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UNIFIED FACILITIES CRITERIA (UFC)

INDUSTRIAL VENTILATION

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UNIFIED FACILITIES CRITERIA (UFC)

INDUSTIAL VENTILATION

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

(NOTE: When a UFC supersedes another service publication, include a supersedure statement in accordance with the following example.)

This UFC supersedes Military Handbook 1003/17C, dated February 1996.

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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.

1-3 **SPECIFIC PROCESSES**. The specific processes addressed in this handbook are asbestos delagging, torpedo refurbishing (Otto Fuel II), fiberglass reinforced plastic fabrication and repair, abrasive blasting, woodworking, battery maintenance, paint spray booths, and aircraft corrosion control hangers.

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*. 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:

- Effected industrial shop.
- Public works.
- Health and safety office.
- Cognizant Regional Engineering Office (REO) (for example: Navy Engineering Field Division, Army Corps of Engineers Division, 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 and safety offices.

NOTE U.S. NAVY: BUMED or activity IH. Use Naval Environmental Health Center as a back-up.

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

2-3 **DESIGN PROCEDURE**. Refer to the ACGIH IV Manual, *Industrial Ventilation; A Manual of Recommended Practice*, Chapter 5, "Exhaust System Design Procedure," for system design calculations. Design all industrial ventilation systems in accordance with paragraphs 2-3.1 through 2-3.8.

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**. 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.

2-3.3 **Step 3**. 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.

2-3.4 **Step 4**. 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.

2-3.5 **Step 5**. Determine the exhaust volumetric flow, in cubic meters per second (m^3/s) [cubic feet per minute (cfm)], required to maintain the capture velocity determined in paragraph 2-3.4.

2-3.6 **Step 6**. 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.

2-3.7 **Step 7**. Size ductwork using the balance by design or the blast gate method. Maintain the required minimum transport velocity throughout the system.

2-3.8 **Step 8**. Determine requirements for replacement air. Based on the process, determine if the room should be under slightly negative, neutral or slightly positive 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 Manual for primary guidance. See paragraphs 2-4.1 through 2-4.5 for additional guidance. Chapters 3 through 10 provide design guidance for specific types of facilities.

2-4.1 **Ductwork**. In addition to the recommendations of the ACGIH IV Manual, 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.

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 paragraph 2-4.5 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. 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.

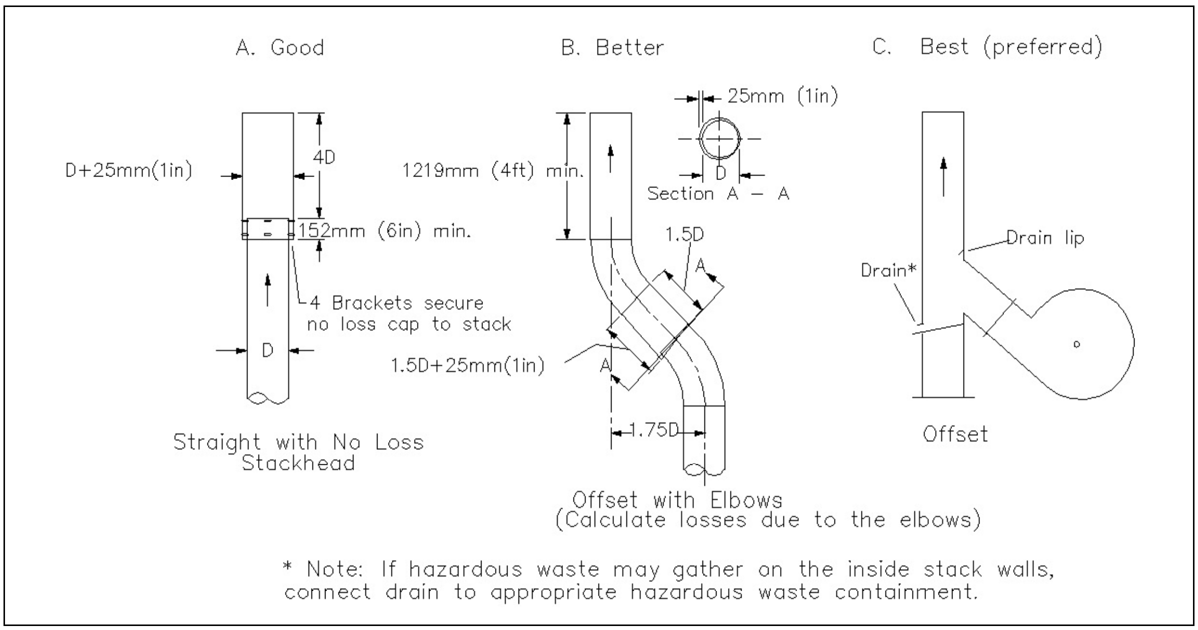
2-4.2.2 **Location**. Locate the exhaust fan after the air pollution control equipment to protect fan blades from contaminated air-stream. Provide access for maintenance to all fans, including ladders and guardrails where necessary. Refer to NFPA 70, *National*

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 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.

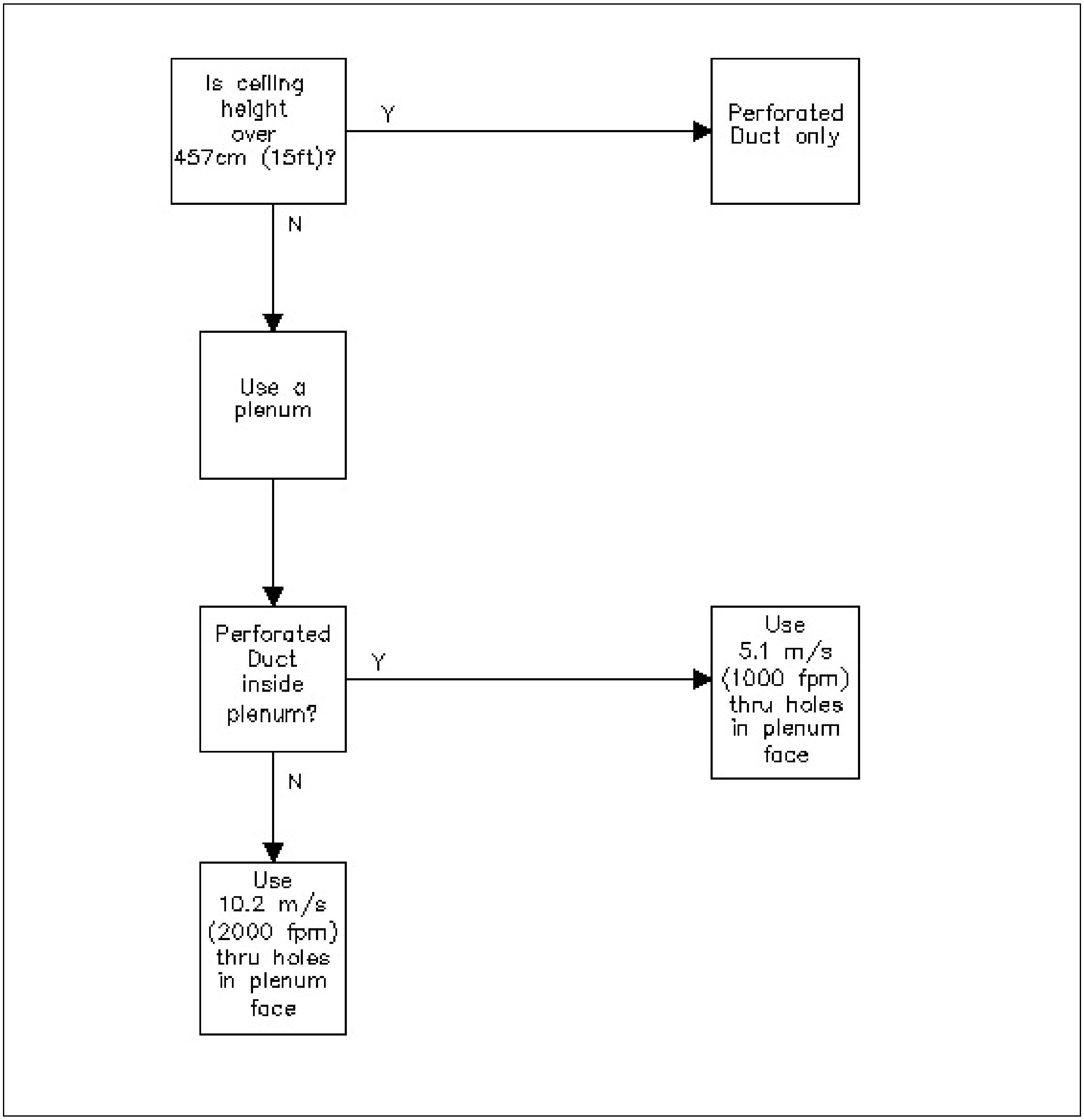


2-4.3.2 **Location and Structural Considerations**. Refer to ASHRAE Handbook, *Fundamentals* for information on airflow around buildings. Do not select stack locations based on prevailing winds. A stack must provide effluent dispersion under all wind conditions. Refer to UFC 1-200-01, *Design: General Requirements* for exhaust stack structural design considerations. Some structural considerations are wind load, lightning protection, and stack support. Refer to MIL-HDBK-1004/6, *Lightning (and Cathodic) Protection* and 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. 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. The method of distributing replacement air and the quantity of replacement air are critical with respect to exhaust air. 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**. Control the ventilated space pressure by modulating the quantity of replacement air. Use a variable frequency drive (VFD) motor to control the fan speed (see MIL-HDBK-1003/3, *Heating, Ventilating, Air Conditioning, and Dehumidifying Systems* for information of VFD motors). Using barometric dampers to control replacement air quantity is inefficient and unreliable. Sensor controlled transfer grilles are acceptable provided there will not be a problem with contaminated migration.

2-4.5.2 **Plenum Design**. 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 6.3 mm and 9.5 mm (1/4 in and 3/8 in). Perforated plenums work best when ceiling height is less than 4.58 m (15 ft). Use either of the following two choices for replacement air plenum design:

a. Design for 5.1 m/s (1,000 fpm) 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 10.2 m/s (2,000 fpm) 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.

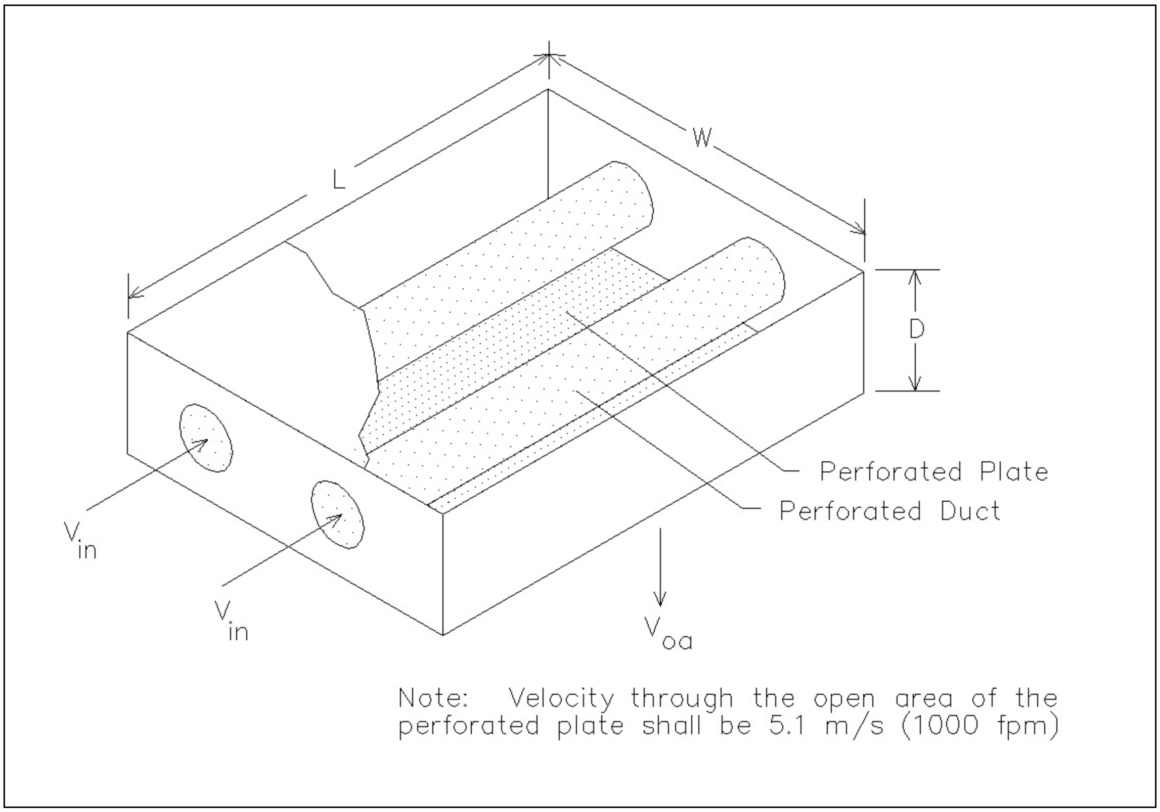
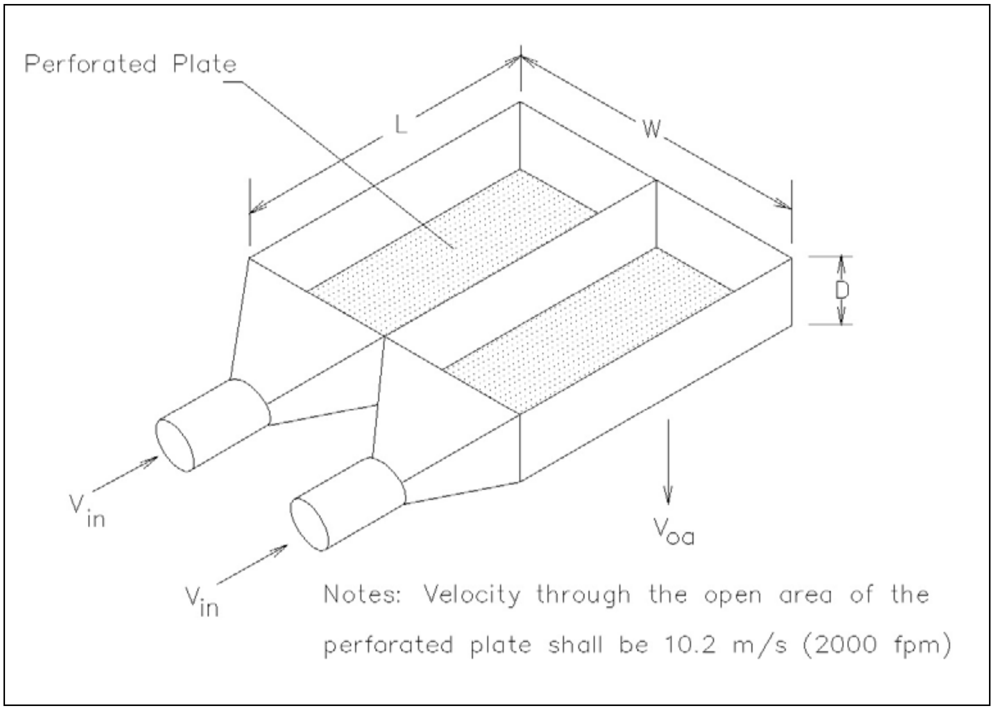


Figure 2-4. Plenum design without perforated duct.



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 4.58 m (15 ft). 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.

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, with gauge readouts, across each replacement air filter section. Set points on the gauge to trigger an alarm when the pressure drops or gains across the filter exceed the manufacturer's recommended value. A pressure drop occurs when there is a blow through a filter and a pressure gain occurs when the filter gets loaded.

2-5.1.2 Operating light on replacement air system fan motor.

2-5.1.3 Static pressure sensor at the outlet of the replacement air fan with a gauge readout. Set the points on the gauge to trigger an alarm when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.4 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. Set the points on the gauge to trigger an alarm 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 Differential pressure sensor across each exhaust air-cleaning device with gauge readout. Set points on the gauge to trigger an alarm when the pressure drop across the device exceeds the manufacturer's recommended value.

2-5.1.6 Static pressure sensor at the exhaust fan inlet with gauge readout. Set the points on the gauge to trigger an alarm when the pressure is lower than the recommended range (as determined by baseline testing).

2-5.1.7 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.

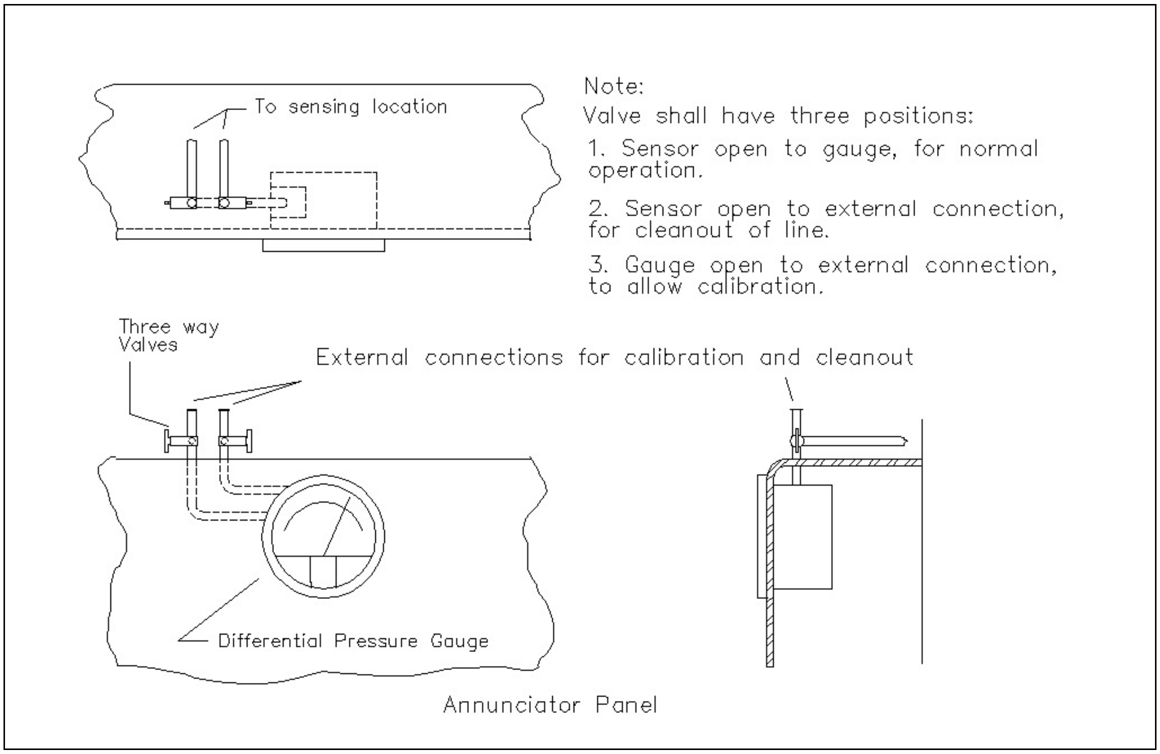
2-5.1.8 Operating ranges on all gauges clearly marked. Locate gauges on an annunciator panel (except hood static pressure gauges). Provide a 3-way valve at each gauge connection for cleanout and calibration; see Figure 2-5.

2-5.1.9 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 continuously monitor 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 paragraph 2-5.1. 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 should 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.”

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. Specify that all testing will be done in accordance with the ACGIH IV Manual, Chapter 9, "Monitoring and Testing 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. Refer to ASHRAE Handbook, *HVAC Systems and Equipment* and MIL-HDBK-1003/3 for details.

2-6.3 **Recirculation**. Industrial ventilation systems use a large quantity of air. Exhaust air recirculation is discouraged for most Naval industrial processes and prohibited by OPNAVINST 5100.23 for processes generating lead and asbestos. Follow the re-circulated air guidelines set forth in UFC 3-600-01, *Design: Fire Protection Engineering for Facilities* and 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 Manual and ANSI 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.

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:

KEEP DOOR CLOSED **THIS DOOR MUST BE CLOSED FOR EFFECTIVE CONTROL OF CONTAMINANTS**

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 of any kind of activity in advance, both to fulfill the design goals and prevent the need for corrections at a later stage.

2-7.2.1 **Criteria**. Specify the lowest noise emission level that is technologically and economically feasible. Each DOD service branch has a permissible noise level specified in its safety and health manual. It is not adequate to specify that individual pieces of equipment do not produce noise levels in excess of that permissible level. Determine the sound power levels for each piece of equipment. Use this information to predict the acoustic characteristics of the workspace and the resulting ambient noise level. Specify the appropriate noise control method if the total predicted ambient noise level is in excess of the requirements in the applicable safety and health manual. For additional information on noise control refer to UFC 3-450-01, *Design: Noise and Vibration Control*; DHEW 79-117, *NIOSH Industrial Noise Control Manual*; OSHA Pub 3048, *Noise Control, A Guide for Workers and Employees;* and NAVFAC P-970, *Protection Planning in the Noise Environment*.

2-7.3 **Respiratory Protection**. 29 CFR 1910.134(d), *Respiratory Protection* specifies requirements for respiratory protection. Consult with an industrial hygienist 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. 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. Consider installing a panel to permit the IH to test air quality on a routine basis.

NOTE for USAF: The test panel is required for quarterly testing.

2-7.3.2 **Air Compressors**. Oil lubricated breathing air compressors require a high temperature or carbon monoxide alarm or both. If only a high temperature alarm is used, the air supply must be monitored to ensure the breathing air does not exceed 10 parts per million (ppm) carbon monoxide. Compressors that are not oil lubricated must still have the carbon monoxide level monitored to ensure it is below 10 ppm. Compressors used to supply breathing air must be constructed and situated 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 5.56 ^{o}C (10 ^{o}F) below the ambient temperature. The breathing air system must have suitable inline air-purifying sorbent beds and filters. Sorbent beds and filter will have to be maintained per manufacturer's instructions.

2-7.4 **Emergency Showers and Eyewash Stations**. Provide where required. Design in accordance with UFC 3-420-01, *Design: Plumbing Systems*.

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 facility. 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, consider using ASHRAE Guideline 1, *The HVAC Commissioning Process*.

CHAPTER 3

ASBESTOS DELAGGING FACILITIES

3-1 **FUNCTION.** An asbestos delagging facility provides a complete workshop to remove asbestos insulation from piping and mechanical equipment during ship repair. 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

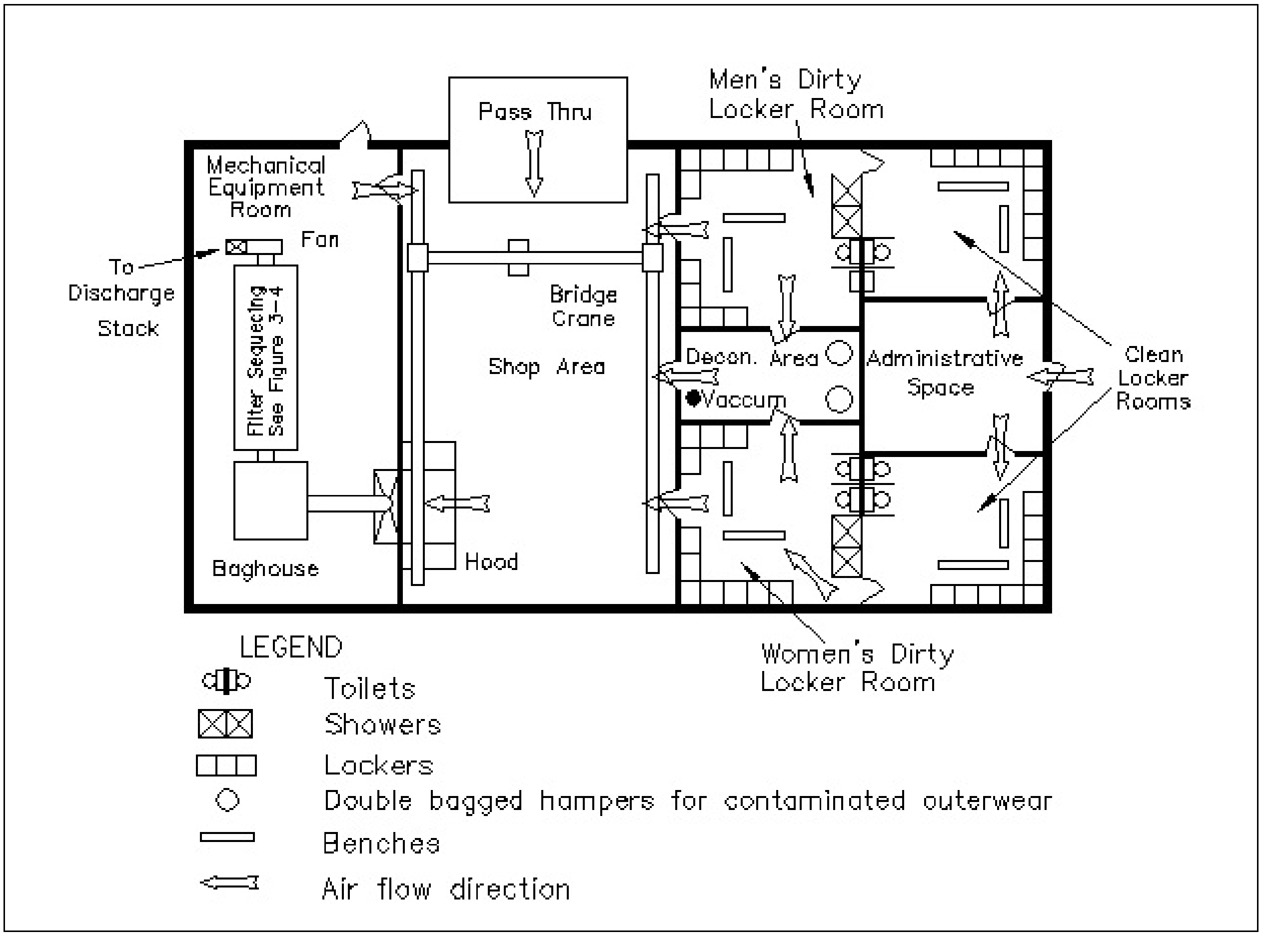
3-2.1 **Airborne Contamination**. When asbestos insulation is delagged, the asbestos fibers are dispersed into the air, creating a health hazard. 29 CFR 1910.1001, *Asbestos, General Industry* and 29 CFR 1915.1001, *Asbestos, Shipyards* dictate protective measures for workers in these facilities, including respirator 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 administrative area. They put on protective outerwear and proceed to the shop area. After performing delagging, workers vacuum their protective outerwear and dispose of them in containers provided in the decontamination area. 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.

3-3 **TYPICAL FLOOR PLANS.** Design floor plans to meet the requirements of 29 CFR 1910.1001 and 29 CFR 1915.1001 and paragraph 3-2.3. 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 a minimum capture velocity of 0.762 m/s (150 fpm) to capture all the contaminants at the source.

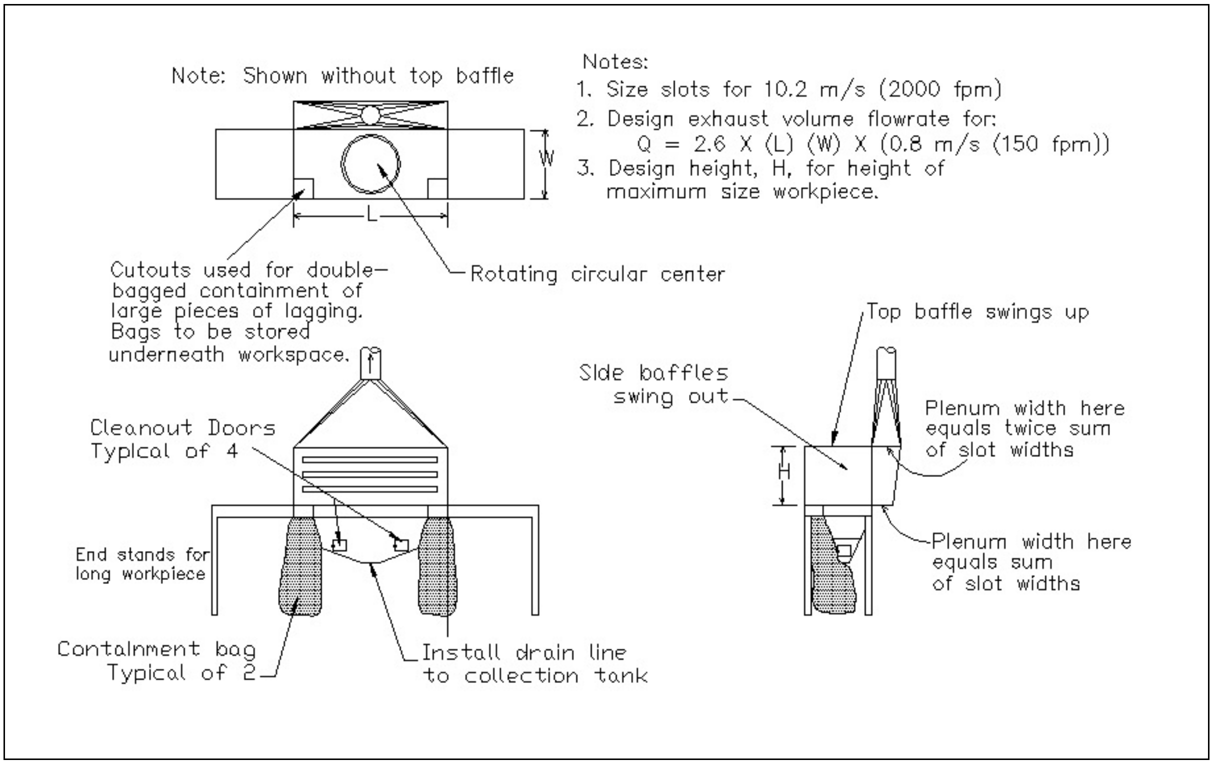
3-5.1 **Hood Design**. Design asbestos delagging hood to enclose the work piece as much as possible. Do not use small portable hoods with flexible ductwork because they do not provide consistent capture.

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:

a. 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.

b. The top baffle swings up to allow access to overhead cranes.

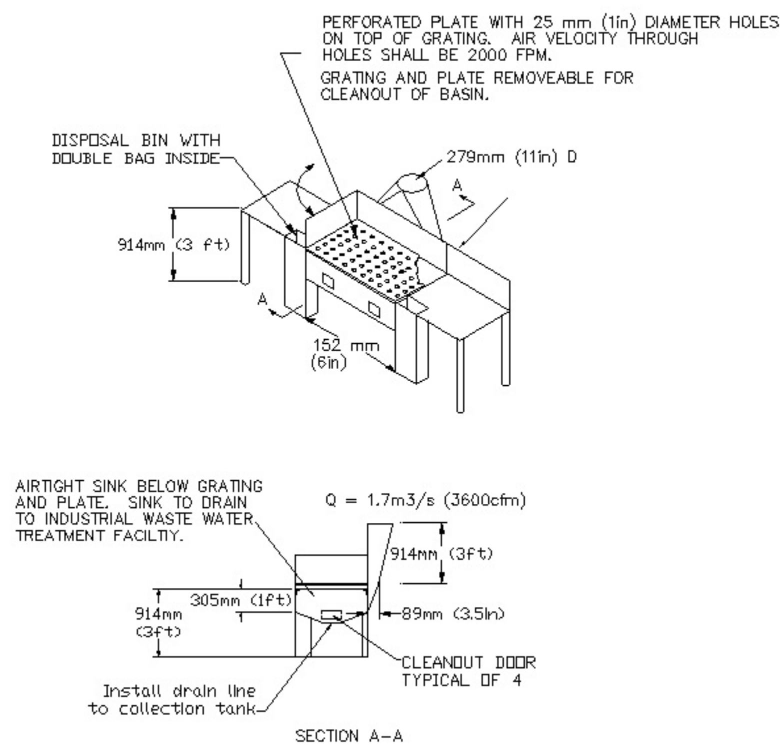
Figure 3-2. Exhaust hood for high profile work pieces.



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).

3-5.3 **Ductwork**. Size the exhaust ductwork to provide a minimum transport velocity of 25.4 m/s (5,000 fpm). The high velocity is necessary because the practice of wetting the fibers makes them heavier and more difficult to transport. See paragraph 2-4.1 for general duct considerations.

Figure 3-3. Exhaust hood for low profile work pieces.



3-5.4 **Fans**. See paragraph 2-4.2 for general fan considerations.

3-5.5 **Weather Stack Design and Location**. See paragraph 2-4.3.

3-5.6 **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.

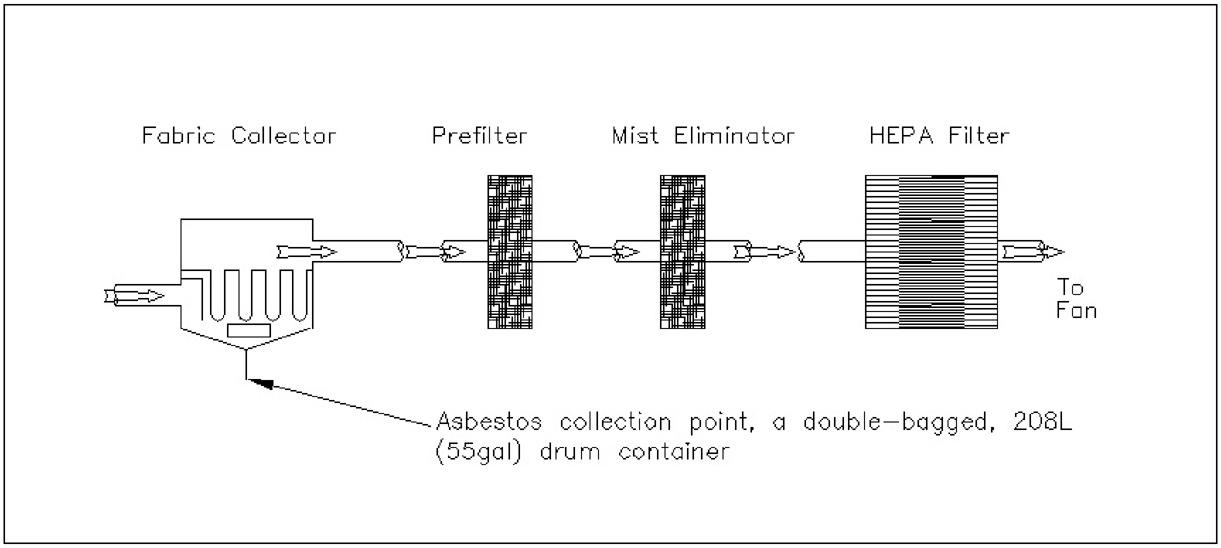
a. Have all collectors deliver the collected asbestos to a common pickup point to minimize the risk of exposure. Provide a double acting valve at each collector hopper throat, in accordance with the ACGIH IV Manual, Chapter 4.

b. Use a single chamber, shaker type collector to minimize the number of collection points.

3-5.6.1 **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*.

3-5.6.2 **Sequencing**. Figure 3-4 illustrates the required sequence of air cleaning devices.

Figure 3-4. Sequence of air cleaning devices for asbestos delagging.



3-5.7 **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.

3-5.7.1 Design a central vacuum cleaning system, which consists of a motor driven exhauster interconnected with bag type separators.

3-5.7.2 Connect the separator to rigid tubing, which extends throughout the plant. Terminate the rigid tubing with inlet valves at the various workstations. Provide flexible hose connections to allow workers to do shop cleanup and to decontaminate their protective outerwear.

3-5.7.3 Use local exhaust hoods and high velocity exhaust takeoffs for each hand tool. Table 3-1 and the ACGIH IV Manual provide examples of tools and exhaust system for specific operations.

3-5.7.4 Ensure proper capture velocity is produced at each local exhaust hood. Design vacuum systems to reach within 12.7 mm (1/2 inch) of the contaminant source.

3-5.7.5 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 m^3/s (cfm)	Hose Size mm (in.)
Pneumatic chisel	0.06 (125)	38 (1.5)
Radial wheel grinder	0.07 (150)	38 (1.5)
Cone wheel grinder, 2 inch	0.07 (150)	38 (1.5)
Cup stone grinder, 4 inch	0.09 (200)	51 (2.0)
Cup type brush, 6 inch	0.12 (250)	51 (2.0)
Radial wire brush, 6 inch	0.08 (175)	38 (1.5)
Hand wire brush, 3 x 7 inches	0.06 (125)	38 (1.5)
Rip out knife	0.08 (175)	38 (1.5)
Rip out cast cutter	0.07 (150)	38 (1.5)
Saber saw	0.07 (150)	38 (1.5)
Saw abrasive, 3 inch	0.07 (150)	38 (1.5)
General vacuum	0.09 (200)	51 (2.0)

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

3-5.7.6 Design the air volume for no less than two parts of air to one part of asbestos to be captured by weight.

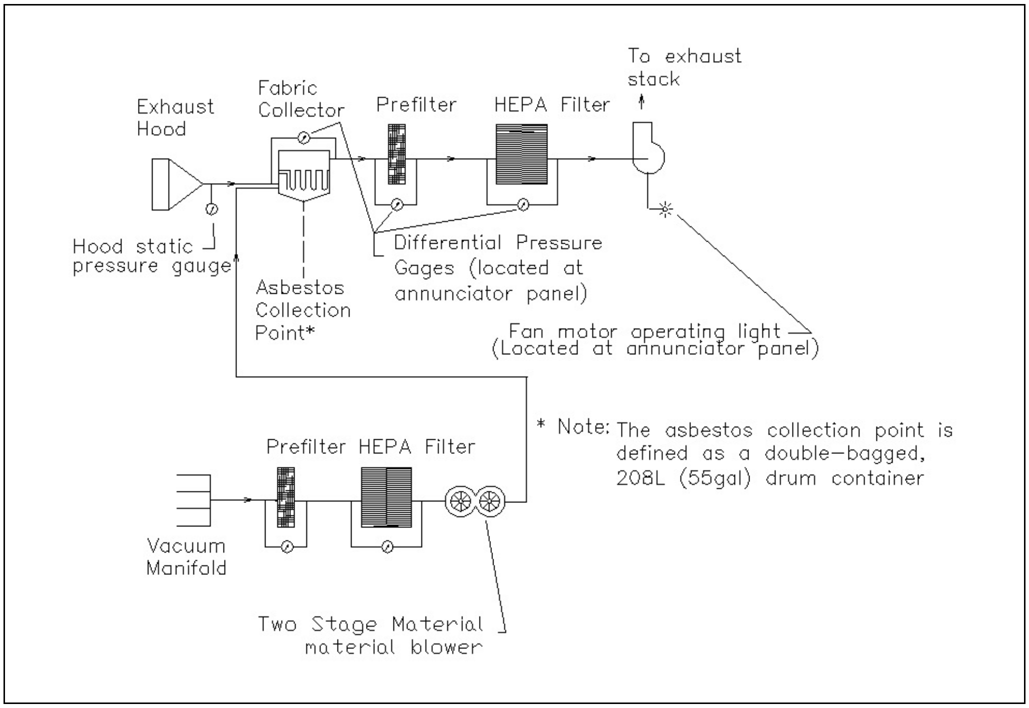
3-5.7.7 Design the vacuum hose length less than 7.6 m (25 ft). Locate inlet valves 9 to 10.7 meters (30 to 35 feet) apart when a 7.6-m (25-ft) length of hose is used. Locate tool vacuum hose connection on the ends of the workbench underneath the stands. Size the hose based on: (1) air volume per hose, (2) number of hoses to be used simultaneously, and (3) air velocity required to convey the material to the separators.

3-5.7.8 Use single-ply, lightweight thermoplastic or polyvinyl chloride (PVC) flexible hose, but limit the usage whenever possible.

3-5.7.9 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.

3-5.7.10 Feed the blower directly into the bag house used by the industrial exhaust system (see Figure 3-5) to minimize the number of asbestos collection points.

Figure 3-5. Exhaust and vacuum system schematic diagram



3-5.7.11 Install a prefilter and a HEPA filter in front of the blower to prevent it from becoming contaminated.

3-5.7.12 Design the vacuum system duct to balance with the exhaust system duct where the two systems connect.

3-5.7.13 Use manufacturer guidance to design vacuum system and TM 5-805-4 as preliminary guidance.

3-5.8 **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 12.4 to 24.9 Pa scale (-0.02 to -0.05 inches watergage (wg)) in the shop spaces.

a. Maintain the pressure in decontamination areas, the equipment room, and dirty locker rooms within a range of -2.49 to -9.96 Pa (-0.01 to -0.04 inches wg). Maintain the pressure in clean spaces within a range of +4.98 to +12.4 Pa (+0.02 to +0.05 inches wg). For further replacement air system criteria, see paragraph 2-4.5.

b. See paragraph 2-4.5 for further details.

3-5.8.1 **Heating and Air Conditioning**. If necessary, provide heating and cooling according to MIL-HDBK-1003/3.

3-5.9 **System Controls**. Design system controls in accordance with paragraph 2-5 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 **SAFETY AND HEALH CONSIDERATIONS.** Consult the local industrial hygienists for required respiratory protection in accordance with 29 CFR 1910.1001 (f) and (g), 29 CFR 1915.1001(g) and (h). See paragraph 2-7.3 for additional information.