

UNIFIED FACILITIES CRITERIA (UFC)

INDUSTRIAL VENTILATION



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UNIFIED FACILITIES CRITERIA (UFC)
INDUSTRIAL VENTILATION

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes UFC 3-410-04N, *Industrial Ventilation*, dated 21 October 2004.

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. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

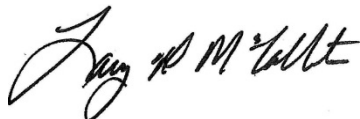
UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force \2\ Civil Engineer Center (AFCEC) /2/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: [Criteria Change Request](#). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site <http://dod.wbdg.org/>.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UFC 3-410-04
13 December 2017

UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 3-410-04, *Industrial Ventilation, 13 December 2017*

Superseding: UFC 3-410-04N, *Industrial Ventilation, 21 October 2004*

Description: This UFC provides criteria for the design of ventilation systems that control contaminants generated from industrial processes.

Reasons for Document: This is a new Joint Service document. This new document represents another step in the Joint Services effort to bring uniformity to the planning, design and construction of military facilities. This UFC was developed to provide design requirements to accomplish the following:

- Assist designers in understanding the system requirements for ventilation systems.
- Provide architects, engineers, and construction surveillance personnel with the essential, minimum requirements for the design of ventilation systems that control contaminants generated from industrial processes.
- Clarify the operational intent of the system design.

Impact: The following will result from the publication of this UFC:

- This UFC creates a single source for common DoD industrial ventilation system criteria and an accurate reference to individual Service-specific documents.
- This UFC facilitates updates and revisions and promotes agreement and uniformity of design and construction between the Services.

Non-Unification Issues: The following are issues that remain non-unified and the reasoning for each:

- Section 2-1 identifies different safety standards for each Service. These standards are operational in nature and have not been unified.

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CHAPTER 1 INTRODUCTION

1-1 SCOPE.

This Unified Facilities Criteria (UFC) provides criteria for the design of ventilation systems that control contaminants generated from industrial processes.

1-2 PURPOSE OF CRITERIA.

Criteria are developed to define requirements during the design of industrial ventilation systems. Chapter 2 provides general criteria and Chapters 3 through 10 provide criteria for specific processes. Use the general criteria presented in Chapter 2 along with the applicable specific criteria presented in Chapters 3 through 10 to design the ventilation system. For all other ventilation applications, use the criteria in Chapter 2.

Criteria contained in this UFC should be interpreted as the minimum required and should be improved where current technology or situation warrants. Users of this UFC are advised to consult the most current edition of the standards.

This UFC does not incorporate individual state and local environmental requirements. It is the sole responsibility of the cognizant design personnel to design an industrial ventilation system that complies with state and local environmental requirements. It is also the responsibility of the cognizant design personnel to design an industrial ventilation system that is energy efficient.

1-3 SPECIFIC PROCESSES.

The specific processes addressed in this UFC are asbestos delagging, torpedo refurbishing (Otto Fuel II), composites fabrication and repair, abrasive blasting, woodworking, battery maintenance, and paint spray booths. Requirements for aircraft corrosion control facilities are located in UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*.

1-4 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide. Where conflicts in requirements appear between sections of any mechanical UFC or applicable codes or laws, the most restrictive requirement will govern.

1-5 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy

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CHAPTER 2 GENERAL REQUIREMENTS

2-1 GENERAL CRITERIA.

Installing engineering controls is the preferred method of controlling hazardous processes as specified in 29 CFR 1910.1000(e), *Air Contaminants* and OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual*, AFOSHSTD 91-501 Air Force Consolidated Occupational Safety standard, and EM 385-1-1 *USACE Safety and Health Requirements Manual*. Properly designed industrial ventilation systems are the most common form of engineering controls.

2-2 COORDINATION.

Form a project design team to direct the design of industrial ventilation projects. Include in the design team representatives from:

- Affected industrial shop.
- Public Works or Base Civil Engineer.
- Health and Safety Office.
- Cognizant Regional Engineering Office (REO) (for example: Navy Facility Engineering Command, Army Corps of Engineers District, and Air Force major command engineering office). The REO representative establishes a design team and acts as the team leader in all cases, except when the cognizant REO grants a variance.
- Industrial Hygiene (IH) Offices.

NOTE U.S. NAVY: BUMED or activity IH. Use Navy and Marine Corps Public Health Center as a back-up.

- Systems or major command program manager (where applicable).
- System safety engineer.
- Environmental manager.

2-3 DESIGN PROCEDURE.

Refer to the ACGIH, *Industrial Ventilation; A Manual of Recommended Practice for Design (IV Design Manual)*, Chapter 9, "Local Exhaust Ventilation System Design Calculation Procedures" for system design calculations. In addition, design all industrial ventilation systems in accordance with Steps 1-9 in the paragraphs below.

2-3.1 Step 1.

Identify all significant contaminant sources that require ventilation control. Request the local industrial hygiene office to provide a source characterization with area diagrams of the contaminant sources, and employee work areas. Also, consider how the system

being designed might affect the performance of any existing processes, industrial ventilation systems or HVAC systems.

2-3.2 Step 2.

Coordinate with permitting agencies to determine specific permitting requirements. Also determine documentation and system monitoring requirements.

2-3.3 Step 3.

Consider how the facility is to be used or expanded in the future. It may be possible to initially specify fans that are capable of handling future needs at minimal increased cost.

2-3.4 Step 4.

Select or design the exhaust hood that best suits the work piece or operation. Design the exhaust hood to enclose the work piece or operation as much as possible. This will reduce the ventilation rates required to provide contaminant control. This UFC provides optimum exhaust hood designs for many of the operations covered.

2-3.5 Step 5.

Determine the capture velocity required to control generated contaminants. Capture velocities in this UFC are specified assuming there are no cross drafts or turbulence that adversely affects the capture efficiency. Reduce potential for cross drafts or turbulence near a given exhaust hood by properly locating and designing the hood with baffles, and also by designing the replacement air system to complement the exhaust system. Pay close attention to how air diffuses into the room near the local exhaust ventilation system.

2-3.6 Step 6.

Determine the exhaust volumetric flow, in cubic feet per minute (cfm) [cubic meters per second (m^3/s)], required to maintain the capture velocity determined in previous step.

2-3.7 Step 7.

Create a line drawing of the proposed system. Include plan and elevation dimensions, fan location and air cleaning device location. Identify each hood, branch duct and main duct sections.

2-3.8 Step 8.

Size ductwork using the balance by design or the blast gate method. Maintain the required minimum transport velocity throughout the system.

2-3.9 Step 9.

Determine requirements for replacement air. Based on the process, determine if the room must be slightly negative or neutral pressure with respect to the surrounding area. The surrounding area can be either outside the building envelope or an adjacent room or hallway. Determine if tempered replacement air is needed.

2-4 DESIGN CRITERIA.

Several design criteria are common to all industrial ventilation systems; use the ACGIH IV Design Manual and this document for primary guidance. If conflicts exist, this UFC takes precedence. See the following paragraphs in Chapter 2 for general requirements, plus Chapters 3 through 9 for design requirements on specific types of facilities. Incorporate the guidelines provided in UFC 1-200-02, *High Performance and Sustainable Building Requirements*, for system design and equipment selection.

2-4.1 Ductwork.

In addition to the recommendations of the *ACGIH IV Design Manual* and requirements of NFPA 91 section on Duct Materials and Construction, consider the following when designing a ventilation system.

- a. Specify duct gage, reinforcement schedule and hanger design and spacing, in accordance with SMACNA RIDCS, *Round Industrial Duct Construction Standards* for round duct and SMACNA RTIDCS, *Rectangular Duct Construction Standards* for rectangular duct.
- b. Install clean-out doors in ductwork that conveys particulate material such as wood dust or blasting grit. Mount clean-out doors on top half of horizontal runs near elbows, junctions, and vertical runs.

2-4.2 Fans.

2-4.2.1 Selection.

Except where specified below, fan selection criteria for replacement air fans and exhaust air fans are identical.

- a. Select exhaust system industrial fans that meet design pressure and volume flow rate requirements and have the AMCA-certified performance seal. The design pressure requirement must account for any system effects caused by non-uniform airflow into or out of the fan. See AMCA 201, *Fans and Systems* for more information on system effects. Specify a

fan class that is appropriate for the design operating point. Do not select fans with forward curved blades for exhaust or recirculating replacement air-systems.

- b. When selecting fan capacity, consider if the process room pressure will be positive, negative or neutral with respect to the external areas. Select a fan that will provide the necessary volumetric flow rate to maintain the desired process room pressure. Ensure that all sources of exhaust air are considered when selecting fan capacity. See the paragraph in Chapter 2 entitled, "Replacement Air" for more details.
- c. Specify fan shafts that have a uniform diameter along the entire length. Use bearings that are rated with an average life of 200,000 hours.
- d. Select only energy efficient motors. If available, select "*NEMA Premium Efficiency*" motors per NEMA MG-1 for motors and generators. Select the motor to handle cold startup amperage for nonstandard air processes.
- e. Specify vibration-isolating couplings at the fan inlet and outlet. Mount all fans on vibration isolating bases.
- f. If the planner's forecasts change in the processes to occur within the next couple of years, which would require an increase in the amount of replacement or exhaust air, then consider purchasing a larger capacity fan and oversized wiring.
- g. Additional fan specification data such as spark resistant construction, drive arrangement, etc. is available in ANSI/AMCA Standards 99-10, "*Standards Handbook*".

2-4.2.2 Location.

Locate the exhaust fan after the air pollution control equipment to protect fan blades from contaminated air-stream. Provide access for maintenance to all fans, including ladders and guardrails where necessary. Refer to NFPA 70, *National Electrical Code* for motor controller and disconnect location requirements. In all cases, install exhaust fans outside the building that they serve. Installing the fan outside the building envelope will isolate the working space from contaminants during fan maintenance, minimize noise inside the building, and ensure that ductwork within the building envelope is under negative pressure.

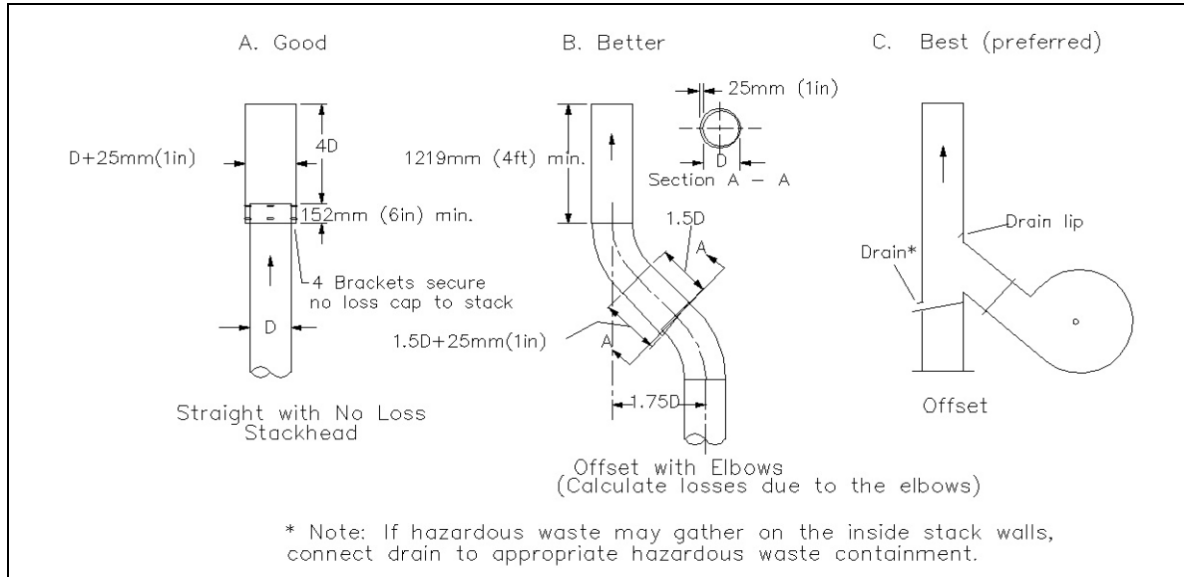
2-4.3 Exhaust Stacks.

2-4.3.1 Design Considerations.

Refer to the ACGIH IV Design Manual for exhaust stack design criteria. The best designs are cylindrical, vertical discharge stacks as shown in Figure 2-1. The best protection from rain, when the ventilation system is not running, is the "offset stack"

design C, as shown in Figure 2-1. Water may still enter the system with straight stack design A. Provide a means to drain water from the fan housing.

Figure 2-1. Exhaust Stack Designs.



2-4.3.2 Location and Structural Considerations.

Refer to ASHRAE Handbook, *Fundamentals* for information on airflow around buildings. Do not select stack locations based exclusively on prevailing winds. A stack must provide effluent dispersion under all wind conditions. Refer to UFC 1-200-01, *General Building Requirements* for exhaust stack structural design considerations. Some structural considerations are wind load, lightning protection, and stack support. Refer to SMACNA GSSDC, *Guide for Steel Stack Design and Construction* for additional information.

2-4.4 Air Pollution Control Equipment.

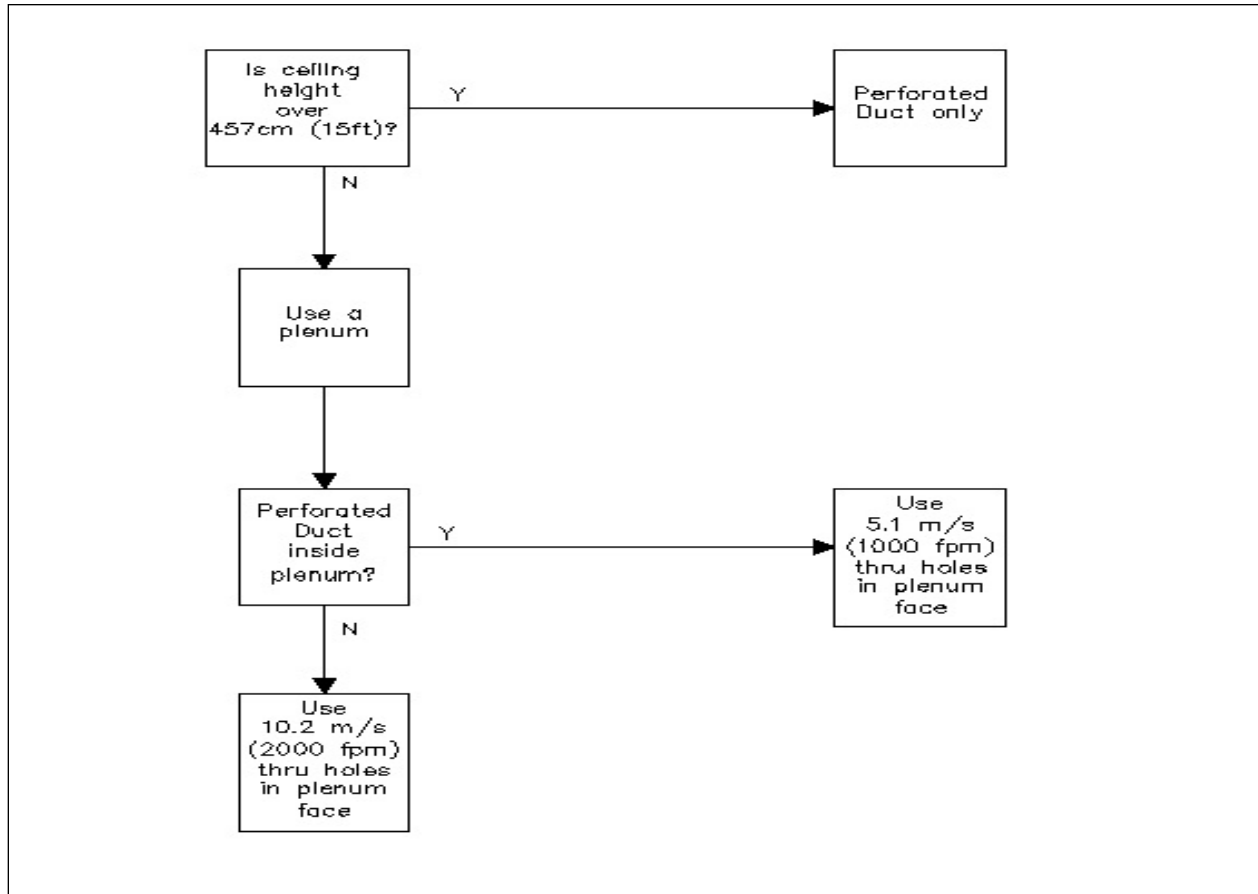
Requirements for air pollution equipment vary by process and geographical region in the United States. Contact the local activity environmental manager to determine the pollution control requirements for the process.

2-4.5 Replacement Air.

Replacement air is as important as exhaust air in controlling industrial process contaminants. The quantity and, in particular, the distribution of the replacement air profoundly affects the exhaust hood performance. Properly designed replacement air will (1) ensure that exhaust hoods have enough air to operate properly, (2) help to eliminate cross-drafts through window and doors, (3) ensure proper operation of natural draft stacks, (4) eliminate cold drafts on workers, and (5) eliminate excessive differential pressure on doors and adjoining spaces. (6) Ensure that replacement air does not draw

from a loading dock or parking lot area or where exhaust air could be drawn into the system. Design the replacement air system in accordance with the decision tree shown in Figure 2-2.

Figure 2-2. Decision Tree For Replacement Air Design.



2-4.5.1 Space Pressure Modulation.

Modulate the replacement air to maintain the required space pressure differential between the process area and adjacent spaces, while maintaining the exhaust flow. Operate all process areas and/or buildings at a slight negative pressure to prevent the controlled contaminant from migrating into clean areas and prevent fugitive emissions to the atmosphere. Use a variable frequency drive (VFD) motor to control the fan speed. Do not use barometric dampers or sensor controlled transfer grilles to control replacement air quantity.

Exhaust hoods require a specific amount of exhaust air to control the contaminant. Certain conditions (e.g., paint curing or unattended lab hood processes) may permit an exhaust flow reduction. Worker protection takes precedence over energy savings.

2-4.5.2 Plenum Design.

The replacement air configuration which provides the most operational flexibility and worker protection is a down flow design, with the replacement air being delivered from the ceiling. The following discussion is based primarily on a down flow system, although a cross flow system may be utilized if the down flow arrangement proves to be impractical. Consider worker breathing zone when designing and balance the energy usage with worker protection.

Use perforated plate to cover as much of the ceiling (or wall opposite the exhaust hood(s)) as practical. The diameter of the perforation should be between 1/4 in and 3/8 in (6.3 mm and 9.5 mm). Perforated plenums work best when ceiling height is less than 15 ft (4.58 m). Use either of the following two choices for replacement air plenum design:

- a. Design for 1,000 fpm (5.1 m/s) replacement air velocity through the open area of the perforated plate if perforated duct is used inside the plenum as shown in Figure 2-3.
- b. Design for 2,000 fpm (10.2 m/s) replacement air velocity through the open area of the perforated plate if the plenum is served with ducts using diffusers, grills or registers as shown in Figure 2-4.

Figure 2-3. Plenum Design With Perforated Duct.

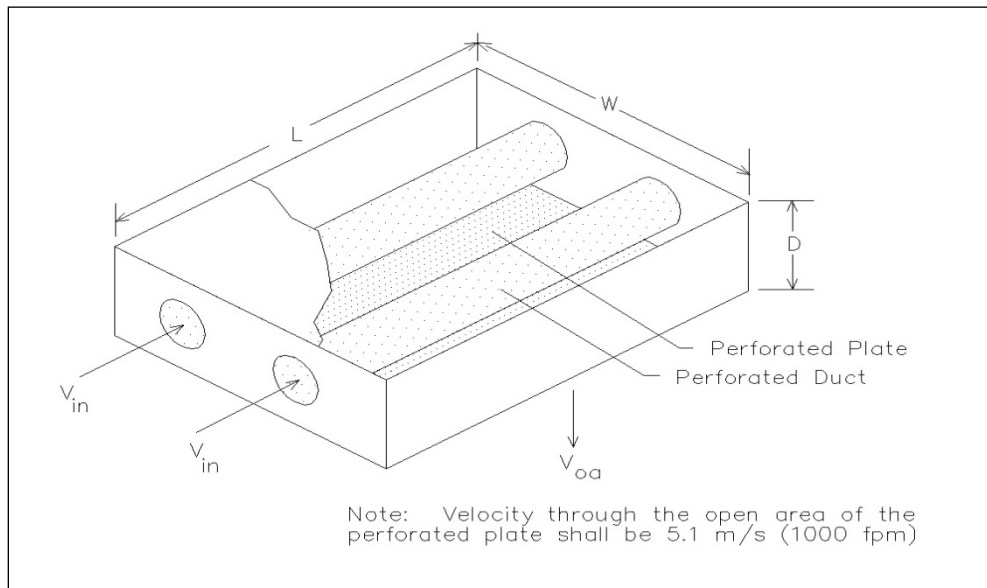
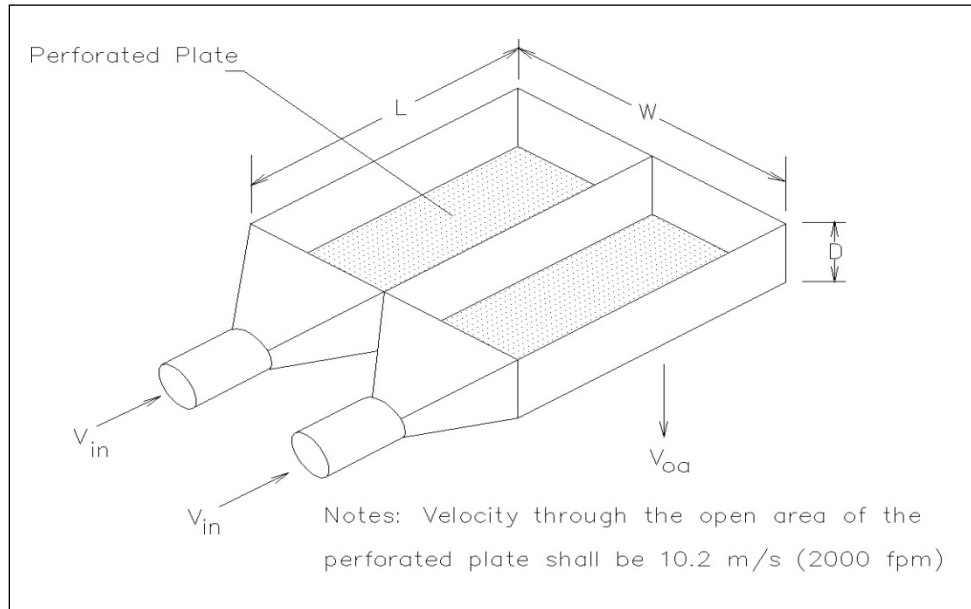


Figure 2-4. Plenum Design Without Perforated Duct.



2-4.5.3 Perforated Duct Design.

Use perforated duct to evenly distribute the flow of replacement air inside a plenum or use alone when ceiling height is greater than 15 ft (4.58 m). Manufacturers provide several different types and sizes of perforated duct. Use recommendations from the manufacturer for duct design. The manufacturer will not only recommend the size, shape, and type of the required perforated duct, but also the location of the orifices and reducers to distribute the air properly.

2-5 CONTROLS.

Provide industrial ventilation system controls and associated alarms to ensure contaminant control, space specific balance and conditioning, a safe and healthy work environment, and system malfunction notification.

Comply with Standard 18, Emergency Air Distribution Shutoff, found in UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*. A hazardous exhaust system may continue to operate if de-energizing the system will violate building codes, fire codes, create an unsafe condition or imperils life safety.

2-5.1 Gauges and Sensors.

Specify gauges and sensors to provide continuous monitoring of system performance. The minimum requirements are:

2-5.1.1 Differential Pressure Sensors

Provide differential pressure sensors, with gauge readouts, across each replacement air filter section and the exhaust air cleaning sections. Program control system alarm set points for each filter differential sensor to indicate when the filter pressure drop falls below the initial “clean” filter differential pressure or rises beyond the final “dirty” filter differential pressure. Provide text and graphical representation for the low pressure alarm and the high pressure alarm indications.

2-5.1.2 Replace Fan Motor Sensors

Operating light on replacement air system fan motor.

2-5.1.3 Static Pressure Sensors

Static pressure sensor at the outlet of the replacement air fan with a gauge readout. Alarms must be triggered when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.4 Hood Static Pressure Sensors

Hood static pressure sensor, for critical processes or process where extremely toxic substances are used, with a gauge mounted in a conspicuous place near the hood. An alarm must be triggered when the static pressure is lower or higher than the recommended range (as determined by baseline testing). Do not use the type of inline flow sensor, which measures the pressure drop across an orifice plate. Use only a static pressure tap and differential pressure gauge.

2-5.1.5 Fan Static Pressure Sensors

Static pressure sensor at the exhaust fan inlet with gauge readout. An alarm must be triggered when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.6 Exhaust Air Motor Sensor

Operating light on exhaust air system motor. When a sensor indicates a malfunction, trigger an alarm that is both audible and visible in the shop space.

2-5.1.7 Gauge Operating Range

Operating ranges on all gauges clearly marked. Locate gauges on an annunciator panel (except hood static pressure gauges). Provide a 3-way valve at each gauge connection for cleanout and calibration; see Figure 2-5.

2-5.1.8 Differential Pressure Sensor Location

Place room differential pressure sensors away from doors, windows, and replacement air discharge.

2-5.2 Interlocks.

Provide an interlocked on-off switch so that the replacement air and exhaust air systems operate simultaneously. When there are multiple fans, clearly label which exhaust fan is interlocked with which supply fan.

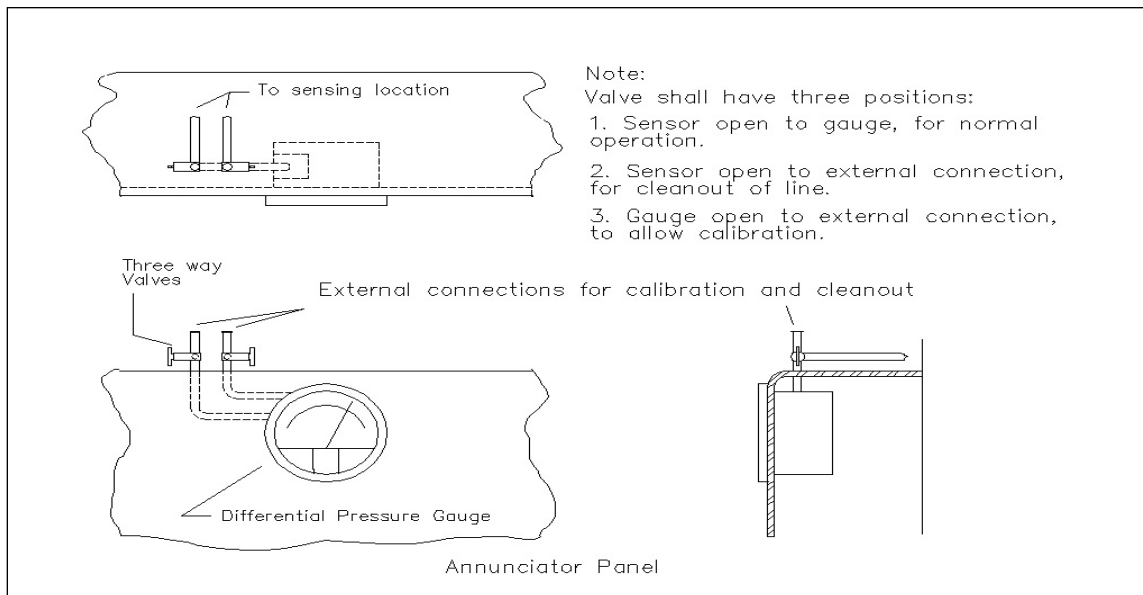
2-5.3 Annunciator Panel.

Provide an annunciator panel to allow for continuous monitoring of ventilation system performance. Locate the panel so it is accessible to shop personnel. The panel must include, but is not limited to, all gauges (except hood static pressure gauges) described in the paragraph in Chapter 2, entitled, "Gauges and Sensors". Mount fan motor operating lights and interlocked ON/OFF switch on the panel. The interlocked switches must clearly show which exhaust and supply fans are interlocked, where multiple fans are used. The panel must indicate what action to take when operation falls outside the prescribed ranges. For example, "examine/replace filter on R.A. unit when this gauge reads outside indicated range." Connect sensor outputs to building DDC systems when available.

2-5.4 Security.

Any networked communications from controls must meet the Information Assurance security requirements of the Activity served.

Figure 2-5. Annunciator Panel.



2-6 OPERATIONAL CONSIDERATIONS.

2-6.1 Provision for System Testing.

Provide access to the fan and motor to measure voltage, amperage, and fan speed. Evaluate and incorporate the use of guard rails, working platforms, and OSHA ladders

into the design where equipment is located at elevation. Specify that all testing will be done in accordance with the ACGIH *Industrial Ventilation, A Manual of Recommended Practice for Operation and Maintenance (IV O&M) Manual*, Chapter 3, "Testing and Measurement of Ventilation Systems."

2-6.2 Energy Conservation.

Incorporate applicable energy conservation measures in the design of all industrial ventilation systems. Criteria herein minimize volume flow rates through appropriate designs. Evaluate life cycle costs for heat recovery systems and specify when appropriate. For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems*.

2-6.3 Recirculation.

Industrial ventilation systems use a large quantity of air. Exhaust air recirculation is discouraged for most industrial processes and prohibited by OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual* for processes generating lead and asbestos. Follow the re-circulated air guidelines set forth in NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids* for fire protection; the *ACGIH IV Design Manual*, Section 10.8, and ANSI AIHA/ASSE Z9.7, *Recirculation of Air from Industrial Process Exhaust Systems* for health protection, and the applicable OSHA standards when recirculation is included in the design.

2-6.4 Maintenance.

Require the contractor provide an operation and maintenance manual for the system and also provide hands-on training for maintenance and shop personnel. Ensure safe and sufficient maintenance access to the system components.

2-7 SAFETY AND HEALTH CONSIDERATIONS.

2-7.1 Posting.

For those systems where the replacement air is critical to the proper operation of the system, consider posting the following sign at each entrance to the ventilated space:



2-7.2 Noise.

Use engineering controls as the primary means of protecting personnel from hazardous noise. It is cheaper to eliminate potential noise problems during the design or procurement stages, than it is to retrofit or modify after installation. Determine the acoustic environment in advance, both to fulfill the design goals and prevent the need for corrections at a later stage.

2-7.2.1 Criteria.

Determine the sound power levels for each piece of equipment used for industrial ventilation. Use this information to predict the acoustic characteristics and the resulting ambient noise level. Refer to UFC 3-101-01, *Architecture*.

Also refer to the appropriate facility-type UFC's for sound transmission requirements (STC's) into adjacent building spaces.

For additional information on noise control refer to UFC 3-450-01, *Noise and Vibration Control*; and OSHA 3048, *Noise Control, A Guide for Workers and Employees*.

2-7.3 Respiratory Protection.

29 CFR 1910.134(d), *Respiratory Protection* specifies requirements for respiratory protection. Consult with an industrial hygienist (IH) or occupational health specialist to determine the appropriate type of respiratory protection required for each process.

2-7.3.1 Breathing Air.

Breathing air for supplied air respirators must meet grade D standards as required by 29 CFR 1910.134(d) and defined in Compressed Gas Association Specification for Air G-7.1. Make up air for the breathing air compressor must be from outside and upwind of any potential exhaust sources. Breathing air couplings must not be compatible with outlets for non-respirable worksite air or other gas systems. Consider providing multiple connection ports for airline respirator hoses to allow worker mobility. Provide a means to permit the IH to test air quality on a routine basis.

2-7.3.2 Air Compressors.

Breathing air systems require a high temperature, carbon monoxide and Oxygen alarm. Alarms must be located where the respirator user and helper can see and hear them. Compressors must have the carbon monoxide level monitored to ensure the air supplied contains below 10 ppm CO. Compressors used to supply breathing air must be constructed and situated with a 30 foot separation from sources of contamination (e.g., exhausts, plumbing vents, loading docks) to prevent entry of contaminated air into the air supply system. The breathing air compressor must minimize moisture content so that the dew point is 10 degrees F (5.56 degrees C) below the ambient temperature. The breathing air system must have suitable in-line air-purifying sorbent beds and filters. Sorbent beds and filter must be maintained per manufacturer's instructions.

2-7.4 Emergency Showers and Eyewash Stations.

Provide in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.

2-7.5 Hygiene Facilities.

These facilities are adjacent to or nearby the operation when employees are exposed to certain stressors such as asbestos, cadmium, lead, etc. The facilities may be as simple

as a hand washing station or as complicated as multiple clean/dirty rooms in an asbestos delagging shop or a facility using metals such as cadmium, lead or hexavalent chromium. Consult with the local industrial hygiene department to determine the extent of and location for these facilities.

2-8 COMMISSIONING.

This process begins before the conceptual design is complete. It is a strategy that documents the occupants' needs, verifies progress and contract compliance and continues throughout the design, build and acceptance process. DOD projects and construction offices have long used parts of the commissioning process for military construction (MILCON) and some smaller projects. To ensure that issues specific to ventilation are not overlooked, use ASHRAE Guideline 1.1, *HVAC &R Technical Requirements for the Commissioning Process*.

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CHAPTER 3 ASBESTOS DELAGGING FACILITIES

3-1 FUNCTION.

An asbestos delagging facility provides a complete workshop to remove asbestos material from piping, mechanical and structural equipment during ship repair and demolition. The ventilation system design discussed in this section is for activities with extensive asbestos removal operations. The design includes: shop and equipment space, clean and dirty locker rooms for men and women, and administrative space to support the coordination and monitoring of facility operation.

3-2 OPERATIONAL CONSIDERATIONS.

3-2.1 Airborne Contamination.

When asbestos material is removed, the asbestos fibers are dispersed into the air, creating a health hazard. 29 CFR 1910.1001, *Asbestos, General Industry* and 29 CFR 1915.1001, *Asbestos, Shipyards* dictate protective measures for workers in these facilities, including respiratory protection and impermeable outerwear. The regulations also prescribe wetting the asbestos material with amended water (water containing a surfactant), if practicable, to reduce the potential for asbestos fibers to become airborne.

3-2.2 Heat Stress.

The physical nature of the work and impermeable outer garments worn by the workers creates heat stress conditions. Provide supplied air respirators with vortex tubes as specified in EPA-560-OPTS-86-001, *A Guide to Respiratory Protection for the Asbestos Abatement Industry*. Consider cooling the replacement air when supplied air respirators are not available. Consider using "micro climate cooling" or "cool suits," mechanically cooled garments, for individual workers.

3-2.3 Employee Workflow.

Workers enter the clean locker rooms through the control point area. They put on protective outerwear and proceed to the work area. After performing asbestos work, workers remove the outer set of disposable booties as they step in to the decon area.

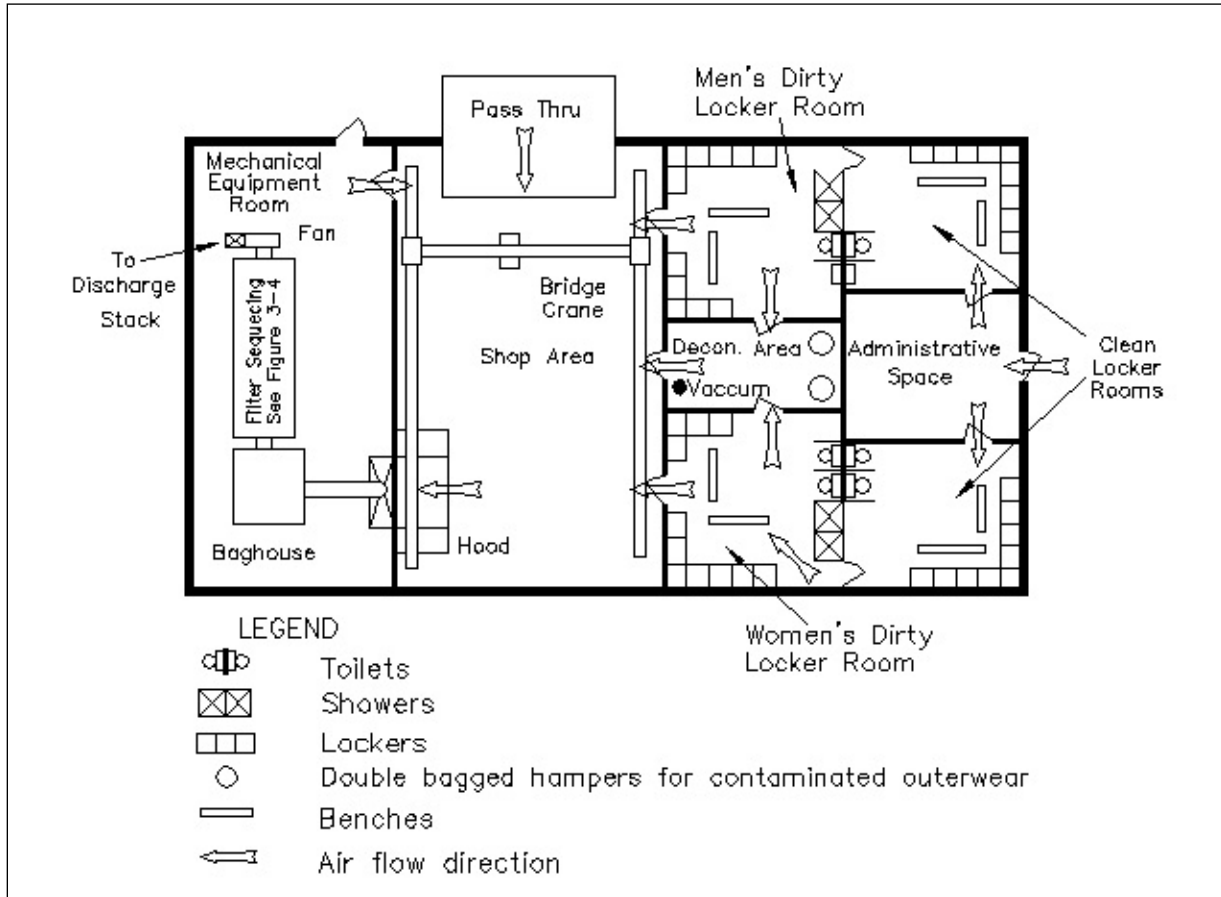
In the Decon room, the workers will vacuum their protective outerwear and dispose of them in containers provided. They enter the dirty locker rooms and remove the remainder of their work garments. Workers then proceed to the clean locker rooms via the showers, which act as a barrier to the migration of asbestos fibers.

In the shower, the worker can remove and wash their respirator and proceed to the clean room to get dressed in their personal clothing and exit to the control point.

3-3 TYPICAL FLOOR PLANS.

Design floor plans to meet the requirements of 29 CFR 1910.1001 and 29 CFR 1915.1001 and the paragraph in Chapter 3 entitled, "Employee Workflow". Figure 3-1 shows a sample delagging facility floor plan.

Figure 3-1. Delagging Facility Floor Plan.



3-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

3-5 EXHAUST AIR.

Design the exhaust air system to generate 4 exchanges of air/hour and .02 inches (0.5 mm) of water column.

3-5.1 Hood Design.

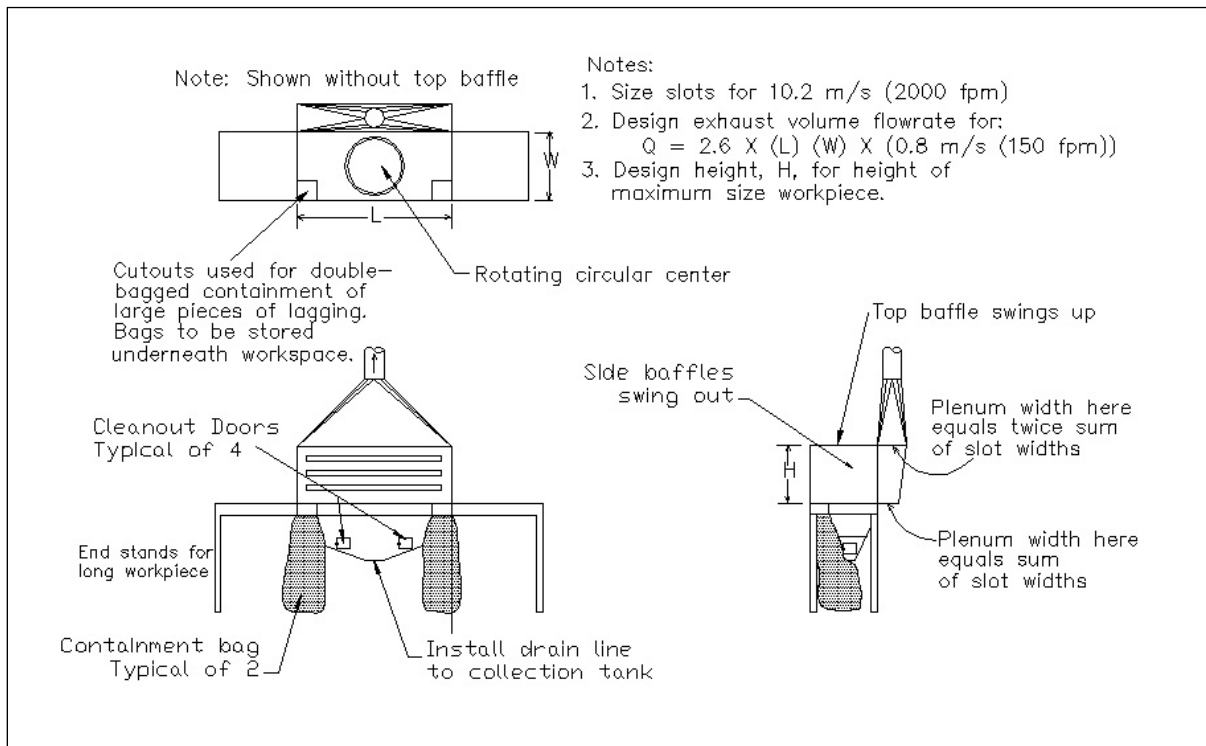
Design asbestos delagging hood to enclose the work piece as much as possible. Do not use small portable hoods with flexible ductwork because they do not provide consistent capture.

3-5.1.1 Typical Hood Design for High Profile Work Pieces.

Figure 3-2 shows a hood design consisting of a workbench with a central, circular area. Mount the circular area on sealed bearings to allow easy turning of heavy work pieces. This design is best for high profile work pieces (for example, boilers, pumps). The hood captures contaminants through the slots into an exhaust plenum. Design each hood with:

- Two cleanout doors on the front and two doors on the sides of the hood for easy access to asbestos debris. Provide two small cutouts in the outer corners of the workbench to place large pieces of lagging in double bagged containment.
- The top baffle swings up to allow access to overhead cranes.

Figure 3-2. Exhaust Hood For High Profile Work Pieces.



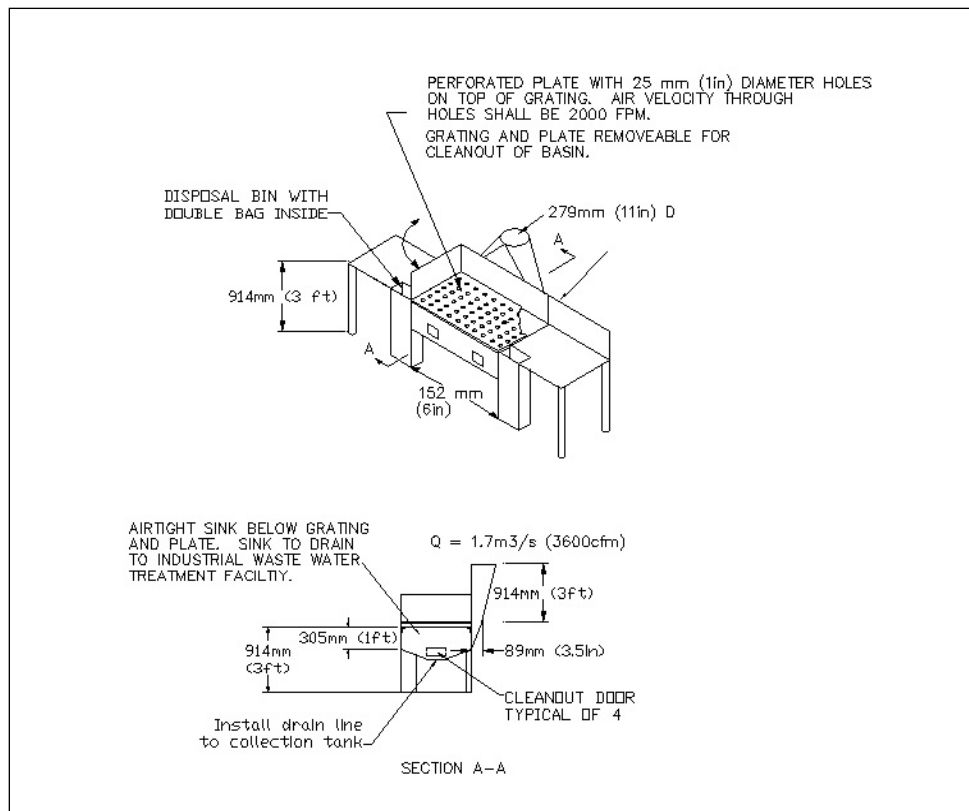
3-5.1.2 Typical Hood Design for Low Profile Work pieces.

Figure 3-3 shows a hood design consisting of a workbench with a grating strong enough to support the heaviest expected work piece. This is a downdraft hood that draws small pieces of lagging through the grating. The perforated plate below the grating creates even airflow over the grating. This design is best for low profile work pieces such as piping. Design each hood with stands and swinging baffles on each end to accommodate long work pieces (e.g., pipes).

3-5.2 Ductwork.

Size the exhaust ductwork to provide a minimum transport velocity of 5,000 fpm (25.4 m/s). The high velocity is necessary because the practice of wetting the fibers makes them heavier and more difficult to transport. See the paragraph in Chapter 2 entitled, "Ductwork" for general duct considerations.

Figure 3-3. Exhaust Hood For Low Profile Work Pieces.



3-5.3 Fans.

See the paragraph in Chapter 2 entitled, "Fans" for general fan considerations.

3-5.4 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, "Exhaust Stacks".

3-5.5 Air Cleaning Devices.

A delagging facility requires multistage filtering, which consists of a fabric filter collector, prefilters, a mist eliminator, and high efficiency particulate air (HEPA) filters. Prefilters extend the life of the HEPA filters. Use "bag in, bag out" styles of HEPA filters, which allow for safe replacement of the filter element without exposure to asbestos. A mist eliminator before the HEPA filter protects it from the moisture generated during asbestos removal.

- a. Have all collectors deliver the collected asbestos to a common pickup point to minimize the risk of exposure. Provide a double acting valve at each collector hopper throat, in accordance with the ACGIH IV Design Manual, Chapter 8, Air Cleaning Devices.
- b. Use a single chamber, shaker type collector to minimize the number of collection points.

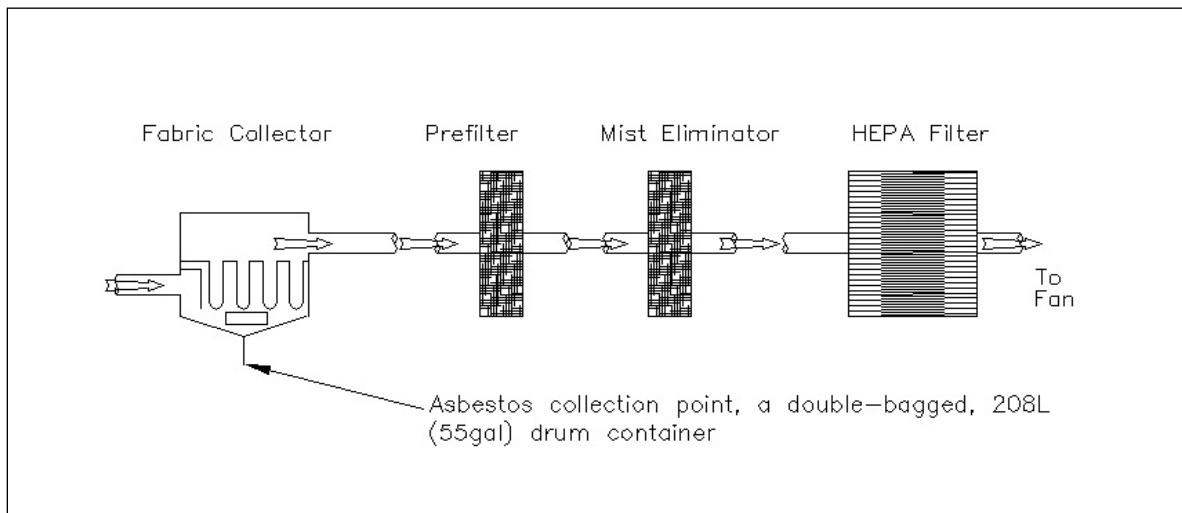
3-5.5.1 Filter Efficiency.

The fabric filter collector requires a minimum efficiency reporting value (MERV) of not less than 15 in accordance with ASHRAE 52.2, *Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*.

3-5.5.2 Sequencing.

Figure 3-4 illustrates the required sequence of air cleaning devices.

Figure 3-4. Sequence Of Air Cleaning Devices For Asbestos Delagging.



3-5.6 Industrial Vacuum System.

Provide a low volume, high velocity (LVHV) central vacuum system at delagging shops to exhaust fibers and dust from power tools (e.g., grinders and saws) when they are used, as specified in 29 CFR 1910.1001.

3-5.6.1 Central Vacuum System

Design a central vacuum cleaning system, which consists of a motor driven exhauster interconnected with bag type separators.

3-5.6.2 Ductwork

Connect the separator to rigid hose or duct, which extends throughout the plant. Terminate the rigid hose or duct with inlet valves at the various workstations. Provide flexible hose connections to allow workers to do shop cleanup and to decontaminate their protective outerwear.

3-5.6.3 Exhaust Tools and Hoods

Use local exhaust hoods and high velocity exhaust takeoffs for each hand tool. Table 3-1 of this UFC and the ACGIH IV Design Manual provide examples of tools and exhaust system for specific operations.

3-5.6.4 Contaminant Capture Distance

Ensure proper capture velocity is produced at each local exhaust hood. Design vacuum systems to reach within 1/2 inch (12.7 mm) of the contaminant source.

3-5.6.5 Pick-up Velocity

Design the pickup air-stream to have a velocity of two to three times the generation velocity for particle sizes from 20 to 30 micrometers (20 to 30 micron.) Design for an additional velocity of: (1) four to five times the generation velocity to pull the particles up through 300 U.S. standard mesh, or (2) six to eight times the generation velocity to pull the particles up through a 20 U.S. standard mesh.

Table 3-1. Minimum Volumes And Vacuum Hose Size For Asbestos Operations.

Hand Tool	Flow rate cfm (m ³ /s)	Hose Size in. (mm)
Pneumatic chisel	125 (0.06)	1.5 (38)
Hand wire brush, 3 x 7 inches	125 (0.06)	1.5 (38)
Rip out knife	175 (0.08)	1.5 (38)
Rip out cast cutter	150 (0.07)	1.5 (38)
Saber saw	150 (0.07)	1.5 (38)
Saw abrasive, 3 inch	150 (0.07)	1.5 (38)
General vacuum	200 (0.09)	2.0 (51)

Adapted from: Hoffman Air and Filtration Systems, "Design of Industrial Vacuum Cleaning Systems and High Velocity, Low Volume Dust Control."

3-5.6.6 Air to Asbestos Ratio

Design the air volume for no less than two parts of air to one part of asbestos to be captured by weight.

3-5.6.7 Hose Lengths and Locations

Design the vacuum hose length less than 25 ft (7.6 m). Locate inlet valves 30 to 35 feet (9 to 10.7 meters) apart when a 25 ft (7.6 m) length of hose is used. Locate tool vacuum hose connection on the ends of the workbench underneath the stands. Size the hose based on: (1) air volume per hose, (2) number of hoses to be used simultaneously, and (3) air velocity required to convey the material to the separators.

3-5.6.8 PVC Hoses

Use single-ply, lightweight thermoplastic or polyvinyl chloride (PVC) flexible hose, but limit the usage whenever possible.

3-5.6.9 Multi-stage Blower

Use a multistage centrifugal blower for the vacuum system. Size the blower for: (1) total system pressure loss associated with the total number of hoses to be used simultaneously, and (2) maximum exhaust flow rate entering the inlet of the blower.

3-5.6.10 Blower to Bag House Relationship

Feed the blower directly into the bag house used by the industrial exhaust system to minimize the number of asbestos collection points.

3-5.6.11 Filters and Location

Install a prefilter and a HEPA filter in front of the blower to prevent it from becoming contaminated.

3-5.6.12 Balance by Design

Design the vacuum system duct to balance with the exhaust system duct where the two systems connect.

3-5.6.13 Noise

Use manufacturer guidance to design vacuum system and UFC 3-450-01, *Noise and Vibration Control* as preliminary guidance.

3-5.7 Replacement Air.

Design replacement air systems with fan inlet guide vanes, variable speed motors, or "eddy current clutch" units to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.05 inches wg (12.4 to 24.9 Pa scale) in the shop spaces.

- a. Maintain the pressure in decontamination areas, the equipment room, and dirty locker rooms within a range of -0.01 to -0.04 inches wg (-2.49 to -9.96 Pa). Maintain the pressure in clean spaces within a range of (+0.02 to +0.05 inches wg (+4.98 to +12.4 Pa).
- b. For further replacement air system criteria, see the paragraph in Chapter 2, entitled, "Replacement Air".

3-5.8 System Controls.

Design system controls in accordance with the paragraph in Chapter 2 entitled, "Controls" and the following:

- a. Position the annunciator panel at the entrance to the dirty space so operators can monitor operating gauges.
- b. Install static pressure sensors at locations that are representative of average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.
- c. Trigger a timer if pressure varies from the specified range. Select timer that automatically resets if the problem is corrected within 60 seconds.
- d. Trigger both visible and audible alarms if the system cannot correct the difficulty within allotted time. Install multiple alarm beacons if operator's view is obscured during delagging. Monitor the shop's negative pressure continuously, using strip chart recorder, so the operator can detect any pressure changes.

- e. Interlock the hand tool power supply with the ventilation system's on-off switch. This will prevent the use of hand tools without ventilation controls.

3-6 TREATMENT OF WASTE EFFLUENT.

All waste water generated in the facility must be considered contaminated effluent and must be filtered to remove solid particulate contaminants prior to entry into the Industrial Waste stream.

Notify and comply with any pretreatment requirements as required by the POTW, state and local authorities prior to discharging any waste water from the facility.

3-7 SAFETY AND HEALTH CONSIDERATIONS.

Consult the local industrial hygienists (IH) for required respiratory protection in accordance with 29 CFR 1910.1001 (f) and (g), 29 CFR 1915.1001(g) and (h). See the paragraph in Chapter 2 entitled, "Respiratory Protection" for additional information.

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CHAPTER 4 OTTO FUEL II FACILITIES

4-1 FUNCTION.

MK-46 and MK-48 torpedo facilities maintain, prepare, and test torpedoes. MK-46 and MK-48 torpedoes use Otto Fuel II, a toxic monopropellant. Further best practices and reference documents can be found in the inactive UFC 4-216-02, *Design: Maintenance Facilities for Ammunition, Explosives, and Toxins*.

4-2 OPERATIONAL CONSIDERATIONS.

Operations in a torpedo facilities create a potential for personnel exposure to one or more of the following: (1) Otto Fuel II, (2) Agitene - parts cleaning solvent used in MK-46 shops, (3) hydrogen cyanide - a product of combustion in torpedoes, and (4) mineral spirits - parts cleaning agent used in MK-48 shops.

4-3 DESIGN CRITERIA.

Design the facilities using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter. Torpedo size differences and maintenance procedures dictate the use of different floor plans and exhaust hood designs for the two types of facilities. Refer to NAVSEA OP5, Volume 1, *Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation and Shipping* for the specific order of operations. In all cases, the industrial ventilation systems must remove hazardous vapor (from Otto Fuel II, and part cleaning solvent) and products of combustion.

4-3.1 Exhaust Air for MK-46 Ventilated Spaces.

The MK-46 floor plan in Figure 4-1 optimizes the workflow while allowing the ventilation system to control airborne contaminants. Figure 4-2 shows an elevation view of this floor plan.

Figure 4-1. Layout for the MK-46 Fuel/Defuel and Afterbody Breakdown Room.

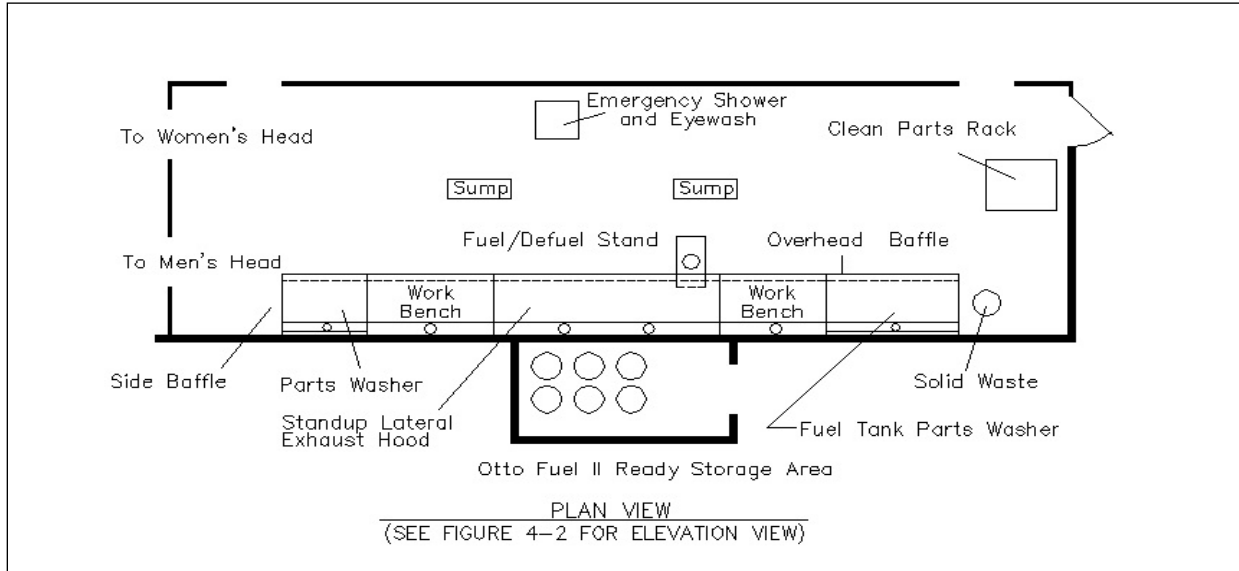
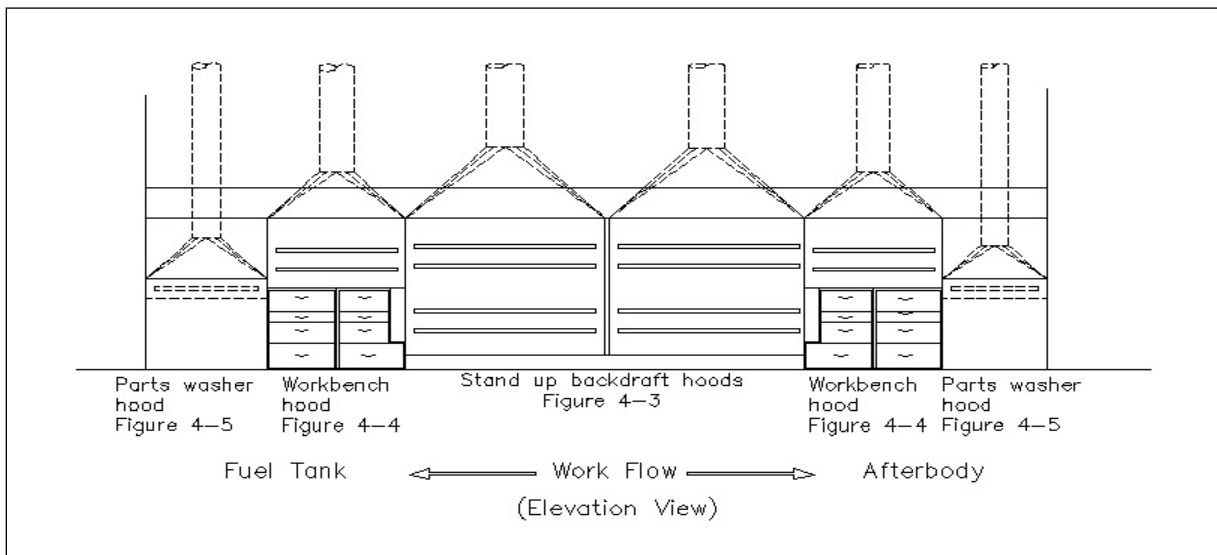


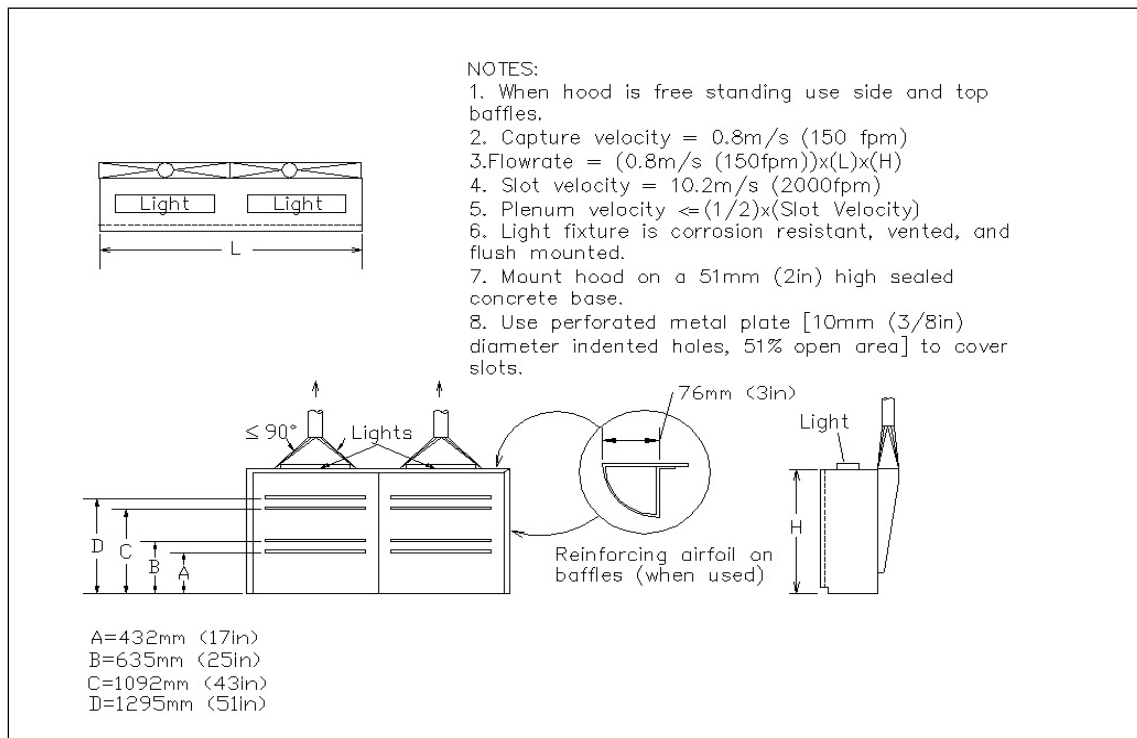
Figure 4-2. Series of Hood in the MK-46 Shop.



4-3.1.1 MK-46 Standup Backdraft Hood.

Workers uncouple the fuel section and the engine section of the torpedo in teardown operations. During these operations, Otto Fuel II remains in the lines, in the components of the engine section, and in the fuel tank. The residual fuel releases vapor into the air. The defueling and refueling processes also release Otto Fuel II vapor. Use the standup backdraft hood as shown on Figure 4-3 to capture Otto Fuel II vapor in afterbody teardown, fueling, and defueling operations.

Figure 4-3. MK-46 Standup Backdraft Hood.

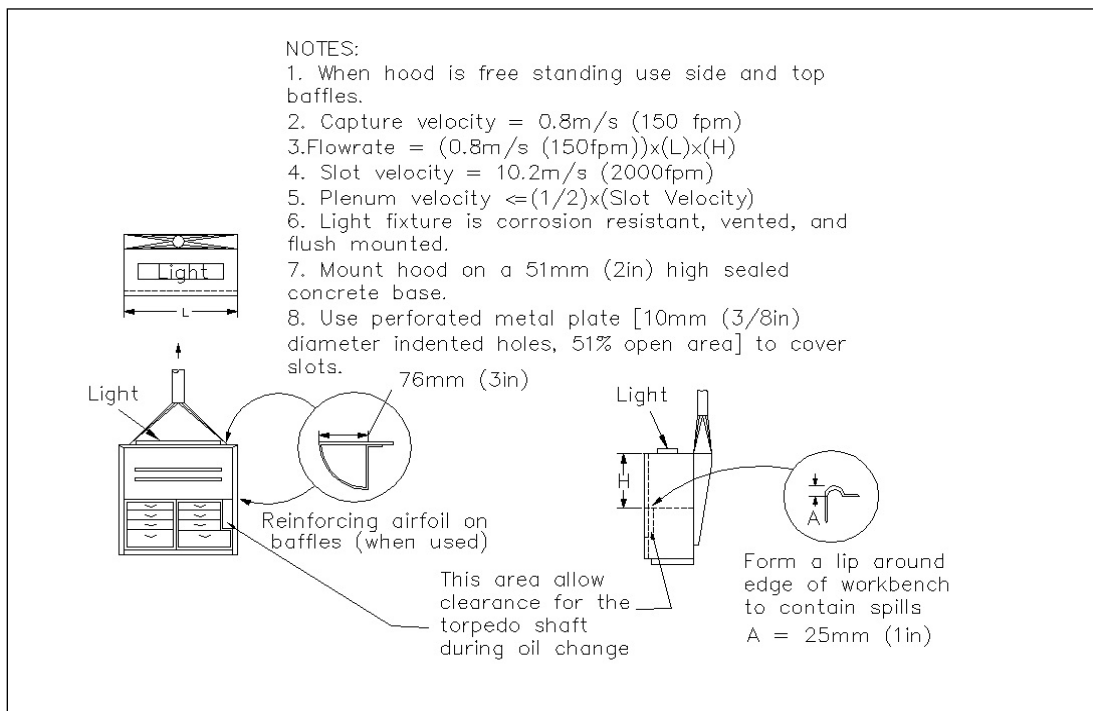


- a. Hood transitions (takeoffs) with an included angle no greater than 90 degrees. Length of the hood, served by an exhaust plenum, is not to exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (2.44 and 4.88 m) in length have two exhaust takeoffs.
- b. Baffles to control airflow from the sides and top of the hood bank as shown on Figure 4-3.

4-3.1.2 MK-46 Workbench Hood.

After defueling and decoupling, workers lift the fuel and engine sections onto two different ventilated workbenches. They remove the stabilizing baffles in the fuel section, inspect, and wipe them clean before loading the baffles into the parts washer. Personnel also dismantle the engine section to inspect the engine, fuel pump, and seawater pump before loading them into the parts washer. Design a backdraft exhaust hood, as illustrated in Figure 4-4, to control contaminants generated by these workbench operations.

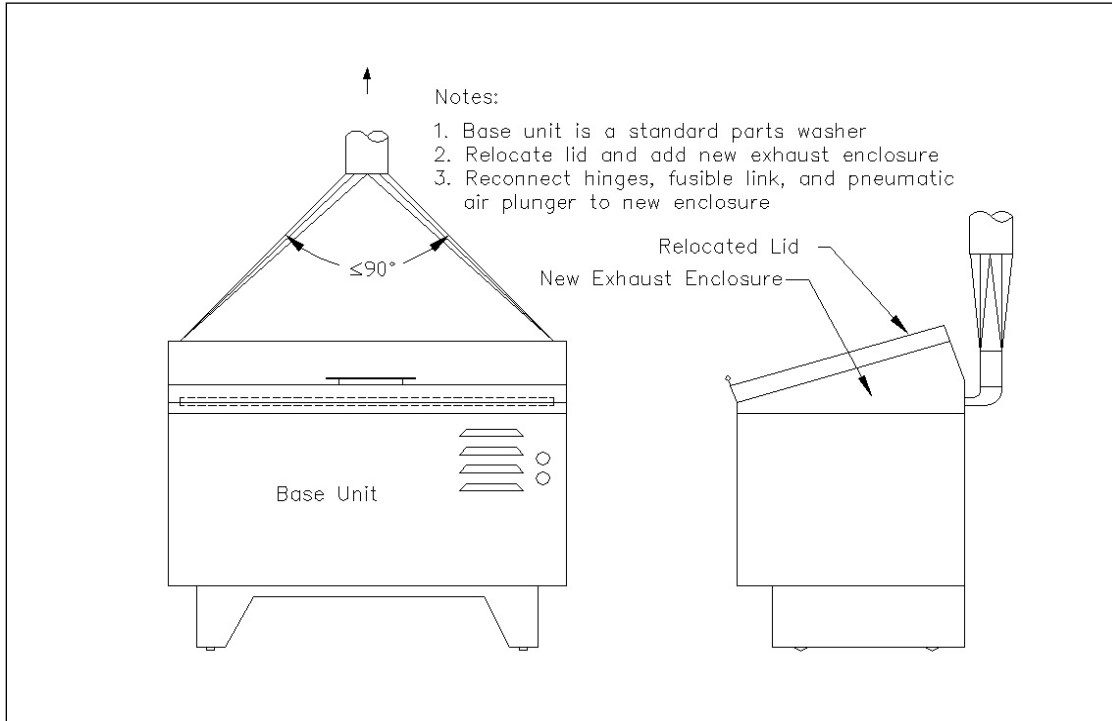
Figure 4-4. MK-46 Workbench Hood.



4-3.1.3 MK-46 Parts Washer Hood.

Design parts washer as shown on Figure 4-5 to clean off oils and excess Otto Fuel II from torpedo components. The parts washer cover must automatically close in case of fire in accordance with NFPA 34, *Standard for Dipping Coating and Printing Processes Using Flammable or Combustible Liquids*. Design the parts washer large enough to completely enclose the work piece. Design the parts washer deep enough to allow a minimum clearance of 6 in (153 mm) between the liquid level and the exhaust slot when the tank is full of parts. Position the parts washer next to the workbenches to shorten the work path and optimize ventilation control.

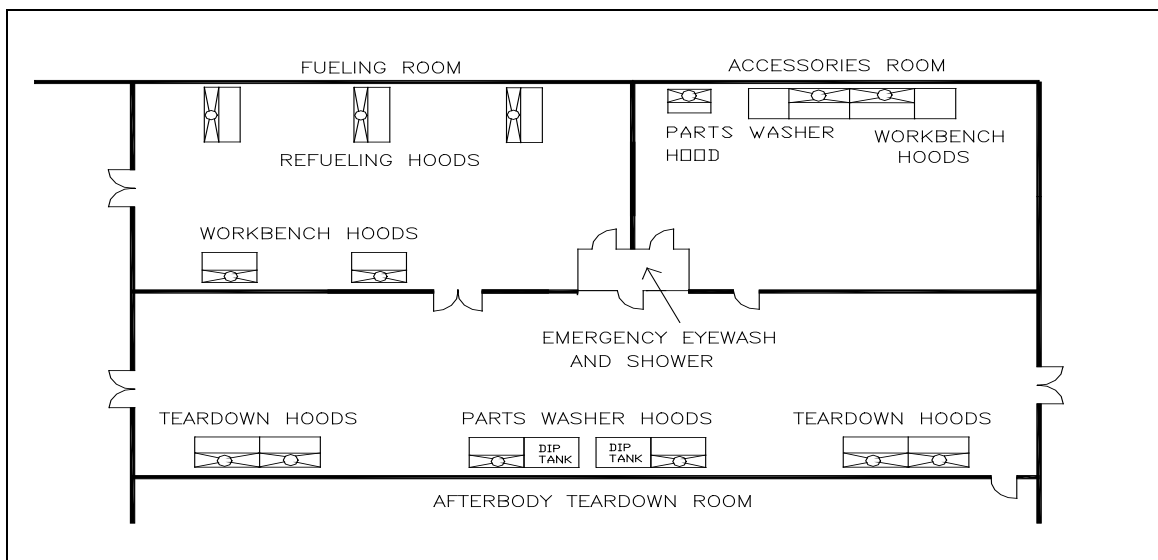
Figure 4-5. MK-46 Parts Washer Hood.



4-3.2 Exhaust Air for MK-48 Ventilated Spaces.

The floor plan shown in Figure 4-6 optimizes the work path while allowing the ventilation system to control airborne contaminants. Obtain detailed MK-48 exhaust hood drawings from Naval Underwater Systems Center.

Figure 4-6. Typical MK-48 Ventilated Space Layout.

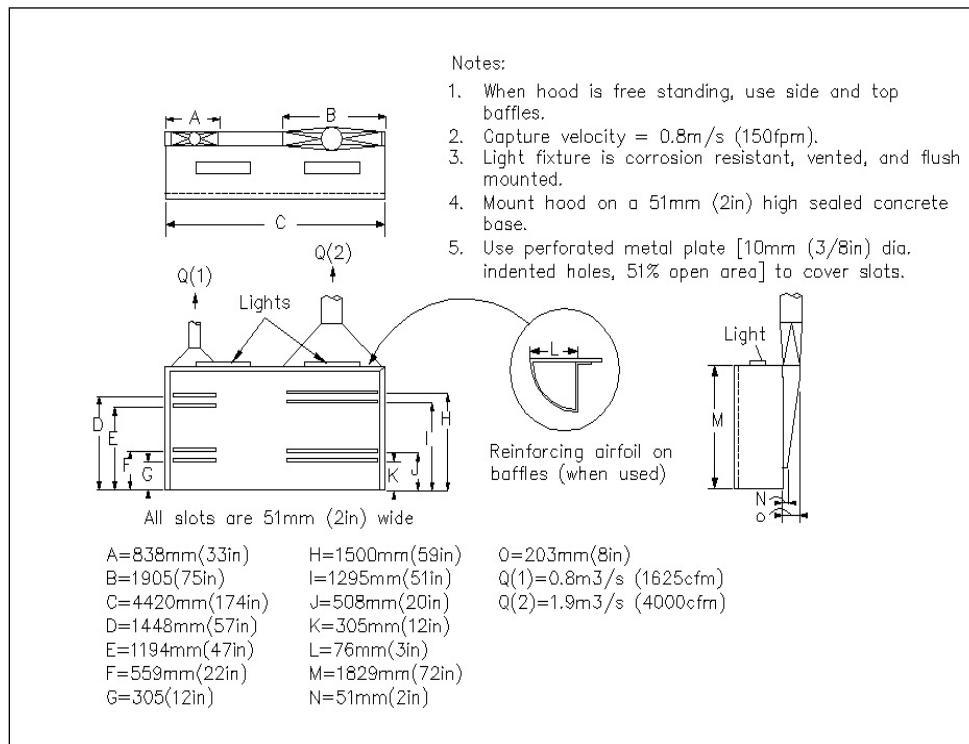


4-3.2.1 MK-48 Afterbody Teardown Hood.

Workers uncouple the fuel section and the engine section of the torpedo in the teardown operations. During these operations, Otto Fuel II remains in the lines and the components of the engine section, and in the fuel tank. The residual fuel releases vapor into the air. Design the afterbody teardown hood as shown in Figure 4-7 to capture Otto Fuel II vapor. Design the hood using the following criteria.

- Install baffles on the top and side of the hood forming a booth.
- Install a 3 in (7 mm) airfoil on the outer edge of the hood. The airfoil, bent inward from the baffle, must provide an airfoil effect and prevent turbulence and backflow.
- Install lighting that is vented and flush mounted in the overhead baffle as shown on Figure 4-7.
- Bolt the hood to the floor, using a continuous natural rubber gasket on hood bottom to create a seal between the hood and the floor.

Figure 4-7. MK-48 Afterbody Teardown Hood.



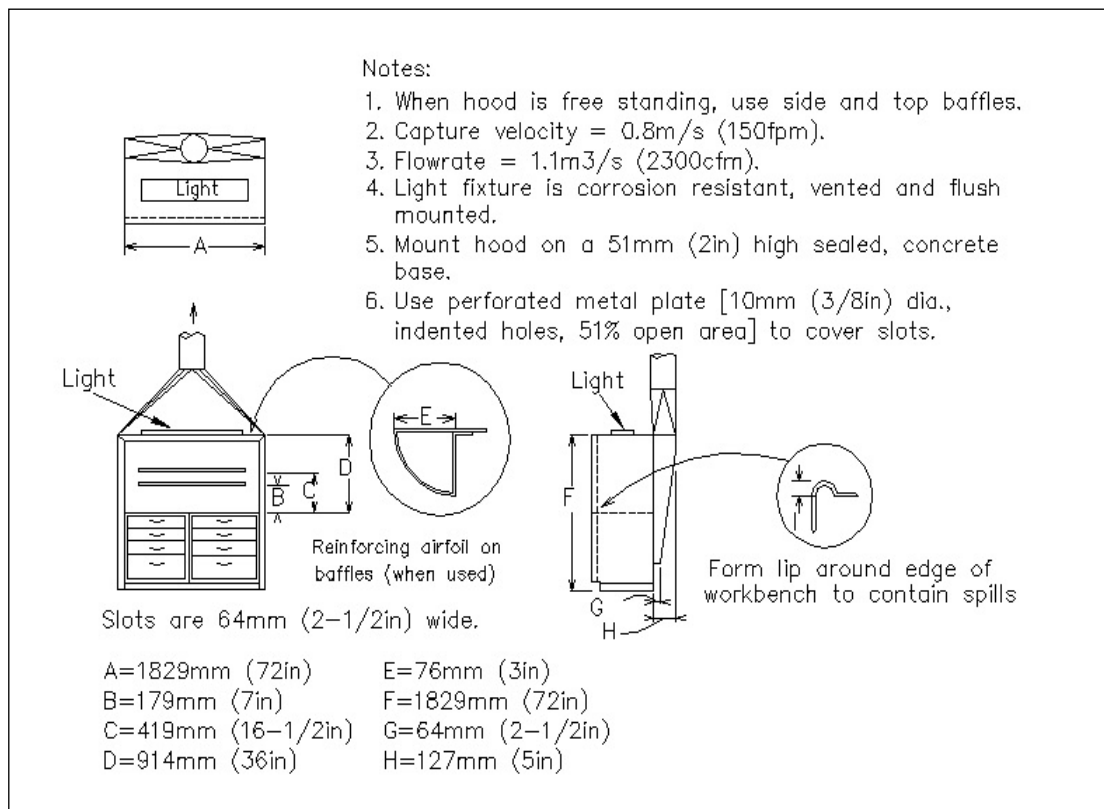
4-3.2.2 MK-48 Workbench Hood.

After defueling and decoupling, personnel dismantle and inspect the fuel tank and the engine section. They then load components of the fuel tank and the engine section into the parts washer. Design a backdraft exhaust hood as illustrated in Figure 4-8 to

control contaminants generated by these workbench operations. Specify the following criteria for workbench hoods:

- a. A 72- by 24-in (1850- x 600-mm) stainless steel workbench top to support the whole exhaust hood. See Figure 4-8 for dimensions of the hoods.
- b. A 3-in (76-mm) airfoil rotated inward to prevent turbulence and backflow.
- c. Lighting that is vented and flush mounted in the top of the exhaust hood.

Figure 4-8. MK-48 Workbench Hood.

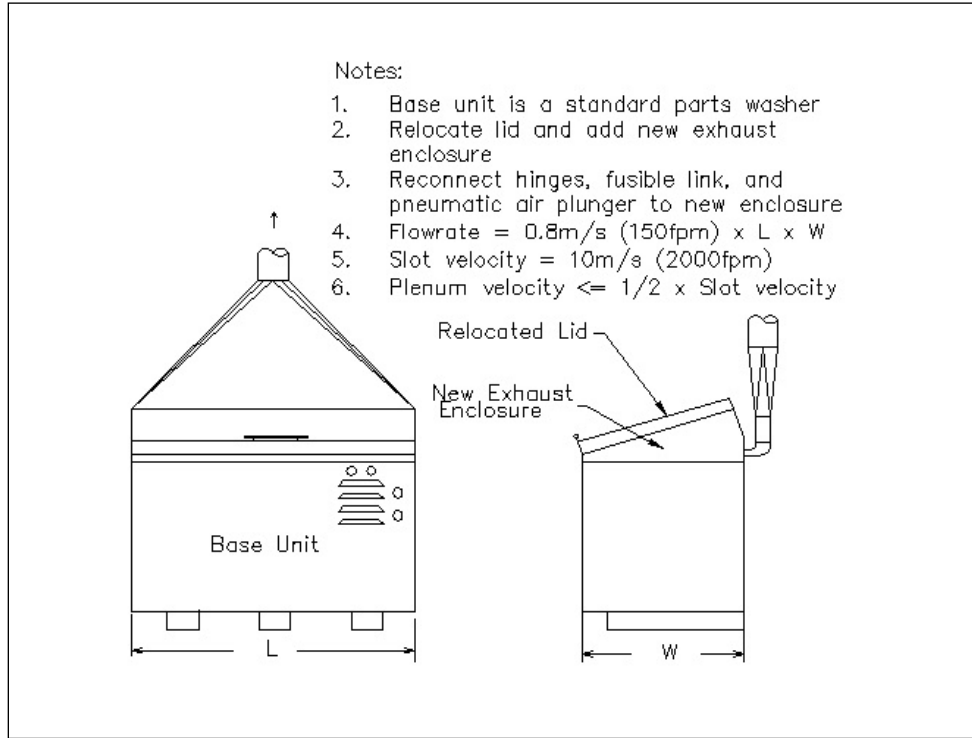


4-3.2.3 MK-48 Parts Washer Hood.

Design or modify the parts washers as shown on Figure 4-9. Specify the following criteria for the parts washers:

- a. Fabricate a new enclosure to mount on top of the parts washer.
- b. Relocate the cover with a pneumatic plunger and a fusible link assembly.
- c. Install an automatic switch to turn on the exhaust fan when the cover is opened and to turn off the exhaust fan when the cover is closed.

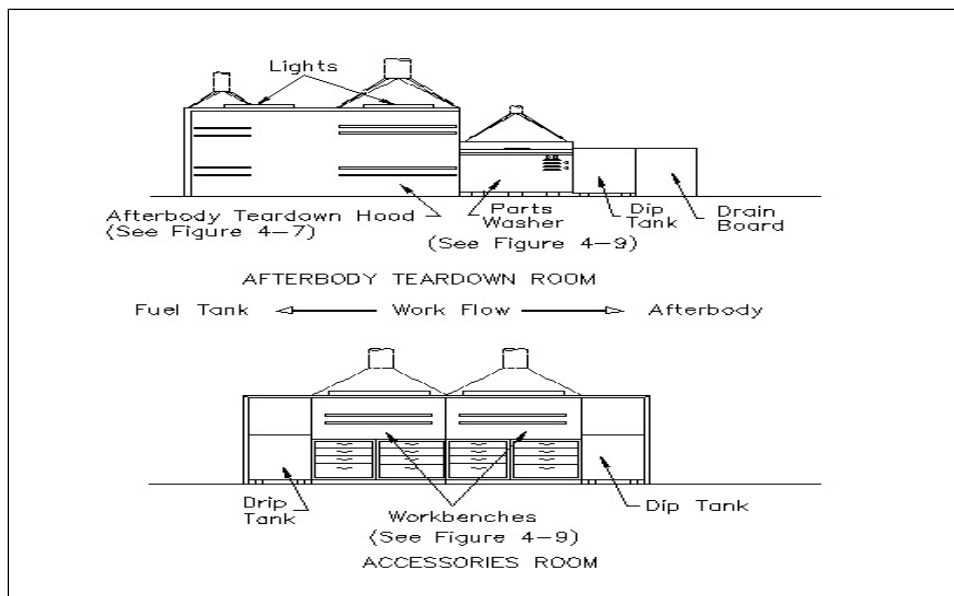
Figure 4-9. MK-48 Parts Washer Hood.



4-3.2.3 Workflow in Afterbody Teardown Room and Accessories Room.

Figure 4-10 illustrates the workflow in both the afterbody teardown room and the accessories room with the proper sequence of hoods.

Figure 4-10. MK-48 Hood Sequence Afterbody Teardown and Accessories Rooms.

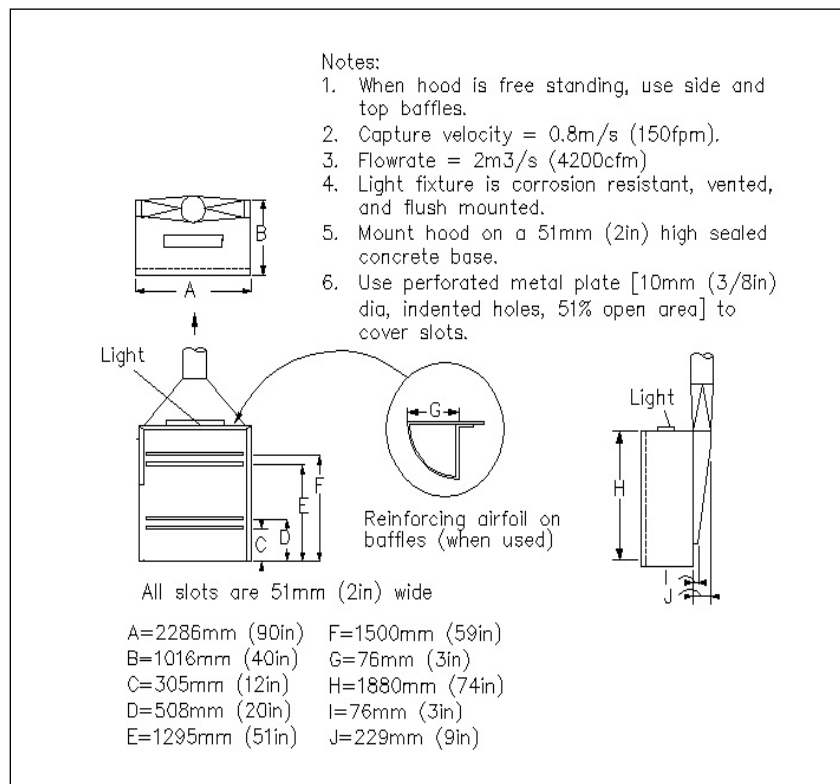


4-3.2.4 MK-48 Refueling Hood.

Before refueling, personnel connect the hoses from the fueling equipment to the fuel tank. Once the fueling operation has begun, the operator does not need access to the fuel tank, except to see the hose connections. Therefore, design an enclosing hood to reduce ventilation rates and decrease the potential for exposure to a spill during fueling. Design the hood as illustrated in Figure 4-11. Specify the following criteria for the refueling hoods.

- A 3-in (76 mm) airfoil rotated inward to prevent turbulence and backflow.
- Lighting that is vented and flush mounted in the top of the exhaust hood.
- Hood that bolts the floor, using a continuous natural rubber gasket on hood bottom to create a seal between the hood and the floor.
- Design the exhaust such that the dip tank can be cleaned using the work station exhaust.

Figure 4-11. MK-48 Refueling Hood.



4-3.2.5 Ductwork.

Follow criteria as specified in the paragraph in Chapter 2 entitled, "Ductwork" for both MK-46 and MK-48 shops and the following:

- a. Fabricate all ductwork in contact with Otto Fuel II vapors with (black) carbon steel. Require all joints be either butt welds or flanges.
- b. Size the duct to maintain a minimum transport velocity of 2,500 fpm (12.7 m/s).

4-3.2.6 Fans.

Select fans as specified in the paragraph in Chapter 2 entitled, "Fans".

4-3.3 Weather Stack Design and Location.

Proper dispersion from the stack is critical because Otto Fuel II exhaust is not filtered. See the paragraph in Chapter 2 entitled, "Exhaust Stacks".

4-3.4 Air Cleaning Devices.

Due to the quantities and types of contaminants generated by these processes, there is no requirement for air pollution control equipment.

4-3.5 Replacement Air.

Design replacement air systems to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.06 inches wg (-5.0 to -14.9 Pa) in the spaces with a potential for personnel exposure. Maintain the spaces with a low potential for personnel exposure at a differential pressure ranging from +0.01 to +0.05 inches wg (2.49 to 12.4 Pa).

4-3.5.1 Quantity and Distribution.

Distribute air to produce laminar flow of air from supply to exhaust in the workspace. Use vertical supply distribution method as shown on Figure 4-12. Horizontal supply distribution method as shown on Figure 4-13 is adequate if, and only if, all exhaust hoods are located on the wall opposite the supply plenum. See the paragraph in Chapter 2 entitled, "Replacement Air" for detailed criteria.

Figure 4-12. Vertical distribution method.

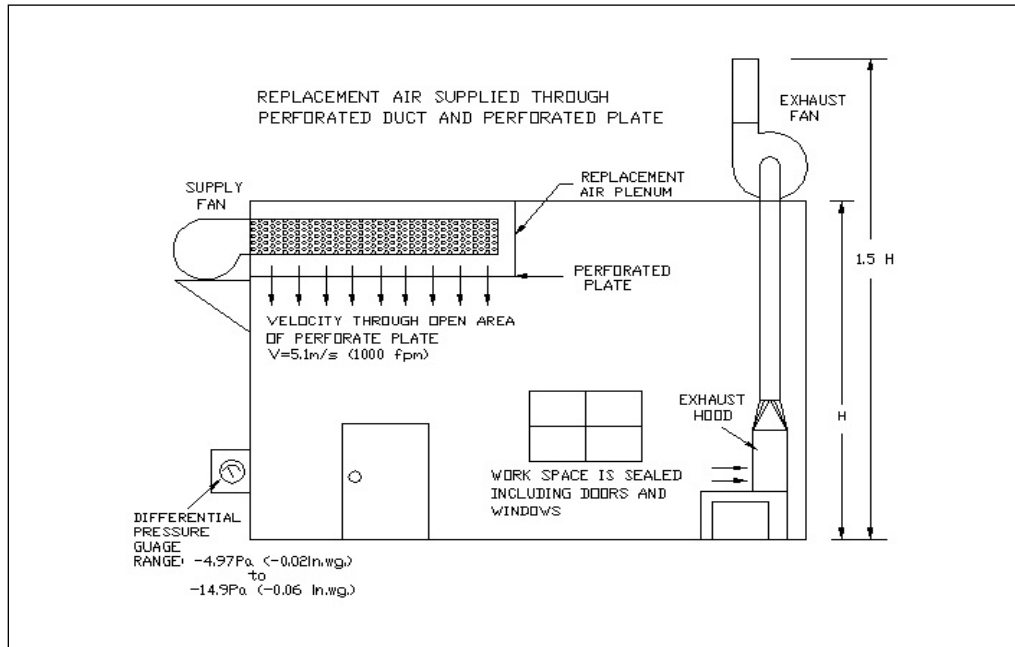
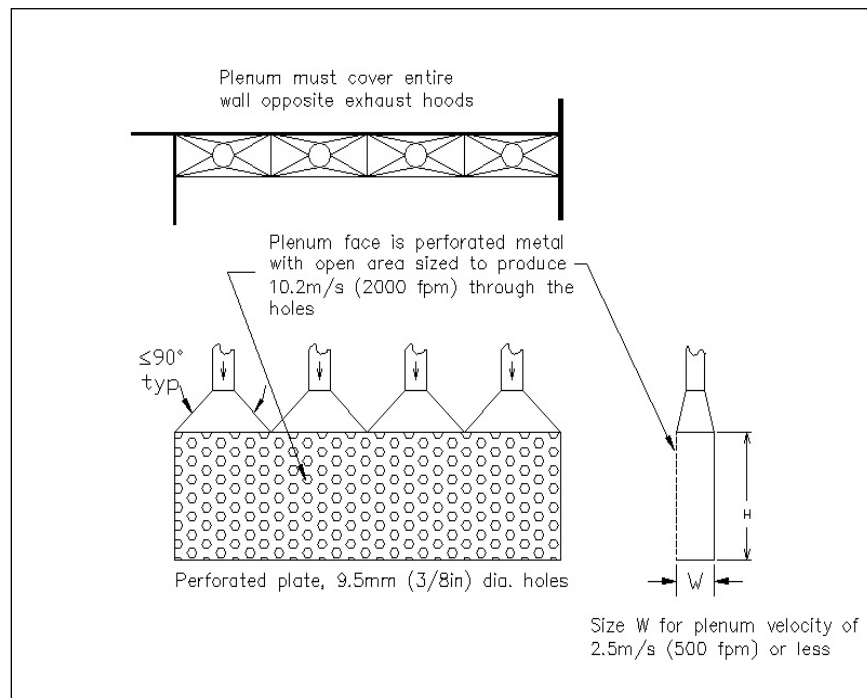


Figure 4-13. Horizontal Distribution Method.



4-3.5.1.1 Vertical Distribution Method.

Design a drop ceiling with perforated plate to form a plenum in accordance with the paragraph in Chapter 2 entitled “Plenum Design”.

4-3.5.1.2 Horizontal Distribution Method.

Design the wall plenum to cover the entire wall opposite the hoods. Size the open area of the perforated sheet for 2,000 fpm (10.16 m/s) through the holes. See Figure 4-13 for more details.

4-3.6 Heating and Air Conditioning.

Design heating, air conditioning, and humidity control according to UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems*. Temper the replacement air to provide a minimum winter design temperature of 65 degrees F (18 degrees C) and a maximum summer design temperature of 78° F (25.6° C), with a relative humidity of 50 percent +/- 10 percent. Do not separate the air conditioning system from the replacement air system. See the paragraph in Chapter 2 entitled, "Energy Conservation" for criteria on heat recovery systems. Do not re-circulate exhaust air.

4-4 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, "Controls" and the following:

- a. Position an annunciator panel at the entrance to the space with a potential for personnel exposure so operators can monitor operating gauges.
- b. Install static pressure sensors at locations that are representative of average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.
- c. Trigger a timer if the pressure varies from the specified range. Select a timer that automatically resets if the problem is corrected within 60 seconds.
- d. Trigger both visible and audible alarms if the system cannot correct the difficulty within the allotted time.

4-5 SAFETY AND HEALTH CONSIDERATIONS.

29 CFR 1910 requires specific criteria for the safety and health of operators. The physical nature of the work and the use of protective clothing increase the potential for heat stress. Consider cooling the replacement air to reduce this potential. Refer to NAVSEA S6340-AA-MMA-010, *Otto Fuel II Safety, Storage, and Handling Instructions* for complete operational considerations.

4-5.1 Emergency Shower and Eyewash Stations.

Provide combination emergency shower and eyewash stations in the immediate area of Otto Fuel II use. Design in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.

CHAPTER 5 COMPOSITE FABRICATION AND REPAIR FACILITIES

5-1 FUNCTION.

Composite shops and facilities primarily fabricate and repair aircraft and shipboard components. Both include a shop area, a mechanical equipment area, and a decontamination area (for protective clothing).

5-2 OPERATIONAL CONSIDERATIONS.

Composite fabrication and repair operations include sanding, buffing, fabric cutting, grinding, lay up, and wet spray up. These operations produce dust and vapor that constitute health hazards. The protective clothing that the workers wear and the physical nature of the work creates a potential for heat stress.

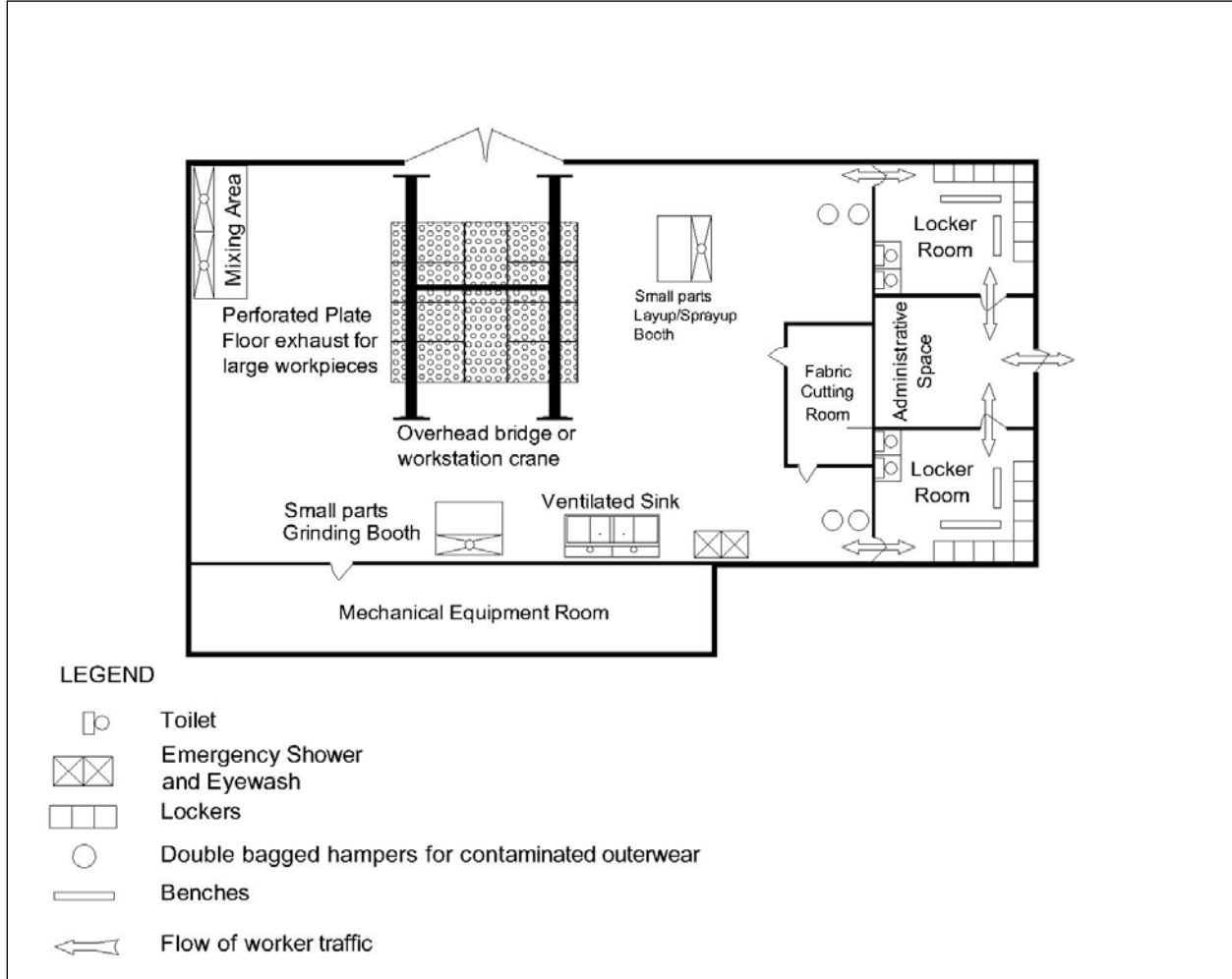
- a. Consider using airless spray equipment to reduce hazardous vapors in the shop. Initial cost for this equipment is greater than traditional compressed air systems. Benefits include overspray reduction and less accumulation of resin and fiberglass over the life of the equipment. A disadvantage of these systems is their limited pattern and flow adjustment capability.
- b. Consider using low monomer polyester material, closed molding systems or low-VOC resin systems, and airless and air-assisted spray equipment to avoid the need for expensive air pollution devices.
- c. Isolate conventional grinding operations from the mixing areas and the lay up and spray up areas. The combined hazard of dust and flammable vapors is potentially explosive. Post signs in the lay up and spray up areas and the mixing area without low volume-high velocity (LVHV) connectors that read:

DANGER
DO NOT GRIND, CUT, OR SAW
FIBERGLASS IN THIS AREA

5-3 FLOOR PLAN.

Figure 5-1 shows typical floor plans for Composite fabrication and repair facility. The workers enter the clean locker rooms through the administrative area. They put on protective outerwear and proceed to the shop area. After performing their work, shop personnel vacuum, then discard their protective outerwear in containers near the entrances to the locker rooms. The workers then enter the locker rooms where they remove the remainder of their work garments.

Figure 5-1 Example Floor Plan for a Composite Facility.



5-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

5-4.1 Exhaust Air System.

Provide an exhaust system that captures contaminated air generated during FRP fabrication and repair operations. Refer to Chapter 2 of this UFC; UFC 3-600-01, *Fire Protection Engineering For Facilities*; NFPA 33, *Standard Spray Application Using Flammable or Combustible Materials*; NFPA 68, *Standard on Explosion Protection by Deflagration Venting*; NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*; NFPA 654, and the specific requirements of this Chapter.

5-4.2 Hood Design.

The sizes and shapes of work pieces in FRP fabrication and repair facilities vary. Design separate hoods for processes producing only particulate and only vapor, and both particulate and vapor. Consider a molding system that completely encloses the work piece if the facility repeatedly manufactures the same work piece. Design exhaust hoods to enclose all processes to the greatest possible extent without inhibiting operations. Baffle all exhaust hoods to reduce cross drafts and improve hood efficiency. Table 5-1 summarizes recommended exhaust hoods, capture velocities, and air pollution control devices for each operation.

Table 5-1. Recommended Hood, Capture Velocity, and Air Pollution Device

Operation (expected contaminant)	Hood Type	Recommended Capture Velocity (fpm (m/s))	Air Cleaning Device (see notes)
Chemical Mixing (vapors)	Workbench (Figure 5-2)	100 (0.51 m/s)	1
Lay up (Vapors)	Workbench/Floor Exhaust (Figure 5-3)	100 (0.51 m/s)	1
Spray up (Vapors)	Spray up Booth (Figure 5-4)	100 (0.51 m/s)	1
Grind,Cut,Saw (Particulate)	Workbench/Floor Exhaust (Figure 5-3)	150 (0.76 m/s)	2
Cleanup (Vapors)	Ventilated Sink (Figure 5-5)	100 (0.51 m/s)	3 or 1
Hand Tools (Particulate)	LVHV Vacuum System	Not applicable	2

NOTES: (1) Determined by the local air pollution regulatory agency, (2) fabric collector, and (3) substitute an aqueous emulsion cleaner for acetone.

5-4.2.1 Plenum Velocity.

Design the plenum velocity at least one-half, but no greater than, the velocity through the perforated plate or layered prefilter to create an even airflow over the hood face. Design the hood-to-duct transition with an included angle of no more than 90 degrees.

5-4.2.2 Hood Length.

Specify that the length of the hood served by each exhaust plenum will not exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (2.44 and 4.88 m) in length will have two exhaust takeoffs. Provide cleanout doors in the plenum to allow removal of accumulated particulate.

5-4.2.3 Portable Hand Tools.

Use portable hand tools with Low Volume High Velocity (LVHV) vacuum systems for sawing, cutting, and grinding on all work pieces. Ensure that the tools, with their vacuum hoses, are properly sized for the work piece internal angles and curvature. LVHV systems are described in the paragraph in Chapter 5 entitled, "Industrial Vacuum System".

Figure 5-2. Workbench Hood.

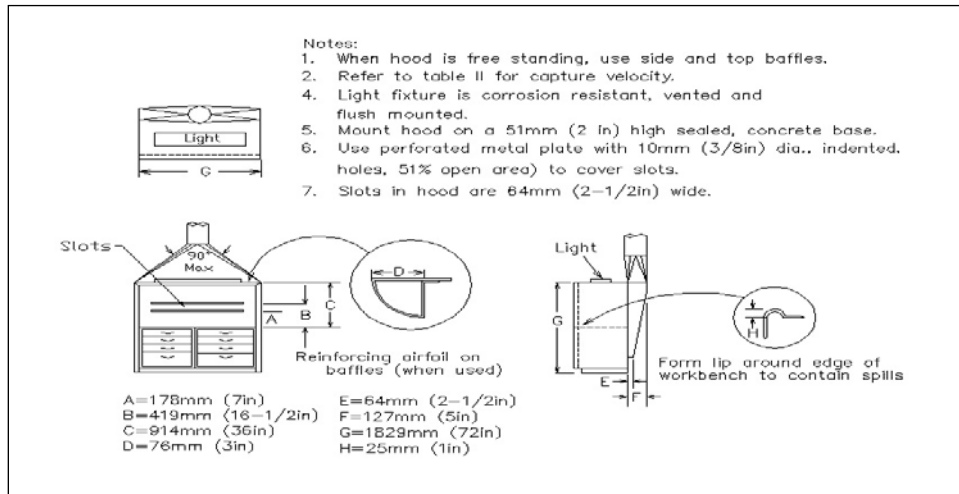
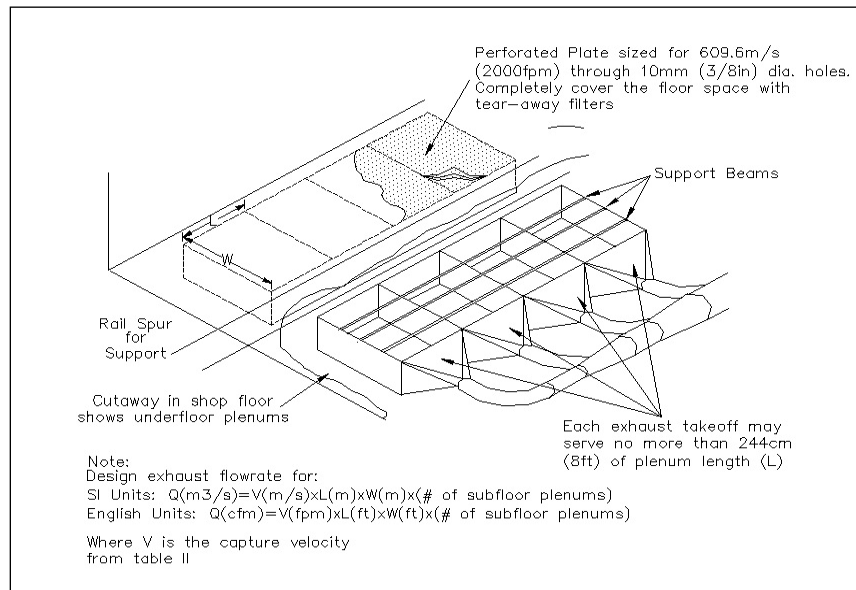


Figure 5-3. Floor Exhaust.



NOTE: Mount the work piece on a mechanism for easy rotation. This will reduce the dead air space that occurs when working on radomes, boat hulls, and other large objects.

Figure 5-4. Spray Up Booth.

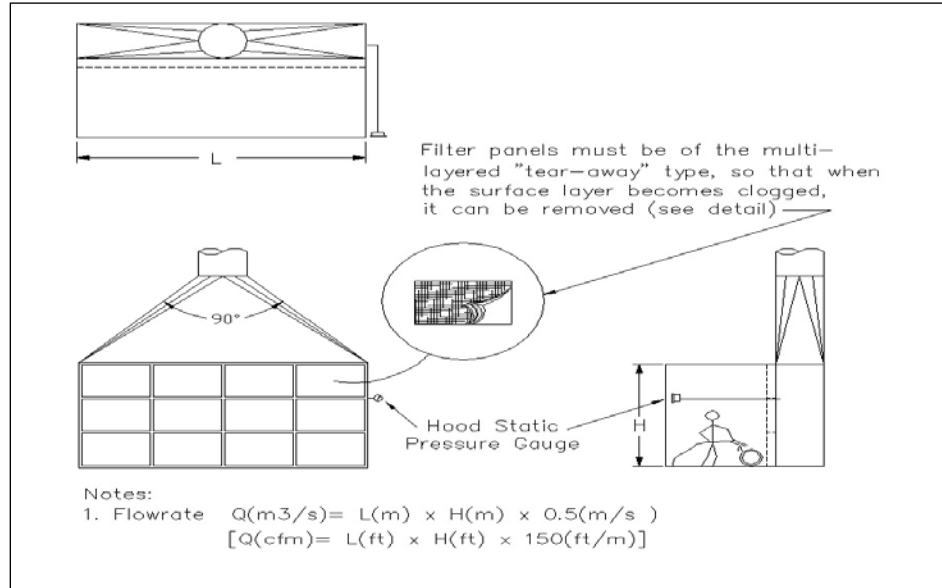
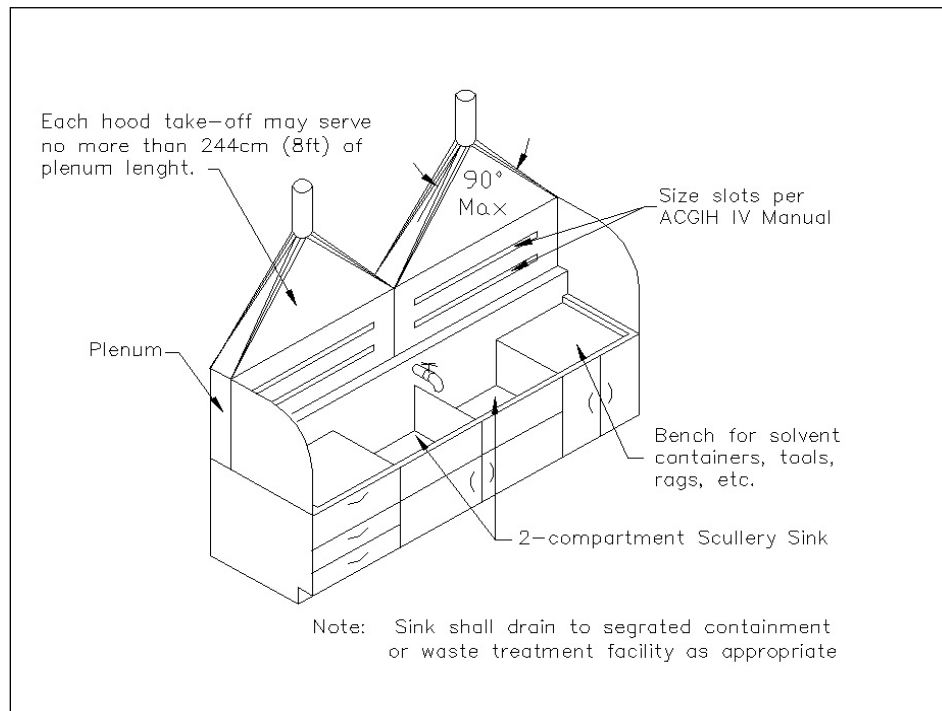


Figure 5-5. Ventilated Sink.



5-4.2.4 Spray Up Booths.

Design a spray up booth as shown on Figure 5-4. Use the spray up hood design in shops where spray up and lay up are performed in the same booth. Separate operations in this booth from any cutting, grinding, and sawing operations when conventional hand tools are used.

5-4.2.5 Ventilated Workbench and Sink.

Design a ventilated workbench as shown in Figure 5-2 for small work pieces. Use a similar workbench for resin preparation and mixing as shown on Figure 5-5. Eliminate the drawers and increase the size of the hood face by extending it to the floor if collection drums are used during resin preparation. Use aqueous emulsion cleaners to reduce styrene and acetone exposure.

5-4.3 Ductwork.

Design a 3,500 fpm (17.8 m/s) minimum transport velocity for LVHV hand tools, and grinding and spray up operations to prevent particulate material from collecting in the ductwork.

- a. Size the ductwork carrying vapor generated during lay up and mixing operations for a minimum transport velocity of 2,500 fpm (12.7 m/s). Use sheet metal as duct material since it is non-combustible. Route the ductwork directly to fans located outdoors. See the paragraph in Chapter 2 entitled, "Ductwork" for further information on ductwork.
- b. Consult with a fire protection engineer and use UFC 3-600-01, *Fire Protection Engineering For Facilities* to design a fire protection system for the ductwork when required. Condensation of flammable vapors, i.e. styrene and acetone, may occur and pool in the ductwork as it passes through an area with a lower temperature.

5-4.4 Fans.

See the paragraph in Chapter 2 entitled, "Fans" for general considerations.

5-4.5 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, "Exhaust Stacks" for exhaust stack design guidance.

5-4.6 Air Cleaning Devices.

Use separate air cleaning devices for grinding, buffing and polishing operations where particulate material is generated. Use separate air cleaning devices for lay up and mixing operations where flammable vapors are generated. Consult the air pollution control authorities for details on local requirement.

5-4.6.1 Grinding Operations and Hand Tools.

Use a fabric collector for grinding operations and LVHV hand tools. Consider using a disposal chute with a motor-driven rotary air lock in shops with a large particulate volume.

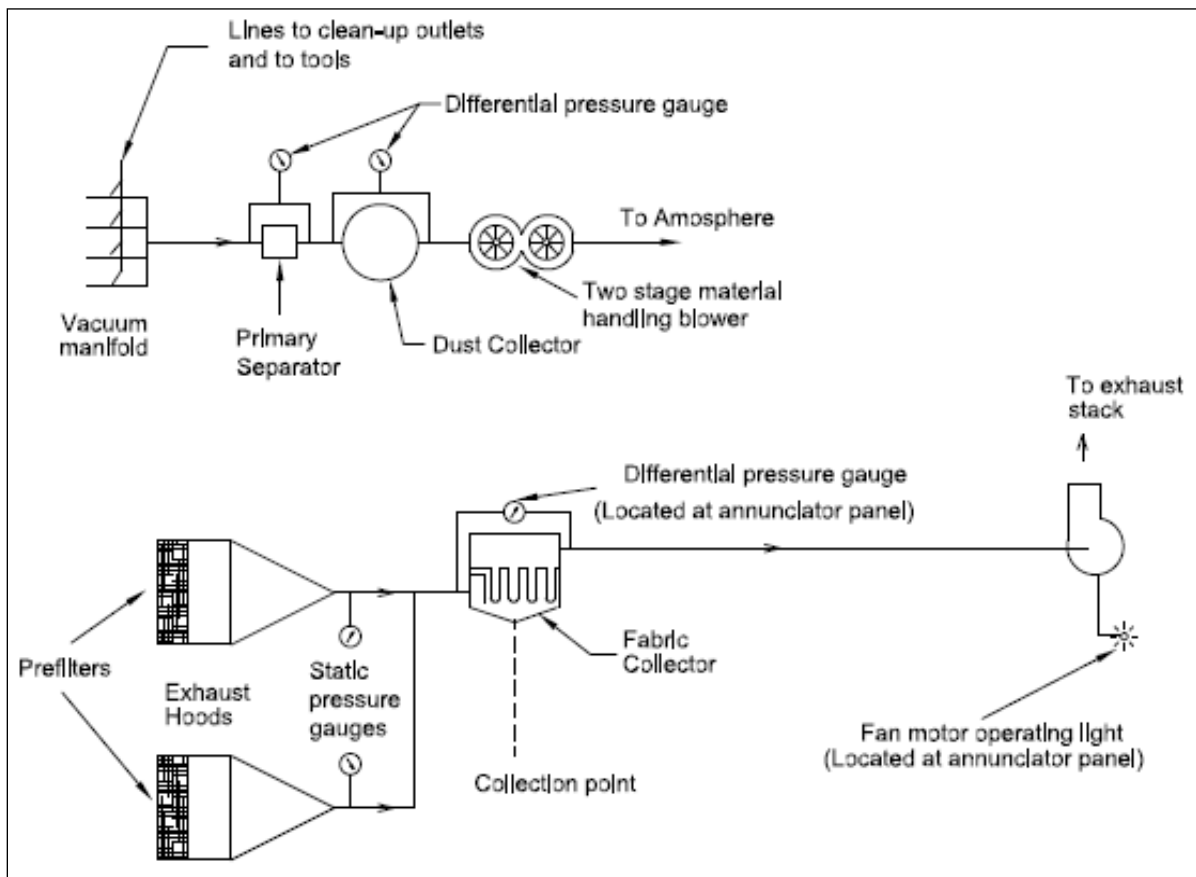
5-4.6.2 Spray Up Operations.

Spray-up operations release a combined contaminant of wet resin laden fiber and organic vapors. Therefore, separate spray up operations from all other operations. Install an air-cleaning device for vapors. Install layered prefilters on the spray up hood face instead of the perforated plate to prevent wet airborne resin from hardening in the ductwork and collectors. Peel off and discard a layer of the prefilter when its surface becomes loaded as indicated by the hood static pressure gauge. This continues until only the base filters remain. After that, replace the entire prefilter section. Specify a filter material that is not damaged by the styrene and acetone vapor produced in Composites facilities.

5-4.7 Industrial Vacuum System.

Install a vacuum system; see Figure 5-6, to exhaust fibers, dry resin and dust from LVHV hand tools when they are used. The vacuum system also allows workers to conduct shop cleanup and to decontaminate their protective outerwear. ACGIH IV Design Manual, Chapter 13, Section 13.40, Low Volume-High Velocity Exhaust Systems, gives design details and illustrates power tools using LVHV vacuum systems. The large size and high terminal velocity of the particulates produced by the hand tools requires a high velocity vacuum take-off hood for each tool. Generally, design the takeoff hood into the tool's safety guard.

Figure 5-6. Exhaust System Schematic.



5-4.7.1 Vacuum System Design.

Design the vacuum system in accordance with the following criteria:

- a. Ensure each take-off hood produces the proper capture velocity. This is the most important consideration in designing the vacuum system. Design the hood to capture contaminants as close as possible to the point of generation. Design vacuum systems to capture contaminants within 1/2 inch (12.7 mm) of the source.
- b. Design the capture air-stream to have a velocity of two to three times the generation velocity for particles of 20 to 30 micrometers (20 to 30 microns.) Design for an additional velocity of:
 1. Four to five times the generation velocity to pull the particles up through 300 U.S. standard mesh, or
 2. Six to eight times the generation velocity to pull particles up through 20 U.S. standard mesh.
- c. Design the air volume for no less than two parts of air to one part of material to be captured by weight.
- d. Design the vacuum hose length less than 25 ft (7.6 m). Locate inlet valves 30 to 35 ft (9 to 10.7 m) apart when a 25ft (7.6 m) length of hose is used. Locate the tool vacuum hose connection on the ends of the workbench underneath the stands. Size the hose based on the following:
 1. Air volume per hose.
 2. Number of hoses to be used simultaneously.
 3. Transport velocities.
- e. Use either a multistage centrifugal or turbine blower, positive-displacement blower or a regenerative blower for the vacuum system. Size the blower according to the following:
 1. The total system pressure loss associated with the total number of hoses to be used simultaneously.
 2. The maximum exhaust flow-rate entering the inlet of the blower.
- f. Place the primary separator and dust collector ahead of the vacuum exhaust blower to minimize wear to the blower.
- g. Use the manufacturer's data to complete the design because the LVHV system design data is largely empirical.

5-5 REPLACEMENT AIR.

Design replacement air systems to maintain a pressure (relative to the atmosphere) ranging from -0.02 to -0.06 in wg (-4.97 to -14.9 Pa) in the shop space and the protective clothing decontamination areas. Maintain the clean spaces at a positive pressure differential relative to dirty spaces. See the paragraph in Chapter 2 entitled, "Replacement Air" for further details. Provide each ventilated space with a dedicated replacement air system. Conduct a study of the curing requirements of the resin before specifying temperature and humidity ranges. Do not re-circulate exhaust air.

5-6 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, "Controls" and the following:

- a. Position the annunciator panel at the entrance to the dirty space so operators can monitor operating gauges.
- b. Install static pressure sensors at locations that are representative of the average static pressure in each controlled space. This will ensure that desired differential pressures are maintained.
- c. Interlock the hand tool power supply with the main ventilation system's on/off switch and with the vacuum system. This will prevent the use of hand tools without ventilation controls.

5-7 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, "Safety and Health Considerations". Provide combination emergency shower and eyewash stations in the workspace. Design in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.

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CHAPTER 6 ABRASIVE BLASTING FACILITIES

6-1 FUNCTION.

Workers prepare the surface of aircraft, shipboard, mechanical, utility, and other equipment in abrasive blasting facilities for surface coating, welding, and other operations.

This Chapter does not apply to temporary blasting enclosures.

Criteria for the design of Dry Media Blast (DMB) Aircraft Depaint Hangars are contained in UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*.

6-2 OPERATIONAL CONSIDERATIONS.

Silica sand is prohibited from use in fixed location enclosures. Avoid using agricultural media (e.g. peach pits, rice hulls, walnut shells). They are particularly susceptible to explosions.

6-3 DESIGN CRITERIA.

Apply the general technical requirements of Chapter 2 and the specific requirements of this Chapter to ensure the proper function, operation and maintenance of an abrasive blasting facility. Use this information when assembling a specification package for an enclosure manufacturer or inspecting an enclosure already in place.

6-3.1 Exhaust Air.

Determine the type of dust hazard and the minimum average air velocity through the blasting enclosure in accordance with 29 CFR 1910.94(a), *Abrasive Blasting*; ANSI/AIHA/ASSE Z9.4, *Abrasive-Blasting Operations— Ventilation and Safe Practices for Fixed Location Enclosures*, sections 4, 5, 6 and A7; NFPA 68, *Standard on Explosion Protection by Deflagration Venting*; NFPA 69, *Standard on Explosion Prevention Systems*; NFPA 70; NFPA 91; NFPA 654; NFPA 484 *Standard for Combustible Metals* when blasting on materials containing aluminum, magnesium, titanium, zirconium and lithium, respectively.

6-3.2 Blasting Cabinets.

Install baffles around air inlets to prevent abrasive material from escaping from the cabinet. Use a minimum inward air velocity of 500 fpm (2.54 m/s) at all operating openings. Discharge the exhaust air outside the building.

6-3.3 Walk-in Blasting Enclosures.

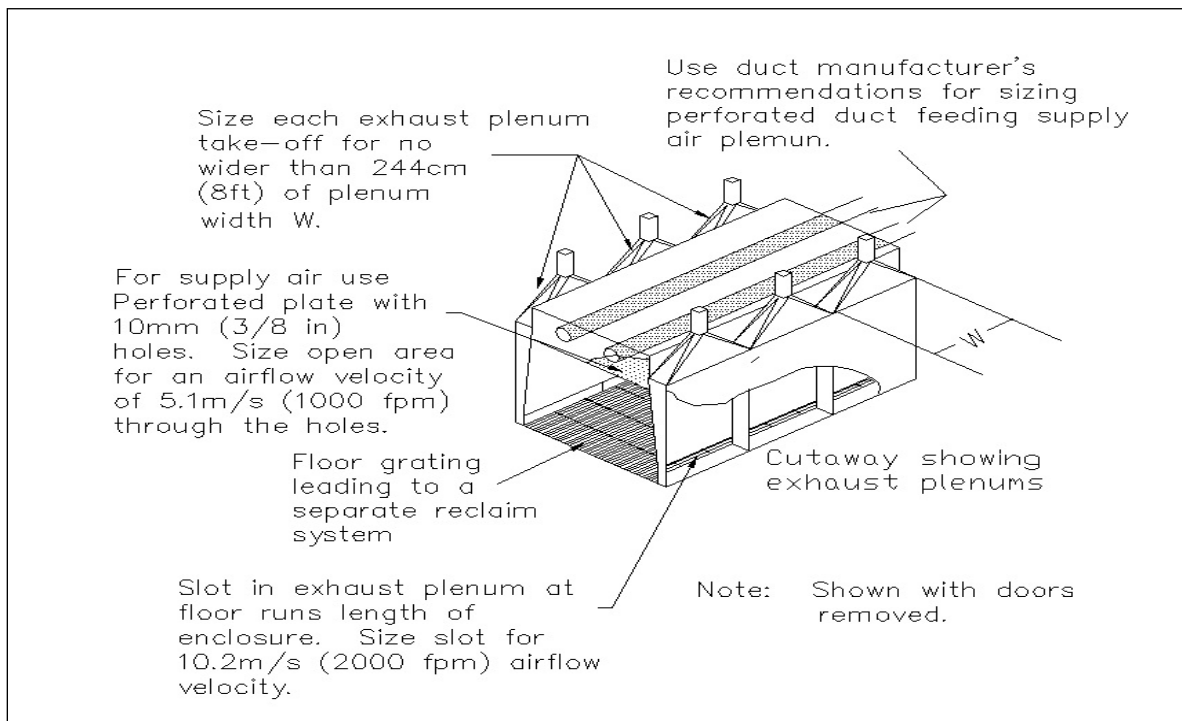
Design the enclosure so that the air flows from either the ceiling to the floor (downdraft), Figure 6-1, or from one wall to the opposite wall (crossdraft), Figure 6-2, and the following:

- a. Consider the geometry of the room and how work pieces are positioned within the room, and the number of workers and their locations when selecting a downdraft or a crossdraft design.
- b. Minimize the area of a blasting room to reduce the volumetric airflow rate. Allow at least 4 ft (1.22 m) of clearance between the work piece and the ceiling, walls, and doors of the room. Add extra clearance to accommodate internal fixtures such as tables and hoists.
- c. Isolate the abrasive blasting rooms from other processes, functions and activities, whenever possible. Place blasting rooms outside, away from administration and other spaces. Protect the blasting room and related equipment from rainwater and moisture intrusion. As a minimum, put a roof or cover over the blasting room.

6-3.3.1 Downdraft.

The downdraft design provides superior visibility. In addition, a downdraft design is preferred since contaminated air is usually drawn away from the worker's breathing zone. When more than one operator works in an enclosure, contaminated air generated from one operation is less likely to migrate into the other operator's breathing zone. Use a perforated plate with 3/8-in (9.53 mm) diameter holes, as shown in Figure 6-1, to uniformly distribute the airflow over the entire cross-section of the enclosure. Use a perforated duct inside the plenum to help evenly pressurize the plenum.

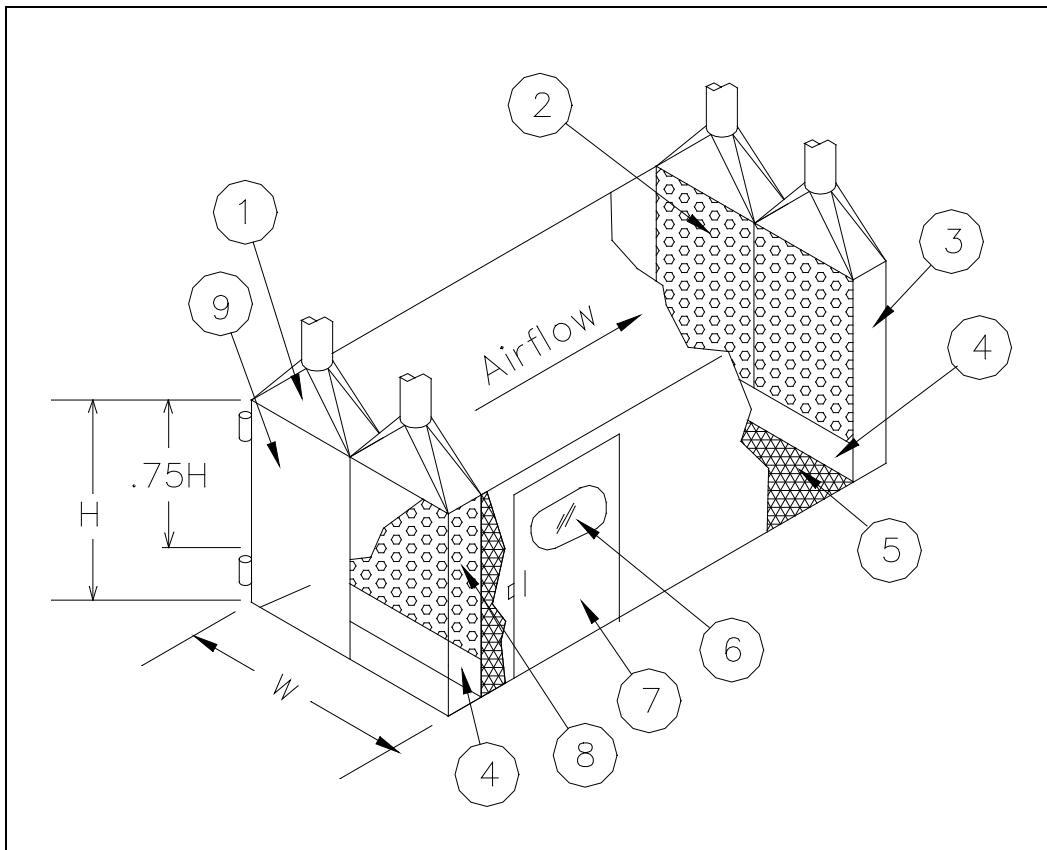
Figure 6-1. Downdraft Blast Enclosure.



6-3.3.2 Crossdraft.

Consider the work locations of operators when positioning the replacement and exhaust air plenums. Do not allow any operator to blast upstream of coworkers. Use a perforated plate with 3/8-in (9.53 mm) diameter holes; see Figure 6-2, to uniformly distribute airflow over the entire cross-section of the enclosure.

Figure 6-2. Crossdraft Blast Enclosure.



NOTES:

1. For mechanically supplied replacement air, use maximum plenum take-off width of 8 ft (2.44 m). Plenum serves as material door.
2. Perforated plate with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 2000 fpm (10.16 m/s) through holes.
3. Size the exhaust plenum for a maximum plenum velocity of 1000 fpm (5.08 m/s). Size any supply plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
4. Lift up flap to remove material from behind plenum.
5. Floor grating.
6. Observation window.
7. Personnel door.
8. Perforated plate, from floor to ceiling and wall-to-wall, with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 1000 fpm (5.080 m/s) through holes.
9. Hinged plenum equipment doors.

6-3.4 Access Doors and Observation Windows.

Provide an observation window and an access door in accordance with 29 CFR 1910.94(a)(3)(i)(d) and (e) and ANSI/AIHA/ASSE Z9.4 sections 5.3 and 5.4. Position the observation window in the blast room walls and door as necessary so workers inside the room can be seen from outside the room at all times. Use several doors and windows in large rooms. Provide emergency exits on opposing walls. Make personnel and equipment doors operable from both inside and outside of the room.

6-3.5 Air Cleaning Devices.

See the paragraph in Chapter 2 entitled, "Air Pollution Control Equipment". Design in accordance with 29 CFR 1910.94(a)(4)(iii) and ANSI/AIHA/ASSE Z9.4, section 6.3. Consider using a pulse-jet, pleated paper cartridge type dust collector and the following.

- a. Replaceable explosion vents on the collector hoppers in accordance with NFPA 68.
- b. Platforms leading to all elevated access hatches.
- c. Fan located on the clean side of the collector.
- d. Place dust collectors outside of the building for all blasting applications. NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, specifically requires that the air pollution equipment be located outside when blasting on aluminum or aluminum alloys.

6-3.6 Recirculation.

Do not recirculate exhaust air when operations generate toxic materials. If exhaust air recirculation is permitted, design the system in accordance with the ACGIH IV Design Manual (Section 10.8), ANSI/AIHA/ASSE Z9.4 (section 6.3) and ANSI AIHA/ASSE Z9.7, 29 CFR 1910.1025 (lead), and 29 CFR 1910.1027 (cadmium). The outdoor air volumetric airflow rate must be sufficient to keep the contaminant below 25 percent of the MEC.

6-3.7 Media Reclamation.

Design in accordance with 29 CFR 1910.94(a)(4)(ii) and ANSI/AIHA/ASSE Z9.4, section 6.2. Do not integrate the exhaust ventilation system with the media recovery system.

- a. Protect the media recovery system and ductwork from moisture and rainwater intrusion to keep the media from caking and plugging up the system.
- b. Use mechanical recovery systems such as rotary screw conveyors for heavy media (steel shot).

- c. Consider using pneumatic recovery system instead of mechanical recovery system for plastic media.

6-3.8 Ductwork.

See the paragraph in Chapter 2 entitled, “Ductwork”. Do not use spiral lock seam duct. Size the exhaust ductwork to maintain a minimum transport velocity of 3,500 fpm (17.8 m/s). Specify flat backed elbows per the ACGIH IV Design Manual, Chapter 5, Figure 5-16.

6-3.9 Fans.

See the paragraph in Chapter 2 entitled, “Fans”. Use centrifugal fans with backward curved blades, whenever possible. Centrifugal fans with radial blades are less efficient, but still acceptable. Place the exhaust fan and the outlet ductwork outside of the building.

6-3.10 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks” for design guidance.

6-3.11 Replacement Air Ventilation Systems.

See the paragraph in Chapter 2 entitled, “Replacement Air”. Design dedicated mechanically supplied replacement air systems to maintain room static pressures (relative to the atmosphere) ranging from -0.02 to -0.06 in wg (-4.98 to -14.9 Pa).

Blast booths often do not have mechanical replacement air. In this case, there is no control over the room static pressure for non-mechanical replacement air systems. The extra negative pressure reduces exhaust fan performance. If mechanically supplied replacement air is not feasible, ensure that the room static pressure and the resistance through filters and louvers are included when sizing the exhaust fan.

6-3.12 Heating and Air Conditioning.

For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems*.

6-3.13 System Controls.

Design system controls in accordance with the paragraph in Chapter 2 entitled, “Controls” and the following.

- a. Install static pressure sensors at locations that represent the average static pressure in each blasting room. This will enhance monitoring and maintenance of desired blasting room pressures.
- b. Interlock the blasting tool power supply with the ventilation system's on-off switch. This will prevent the use of blasting tools without ventilation controls.

6-4 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, "Safety and Health Considerations", 29 CFR 1910.94(a)(5), and ANSI/AIHA/ASSE Z9.4, section 7, for general requirements. Consider the following.

6-4.1 Respiratory Protection.

Follow the guidelines in 29 CFR 1910.94(a)(5) for respiratory protection requirements. The operator must wear a continuous-flow, air-line respirator that covers the head, neck, and shoulders. Consider providing each respirator hood with an adjustable, vortex-type climate control system.

6-4.2 Air Supply and Air Compressors.

For large booths, consider providing multiple air hose connection points along the perimeter of the enclosure to accommodate work in various parts of the booth.

6-4.3 Noise.

See the paragraph in Chapter 2 entitled, "Noise". Carefully select the blast nozzle. Nozzle noise generation depends greatly on the discharge velocity. Consider using sound barriers or dampening materials on enclosure walls. Protect the dampening material from abrasive blast as much as possible. Isolate the air compressor, media recirculation, and air pollution equipment to minimize noise exposure.

6-4.4 Hygiene Facilities.

Provide clean change rooms, shower facilities, and lunchroom facilities in accordance with OSHA regulations.

CHAPTER 7 WOOD SHOP FACILITIES

7-1 FUNCTION.

Wood shops differ in size and function. Use the design criteria in this chapter as a general guideline for developing ventilation systems for wood shops.

7-2 OPERATIONAL CONSIDERATIONS.

A properly designed ventilation system will control the dust level within the shop. Exposure to wood dust may lead to health problems. The accumulation of wood dust can create explosion and fire hazards. Even if a ventilation system is installed to collect most of the dust, manual cleaning at each machine and throughout the shop is still necessary. Restrict woodworking exhaust systems to handling only wood dust. Do not connect any other process that which could generate sparks, flames, or hot material to a woodworking exhaust system.

7-3 FLOOR PLAN LAYOUT.

Contact the shop personnel who will be working with the machinery to get their input on workflow and specific equipment. Design the ventilation system to complement equipment layout and minimize housekeeping.

7-4 DESIGN CRITERIA.

Design the facility using general technical requirements in Chapter 2 of this UFC, NFPA 664, *Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities* and the specific requirements in this chapter.

7-4.1 Dust Collection System.

Calculate the system capacity on the basis that the system operates with all hoods and other openings, such as floor sweeps, open. Refer to the ACGIH IV Design Manual, Chapter 13, (Section 13.95), for determining the exhaust flow rate for specific wood shop machines.

7-4.1.1 System Layout.

Lay out the system to meet the shop requirements. Consider locating machines with the greatest hood resistance as close as possible to the fan. In most cases, ductwork is located along the ceiling and walls; however, running ductwork under removable grates or panels in the floor may reduce duct lengths and leave more working space around machinery. Refer to NFPA 650, *Pneumatic Conveying Systems for Handling Combustible Particulate Solids* and NFPA 664 for information on wall penetrations and clearances.

7-4.1.2 Plenum Exhaust System.

An alternative to the tapered system is a plenum system, described in the ACGIH IV Design Manual, Chapter 5. A plenum system allows equipment to be moved in the

shop and may be more efficient. Ducts can be added or removed, as equipment needs change. See the ACGIH IV Manual Chapter 5 (Section 5.5) for further considerations.

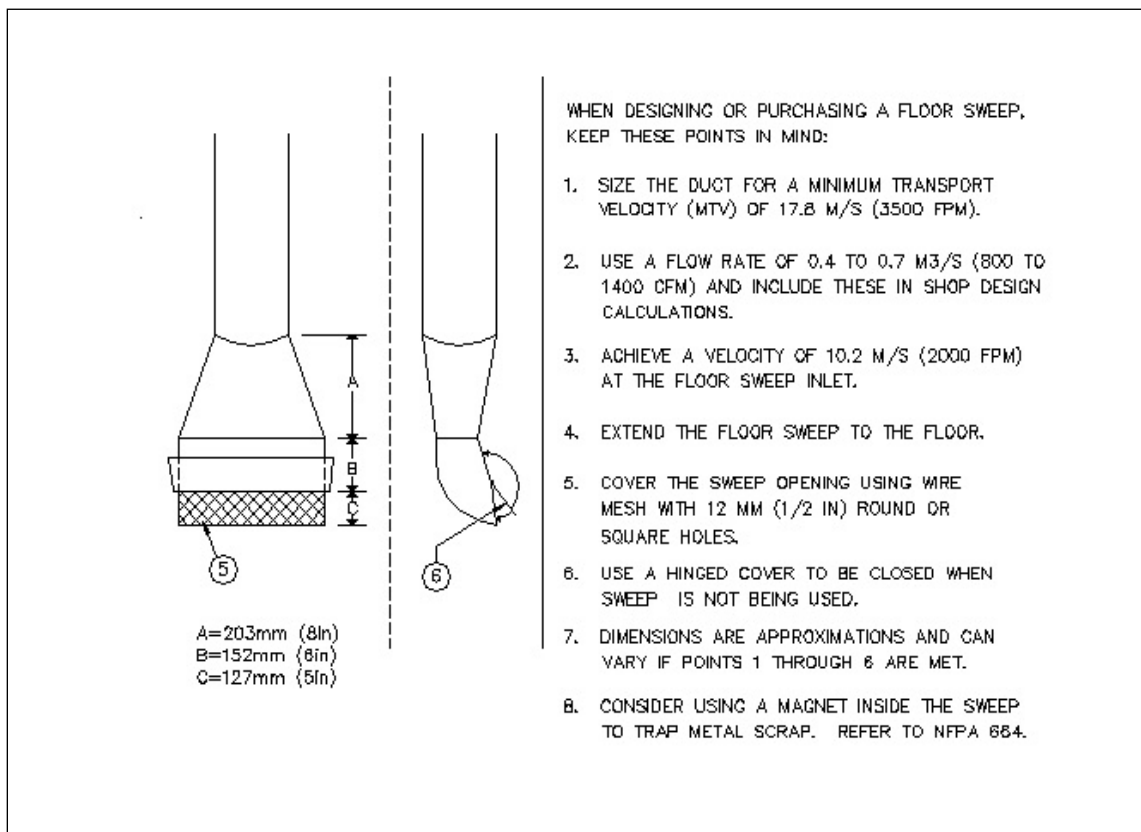
7-4.2 Hood Design.

Provide a hood for each operation that produces dust. This includes sawing, shaping, planing, and sanding operations. Design and position all hoods so the wood dust will fall, be projected, or be drawn into the hood in the direction of the airflow. Construct hoods of noncombustible materials. Ensure the hoods do not interfere with worker operations. In some cases, the exhaust hood may be utilized as a safety guard. Refer to the ACGIH IV Design Manual, Chapter 13 (Section 13.95) for woodworking hood designs. Modify the drawings as necessary to meet the specific equipment and process requirements.

7-4.3 Floor Sweeps.

If the design includes floor sweeps, include a means, such as magnetic separators, to prevent scrap metal from entering the system. Figure 7-1 shows a basic floor sweep design. The floor sweep is only opened during shop clean up. If the system design calculations indicate that, when opened, the floor sweep provides a transport velocity of less than 3,500 fpm (17.78 m/s), design the system to include floor sweeps in the normally opened position without a hinged cover.

Figure 7-1. Floor Sweep



7-4.4 Ductwork.

See the paragraph in Chapter 2 entitled, “Ductwork” for general ductwork design. See NFPA 664 for specific requirements on wood shop ductwork construction. Size the ductwork to maintain a minimum transport velocity as specified in the ACGIH IV Design Manual, Chapter 13.95, Woodworking. Use only metal ductwork and conductive flexible hose. Bond and ground all ductwork in accordance with NFPA 664. The ductwork must be designed on the basis that all hoods and other openings connected to the system are open.

7-4.5 Blast Gates.

Provide blast gates only for the specific purpose of balancing the airflow. Do not use blast gates to isolate equipment from the exhaust system with the intent to reduce the overall airflow requirement. When possible, install blast gates on horizontal runs and orient the gate so the blade is on the top half of the duct and opens by pulling the blade towards the ceiling. When possible, blast gates must be installed at a location not easily accessible to shop personnel. After final balancing and acceptance, secure the blade and mark its position so that it can be returned to the balanced position if inadvertently moved. When the blast gate cannot be placed out of the reach of shop personnel, then lock the blade in position. For example, drill a hole through the body and blade of the gate and then insert a bolt and tack weld it.

7-4.6 Duct Support.

If sprinkler protection is provided in the duct, horizontal ductwork must be capable of supporting the weight of the system, plus the weight of the duct half-filled with water or material being conveyed, whichever has the higher density.

7-4.7 Clean Out Panels.

See the paragraph in Chapter 2 entitled, “Ductwork”.

7-4.8 Exhaust Fans.

See the paragraph in Chapter 2 entitled “Fans”.

7-4.9 Weather Stack Design and Location.

See the paragraph in Chapter 2 entitled, “Exhaust Stacks”.

7-4.10 Air Cleaning Devices.

See the paragraph in Chapter 2 entitled, “Air Pollution Control Equipment”. Locate the air-cleaning device outside the building.

7-4.11 Building Heating and Air Conditioning.

For HVAC-related issues use UFC 3-410-01, *Heating, Ventilation, and Air Conditioning Systems*.

7-5 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, “Safety and Health Considerations” and the following items.

- a. Refer to section 7.2.2 of ANSI O1.1, *Woodworking Machinery, Safety Requirements* for personal protective equipment.
- b. Provide a means for separately collecting and disposing of any metal scrap such as nails, band iron, or any wood containing metal. Do not use the woodshop ventilation system to pick up these materials.
- c. Avoid the use of wood painted with paints containing lead, hexavalent chromium, cadmium, or coated with wood preservatives. Otherwise, consult an industrial hygienist (IH) to determine the exposure level and the level of respiratory protection needed.
- d. Use sharp and clean blades at the correct feed rate to generate less heat. The generated heat can raise the wood or wood-containing product to ignition temperature that could start a fire.

CHAPTER 8 BATTERY MAINTENANCE FACILITIES

8-1 FUNCTION.

Battery maintenance facilities contain space and equipment for receiving, cleaning, testing, charging, and issuing batteries. Sizes range from a small booth to a room with storage area. In these facilities, batteries are not in operation while being charged. Two types of electrochemical battery in general use are lead-acid and nickel-cadmium (NICAD). This chapter does not address battery-post repair operation. For stationary battery installations where batteries are operated on a continuous float charge and no battery maintenance is involved, use UFC 3-520-05 *Stationary Battery Areas*.

8-2 OPERATIONAL CONSIDERATIONS.

Batteries generate a small amount of hydrogen and other gases while they are being charged or discharged. Hydrogen build-up could lead to an explosion. Provide ventilation to keep the hydrogen concentration below 25 percent of the LEL (LEL = 4 percent) to prevent an accumulation of an explosive mixture.

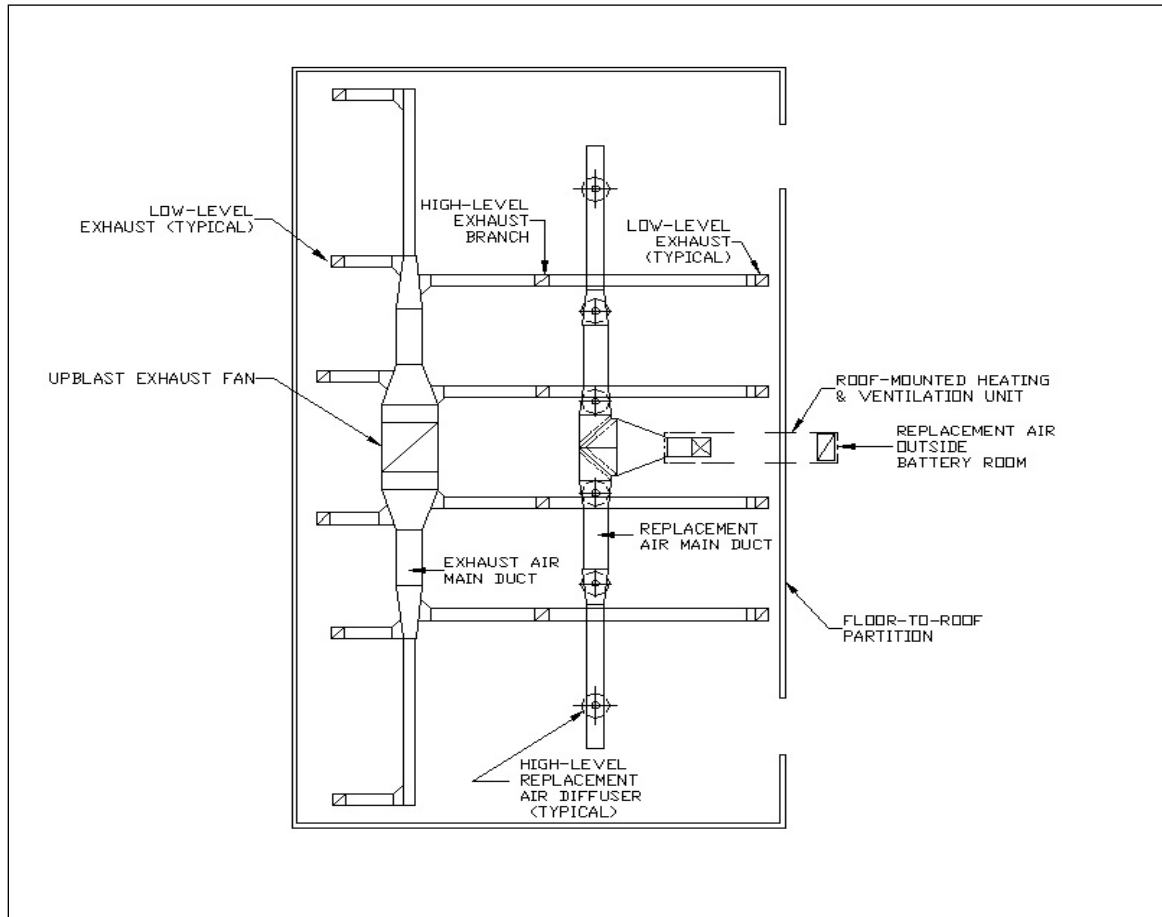
8-3 DESIGN CRITERIA.

Design the ventilation system using general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

8-3.1 Exhaust System.

Design exhaust ventilation to have both high-level exhaust for hydrogen and low-level exhaust for electrolyte spills (acid mist and odors). Distribute one-third of the total exhaust flow rate to the high-level exhaust to ventilate all roof pockets. Locate low-level exhaust at a maximum of 1-ft (304.8-mm) above the floor. Do not re-circulate exhaust air back to the maintenance facility. Exhaust all air directly to the outdoors through a dedicated exhaust duct system. See Figure 8-1 for a floor plan of a battery maintenance room.

Figure 8-1. Ventilation System for Battery Maintenance Facilities.



8-3.1.1 Minimum Flow Rate Calculation.

To determine the amount of required volumetric airflow rate, the amount of hydrogen produced must be calculated for the total number of battery cells in the room. Hydrogen generation, heat generation and proximity factor into the ventilation calculation. The volume of hydrogen generated is governed by the amount of charging current (ampere) supplied to the fully charged battery by the charger. Significant amounts of hydrogen are evolved only as the battery approaches full charge. Refer to IEEE Standard 1635 / ASHRAE Guideline 21, "Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications", Section on HVAC System Design for Ventilation.

8-3.2 Ductwork.

Design ductwork in accordance with the paragraph in Chapter 2 entitled, "Ductwork". Use FRP or PVC ductwork.

8-3.3 Fans and Motors.

Select fans in accordance with the paragraph in Chapter 2 entitled, "Fans". Use AMCA 201, Type B spark resistant construction and explosion proof motors. Fans must have non-sparking wheel. Locate the motor outside of the air stream.

8-3.4 Weather Stack Design and Location.

Avoid re-entry of exhaust air by discharging the exhaust high above the roof line or by assuring that no window, outdoor intakes, or other such openings are located near the exhaust discharge. See the paragraph in Chapter 2 entitled, "Exhaust Stacks" for additional considerations.

8-3.5 Air Cleaning Device.

Due to the quantities and types of contaminants generated by this process, there is no requirement for air pollution control equipment.

8-3.6 Replacement Air.

Design a replacement air system in accordance with the paragraph in Chapter 2 entitled, "Replacement Air". Design the replacement (makeup) air volumetric flow rate equal to 95 percent of the exhaust airflow rate to maintain the space under a negative pressure and prevent the migration of fumes and gases into adjacent areas. Provide means for air flow to ensure a negative pressure relationship. duct system. Makeup air can be transferred from a Class 1 or Class 2 area in the facility as defined in ANSI/ASHRAE 62.1, Ventilation for Acceptable Indoor Quality, or supplied directly. If supplied directly, it must be filtered.

8-3.7 System Controls.

Design system control in accordance with the paragraph in Chapter 2 entitled, "Controls" and the following criteria:

- a. Interlock the charging circuit and the exhaust fan in the shop to ensure chargers will not operate without ventilation.
- b. Provide indicator light showing that the exhaust system is functioning properly.

8-4 SAFETY AND HEALTH CONSIDERATIONS.

In accordance with 29 CFR 1926.403, *Battery Rooms and Battery Charging*, provide the following.

- a. Face shields, aprons, and rubber gloves for workmen handling acids or batteries.

- b. Combination emergency shower and eyewash stations within 25 ft (7.6 m) of the work area. Design in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.
- c. Facilities for flushing and neutralizing spilled electrolyte, and for fire protection.
- d. Non-slip rubber insulating matting in front of all charging benches to protect personnel from electric shock and slipping hazards
- e. Warning signs, such as: “Hydrogen, Flammable Gas, No Smoking, No Open Flames.”

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CHAPTER 9 PAINT SPRAY BOOTHS

9-1 FUNCTION.

Paint spray booths provide surface finishing capabilities for a wide range of parts, equipment, and vehicles. Paint spray booth sizes range from bench type units for painting small parts, to large walk-in booths or rooms for painting vehicles, tractors or large equipment.

9-2 OPERATIONAL CONSIDERATIONS.

During paint spray operations, paint is atomized by a spray gun and then deposited on the object being painted. Depending on the application equipment and spray method used, transfer efficiencies vary greatly. Transfer efficiency is the amount of paint solids deposited on a surface divided by the total amount of paint sprayed, expressed as a percentage.

- a. Use equipment with a high transfer efficiency, such as electrostatic or high volume low pressure (HVLP) spray guns, to reduce overspray. Overspray is the paint that is sprayed but not deposited on the surface being painted. This equipment not only saves in paint cost, but also reduces volatile organic compound (VOC) emissions and maintenance requirements.
- b. Warm the paint before applying, whenever possible. This lowers the paint viscosity enabling spray painting at a lower pressure, thereby minimizing the amount of overspray generated. The lower viscosity also decreases the quantity of solvent used to thin the paint prior to spraying. This results in reduced solvent consumption and VOC emissions.

9-2.1 Painting Equipment Types.

Spray-painting equipment must conform to national, state, and local emission control requirements. One of these requirements is transfer efficiency. Five primary types of paint spraying equipment and their typical transfer efficiencies include:

1. Conventional air spray (25 percent transfer efficiency).
2. Airless spray (35 percent transfer efficiency).
3. Air-assisted airless spray (45 percent transfer efficiency).
4. Electrostatic spray (65 percent transfer efficiency).
5. High volume/low pressure (HVLP) spray (up to 75 percent transfer efficiency).

9-3 DESIGN CRITERIA.

Design or procure paint spray booths in accordance with the general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter. Design paint spray booths in accordance with the requirements of NFPA 33, *Standards for Spray Application Using Flammable or Combustible Materials*.

9-3.1 Walk-in Spray Paint Booths.

The ventilation system for a walk-in booth is mainly to prevent fire and explosion. A well-designed ventilation system will also reduce paint overspray, help control workers' exposure, and protect the paint finish. Workers must use appropriate respiratory protection irrespective of the airflow rate.

- a. Ensure the ventilation system for a walk-in booth meets the requirements of 29 CFR 1910.94 and 29 CFR 1910.107 and the appropriate guidelines in the painting operations section ACGIH IV manual.
- b. Do not re-circulate exhaust air while painting.

9-3.1.1 Exhaust Configurations.

The two main ventilation system configurations are downdraft and crossdraft. In a downdraft booth, air enters through filters in the ceiling of the booth and leaves through filters that cover trenches under a metal grate floor. In a crossdraft booth, air enters through filters in the front of the booth and leaves through filters in the back of the booth. Both configurations are commercially available.

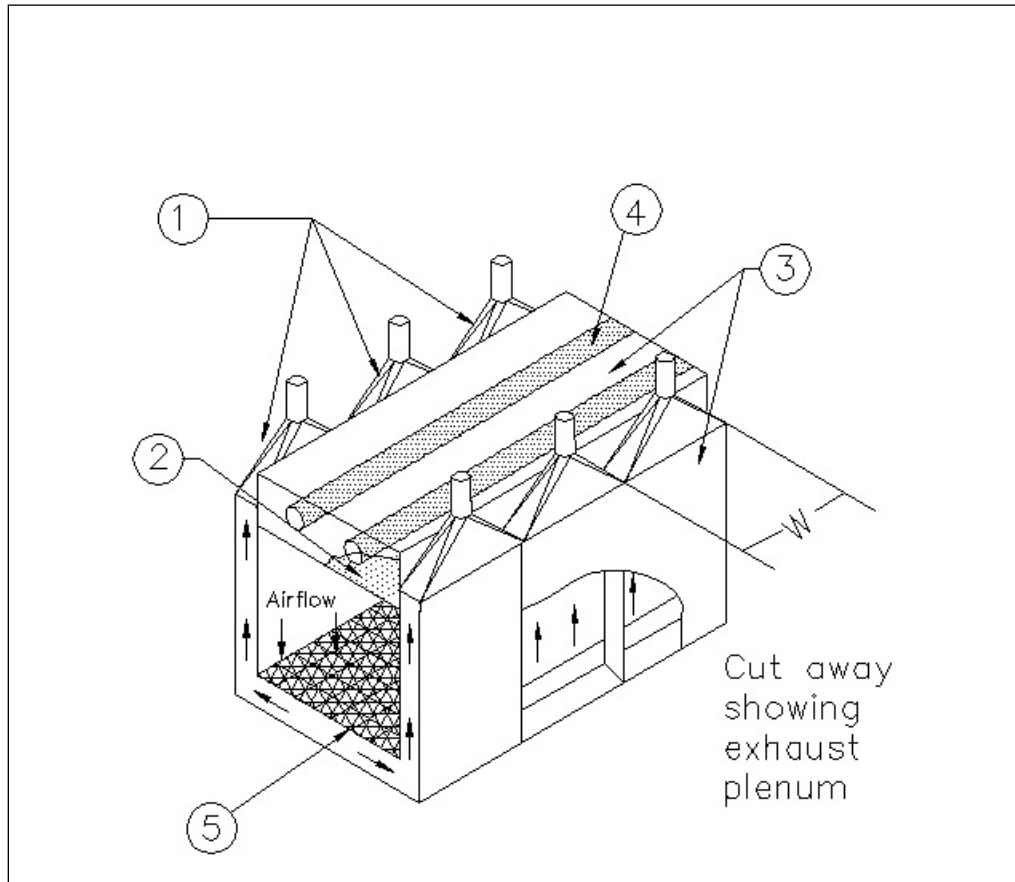
9-3.1.1.1 Downdraft Paint Spray Booths.

Downdraft booth configuration provides a cleaner paint job than the crossdraft booth configuration and controls exposures to workers better than crossdraft booth configuration. Figure 9-1 is an example of a downdraft configuration.

9-3.1.1.2 Crossdraft Paint Spray Booths.

The crossdraft paint spray booth usually requires less total volumetric airflow rate than the downdraft spray paint booth because the vertical cross-sectional area of the booth is often smaller than the booth footprint area. Figures 9-2 and 9-3 are examples of drive-through crossdraft paint spray booth configurations.

Figure 9-1. Walk-In Downdraft Paint Booth.

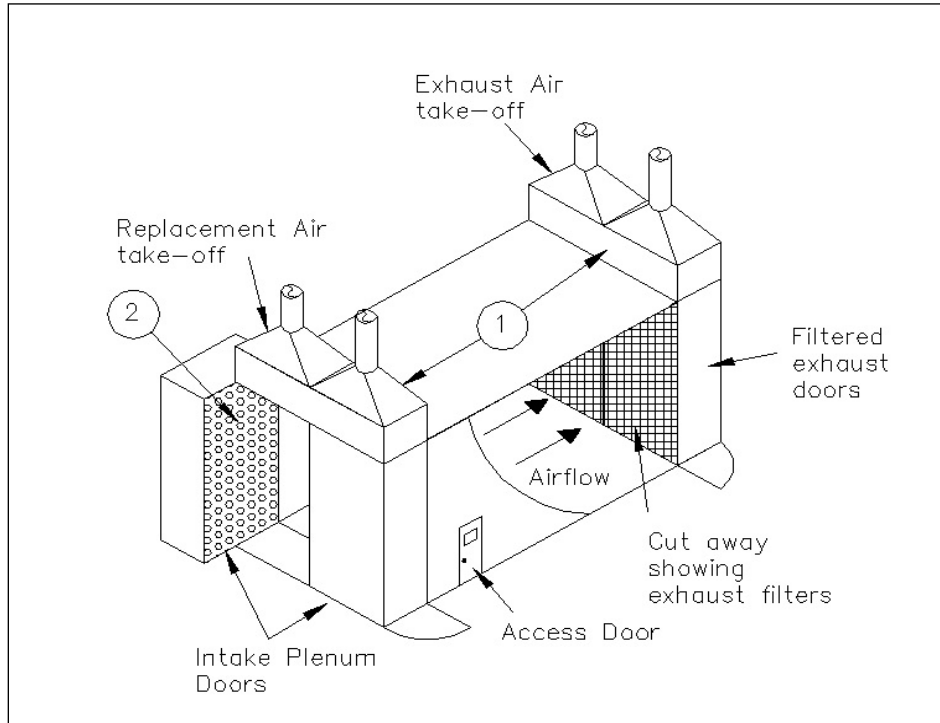


Drawing shown with doors removed

NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width (W).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 1,000 fpm (5.08 m/s) through holes.
3. Size exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
4. Use manufacturer's recommendations for sizing perforated ductwork.
5. Removable filters and floor grating.

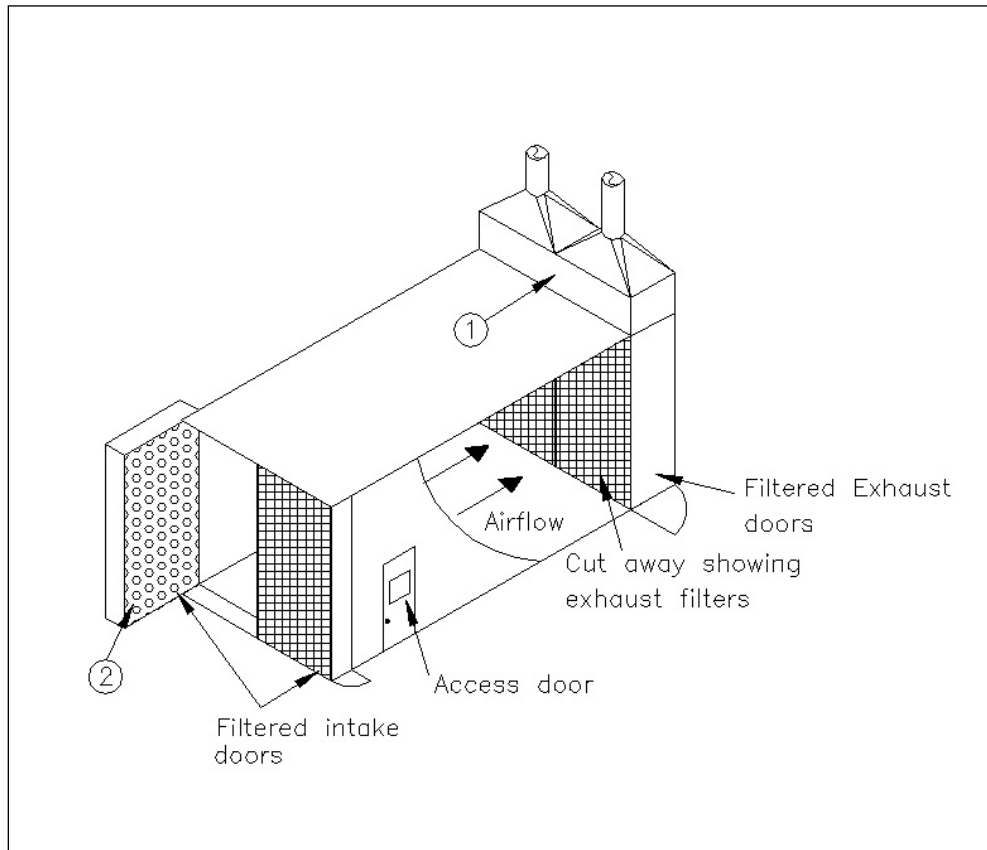
Figure 9-2. Drive-Through Cross Draft Paint Booth with Mechanical Replacement Air.



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

Figure 9-3 Drive-Through Crossdraft Paint Booth With No Mechanical Replacement Air



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s). Size replacement air plenum for a maximum plenum velocity of 500 fpm (2.54 m/s).
2. Perforated plate with 3/8-in (9.53-mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

9-3.1.2 Paint Spray Booth Exhaust Filtration System.

There are two types of exhaust air filtration systems. The first type is a water wash system. A water curtain is created at the exhaust plenum by a pump providing continuous circulation of water. The second type is a dry filter system, where the exhaust air passes through filter media. Consider the following.

- a. Do not design or purchase the water wash paint spray booths. The water wash system requires more energy to operate than the dry filter system. The wastewater must be treated and the hazardous constituents removed (often at great cost to the generating facility) before it may be discharged to a municipal treatment plant.

- b. Neither water wash nor dry filter filtration systems can reduce the concentration of volatile organic compounds in the exhaust air stream. Consult the environmental department for controlling volatile organic compounds.

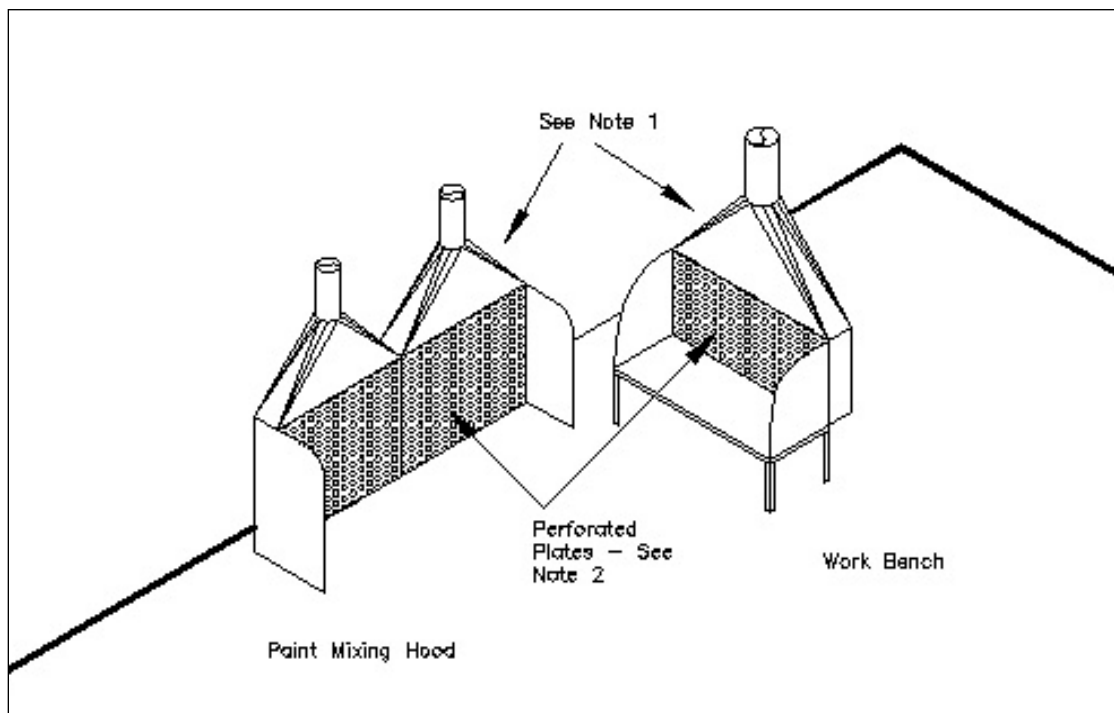
9-3.2 Storage and Mixing Room.

Refer to the ACGIH IV Manual, Paint Mix Storage Room, VS-75-30 for the design of ventilation system.

9-3.3 Small Spray Booths and Paint Mix Hoods.

Refer to the ACGIH IV Design Manual for the design of ventilation system. Figure 9-4 is an example of a workbench and a floor hood designed for paint mixing and small spray applications. ACGIH P.13-120 figure VS-75-02 states that $Q=125\text{cfm}/\text{ft}^2$ for face area up to 4ft^2 and $Q=100\text{cfm}/\text{ft}^2$ for face area over 4ft^2 .

Figure 9-4 Paint Mixing Hood and Work Bench



NOTES:

1. Size each plenum take-off for no more than 8 ft (2.44 m) of plenum width. Size each plenum for a maximum plenum velocity of 1,000 fpm (5.08 m/s).
2. Perforated plate with 3/8-in (9.53 mm) holes. Size open area for an airflow velocity of 2,000 fpm (10.16 m/s) through holes.

9-4 FANS AND MOTORS.

Use explosion proof motor and electrical fixtures for exhaust fan. Do not place electric motors, which drive exhaust fans, inside booths or ducts. See Section 2-4.2 entitled, "Fans" for more detailed information about fan selection.

9-5 REPLACEMENT AIR.

There is no control over the room temperature or room static pressure for non-mechanical replacement air systems. Dust from outside often enters the paint spray booths through cracks and damages the paint finish. If painting operations require neutral air pressure inside the booth, provide a mechanical replacement air system to maintain a neutral air pressure inside the booth and prevent dust from entering the paint spray area. The neutral air pressure will also prevent paint overspray and vapors from escaping the booth and migrating into adjacent work areas.

9-5.1 Air Distribution.

Distribution of replacement air within the spray booth is as significant as the average air velocity through the booth. Distribute the replacement air evenly over the entire cross section of the booth to prevent turbulence or undesirable air circulation. The preferred means of distributing the replacement air is through perforated plate as shown in Figures 9-1, 9-2, and 9-3. See the paragraph in Chapter 2 entitled, "Replacement Air" for additional replacement air design criteria.

9-5.2 Heating and Air Conditioning.

See the paragraph in Chapter 2 entitled, "Replacement Air". Most new paint spray booth ventilation systems have a painting mode and a curing mode. Do not re-circulate air during the painting mode. About 10 percent of the booth airflow is from outside the booth and 90 percent of the exhaust air is recycled during curing. Review the paint drying requirements before specifying temperature and humidity ranges. Refer to ANSI AIHA/ASSE Z9.7 for exhaust air re-circulation requirements.

9-6 SYSTEM CONTROLS.

Design system controls in accordance with the paragraph in Chapter 2 entitled, "Controls".

9-7 SAFETY AND HEALTH CONSIDERATIONS.

See the paragraph in Chapter 2 entitled, "Safety and Health Considerations". Provide combination emergency shower and eyewash stations in the workspace. Design in accordance with UFC 3-420-01, *Plumbing Systems*, Appendix D.

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APPENDIX A REFERENCES

DEPARTMENT OF THE AIR FORCE

AFOOSH STD 91-501, *Air Force Consolidated Occupational Safety Standard*,
http://static.e-publishing.af.mil/production/1/usafe/publication/afoshstd91-501_usafesup_i/afoshstd91-501_usafesup_i.pdf

AIR MOVEMENT AND CONTROL ASSOCIATION, INC.

<http://www.amca.org/>

AMCA 201, *Fans and Systems*

AMCA 99-2408, *Standards Handbook: Operating Limits for Centrifugal Fans*
(Performance Classes)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS, INC

<http://www.acgih.org/>

ACGIH IV *Design Manual, Industrial Ventilation; A Manual of Recommended Practice, For Design*

ACGIH IV *Manual, Industrial Ventilation; A Manual of Recommended Practice, For Operation and Maintenance*

AMERICAN NATIONAL STANDARDS INSTITUTE, INC.

<http://www.ansi.org/>

ANSI O1.1, *Woodworking Machinery, Safety Requirements*

ANSI/AIHA/ASSE Z9.4, *Abrasive-Blasting Operations– Ventilation and Safe Practices for Fixed Location Enclosures*

ANSI AIHA/ASSE Z9.7, *Recirculation of Air from Industrial Process Exhaust Systems*

AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR CONDITIONING ENGINEERS, INC.

<http://www.ashrae.org/>

ASHRAE *Handbook, Fundamentals*

ASHRAE *Handbook, HVAC Systems and Equipment*

ASHRAE Standard 52.2, *Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*

ASHRAE Guideline 1, *HVAC &R Technical Requirements for the Commissioning Process*

DEPARTMENT OF THE ARMY

Army EM 385-1-1, *Safety and Health Requirements*,
<http://140.194.76.129/publications/eng-manuals/>

DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA PROGRAM

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UFC 1-200-01, *General Building Requirements*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-101-01, *Architecture*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-420-01, *Plumbing Systems*

UFC 3-450-01, *Noise and Vibration Control*

UFC 3-520-05, *Stationary Battery Areas*

UFC 3-600-01, *Fire Protection Engineering For Facilities*

UFC 4-211-02, *Aircraft Corrosion Control and Paint Facilities*

UFC 4-216-02, *Design: Maintenance Facilities for Ammunition, Explosives, and Toxins (Inactive)*

U.S. ENVIRONMENTAL PROTECTION AGENCY

<http://www.epa.gov>

EPA-560-OPTS-86-001, *A Guide to Respiratory Protection for the Asbestos Abatement Industry*

DEPARTMENT OF LABOR

29 CFR 1910.94(a), *Abrasive Blasting*

NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION

<http://www.nema.org>

NEMA MG-1, *Standard for Motors and Generators*

NATIONAL FIRE PROTECTION ASSOCIATION

<http://www.nfpa.org>

NFPA 33, *Standard Spray Application Using Flammable or Combustible Materials*

NFPA 34, *Standard for Dipping Coating and Printing Processes Using Flammable or Combustible Liquids*

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 69, *Standard on Explosion Prevention Systems*

NFPA 70, *National Electrical Code*

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*

NFPA 484, *Standard for Combustible Metals*

NFPA 650, *Pneumatic Conveying Systems for Handling Combustible Particulate Solids*

NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*

NFPA 664, *Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

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OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual*,
<http://doni.daps.dla.mil/OPNAV.aspx>

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<http://www.navsea.navy.mil/>

NAVSEA OP5, Volume 1, *Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping*

NAVSEA S6340-AA-MMA-010, *Otto Fuel II Safety, Storage, and Handling Instructions*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

<http://www.osha.gov/>

29 CFR 1910.107, *Spray Finishing Using Flammable and Combustible Materials*

29 CFR 1910.134, *Respiratory Protection*

29 CFR 1910.1000, *Air Contaminants*

29 CFR 1910.1001, *Asbestos, General Industry*

29 CFR 1910.1025, *Lead*

29 CFR 1910.1027, *Cadmium*

29 CFR 1915.1001, *Asbestos, Shipyards*

29 CFR 1926.403, *Battery Rooms and Battery Charging*

OSHA 3048, *Noise Control, A Guide for Workers and Employees*

SHEET METAL AND AIR CONDITIONING CONTRACTORS NATIONAL ASSOCIATION

<http://www.smacna.org/>

SMACNA GSSDC, *Guide for Steel Stack Design and Construction*

SMACNA RIDCS, *Round Industrial Duct Construction Standards*

SMACNA RTIDCS, *Rectangular Duct Construction Standards*

COMPRESSED GAS ASSOCIATION

<http://www.cganet.com/>

G-7.1, *Commodity Specification for Air*

APPENDIX B GLOSSARY

B-1 TERMS

Air cleaner	A device designed for the purpose of removing atmospheric airborne impurities such as dusts, gases, vapors, fumes, and smoke. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters.)
Air filter	An air cleaning device to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: loadings up to 3 grains per thousand ft³ (0.0069 g/m³). Note: Atmospheric air in heavy industrial areas and in-plant air in many collectors are then indicated for proper air cleaning.
Air, standard	Dry air at 70 degrees F, 21.11 degrees C, and 29.92 in. Hg barometer. This is substantially equivalent to 0.075 pounds per cubic feet (lb/ft³). Specific heat of dry air = 0.24 Btu/lb-F (1.004 kJ/(kg.K).
Aspect ratio (AR)	Ratio of the width to the length; AR = W/L.
Blast gate	Sliding damper.
Capture velocity	Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
Dust	Small solid particles created by the breaking up of larger particles by processes crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, and sweeping.
Dust collector	Air cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: loadings 0.003 grains per cubic foot and higher.
Fan class	This term applies to the fan's performance abilities. The required fan class is determined according to the operating point of the ventilation system. AMCA 99-2408 provides a set of five minimum performance limit

standards (Class I through V) which manufacturers use to apply the correct class to their fans.

FRP	Fiberglass reinforced plastic used in construction of such items as boats and airplanes. It is also used for ductwork in corrosive environments.
Fumes	Small, solid particles formed by the condensation of vapors of solid materials.
Gases	Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
Gravity, specific	Ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2 degrees F (4 degrees C) is the standard substance usually referred to for gases, dry air, at the same temperature and pressure as the gas is often taken as the standard substance.
Hood	A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.
Humidity, relative	Ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.
Lower explosive limit (LEL)	Lower limit of flammability or explosiveness of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 degrees F (121 degrees C). Above these temperatures, it must be decreased by a factor of 0.7 since explosiveness increases with higher temperatures.
Manometer	An instrument for measuring pressure; essentially a U-tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted in the instrument.
Micron	A unit of length; approximately 1/25,000 of an inch (the thousandth part of 1 millimeter or the millionth of a meter).
Mists	Small droplets of materials that are ordinarily liquid at normal temperature and pressure.

Plenum	A pressure equalizing chamber.
Pressure, static	Potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse the pipe.)
Pressure, total	The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).
Replacement air	Ventilation term used to indicate the volume of controlled outdoor air supplied to a building to replace air being exhausted. It may require heating, cooling, or humidity control.
Slot velocity	Linear flow rate of contaminated air through a slot. Usually measured in meters per second (m/s) [feet per minute (fpm)].
Smoke	An air suspension (aerosol) of particles, usually not solid, often originating in a solid nucleus, formed from combustion or sublimation.
Threshold limit values	Values, established by ACGIH, for airborne toxic materials (TLV) as guidelines in the control of health hazards and represent time-weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects.
Transport (conveying))	Minimum air velocity required to move the particulates in the air stream, measured in fpm (m/s).
Vapor	The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature.
Work piece	The item being created or repaired using equipment or machinery that, while operating, generates a fume, gas, vapor, or particulate hazardous to the health of the operator. Landing gear, torpedo parts, cabinetry, lagged piping are examples of work pieces. Parts washers, wood saws, and degrease units are example equipment.

B-2

ABBREVIATIONS AND ACRONYMS

A

ACGIH	American Conference Of Governmental Industrial Hygienists, Inc.
ACH	air changes per hour
AMCA	Air Movement and Control Association, Inc.
ANSI	American National Standards Institute, Inc.
AR	Aspect ratio
ASHRAE	American Society of Heating, Refrigeration And Air Conditioning Engineers, Inc.

C

C	Degrees Celsius
cfh	cubic feet per hour
cfm	cubic feet per minute
cfm/ft ²	cubic feet per minute per square foot
CFR	Code of Federal Regulations
cm	centimeter
cms	cubic meters per second
CO	carbon monoxide

D

D	depth
dbA	decibels on the A-weighted scale
DDC	direct digital controls

E

EM	Engineering Manual
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F

F	Degrees Fahrenheit
fpm	feet per minute
FRP	fiberglass reinforced plastic
Ft	feet

G

GSSDC	Guide for steel stack design and construction
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H

H	Height
HEPA	high efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
HVLP	High volume, low pressure

I

IH	industrial hygienist
IMC	International Mechanical Code
In	inch(es)
IV	Industrial ventilation

L

LEL	Lower Explosive Limit
LVHV	low volume, high velocity

M

m	meter
MEC	minimum explosive concentration
MERV	minimum efficiency reporting value
MILCON	Military Construction
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
mm	millimeter
m/s	meter per second
MSDS	Material Safety Data Sheet

N

NAVAIR	Naval Air System Command
NAVFAC	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NICAD	nickel-cadmium
NIOSH	National Institute of Occupational Safety and Health

O

O/I	organization and intermediate
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Safety and Health Administration

P

Pa	Pascal
PEL	permissible exposure limit
PPE	personal protective equipment
PVC	polyvinyl chloride

R

REO	Regional Engineering Office
RIDCS	Round industrial duct construction standard

S

SCBA	self-contained breathing apparatus
SMACNA	Sheet Metal And Air Conditioning Contractors National Association

T

TLV	Threshold Limit Value
TWA	time-weighted average

U

UFC	Unified Facilities Criteria
UPS	Uninterruptible Power Supply

V

VFD	variable frequency drive
VOC	Volatile Organic Compound

W

W	width
wg	water gage