled exchange of the building's interior air with outside air). Though less tightly constructed than buildings with forced-air ventilation systems, such buildings can be made less vulnerable to external releases by closing windows and doors so that the paths of entry for outside air are smaller and more scattered.

Though tightly sealed, a building does not completely prevent contaminated air from entering; it only minimizes the rate of infiltration. Outside air enters more slowly, but once the external hazard has passed, the building has a higher level of contamination than the outside air, and the internal building air must be purged.

E-3.4 **Protection by Natural Filtration**

To a very limited degree, a building acts as a natural filter. Natural filtration occurs as a small portion of vapors, gases, and aerosols that enter a building become deposited in the building shell or on interior surfaces as air passes into and out of the building.

E-4 **PROTECTIVE ACTIONS FOR PERCEPTIBLE HAZARDS**

Once the presence of an airborne hazard is detected, there are four possible protective actions:

- Evacuation
- Sheltering in place
- Ventilation and purging
- Use of protective masks

These actions do not provide protection on a continuous basis, of course, but are implemented singly or in combination for relatively short periods when a hazard is present or known to be imminent. These actions apply only in response to perceptible chemicals, agents detectable by automatic detectors, or events resulting in the release of agents, such as an explosion at a chemical storage facility or a highway accident involving a chemical transport vehicle.

E-4.1 **Evacuation**

Evacuation and sheltering in place are two protective actions planned for, and employed by, many U.S. communities in the event of an accidental release of toxic chemicals. Evacuation is the most common protective action when an airborne hazard, such as smoke or an unusual odor, is perceived in a building. In most cases, existing plans for fire evacuation apply. Evacuation is the simplest and most reliable action but may not be the best course of action in all situations for an external release, particularly one that is widespread. In cases of non-fire evacuation, actions should be based on the following:

- Is the source of the hazard external or internal? If the hazardous material source is external and an agent has enveloped the building, evacuation is not the safest option. If the hazardous material plume is approaching or surrounding the building so that the building personnel cannot safely exit a building, the use of sheltering in place should be considered. Once the hazardous material has begun to infiltrate the building, however, evacuation and the use of protective masks is appropriate. These are also the appropriate actions if the source is determined to be internal.
- Could evacuation lead to other risks, such as taking the occupants from the physically secure environment of the building into the streets? Evacuation routes may also be hazardous in that they take people through contaminated areas while leaving the building.

E-4.2 **Sheltering in Place**

Sheltering in place can attain a substantial level of protection. It is appropriate if the hazard is known to originate outside the building and if there is no indication that the hazardous material has begun to enter the building. Although typically used for protection against an external release, sheltering in place may also be used for an internal release. For more information, refer to Appendix D, Sheltering in Place.

E-4.2.1 **Advantages and Disadvantages**

The advantage of sheltering in place is that it can be implemented more rapidly than evacuation. The protection factor is variable, however, and diminishes with time. There is also potential for increased carbon dioxide levels in sheltering areas with high population densities. In addition, the protection capability is lower than can be provided by high-efficiency filtration of the outside air introduced to overpressurize the building to counteract the wind and building stack effect induced infiltration.

E-4.2.2 **Sheltering in Place of the Entire Building**

In a residential building, actions for sheltering (closing windows and doors and turning off all air conditioners, fans, and combustion heaters) are relatively simple. In an office building, actions for sheltering (turning off all AHUs and closing all dampers) may require more time and planning. Therefore, a protective action plan for an office building should include operational procedures for the following:

- Identifying all AHUs and fans and the switches needed to deactivate them
- Locating shut-off switches so they are easily accessible and relocating them if necessary (but not on the exterior of a building or on the roof)
- Purging the building after an internal release, as follows:
 - Open operable windows and doors.
 - Turn on smoke fans.
 - Turn on the AHUs and fans that were turned off to shelter in place.
 - Open the outside air dampers to the maximum capability of the AHU.

E-4.2.3 **Sheltering in Place in a Safe Area**

Safe areas, such as one building floor or a safe room, can demonstrate an increased protection capability over sheltering in place of the entire building. It is more complex, however, to shelter in place on one or more floors of a multistory building or a designated safe room after an internal release has occurred on another floor of the building. The use of a separate floor requires the following protective actions:

- Isolate the stairwells by closing fire doors.
- Expediently seal elevators with plastic and tape.

- Do not use the elevators.
- Maintain clear evacuation routes should evacuation be necessary.

The following are important considerations for safe areas:

- Safe rooms for protection against an external release should be located within the building's interior and should be sealed. An internal location greatly reduces the effect of wind conditions and minimizes the internal-to-ambient temperature gradient-induced stack effect and infiltration rate.
- There is the potential of contaminating the safe area during in-processing of personnel, who may be contaminated and may, upon entry, contaminate the safe area.
- Recirculation filtration units that incorporate HEPA filtration and carbon adsorption will greatly increase the safe area protection capability.
- The integrity of the protected area envelope must be maintained during sheltering.
- Comfort cooling can be provided in safe areas as long as the HVAC system is a split evaporator and condenser cooling system.

E-4.2.4 **Carbon Dioxide Levels**

Increases in carbon dioxide levels and decreases in oxygen are a planning consideration for sheltering in place for longer durations, with higher population densities and a tight building envelope. Though safe areas are generally for short-duration events and a moderate population concentration, carbon dioxide levels increase within limits, and to a lesser extent, oxygen levels decrease within the safe area. The increase in carbon dioxide levels during extended periods of sheltering in place at reduced outside air intake rates is more of a concern than the depletion of oxygen. The elevated concentrations of carbon dioxide far exceed the necessity to replenish the oxygen levels in the safe area.

E-4.3 **Ventilation and Purging**

After passage of an external release, an effective method for purging the hazard from the building is to energize the building's ventilation system and, if available, the smoke purge system. This reduces the hazard to which building occupants are exposed. After an internal release, if the hazard is a chemical agent and has been contained, the ventilation system should be energized to 100 percent outside air. After an external or internal release, if the building is so equipped, the smoke purge fans should also be energized.

E-4.4 Use of Protective Masks

New models of universal-fit escape masks have been developed for protection against chemical and biological agents. Such masks form a seal at the wearer's neck and therefore fit a wider range of sizes than traditional masks that seal around the face. These masks do not require special fitting techniques or multiple sizes and can be used by people with facial hair. They are designed to store compactly and are practical to store at employees' desks. Employees can also carry them on their belt. These masks have protective capability equivalent to that of military protective masks and have a 5-year shelf life.

The filters of these masks contain HEPA filtration media and packed carbon beds to remove biological aerosols as well as chemical vapors and gases. Although the carbon adsorbers are designed to filter a broad range of toxic chemicals, they cannot filter all chemicals. An important consideration in planning for the use of escape masks is that their filters are not effective against certain chemicals of high vapor pressure, such as carbon monoxide and carbon dioxide buildup, ammonia, chlorine, and formaldehyde.

E-5 BUILDING-SPECIFIC PROTECTIVE ACTION PLANS

To ensure that the protective actions will be effective, there must be a protective action plan specific to each building, along with training and familiarization of building occupants. A protective action plan is important in an emergency involving airborne hazards. Such a plan provides the ability to respond rapidly to perceptible hazards of all types and to select the best course of action.

The following presents basic considerations and procedures for the protective actions to be addressed in the plan. The information is organized based on the four steps in preparing and implementing a protective action plan:

1. Conduct a building survey.
2. Write specific procedures for the following:
 - Hazard determination
 - Decision-making process based on conditions and events
 - Communication of emergency instructions to building occupants
 - Evacuation, sheltering in place, ventilation and purging, and use of protective masks
 - Special situations
3. Designate and train protective action coordinators (PACs).
4. Train building occupants.

E-5.1 **Step 1 – Conduct a Building Survey**

The purpose of the building survey is to gather information about the building's ventilation system and the characteristics that determine the building's protective capability and vulnerability to an airborne hazard. The building survey is a means of determining what protective actions are practical given the vulnerability to an accidental or intentional release and what hazardous chemicals are stored or used in or near the building.

E-5.1.1 **Identify Features Pertinent to Protective Actions**

The following outlines how to conduct this portion of the building survey:

- Determine the number of people to be sheltered.
- Determine applicable local codes that may govern or limit the use of safe areas.
- Determine the building's type of ventilation system – all forced-air ventilation duct system with AHUs, combination air-water system using unit ventilators with either split system or through-the-wall units, or natural ventilation.
- If the building has a ventilation system, determine the number of HVAC zones and AHUs, the locations of switches to de-energize the units and close the intake and exhaust dampers, and the locations of the outside air intakes (at ground level or elevated).
- Determine whether the building has smoke purge fans and whether the outside air intakes of the smoke purge fans are at ground level or elevated.
- Determine the locations of the smoke purge fans and identify the control function to energize the fans.
- Determine whether the building has motorized dampers in working condition on outside air exhaust and outside air intakes.
- List all exhaust fans and their locations and identify of the controls for each.
- Determine whether stairwells are protected from smoke.
- Determine whether the building has a public address system. If so, record the locations of the broadcast microphone and controls.
- Identify the methods for building personnel to communicate with building security personnel.

- Obtain a copy of the building evacuation routes posted for a fire emergency.
- Identify possible safe areas.
- For safe rooms, identify locations (generally interior rooms) that are unaffected by wind or temperature gradient-induced stack effects.
- Identify the designated shelter-in-place protected area envelope.
- List shelter-in-place or safe area locations and post the list next to the fire evacuation plans or in a designated location.
- Determine the number of people that can be sheltered in this area.
- Identify procedures necessary to prepare the area as a shelter or safe room.
- De-energize and isolate all ventilation equipment that draws in outside air or exhausts internal air to the exterior.
- Close doors and windows and expediently seal designated exterior building openings.
- Energize any HVAC equipment required for internal cooling and filtering of the safe room.
- Identify procedures for personnel in-processing to the safe room.
- Communicate with emergency personnel to determine the expected sheltering time and potential evacuation routes.

E-5.1.2 Gather Information on Hazardous Chemicals in the Proximity

The following outlines how to conduct this portion of the building survey:

- Determine what hazardous chemicals, if any, are stored in the building and their storage locations.
- Determine what hazardous chemicals are used in the building on a regular basis.
- Obtain the material safety data sheets for these chemicals and record the warning properties listed.
- Determine what ventilation systems (such as hoods or glove boxes) are in place to contain or isolate a release of these chemicals at the source.

- Query the local emergency planning commission, fire department, or hazardous materials (HAZMAT) response team about hazardous chemicals that are processed near the building or stored at an off-site location. Compile a list of the chemicals that are potentially hazardous, their approximate distance from and direction in relation to the building, their warning properties, and the prevailing wind direction at the site of the building.
- Determine whether protective masks will remove the potential chemicals.

E-5.1.3 **Perform a Vulnerability Assessment**

The following outlines how to conduct this portion of the building survey:

- If the building has mechanical ventilation with a duct system, record the location of all outside air intakes and whether they are at ground level and accessible to the public.
- List the locations of mechanical rooms having AHUs and note whether each mechanical room is kept locked and which have outside entrances.
- Determine whether the lobby, mailroom, delivery area, and any public access areas of the building share an AHU with other portions of the building.
- Determine whether the lobby, mailroom, delivery area, and any public access areas of the building are open to the remainder of the building, where an agent release in one of these areas could easily be disbursed into the rest of the building.

E-5.2 **Step 2 – Write Procedures**

This step outlines important considerations for five sets of procedures to prepare for the building-specific plan.

E-5.2.1 **Hazard Determination**

This set of procedures lists criteria for the PAC to use in determining if and when a hazard exists and in initiating protective actions. The following indicate that there is an airborne hazard requiring emergency response:

- Sensory indications
 - Strange or pungent odor in the building
 - Irritation of the eyes or throat reported by people in or near the building
 - Smoke or a fog in the building
 - Noises such as the release of gas under pressure in or near the building

- Symptoms
 - People reporting nausea, collapse, choking, or irritation of the eyes or throat
 - Observation of these symptoms in other people in or near the building
- Evidence of malicious acts
 - Finding a spray device (a pressurized cylinder; a container of liquid, gas, or powder; batteries with pump and nozzle) in or near the building
 - Finding a suspicious parcel left unattended in or near the building
 - Receiving a letter or parcel with markings indicating hazardous materials
- Information reported on a hazardous release
 - Notification from authorities that there is an outdoor hazard, such as an accident involving a storage site, tanker truck, or rail car
 - Notification that there is an internal spill of cleaning material or a release of hazardous material stored indoors

E-5.2.2 **Decision-making Process Based on Conditions and Events**

This set of procedures tells how to decide on the best action to take when an airborne hazard exists in the building:

- Quickly determine whether the source of the hazard is inside or outside the building. This is the most important step in deciding on the best protective action.
- If the source of the hazard is clearly inside, such as a spill of cleaning solution or an accidental release of hazardous chemical stored in the building:
 - Evacuate the affected floor(s).
 - Initiate purging of the affected area with the ventilation system and with smoke fans, if available.
 - Consider using protective masks, based on indications of the type of chemical. Note that masks may not provide protection for certain types of chemicals.

- If the source of the hazard is clearly inside, such as an anthrax letter:
 - Consider having the building occupants use protective masks.
 - Evacuate all personnel from the hazardous area.
 - Initiate shelter-in-place procedures, de-energize the ventilation system, and communicate the characteristics of the hazardous agent to the fire department.
 - Isolate the hazardous area with expedient sealing measures and ensure that protective masks are used.

- If the source is clearly outside the building:
 - Initiate sheltering.
 - Communicate with the fire department about the likely duration of the event (that is, the length of time until the release will be contained).
 - If the hazardous material has begun to enter building, use protective masks, if available.

- If the source cannot be determined quickly, take the following actions based on the *most likely* location while continuing to investigate:
 - Evacuate and initiate purging if there are symptoms but no odor or other sensory indications. Evacuate upwind and away from the most likely location of the release.
 - Use protective masks if odor or other signs exist.
 - Determine whether the air is clean outside the building. If so, evacuate.
 - Check for other possible indicators of the source. For example, if there are visible signs outside the building, such as people fleeing or responding to an airborne hazard, the release is likely to be external. In a multistory building, if no signs or symptoms are apparent on adjacent floors, the release is likely to be internal and on one floor.

E-5.2.3 **Communication of Emergency Response Instructions to Building Occupants**

This set of procedures addresses the preparation of messages and the selection of a warning system for building occupants:

- Prepare a warning message for each protective action in advance of an event.

- Word all messages so they are clear and effective without causing panic and enable the appropriate actions to be taken as rapidly as possible. For example, a possible warning over the intercom is: “Attention, there is an unusual odor on parts of the second floor. If you are on this floor, proceed down the stairs and exit the building into the parking lot.”
- In messages for evacuation, include, as applicable, instructions to avoid certain areas that are known to present a hazard.
- In messages for sheltering in place, include instructions, as applicable, for turning off fans, turning off unit ventilators, and closing all windows and doors (in buildings with natural ventilation).
- Select a warning system based on the following considerations:
 - A public address system serving all parts of the building is the most efficient means of communicating emergency response instructions.
 - An Intranet-type computer system installed on employees’ personal computers is another potential warning system.
 - The telephone is a less efficient and less reliable warning method.
 - A tone-alert or audible alarm system can be used as long as the alarm sounds are easy to differentiate from other alarms employed in the facility.
 - Emergency alarms must be accessible to persons with disabilities, including those with sensory impairments. For building occupants with disabilities, emergency alarm systems may require audible and visual features. Visual strobes serve to notify people who are deaf or hard of hearing that the alarm has sounded. Visual appliances should meet building specifications that address intensity, flash rate, mounting location, and other characteristics. In general, it is not sufficient to install visual signals only at audible alarm locations. Audible alarms installed in corridors and lobbies can be heard in adjacent rooms, but a visual signal can be observed only within the space where it is located.
 - Nonverbal warning systems are more dependent on training and familiarization of all building occupants and are generally less effective than oral instructions.

E-5.2.4 Evacuation, Sheltering in Place, Ventilation and Purging, and Use Protective Masks

This set of procedures addresses the feasibility of evacuation, sheltering in place, ventilation and purging, or use of protective masks based on information gathered in the building survey.

E-5.2.4.1 Evacuation

Evacuation is practical for virtually all buildings. The procedure for evacuation should include the following:

- Examine the fire evacuation routes available for the building.
- Identify areas of rescue assistance or areas of refuge spaces that meet required fire-resistance, smoke protection, and ventilation design specifications and where persons unable to use stairs can call for and await evacuation assistance from emergency personnel. Note the following:
 - Such areas are often incorporated into the design of fire stair landings but can be provided in other recognized locations.
 - For newly constructed buildings, areas of rescue assistance must include access to two-way communication devices so that users can place a call for evacuation assistance. An exception may be provided for buildings equipped with sprinkler systems that have built-in signals used to monitor the system's features.
 - Horizontal exits, which use fire barriers, separation, and other means to help contain the spread of CBR hazards on a floor, can substitute for areas of rescue assistance provided they meet applicable building codes. Horizontal exits enable occupants to evacuate from one area of a building to another area or building that is on approximately the same level and provides safety from smoke and fire.
- Avoid the following:
 - Evacuation routes through areas where agent releases may have occurred
 - Evacuation routes that pass through the main lobby, as the lobby is publicly accessible and thus a potential location for an agent release
 - The use of elevators in multistory buildings, as elevator movement promotes the exchange of air between and among floors
- When emergency conditions exist, identify evacuation elevators that will remain functional. If present, these elevators may feature, among other things, back-up power supply and pressurization and ventilation systems to prevent CBR hazards and smoke buildup.

E-5.2.4.2 **Sheltering in Place**

Sheltering in place is practical in most buildings. The procedure for sheltering in place should include the following:

- Explain how to terminate sheltering in place by turning on all fans as soon as authorities determine the hazard outdoors has passed.
- List all switches that control AHUs, outside supply air fans, exhaust fans, and unit ventilators or room air conditioners.
- Describe each switch and its location.
- Label each switch “for sheltering in place.”
- If smoke purge fans are available, mark and list the switches controlling these fans for use during sheltering termination.
- If the building is equipped with a fire alarm control system, note that the fire alarm system can be modified with a shelter-in-place mode to de-energize the ventilation system and close outside air intakes.
- If the building ventilation system is so equipped, note that a purge mode can be used to energize the ventilation and smoke purge systems.

E-5.2.4.3 **Ventilation and Purging**

Purging requires that the building have a forced-air ventilation system. The procedure for ventilation and purging should include the following:

- List the switches that control the ventilation and smoke purge fans.
- Describe each switch and its location.
- Label each switch “purge fan control.”
- Use ventilation and purge fans primarily for an internal release.
- Note that purge fans having intakes at ground level should not be used if there is a possibility that the source of the hazard is outside the building.
- Note that purge fans having intakes elevated on a high-rise building may be used even if the source of the hazard is unknown (inside or outside the building).

E-5.2.4.4 Use of Protective Masks

The use of protective masks requires that the masks be issued to the people who work or reside in the building. The procedure for using protective masks should include the following:

- If protective masks have been issued, conduct training on how to put on and wear the masks.
- Fit test the masks (if applicable).
- Maintain a record of the manufacture date of each mask to allow the masks to be replaced when their shelf life has expired.
- Institute a maintenance program.
- List situations in which the mask would not provide protection based on the types of chemicals stored or used regularly in the building or in the proximity. If there is uncertainty regarding a specific chemical, state that the manufacturer of the mask should be contacted.
- List the characteristic warning properties of chemicals used and stored in or near the building for which the mask is not effective.

E-5.2.5 Special Situations

This set of procedures addresses special situations with respect to sampling agents and handling contaminated mail.

E-5.2.5.1 Capturing a Sample

If an emergency involving an airborne hazard occurs in a building, it is beneficial to identify the chemical or aerosol producing the hazard. Items to include in the procedure for capturing a sample are as follows:

- Purpose – Identification of the chemical or aerosol serves three purposes: (1) to know the proper medical treatment to administer if people become ill, (2) to help determine the cause and source of the hazard, and (3) to obtain forensic evidence if the release is a result of a deliberate act.
- Type of sample – Identification of the chemical or aerosol requires capturing an air sample or, in some cases, a liquid sample.
- Assistance with sampling – Assistance is available from the fire department.
- Equipment – Air-sampling equipment is available for capturing aerosols and chemicals.

- **Methods** – Methods for collecting samples are not included herein (refer to the source cited below for further information).
- **Timeliness** – Chemicals of high vapor pressure tend to dissipate rapidly, so the samples should be taken as soon as possible without exposing people to the hazards.
- **All-clear determination** – To ensure that it is safe to return to the building and resume normal operations, air sampling may also be necessary for an all-clear determination.

For more information on sampling, refer to OPNAV 3440.17C, Appendix 8.

E-5.2.5.2 Handling Mail that May Contain Toxic Substances

Mail may be received in the mailroom with a note indicating that a toxic substance (such as anthrax spores) is enclosed. To address this situation, the simplest procedure is as follows:

- Although such notes are likely to be a hoax, treat them in a manner that prevents release and spread of the material if the material is indeed hazardous.
- Place a container suitable for hazardous waste in the mailroom and designate it for letters or packages that may contain toxic substances.
- If such a letter is received, place it in the container using care to handle the letter in a manner that will not aerosolize powder or cause release from the letter or package.
- Once the item is contained, handle it as hazardous material.
- Evacuate the area until authorities have given an all clear.
- Provide the item to authorities for testing and forensic evaluation.

E-5.3 Step 3 – Designate and Train Protective Action Coordinators

The role of the PAC is similar to that of the building fire marshal. Considerations for designating and training the PACs include the following:

- Note that the PAC has the decision-making responsibility to evacuate, shelter in place, use protective masks, or turn on purge fans. The PAC contacts emergency response personnel when a CBR event occurs.
- Designate a PAC for each duty cycle or shift.

- Train the PAC appropriately to provide a thorough understanding of the protective action plan.
- Ensure accessibility to the PAC by pager, radio, phone, or direct communication at all times.

E-5.4 **Step 4 – Train Building Occupants**

This step involves training the people who work in the building to follow the procedures for CBR emergencies. The objectives are as follows:

- To develop an awareness of potential airborne hazards. When trained, the people in the building can detect hazards and reduce the response time by being aware of odors, symptoms, and suspicious activities. The training should therefore include familiarization with the following:
 - The warning properties of hazardous chemicals stored or used in or near the building
 - Suspicious activities relating to outside air intakes, mechanical rooms, and abandoned parcels within the building
 - Evacuation procedures
 - Sheltering-in-place procedures
 - Recognizing building alarms and warnings
 - Reporting procedures if suspicious activities or items are observed
- To develop an understanding of the responses and protective actions and how to carry out each of the possible protective actions.
- To inform building occupants about the PACs and how to contact them.

APPENDIX F

DETERMINING THE BUILDING PROTECTION FACTOR

F-1 INTRODUCTION

Buildings can be evaluated to determine their protection factor by using an air pressurization and leakage test. The test results in an infiltration rate in air changes per hour. The air exchange rate of a building can be limited by incorporating common weatherization sealing measures, closing and sealing all windows and doors, de-energizing all ventilation equipment, and sealing off outside air intake and exhaust ductwork with low-leakage dampers.

Shelter-in-place protection involves sealing a building to limit the exchange of internal building air with the exterior hazardous chemical cloud. Shelter-in-place protection does not incorporate filtration system equipment that overpressurizes the building; instead, it is primarily a passive measure that provides short-term protection to the building's occupants that exceeds the protection afforded to an unprotected person located in exterior ambient conditions. Shelter-in-place building protection and sealing measures generally range from expedient sealing measures to enhanced shelter-in-place building component improvements. Other considerations such as air conditioning of recirculated air in operational critical areas or for health reasons should be evaluated.

F-2 BUILDING AIR EXCHANGE

Buildings typically have three different methods of air exchange: (1) by forced mechanical ventilation, (2) by natural ventilation through open windows and doorways, and (3) by infiltration through unintentional openings. An accurate determination of the air exchange rate of a building requires the use of a tracer gas. The physical testing of a building by tracer gas is both time consuming and expensive.

Therefore, calculated air exchange techniques have been developed for estimating the air exchange rate of a building. The rate cannot be reliably determined based solely on building construction and visual inspection. Assumptions in the air leakage area must be made to determine an air exchange rate. Therefore, predicted building air exchange rates by visual inspection alone can differ from the tracer gas measurement rate by as much as 40 to 100 percent or more (2001 *ASHRAE Handbook Fundamentals*, Chapter 26). To lower this uncertainty to approximately 7 to 20 percent (2001 *ASHRAE Handbook Fundamentals*, Chapter 26), the effective leakage area (ELA) of the proposed protected area envelope can be determined by building pressurization and air leakage testing. The pressurization and air leakage test is performed using a blower door assembly, which is a calibrated device that measures the airflow rate into the facility during pressurization and out of the facility during depressurization. The blower door assembly tests the facility at different pressures, measuring the associated airflow and thereby determining the air leakage characteristics of the protected area envelope.

F-2.1 **Forced Ventilation**

Forced ventilation is accomplished by two means: (1) the building's mechanical system supplying outside air and exhausting air by the same ventilation system, and (2) the building's exhaust system (such as the bathroom exhaust and kitchen hoods).

F-2.2 **Natural Ventilation**

Natural ventilation is the exchange of the building's internal air with outside air by means of intentional openings in the building envelope (such as open doors and windows). The driving mechanisms of natural ventilation air exchange are atmospheric temperature and wind conditions.

F-2.3 **Infiltration**

Infiltration is the uncontrolled exchange of the building's indoor air with outdoor air. This exchange is driven by atmospheric temperature and wind conditions through unintentional openings in the building envelope. These unintentional openings are what define the leakage rate of the building envelope and are the basis for determining the suitability of a building for sheltering in place. During an emergency, the ventilation system of a building modified with enhanced shelter-in-place measures is de-energized. Simultaneously, all outside air intake and exhaust ductwork is sealed with low-leakage isolation dampers, and all exterior doors and windows are closed. This action removes the forced and natural ventilation air exchange mechanisms. Therefore, the remaining building air exchange occurs through the building envelope.

F-3 **DETERMINING BUILDING INFILTRATION AIR EXCHANGE**

The driving mechanisms of the building air exchange by infiltration are wind pressure and the stack effect. Pressure differences across the building envelope and the envelope ELA determine the air infiltration rate and resulting air exchange rate for a particular building.

F-3.1 **Wind Pressure**

The pressure developed by wind is positive on the windward side of a building and negative on the leeward side of a building. Pressures on the building's sides parallel to the wind are positive or negative depending on the wind angle and building shape. For this illustration, the wind is assumed to be perpendicularly directed to the windward building face, parallel to the building sides, and perpendicularly directed away from the leeward side. Wind pressure acting on a building's face is defined by equation F-1, below (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 18).

$$P_w = C_1 C_p \rho (v^2/2) \quad (\text{eq. F-1})$$

where

- P_w = surface pressure, in wg
- C_1 = unit conversion factor = 0.0129
- C_p = surface pressure coefficient, dimensionless = 0.6 (2001 *ASHRAE Handbook Fundamentals*, Chapter 16)
- ρ = air density, lb_m/ft³
- v = wind speed, mph

F-3.2 Stack Effect

The pressure caused by the air temperature difference and resulting air density differences drives air infiltration into the lower portion and exfiltration on the upper portion of the building during cooler outdoor-to-indoor building temperature conditions, as in the winter. During summer or warmer outdoor-to-indoor conditions, the air infiltration and exfiltration airflow is reversed. Pressures due to stack effect are determined by equation F-2, below (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 17).

$$\Delta P_s = C_2 \rho_o [T_o - T_i/T_i] g (H_{NPL} - H) \quad (\text{eq. F-2})$$

where

- ΔP_s = pressure difference due to stack effect, in wg
- C_2 = unit conversion factor = 0.00598
- ρ_o = outdoor air density, lb_m/ft³
- T = temperature, °R
- g = gravitational constant, 32.2 ft/s²
- H_{NPL} = height of neutral pressure level
- H = height of observation, ft

subscripts

- o = outside
- i = inside

F-3.3 Effective Leakage Area

The ELA of a protected area is a calculated area that is equivalent to the sum of all openings in the protected area envelope. The ELA can be determined by leakage testing of the proposed protected area envelope and application of the leakage area equations as presented in the 2001 *ASHRAE Handbook Fundamentals*, Chapter 26. The ELA can be determined by use of building pressure data by equation F-3, below (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 33).

$$A_L = C_5 Q_r [(\rho/2\Delta P_r)^{0.5}/C_D] \quad (\text{eq. F-3})$$

where

- A_L = ELA, in²
- C_5 = unit conversion factor = 0.186
- Q_r = predicted airflow rate at ΔP_r (from curve fit pressurization test data), cfm
- ρ = air density, lb_m/ft³
- ΔP_r = reference pressure difference, in wg
- C_D = discharge coefficient, generally = 1.0

F-3.4 Infiltration Building Air Exchange

To determine the infiltration rate (Q), the wind and stack effect pressures are added together to obtain a resulting pressure acting against the building face. This resulting pressure and the estimated building ELA can be used to calculate the building's infiltration rate by equation F-4, below (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 33).

$$A_L = C_5 Q_r (\rho/2\Delta P_r)^{0.5}/C_D \quad (\text{eq. F-4})$$

where

- A_L = ELA, in²
- C_5 = unit conversion factor = 0.186
- Q_r = predicted airflow rate at ΔP_r (infiltration rate), cfm
- ΔP_r = pressure difference, in wg
- C_D = discharge coefficient, generally = 1.0

Equation F-5, below, (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 35) is used to convert the ELA from one reference pressure at a corresponding airflow rate to another reference pressure.

$$Q_{r,2} = C_6 C_{D,1} A_{r,1} (2/\rho)^{0.5} (\Delta P_{r,1})^{0.5-n} (P_{r,2})^n \quad (\text{eq. F-5})$$

where

- $Q_{r,2}$ = airflow rate at reference pressure $\Delta P_{r,2}$, cfm (infiltration rate)
- C_6 = unit conversion factor = 5.39
- $C_{D,1}$ = discharge coefficient used to calculate $L_{r,1}$, generally = 1.0
- $A_{r,1}$ = leakage area at reference pressure, in²
- ρ = air density, lb_m/ft³
- n = flow exponent, dimensionless, generally = 0.65

For this air exchange rate illustration, the above equations are used to determine the air exchange rate of the buildings that are taller than three stories. Equation F-6, below, (2001 *ASHRAE Handbook Fundamentals*, Chapter 26, equation 40) is used to determine the air exchange rate for one- to three-story buildings.

$$Q = A_L(C_s\Delta t + C_w v^2)^{0.5} \quad (\text{eq. F-6})$$

where

- Q = airflow rate, cfm
- A_L = ELA, in^2
- C_s = stack coefficient, $\text{cfm}^2 \times \text{in}^{-4} \times \text{°F}^{-1}$
- Δt = indoor-outdoor temperature difference, °F
- C_w = wind coefficient, $\text{cfm}^2 \times \text{in}^{-4} \times \text{mph}^{-2}$
- v = average wind speed, mph

Estimates of air changes per hour (ACH) are based on knowledge of the building characteristics, including floor area, building height, type of construction, wind speed, and building indoor-to-outdoor ambient temperature differences. The building air exchange rate is then calculated by the amount of air infiltration calculated by the equations above divided by the building volume, as indicated in equation F-7, below (2001 ASHRAE Handbook Fundamentals, Chapter 26, equation 2).

$$\text{ACH} = 60Q/V \quad (\text{eq. F-7})$$

where

- ACH = air changes per hour
- Q = building infiltration rate, cfm
- V = building volume, ft^3

The building protection factor is then determined by equation F-8, as follows:

$$\text{PF} = RT / (RT + e^{-Rt} - e^{R(T-t)}) \quad (\text{eq. F-8})$$

where

- PF = protection factor, dose outdoor/dose indoor
- R = air exchange rate
- T = time of exposure
- t = time of occupancy

APPENDIX G

CP FILTRATION SYSTEM EQUIPMENT

G-1 CP FILTRATION SYSTEM DESIGN

If the CP filtration system is located in a contaminated environment (that is, outside the protected area envelope), it must be designed as a blow-through system with the blower located before the CP filtration system. If the CP filtration system is located in a clean environment (that is, inside the protected area envelope) and draws in the contaminated air through a ductwork system, it must be designed as a draw-through system with the blower located after the CP filtration system. The total static pressure of the CP filtration system blower must be designed to include the filtration system with dirty filters, ductwork system pressure losses, and the overpressure requirement of the protected area.

G-2 CP FILTRATION SYSTEMS

The filtration system is the most critical part of the CP system. The following discusses filtration equipment that is available from both military and commercial suppliers.

G-2.1 Military Carbon Adsorbers

Military carbon adsorbers are typically provided as government-furnished equipment (GFE). Military equipment provided as GFE has the advantage of being pre-approved for use on government installations, while a commercially available carbon adsorber requires additional government quality testing. After initial installation, filter change-out, and periodic testing (typically yearly), all systems require in-place challenge testing as indicated in Appendix H, CP Filtration System Testing Requirements.

G-2.1.1 M98 – Gas-Particulate Filter Set, 94.4 L/s (200 cfm)

The M98 adsorber is a military-developed and -produced carbon adsorber (gas filter). The filtration equipment, as a set or the separate particulate filter and carbon adsorber, is available as GFE from the U.S. Army Depot (refer to Table G-1, M98 Government-Furnished Equipment Data). The radial-flow filter set particulate filter conforms to MIL-PRF-51526A(EA), and the carbon adsorber conforms to MIL-PRF-51527A(EA). Figure G-1 indicates the dimensions of the commonly used Type II radial-flow particulate filter, and Figure G-2 shows the dimensions of the Type II radial-flow gas filter. The M98 has a residence time of 0.19 seconds at 94.4 L/s (200 cfm) and 0.25 seconds at 70.8 L/s (150 cfm). The military provides and manages quality control and testing.

Table G-1. M98 Government-Furnished Equipment Data

Category	Data
Item manager	Soldier, Biological and Chemical Command Attn: AMSSB-HB (RI), Rock Island, IL 61299-7390 Phone: (309) 782-4265 or (309) 782-5455
Material developer	Edgewood Chemical Biological Center Attn: AMSSB-REN-P, APG, MD 21010-5424 Phone: (410) 436-5682 or (410) 436-5512
Ordering data, with National Stock Number (NSN)	Gas-Particulate Set, M98 ¹ : NSN 4240-01-369-6533 Gas-Particulate Set, M98 ² : NSN 4240-01-486-1344 Particulate Filter, 200 cfm: NSN 4240-01-066-3266 Gas Filter, 200 cfm: NSN 4240-01-297-7066
Availability and pricing	Contact item manager for availability and pricing.
Size and weight (Type II)	Particulate Filter: For dimensions, refer to Figure G-1 (7.75 lb). Gas Filter: For dimensions, refer to Figure G-2 (35.5 lb).

¹ Provided with Level A pack for worldwide transport and long-term storage.

² Provided with Level B pack for transport within the continental U.S. (CONUS) and 1-year storage.

Figure G-1. Radial-Flow Particulate Filter, 200 cfm

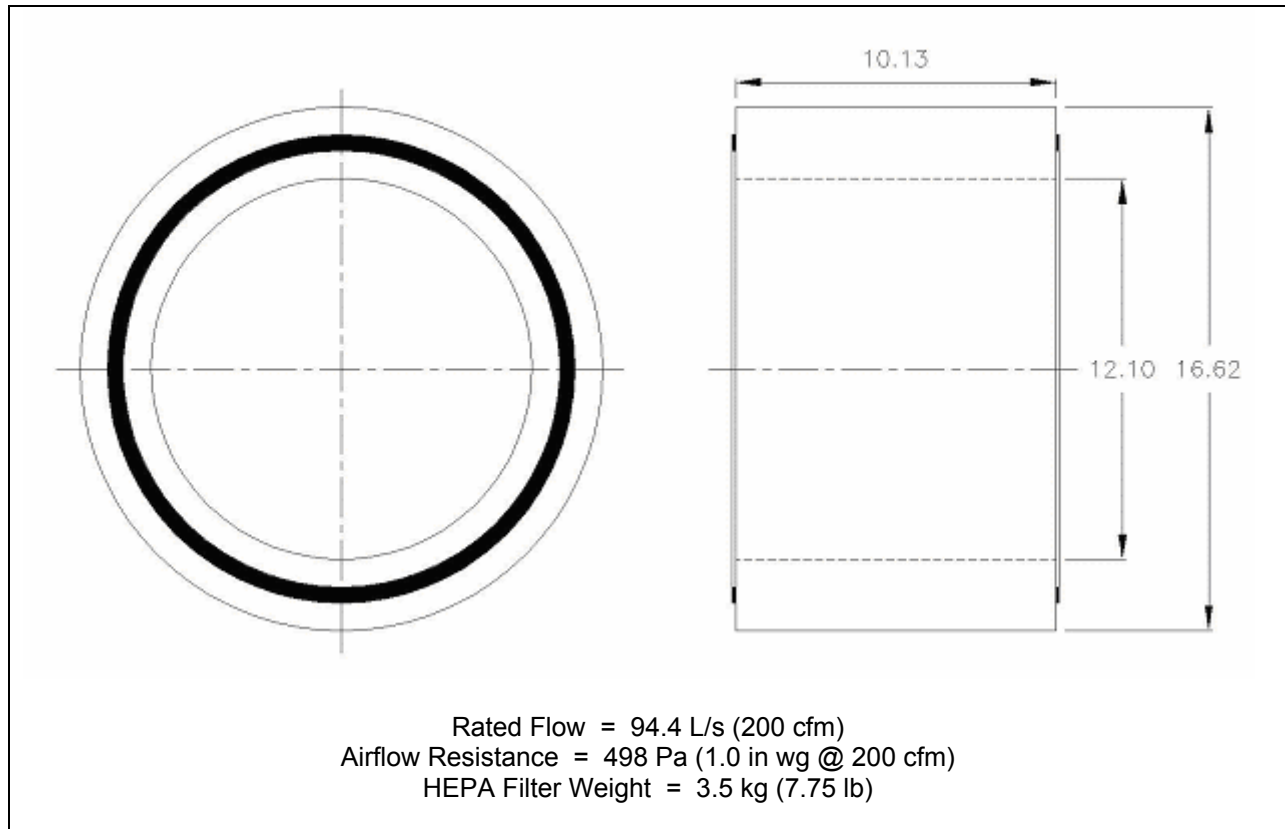
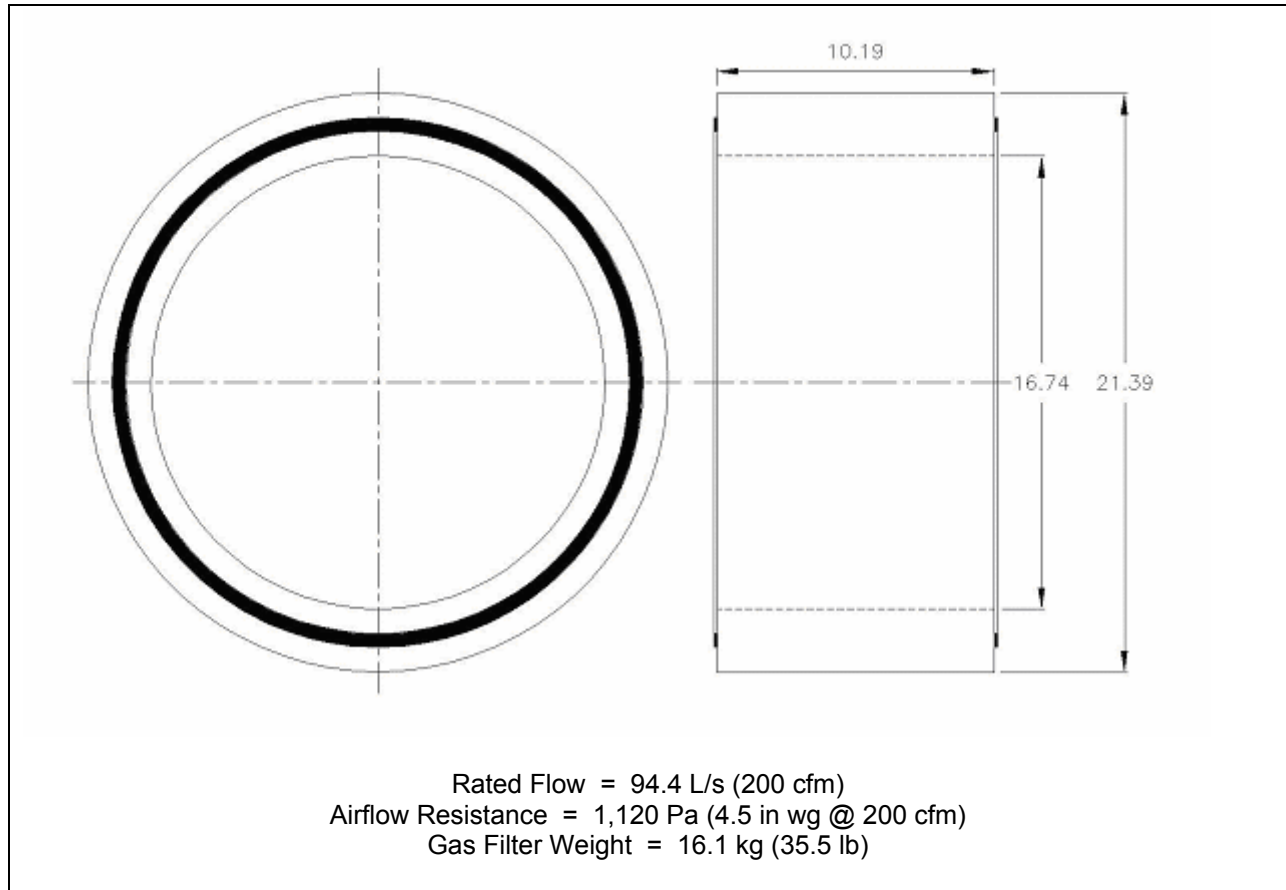


Figure G-2. Radial-Flow Gas Filter, 200 cfm



G-2.1.2 M49 Adsorber

The M49 adsorber is a military-developed and -produced gas adsorber. Quality control and testing are also provided and managed by the military. The M49 adsorber is of modular design and can be stacked in multiples to achieve a higher airflow rate. It comes in two sizes: 283 L/s (600 cfm) and 566 L/s (1,200 cfm). To procure the M49 adsorber, refer to Table G-2, M49 Government-Furnished Equipment Data. Unlike commercially available carbon adsorbers, the M49 requires only one stage of filtration for an airflow rate of 566 L/s (1,200 cfm). The pressure drop for the M49 is approximately 375 Pa (1.5 in wg). The M49 carbon trays are refillable by the government. The M49 adsorber, shown in Figures G-3, G-4, G-5, and G-6, requires prefilters, HEPA filters, and test sections or test points similar to those of commercial filtration systems.

Table G-2. M49 Government-Furnished Equipment Data

Category	Data
Item manager	Soldier, Biological and Chemical Command Attn: AMSSB-HB (RI), Rock Island, IL 61299-7390 Phone: (309) 782-4265 or (309) 782-5455
Material developer	Edgewood Chemical Biological Center Attn: AMSSB-REN-P, APG, MD 21010-5424 Phone: (410) 436-8088 or (410) 436-5512
Ordering data, with NSN	Gas-Filter Tray, 120 cfm: NSN 4240-01-312-9146 Gas-Filter Assembly, 600 cfm: NSN 4240-01-313-0721 Gas-Filter Assembly, 1,200 cfm: NSN 4240-01-312-2940
Availability and pricing	Contact item manager for availability and pricing.
Size (in.) and weight (lb)	Gas Filter Tray: 3.5 x 23.8 x 33.6 in. (55 lb) Gas-Filter Assembly, 600 cfm: 24.0 x 24.2 x 28.2 in. (433 lb) Gas-Filter Assembly, 1,200 cfm: 24.0 x 24.2 x 50.6 in. (780 lb)

Figure G-3. 120 CFM Tray

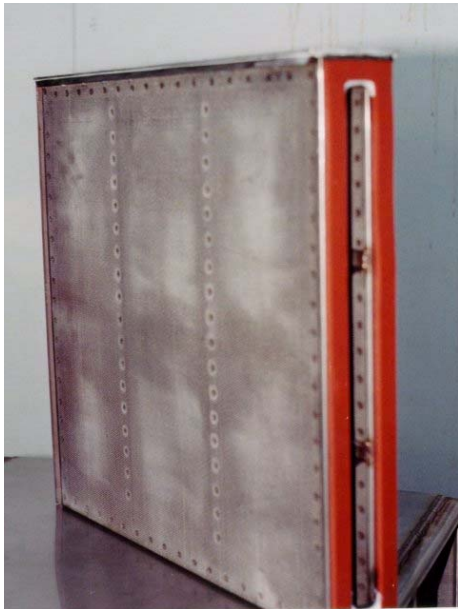


Figure G-4. 600 CFM M49



Figure G-5. M49 with Side Panel Installed



Figure G-6. 2-1200 CFM M49 Installed with HEPA Filters and Prefilters



G-2.2 Commercial Carbon Adsorbers

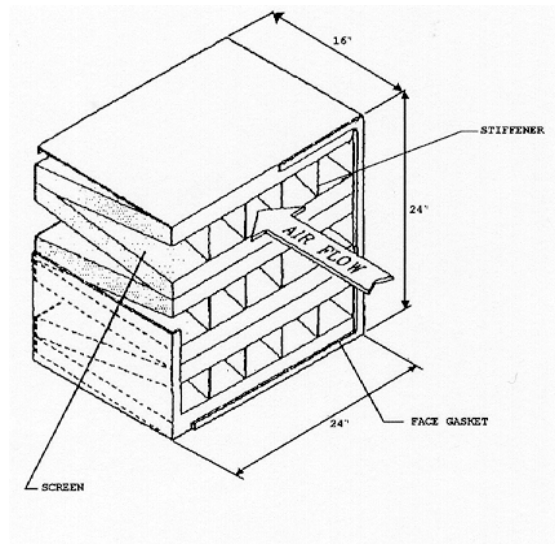
In commercial carbon adsorbers, the adsorber charcoal bed must be designed to adsorb aerosol with a minimum residence time of 0.25 seconds, and the carbon media must meet the requirements of MIL-PRF-32016(EA). For unknown threats and adsorption of volatile agents, ASZM-TEDA carbon conforming to EA-C-1704 must be used. If the threat is known, the use of ASZM-TEDA may not be required, depending on the chemical volatility of the threat. If agents of higher volatility, such as hydrogen cyanide and cyanogen chloride, are not a threat, high-activity carbon (not impregnated carbon) will suffice.

The filter manufacturer must perform lot testing at ERDEC as stated in MIL-PRF-32016(EA), with funding provided by the user. The carbon adsorber shall meet the requirements for airflow resistance, refrigerant leak testing, dimethylmethylphosphonate (DMMP) breakthrough life testing, moisture content, cyanogen chloride gas life, and gas life capacity testing, as specified in Unified Facilities Guide Specification (UFGS)-15860A. The manufacturer can refill filters not contaminated by chemical surety materials or by super-toxic materials, but the owner must dispose of any contaminated carbon in accordance with local, state, and federal regulations.

G-2.2.1 V-bed Carbon Adsorbers

V-bed carbon adsorbers consist of 2-inch-thick panels configured as a V-bed similar to the shape of a Type I cell per IEST RP-CC-008, as shown in Figure G-7. V-bed adsorbers have an airflow rate capacity of 472 L/s (1,000 cfm) for a cell having a depth of 610 by 610 by 406 mm (24 by 24 by 16 in.) and an airflow rate capacity of 590 L/s (1,250 cfm) for a cell having a depth of 610 by 610 by 457 mm (24 by 24 by 18 in.), with a residence time of 0.125 seconds and a pressure drop of 870 Pa (6 in wg). To increase the residence time to 0.25 seconds, the airflow rate through each cell must be reduced by one half, or two cells must be installed in series. All inner and outer case materials must be Type 304 stainless steel. The adsorber design may include a means to obtain samples of the adsorbent.

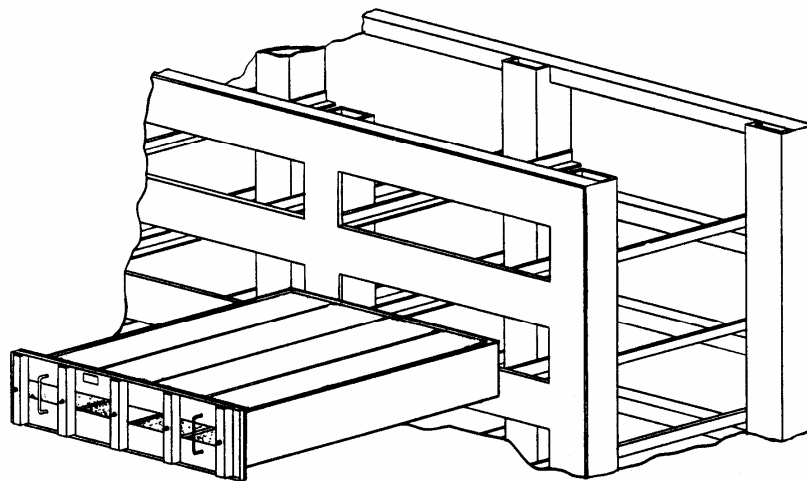
Figure G-7. V-bed Carbon Adsorber



G-2.2.2 Type II Tray Carbon Adsorbers

The Type II tray carbon adsorbers, shown in Figure G-8, must meet the requirements of ASME AG-1 and recommended practices of IEST-RP-CC-008. Individual trays are 610 mm (24 in.) wide and 160 mm (6.3 in.) high. They are rated for an airflow rate of 157 L/s (333 cfm), with a residence time of 0.25 seconds and a pressure drop of 870 Pa (3.5 in wg). All inner and outer case materials must be Type 304 stainless steel. The adsorber design may include a means to obtain samples of the adsorbent.

Figure G-8. Type II Tray Carbon Adsorber



G-2.3 **Roughing Filter**

Continuously operated CP filtration systems must have a roughing filter with an average efficiency of 30 to 35 percent when tested in accordance with ASHRAE Standard 52.1. The roughing filter extends the life of the intermediate filter or prefilter and reduces its change frequency.

G-2.4 **Prefilter**

The prefilter or intermediate filter must have an average recommended minimum efficiency of 80 to 85 percent when tested in accordance with ASHRAE Standard 52.1. The prefilter extends the life of the HEPA filter and reduces its change frequency. Where 95 percent postfilters are used, it is recommended that the prefilters be of the same 95 percent efficiency.

G-2.5 **HEPA Filter**

The HEPA filter frame and filter media must meet the construction, material, testing, qualification, and documentation requirements of ASME N509, ASME N510, and Underwriters Laboratories Inc. (UL) 586. The filter efficiency must be 99.97 percent at a 0.3- μ m-diameter particle size when tested in accordance with the MIL-STD 282 DOP test method. The filter media must meet the requirements of ASME AG-1.

G-2.6 **Military Filter Housings**

Military filter housings are typically designed and constructed for tactical military CP systems to meet equipment-induced shock. In some cases, military filter housings are airdrop certified.

G-2.6.1 **Fan Filter Assemblies**

Fan filter assemblies (FFAs) are military-developed units consisting of a fan and motor assembly and filter housing, as shown in Figure G-9. FFAs are available in 190 L/s (400 cfm), 285 L/s (600 cfm), and 475 L/s (1,000 cfm) sizes, with two, three, or five M98 radial-flow filter sets. FFAs are available from government manufacturers (refer to Table G-3). The modular FFAs can be stacked and nested to create large-capacity CP filtration systems, as shown in Figure G-10.

Figure G-9. Fan Filter Assembly

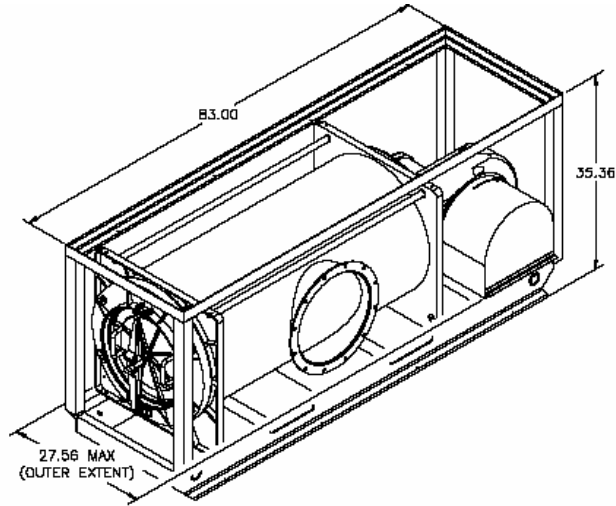


Figure G-10. Modular Fan Filter Assembly Units

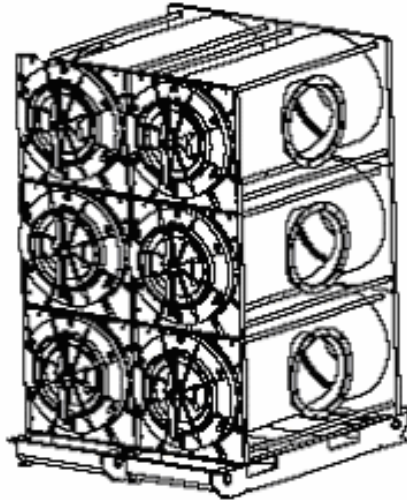


Table G-3. Military Off-the-Shelf Fan Filter Assembly Data

Fan Filter Assembly Number	Air Flow	National Stock Number
FFA-200	95 L/s (200 cfm)	NSN 4230-01-485-6180
FFA-400	190 L/s (400 cfm)	NSN 4230-01-485-6184
FFA-580	285 L/s (600 cfm)	NSN 4230-01-485-6182
FFA-800	380 L/s (800 cfm)	NSN 4230-01-485-6182
FFA-1000	475 L/s (1,000 cfm)	NSN 4230-01-485-6183

G-2.6.2 Navy Filter Housing

The Navy standard CBR filter housing, shown in Figure G-11, consists of a fan, an inlet plenum, and filter tubes in a two-wide by three-high arrangement. Each filter tube contains five M98 radial-flow HEPA filter and carbon adsorber sets and has an airflow capacity of 354 L/s (750 cfm) with a residence time of 0.25 seconds or an airflow capacity of 472 L/s (1,000 cfm) with a residence time of 0.19 seconds. The housings are of aluminum construction and can be designed with any number of filter tubes to meet the desired airflow for a project.

Figure G-11. Navy Standard CBR Filter Housing Assembly (6,000 cfm)



G-2.7 Commercial Filter Housings

Commercial CP filtration systems are designed to meet applicable nuclear industry standards and quality assurance requirements for nuclear facility applications in ASME AG-1 and N509. Commercial filtration systems used for certain applications, primarily for nuclear material containment, warrant the use of ASME NQA-1 and generic seismic requirements in Institute of Electrical and Electronics Engineers (IEEE) Standard 344; however, generally these requirements are not applicable to CP for buildings. The filtration systems must be quality assurance tested in accordance with ASME N510, as described in Appendix H, CP Filtration System Testing Requirements. Tests include housing leak and pressure test, airflow capacity and distribution test, air-aerosol mixing uniformity test, mounting frame pressure leak test, and performance testing of systems.

G-2.7.1 Multi-Cell Radial Flow Filtration Unit

A blow-through two-wide by two-high multi-cell radial-flow (MCRF) filtration unit is shown in Figure G-12 and illustrated in Figure G-13. The unit consists of a roughing filter, prefilter, fan, HEPA filter and carbon adsorber sections, and an access plenum. The face velocity through the unit is 1.90 to 2.54 m/s (375 to 500 ft/min), and heating and cooling coils can be easily added to the unit. When conditions are such that condensation may form inside or outside of the unit, the unit should be insulated or installed in a double-wall housing. Commercial HEPA filters are used, and up to 10 M98 radial-flow carbon adsorbers can be installed in radial-flow filter tubes in the adsorber section, as shown in Figure G-14. The filter housing must conform to the applicable sections of ASME AG-1 and N509 and must be constructed of Type 304 stainless steel. For large systems, walk-in plenum, face-mounted HEPA filters are used, as illustrated in Figure G-13. Test sections can be provided with the CP filtration system to ease in-place leak testing of the system, to isolate the filter section that fails the leak test, and to provide for future leak testing of the filtration system. To test the HEPA filters, test sections or ports are required for sampling after the HEPA filter. To test the carbon adsorbers, injection and sampling ports are located before and after the filtration system adsorber section. Test ports must be located where good mixing can occur, or the test ports must be located approximately 10 duct diameters before and after the CP filtration system.

Figure G-12. Multi-Cell Radial-Flow (MCRF) Filtration Unit



Figure G-13. Multi-Cell Radial-Flow (MCRF) Filtration Unit Diagram

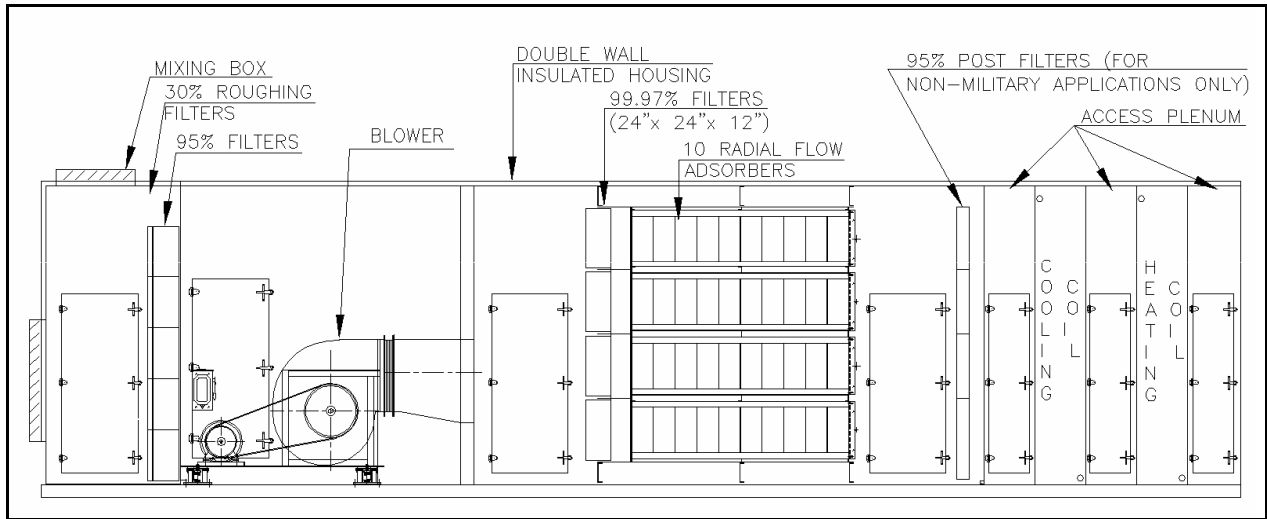


Figure G-14. Radial-Flow Filter Tubes

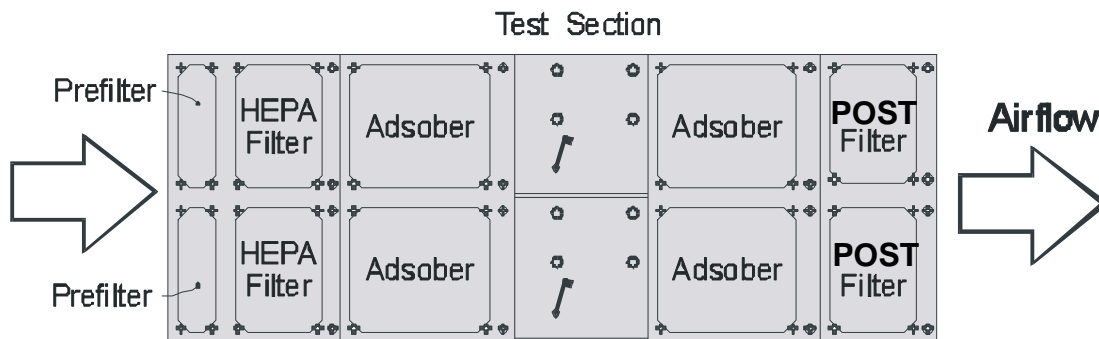


G-2.7.2 Commercial Nuclear-Grade (ASME AG-1, Type IV, V-bed) Filtration Systems

Commercial V-bed filtration systems are of modular sectional design, and each section can filter 165 L/s (350 cfm) to 590 L/s (1,250 cfm), with two stages of adsorption, as shown in Figure G-15. The CP filtration system requires a HEPA filter, either one or two stages of adsorbers, and a 95 percent postfilter to meet ASME AG-1 requirements. Usually, a 30 percent roughing filter and an 85 percent prefilter are used upstream of the HEPA filter to collect large dust particles and extend the life of the HEPA filter. The actual type and number of filters required depends on what is to be filtered. Test sections can be provided with the CP filtration system to ease in-place leak testing of the system, to isolate the filter section that fails the leak test, and to provide for future leak testing of the filtration system. To test two stages of adsorption, a test section is required between the stages. To test HEPA filters, test sections or ports are required for sampling after the HEPA filter. To test the carbon adsorbers, typically injection and sampling ports located before and after the CP filtration system are adequate for testing a single-stage adsorption system. Test ports must be located where good mixing can occur, or the test ports must be located approximately 10 duct diameters before and after the filtration system. UFGS-15860A can be used to specify housing and filter design requirements.

The filter housing can be of bag-in and bag-out design, conforming to the applicable sections of ASME N509, and must be constructed of Type 304 stainless steel. For applications where contaminants are continuously filtered, bags must be provided for the bag-in and bag-out ports. For applications where contaminants are rarely filtered, bags are not required for the bag-in and bag-out ports.

Figure G-15. V-bed Carbon Adsorber Arrangement



APPENDIX H

CP FILTRATION SYSTEM TESTING REQUIREMENTS

H-1 ACCEPTANCE TESTS

MCRF and commercial filter housings must be tested in accordance with the procedures in ASME N510; FFAs and Navy filter housings do not need to be tested. Tests include housing leak and pressure test, airflow capacity and distribution test, air-aerosol mixing uniformity test, and mounting frame pressure leak test.

H-1.1 Visual Inspection

Visual inspection must be performed in accordance with ASME N510.

H-1.2 Housing Leak and Pressure Test

The CP filtration system housing must be factory leak tested in accordance with ASME N510, Section 6, using the pressure decay method. The maximum housing leakage rate acceptance criteria must be 0.2 percent of the housing volume at 2,480 Pa (10 in wg) pressure differential per hour, in accordance with Energy Research and Development Administration (ERDA) 76-21, Nuclear Air Cleaning Handbook, Table 4.5. The housing must be tested both positively and negatively to the design pressure of $\pm 5,000$ Pa (± 20 in wg) or to the system design pressure before performing the ERDA 76-21 housing leak acceptance criteria test.

H-1.3 Airflow Capacity and Distribution Test

The airflow across each filtration element bank must be measured to verify that it meets the designed airflow rate under actual field conditions. The test must also verify that the airflow is distributed evenly across each filtration element bank. All tests must be in accordance with ASME N510, which requires the airflow distribution through each filter to be within ± 20 percent of the average readings taken.

H-1.3.1 Air-Aerosol Mixing Uniformity Test

A challenge gas must be introduced into the air stream upstream of the filtration system to verify that the gas has uniformly mixed before entering the filtration element bank. The test procedure must follow and comply with ASME N510.

H-1.3.2 Mounting Frame Pressure Leak Test

The filtration elements at each housing location must be removed and replaced with a test blank. The filtration element housing and housing seal must be tested in accordance with ASME N510. The air that bypasses the test blank must be measured and recorded as an air leakage rate, repaired, and retested. After testing is completed, the blank must be removed and the filtration elements reinstalled.

H-2 FIELD ACCEPTANCE TEST

After installation, all CP filtration systems must be field tested for leaks using a mechanical test method. The testing after installation must occur in accordance with ASME N510, and an independent testing agency is recommended. The testing agency must be certified in accordance with ASME NQA-1 or approved equal. The HEPA filter system housing and HEPA filters must be challenged with DOP, Emory 3004, or approved equal. The HEPA filter aerosol penetration must be less than 0.03 percent at the 0.3-micron particulate challenge test. The carbon adsorber system housing and carbon adsorber must be challenged with decafluoropentane (HFC-4310) or approved equal, with the downstream concentration not to exceed 0.1 percent of the upstream concentration.