INCH-POUND
MIL-HDBK-1003/17A
31 JANUARY 1990
SUPERSEDING
MIL-HDBK-1003/17
30 SEPTEMBER 1987

MILITARY HANDBOOK

INDUSTRIAL VENTILATION SYSTEMS

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ABSTRACT

This handbook provides the basic design guidance for industrial ventilation systems at military installations. It is intended for use by experienced architects and engineers. It includes ventilation design data for specific processes, including asbestos delagging, torpedo maintenance, metal cleaning and electroplating, fiberglass reinforced plastic repair and lay up, abrasive blasting, spray coating, foundry operations and woodworking.

FOREWORD

This military handbook was developed from an evaluation of facilities in the Shore Establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other government agencies, and the private sector. It uses, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from these criteria, in planning, engineering, design, and construction of Naval shore facilities, cannot be made without prior approval of NAVFACENGCOMHQ Code 04.

Design cannot remain static any more than the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commanding Officer (Code 111), Naval Energy and Environmental Support Activity, Port Hueneme, CA 93043; telephone (805) 982-3499.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGNS (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

MECHANICAL ENGINEERING CRITERIA MANUALS

Document Number	Title	Preparing Activity
DM-3.01	Plumbing	WESTDIV
MIL-HDBK-1003/2	Incinerators	WESTDIV
DM-3.03	Heating, Ventilating, Air Conditioning and Dehumidifying Systems	WESTDIV
DM-3.4	Refrigeration Systems for Cold Storage	WESTDIV
DM-3.5	Compressed Air and Vacuum Systems	WESTDIV
DM-3.6	Central Heating Plants	NEESA
MIL-HDBK-1003/7	Fossil Fuel Power Plants (Proposed)	NEESA
MIL-HDBK-1003/8	Exterior Distribution of Utility Steam, HTW, CHW, Fuel Gas and Compressed Air	WESTDIV
DM-3.09	Elevators, Escalators, Dumbwaiters, Access Lifts, and Pneumatic Tube Systems	WESTDIV
DM-3.10	Noise and Vibration Control for Mechanical Equipment (Tri-Service)	HQTRS
MIL-HDBK-1003/11	Diesel Electric Generating Plants	WESTDIV
MIL-HDBK-1003/12	Boiler Controls	NEESA
MIL-HDBK-1003/13A	Solar Heating of Buildings and Domestic Hot Water	WESTDIV
DM-3.14	Power Plant Acoustics (Tri-Service)	ARMY
DM-3.15	Air Pollution Control Systems for Boilers and Incinerators (Tri-Service)	NEESA
MIL-HDBK-1003/17	Industrial Ventilation Systems	NEESA
MIL-HDBK-1003/19	Design Procedures for Passive Solar Buildings (Proposed) (Tri-Service)	CESO

NOTE: Design manuals, when revised, will be converted to military handbooks and listed in MIL-BUL-34.

INDUSTRIAL VENTILATION SYSTEMS

CONTENTS

APPENDICES

FIGURES

Page

TABLES

Section 1: INTRODUCTION

1.1 Scope. This handbook provides criteria for the design of industrial ventilation systems that control contaminants generated from specific industrial processes. Use the general criteria presented in Section 2 and the criteria given in the section for the particular process. Criteria in Section 2 are to be used for all industrial ventilation applications. The specific processes addressed in this handbook are asbestos delagging, torpedo refurbishing, metal cleaning and electroplating, fiberglass reinforced plastic repair and lay up, abrasive blasting, spray painting, foundry operations, and woodworking. This handbook provides a system concept for each specific process rather than just criteria for the various components. The industry standard, the American Conference of Governmental Industrial Hygienists (ACGIH) Manual, Industrial Ventilation, A Manual of Recommended Practice, provides component criteria rather than system criteria.

1.2 Mandatory Standards. The requirements in this handbook are based on mandatory standards set forth in Title 29, Code of Federal Regulations (CFR), part 1910, Occupational Safety and Health Standards (29 CFR 1910), and the national consensus standards. Individual state and local requirements are not incorporated into this handbook. It is the sole responsibility of the cognizant design personnel to design an industrial ventilation system that complies with state and local. Users of this handbook are cautioned to consult the most current edition of the standards. These standards are frequently revised and updated. For this reason, the year of publication of standards and codes is omitted from this handbook. This handbook does not duplicate materials covered elsewhere in Department of Defense (DOD) criteria documents. Applicable criteria documents are referenced for appropriate topics. Also, requirements contained in this handbook should be interpreted as minimum criteria and should be improved where current technology or situation warrants.

1.3 Cancellation. This military handbook cancels and supersedes MIL-HDBK-1003/17 of 30 September 1987.

Section 2: GENERAL TECHNICAL REQUIREMENTS

2.1 General Design Criteria

2.1.1 Coordination. A project design team shall be formed to direct the design of industrial ventilation projects. The design team shall include representatives from the following:

a) Cognizant industrial shop,

b) Public works office,

c) Health and safety office,

d) Cognizant Regional Engineering Office (REO) (e.g., Navy Engineering Field Division, Army Corps of Engineers Division and Air Force major command engineering office),

e) Cognizant industrial hygiene office,

f) Cognizant system command program manager (where applicable).

The REO representative shall act as team leader in all cases, except when the cognizant REO grants a variance.

2.1.2 Design Procedure. Refer to ACGIH Manual Chapter 5, Exhaust System Design Procedures, for guidance on system calculations. Steps 1-10 of para. 2.1.2.1 through 2.1.2.10 shall be used for all ventilation system designs.

2.1.2.1 Step 1. Identify all significant contaminant sources that require ventilation control. The cognizant industrial hygiene office should provide a source characterization with area diagrams of the contaminant sources, and employee work areas with percentage of time spent in each area. Consider also how the system under design might affect the performance of any existing processes or ventilation systems.

2.1.2.2 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.

2.1.2.3 Step 3. Select or design the exhaust hood that best suits the workpiece or operation. Enclose the workpiece or operation to the maximum extent (e.g., using baffles). This will reduce the ventilation rates required to provide contaminant control. This handbook provides optimum exhaust hood types for many of the operations covered.

2.1.2.4 Step 4. Determine the capture velocity required to control generated contaminants. All capture velocities specified in this handbook assume there are no crossdrafts or turbulence that adversely affect capture efficiency. The potential for crossdrafts or turbulence near a given exhaust hood can be greatly reduced if the hood is properly located and designed with baffles, and if the replacement air system is designed to complement the exhaust system.

2.1.2.5 Step 5. Determine the exhaust flow rate in cubic feet per minute (cfm) required to maintain the capture velocity arrived at in Step 4.

2.1.2.6 Step 6. Design the exhaust system ductwork based on the following:

a) Size the duct to maintain the minimum transport velocity throughout the system. Route the duct as directly as possible with respect to other criteria in this handbook. Use low-loss fittings (refer to para. 2.1.3.1).

b) Provide a balanced system without blast gates or adjusting dampers in accordance with the ACGIH Manual, Chapter 5.

c) Ensure that construction materials are suitable for the given application.

d) Provide for connections at the fan inlet and outlet that minimize fan system effects (refer to para. 2.1.3.2).

e) Provide test ports to allow standardized performance testing in accordance with the ACGIH Manual (refer to para. 2.1.3.6).

2.1.2.7 Step 7. Select an air cleaning device, based on the cognizant regulatory agency (e.g., state, or local) requirements for air emissions.

2.1.2.8 Step 8. Size, select, and position the fan for the most effective operation (refer to para. 2.1.3.2).

2.1.2.9 Step 9. Provide a discharge stack with sufficient height and exit velocity to ensure contaminant dispersion (refer to para. 2.1.3.3).

2.1.2.10 Step 10. Provide a sufficient quantity of replacement air, and distribute it so that it does not create turbulence near the hood. Temper the air to provide a comfortable working environment (refer to para. 2.1.3.4).

2.1.3 Common System Criteria. Several design areas are common to all industrial ventilation systems. The criteria given in para. 2.1.3.1 through 2.1.5.4 provide general guidance. Design guidance particular to specific types of facilities are given in subsequent sections.

2.1.3.1 Ductwork. Design all ductwork in accordance with Sheet Metal and Air Conditioning Contractors National Association (SMACNA), Guide 15d, Accepted Industry Practice for Industrial Duct Construction: the ACGIH Manual, Section 8; and American National Standards Institute (ANSI), Z9.2, Fundamentals Governing the Design and Operation of Local Exhaust Systems. Where plastic ductwork is used, design it in accordance with the SMACNA manual Thermoplastic Duct Construction. Such ductwork shall be fire resistant and self extinguishing. Ductwork for industrial exhaust air shall provide the most direct possible route from intake to discharge with respect to the other criteria herein. Good duct design minimizes total system resistance and operating costs while maximizing system effectiveness. Design duct systems to operate in accordance with the ACGIH Manual, Section 5, Method A, in a balanced fashion without the use of blast gates or adjusting dampers. Specify round ductwork whenever possible to minimize cost.

a) Elbow Design. Figure 1 shows proper duct elbow design. The ratio of radius of centerline curvature to duct diameter shall not be less than 2:1. A ratio of 2.5:1 is preferred. Figure 2 shows a rectangular elbow. If a rectangular duct must be used, keep the aspect ratio (width divided by depth) in the elbows greater than or equal to 1.0.

b) Branch Entry Design. Branch entries are a common source of design problems. Design expansions at branch entries so that the minimum transport velocity is maintained in all segments, as illustrated in Figure 3. Do not design expansions based on an arbitrary increase in flow area. Figure 4 illustrates proper and improper design. Design the branches to enter at expansions, not before or after them. The entry angle should be 30 degrees but shall not exceed 45 degrees. Branches should enter at the top or the side of the main duct with no two branches entering the same transition. Where two branches enter a main duct, use the dual design shown in Figure 5. For proper "wye" connection design, see Figure 6. Never use the "tee" design labeled "not acceptable" in Figure 6.

2.1.3.2 Fans.

a) Selection. Fan selection criteria for replacement air fans and exhaust air fans are identical. Select industrial fans that meet pressure and volume flow rate requirements and are able to run 25 percent faster than design speed. As a minimum, fans should be class II construction. Fans with forward curved blades are not acceptable. Specify fan shafts that have a uniform diameter along the entire length and bearings that are rated at no fewer than 200,000 hours. Select electric lines and fan motor starters that are one size greater than required by the National Electrical Code. The reason for the increased fan construction and the oversized electrical supply is that unforeseen fan system effects often cause more system resistance than anticipated during fan selection. Air Movement and Control Association, Inc. (AMCA), Publication 201, Fan Application Manual-Fans and Systems describes fan system effects in detail. Chapter 6 of the ACGIH manual summarizes this information. For nonstandard air processes (e.g., elevated temperatures and humidity), the exhaust fan motor must be selected to handle cold startup amperage.

b) Installation. Provide a long straight section of duct (5 diameters minimum) immediately upstream of the fan inlet. This ensures a uniform air velocity profile that allows the fan to operate at its rated performance. Also, specify that the fan discharge into a straight section of duct at least 3 diameters long (refer to AMCA Publication 201). Specify vibration isolating couplings at the fan inlet and outlet. In all cases, install exhaust fans outside the building which they serve to isolate the working space from contaminants during fan maintenance. This minimizes noise and ensures negatively pressurized ducts in the building. All fans shall be licensed to carry the AMCA Certified Air Performance Seal. Select only energy-efficient motors. All fans shall be mounted on vibration isolating

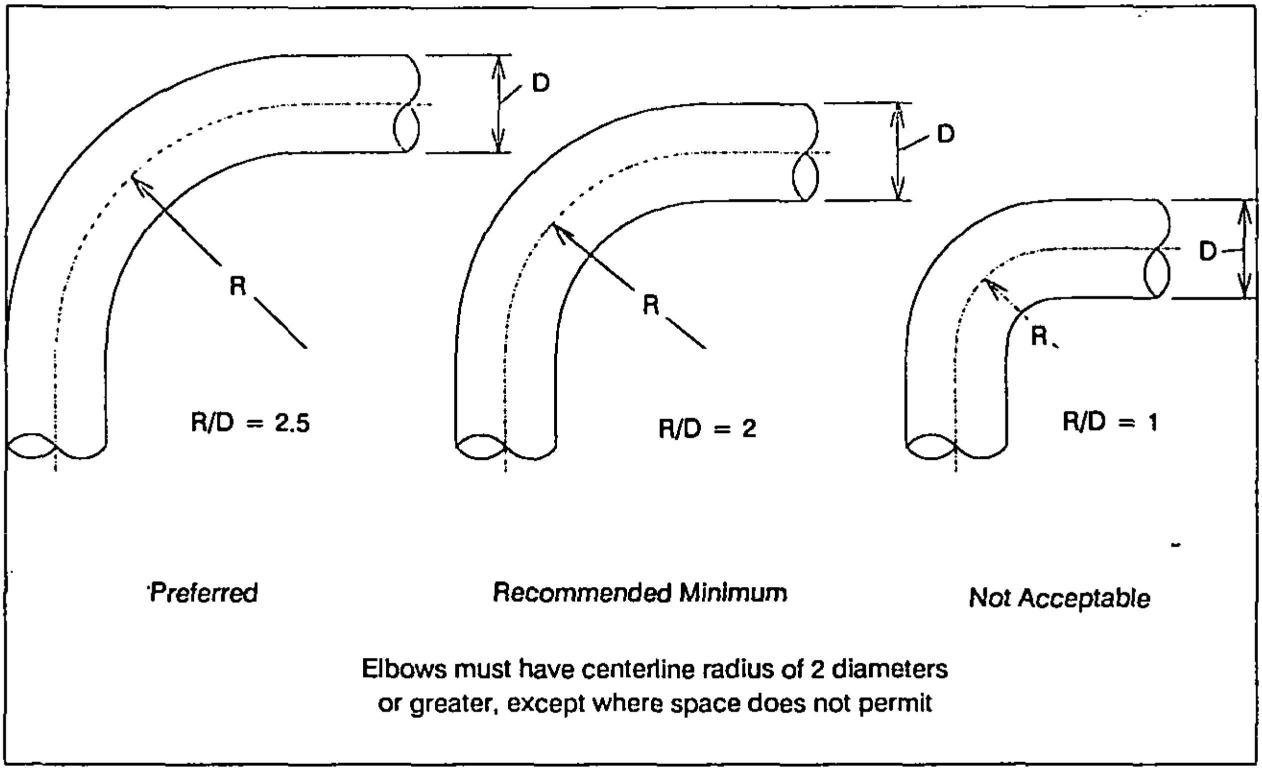


Figure 1
Duct Elbow Design

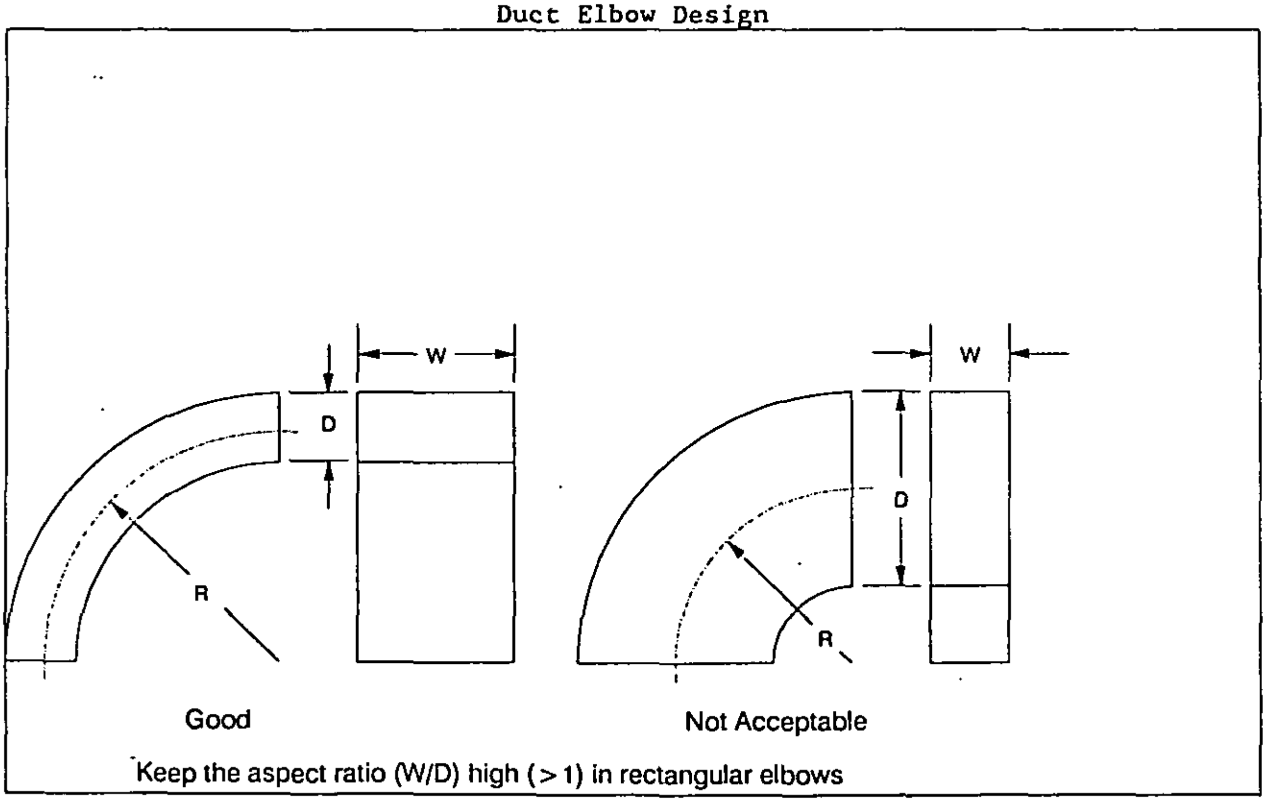


Figure 2
Rectangular Elbow Design

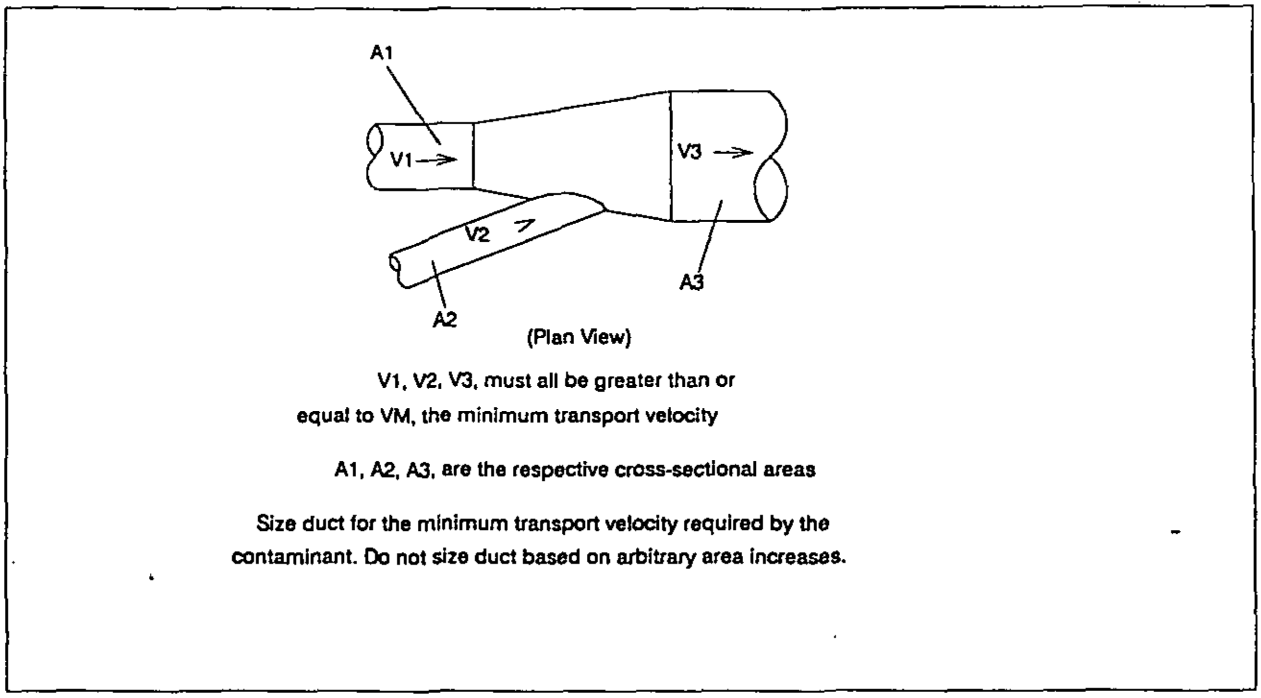


Figure 3
Branch Entry Sizing to Maintain Transport Velocity

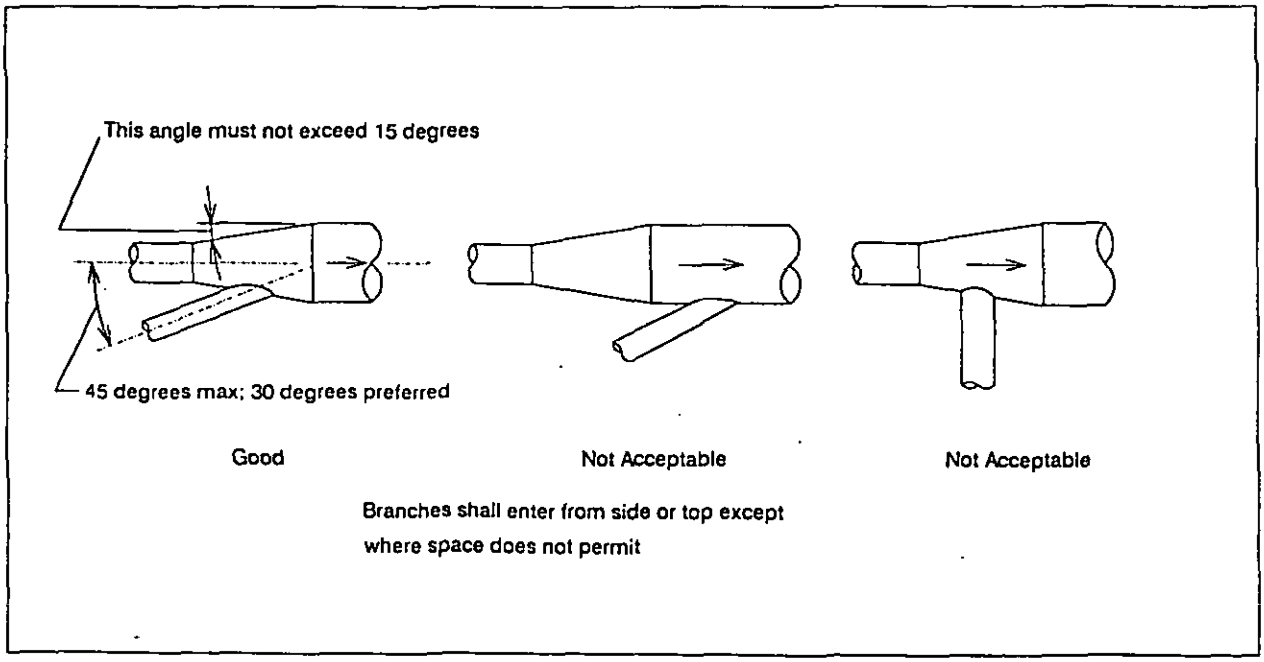


Figure 4
Branch Entry Orientations

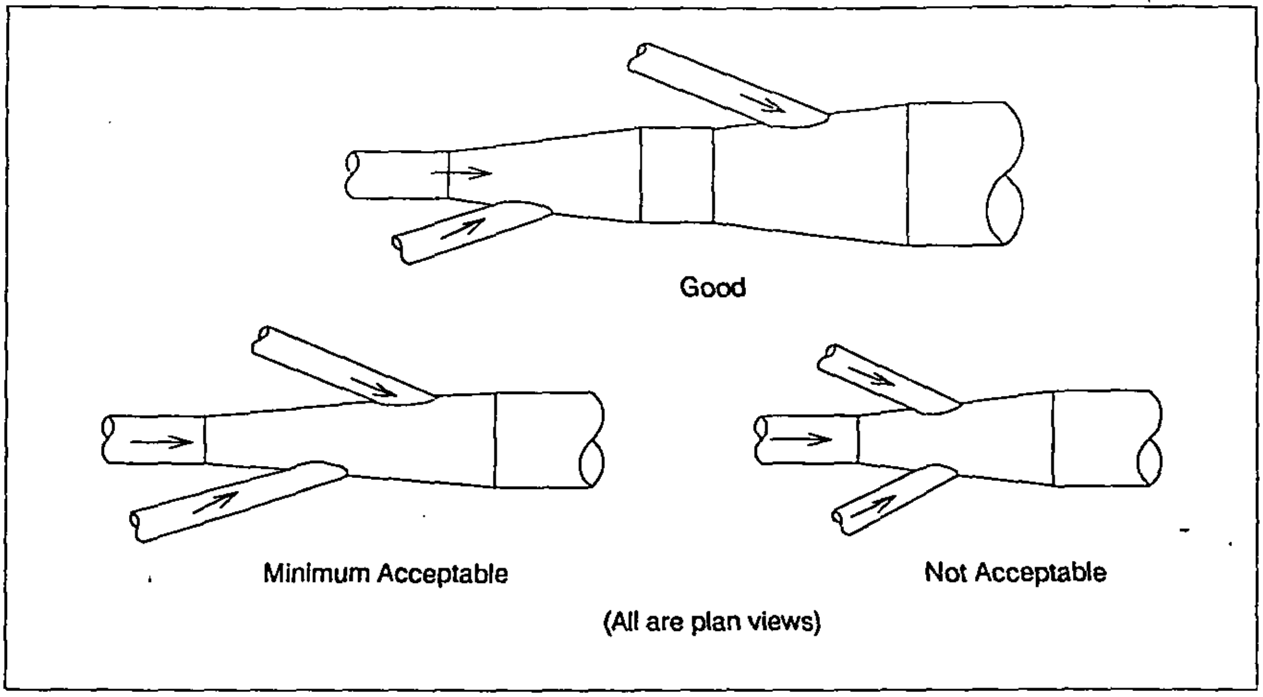


Figure 5
Dual Branch Entry Design

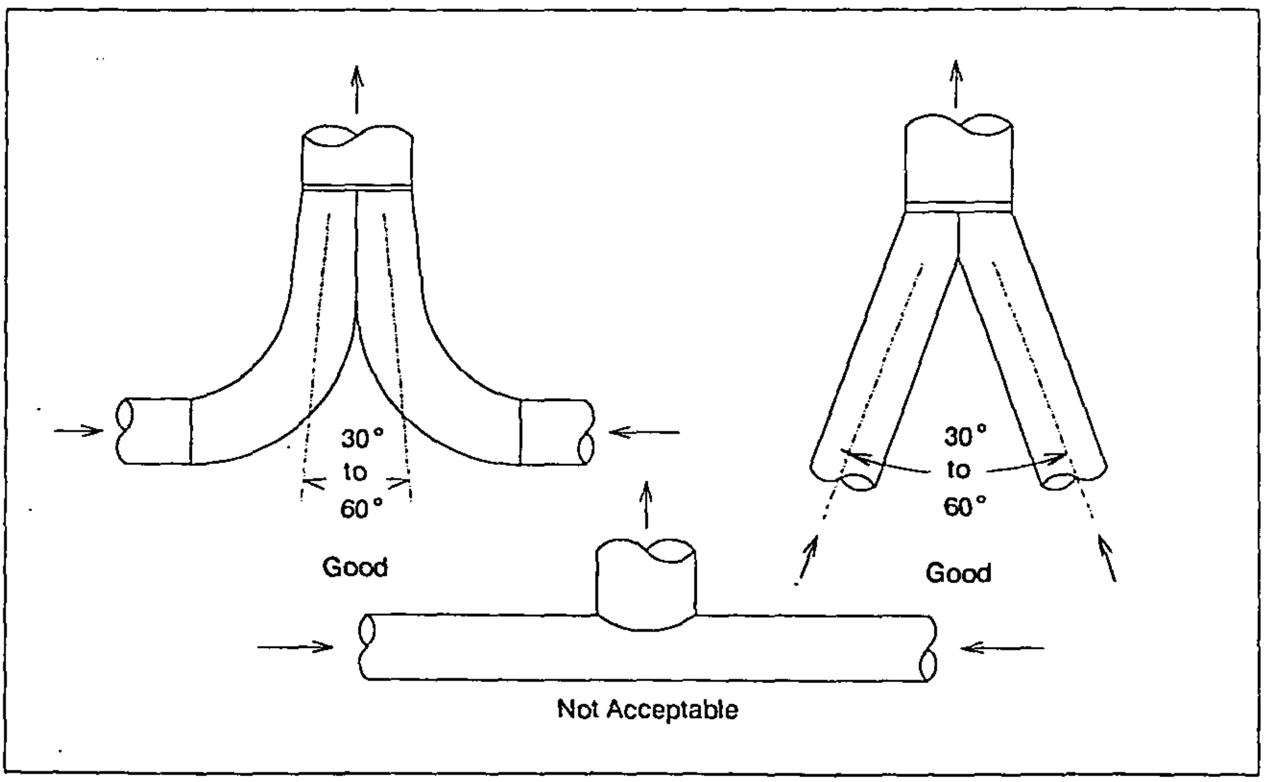


Figure 6
Wye Connections

bases. Provisions shall be made for maintenance access to all fans, including ladders and guardrails where necessary.

2.1.3.3 Exhaust Stacks.

a) Exhaust Effluent Considerations. Airflow over a building creates an eddy zone as shown in Figure 7. Exhaust effluent must be discharged outside this eddy zone to provide adequate dispersion and to prevent re-entry of the exhaust air into replacement air intakes. The eddy zone height depends on building shape and wind velocity; an approximate range is shown in Figure 7. In all cases, the exhaust stack must extend above the eddy zone. Evaluate the effect of local topography and present and planned structures on effluent dispersion. The ratio of discharge velocity to wind velocity must be at least 1.5:1 to provide good effluent breakaway as shown in Figure 8. The most efficient way to increase stack discharge velocity is to provide a nozzle at the top of the stack. This will, of course, add resistance which must be accounted for in the calculations. For additional information on airflow around buildings, refer to American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), ASHRAE Fundamentals Handbook.

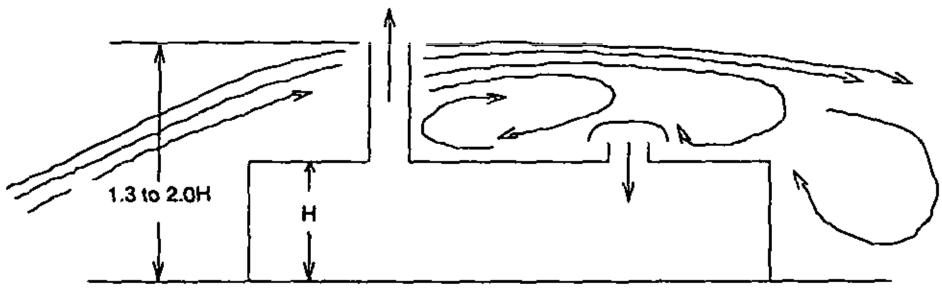
b) Design Considerations. The best designs are cylindrical, vertical discharge stacks as shown in Figure 9. In no case shall a stack discharge horizontally. The offset styles shown in Figure 9 are acceptable, but each has a greater associated resistance to flow than the straight style with the no-loss stackhead. Do not use deflecting weather caps, because they give inferior weather protection and result in detrimental effluent dispersion. To prevent any rain or condensation from running down the inside of the stack, use a stack diameter which will produce a minimum stack velocity of 2,600 feet per minute (fpm).

c) Location and Structural Considerations. Do not select stack locations based on prevailing winds. A stack must provide effluent dispersion under all wind conditions. Refer to the Naval Facilities Engineering Command Structural Engineering Criteria Manuals for considerations when designing exhaust stacks. Some structural considerations are wind load, lightning protection, and stack support. Refer to MIL-HDBK-1004/6 Lightning Protection. See also the SMACNA publication, Guide for Steel Stack Design and Construction.

2.1.3.4 Replacement Air

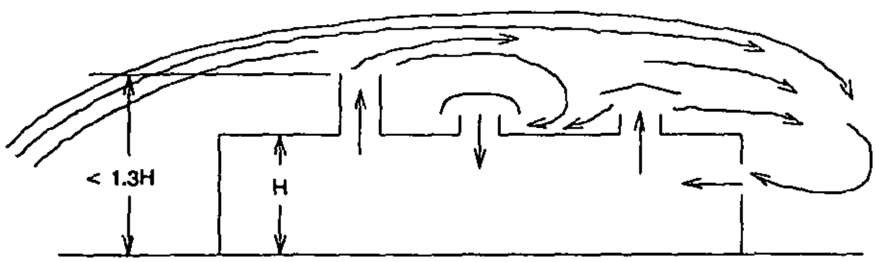
a) General Considerations. Industrial ventilation is defined as the exhaust and simultaneous replacement of air in a space. Replacement air is as important as exhaust air in controlling of industrial process contaminants. The method of replacement air distribution and the quantity of replacement air are critical with respect to exhaust air.

b) Criteria. Modulate replacement air, not exhaust air, to control and maintain design negative or positive pressures inside a ventilated space. Design the quantity of replacement air in accordance with the criteria given in each of the succeeding chapters of this handbook for particular process systems.



Good

Stack extends above eddy zone;
Effluent is dispersed and does not enter inlet.



Not Acceptable

Stack too short (left); stack has poor cap (right);
Effluent is not dispersed, and may enter inlets.

These guidelines apply to the simple case of a low building without surrounding obstructions on reasonably level terrain.

Reference: Clark, J.H., "Air Flow Around Buildings", Heating, Piping, and Air Conditioning, 39, 5, May, 1967, pp. 145-154.

Figure 7
Stack Height Relative to Eddy Zone

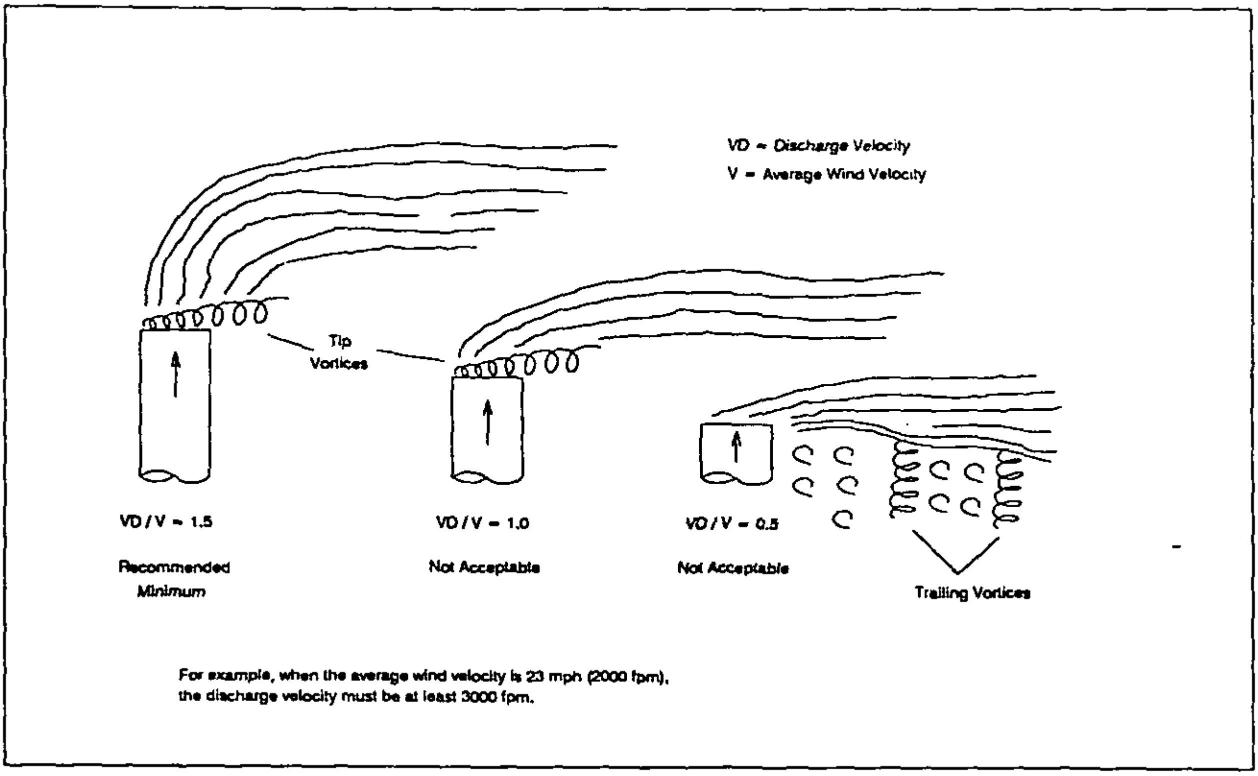


Figure 8
Discharge Velocity and Effluent Dispersion

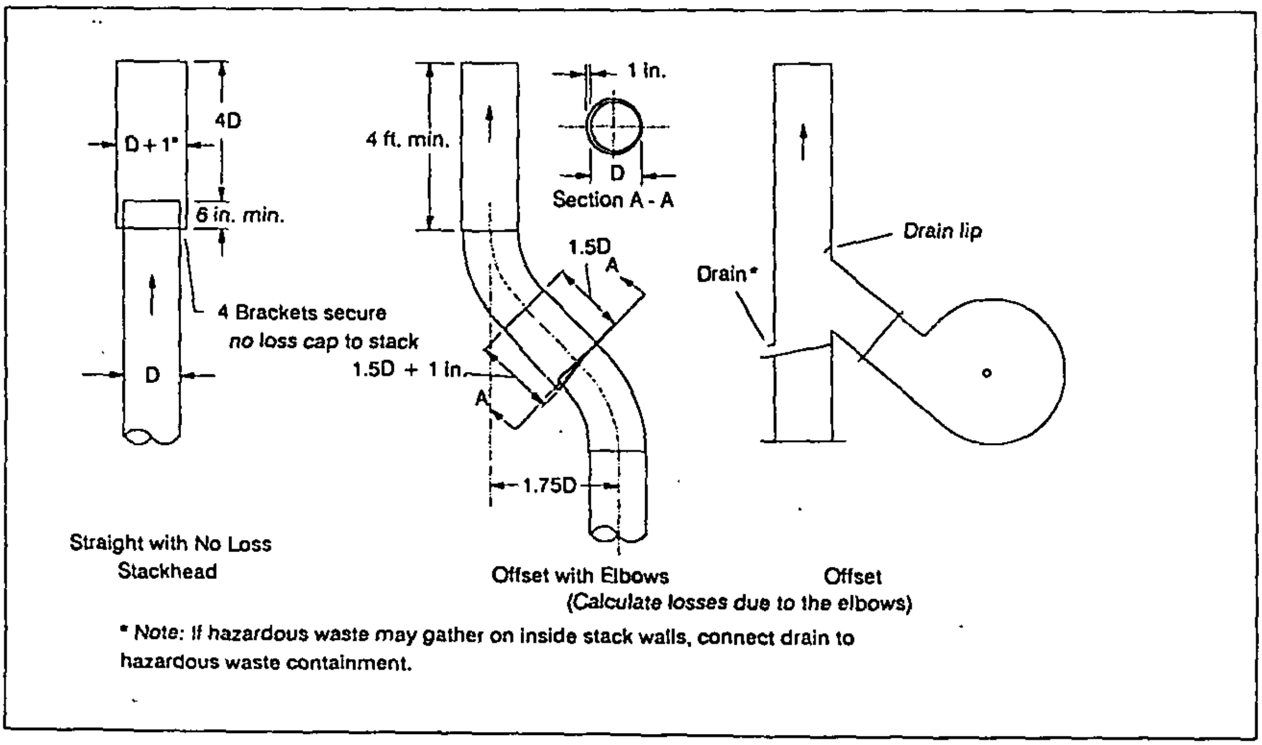


Figure 9
Exhaust Stack Designs

c) System Design. Design the replacement air system in accordance with the decision tree shown in Figure 10.

d) Plenum Design. There are two alternatives for replacement air plenum design. If perforated duct is used inside the plenum as shown in Figure 11, then the design replacement air velocity through the open area of the perforated plate shall be 1000 fpm. If this plenum is served with ducts using diffusers, grills or registers, the replacement air velocity through the open area of the perforated plate shall be 2000 fpm. For the replacement air plenum without perforated duct, the plenum cross-sectional area (perpendicular to flow) shall be a minimum of four times greater than the open area upstream of the cross section as shown in Figure 12. The plenum face should not use an open area less than 5 percent. Use perforated plate to cover as much of the ceiling (or wall opposite the exhaust hoods) as is practical.

e) Perforated Duct Design. Perforated duct can be used to evenly distribute the flow of replacement air inside the plenum. The design method shown in Figure 13 can be used to determine the cross-sectional areas and

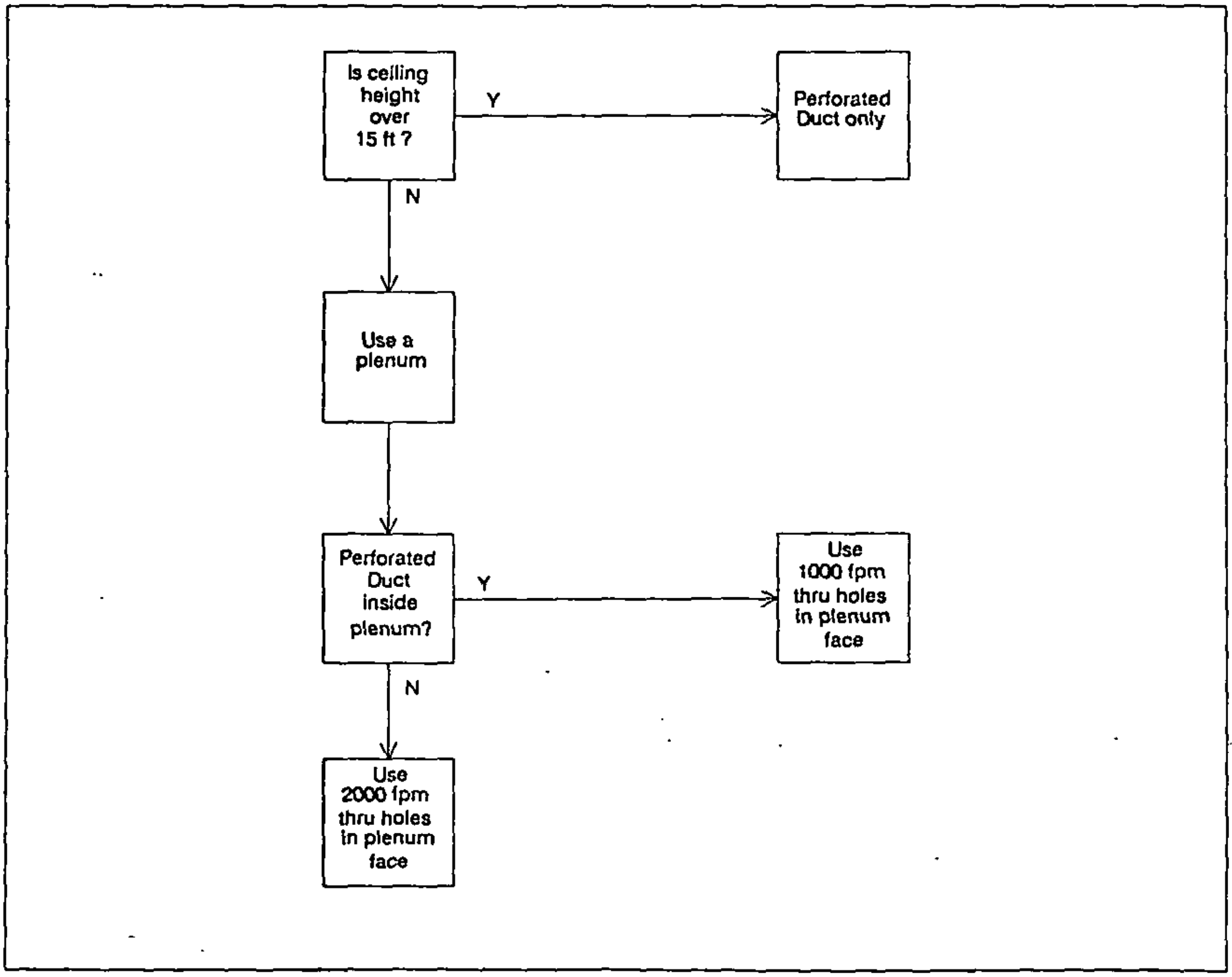


Figure 10
Decision Tree for Replacement Air Design

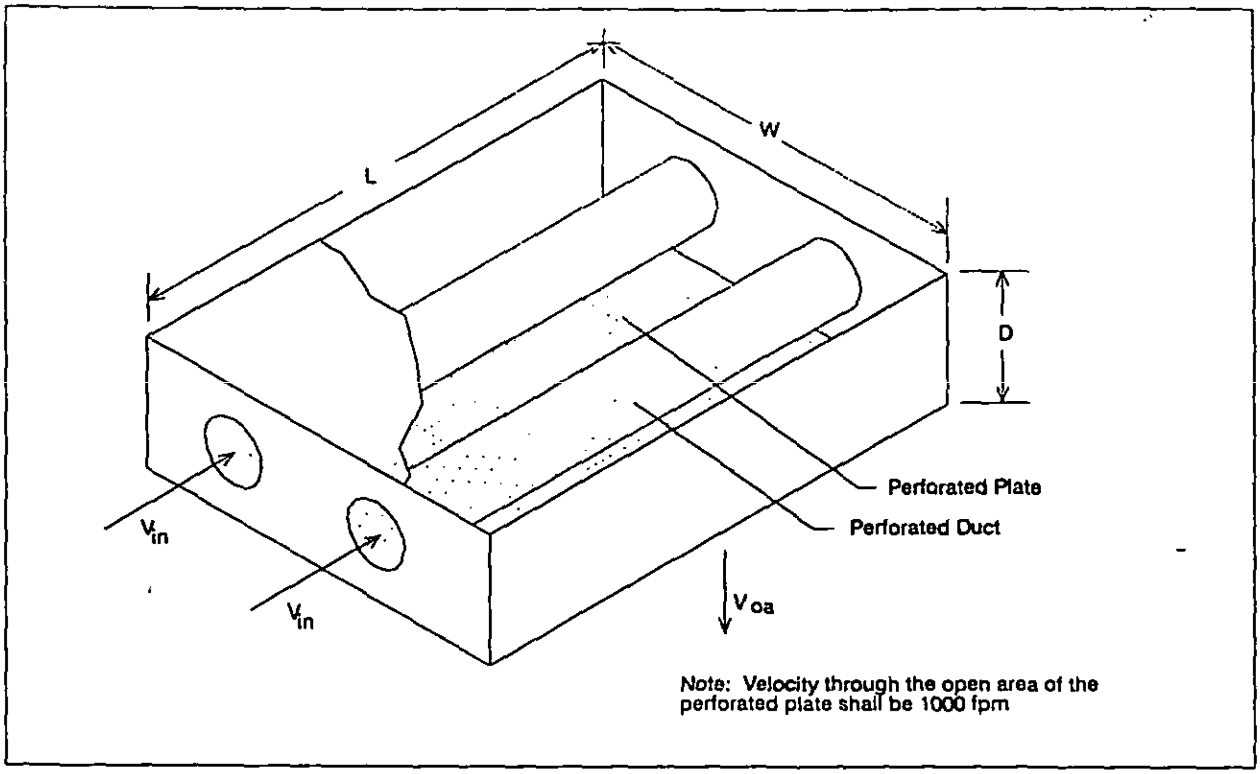


Figure 11
Plenum Design with Perforated Duct

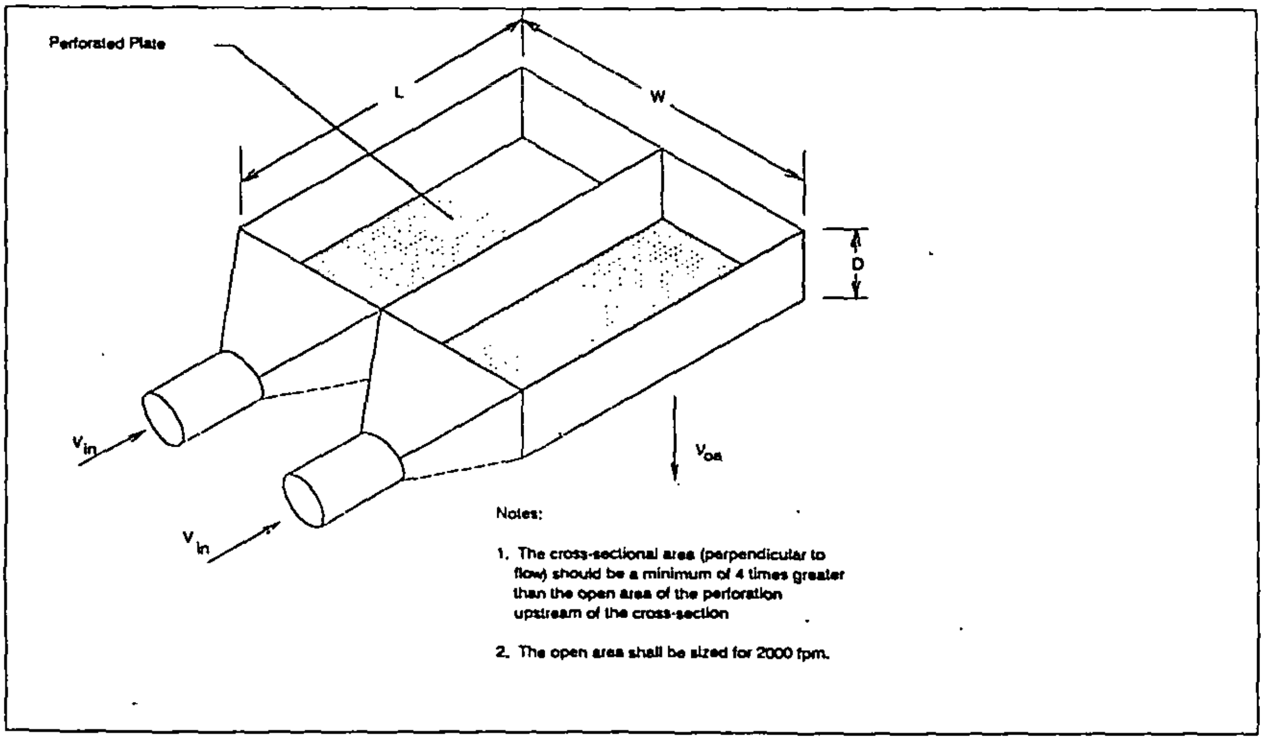


Figure 12
Plenum Design Without Perforated Duct

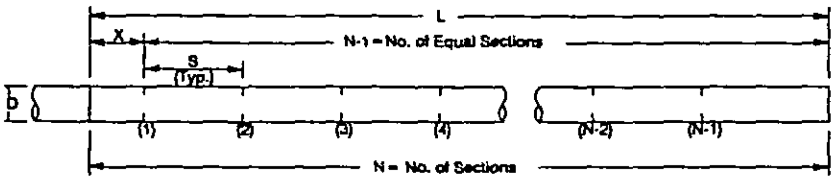
PERFORATED DUCT
WITH CONSTANT DIAMETER

1. Inlet Velocity: 1000 - 1200 fpm preferable. 1600 - 1800 maximum

2. Length of duct to first orifice:

X = 3' for D = 6"-12"
X = 4' for D = 13"-24"
X = 5' for D = 24" or larger

3. Divide remainder of duct (L-X) into equal lengths of 7'-9" each



4. Sizing of open area of orifices.

D = duct diameter
A(D) = cross-sectional area of duct
A(1) = open area of orifice at (1)
A(2) = open area of orifice at (2)
A(N-2) = open area of orifice at (N-2)
A(N-1) = open area of orifice at (N-1)

D(1) = diam of orifice at (1)
D(2) = diam of orifice at (2)
D(N-2) = diam of orifice at (N-2)
D(N-1) = diam of orifice at (N-1)

$$A(1) = \frac{N-1}{N} \times A(D) \qquad D(1) = \sqrt{\frac{4A(1)}{\pi}}$$

$$A(2) = \frac{N-2}{N-1} \times A(D) \qquad D(2) = \sqrt{\frac{4A(2)}{\pi}}$$

Note:
Round off values of D(1), D(2),...D(N-1) to nearest 1/2"

$$A(3) = \frac{N-3}{N-2} \times A(D) \qquad D(3) = \sqrt{\frac{4A(3)}{\pi}}$$

$$A(N-2) = \frac{N-(N-2)}{N-(N-3)} \times A(D) = \frac{2}{3} D \qquad D(N-2) = \sqrt{\frac{4A(N-2)}{\pi}}$$

$$A(N-1) = \frac{N-(N-1)}{N-(N-2)} \times A(D) = \frac{1}{2} D \qquad D(N-1) = \sqrt{\frac{4A(N-1)}{\pi}}$$

Figure 13
Design Procedure for Perforated Duct

diameters of open area for each orifice or reducer placed inside the duct. Orifices or reducers are used to control the amount of flow through the perforated duct so air is distributed evenly along the length of the duct.

Use oval duct if there are space constraints that limit the use of round duct. To use oval duct in place of round duct, design the replacement air-volume flow rate and velocity for round duct. Next, determine the corresponding equivalent cross-sectional area for the same flow rate for the oval duct using round to oval area equivalence tables.

f) <u>Air Handling Unit Design.</u> Select a replacement air fan that has the capacity to provide 110 percent of the total exhaust air-volume flow rate (or the capacity to run at 125 percent of the design fan speed). The extra capacity is required for control flexibility. Centrifugal fans with backward inclined airfoil blades are recommended for the replacement air systems. Design filter boxes to hold replaceable (throwaway) filters. The outside air intake shall be through a unit-mounted louver, complete with a built-in rain lip, vertical rain louvers, and a bird screen. Coils shall be removable and shall contain heating coils in a common or individual casing. Steam coils, where used, shall be vertical. Seal coils to the casing to prevent air leakage around the coils. Where electric coils are used, the Underwriters Laboratories (UL) Standard 1096 Electric Central Air Heating Equipment is recommended. For gas fired systems, the heater elements shall be American Gas Association (AGA) Z21.47 and AGA certified. They shall cover at least 70 percent of the air outlet area to minimize bypass air and to reduce surface temperature. Gas burners shall be electric ignition type.

2.1.3.5 Controls

a) Strategy. Provide industrial ventilation system controls and associated alarms to ensure that the system maintains contaminant control, space-specific balance and conditioning, a safe and healthy work environment, and notification of a system malfunction. To maintain design pressure in a ventilated space, controls must be provided. Because a given operation requires a constant exhaust volume flow rate, the replacement air must be controlled to maintain the design pressure in the ventilated space. Control the ventilated space pressure by modulating the quantity of replacement air. This can be accomplished with variable speed motors (which are relatively inefficient) or with magnetically coupled "eddy-current" drives between fan and motor (which are relatively costly), or fan inlet guide vanes. Control of replacement air quantity with dampers is inefficient and unreliable. Room air pressure sensors shall signal the appropriate control device. Place room differential pressure sensors away from doors, windows, and replacement air discharge. At all entrances to each ventilated space, provide signs that state:

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

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

b) Gauges and Sensors. Provide continuous monitoring of system performance. The minimum requirements are:

1) Differential pressure sensors across each replacement air filter section with a gauge readout, and set points on the gauge to trigger an alarm when the pressure drop across the filter exceeds the manufacturer's recommended value.

2) Replacement air system fan motor operating light.

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

4) Hood static pressure sensor, with a gauge mounted in a conspicuous place near the hood, with set points on the gauge to trigger an alarm when the static pressure is lower than the recommended range (as determined by baseline testing). Do not use the type of in-line flow sensor which measures the pressure drop across an orifice plate. Use only a static pressure tap and differential pressure gauge.

5) Differential pressure sensor across each exhaust air cleaning device with gauge readout, and set points on the gauge to trigger an alarm when the pressure drop across the device exceeds the manufacturer's recommended value.

6) Static pressure sensor at the exhaust fan inlet with gauge readout and setpoints on the gauge to trigger an alarm when the pressure is lower than the recommended range (as determined by baseline testing).

7) Exhaust air system motor operating light.

When a sensor indicates a malfunction, an alarm which is both audible and visible in the shop space, shall be triggered.

All gauges shall have clearly marked operating ranges and shall be located on an annunciator panel (except hood static pressure gauges). Provide a three-way valve at each gauge connection for cleanout and calibration, see Figure 14.

c) Annunciator Panel. Provide an annunciator panel to continuously monitor ventilation system performance. Centrally position the panel so it is accessible to shop personnel. The panel shall include, but not be limited to, all gauges (except hood static pressure gauges) described in para. 2.1.3.5. Position fan motor operating lights and interlock on-off switch on the panel. The interlock switches shall clearly show which exhaust and supply fans are interlocked, where multiple fans are used. The panel should indicate what action is to be taken when operation falls outside the prescribed ranges, e.g. "examine/replace filter on R.A. unit when this gauge reads outside indicated range".

2.1.3.6 Provision for System Testing. Provide ports to allow system performance testing. Position the ports as shown in Figure 15. Position each port in the same duct cross-sectional plane as the continuous monitoring sensor. In addition, provide access to the fan motor to measure voltage and amperage and fan speed. Specify that all testing shall be done in accordance with the ACGIH Manual, Section 9.

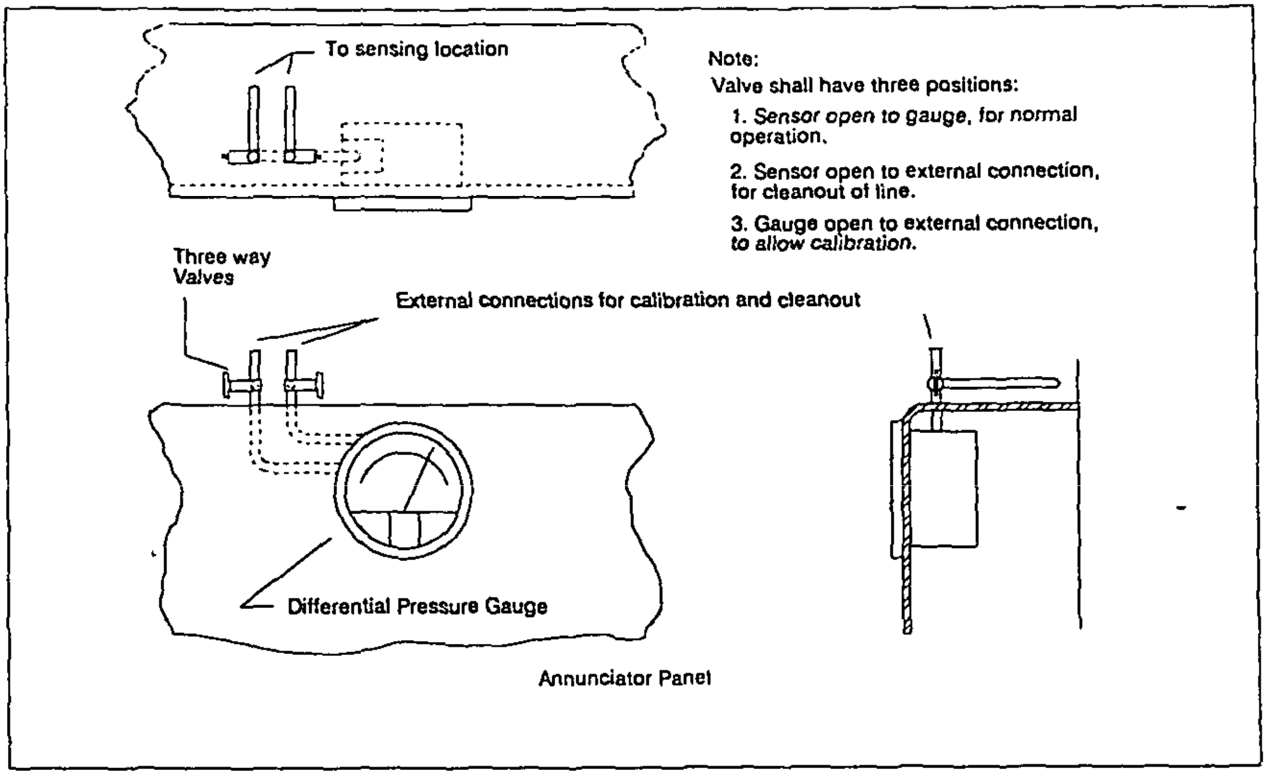
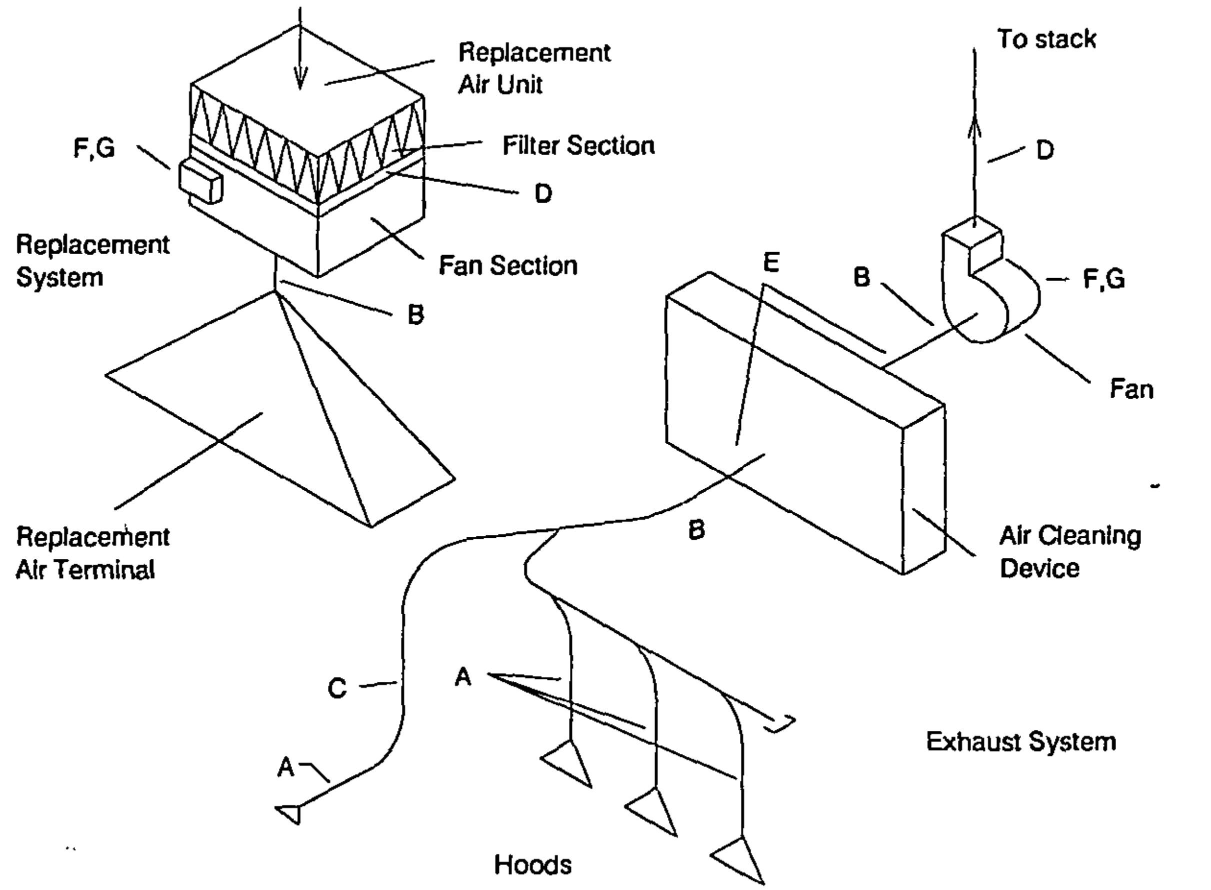


Figure 14
Annunciator Panel

2.1.4 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 Equipment Handbook. Rotary air wheel heat recovery systems are prohibited, even if they incorporate purge air sections. Refer to NAVFAC DM-3.03, Heating, Ventilating, Air Conditioning, and Dehumidifying Systems for further detail.

2.1.5 Noise Control. The primary means of protecting personnel from hazardous noise shall be through the application of engineering controls. It is cheaper to eliminate potential noise problems in the design or procurement stage for new equipment than it is to make retrofits or modifications after installation. Personal hearing protection is not an acceptable permanent control strategy.

2.1.5.1 Site Plan. Guidance for the selection of building sites for facilities at naval installations is contained in NAVFAC P-970, Protection Planning in the Noise Environment. The publication is intended to be a procedural tool for use by installation planners to develop an acceptable noise level. This guidance is applicable to existing or expected noise environments and describes noise reduction techniques that may render marginally acceptable locations suitable for use. These guidelines are also consistent with the Air Installation Compatible Use Zone (AICUZ) Program. Additional information is provided in AICUZ Program and in MIL-HDBK-1190,



Point	Measurement	Location of Measurement
A	Hood Static Pressure	3 Duct diameters from hood (flanged or plain hoods) 1 Duct diameter from hood (tapered hoods)
B	Velocity and Static P.	Branches and mains; preferably 7.5 diameters downstream from the nearest disturbance (elbow, entry, etc.) Also at fan inlet
C	Centerline VP	Small ducts (less than 3" dia.) only; take centerline VP
D	Static Pressure	Outlet of Exhaust Fan, Inlet of Replacement Air Fan
E	Static Pressure	Inlet and outlet of air cleaning device
F	Fan Motor Amps & Volts	Motor power box
G	Fan RPM	Fan shaft

Figure 15
Testing Point Locations

Facility Planning and Design Guide.

2.1.5.2 Specifications Specify the lowest noise emission level that is technologically and economically feasible. The objective is to ensure, if feasible, an A-weighted sound level of 84 decibels (dBA) or less at all locations in which personnel are required to work. It is not adequate to specify that individual pieces of equipment shall not produce noise levels in excess of 84 dBA. The sound power levels for each piece of equipment shall be determined. Use this information to predict the acoustic characteristics of the workspace and the resulting ambient noise level. If the predicted ambient noise level is in excess of 84 dBA, provisions for appropriate noise controls need to be added during design.

2.1.5.3 Architectural Design. Specific criteria applicable to architectural acoustics are contained in NAVFAC DM-1.03, Architectural Acoustics. The manuals in the DM-1 series provide practical information that will be useful in understanding and resolving acoustic problems. The acoustic environment of any kind of activity shall be determined in advance, both to fulfill the design goals and prevent the need for corrections at a later stage. The manuals discuss acoustic problems of sound transmission between spaces and the behavior of sound within spaces. However, these manuals are not intended to replace the architects' use of an acoustic noise control consultant.

2.1.5.4 Criteria. Additional criteria related to acoustics and vibration are listed below:

Subject	Source
Noise and Vibration Control of Mechanical Equipment	Tri-Service Manual NAVFACDM-3.10 Army TM-5-805-4 AFM 88-37
Industrial Noise Control Manual	DHEW (NIOSH) Publication No. 79-117
Human Engineering Design Criteria for Military Systems, Equipment, and Facilities	MIL-STD-1472C, Notice 3
Noise Control, a Guide for Workers and Employees	OSHA 3048

Section 3: ASBESTOS DELAGGING FACILITIES

3.1 Function. The asbestos delagging facility provides a complete workshop to delag (remove) asbestos insulation from piping and mechanical equipment during ship repair. The ventilation system design discussed in this section is for activities with extensive ongoing asbestos removal operations. The design takes into account 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 that are dispersed into the air will create a health hazard. 29 CFR 1910 prescribes protective measures for workers in these facilities, including respirator protection and impermeable outerwear. This regulation also prescribes wetting the asbestos material, with amended water (water containing a surfactant) insofar as practicable, to reduce the potential for asbestos fibers to become airborne. If a wet work practice is used, fiber release will be minimized, but the wet asbestos fibers may require a higher duct velocity than dry fibers. Care must be taken in the selection of an air cleaning device suited to a wet airstream.

3.2.2 Heat Stress. The physical nature of the work and the impermeable outer garments which workers wear can create worker heat stress. Where supplied air respirators are used, equip them with vortex coolers. Where supplied air respirators are not used, consider conditioning the replacement air. Consider also the use of "micro climate cooling" or "cool suits" mechanically cooled garments for individual workers.

3.2.3 Ergonomics. Human needs that workers must attend to during a work shift must be considered. The facility design shall allow them to take care of these without going through decontamination procedures each time. The arrows in Figure 16 show the flow of workers during a typical work shift. Workers enter the clean locker rooms through the administrative area. They put on protective outerwear and proceed to the shop area through corridors that bypass the dirty locker rooms. 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. Refer to Chief of Naval Operations Instruction (OPNAVINST) 5100.23, Navy Occupational Safety and Health (NAVOSH) Program Manual for further discussion of procedures during asbestos removal operations.

3.3 Typical Floor Plans. Design floor plans to meet the requirements of 29 CFR 1910.1001 and the previous paragraph. The typical layout shown in Figure 16 addresses these considerations.

3.4 Exhaust Air. Design the exhaust air system to generate a minimum capture velocity at the limits of the workpiece of 150 fpm (0.765 m/s) to ensure control of all contaminants.

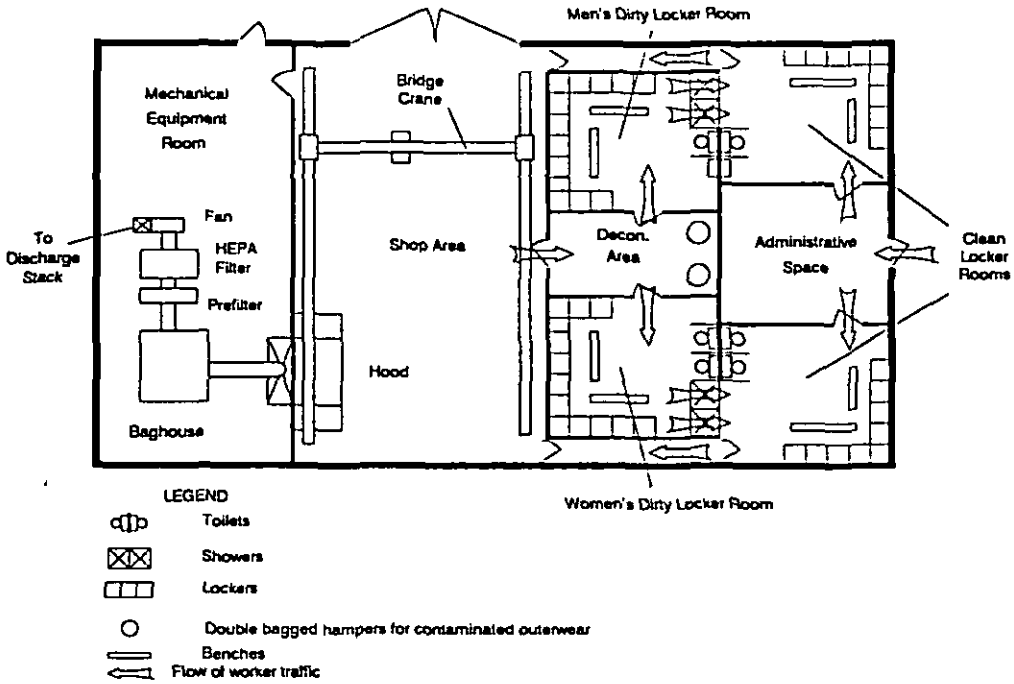


Figure 16
Typical Delagging Facility Floor Plan

3.4.1 Hood Design. The more completely an asbestos delagging hood encloses the workpiece, the more effectively it can control the airborne fibers. Avoid small portable hoods with flexible ductwork because they are inconvenient to move and therefore do not guarantee protection.

Figure 17 and Figure 18 illustrate two optimum hood design alternatives for asbestos delagging facilities. The hood design in Figure 17 consists of a worktable with a circular area in its center that is mounted on sealed bearings and is free to rotate to allow easy turning of heavy workpieces. This design is best for high profile workpieces (e.g., boilers, pumps). The hood backdrafts through the slots and into an exhaust plenum.

The hood in Figure 18 is best for removing small pieces of lagging from low profile workpieces such as piping. The hood consists of a worktable with a grating strong enough to support the heaviest expected workpiece. This hood downdrafts small pieces of lagging through the grating. Even flow over the grating is provided by the perforated plate design below the grating.

There are two cleanout doors on the front and sides of the hoods to facilitate removal of asbestos pieces. Small cutouts in the two outer corners of the worktable are used for double-bagged containment of large pieces of lagging removed from the workpieces. Equip hoods with stands and swinging baffles on each end to accommodate long workpieces (e.g., pipes). The top

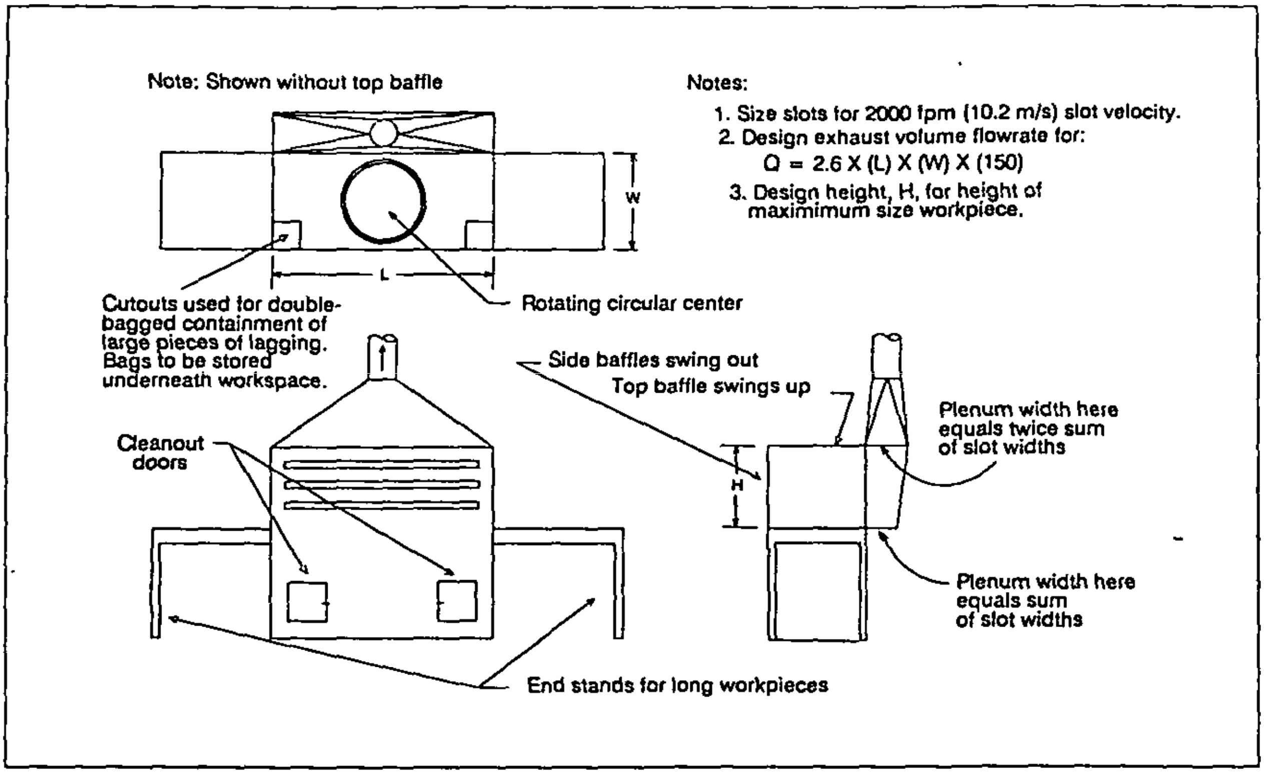


Figure 17
Exhaust Hood for High Profile Workpieces

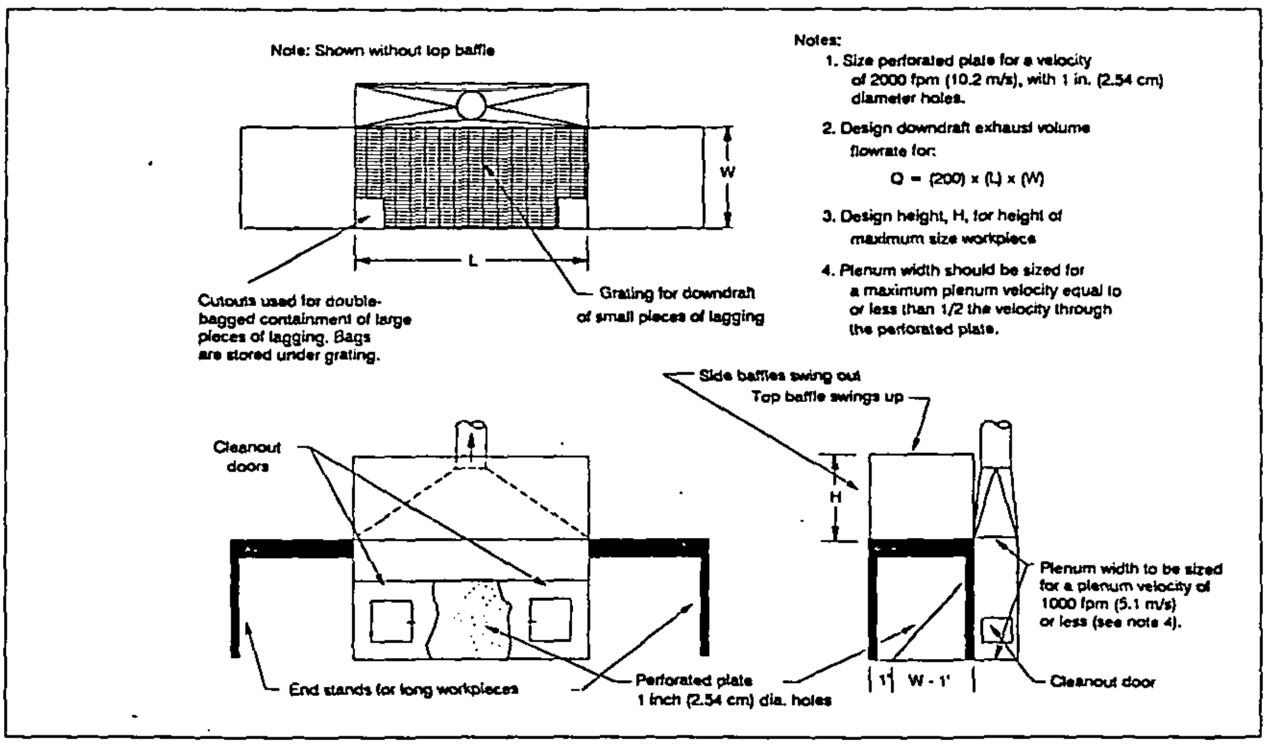


Figure 18
Exhaust Hood for Low Profile Workpieces

baffle shall swing up to allow access from overhead cranes. Because the worktable needs to be ventilated only where delagging is performed, the ventilated section shall be no longer than 8 ft (2.44 m). This will minimize the ventilation rate and conserve energy. Design all slots and perforated plate open area for a velocity of 2000 fpm (10.2 m/s). The plenum velocity shall not exceed one-half of the slot or perforated plate open area velocity. Design the hood-to-duct transition with an included angle of no more than 90 degrees.

3.4.2 Ductwork and Fans

3.4.2.1 Ductwork. The minimum transport velocity for asbestos fibers is 5,000 fpm (25.4 m/s). Size exhaust ductwork for asbestos delagging facilities to provide this minimum velocity in all ductwork. The high velocity is necessary because the practice of wetting the fibers makes them heavier and more difficult to transport. Specify duct hangers that have sufficient strength to support the ductwork should it become half filled with material. Provide cleanout doors adjacent to every bend and vertical riser. In horizontal duct runs, cleanout door spacing shall not exceed 12 ft (3.66 m) for ducts that are 12 in. (0.305 m) or less in diameter. Larger ducts shall have a cleanout door spacing not greater than 20 ft (6.0 m). Refer to para. 2.1.3.1 for general duct considerations. Cleanout doors shall not be located on the bottom side of ductwork.

3.4.2.2 Fans. Backward curved airfoil-type centrifugal fans are recommended for this application. Backward inclined centrifugal fans are less efficient but still acceptable. Refer to para. 2.1.3.2 for general considerations.

3.4.3 Air Cleaning Devices. Figure 19 illustrates the required sequence of air cleaning devices. The baghouse, which contains a fabric filter collector, is followed by prefilters and high-efficiency particulate air (HEPA) filters. HEPA filters are costly and, therefore, must be protected by prefilters. The baghouse and prefilter shall have weight arrestance efficiency of not less than 99.9 and 70 percent, respectively, in accordance with the ASHRAE Standard 52-76 Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter. The HEPA filters shall be of the "bag in, bag out" style which allows for safe replacement of the filter element without exposure to asbestos. HEPA filters shall have an efficiency of 99.97 percent on 0.3 micron particles, as measured by MIL-STD-282, Notice 3, Filter Units, Protective Clothing, Gas-Mask Components and Related Products: Performance Test Methods. All collectors shall deliver the collected asbestos to a common pickup point to minimize the risk of exposure. Provide a double acting valve at each baghouse hopper throat. Refer to ACGIH Manual, Chapter 4. To minimize the number of collection points, use a single-chamber, shaker-type baghouse.

3.4.4 Weather Stack Design and Location. Use a vertical discharge stack with a no-loss stackhead. Refer to para. 2.1.3.3 for further details.

3.4.5 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 required by 29 CFR 1910.1001. Central or stationary vacuum cleaning systems consist of a

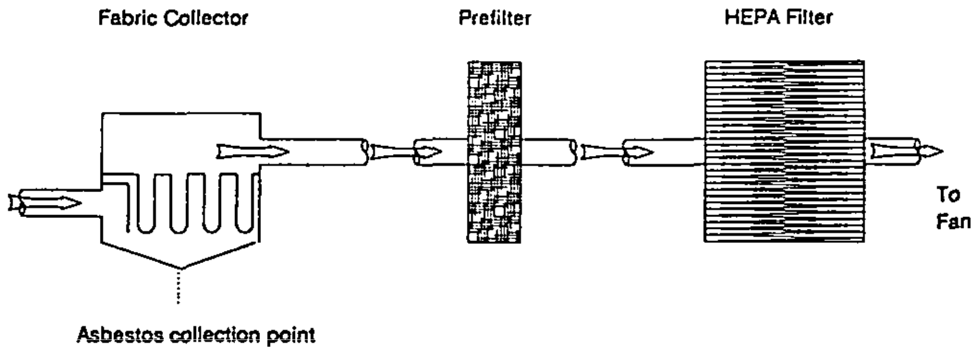


Figure 19
Sequence of Air Cleaning Devices for Asbestos Delagging

permanently installed, motor driven exhauster interconnected with one or two bag-type separators. The separator is connected to rigid tubing extending throughout the plant and terminating with inlet valves at the various workstation locations. Provide flexible hose connections to allow workers to conduct shop cleanup and to decontaminate their protective outerwear.

The high terminal velocity of the contaminant stream produced by various hand tools necessitate the use of local exhaust hoods and high-velocity exhaust takeoffs for each tool. Refer to Table 1 for minimum flow rate and vacuum hose sizes. The ACGIH manual illustrates several examples of power tool hoods, and lists the required capture velocity for various specific operations. The most important consideration in vacuum system design is to ensure that the proper capture velocity is produced at each local exhaust hood. Design vacuum exhaust hoods to pick up contaminants as near as possible to the point of generation. Well-designed vacuum systems pick up contaminants within 1/2 in. (12.7 mm) of the source. Design the pickup airstream to have a velocity of two to three times the generation velocity for particles of 20 to 30 microns, four to five times the generation velocity for particles up through 300 U.S. standard mesh, and six to eight times the generation velocity for particles up to 20 U.S. standard mesh. The air volume required shall be designed based on not less than two parts air to one part of asbestos to be captured by weight.

The vacuum hose length shall not exceed 25 ft (7.6 m). As a general rule, a distance of 30 to 35 ft (9 m to 10.7 m) between two inlet valves for use with a 25 ft length of hose is considered ideal. The hose size depends on the air volume per hose, the number of hoses to be used simultaneously, and the correct air velocities for conveying the material to the separators. Single-ply, lightweight thermoplastic or polyvinyl chloride (PVC) flexible hose shall be used in the system, but should be limited wherever possible. The vacuum system shall use a multistage centrifugal blower. The size of the blower shall be designed according to the total system pressure loss associated with the total number of hoses to be used simultaneously, and for the maximum simultaneous exhaust flow rate entering the inlet of the blower.

Table 1
Minimum Volumes and Vacuum Hose Size for Asbestos Operations

Hand tool	Flow rate (CFM)	Hose Size (in.)
Pneumatic chisel	125	1-1/2
Radial wheel grinder	150	1-1/2
Conewheel grinder, 2 in.	150	1-1/2
Cup stone grinder, 4 in.	200	2
Cup-type brush, 6 in.	250	2
Radial wire brush, 6 in.	175	1-1/2
Handwire brush, 3 x 7 in.	125	1-1/2
Rip out knife	175	1-1/2
Rip out cast cutter	150	1-1/2
Saber saw	150	1-1/2
Saw abrasive, 3 in.	150	1-1/2
General vacuum	200	2

Reference: Hoffman Air and Filtration Systems, Centrifugal Compressor Engineering.

Note: Locate tool vacuum hose connection on the ends of the worktable underneath the stands.

The blower shall feed directly into the baghouse used by the industrial exhaust system (see Figure 20). This minimizes the number of asbestos collection points. The blower shall be preceded by a prefilter and HEPA filter to prevent it from becoming contaminated. Design the vacuum system duct to balance with the exhaust system duct where the two systems connect. Design the entire vacuum system in accordance with NAVFAC DM-3.5, Compressed Air and Vacuum Systems.

3.5 Replacement Air. Design replacement air systems with fan inlet guide vanes, variable speed motors, or "eddy current clutches" units to maintain a negative pressure (relative to the atmosphere) ranging from -0.05 to -0.10 in. water column (wc) (12.4 Pa to 24.9 Pa) in the shop spaces. Maintain the protective clothing decontamination areas, the equipment room and the dirty locker rooms at a negative pressure (relative to the atmosphere) ranging from -0.01 to -0.04 in. wc (2.49 Pa to 9.96 Pa). Maintain the clean spaces at a positive pressure (relative to the atmosphere) ranging from +0.02 to +0.05 in. wc (+4.98 to +12.4 Pa). For further replacement air system criteria, refer to para. 2.1.3.4.

3.5.1 Quantity and Distribution. In the work space, distribute air to produce a laminar air-flow from supply to exhaust. The vertical supply method is preferred. Design a dropped ceiling throughout the dirty space. Use perforated sheet metal with 3/8-in. (9.5 mm) holes. This dropped ceiling must be set above the overhead crane, incorporate flush-mounted light fixtures, and incorporate fire suppression systems.

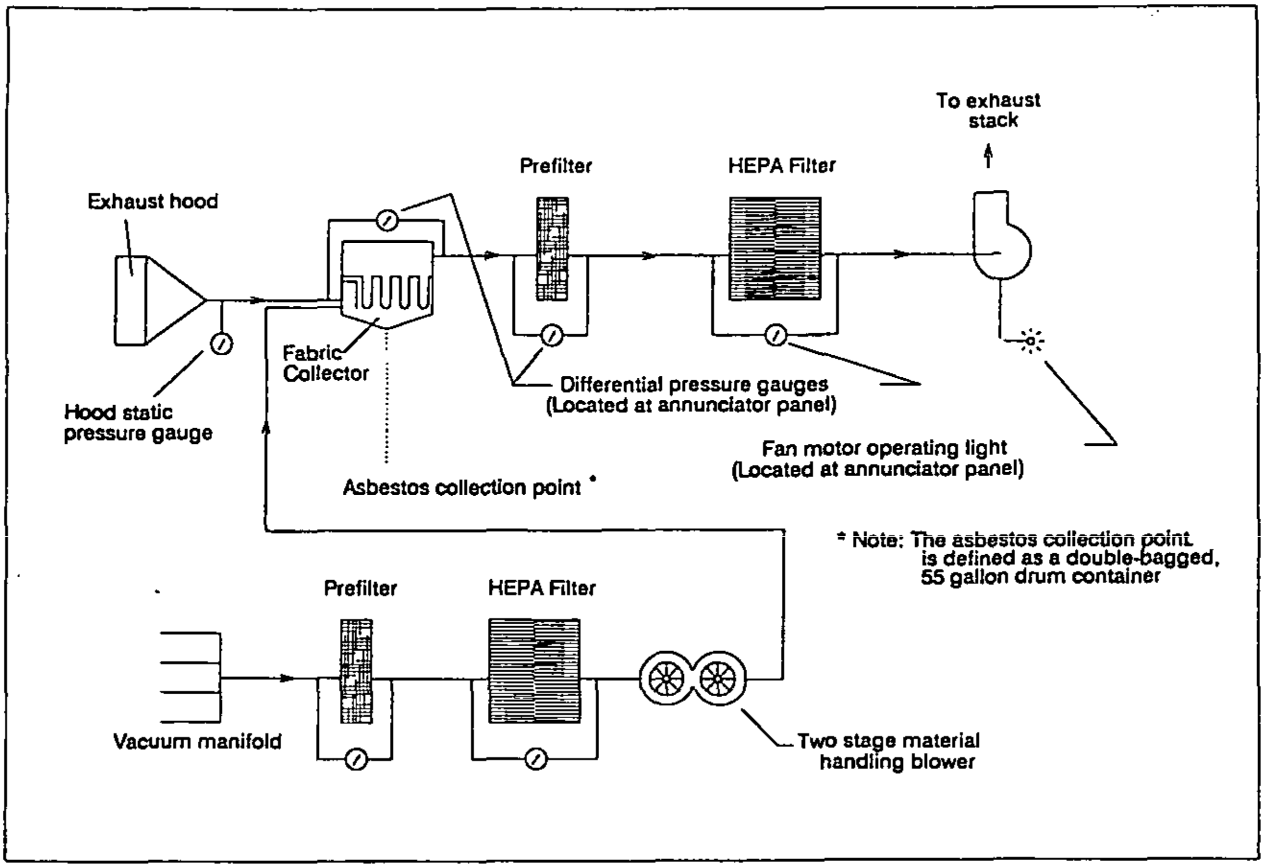


Figure 20
Exhaust and Vacuum System Schematic Diagram

3.5.2 Heating and Air Conditioning. Provide each ventilated space with a dedicated replacement air system. Temper the air in accordance with NAVFAC DM-3.03. Do not recirculate exhaust air.

3.6 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria. Position an annunciator panel at the entrance to the dirty space so that the operator can monitor the operation of the replacement air system, the exhaust air system, and the balance between the dirty and clean spaces. Provide differential pressure sensors at locations that are representative of average static pressure in each controlled space. This will ensure that the desired differential pressures are maintained. If the operation varies from the stated ranges, a timer shall be triggered. If the system cannot correct the difficulty within 60 seconds, the alarm shall be triggered. If the difficulty is corrected within the allotted time, the timer shall be automatically reset. Multiple alarm beacons may be required if the operator's view is obscured during delagging. The negative pressure in the shop shall be monitored continuously by a strip-chart recorder so that any loss of negative pressure will be noted. Tie the power supply for the hand tools to the interlock on-off switch for the ventilation system to prevent the use of hand tools without ventilation controls.

3.7 Safety and Health Items. Federal Regulation 29 CFR 1910.1001(d)(2) prescribes the permissible respirator types for asbestos handling installations. The potential concentration of asbestos fibers in asbestos delagging facilities warrants the use of type "C" supplied-air respirators, pressure demand class. Such respirators require an external supply of compressed air. Backup units on supplemental air purifying respirators fitted with HEPA filters (type H) shall be provided if air supply is interrupted. Refer to Guide to Respiratory Protection in the Asbestos Abatement Industry for further information on respiratory protection. Design breathing air in accordance with NAVFAC DM-3.5. Provide several convenient connection points for the respirator hoses in the work area to allow freedom of movement for the workers. Ensure that the connection for breathing air and vacuum tool connections, if used, are incompatible. This will prevent the use of impure air for breathing purposes. Refer to 29 CFR 1910.134, for additional requirements that will impact the facility design (e.g., respirator cleanup and storage areas).

Section 4: OTTO FUEL II FACILITIES

4.1 Function: MK-46 and MK-48 torpedo facilities maintain, prepare, and test torpedoes. Otto Fuel II is a toxic monopropellant used in the MK-46 and the MK-48. Naval Medical Command Instruction (NAVMEDCOMINST) 6270.1, Health Hazards of Otto Fuel II, gives detailed information on the dangers of exposure to Otto Fuel II. Refer to NAVFAC MIL-HDBK 1028/3 Maintenance Facilities for Ammunition, Explosives, and Toxics for considerations which may impact the design of industrial ventilation systems for these facilities. Torpedo size differences and maintenance procedures dictate the use of different floor plans and exhaust hood design for the two facility types. Refer to Naval Sea Systems Command (NAVSEA), NAVSEA OP5, Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping Vol 1, Rev. 4, for the specific order of operations. In all cases, hazardous vapor, i.e., Otto Fuel II, products of combustion, and solvent vapor, must be removed by the industrial ventilation systems.

4.2 Operational Considerations. An operation is "dirty" when it creates a potential for personnel exposure to one or more of the following:

a) Otto Fuel II
b) Agitine - the parts cleaning solvents used in MK-46 shops
c) Hydrogen cyanide - a product of combustion in the torpedoes
d) Mineral spirits - a parts cleaning agent used in MK-48 shops

During dirty operations, personnel wear disposable, impermeable protective clothing. At the end of the work period, personnel remove and discard protective clothing before exiting from the dirty space. Provide ventilated waste cans, as shown in Figure 21, for contaminated clothing and wipes. There is a potential for accidental spillage of Otto Fuel II during fueling operations. Because of this, design each dirty area to have a slightly negative air pressure relative to adjacent areas. This will help to contain any Otto Fuel II vapor which is not immediately captured by the exhaust hoods. During emergency procedures (e.g., Otto Fuel II spill), workers suit up with protective clothing and self-contained breathing apparatus before entering the contaminated area. After the emergency is controlled, the workers discard the outer layer of protective clothing and go to the showers. The floorplan of the facility should allow this while minimizing the potential for contaminating areas outside the dirty areas. The physical nature of the work, and the use of protective clothing increases the potential for heat stress. Consider cooling the replacement air to reduce this potential. For complete operational considerations, refer to NAVSEA S6340-AA-MMA-010, Otto Fuel II Safety, Storage, and Handling Instructions.

4.3 Exhaust Air

4.3.1 MK-46 Ventilated Spaces. The MK-46 floor plan shown in Figure 22 optimizes the work-flow while allowing the ventilation system to control airborne contaminants. Figure 23 shows an elevation view of this floor plan.

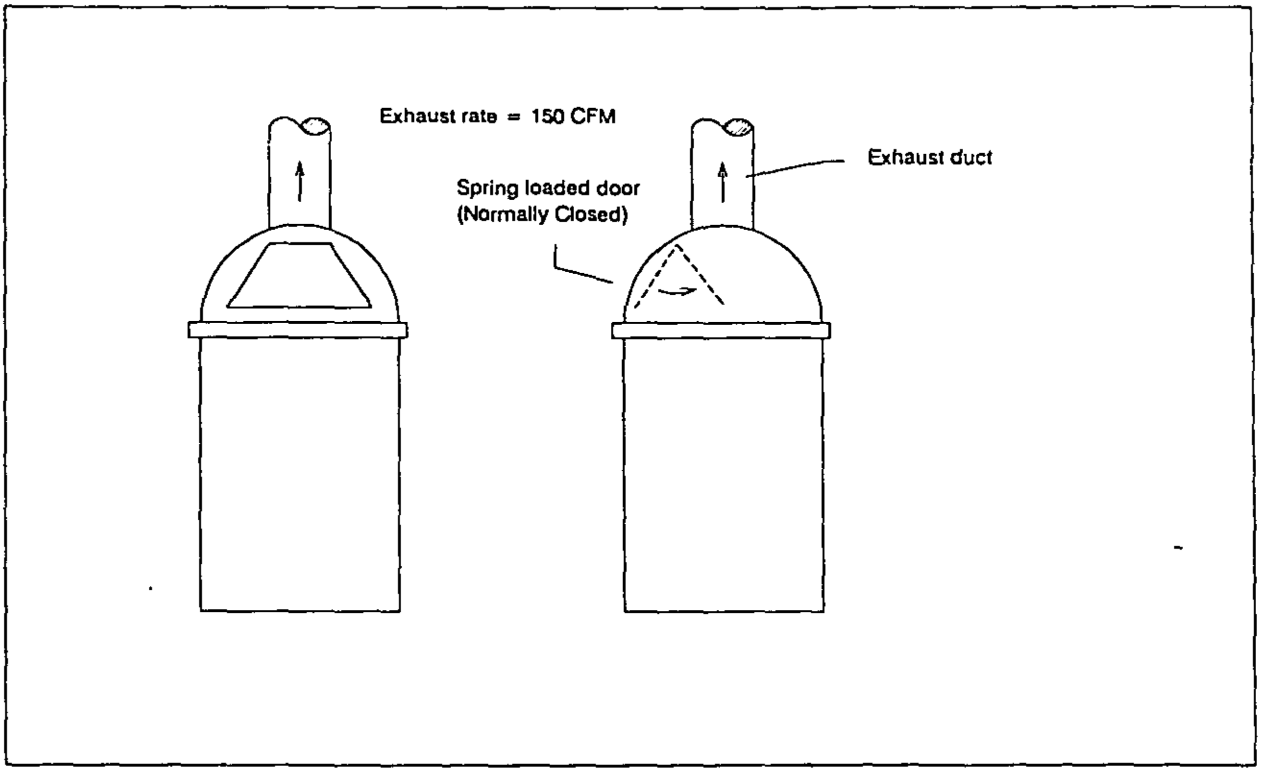


Figure 21
Ventilated Wastecan

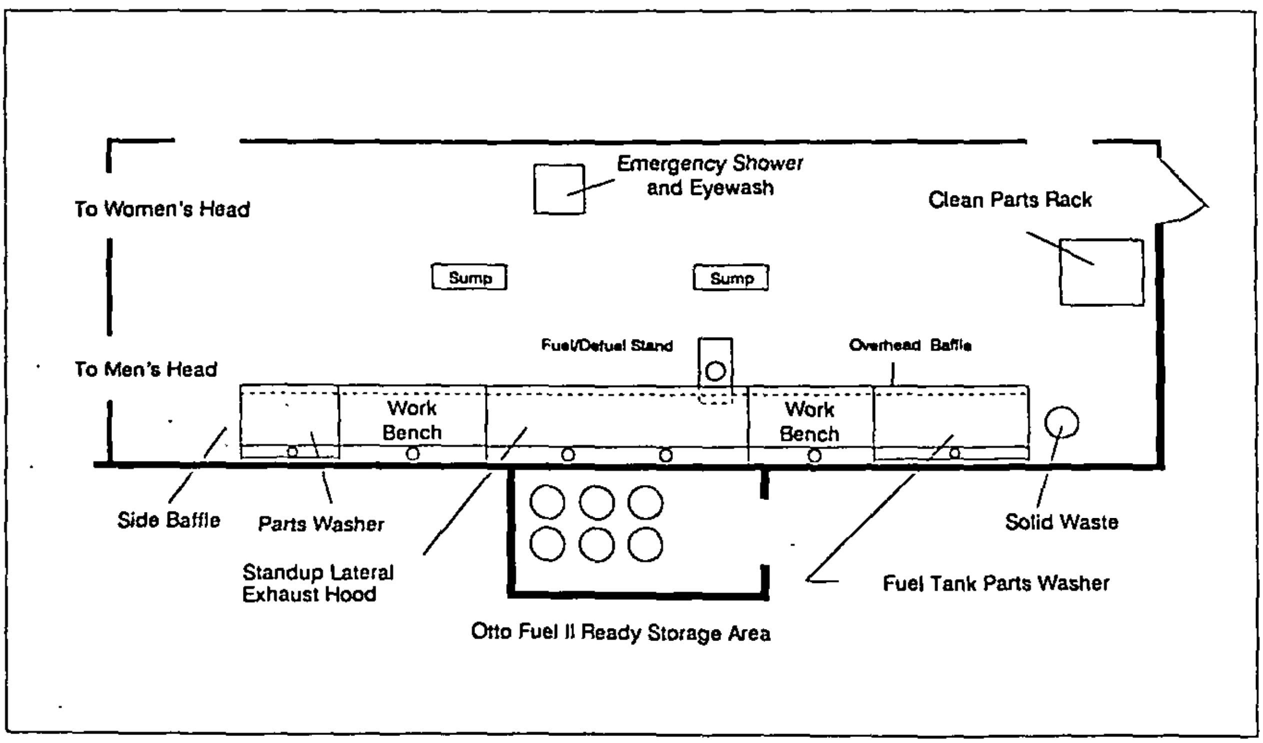


Figure 22
Typical Layout for MK-46 Fuel/Defuel and Afterbody Breakdown Room

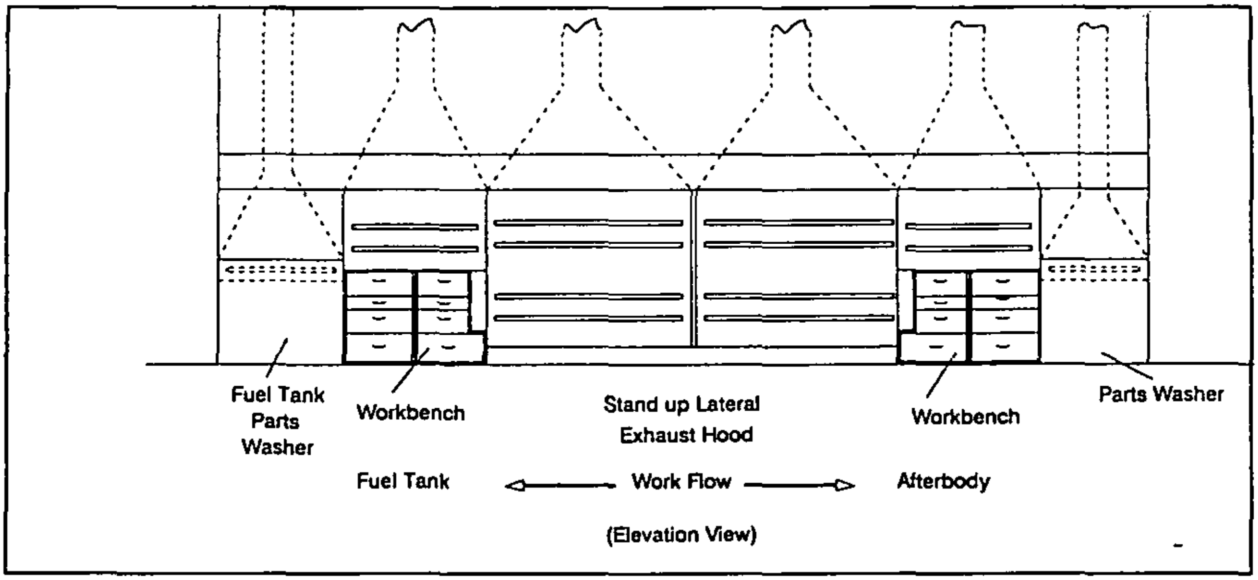


Figure 23
Series of Hood in MK-46 Shop (elevation view)

4.3.1.1 MK-46 Standup Backdraft Hood. The standup backdraft hood is used in fueling, defueling, and afterbody breakdown operations. Figure 24 illustrates the recommended design for this hood. When the fuel section and the engine section are uncoupled, there is fuel remaining in the lines and components of the engine section. This is in addition to the residual amount in the fuel tank. Design these hoods using the following criteria:

a) Design for a capture velocity of 150 fpm (0.765 m/s). Because of the side and top baffles, the face velocity is the same as the capture velocity.

b) Use slots sized for 2000 fpm (10.2 m/s), covered with wire mesh.

c) The plenum velocity shall not exceed one-half the velocity through the perforations.

d) Design hood transitions with an included angle no greater than 90 degrees. The base of the takeoff shall be no longer than 8 ft (2.44 m). If the hood is longer than 8 ft, an additional takeoff is required for each additional 8 ft.

e) Specify baffles to control airflow from the sides and top of the hood bank as shown in Figure 24.

4.3.1.2 MK-46 Workbench Hood. After defueling and decoupling, the fuel section and the engine section are lifted onto two different ventilated workbenches. Stabilizing baffles are removed from the fuel tank, inspected, and wiped clean before being loaded into the parts washer. The engine section containing the engine, fuel pump, and sea-water pump is dismantled, inspected, and then loaded into the parts washer. Design a backdraft exhaust hood, as illustrated in Figure 25, to control contaminants generated by these workbench operations.

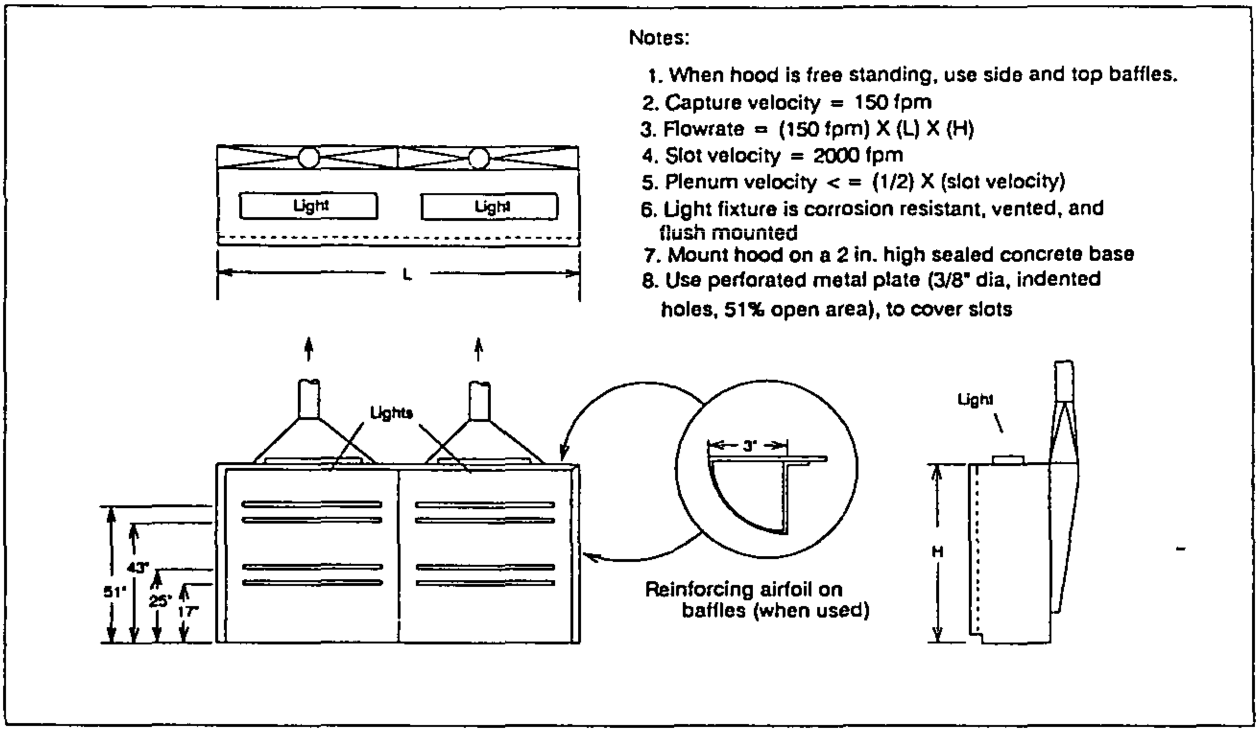


Figure 24
MK-46 Standup Backdraft Hood

4.3.1.3 MK-46 Parts Washer Hood. Torpedo components are cleaned of oils and excess Otto Fuel II in a solvent tank (parts washer) containing a cleaning compound. The parts washer cover must automatically close in case of fire in compliance with NFPA 34, Dipping and Coating Processes Using Flammable and Combustible Liquids. Therefore, the parts washer must be large enough to completely contain the workpiece. Specify that the washer be 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 26 illustrates an optimum exhaust enclosure design for this hood.

4.3.2 MK-48 Ventilated Spaces. The floor plan shown in Figure 27 optimizes the work-flow while allowing the ventilation system to control airborne contaminants. Detailed MK-48 exhaust hood drawings should be obtained from Naval Underwater Systems Center, Code 8113.

4.3.2.1 MK-48 Afterbody Teardown Hood. The afterbody teardown hood is used in the afterbody breakdown operations. Figure 28 illustrates the recommended design for an afterbody teardown hood. When the fuel section and the engine section are uncoupled, there is fuel remaining in the lines and components of the engine section. This is in addition to the residual amount in the fuel tank. Specific design criteria for standup hoods are as follows:

a) Design the hood with baffles on the top and side that form a booth.

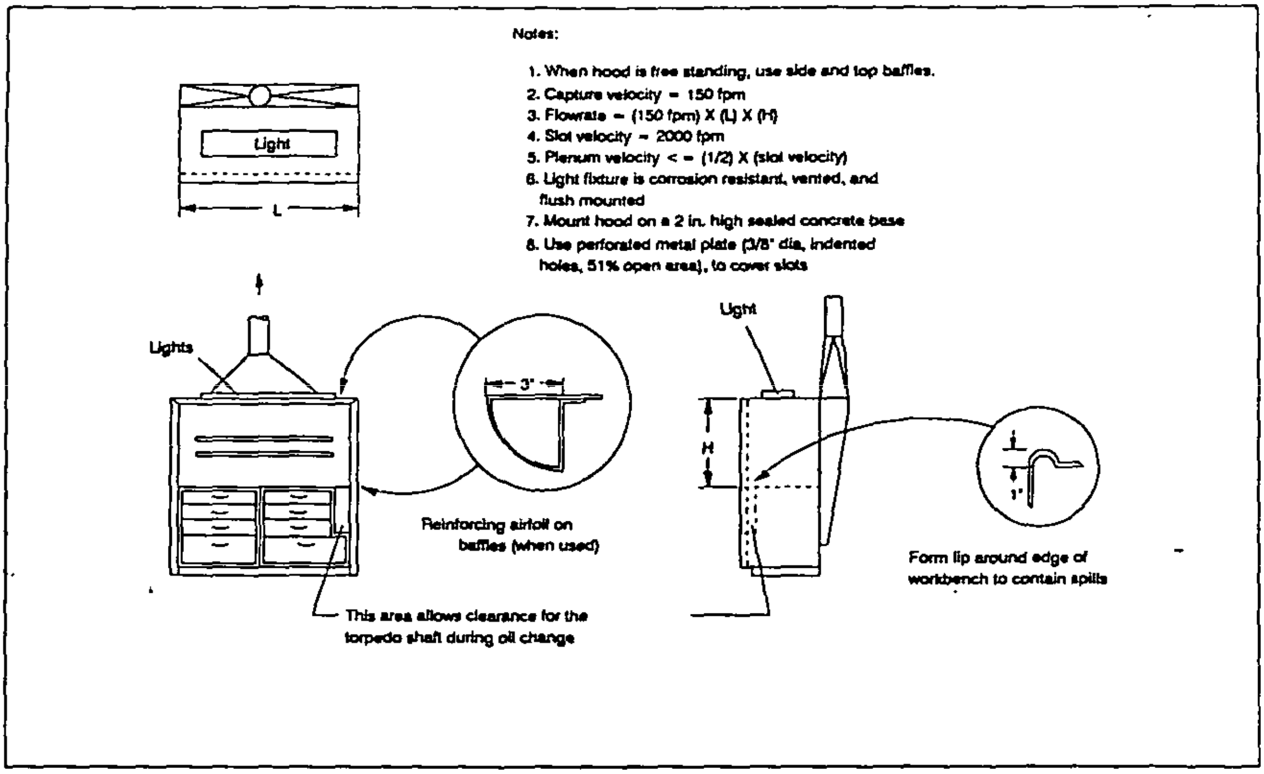


Figure 25
MK-46 Work Bench Hood

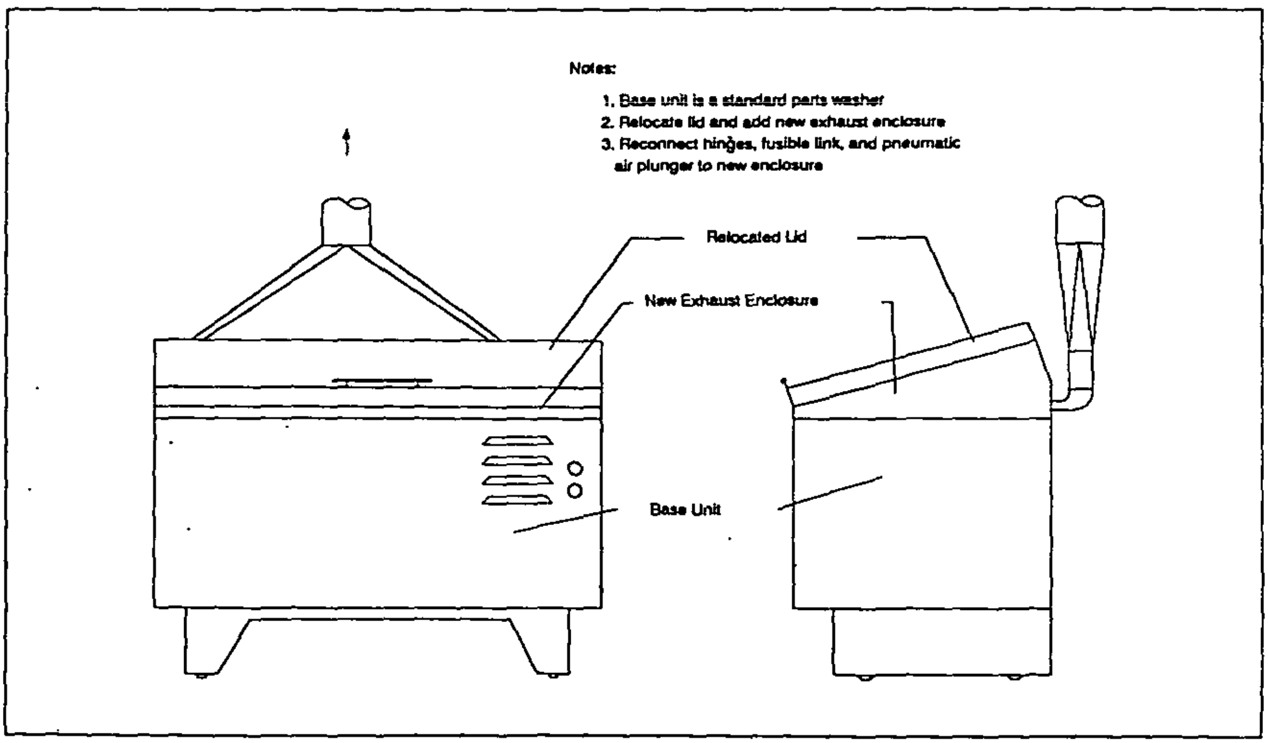


Figure 26
MK-46 Part Washer Hood

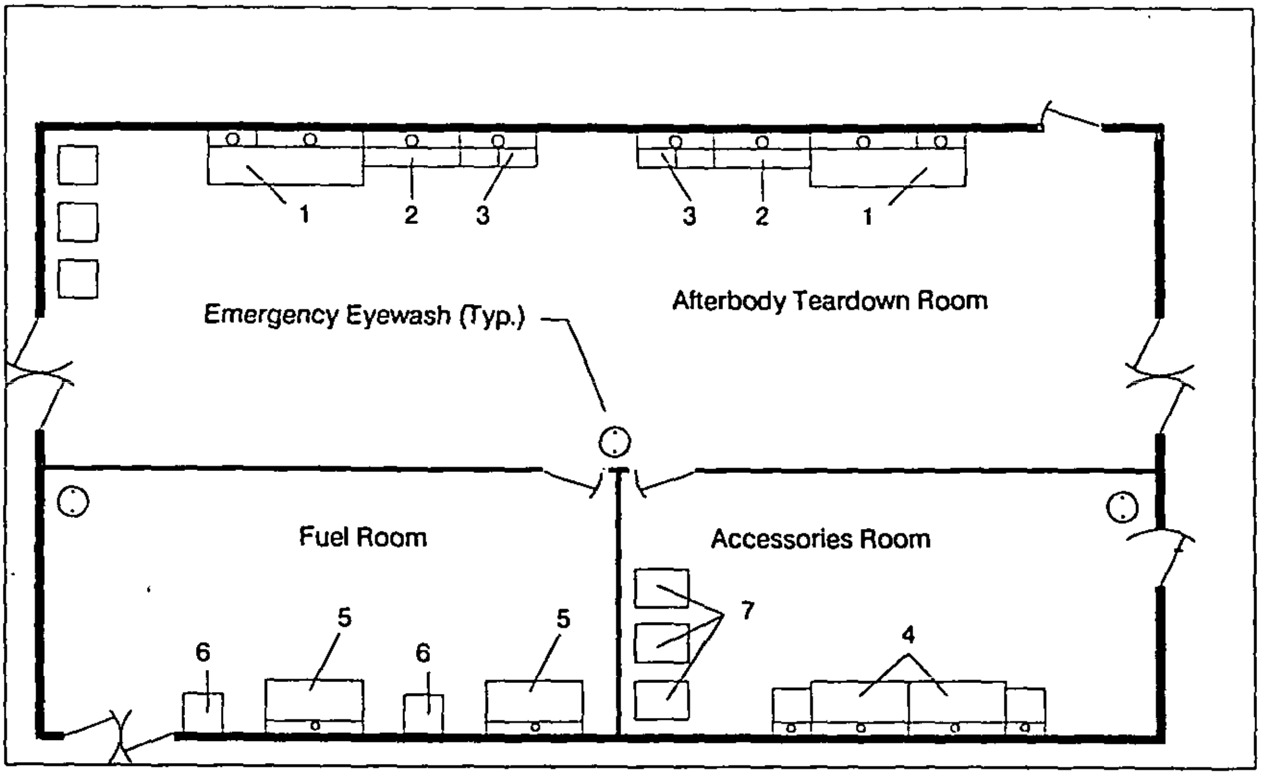


Figure 27
Typical MK-48 Ventilated Space Layout

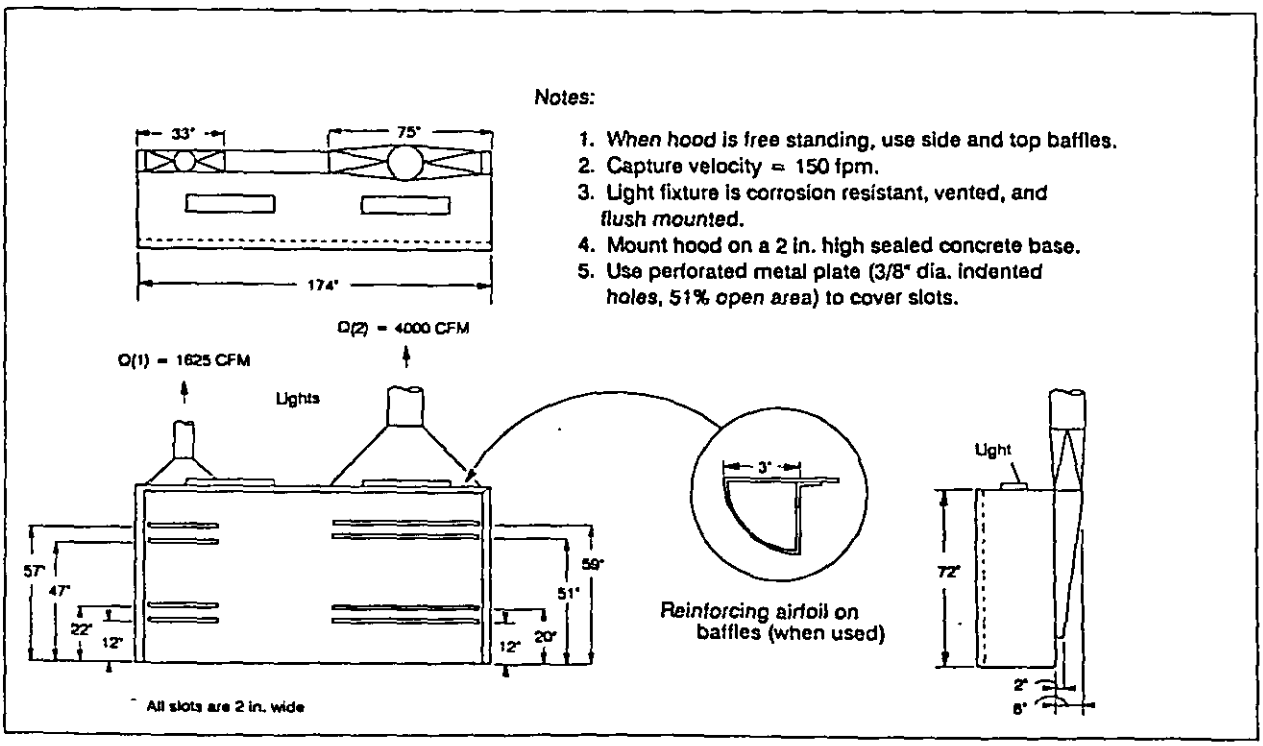


Figure 28
MK-48 Afterbody Teardown Hood

b) Specify a 3 in. (76 mm) airfoil on the outer edge of the hood. The airfoil, bent inward from the baffle, is required to provide an airfoil effect and to prevent turbulence and backflow.

c) Install lighting that is vented and flush-mounted in the overhead baffle, see Figure 28.

d) 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.

4.3.2.2 MK-48 Workbench Hood. After defueling and decoupling, the fuel section and the engine section are dismantled, inspected, and then loaded into the parts washer. Design a workbench exhaust hood as illustrated in Figure 29 to control contaminants generated by these operations. Include the following criteria in specifications for workbench hoods:

a) Provide a 72 x 24 in. (185 x 60 cm) stainless steel workbench top to support the whole exhaust hood. For dimensions of the hoods, refer to Figure 29.

b) Specify a 3 in. (76 mm) airfoil, rotated inward to turn escaping air back into the booth.

c) Install lighting that is vented and flush mounted in the top of the exhaust hood.

4.3.2.3 MK-48 Parts Washer Hood. Torpedo components are taken to the parts washers and are cleaned of oils and excess Otto Fuel II. The parts washers shall be specified and/or modified to accommodate the exhaust hood systems as illustrated in Figure 30. Include the following criteria in the specifications for the parts washers:

a) Provide a new fabricated enclosure to mount on top of parts washer.

b) Relocate cover with a pneumatic plunger and fusible link assembly.

c) Provide automatic switch to turn exhaust fan on when cover is opened and to turn exhaust fan off when cover is closed.

4.3.2.4 Work-flow in Afterbody Teardown Room and Accessories Room. Figure 31 illustrates the work-flow in both the afterbody teardown room and the accessories room with the proper sequence of hoods.

4.3.2.5 MK-48 Refueling Hood. During fueling, hoses from the fueling equipment are connected 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, an enclosing-type hood is used to reduce ventilation rates and decrease the potential for exposure to a spill during fueling. Design the hood as illustrated in Figure 32. Include the following criteria in the specifications for the refueling hoods:

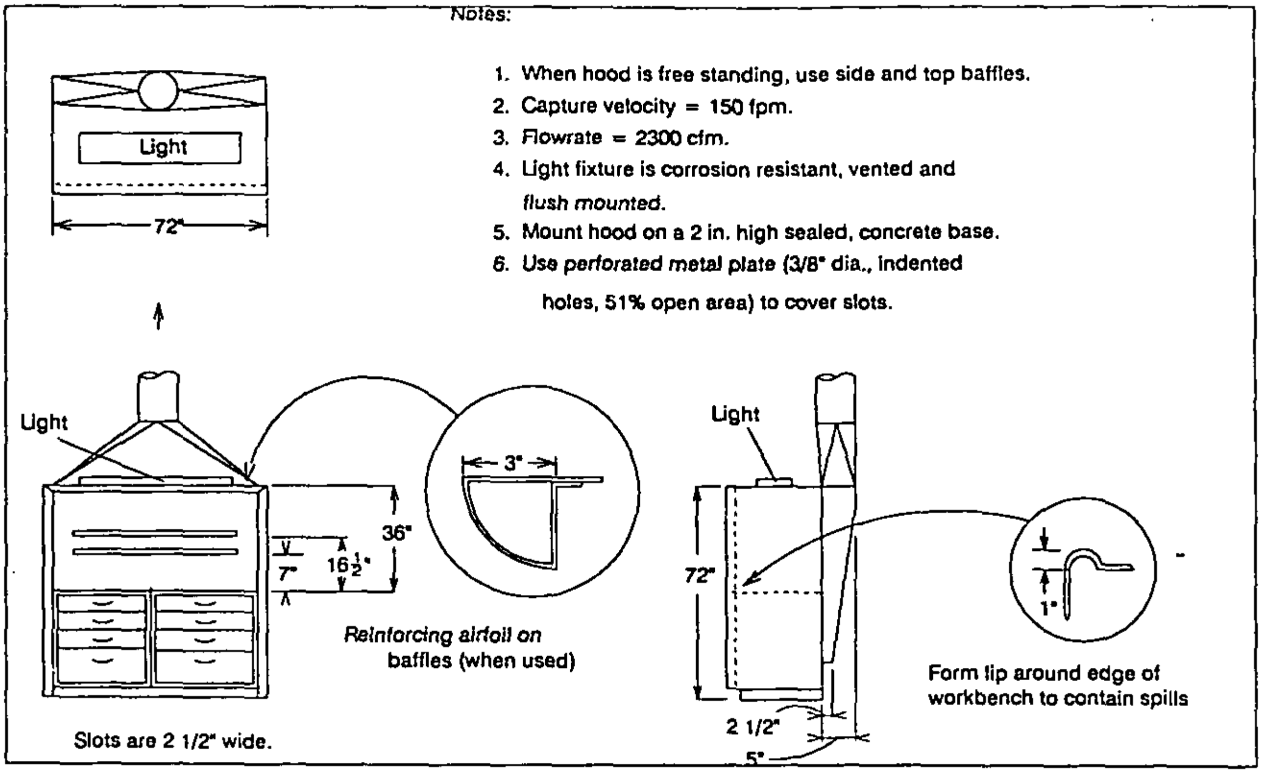


Figure 29
MK-48 Work Bench Hood

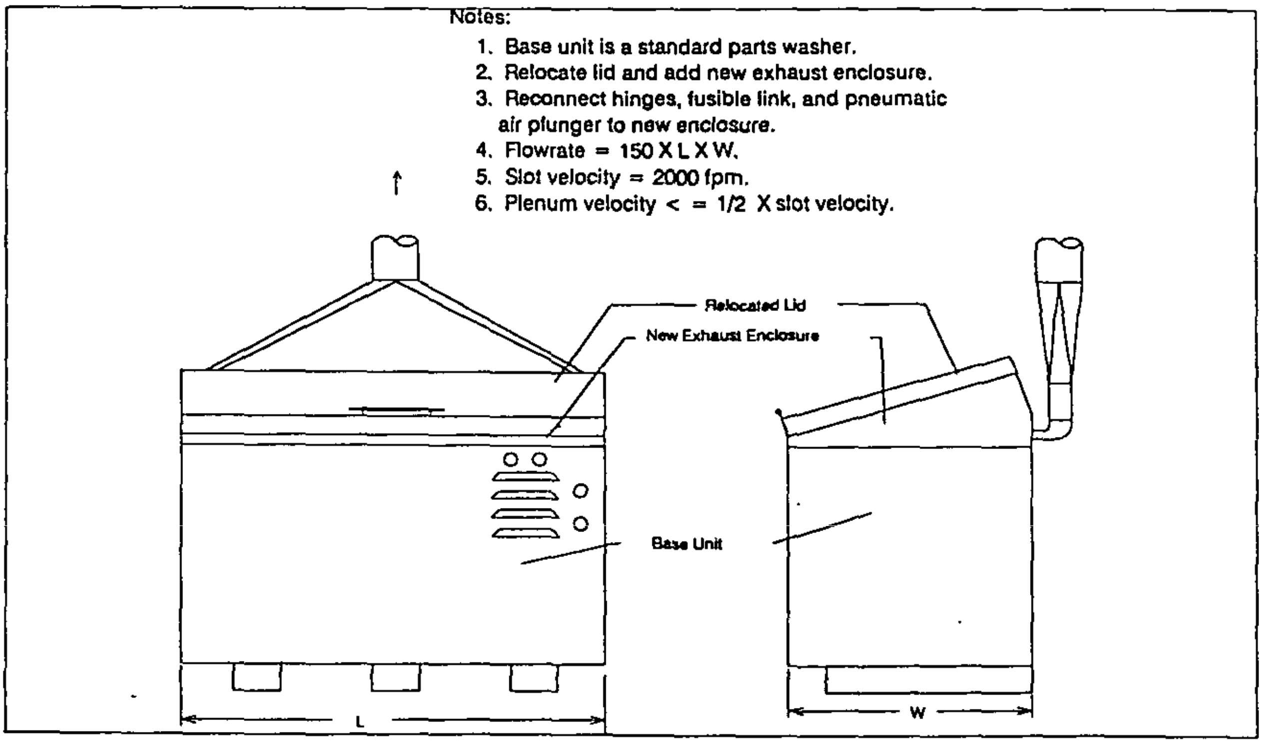


Figure 30
MK-48 Part Washer Hood

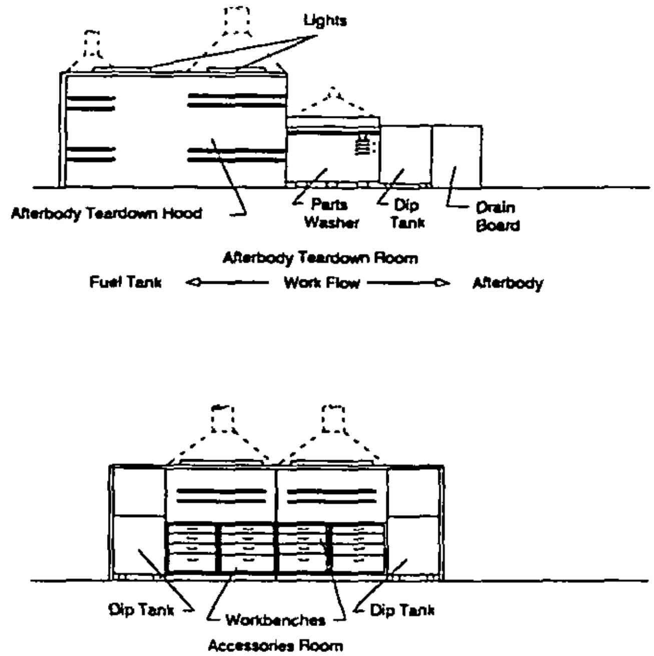


Figure 31
MK-48 Sequence of Hoods in Afterbody Teardown and Accessories Rooms

a) Specify a 3 in. (76.2 mm) airfoil rotated inward to turn escaping air back into the booth.

b) Install lighting that is vented and flush-mounted in the top of the exhaust hood.

c) 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.

4.3.3 Ductwork and Fans. All criteria in para. 2.1.3 apply to both MK-46 and MK-48 shops.

4.3.3.1 Ductwork. Design ductwork in accordance with criteria established in para. 2.1.3.1 of this handbook, SMACNA Guide 15d, and the following:

a) Fabricate all ductwork in contact with Otto Fuel II vapors with (black) carbon steel. Butt welds, angle or bar flanges, are required for joints.

b) Size the duct to maintain a minimum transport velocity of 2,500 fpm (12.7 m/s).

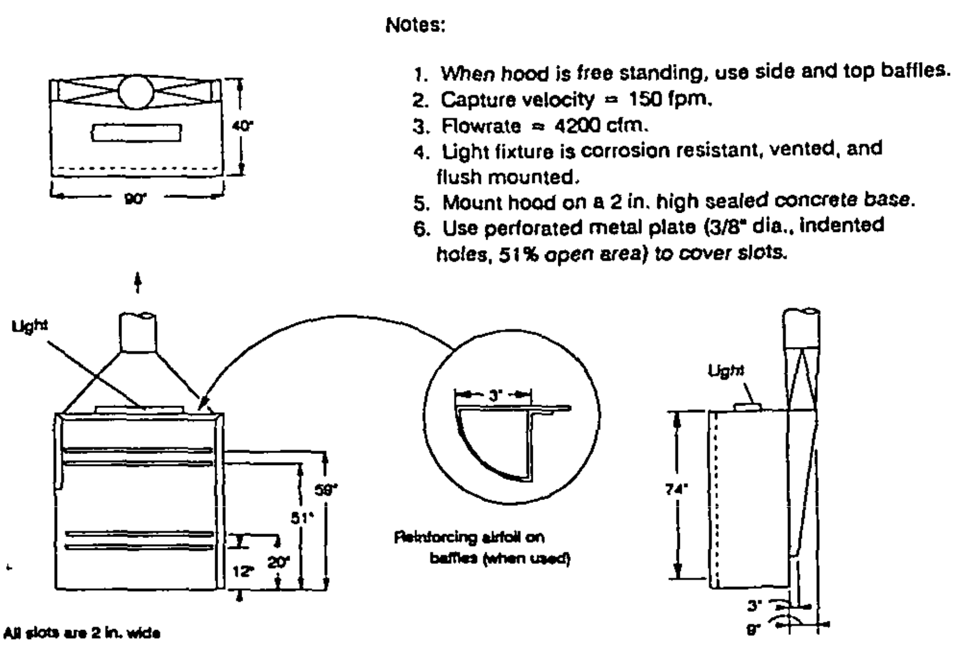


Figure 32
MK-48 Refueling Hood

4.3.3.2 Fans. Select fans in accordance with criteria in para. 2.1.3.2. Backward inclined airfoil fans are the most efficient and quiet, but a centrifugal fan with backward inclined blades is also acceptable.

4.3.4 Air Cleaning Devices. Due to the quantities and types of contaminants generated by these processes, there is no requirement at this time for air pollution control equipment.

4.3.5 Weather Stack Design and Location. A vertical discharge stack with no-loss stackhead is recommended for Otto Fuel II operations exhaust air. Refer to para. 2.1.3.3 for further considerations. To obtain good dispersion from the stack, exit velocity must be at least 1.5 times the average wind velocity. For example, when the average local wind velocity is 18.9 miles per hour (8.45 m/s), the stack discharge velocity must be at least 2,500 fpm (12.7 m/s). Because Otto Fuel II exhaust is not filtered, proper dispersion is critical. Discharge the contaminants from the stack at a minimum ground-to-exit distance of 1.5 times the building height. When the facility is located in hilly terrain or near taller buildings, use taller stacks to ensure good dispersion.

4.4 Replacement Air. Design replacement air systems to maintain a negative pressure (relative to the atmosphere) ranging from -0.05 to -0.10 in. wc (-12.4 to -24.9 Pa) in the dirty spaces. Maintain the clean spaces at a positive differential pressure (relative to the atmosphere) ranging from +0.01 to +0.05 in. wc (2.49 to 12.4 Pa).

4.4.1 Quantity and Distribution. In the work space, distribute air to produce laminar flow of air from supply to exhaust. The vertical supply method is preferred to horizontal supply. Horizontal supply (see Figure 33) is adequate if, and only if, all exhaust hoods are located on the wall opposite the supply plenum. See section 2.1.3.4 for detailed criteria.

4.4.1.1 Vertical Distribution Method. Design a dropped ceiling with perforated plate to form a plenum in accordance with section 2.1.3.4.

4.4.1.2 Horizontal Distribution Method. When a wall plenum is used, it shall cover the entire wall opposite the hoods. Use perforated sheet metal, with open area sized to give 2000 fpm through the holes. For example, if the supply air flow-rate is 13,200 cfm, and the face area of the plenum is 128 sq ft, then 13,200/2000 = 6.6 sq ft of open area. This is equivalent to 6.6/128 = 5 percent open area. See figure 33.

4.4.2 Heating and Air Conditioning. Design heating, air conditioning, and humidity control in accordance with NAVFAC DM-3.03. Temper the replacement air to provide a minimum winter design temperature of 65 °F (18 °C) and a maximum summer design temperature of 75 °F (24 °C), with a maximum relative humidity of 50 percent. Do not separate air conditioning system from the replacement air system. Occasionally very cold conditioned air is added directly into a room to temper the air. This is not recommended because negative pressure can not be easily maintained. Cool the replacement air. This will give greater control over the quantity of replacement air. Refer to 2.1.4 for criteria on heat recovery systems. Do not recirculate exhaust air.

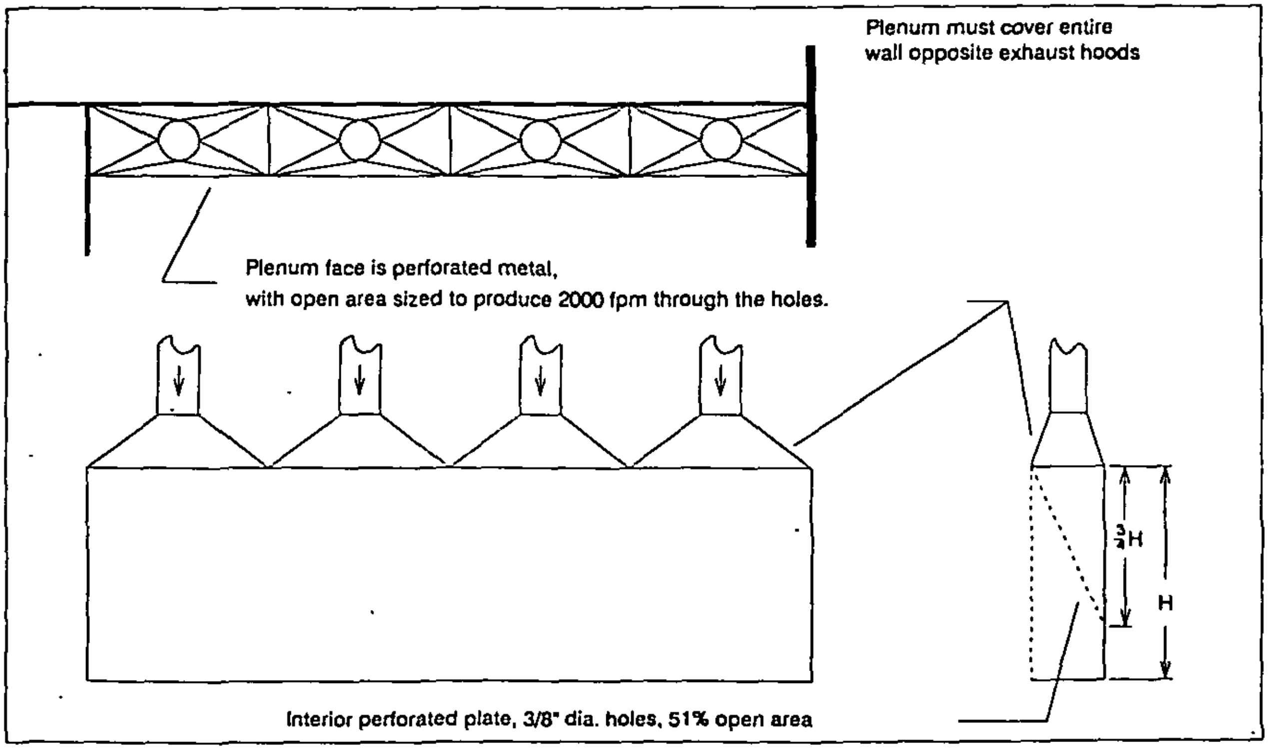


Figure 33
Horizontal Laminar Flow Supply Plenum

4.5 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria. Position the annunciator panel at the entrance to the dirty space so that the operators can monitor the operation of the replacement air system, the exhaust air system, and the balance between the dirty and clean spaces. Provide differential pressure sensors at locations that are representative of the average static pressure in each controlled space. If the differential pressures vary from the stated ranges, a timer shall be triggered. If the system cannot correct the difficulty within 60 seconds, a visible and audible alarm shall be triggered in the dirty space. If the difficulty is corrected within the allotted time, the timer shall be automatically reset. Where possible, the use of just one exhaust fan and just one supply fan simplifies control of differential pressure.

4.6 Safety and Health Items. 29 CFR 1910 and Bureau of Naval Medicine (NAVMED) P-5112, The Navy Environmental Health Bulletins require specific criteria for the safety and health of operators. Combination emergency eyewash and deluge showers (see Figure 34) are required in the immediate area of Otto Fuel II use. Refer to ANSI Z358.1, Emergency Eyewash and Shower Equipment for performance requirements on combination units. Design criteria include:

a) Location - Provide combination units within 10 seconds and 100 ft (30 m) of the potential hazard. Do not allow a wall or door to separate showers from the hazard. Position showers in a location that is a safe distance from electrical apparatus and power outlets, and as far away as possible from the contamination source.

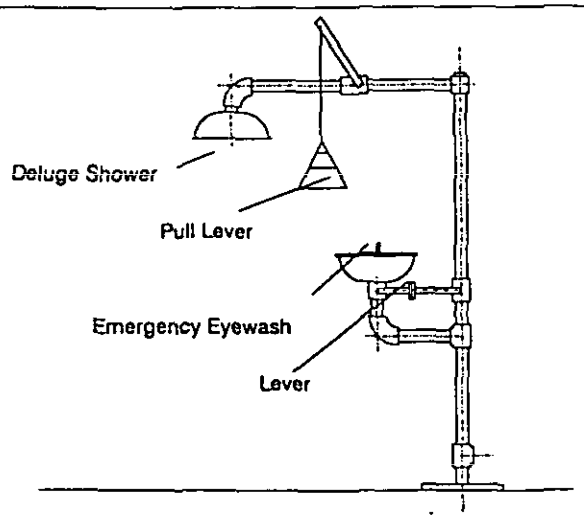


Figure 34
Emergency Deluge Shower

b) Valve controls - Position valves so that they can be turned on easily and will remain actuated until a deliberate effort is made to turn them off. Hand or foot valves are acceptable

c) Sumps - Contain deluge shower discharge in a lined sump.

d) An alarm horn to alert fellow workers of hazard.

e) Auxiliary face spray ring on the eyewash.

Section 5: METAL CLEANING AND ELECTROPLATING

5.1 Function. Metal parts and equipment are cleaned (both chemically and mechanically), chemically treated, chemically coated, and electroplated during rework at metal cleaning and electroplating facilities. For additional information, refer to ANSI Z9.1, Practices for Ventilation and Operation of Open-Surface Tanks.

5.2 Operational Considerations

5.2.1 Chemical Cleaning and Electroplating. Contaminants rise from the open surface tanks used in metal cleaning and electroplating operations. The best method of protecting the shop workers from these contaminants is to enclose the tanks as much as possible, while still allowing adequate operator access.

Tanks which are inactive for long periods shall be equipped with tank covers to inhibit the spread of any contaminant vapors. Tanks for long duration processes (18+ hours) shall be equipped with tank covers.

Most electrochemical processes operate at temperatures in excess of 100 °F (37.7 °C). The heat generated usually makes air conditioning the shop economically unfeasible. Propeller or pedestal fans shall never be used to provide heat relief, as they generate high velocity air currents and destroy the effectiveness of the ventilation systems. Employee exposure to airborne contaminants is regulated by 29 CFR 1910.1000. 29 CFR 1910.94(d) gives specific regulations intended to protect the health of the worker in metal cleaning and electroplating shops.

WARNING: Care must be taken to ensure that acids and cyanides are never mixed, either in liquid form or in ductwork. The mixture generates toxic hydrogen cyanide gas. Therefore, areas under cyanide process tanks must be isolated from areas under acid tanks by sumps or berms. The cyanide spill containment capacity shall equal 110 percent of the capacity of the largest cyanide process tank in the containment area.

5.2.2 Mechanical Cleaning (Buffing, Grinding, and Polishing). Mechanical cleaning includes buffing, grinding, and polishing. Material from the workpiece and the grinding wheel break off to form a potential respiratory hazard, and the larger particles can act as projectiles. Accordingly, 29 CFR 1910.94(b) regulates these processes to protect workers from the hazards.

5.3 Exhaust Systems

5.3.1 Chemical Cleaning and Electroplating Hood Design. Most operations in chemical cleaning and electroplating facilities are performed in open tanks, vats, or pots. Exhaust hoods are categorized as one sided lateral, push-pull, pull-pull, or enclosing type. Use Figure 35 to determine the appropriate type of exhaust hood. Push-pull and enclosing-type exhaust hoods, when applicable, require 50 to 70 percent less airflow to provide the same control of contaminants. This allows significantly reduced operating costs.

The toxicity and rate of generation of contaminants will vary from process to process, and therefore, different ventilation rates are used. In the interest of simplicity, each tank is assigned a hazard class from A-1 to D-4, with A-1 the most hazardous. Refer to the ACGIH Manual, Tables 10.5-6 through 10.5-8 for the hazard classes of several common plating solutions.

For solutions not listed there, refer to the ACGIH Manual, Table 10.5-1 , Determination of Hazard Potential, and Table 10.5-2, Determination of Rate of

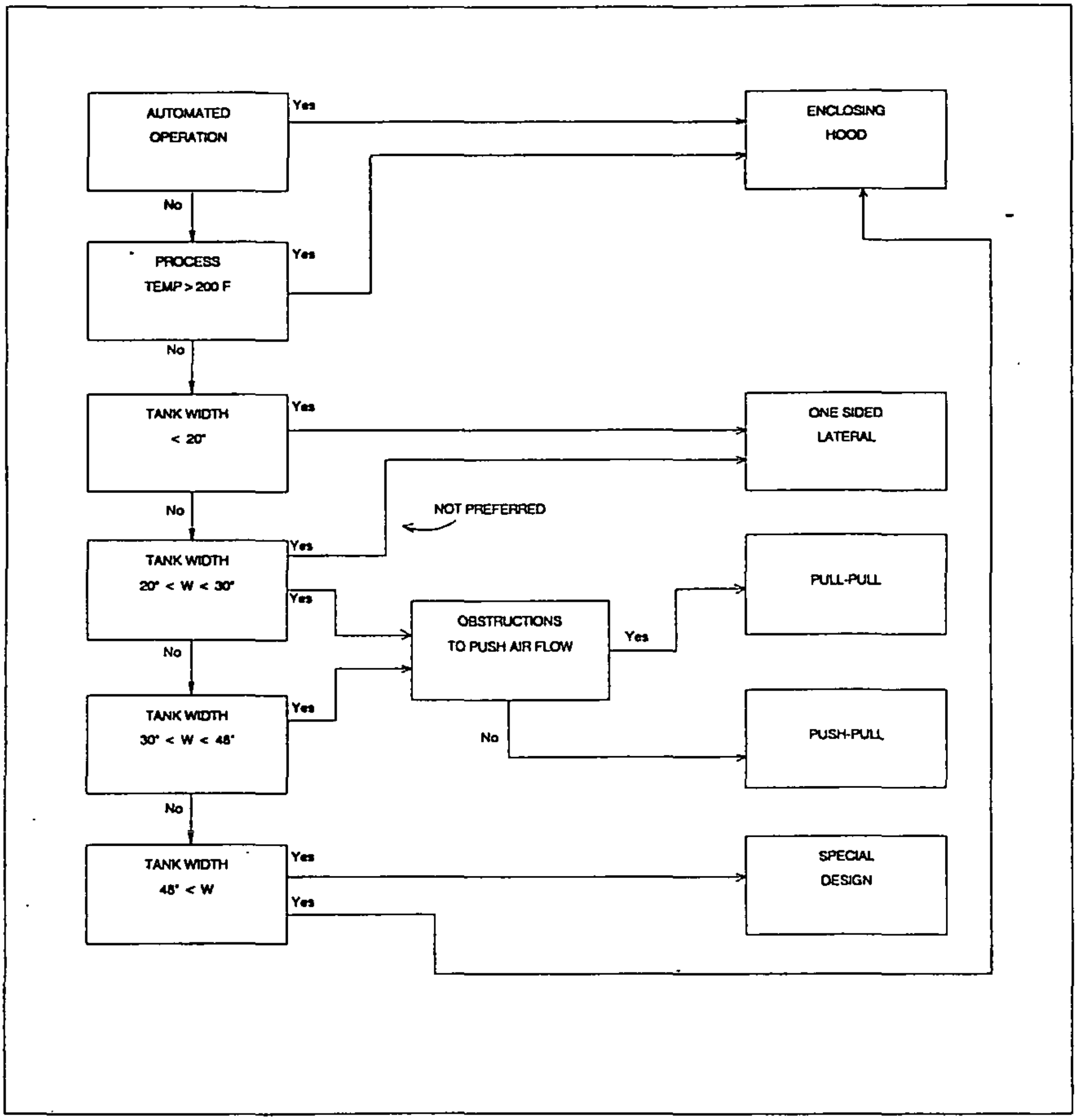


Figure 35
Decision Process for Open Surface Tank Hoods

Gas, Vapor, or Mist Evolution. Also refer to ANSI Z9.1, and Appendix A, Chemical Data, Tables A3 through A5. The cognizant industrial hygiene office should determine the hazard class for each tank.

To reduce mist generation associated with compressed air agitation, provide low-pressure agitation using a low-pressure air circulator as shown in Figure 36.

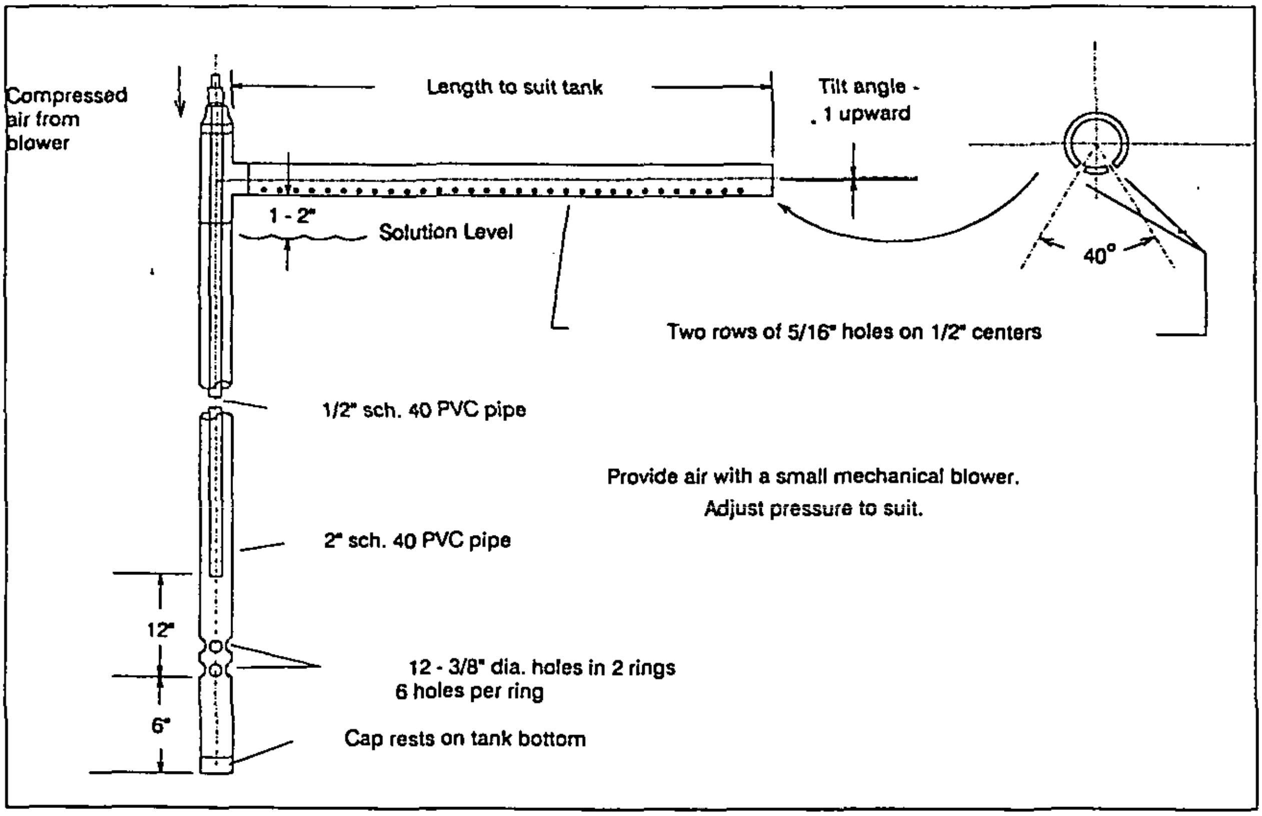


Figure 36
Air Agitator for Open Surface Tanks

The following criteria apply to all exhaust hood types for all open surface tanks. Refer to Figure 37.

a) Baffles: Constructed of a material compatible with the tank solution, sized for a minimum height (above the tank lip) 25 percent of the tank width, and positioned at the ends of the tank, perpendicular to the hood face.

b) Dragout Covers: Constructed of the same material as the baffles, overlapping the baffles, and sloping toward the first tank. Baffles and dragout covers must be easily removable for utility maintenance.

c) Tank Covers: Constructed of a material compatible with the process chemicals and operating conditions. Tank covers should be used on all processes when feasible. Good candidates are caustic cleaning, solvent vapor degreasing and acid cleaning.

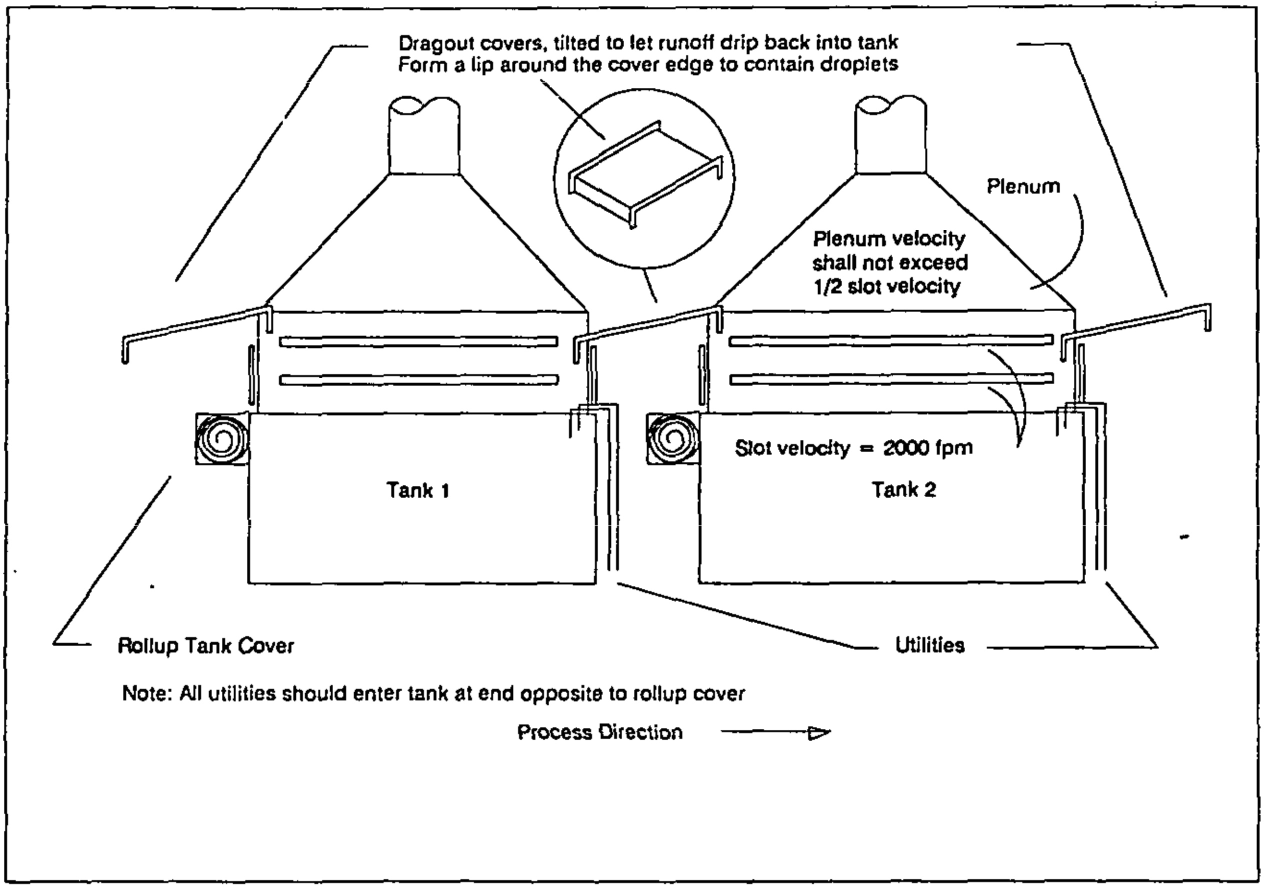
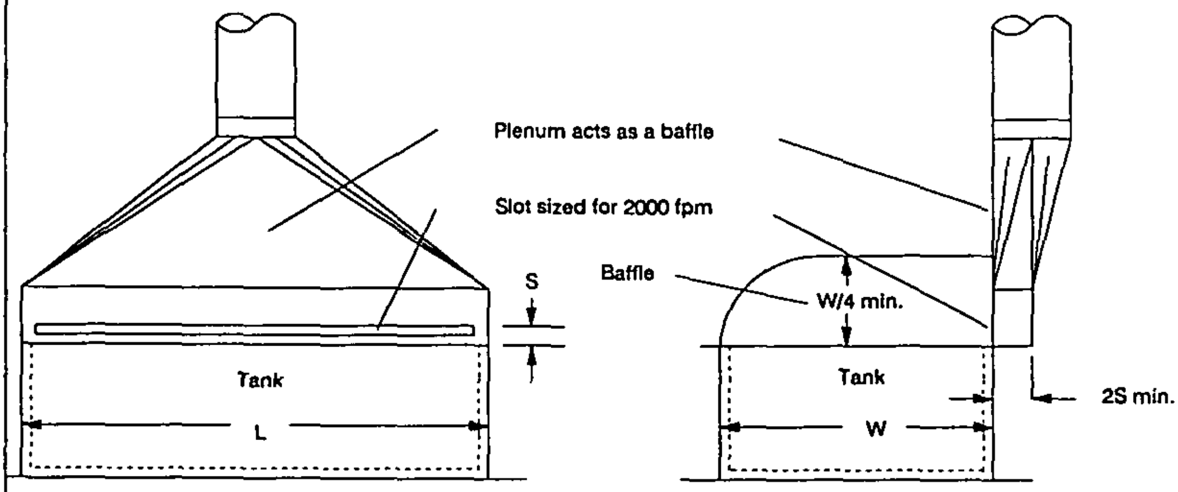


Figure 37
Hood Optimization Features

d) Slots: All slots in all exhaust hoods shall be designed to have a velocity through the slot of 2000 fpm (10.2 m/s).

e) Plenums: All exhaust hood plenums shall have a velocity not greater than one half of the slot velocity (i.e., plenum velocity shall not exceed 1000 fpm (5.08 m/s)).

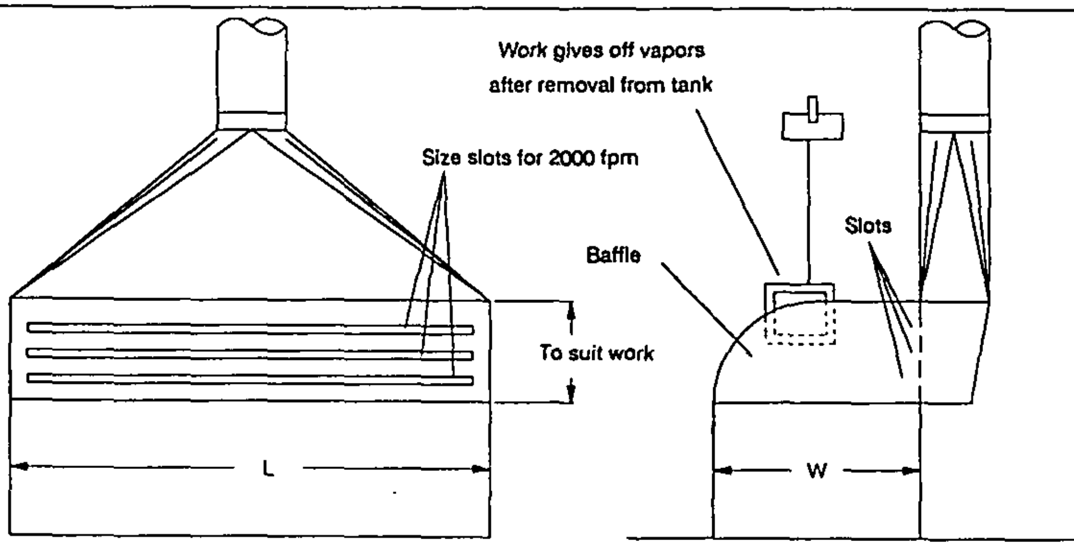
5.3.1.1 Lateral Exhaust Hoods. Figures 38 through 42 illustrate several configurations for lateral exhaust hoods. The configurations shown in Figures 38, 39, and 40 are preferred because the plenum and transition act as a baffle to room air currents. Figure 43 illustrates a hood for a solvent degreasing tank. Note how the exhaust plenum in Figure 43 (squared plenum) differs from the exhaust plenum in Figure 42 (tapered plenum). The solvent degreasing tank exhaust plenum will function properly, even though it is not tapered, because of its relatively low (500 fpm (2.54 m/s)) velocity. If the velocity or air volume over a degreasing tank is too high, the solvent vapor may be drawn into the duct, greatly increasing the loss of solvent.



Notes:

1. Pipes should enter along the width dimension; gaps in the baffle around the pipes should be filled.
2. S = Slot width

Figure 38
Lateral Exhaust Hood with Upward Plenum and Transition



Notes:

1. Pipes should enter tank along the width; gaps in the baffle should be filled.
2. Plenum velocity must be < = (1/2) X (slot velocity)

Figure 39
Lateral Exhaust Hood for Pickling Tank

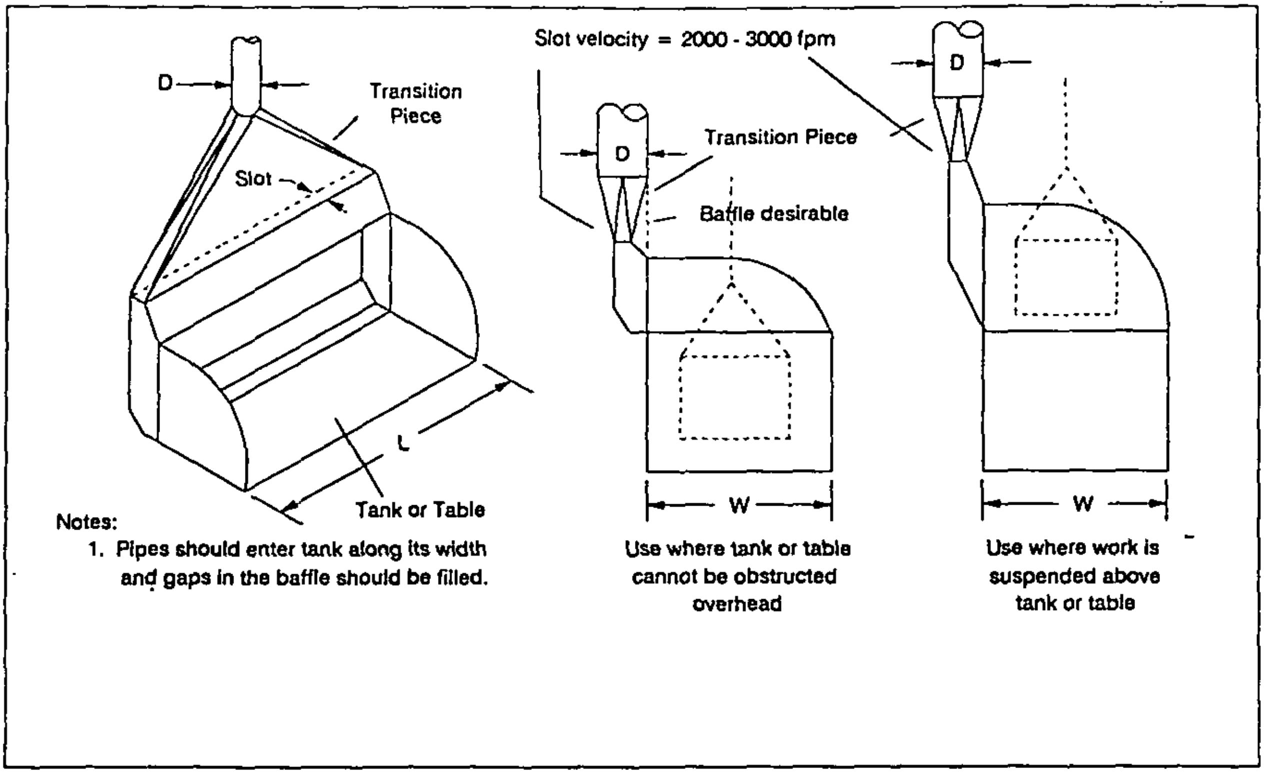


Figure 40
Lateral Hood for Solutions with a High Vaporization Rate

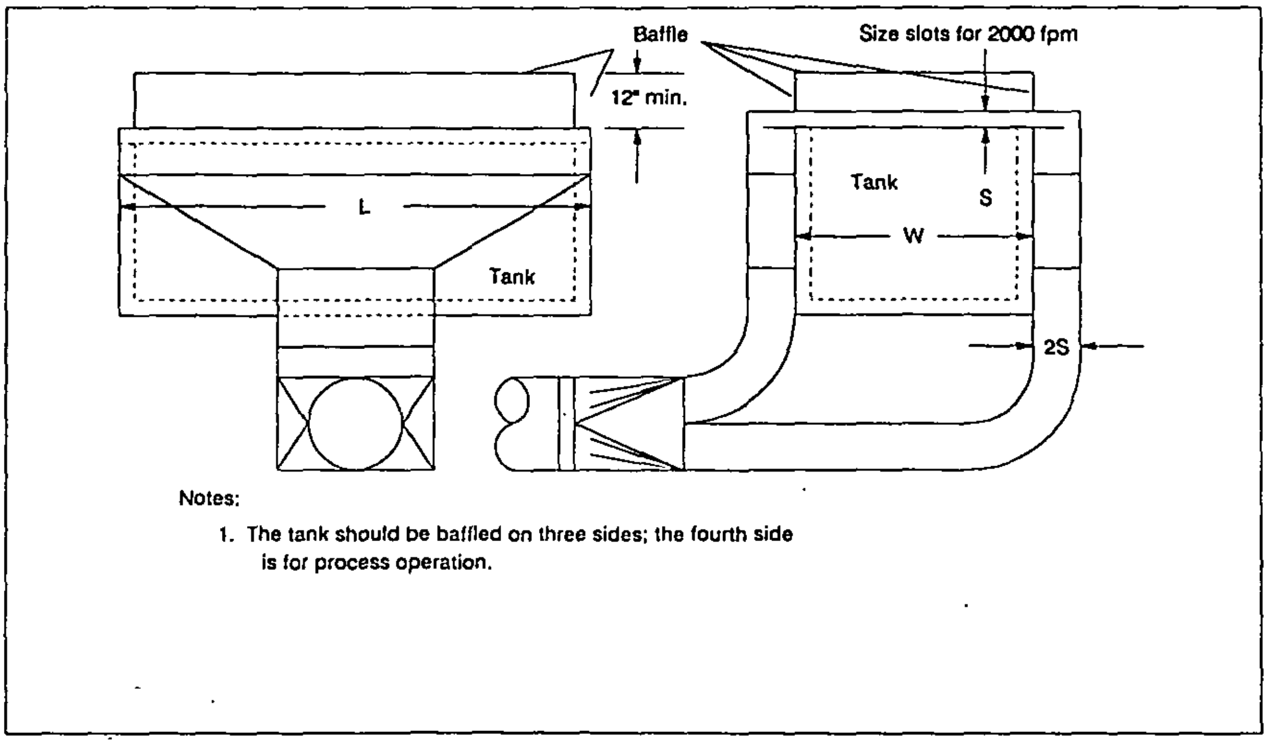
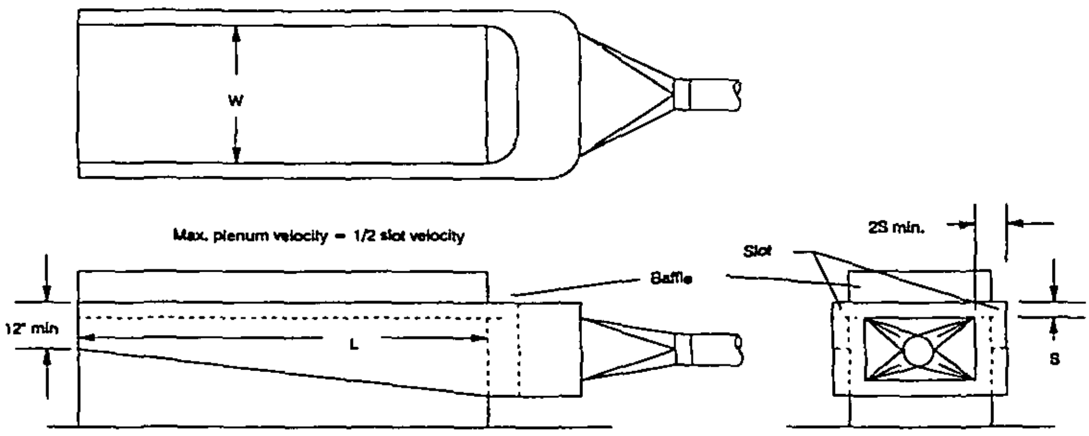


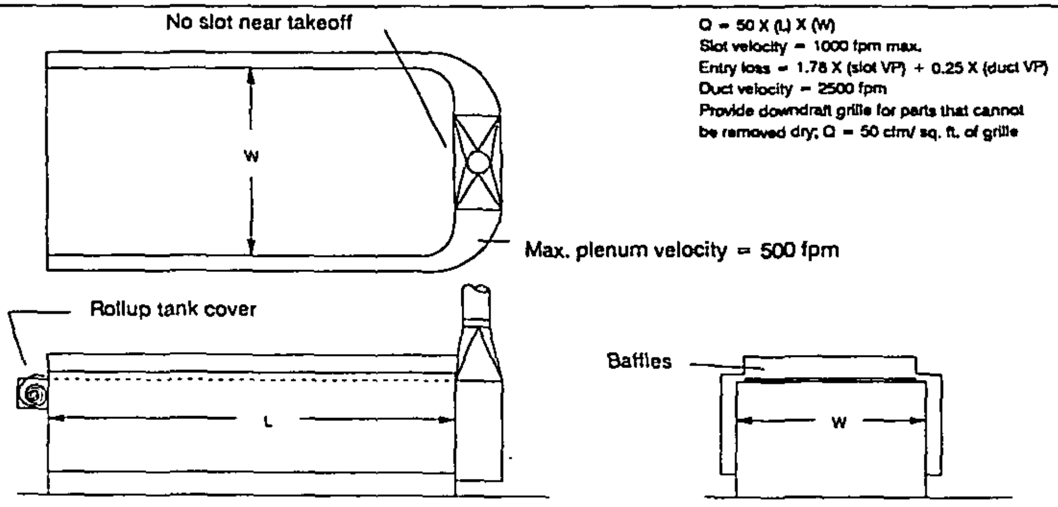
Figure 41
Lateral Exhaust Hood with Downward Plenum



Notes:

1. Size slots for a velocity of 2000 fpm
2. *The liquid level must be kept at least 8 in. below the slot*
3. Use multiple takeoffs if L exceeds 8 ft.
4. Slot permitted on one side only for tanks where L < 20 in.
5. Tank should be baffled on 3 sides only; fourth side is for process operation

Figure 42
Lateral Exhaust Hood with End Takeoff



Notes:

1. Separate flue for combustion products if direct-fired unit.
2. For cleaning operation, an air line respirator is necessary.
3. For pit units, the pit should be mechanically ventilated.
4. For further safeguards, see VS-501.1, ACGIH Industrial Ventilation Manual.
5. Baffle tank on 3 sides only; fourth side is for process operation.

Figure 43
Lateral Exhaust Hood for Solvent Degreasing Tank

To determine the required exhaust volume for a given tank, determine the hazard class, as described in paragraph 5.3.1. Using Table 2, determine the corresponding capture velocity. Proceed to either Table 3 or Table 4, depending on whether or not the tank is baffled, and determine the exhaust flow rate in cfm per square foot of tank surface area. Multiply this figure by the actual surface area of the tank to arrive at the exhaust flowrate.

Table 2
Minimum Capture Velocities for Lateral Exhaust Hoods in Undisturbed Air

Hazard Class	Capture Velocity fpm (m/s)
A-1, A-2	150 (0.762 m/s)
A-3, B-1, B-2, C-1	100 (0.508 m/s)
B-3, C-2, D-1	75 (0.381 m/s)
A-4, C-3, D-2	50 (0.254 m/s)
B-4, C-4, D-3, D-4	General Room Ventilation

Notes:
1. Table applicable for room with cross-drafts less than 75 fpm (0.381 m/s). Install baffles, relocate tank, or redesign supply air system if crossdrafts greater than 75 fpm (0.381 m/s) are expected.
2. Where complete control of water vapor from hot processes is desired, use next highest capture velocity.

Table 3
Minimum Volume Rates Required for Lateral Exhaust Hoods without Baffles In cfm per ft^2 (and m^3/s per m^2) of Tank Surface Area

Required Minimum Capture Velocity fpm	(m/s)	Tank Width/Length (W/L) Ratio 0.00-0.09	0.10-0.24	0.25-0.49	0.50-1.00
150	(0.762)	225(1.14)	250(1.27)	250(1.27)	250(1.27)
100	(0.508)	150(0.762)	175(0.889)	200(1.02)	225(1.14)
75	(0.381)	110(0.559)	130(0.660)	150(0.762)	170(0.863)
50	(0.254)	75(0.381)	90(0.457)	100(0.508)	110(0.559)

Notes:
1. Use W/2 as tank width for tank with manifold along the centerline or with hoods on two parallel sides.
2. For a circular tank with lateral exhaust manifold up to half the circumference, use W/L = 1.0; for over half the circumference, use W/L = 0.5.

Table 4
Minimum Volume Rates for Lateral Exhaust Hoods with Baffles or Against a Wall
In cfm per ft^2 (and m^3/s per m^2) of Tank Surface Area

Required Minimum Capture Velocity fpm	(m/s)	Tank W/L Ratio 0.00-0.09	0.10-0.24	0.25-0.49	0.50-1.00
150	(0.762)	150(0.762)	190(0.965)	225(1.14)	250(1.27)
100	(0.508)	100(0.762)	125(0.635)	150(0.762)	175(0.889)
75	(0.381)	75 (0.381)	90 (0.457)	110(0.559)	130(0.660)
50	(0.254)	50 (0.254)	60 (0.254)	75 (0.305)	90 (0.457)

Notes:
1. These values are for hoods with baffles (including hoods with upward plenums) and hoods against a wall.
2. Use W/2 as tank width for tanks with hoods along the center line or on two parallel sides.
3. For a circular tank with lateral exhaust manifold up to half the circumference, use W/L = 1.0 (tank diameter), for over half the circumference, use W/L = 0.5 (tank diameter).

5.3.1.2 Pull-Pull Exhaust Hoods. The pull-pull exhaust system has parallel hoods on opposite sides of an open surface process tank. The examples in Figures 41, 42, and 43 are pull-pull hoods. When computing the required exhaust volume for a pull-pull system, use the same method as for laterally exhausted tanks, but substitute (W/2)/L for W/L as the tank aspect ratio. This is because each hood effectively exhausts one-half of the tank width. Pull-pull systems require somewhat lower flow rates for this reason.

5.3.1.3 Push-Pull Exhaust Hoods. The principal advantage of the push-pull ventilation system is that exhaust air volumes are much lower than for laterally exhausted tanks. This results in energy savings. In push-pull systems, a low-volume plane of air is pushed across the surface of the tank, entraining the contaminated air above the tank surface and pushing it toward the exhaust hood. The plane of air collects the contaminated air and delivers it to the exhaust airstream. The push air terminal momentum is critical. The most common error in operating a push-pull system is providing excess push air. This overpowers the exhaust airstream and spills airborne contaminants out of the exhaust control zone. However, too little push air can also result in airborne contaminant spillage. Therefore, specify a 20 percent adjustability in the push air volume flow rate. Specify that the adjusting mechanism will be locked in place after the system is balanced. The push-air plenum shall rest on the edge of the tank or be baffled to the edge of the tank. This will eliminate the low pressure zone under the push air jet stream and prevent airborne contaminants from escaping between the push plenum and the edge of the tank. Two methods based on empirical data developed in the laboratory and the field are discussed below. Each method provides control of contaminants generated from operations conducted in open surface tanks.

a) Push-Pull Method 1. Empirical data developed at the National Institute of Occupational Safety and Health (NIOSH) provide these criteria.

Design the pull volume flow rate (Q) to be 75 cfm (2.12 m^3/min) per square foot of tank surface area. Size the exhaust hood slots for a velocity of 2,000 fpm (10.2 m/s). Push-volume flow rate (Q) equals 18.5 cfm (.524 m^3/min) per foot of tank length. The push jet plenum shall extend the entire length of the tank. The push-air jets shall be 1/4-in. (6.35 mm) diameter holes spaced 3 diameters (3/4 in. (19.1 mm)) on center. The push-air plenum cross sectional area shall be greater than four times the total jet area. Baffle the sides of the tank. Figure 44 illustrates this criteria.

b) Push-Pull Method 2. Criteria for this method are based on laboratory and field test data. This data is documented in the NIOSH 75-108, Development of Design Criteria for Exhaust Systems for Open Surface tanks. Calculate the exhaust volume flow rate (Q) by taking 50 percent of the minimum volume flow rate for a simple lateral hood, based on the hazard class for the tank contents. The push air flow rate (Q) is 5 cfm (.142 m^3/min) per square foot of tank surface area. A flat pattern spray nozzle with swivel attachment shall be placed every 6 in. (152.4 mm) on center, beginning 3 in. (7.62 cm) from the end of the tank. The adjustable nozzles may give somewhat better performance than drilled openings. The push-air plenum pressure shall be between 2 and 4 in. wc (498 and 996 Pa). The push-air plenum cross sectional area shall be 4 times the total jet area. Refer to Appendix A for a design calculation example.

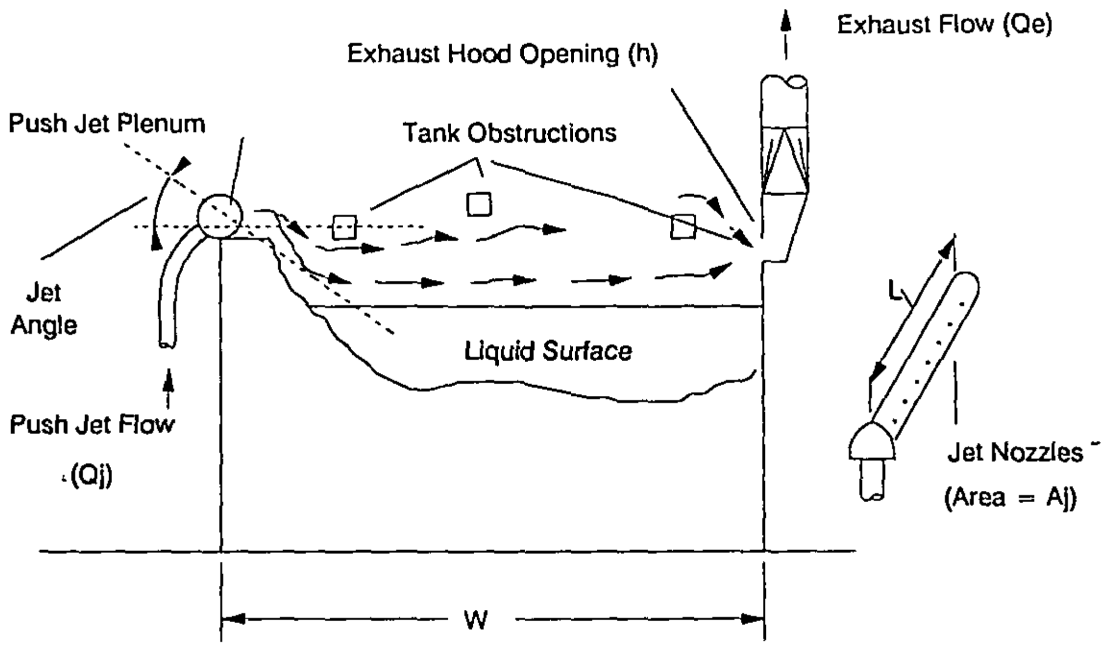
5.3.1.4 Enclosing Hood. An enclosing hood (see Figures 45 and 46) projects over the entire surface of the tank and is enclosed on at least two sides. Refer to Table 5 to determine the capture velocity. The exhaust flow rate (cfm) is based on the capture velocity and the open area of the enclosure. For a design problem example, refer to Appendix A.

Table 5
Minimum Capture Velocities for Enclosing Hoods in Undisturbed Air

Hazard Class	One Side Open fpm	(m/s)	Two Sides Open fpm	(m/s)
A-1,A-2	100	(0.508)	150	(0.762)
A-3,B-1,B-2,C-1	75	(0.381)	100	(0.508)
B-3,C-2,D-1	65	(0.330)	90	(0.457)
A-4,C-3,D-2	50	(0.254)	75	(0.381)
B-4,C-4,D-3,D-4		General Room Ventilation		

Notes:
1. Table applicable for room with crossdrafts less than 75 fpm (0.381 m/s). Install baffles, relocate the tank, or redesign the supply air system if crossdrafts greater than 75 fpm (0.381 m/s) are expected.
2. Where complete control of hot water is desired, design as next highest class.

5.3.2 Buffing, Grinding, and Polishing Hoods. Buffing, grinding, and polishing operations are commonly performed at metal cleaning and electroplating facilities. These operations generate finely dispersed (and



Push-Pull Hoods

Push Jet Plenum Circular

Jet Nozzle Drilled holes, 1/4" dia. spaced 3/4" on centers
Jet plenum cross sectional area shall be >= 4 X (total jet nozzle area)

Nozzle Angle Use min. angle necessary to clear nearby obstructions (0 to 20 deg. downward).

Push Jet flow Qj = 18.5 cfm per linear foot of push air plenum

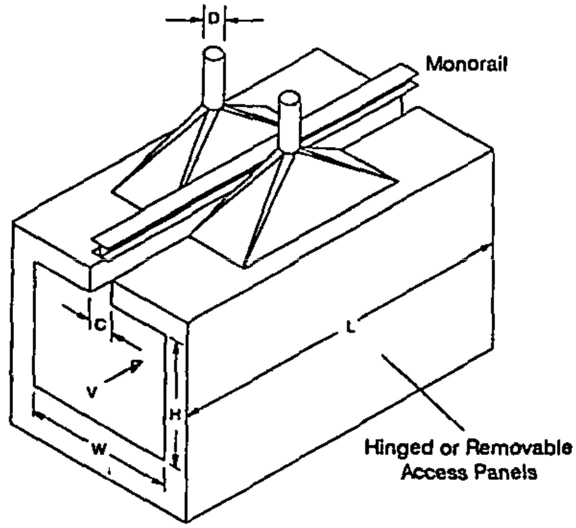
Exhaust Flow Qe = 75 cfm per sqft of tank area

Slot Velocity Size slots for 2000 fpm min. slot velocity

Liquid Level Allow 6" min. freeboard in the tank

Design the push air system to enable a +/- 10 % adjustment from design push jet flow

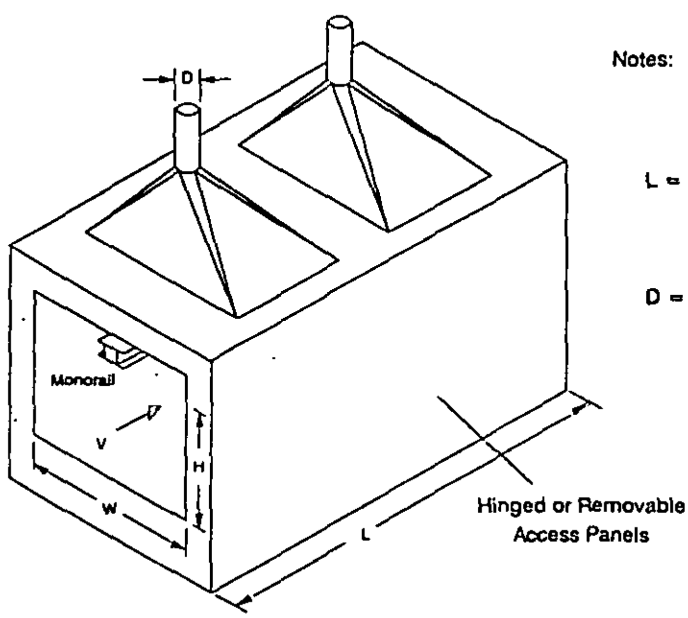
Figure 44
Push - Pull Ventilation System



Notes:

1. Q = Exhaust Volume in cfm; equals (A) X (V).
2. H = Height of opening in feet.
3. W = Width of opening in feet.
4. C = Width of opening in feet.
5. L = Length of monorail slot opening.
6. A = Area of opening in enclosure = 2 X (H) X (W) + (C) X (L).
7. V = Minimum capture velocity. (See table 5).
8. Duct velocity = 2500 fpm
9. Entry loss = entry loss factor for tapered hood times duct velocity pressure.
10. Make C, W, and H only large enough to pass work and hanger.

Figure 45
Enclosing Hood with Outside Monorail



Notes:

Q = Exhaust Volume in cfm; equals (A) X (V)
H = Height of rectangular opening, feet
W = Width of opening, feet
L = Length of enclosure, feet
A = Area of opening in enclosure
= 2 X (H) X (W)
V = Minimum capture velocity. (See table 5)
D = Duct diameter
Duct velocity = 2500 fpm, min.
Entry loss = entry loss factor for tapered hood times duct VP.
Make W and H only large enough to pass work and hanger

Figure 46
Enclosing Hood with Inside Monorail

sometimes flammable or combustible) contaminants. Therefore, the minimum exhaust volume shall be sufficient to maintain a contaminant level below 25 percent of the Lower Explosive Limit (LEL) of the material, in all areas of the exhaust system. Specify shaped "receiving" hoods for these operations as required in 29 CFR 1910.94(b). The hoods have a three-fold purpose: (1) to prevent contaminants from entering the operator's breathing zone, (2) to control ejected dust and dirt particles acting as projectiles, and (3) to serve as a guard or safety device in case the wheel explodes or breaks apart. Particles are formed from the workpiece, its coatings, and the wheel material. Good contaminant control is achieved when proper ventilation rates are used and when at least 75 percent of the wheel is covered by the shaped hood. Portable hoods with flexible ducts are not recommended. Design an exhaust hood that completely encloses the workpiece, similar to a glove box, if the workpiece is highly toxic, radioactive, or explosive. Minimum criteria for the following shaped hoods are given in the ACGIH Manual, Chapter 5:

Type of Hood	Figure No.
Horizontal Double Spindle Disc Grinder	VS-408
Horizontal Single Spindle Disc Grinder	VS-409
Vertical-Spindle Disc Grinder	VS-410
Grinder Wheel Hood Speeds Below 6,500 sfm (33.0 m/s)	VS-411
Grinder Wheel Hood Speeds Above 6,500 sfm (33.0 m/s)	VS-411.1
Buffing and Polishing Wheel	VS-406
Metal Polishing Wheel	VS-403
Backstand Idler Polishing Machine	VS-402
Buffing Lathe	VS-407

5.4 Ductwork and Fans.

5.4.1 Metal Cleaning and Electroplating Ductwork and Fans.

5.4.1.1 Ductwork. Follow the general criteria provided in para. 2.1.3.1. Design the exhaust air ductwork to maintain a minimum transport velocity of 2,500 fpm (12.7 m/s). For guidance on duct construction materials, refer to SMACNA publication 15d, "Corrosion Chart." When using fiberglass-reinforced plastic (FRP) ductwork, specify that it be fire-retardant. Acid and cyanide operations shall be ventilated by separate exhaust systems to prevent mixing.

5.4.1.2 Fans. Specify the fans in accordance with criteria provided in para. 2.1.3.2. Specify the exhaust fans as backward inclined and centrifugal. Never place the fan motor in contact with the airstream. When potentially explosive or flammable particles, vapors, or fumes are ventilated, specify that the fan shall have a nonferrous impeller and a nonferrous ring around the opening through which the shaft passes. Ferrous hubs, shafts, and hardware are allowed, provided construction is such that a shift of the impeller or shaft will not permit two ferrous parts of the fan to rub or strike. Steps must also be taken to ensure that the impeller, bearings, and shaft are adequately attached and restrained to prevent a lateral or axial shift in these components.

5.4.2 Buffing, Grinding, and Polishing Ductwork and Fans

5.4.2.1 Ductwork. Follow design criteria provided in para. 2.1.3.1. Specify Class II duct construction in accordance with SMACNA publication 15d. If buffing operations are performed, specify a minimum duct transport velocity of 4,500 fpm (22.9 m/s). However, when only light grinding and polishing are performed, the duct minimum velocity shall be 3,500 fpm (17.8 m/s). Specify duct hangers with sufficient strength to support the ductwork in case the duct becomes half-filled with material. Provide cleanout doors adjacent to every bend and vertical riser. In horizontal duct runs, cleanout door spacing shall not exceed 12 ft (3.66 m) for ducts 12 in. (30.5 cm) or less in diameter. Larger ducts shall have a cleanout door spacing not exceeding 20 ft (6.09 m). Locate all cleanout doors on the side or top of the ductwork.

5.4.2.2 Fans. Specify the fans in accordance with criteria provided in para. 2.1.3.2. Specify that the fan shall have a nonferrous impeller and a nonferrous ring around the opening through which the shaft passes. Ferrous hubs, shafts, and hardware are allowed, provided construction is such that a shift of the impeller shaft will not permit two ferrous parts of the fan to rub or strike. Steps must also be taken to ensure that the impeller, bearings, and shaft are adequately attached and restrained to prevent a lateral or axial shift in these components.

5.5 Air Cleaning Devices.

5.5.1 Chemical Cleaning and Electroplating Air Cleaning Devices. Specify air cleaning devices to comply with applicable regulations and prevent deterioration of surrounding buildings, equipment, and vehicles. Hard chrome and hydrochloric acid (HCl) tanks require air pollution control devices. Other processes such as nickel plating metal cyanide plating and nitric acid may need emission control devices, depending on local air emission regulations.

5.5.1.1 Mesh Pad Mist Eliminator. See Figure 47. The mesh pad mist eliminator is well suited for controlling chromic acid plating emissions. These emissions are relatively large mist droplets (greater than 5 microns). Mesh pad mist eliminators typically offer operational simplicity, reasonable initial cost, and low-volume concentrated wastewater, thereby reducing waste treatment requirements. Exhaust system design and ambient conditions can reduce mesh pad mist eliminator efficiency. Lengthy exhaust systems and/or low ambient humidity may cause chromic acid mist to dehydrate into finer, less collectible mist. Mesh pad mist eliminator vendors must incorporate a solution to this problem in their design. Some vendors recommend mesh pad wash cycles. Other designs locate the device close to the plating tanks producing the mist so that it can be collected before dehydration occurs. Others may include an exhaust humidification system. Design criteria for mesh pad mist eliminators are as follows:

a) The mist eliminator shall have a minimum overall collection efficiency of 98 percent on a chromic acid mist, regardless of mist droplet sizes.

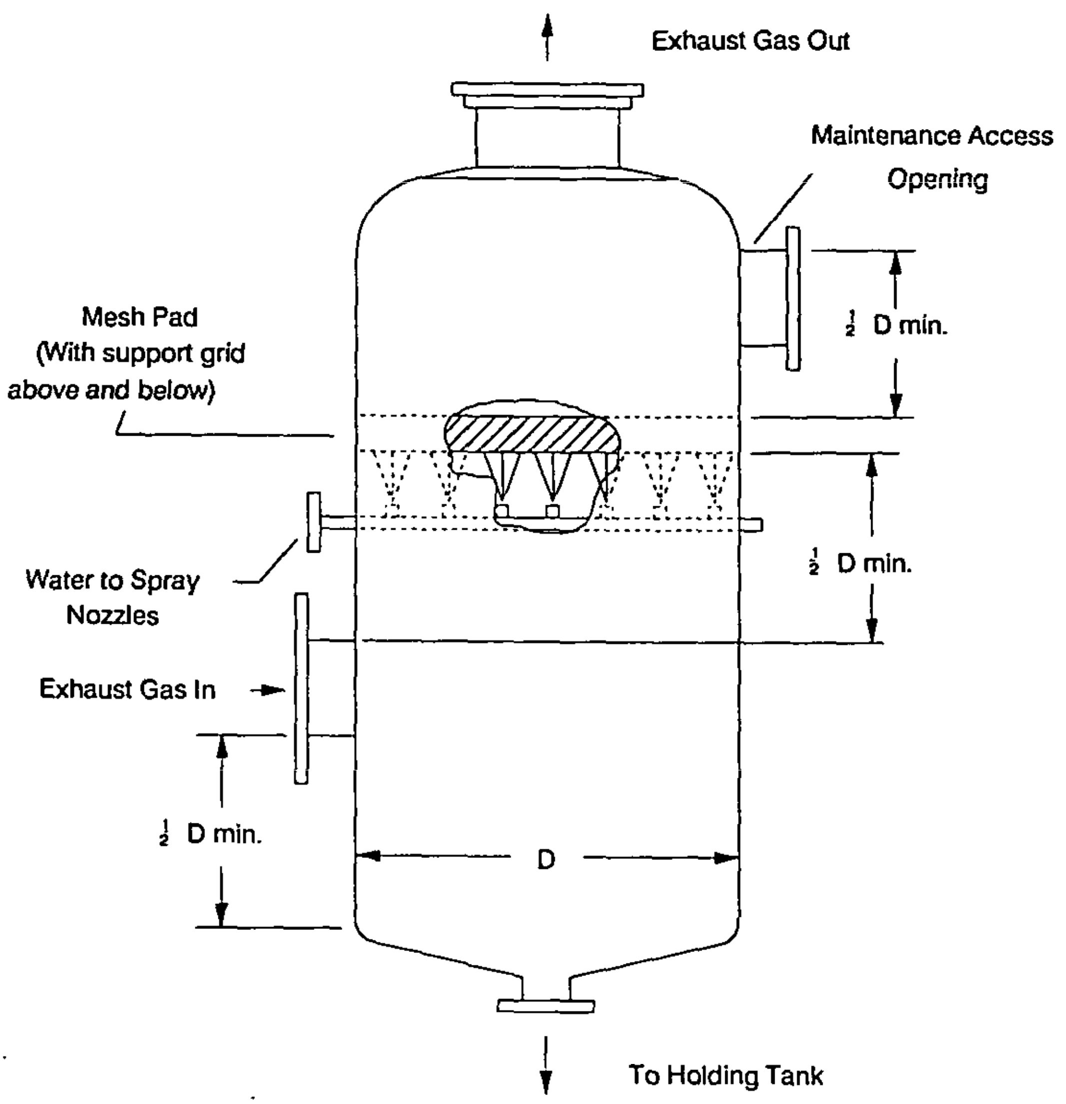


Figure 47
Mesh Pad Mist Eliminator

b) Mesh pad cross-sectional area shall be sized for a maximum of 600 fpm (3.05 m/s) air velocity.

c) The maximum allowable pressure drop across the mist eliminator shall be 2 in. water column (wc).

d) The mist eliminator shall be constructed of fiberglas reinforced plastic (FRP) material.

e) The removable replaceable mesh pad shall be a 6 in. minimum thickness, constructed of polypropylene material with a minimum density of 9 lb/ft^3 (144 Kg/m^3). The surface area per unit volume of the pad shall be 86 ft^2/ft^3, minimum.

f) Support grids are required above and below the mesh pad to prevent movement. The support grids shall be designed to withstand a 6 in. (wc) pressure drop across the pad without deflection.

g) The mist eliminator shall be equipped with a recirculating wash down system. The washdown system shall include a bank of spray nozzles located below the mesh pad. The spray nozzle system shall be operable with or without the exhaust fan running. Arrange the spray nozzle piping network so that all lower portions of the mesh pad are rinsed. Mist eliminator design shall not permit reentrance of rinse water. Construct the piping system as follows:

(1) The spray nozzle system (including the spray nozzles) shall be made of polyvinyl chloride (PVC). Pipes and fittings shall be schedule 80 PVC. Valves shall be union end PVC ball valves. (Nozzles shall be replaceable and connected to piping using "T" unions.)

(2) A flow meter and a flow control valve shall be installed on the water line leading to the spray nozzle system.

(3) The system shall include a sump with minimum capacity 1.5 times the recirculation flowrate.

(4) Wash down cycles shall be controlled by a 24 hour adjustable timer. The wash cycle interval shall be variable in 1 minute increments.

h) The drain pipe flanged to the base of the mist eliminator shall be a minimum of 4 in. diameter. The drain pipe shall be schedule 80 PVC pipe. A check valve or p-trap must be installed in the drain pipe. This prevents pulling tramp air through the drain pipe. The drain pipe shall terminate at a holding tank. The chromic acid collected in the holding tank can then be pumped to the hard chrome tanks as required. The holding tank pump, or "sump pump" shall be separately mounted adjacent to the holding tank. The pump shall be vertical sealless, self-priming column centrifugal type. All outdoor fluid systems must be freeze protected.

i) A 24 in. (61.0 cm) diameter inspection hatch shall be installed in the mist eliminator shell above the level of the mesh pad for maintenance access.

j) Differential pressure taps shall be installed above and below the mesh pad. The differential pressure gauge must be placed in the annunciator panel in the shop at an easily accessible location. The differential pressure gauge must be set to trip an audible "acknowledge" alarm when differential pressure across the pad exceeds 1.0 in. wc (10.1 KPa) above the normal operating differential pressure range. The alarm indicates that a wash down of the mesh pad is necessary. The alarm should also sound when the differential pressure across the pad falls more than 1.0 in. (10.1 KPa) below the normal range. When this occurs, a hole or other damage to the pad may have occurred.

k) A three way valve shall be installed on each pressure gauge signal line so the operator may periodically blow out the lines to prevent blockage. These valves also allow the gauge to be zeroed while the system is operating. These three way valves must be placed adjacent to the pressure gauges on the annunciator panel.

5.5.1.2 Vertical Counterflow Wet Scrubber. A vertical counterflow wet scrubber (Figure 48) shall be used whenever local regulations require a total weight chromic acid collection efficiency greater than 98 percent. At the time of this writing (August 1988), some air quality management districts are considering requiring a 99.8 percent collection efficiency on chromic acid emissions. There is no data at this time showing that any device exists which is capable of 99.8 percent removal of chromic acid mist.

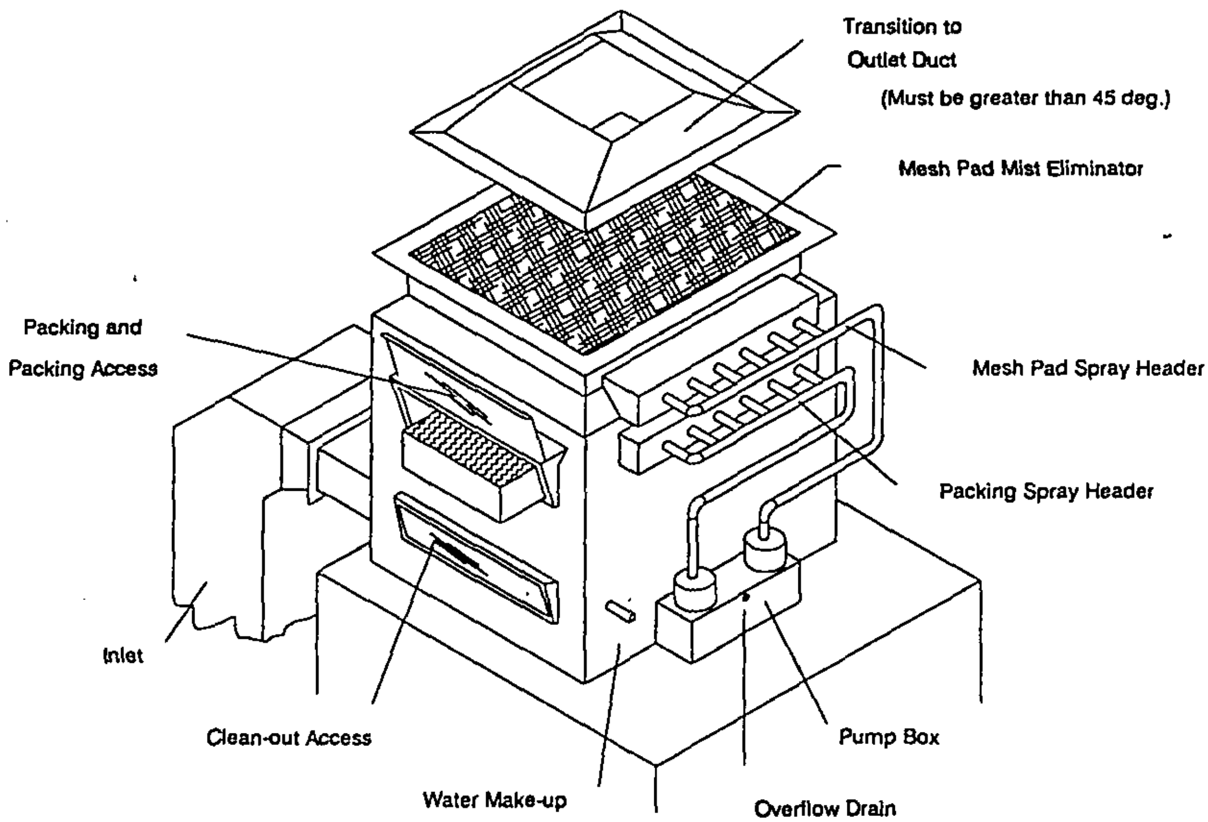
Scrubbers are widely used for controlling hydrochloric acid emissions, and emissions from other acid and caustic processes. Consult the local regulatory agency for specific requirements. Design criteria for these scrubbers are as follows:

a) A removal efficiency of 98percent is required for total hydrochloric acid, sulfuric acid and sodium hydroxide emissions unless local regulations require additional control.

b) Scrubber cross-sectional area shall be sized for a maximum of 500 fpm (2.54 m/s) air velocity.

c) The maximum allowable pressure drop across the scrubber shall be 3 in. wc (30.4 KPa).

d) The material of construction for the wet scrubber shell shall be FRP. Exterior surfaces shall incorporate a color additive gel coat that shall be totally resistant to ultraviolet radiation. Interior and exterior coatings shall not be acetone sensitive. A wax-containing resin coating must be used on all interior surfaces. A synthetic veil shall coat the interior surface to isolate the glass fibers of the wall. Exposed glass fibers tend to wick contaminants into the walls of the scrubber, leading to deterioration.



Note: Scrubber shall have remote (indoor) sump where freeze protection is required.

Figure 48
Vertical Counterflow Wet Scrubber

e) The outlet cleaning device immediately downstream of the scrubber packing shall be a mesh pad mist eliminator. Chevron mist eliminators cannot capture particles of less than 5 microns in diameter, and are therefore unacceptable. Refer to the design criteria for mesh pad mist eliminators (and their washdown systems) in section 5.5.1.2. For mesh pad mist eliminators immediately downstream of scrubbers, design for a maximum air velocity at the pad of 500 fpm (2.54 m/s).

f) Scrubber packing shall be constructed of polypropylene or PVC. Structural support plates and reinforcement shall be FRP and be able to withstand a pressure of 20 pounds per square in. (psi) (137.8 PA) with no deflection. Spray nozzles shall be polypropylene or PVC, and shall be of a non-clogging type. The nozzles shall be replaceable from the exterior of the scrubber. Nozzles shall be fitted using union joints. Do not thread nozzles directly into piping. Section 5.5.1.1, item h, gives details on recirculation piping. Both the continuous scrubber packing spray system and the intermittent mesh pad washdown system can use a common sump.

(1) Scrubber packing flowrate shall be a minimum of 4 gpm (15.1 L/min) per square foot of packing cross-sectional area.

(2) The recirculation pump shall incorporate an inlet filter that is serviceable from the outside of the scrubber.

(3) Minimum scrubber sump capacity shall be 1.5 times the volume required by the recirculation system.

g) Differential pressure gauges shall be mounted on the annunciator panel. The scrubber shall have pressure taps upstream from the scrubber packing and downstream from the mist eliminator. These taps shall be connected to the differential pressure gauges using leak-free tubing.

h) An inspection hatch for maintenance access shall be specified. Hatch location shall be above the scrubber packing and below the mesh pad mist eliminator, giving easy access to the spray nozzles.

i) A three way valve shall be installed on each differential pressure gauge signal line to allow periodic blowout of the signal lines. These valves also allow the gauges to be zeroed while the system is operating. Locate these three-way valves on the annunciator panel adjacent to the pressure gauges.

If a wet scrubber is chosen as the control device for chromic acid emissions, a horizontal chevron mist eliminator (Figure 49) shall be installed upstream of the scrubber. A chevron mist eliminator will collect over 80 percent of the chromic acid mist, reducing the wastewater stream from the wet scrubber. Design criteria for chevron mist eliminators are given in the next paragraph.

5.5.1.3 Chevron Mist Eliminator. See figure 49.

a) The mist eliminator housing shall be constructed of fiber reinforced plastic. The chevron blades shall be constructed of polypropylene.

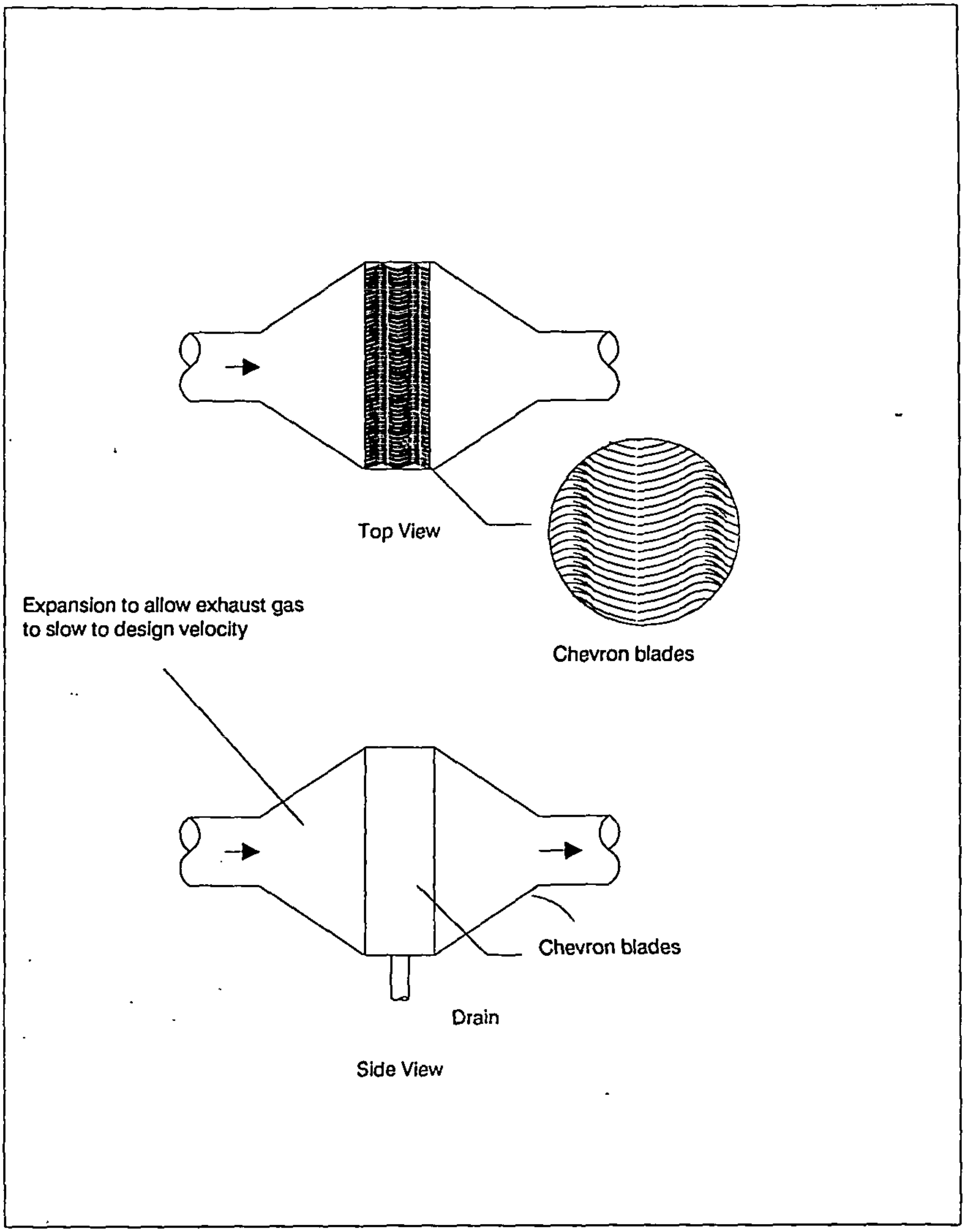


Figure 49
Chevron Mist Eliminator

b) Design velocity shall be 1200 fpm (6.10 m/s). Removal efficiency at design velocity shall be 100 percent for all particles with diameters greater than 20 microns.

c) Maximum allowable pressure drop across the mist eliminator shall be 1.0 in. wc (10.1 KPa).

d) A bank of spray nozzles shall be located directly upstream of the chevron blades for periodic washdown. The washdown system shall be once-through with run-off drained (or pumped) directly into a holding tank. Contents of the holding tank shall be used to replenish plating tanks. Pipes and fittings for the washdown system shall be schedule 80 PVC. Valves shall be union end ball valves constructed of PVC. Nozzles shall be connected to piping using "T" unions. Nozzles screwed directly into piping incur fatigue and are not acceptable.

e) Washdown cycles shall be automatically controlled using a timer adjustable in increments of one minute over a 24 hour period.

f) Access panels shall be located for ease of maintenance and removal of all internal components.

5.5.2 Air Cleaning Devices for Buffing, Grinding, and Polishing. Specify a dust collector for controlling emissions from these operations. Accumulations of lint or combustible metals (e.g., magnesium) can create fire and explosion hazards. Therefore, always position the dust collector outdoors and equip it with explosion relief vents designed per NFPA-68, Deflagration Venting. Make sure that all parts of the ductwork and dust collector are grounded to prevent build-up of static charges. For extremely hazardous materials, specify a wet collector.

5.6 Discharge Stack Design and Location. Use discharge stacks fabricated from fiberglas reinforced plastic for any operations which may have corrosive emissions. Use steel stacks designed per SMACNA's Guide for Steel Stack Design and Construction for any processes which may have solvent emissions, and for buffing, grinding, and polishing emissions.

5.7 Replacement Air. Most plating shops are likely to use a number of separate air handling units to provide replacement air. In the interest of energy conservation, size each unit to replace an amount of air corresponding to the amount exhausted by one exhaust fan. Design these two fans to be interlocked so that when an exhaust fan is shut down (as in the case of a plating line being taken out of service), the corresponding air handling unit is shut down and the correct amount of air is always supplied to the shop. Design perforated ductwork, para. 2.1.3.4, and dedicate one perforated duct to each air handling unit. If the perforated ducts are all connected to a single supply plenum, ineffective air distribution will result.

To prevent airborne contamination from migrating out of these shops, balance the replacement air handling units to provide slightly less (90-95 percent) of the exhaust air quantity. This will create a slightly negative (-0.05 to -0.10 in. wc (-12.4 to -24.9 Pa)) pressure in the shop area.

Never recirculate any exhaust air.

5.7.1 Heating and Cooling Design air heating in accordance with para. 2.1.3.4, and with NAVFAC DM-3.03. Consider the use of heat recovery equipment for cold weather locations, but do not specify a heat exchanger which has the potential for mixing any exhaust air with replacement air, as is the case with rotary wheel heat exchangers.

5.8 System Controls. Interlock the exhaust and replacement air fans as stated in para. 5.7.

Section 6: FIBERGLASS REINFORCED PLASTIC FABRICATION AND REPAIR FACILITIES

6.1 Function. Fiberglass reinforced plastic (FRP) shops and facilities primarily fabricate and repair aircraft and shipboard components. Both FRP shops and facilities shall include a shop space, a mechanical equipment space and an area for decontaminating protective clothing.

6.1.1 Operational Considerations. FRP 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 create a potential for heat stress.

6.1.2 Ergonomics. The arrows in Figure 50 show the traffic pattern during a typical work shift. The workers enter the clean locker rooms through the administrative area. They put on protective outerwear and proceed to the shop area through corridors which bypass the dirty locker rooms. After performing

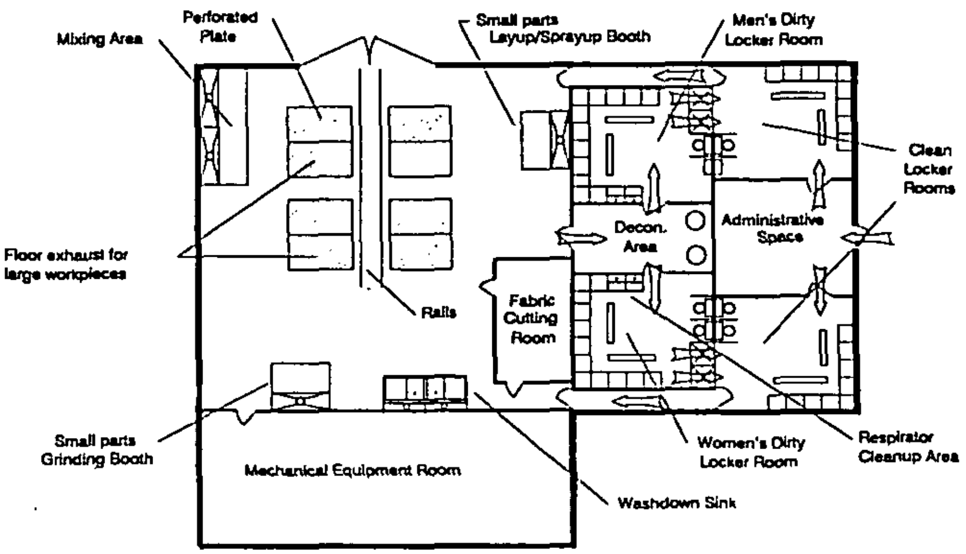


Figure 50
Typical Floor Plan for FRP Facility

their work, shop personnel vacuum their protective outerwear and discard it in containers provided in the decontamination area. The workers then enter the dirty locker rooms where they remove the remainder of their work garments. They proceed to the clean locker rooms via the showers, which act as a barrier to the migration of glass fibers, vapors and resin dust.

To reduce potentially hazardous vapors in the shop, consider using airless spray equipment. While the initial cost for this equipment is greater than traditional compressed air systems, overspray and fog are reduced and less resin and fiberglass is required over the life of the equipment. One disadvantage of these systems is their limited pattern and flow adjustment capability.

6.2 Typical Floor Plans. Design floor plans for FRP fabrication and repair facilities to meet Occupational Safety and Health Administration (OSHA) requirements and to be functional. Position the locker rooms and shop spaces so workers do not have to go through decontamination procedures many times per day while attending to their bodily needs. The typical floor plan shown in Figure 50 addresses these considerations.

6.3 Exhaust Air. Provide local exhaust which captures contaminated air generated during FRP fabrication and repair operations.

Design the entire exhaust air system in accordance with MIL-HDBK 1008, Fire Protection for Facilities Engineering, Design and Construction; NFPA 33, Spray Applications Using Flammable and Combustible Materials; NFPA 91, Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal or Conveying, NFPA 654, Standard for the Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries and NFPA 68.

FRP dust will burn and even explode in a manner similar to fine wood dust. When exhausted materials are flammable or combustible, the exhaust volume shall be sufficient to maintain a contaminant level below 25 percent of the (LEL) of the material in all areas of the exhaust system. Vapor condensation may occur in ductwork as it passes through an area with a lower temperature. A fire hazard can be created if the flammable vapors from styrene and acetone condense and pool in the ductwork. (LVHV) hand tools as described in para. 6.3.5, may be used in hoods generating vapors if space is limited. However, conventional grinding operations must be isolated from the mixing areas and lay up and spray up areas. Because the combined hazard of the dust and flammable vapors is potentially explosive, post signs in the lay up and spray up areas and the mixing area without LVHV connectors that read:

DANGER

DO NOT GRIND CUT OR SAW FIBERGLASS IN THIS AREA

The LEL, also referred to as the lower flammability limit, is the minimum concentration of chemical below which the chemical and air mixture is too "lean" to burn or explode. Listed as percent by volume in air, the LEL for volatile chemicals can be found on the Material Safety Data Sheet (MSDS). If the LEL is not listed on the MSDS request the information from the manufacturer. Generally, if the ventilation system removes vapor to meet the Threshold Limit Value (TLV) requirements, the LEL requirement is also met. However, the LEL value must be checked and Appendix B shows a sample calculation.

6.3.1 Hood Design. The sizes and shapes of workpieces in FRP fabrication and repair facilities vary greatly. Design separate hoods for processes producing only particulate, only vapor, and both particulate and vapor. Table 6 summarizes recommended hood types and air pollution control for each operation.

Table 6
Recommended Hoods and Air Pollution Devices for FRP Operations

Operation (Expected contaminant)	Hood Type (Figure Number)	Air Cleaning Device (See Notes)
Chemical Mixing (Vapors)	Workbench (53)	1
Lay up (Vapors)	Workbench/Large Piece (53/52/51)	1
Spray up (Vapors)	Spray up (52)	1
Grind,Cut,Saw (Particulate)	Workbench/Large Piece (53/51)	2
Cleanup (Vapors)	Washdown (54)	3 or 1
Hand Tools (Particulate)	LVHV Vacuum System	2

NOTES: (1) Determined by the local air pollution regulations but may include an afterburner or a carbon adsorber.
(2) Fabric Collector
(3) Substitute an Aqueous Emulsion Cleaner for Acetone

Portable hand tools with LVHV vacuum systems are recommended for sawing, cutting, and grinding on all workpieces. Ensure that the tools, with their vacuum hoses, are properly sized for the workpiece internal angles and curvature. LVHV systems are described in para 6.3.5.

Consider an enclosed molding system which completely encloses the workpiece if the facility repeatedly manufactures the same workpiece.

Care must be taken to design exhaust hoods that enclose all processes to the greatest possible extent, without inhibiting operations. Baffle all exhaust hoods to reduce crossdrafts and to improve hood efficiency. Ensure that a capture velocity of no less than 150 fpm (0.76 m/s) is generated by the hood to control contaminants. For all hood, except the spray up hood, design the face using perforated plate with 3/8-in. (9.5 mm) holes and a velocity through the holes of 2000 fpm (10.2 m/s). Spray up booths use a layered prefilter. The plenum velocity must be less than one-half the velocity through the perforated holes or layered prefilter to create even airflow over the hood face. Design the hood-to-duct transition with an included angle of no more than 90 degrees. Specify that the length of the hood served by each exhaust plenum shall not exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (2.44 and 4.88 m) in length shall have two exhaust takeoffs. Provide cleanout doors in the plenum to allow removal of accumulated particulate.

6.3.1.1 Hoods for Large or Concave Pieces. When the workpiece has large or concave surfaces, specify a floor exhaust plenum as shown in Figure 51. Consider mounting the workpiece on a cart that rotates the workpiece easily. This will reduce the dead air space that occurs when radomes, boat hulls, etc. are placed on the floor.

6.3.1.2 Spray up Booths. Design a spray up booth of the type shown in Figure 52. In shops where spray up and lay up are performed in the same booth, use the spray up hood design. Separate operations in this booth from any cutting, grinding and sawing operations when conventional hand tools are used.

6.3.1.3 Ventilated Workbench. For small workpieces, design a ventilated workbench as shown in Figure 53. A similar workbench is required for resin preparation and mixing. If 55-gallon drums are used during resin preparation, eliminate the drawers and increase the size of the hood face by extending it to the floor. To reduce styrene and acetone exposure, consider using aqueous emulsion cleaners.

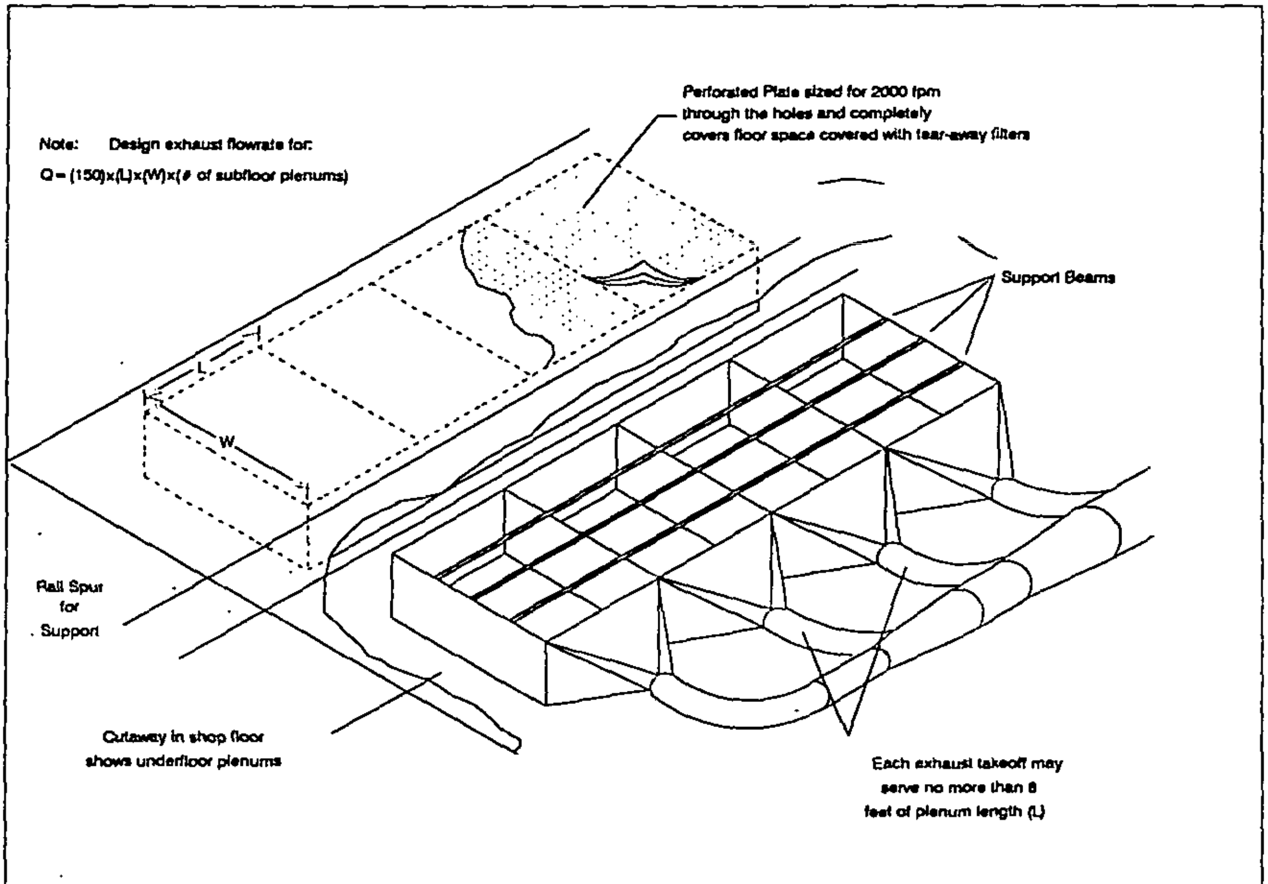


Figure 51
Floor Exhaust

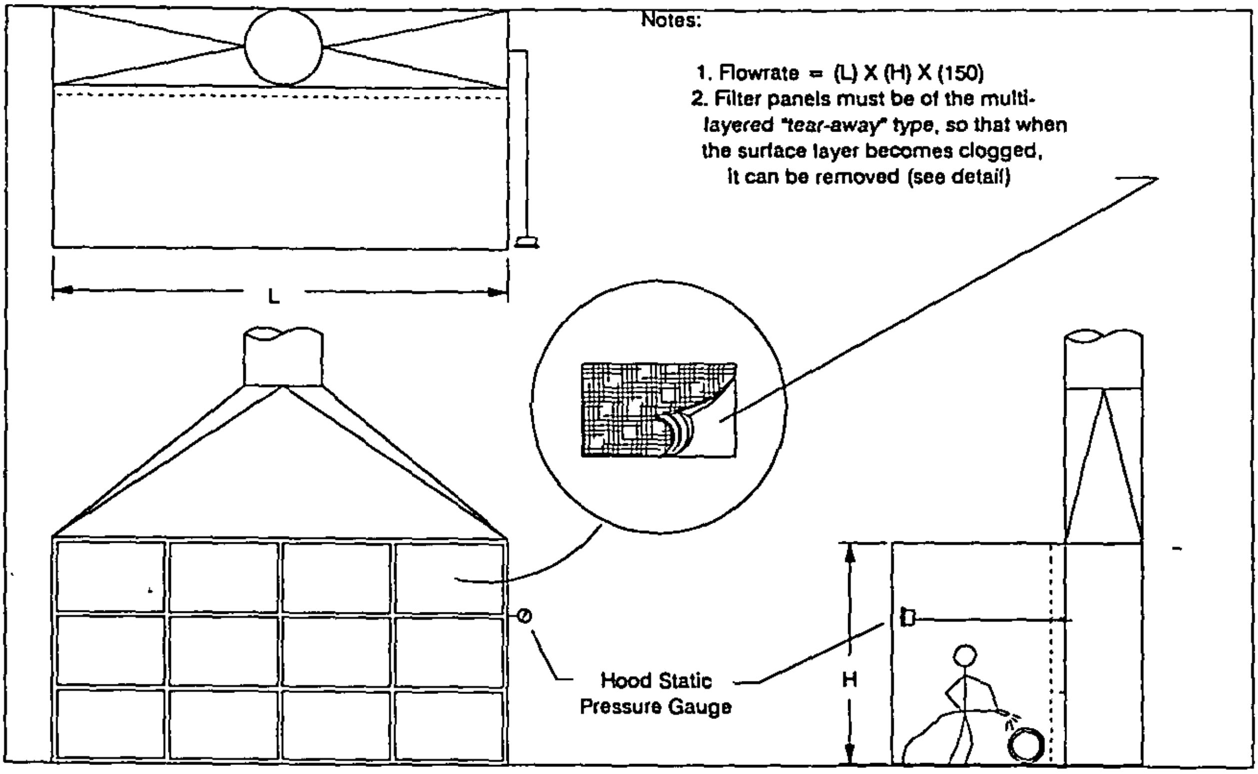


Figure 52
Spraying Booth

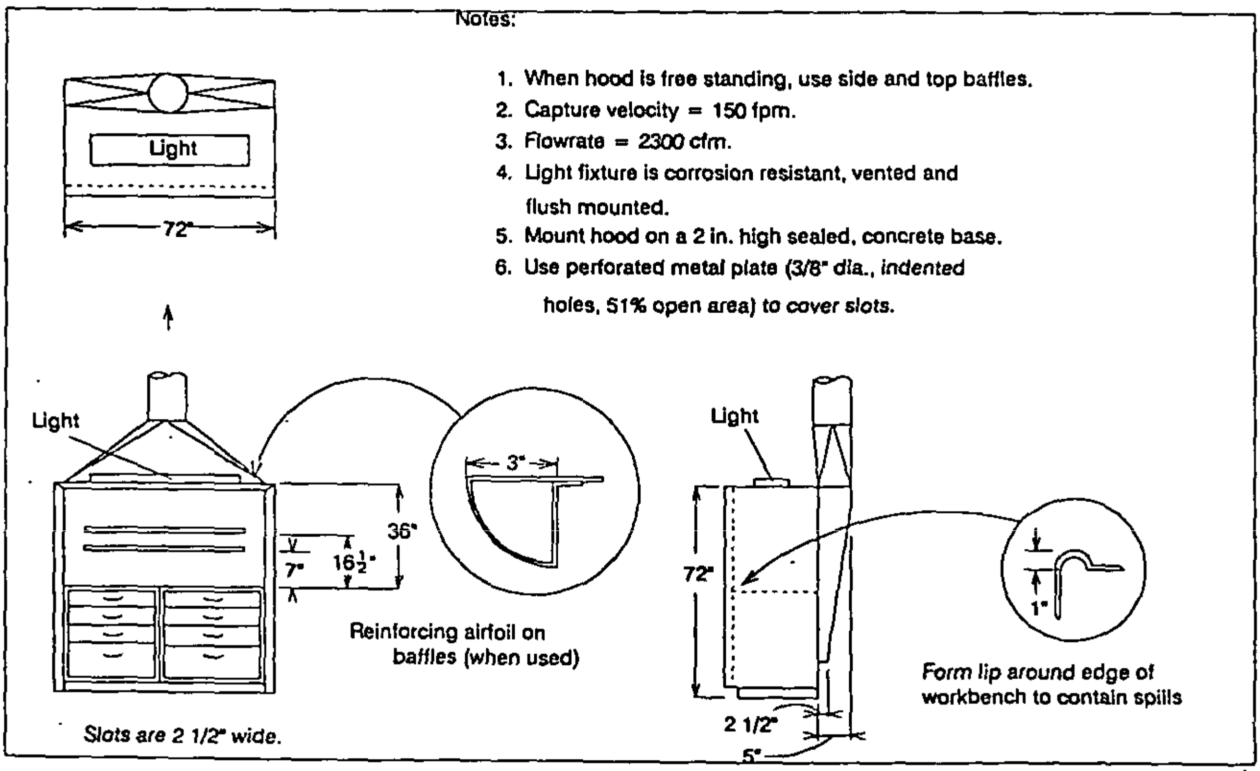


Figure 53
Workbench Hood

6.3.1.4 Ventilated Solvent Washdown Sink. In all FRP lay up and repair facilities, specify a ventilated solvent washdown sink as shown in Figure 54.

6.3.2 Ductwork and Fans. The minimum transport velocity for LVHV hand tools, grinding and spray up operations is 3,500 fpm (17.8 m/s) to prevent particulate material from collecting in the ductwork. Size ductwork carrying vapor (e.g. 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 not combustible. Route the ductwork directly to fans located outdoors. For further information on ductwork, refer to para. 2.1.3.1.

Duct hangers shall have sufficient strength to support the ductwork if it becomes half-filled with material. Cleanout doors shall be provided adjacent to every bend and vertical riser. In horizontal runs, cleanout door spacing shall not exceed 12 ft (3.66 m) for ducts 12 in. (30.5 cm) or less in diameter. Larger ducts shall have a cleanout door spacing not exceeding 20

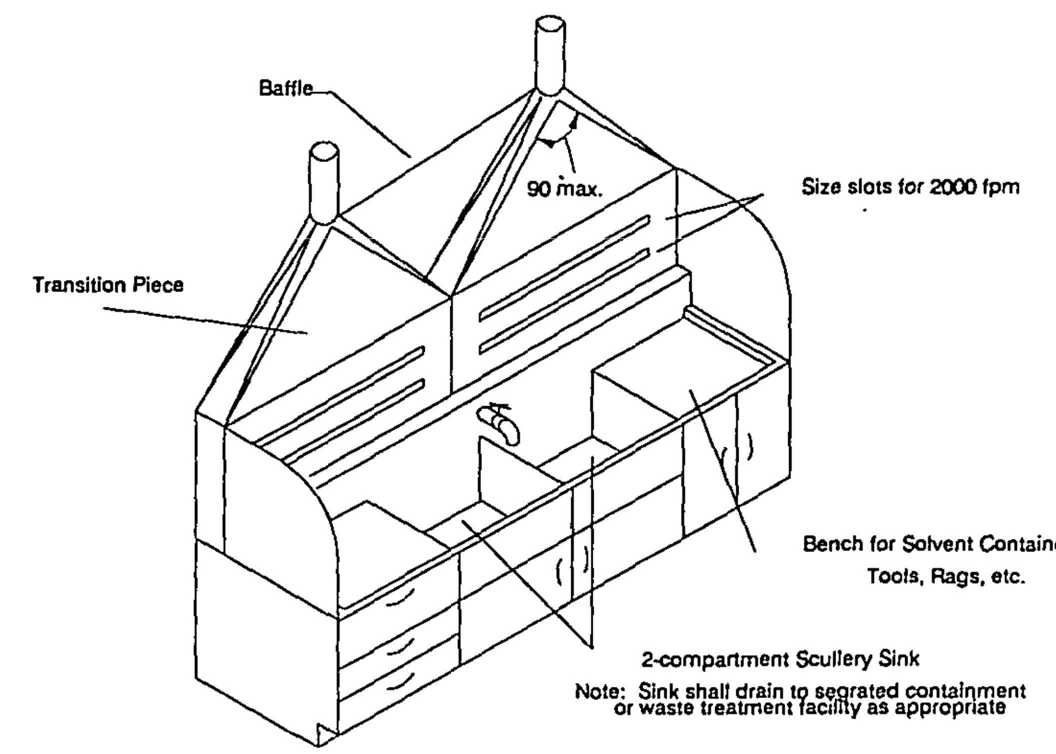


Figure 54
Ventilated Sink

ft (9.14 m). Locate cleanout doors on the side or top of the duct. Consult with a fire protection engineer and use MIL-HDBK 1008A to design a fire protection system for the ductwork, if required.

The most suitable fan for these operations is a centrifugal unit with backward inclined airfoil blades. A backward inclined unit is less efficient but still acceptable. For more details on fan selection refer to para. 2.3.3.

6.3.3 Air Cleaning Devices. Use separate air cleaning devices for grinding, buffing and polishing operations where particulate material is generated and lay up and mixing operations where flammable vapors are generated.

Volatile Organic Compound (VOC) emission laws are becoming more strict. Air pollution control devices such as afterburners, adsorbers, absorbers or condensers may be required for mixing booths, spray up and lay up booths. Consult the air pollution control authorities for details on local requirements. These expensive devices can usually be avoided by using low monomer polyester material, closed molding systems or low-VOC resin systems and airless and air-assisted spray equipment.

Use a fabric collector for grinding operations and the LVHV hand tools. In shops with a large particulate volume, equip the fabric collector disposal chute with a motor-driven rotary air lock.

Spray up operations release a combined contaminant of wet resin laden fiber and organic vapors. Therefore, separate spray up operations from all other operations. Spray up hoods use layered prefilters instead of a perforated hood face and an air cleaning device for vapors. The prefilter is required to prevent wet airborne resin from hardening in the ductwork and collectors. When the prefilter surface becomes loaded, as indicated by the hood static pressure gauge, a layer is peeled off and discarded. This continues until only the base filters remain. The prefilter section is then replaced. Because styrene and acetone vapor are produced in FRP facilities, specify filter material that is not damaged by these chemicals.

6.3.4 Weather-Stack Design and Location. Refer to para. 2.1.3.4 for design guidance for exhaust stacks.

6.3.5 Industrial Vacuum System. Provide a permanently installed vacuum system (see Figure 55) at fiberglass shops 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.

The ACGIH manual 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, the takeoff hood is designed into the tool's safety guard. Refer to Table 7 for minimum exhaust volumes and vacuum hose sizes.

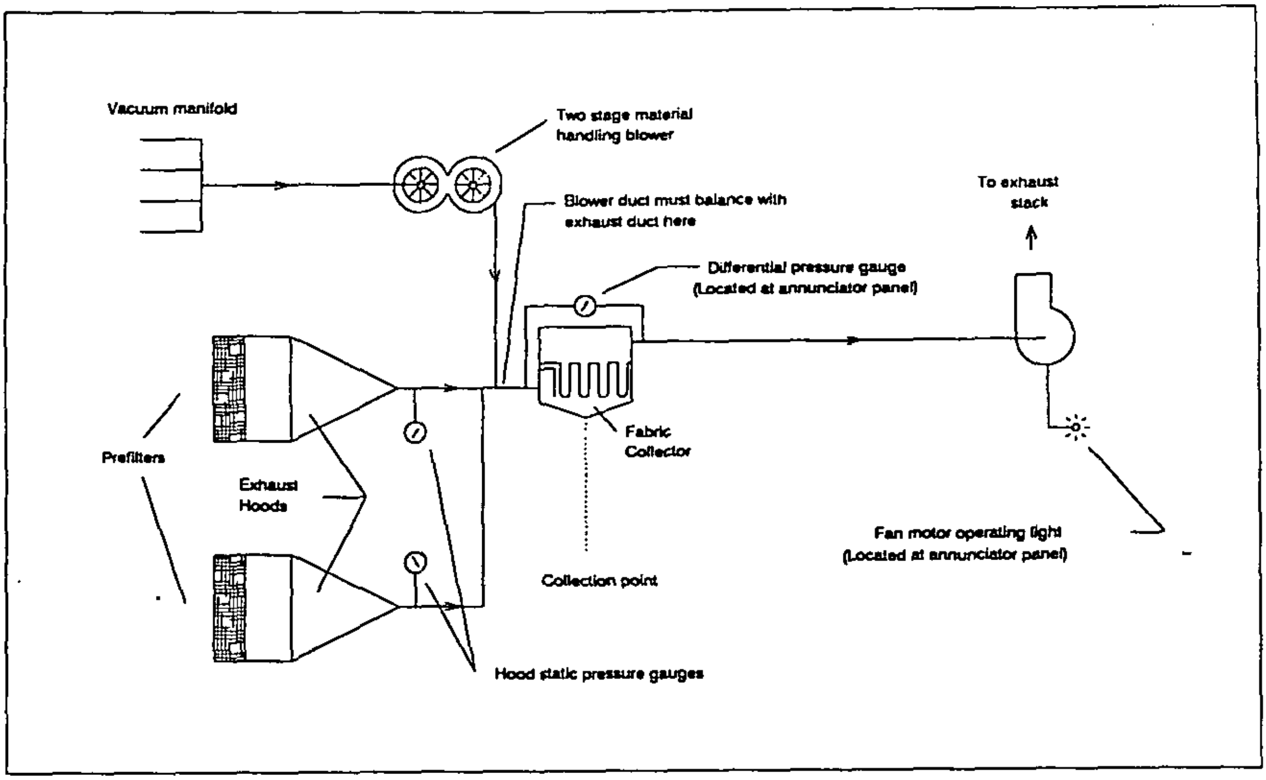


Figure 55
Exhaust System Schematic

Table 7
Minimum Volumes and Vacuum Hose Size for FRP Operations

Hand Tool	Flow Rate (CFM)	Hose Size (in.)
Pneumatic chisel	125	1-1/2
Radial wheel grinder	150	1-1/2
Conewheel grinder, 2 in.	150	1-1/2
Cup stone grinder, 4 in.	200	2
Cup-type brush, 6 in.	250	2
Radial wire brush, 6 in.	175	1-1/2
Hand wire brush, 3 x 7 in.	125	1-1/2
Rip out knife	175	1-1/2
Rip out cast cutter	150	1-1/2
Saber saw	150	1-1/2
Saw abrasive, 3 in.	150	1-1/2
General vacuum	200	2

Reference: Hoffman Air and Filtration Systems, Centrifugal Compressor Engineering.

Note: Locate tool vacuum hose connection on the ends of the worktable underneath the stands.

The most important consideration in vacuum system design is to ensure that the proper capture velocity is produced at each take-off hood. Design the hood to pick up contaminants as close as possible to the point of generation. Well-designed vacuum systems pick up contaminants within 1/2 in. (1.26 cm) of the source. There are two other considerations. First, design the pickup airstream to have a velocity of two to three times the generation velocity for particles of 20 to 30 microns, four to five times the generation velocity for particles up through 300 U.S. standard mesh, and six to eight times the generation velocity for particles up through 20 U.S. standard mesh. Secondly, base the air design volume on no fewer than two parts of air to one part of material to be captured, by weight.

The vacuum hose length shall not exceed 25 ft (7.6 m). As a general rule, a distance of 30 to 35 ft (9.0 to 10.7 m) between two inlet valves for use with a 25 ft (7.6 m) length of hose is considered ideal. The hose size depends on the air volume per hose, the number of hoses to be used simultaneously, and the transport velocities.

The vacuum system shall use a multistage material handling blower. Design the blower size using the maximum volume and total system pressure loss associated with simultaneous tool use. The blower shall feed into the dirty side of the fabric collector used for the particulate laden exhaust air generated from grinding operations using conventional tools. This configuration minimizes the number of FRP collection points. Because the LVHV system design data is largely empirical, use the manufacturer's data to complete the design. Use NAVFAC DM 3.5 to design the vacuum system.

6.4 Replacement Air. Design replacement air systems that modulate airflow to maintain, in the shop space, a negative pressure (relative to the atmosphere), ranging from -0.05 to -0.10 in. wc (-12.5 to -24.9 Pa). Maintain the protective clothing decontamination areas, the equipment room and the dirty locker rooms at a negative pressure (relative to the atmosphere) ranging from -0.01 to -0.04 in. wc (-2.49 to -9.96 Pa). Maintain the clean spaces at a positive pressure (relative to the atmosphere) ranging from +0.01 to +0.05 in. wc (+2.49 to +12.5 Pa). For replacement air system criteria, refer to para. 2.1.3.4.

6.4.1 Quantity and Distribution. In the work space, distribute air to produce a laminar flow of air from supply to exhaust. The vertical supply method is preferred to the horizontal supply method. See para. 2.1.3.4.

6.4.2 Heating and Air Conditioning. Each ventilated space shall have a dedicated replacement air system. Temper the air in accordance with NAVFAC DM 3.03. Conduct a study of the curing requirements of the resin before specifying temperature and humidity ranges. Do not recirculate exhaust air.

6.5 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria.

Position an annunicator panel at the entrance to the dirty space so that the operators can monitor the operation of the replacement air system, the exhaust air system and the balance between the dirty and clean spaces.

Provide differential pressure sensors at locations that are representative of average static pressure in each controlled space. If the pressure varies from the ranges stated in para. 6.4, a timer shall be triggered. If the system cannot correct the difficulty within 60 seconds, the alarm shall be triggered. If the difficulty is corrected within the allotted time, the timer shall be automatically reset. Multiple alarm beacons may be required if the operator's view is obscured during grinding. To prevent the use of hand tools without ventilation control, tie the hand tool power supply to the interlock on-off switch for the ventilation systems.

6.6 Safety and Health Items. Specific criteria for safety and health items follow in para. 6.6.1 and 6.6.2.

6.6.1 Respirators. 29 CFR 1910.1000 prescribes the maximum allowable concentrations of styrene, acetone, various solvents and glass fibers. If the process requires chemicals (e.g. methyl ethyl ketone peroxide) not listed in 29 CFR 1910.1000, use guidelines established by the ACGIH. Protection from specific resins and solvents used in the shop and glass fiber protection will require a stacked cartridge respirator system. Provide space in the dirty locker room to clean respirators.

Consider using air-line respirators. If air-line respirators are used, provide several convenient connection points for the respirator hoses, allowing freedom of movement for workers. To prevent the inadvertent use of unfiltered plant compressed air for breathing air, provide a different type connector for the air-line respirators. For general design considerations for breathing air supply systems, refer to NAVFAC DM-3.5 and ANSI Z88.2, Practices for Respiratory Protection.

6.6.2 Combination Emergency Eyewash and Deluge Shower. Specify a combination emergency eyewash and deluge shower when the potential for exposure to irritants (e.g. styrene, methyl ethyl ketone peroxide) exist. Refer to para. 4.6 for design criteria.

Section 7: ABRASIVE BLASTING FACILITIES

7.1 Function. Abrasive blasting facilities provide paint preparation capabilities for aircraft, shipboard, mechanical, and utility equipment components.

7.2 Operational Considerations. During abrasive blasting operations, abrasives and surface coatings are shattered to varying degrees depending on the materials. This generates dust which may contain particles of respirable (0 to 5 micron) size. In many cases, the composition and toxicity of the dust creates a health hazard. Enclose blasting operations so that the exposure to hazards is limited to those personnel performing the operation.

Due to the abrasive and dust-laden atmosphere in the work area, personnel are required to wear heavyweight clothing and a supplied air respirator. 29 CFR 1910.94(a) requires that specific criteria be implemented during the design of these facilities to protect workers from the health and safety hazards.

7.3 Exhaust Air. The exhaust air system shall draw the flow of air past the worker, toward and past the workpiece, and into the exhaust plenum, thereby giving maximum protection to the worker. All exhaust air from abrasive blasting operations shall be discharged outdoors, through an appropriate air cleaning device. Where flammable or combustible materials are used, design the entire exhaust air system in accordance with NFPA 33, 68, 91, and 654. Engineering controls shall be used to reduce noise exposure to the workers wherever feasible. Careful blast nozzle selection plays an import role, since noise generation is a high power function of discharge velocity. Sound barrier material may also be needed on the enclosure walls.

7.3.1. Blasting Enclosures. Design the enclosure so that the exhaust air flows either from ceiling to floor (downdraft) or from one wall to the opposite wall (crossdraft) as shown in Figures 56 and 57, respectively.

In determining whether to use a crossdraft or a downdraft design, consideration must be given to the geometry of the enclosure. A downdraft design is more desirable in that the contaminated air is almost always directed away from the worker's breathing zone and there is superior visibility. However, a downdraft design is usually less cost effective than a crossdraft design since the horizontal cross section usually has a larger area than the vertical cross section, and therefore requires more air flow to obtain the same average velocity through the enclosure. Refer to Table 8 for required flow rates for various sized booths. Crossdraft blasting enclosures shall always be ventilated through the smaller cross sectional area of the enclosure.

Use perforated, plate as shown in Figures 56 and 57, so that the airflow is uniformly distribute over the entire cross section of the enclosure. The minimum airflow rate shall be maintained everywhere through the enclosure within 20 percent.

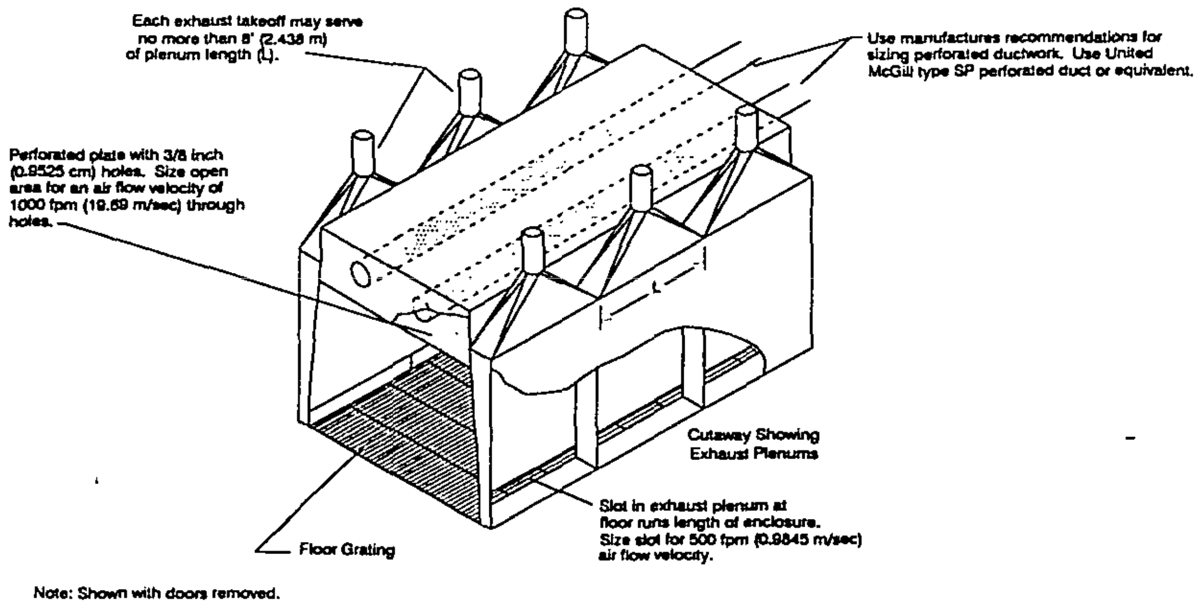


Figure 56
Downdraft Blast Enclosure

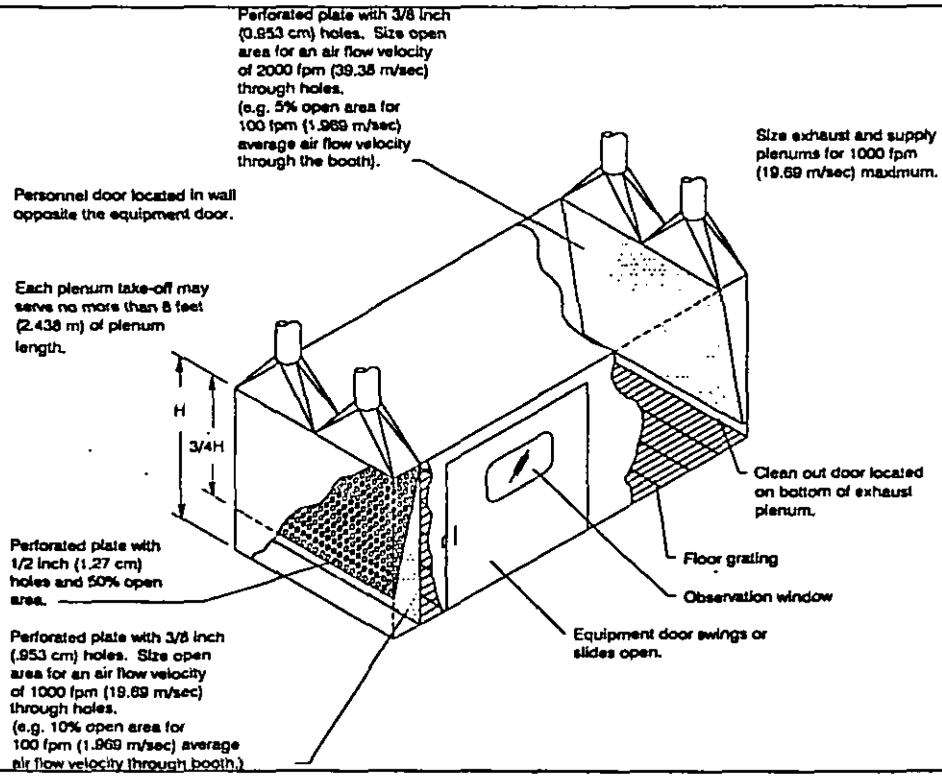


Figure 57
Crossdraft Blast Enclosure

Table 8
Air Velocities for Blasting Enclosures
units are in feet per minute
(units in ( ) are in meters per second)

	Downdraft				Crossdraft
Ft^2 of Floor Area (m^2 of Floor Area)	0-100 (0 to 9.29)	100-200 (9.29 to 18.6)	200-300 (18.6 to 27.9)	300-400 (27.9 to 37.2)	
Type of Abrasives (1) Abrasives containing more than 5 percent free silica; materials that may generate airborne asbestos fibers or free-silica-containing dusts; coatings containing lead, chromates or other similarly toxic compounds having a permissible exposure limit of less than 1 mg/m^3.	90 (0.457)	70 (0.356)	60 (0.305)	60 (0.305)	100 (0.508)
(2) Abrasives containing 5 percent free silica or less; coatings having permissible exposure limits from 1 to 5 mg/m^3.	60 (0.305)	50 (0.254)	40 (0.203)	35 (0.178)	80 (0.406)
(3) Low toxicity materials, such as abrasives of steel or aluminum (oxide and contaminants, such as iron oxide scale, having permissible exposure limits of 5 mg/m^3 or greater.	40 (0.203)	35 (0.178)	30 (0.152)	20 (0.102)	60 (0.305)
(4) Shot peening on clean metal with metal shot.	30 (0.152)	20 (0.102)	20 (0.102)	20 (0.102)	50 (0.254)

Notes: 1. Ventilation rates may need to be greater than those in the table, depending on individual circumstances. Consideration shall be given to higher rates when the composition of the workpiece is such that upon breakdown from the abrasive impact, toxic contaminants are released into the work area. Consider also the composition of the abrasive (e.g., beryllium in copper slag).

Design all doors to be flanged and sealed tightly. Make personnel doors operable from both the inside and outside of the enclosure. Material doors need only be operable from the outside.

Do not integrate the exhaust ventilation system with the abrasive recovery system. A separate abrasive recovery system shall be provided.

Observation windows made of safety glass protected by screening on the outside of the window shall be provided for all blasting enclosures. The screen retains the glass in case of an explosion.

7.3.2 Blasting Cabinets. Baffle all air inlets to prevent abrasive material leakage. The minimum inward air velocity at all operating openings shall be 500 fpm (2.54 m/s). Specify that the exhaust air be discharged outside and be replaced by 100 percent untempered outside air.

7.3.3 Ductwork and Fans. Size the exhaust ductwork to maintain a minimum transport velocity of 3,500 fpm (17.8 m/s). All elbows in ductwork carrying abrasive material shall be specified as flat backed (see Figure 58). The duct hangers shall have sufficient strength to support the ductwork if it becomes half filled with material. Cleanout doors shall be provided adjacent to every bend and vertical riser. In horizontal duct runs, cleanout door spacing shall not exceed 12 ft (3 m) for ducts 12 in. (30.5 cm) or less in diameter. Larger ducts shall have a cleanout door spacing not exceeding 20 ft (6.10 m). Refer to para. 2.1.3.2 for general duct considerations.

Use centrifugal fans with backward curved airfoil blades. Backward inclined centrifugal fans without airfoil blades are less efficient, but still acceptable. If the replacement air is not mechanically supplied, size the exhaust fan for the total system resistance and include replacement air duct resistance. For further information about fan selection and connection, refer to para. 2.1.3.3.

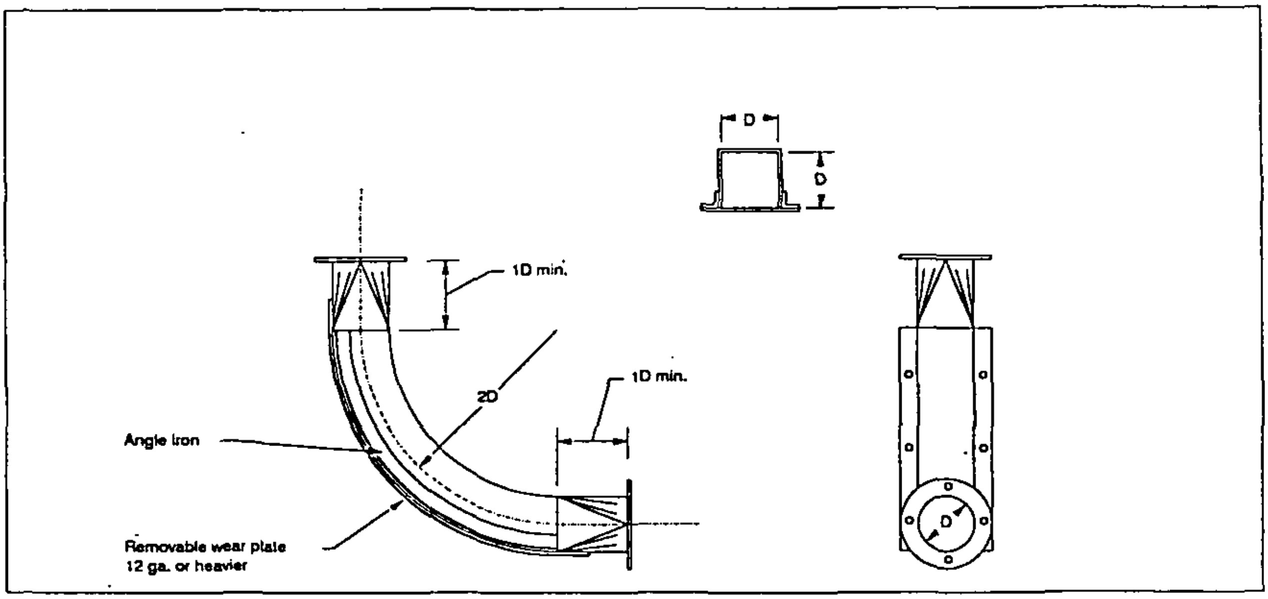


Figure 58
Flat Back Duct Elbow

7.3.4 Air Cleaning Devices. The air cleaning device shall be a pulse-jet, pleated paper cartridge type baghouse and shall provide a 99.9 percent weight arrestance efficiency in accordance with the ASHRAE Standard 52- 76. The "air-to-cloth" ratio (the ratio of flow rate in cfm to filter area in square feet) shall be between 1.5:1 and 2:1. The pulse-jet controls shall include the following:

a) Pulse interval range of 0 to 5 minutes.

b) Pulse duration range of 0 to 2 seconds.

c) Photohelic gauge with remotely mounted alarm.

d) Option to use upper static pressure setpoint on photohelic gauge to trigger cleaning cycle.

The baghouse shall also include the following:

a) Perforated plate at the inlet to evenly distribute incoming dirty air across filters.

b) Access hatch on baghouse inlet (24" x 24" min.) (0.610 m x 0.610).

c) Access hatch on hopper (24" x 24" min.) (0.610 m x 0.610 m).

d) Rotary airlock, 10" (0.254 m) diameter minimum, on hopper throat.

e) Replaceable explosion vents designed per NFPA-68 located on baghouse hoppers where the potential for explosion of accumulated dust exists.

f) Platforms leading to all elevated access hatches.

g) The fan shall always be on the clean side of the baghouse.

7.3.5 Weather Stack Design and Location. Refer to para. 2.1.3.4 for design guidance for exhaust discharge stacks.

7.4 Replacement Air. Design the replacement air system to maintain a negative pressure (relative to the atmosphere) ranging from -0.05 to -0.10 in. wc (-12.4 to 24.9 Pa) in the abrasive blasting enclosure. Maintain any mechanical equipment spaces at a negative pressure (relative to the atmosphere) ranging from -0.01 to -0.04 in. wc (-2.49 to -9.96 Pa). Maintain the administrative spaces and locker rooms at a positive pressure (relative to the atmosphere) ranging from +0.0 to +0.05 in. wc (+0.0 to +12.4 Pa). Design a dedicated replacement air system for all abrasive blasting enclosures.

7.4.1 Quantity and Distribution. Design the replacement air system to provide 10 percent less air than is exhausted. This should produce the required relative negative pressure in the enclosure. Abrasive blasting enclosures shall have a ceiling or wall supply plenum which is directly opposite the exhaust (ceiling to floor airflow or wall to opposite wall). The preferred means of distributing the replacement air in the enclosure is through perforated plate and duct as shown in Figures 56 and 57.

7.4.2 Heating and Air Conditioning. Design all heating and air conditioning in accordance with NAVFAC DM-3.03. Do not recirculate exhaust air.

7.5 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria. Position an annunciator panel at the entrance to the blasting enclosure so that the operators can monitor the operation of the replacement and exhaust air systems, the pressure drop across the baghouse, and the relative pressure difference between the dirty and clean spaces.

Provide differential pressure sensors at locations that are representative of the average static pressure in the blasting enclosure. If the operation varies from the ranges stated in para. 7.4, a timer shall be triggered. If the system cannot correct the difficulty within 60 seconds, the alarm shall be triggered. If the deficiency is corrected within the allotted time, the timer shall be automatically reset. The alarm shall be both visible and audible in the blasting enclosure, so that the worker always receives dual notice of system failure. Multiple alarm beacons may be required, if the operator's view is obscured during blasting. Interlock the ventilation system with the blasting machine, so that blasting may not be done without ventilation.

7.6 Safety and Health Items

7.6.1 Breathing Air. Federal regulation 29 CFR 1910.94(a)(5) describes the type of respiratory protection equipment that must be used in abrasive blasting facilities. Whenever work is performed inside a blasting enclosure, the operator shall wear a continuous-flow, air-line respirator that covers the wearer's head, neck, and shoulders. Provide each hood with a vortex type climate control that is adjustable.

Several air hose connection points shall be provided along the perimeter of the enclosure to allow freedom of movement for the operator. Design the respirator air supply in accordance with 29 CFR 1910.134(d) and NAVFAC DM-3.5.

Section 8: PAINT SPRAY FACILITIES

8.1 Function. Paint spray shops and facilities provide surface finishing capabilities for a wide range of parts, equipment, vehicles, and aircraft. Spray booth sizes range from small bench type units designed to paint small parts, to large chambers that are used for painting aircraft. Paint spray shops and facilities shall include a shop space, a mechanical equipment space, and an area for decontaminating protective clothing.

8.2 Operational Considerations. During paint spray operations, paint is atomized by a spray gun and then deposited on to the object being painted. Depending on the application equipment and spray method used, transfer efficiencies vary greatly. Transfer efficiency is defined as the amount of paint solids deposited on a surface divided by the total amount of paint sprayed, expressed as a percentage. Overspray is the paint that is sprayed but not deposited on the surface to be painted. By using application equipment and methods that reduce the amount of overspray generated, exhaust and replacement air requirements are reduced, less maintenance is required, and a cost savings is realized due to the reduced paint usage. Conventional air spray equipment has an accepted transfer efficiency of approximately 25 percent, while airless and electrostatic spray equipment have efficiencies of 45 percent and 60 percent to 70 percent respectively.

Spraying heated paint further increases benefits, since the heated paint has a lower viscosity which enables the paint to be sprayed at a lower pressure thereby reducing the amount of overspray generated. The lower viscosity also reduces the quantity of solvent which must be used to thin the paint, prior to spraying. This results in reduced solvent consumption as well as reduced volatile organic compound (VOC) emissions.

8.3 Exhaust Air. See 29 CFR 1910.94(C) and 29 CFR 1910.107. The exhaust air system shall draw the airflow past the operator, toward and past the workpiece, and into the exhaust intake thereby giving maximum protection to the worker. The minimum capture velocity for bench sized units is 200 fpm (1.02 m/s). For booths using spray methods with a transfer efficiency less than 65 percent, 100 fpm (0.508 m/s) shall be used as the minimum capture velocity. Booths using methods with transfer efficiencies greater than 65 percent shall have a capture velocity of no less than 60 fpm (0.31 m/s) where there are negligible crossdrafts and 100 fpm (0.508 m/s) where crossdrafts are up to 50 fpm (0.254 m/s). Where crossdrafts are in excess of 50 fpm, action must taken to further enclose the painting operation so the crossdraft is reduced.

All exhaust air shall be discharged outdoors after passing through an appropriate air cleaning device and exhaust stack. Exhaust air shall not be recirculated. In addition, design the entire exhaust air system in accordance with NFPA 33, 68, 91, and 654.

8.3.1 Spray Area Design. The sizes and shapes of workpieces which require paint spray finishing vary greatly. Spray booths shall be designed to enclose the painting operation to the maximum possible extent in order to contain the paint overspray with a minimum volume of air and to avoid disturbances from room air currents.

8.3.1.1 Spray Booths. Design paint spray booths in accordance with 29 CFR 1910.94, 29 CFR 1910.107 and Figure 59. The air flow must be in a direction that carries the contaminated air away from the workers breathing zone. If necessary, manlifts, workpiece turntables, or other means shall be provided in order to maintain the proper orientation of air flow.

8.3.1.2 Ventilated Workbench. For smaller workpieces design a workbench as shown in Figure 60. Adjust the hood depth to the size of the workpiece.

8.3.2 Air Cleaning Devices. Provide replaceable, dry filter pads that cover as much of the entire wall opposite the supply air as possible (see Figure 59). The filter pads not only remove the paint overspray from the air stream, but also help to distribute the air within the booth. Provide a differential pressure gauge across the filter section to indicate when the filters require changing. The maximum pressure drop across the filters shall be clearly marked on the pressure gauge and easily visible to workers. An alarm and flashing light labeled exhaust filters shall be activated when the pressure drop across the filters indicates that they require maintenance.

8.3.3 Ductwork and Fans. The plenum to duct transition shall have an included angle of no more than 90 degrees. Each exhaust takeoff may serve no more than 8 ft (2.44 m) of plenum length. Size ductwork to maintain a minimum airflow velocity of 2500 fpm (12.7 m/s). The ductwork shall be adequately supported throughout its length to sustain its weight plus any accumulation of material in the interior. In horizontal runs, cleanout door spacing shall not exceed 12 ft (3.66 m) for ducts 12 in. (0.305 m) or less in diameter. Larger ducts shall have a cleanout door spacing not exceeding 20 ft (6.10 m). Locate cleanout doors on the side or top of the duct.

The most suitable fan for these operations is a centrifugal unit with backward curved airfoil blades. A fan with backward inclined blades is less efficient but still acceptable. For low pressure applications (less than 2 in. wc fan static pressure), a tubeaxial or vaneaxial fan is also appropriate. Use explosion proof fixtures and a non-sparking fan. Electric motors driving exhaust fans shall not be placed inside booths or ducts. Also, belts shall not enter the duct or booth unless the belt and pulley within the duct or booth are thoroughly enclosed. For more detailed information about fan selection, refer to para. 2.1.3.2.

8.3.4 Weather and Stack Design and Location. Refer to para. 2.1.3.3 for design guidance for exhaust stacks.

8.4 Replacement Air. Design the paint area so that the replacement air enters directly opposite from where the air is exhausted. Provide a differential pressure gauge across the inlet filters for the replacement air to activate an alarm and flashing light labeled inlet filters when the pressure drop across the filters indicates that they require maintenance. For booths designed to include a replacement air system as shown in Figure 59, provide a differential pressure gauge across the inlet filters. Design the pressure gauge to activate an alarm and flashing light labeled "inlet filters" when the pressure drop across the filters indicates that they require maintenance.

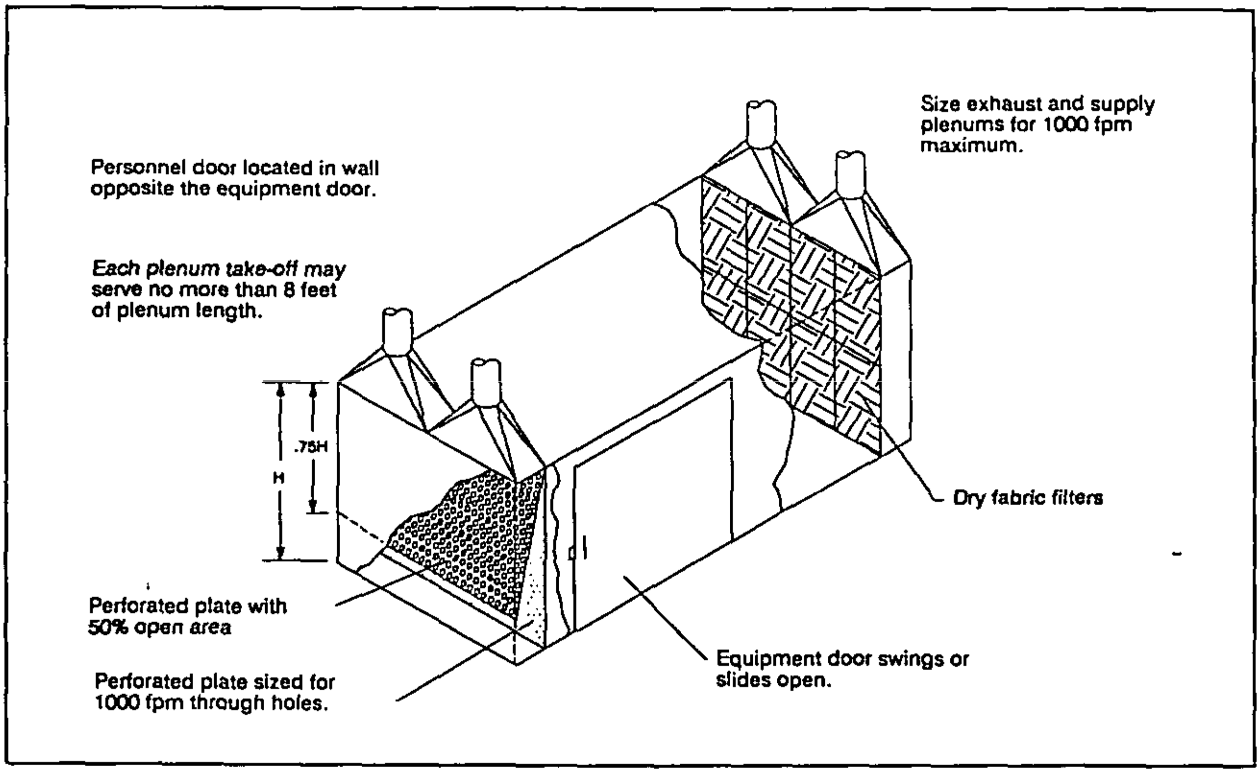


Figure 59
Spray Painting Booth

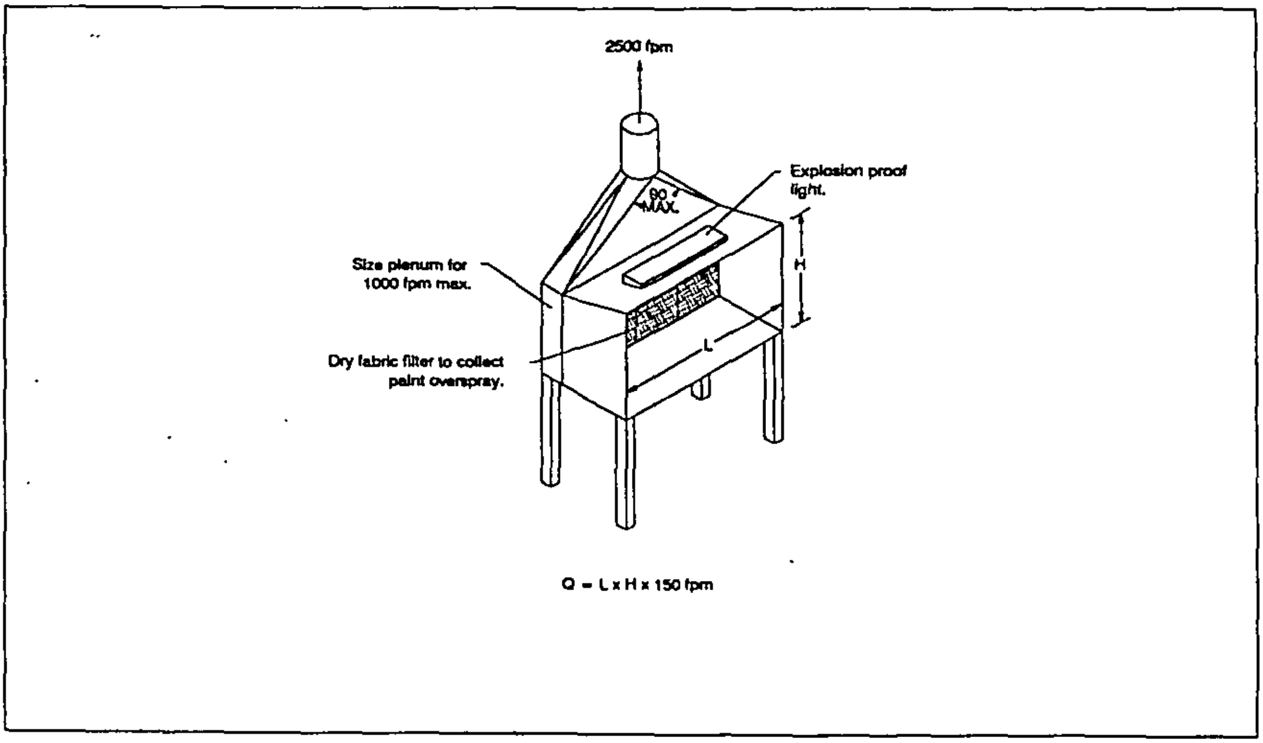


Figure 60
Spray Painting Bench

8.4.1 Quantity and Distribution. Design the replacement air system to provide 5 percent less air than is exhausted. This should produce a pressure ranging from 0.0 to -0.05 in. wc (0.0 to -12.4 Pa) in spray enclosure. This will prevent paint overspray and vapors from escaping the booth and migrating into adjacent work areas.

The distribution of replacement air within the spray booth is as significant as the average air velocity through the booth. The replacement air must be distributed evenly over the entire cross section of the booth to prevent turbulence or undesirable air circulation within the booth. The preferred means of distributing the replacement air is through perforated plate as shown in Figure 59.

8.4.2 Heating and Air Conditioning. Provide each ventilated booth with a dedicated replacement air system. Temper the air in accordance with NAVFAC DM-3.03. Review the paint drying requirements before specifying temperature and humidity ranges. Do not recirculate exhaust air.

8.5 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria.

Position the annunciator panel at the entrance to the paint booth so that the operators can monitor the operation of the replacement air, the exhaust air, and the pressure inside the booth relative to the outside.

Provide differential pressure sensors at locations that are representative of the average static pressure inside the paint booth. If the pressure varies from the range stated in para. 8.4.1, a timer shall be triggered. If the system cannot correct the difficulty within 60 seconds, the alarm shall be triggered. If the difficulty is corrected within the allotted time, the timer shall be automatically reset. Multiple alarm beacons may be required if the operator's view is obscured during painting operations.

8.6 Safety and Health Items.

8.6.1 Respiratory Protection. Respiratory protection is required when coatings that contain significant amounts of toxic materials such as lead, chromium, or reactive compounds (isocyanates and epoxy curing agents) are being sprayed. 29 CFR 1910.1000 prescribes the maximum allowable concentrations of toxic substances. Respiratory protection is also required when an operator must position himself in a booth downstream of the object being sprayed.

Since many other paint constituents are also harmful to the eyes and skin as well as the respiratory system, the use of respiratory protection in the absence of the above conditions should also be considered. When designing a booth to be used with supplied air respirators, provide several convenient connection locations for the respirator hoses, allowing freedom of movement for the workers. The couplings for the respirator hoses shall be unique to the facility and match only the fittings on the hoses for the respirators. For general design considerations for breathing air supply systems, refer to NAVFAC DM-3.5 and ANSI Z88.2.

Section 9: FOUNDRIES

9.1 Function. Founding or casting, is the metal forming process by which molten metal is poured into a prepared mold to produce a metal object called a casting. The foundry of consideration here is typical of a small operation. Refer to the ACGIH Manual for processes not addressed here and for further information on operations using non-standard air. Ventilation will be addressed for the following processes and their associated hazards:

Mixing/Mulling: The mixing of sand with organic binding agents in order to keep the sand bound for molding. Potential Hazard: Silica dust which may cause silicosis, lung cancer and other respiratory disorders.

Melting: The process of melting metal and alloys in a furnace. Potential Hazards: Metal oxide fumes causing metal fume fever; lead fumes, if brass is being melted, may impair the central nervous system and kidneys; infrared radiation may damage skin and eyes; carbon monoxide from gas furnaces causing tissue anoxia; and heat stress.

Pouring: The process of pouring the molten metal into the sand molds. Potential Hazards: Vapors from organic binding agents; silica dust; metal oxide fumes; lead fumes; infrared radiation; and heat stress.

ShakeOut: The removal of sand, scale and excess metal from the castings by vibration. Potential Hazards: Silica dust.

9.2 Operational Considerations: Dust, metal oxide fumes, lead fumes, carbon monoxide, and organic binding agent vapors are generated during foundry operations. Employee exposure to air contaminants is regulated by 29 CFR 1910.1000. Exposure to lead is regulated by 29 CFR 1910.1025. Foundries are especially hazardous work areas because molten metal is extremely hot. Worker safety is critical and is improved with easy equipment access. The ventilation system shall be designed to prevent interference with equipment access. Sometimes, as in the case of ladle transport, a ventilation hood cannot be easily installed to control a process because it may cause interference. In most cases, however, with careful consideration hoods can be installed to control a process without interference.

9.3 Typical Floor Plans. Figure 61 shows a small foundry floor plan. Locate the molds close to the furnaces to minimize the transport distance. Controlling fumes during transport is very difficult. All baghouses and fans should be located outside.

9.4 Exhaust air. Design the exhaust air system to capture contaminants at the point of generation. Any air exhausted during pouring, molten transport, and melting, will be heated as it passes over the process. The heated air has a lower density than standard air, and therefore more of it must be exhausted to maintain the same control velocity of cool air past the process. The following example applies to all processes at elevated temperatures:

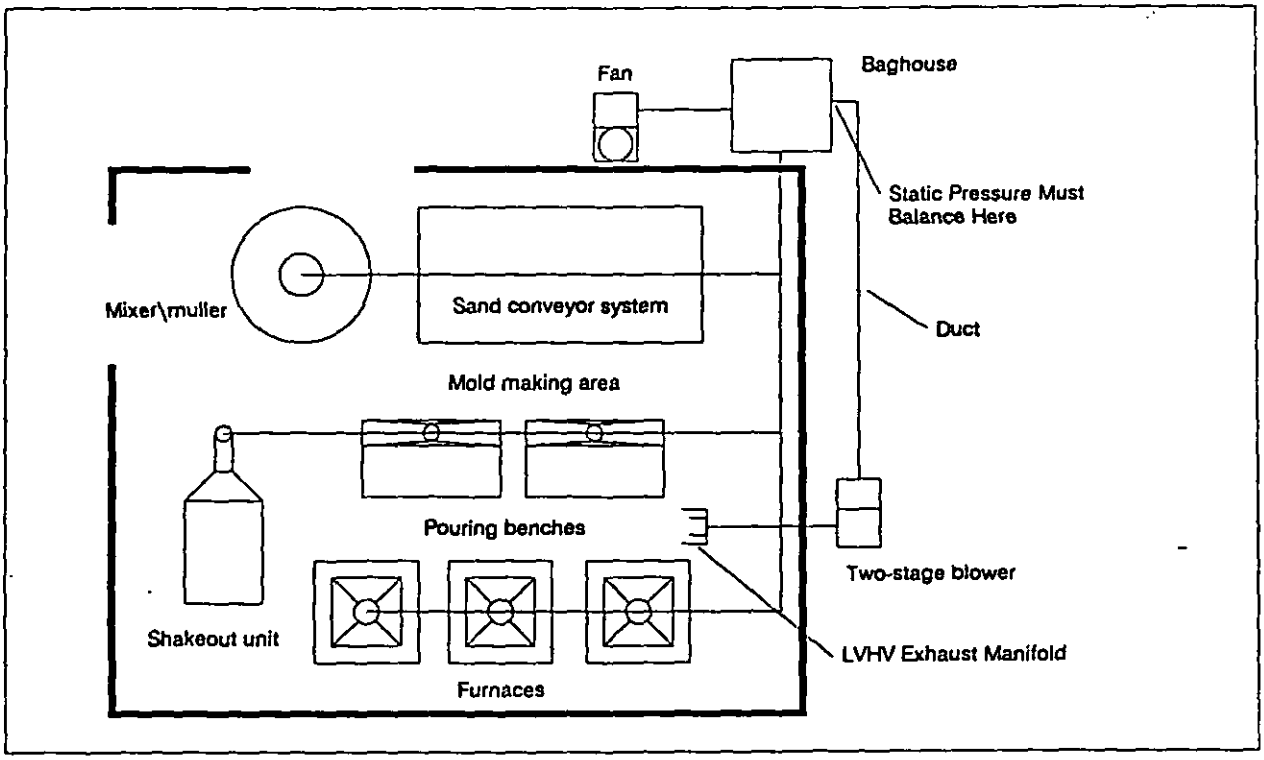


Figure 61
Typical Small Foundry Floor Plan

Example 1: A furnace hood has a face area of 1 ft^2 (0.093 m^2). It is desired to generate a capture velocity 200 fpm (1.016 m/s). As the air passes over the room furnace, it is heated to a temperature of 250 °F (121 °C). What is the flowrate of standard, room temperature air into the hood? What is the flowrate, in actual cubic feet per minute (ACFM) of the heated air flowing in the exhaust duct downstream of the hood? If the fan static pressure (FSP) for an identical system exhausting the same volume of air, only at standard conditions, is 3.0 in. wc, what will the FSP for the hot air system be?

Solution: First, find the absolute temperatures.

$$T_1 = 70\ ^{o}F = 70 + 460\ ^{o}R = 530\ ^{o}R$$

$$T_2 = 250\ ^{o}F = 250 + 460\ ^{o}R = 710\ ^{o}R$$

The flowrate of standard air into the exhaust hood is 200 fpm X 1 ft^2 = 200 cfm. To convert the flowrate of room air into the flowrate of heated air, multiply by the ratio of absolute temperatures:

$$Q_2 = Q_1(T_2/T_1) = 200\ cfm\ (710\ ^{o}R/530\ ^{o}R) = 268\ cfm$$

Since the hot air is less dense than the room temperature air, it incurs a lower friction loss than a similar system exhausting 268 cfm of standard temperature air. The FSP is:

$$FSP_2 = FSP_1(T_1/T_2) = 3.0\ in.\ wc\ (530\ ^{o}R/710\ ^{o}R) = 2.24\ in.\ wc$$

9.4.1 Hood Design. Foundry hoods generally control either dust (from mold materials) or high temperature fumes and vapors. When the temperature of the exhaust air stream is likely to exceed 400 °F (204 °C), use stainless steel sheet metal for the hood. Water cooled or refractory linings are alternatives to stainless steel. Baffle exhaust hoods to the maximum extent possible in order to reduce crossdrafts and to improve hood efficiency. Ensure an adequate capture velocity is generated by each hood to control process generated contaminants. Design slotted hoods to have a minimum slot velocity of 2000 fpm (10.16 m/s), a plenum velocity of not greater than one-half the slot velocity, and hood-to-duct transition with an included angle of no more than 90 degrees. Specify that the length of the hood served by each exhaust plenum shall not exceed 8 ft (2.44 m). For example, hoods between 8 and 16 ft (4.88 m) in length shall have two exhaust takeoffs. Provide cleanout doors in the plenum for accumulated particulate.

9.4.1.1 Mixer/Muller. Use a canopy hood as shown in Figure 62.

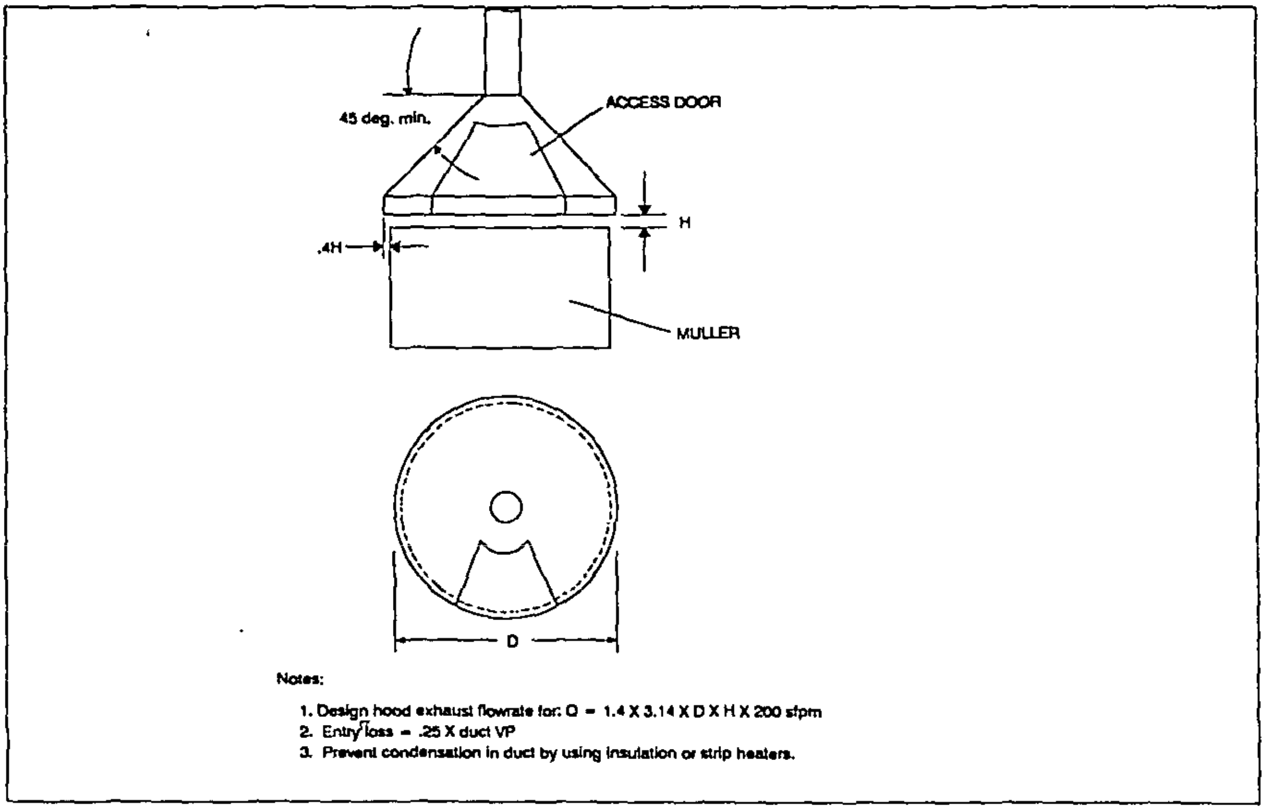
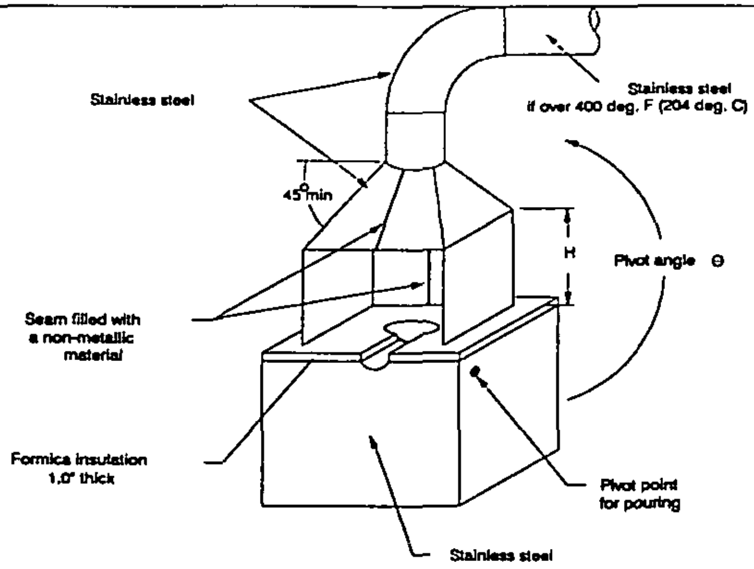


Figure 62
Mixer / Muller Hood

9.4.1.2 Furnaces. The hood shown in Figure 63 is for an induction furnace. An electric current can be induced through a metallic hood from the induction coils inside the furnace. This induction current through the hood will cause the hood to heat up. To prevent this, insulate the hood from the furnace with a formica plate and split the hood with a nonmetallic seam.

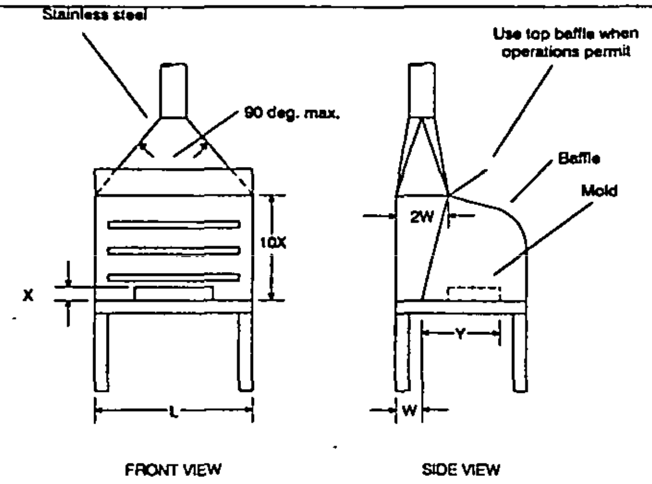
9.4.1.3 Mold Pouring Station. Design an upright hood as shown in Figure 64 to draw contaminants away from the pourer.



Notes:

1. Design hood exhaust flowrate for:
   Q = 200 SCFM/sq ft of hood face
2. Entry loss = (.50 x Face VP) + (.25 x Duct VP)
3. CAUTION: Air must be drawn into hood before melting.
   Hood may melt from intense heat otherwise.
4. Design height, H, for height of maximum
   workpiece.

Figure 63
Furnace Hood



Notes:

1. Design hood exhaust flowrate for: Q = 3.14 X L X Y X 100 sfpm
2. Entry loss = (1.78 X slot VP) + (.25 X duct VP)
3. Size slots for a slot air velocity of 2000 sfpm
4. W = Sum of slot widths
5. X = largest mold thickness

Figure 64
Mold Pouring Station Hood

9.4.1.4 Shakeout Unit. Figure 65 shows a hood for a small foundry shakeout unit.

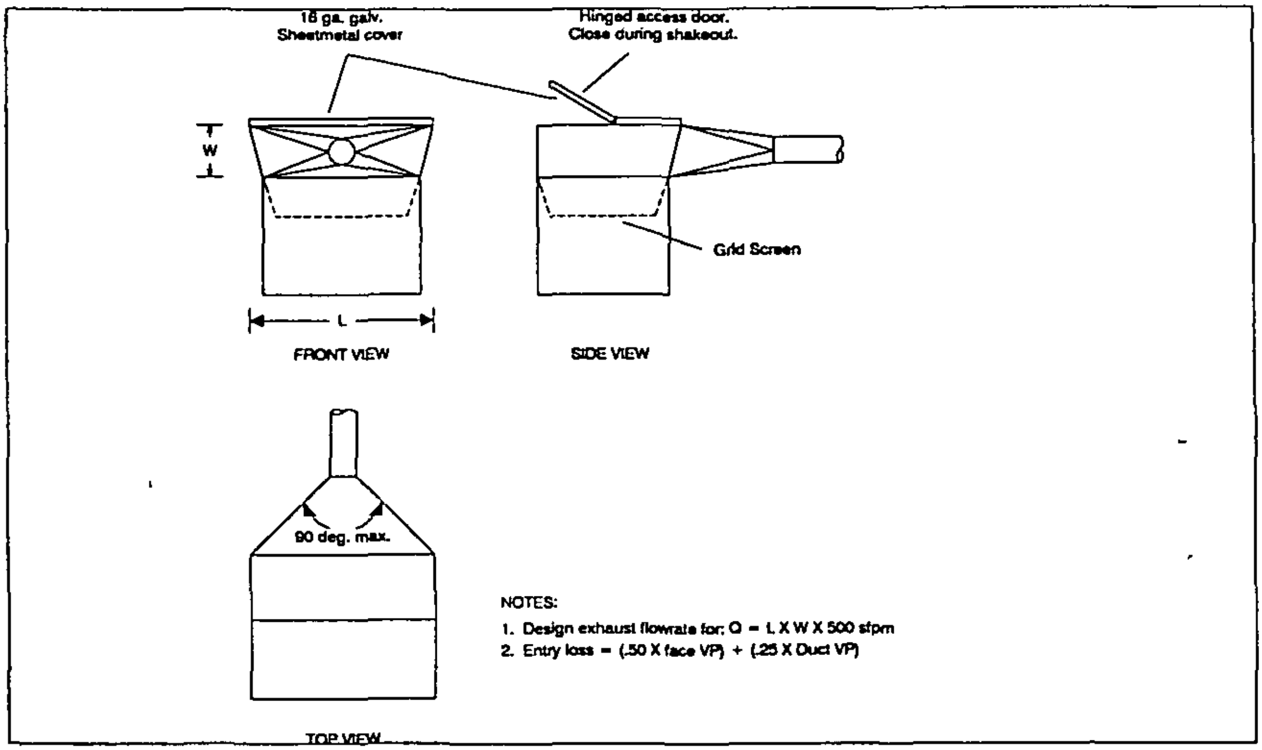


Figure 65
Shakeout Hood

9.4.2 Ductwork and Fans.

9.4.2.1 Ductwork: Since light concentrations of abrasive sand are drawn into foundry ductwork, use SMACNA class III duct construction standards. Ensure the sand does not settle inside the duct with a high airflow velocity of 4000 fpm (20.32 m/s). To allow removal in case some sand does settle, install clean-out access doors near bends and vertical risers. The periodic buildup of sand, oil and water condensate on the inner walls of the duct will require regular inspection and cleaning. Use stainless steel when the air temperature may exceed 400 °F (204 °C). Allow for duct expansion at higher temperatures by designing supports slightly larger than the duct. Ensure the duct does not contact any flammable material. Design the entire air exhaust system in accordance with the NFPA Code 91. Use ball joints and telescopic duct instead of flex duct for movable ducts. Conform to the criteria given is para. 2.1.3.1. Refer to the SMACNA publication 15d for more information regarding duct fabrication and installation.

9.4.2.2 Fans: The most efficient fan for moving the typically large quantities of air required for proper foundry ventilation is a backward inclined airfoil blade fan. Locate this type of fan downstream from the air cleaning device. The abrasive action of particulates and accumulation of sludge will destroy the fan blades otherwise. Locate the fan outside the shop to reduce noise and keep the duct negatively pressurized the inside shop. Conform to the criteria given in para. 2.1.3.2.

9.4.3 Air Cleaning Devices. Consult local air pollution authorities for air cleaning requirements. Figure 61 shows the recommended location of the air cleaning device with respect to the fan, the vacuum system and exhaust hoods. A high-efficiency dust collector will be appropriate for many installations. High temperature cartridges may be required depending on the airstream temperature. Ground the dust collector cartridges to protect against static electricity buildup in the baghouse and install an explosion vent designed per NFPA-68. Use high pressure, reverse pulse air jets to clean the baghouse fabric when the pressure drop across the baghouse reaches a preset limit. This type of cleaning cycle is referred to as "demand pulse" and is done by using a photohelic gauge as the control mechanism for the on\off pulse air jet switch.

9.4.4 Weather Stack Design and Location. Design the exhaust stack in accordance with criteria in para. 2.1.3.3. Refer to SMACNA publication 15d and Guide for Steel Stack Design and Construction for proper stack construction.

9.4.5 Industrial Vacuum System. Provide a LVHV vacuum system (see Figure 61) to exhaust silica dust and metal chips. According to Characterization of Particulate and Lead in a Brass Foundry Using a Close Capture Exhaust System, by Robert B. Jacko, Ph.D.,P.E., good housekeeping with industrial vacuum systems has a substantial impact on lead levels in brass melting and pouring operations. The vacuum system shall use a two-stage material-handling blower. The blower shall feed into the side of the baghouse used by the industrial exhaust system. This will minimize the number of dust collection points. Design the vacuum system duct to balance with the exhaust system duct where the two systems connect. Because design data is largely empirical for LVHV systems, use manufacturer's data to complete the design. Design the entire vacuum system in accordance with NAVFAC DM-3.05.

9.5 Replacement Air. A slightly negative air pressure inside the shop relative to the outside is required. A slightly negative pressure (-.05 to -0.10 in. wc (-12.9 to -24.8 Pa)) will prevent contaminated foundry air from migrating into clean spaces. Refer to para. 2.1.3.4 of this handbook for more information about replacement air.

9.5.1 Quantity and Distribution.

9.5.1.1 Quantity: The quantity of replacement air should be slightly less than the quantity of exhaust air to induce a negative pressure inside the shop. Purchase replacement air units slightly larger than immediately necessary with the knowledge that an increased capacity may be required within a short time. Using the control systems in para. 2.1.3.5, regulate the quantity of replacement air to achieve the required air pressure inside the foundry relative to the outside.

9.5.1.2 Distribution: Use the laminar flow method. See para. 2.2.5.1.

9.5.1.3 Heating and Air Conditioning. Each ventilated space shall have a dedicated replacement air system. Temper the air in accordance with NAVFAC DM-3.03. Do not recirculate exhaust air.

9.6 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria:

CAUTION: DO NOT OPERATE FURNACE WITHOUT VENTILATION CONTROL.

To prevent the operation of the mixer, furnace, shakeout unit, and pouring area without ventilation control, tie the power supply for the equipment to the interlock on-off switch for the ventilation systems.

9.7 Safety and Health Items. Refer to the NIOSH publication 85-116 Recommendations for Control of Occupational Safety and Health Hazards...FOUNDRIES, Appendix F, for OSHA regulations pertaining to the foundry industry.

Section 10: Wood Shop Facilities

10.1 Function. Wood shops throughout the Navy differ in size and function. Therefore, the design criteria in this chapter should be used as broad guidelines for developing a ventilation system for wood shops.

10.2 Health Considerations. Although not considered a health problem prior to 1985, an Occupational Safety and Health Administration (OSHA) decision in that year required a permissible exposure limit (PEL) be established for wood dust. In 1989, a single 8-hour time weighted average (TWA) of 5.0 mg/m^3 and a short term exposure limit (STEL) of 10.0 mg/m^3 for both hardwood and softwood was established. Also, OSHA has established a separate 8-hour TWA limit of 2.5 mg/m^3 for Western red cedar, a highly allergenic species of softwood. ACGIH further recommends a more stringent threshold limit value (TLV) of 1 mg/m^3 for certain hardwoods such as beech and oak. While designers are required by law to comply with the OSHA PEL, designing to meet the ACGIH TLV is recommended.

Exposure to wood dust has long been associated with a variety of adverse health effects, including dermatitis, allergic respiratory effects, and cancer. As many as 300 species have been shown to cause dermatitis. The most common allergic response to wood dust is asthma. In addition, wood dust has been shown to cause mucosal and nonallergic respiratory effects such as throat irritation and bleeding, wheezing, sinusitis, and prolonged colds. Although NIOSH studies have linked exposure to wood dust with various forms of nasal and lung cancers, OSHA contends the results are not conclusive. However, because OSHA concludes that wood dust exposures are harmful and cause loss of functional capacity and material impairment of health, wood dust should be treated as a potentially dangerous and carcinogenic contaminant.

10.3 Typical Floor Plans. Design floor plans of machine, floor and isle layouts as described in ANSI 01.1, Safety Requirements for Woodworking Machinery. The ventilation system should complement equipment layout and minimize housekeeping.

10.4 Common System Criteria.

10.4.1 System Design. Design the system using the velocity pressure method explained in chapter 5 of Industrial Ventilation. Equipment hoods having the greatest resistance should be positioned so that their branch ducts are short, and enter the main duct close to the air cleaning device.

Often, only 40 or 50 percent of the machines are running at one time in a wood shop facility. Therefore, an important consideration is designing for only 50 percent of the total exhaust volume. Those machines which are not operating should not be ventilated. Industrial grade solenoid switches can be used to open or close dampers of machines as they are turned on or turned off, respectively.

10.4.2 Hood Design. Any machine which produces fine dust should be provided with a hood. This includes sawing, shaping, planing, and sanding operations.

Refer to drawing VS-701 through VS-709 in the ACGIH manual for specific hood designs. Hoods shall be made of noncombustible material and shall not interfere with workers as they operate machinery. General hood design characteristics are shown in Figure 66.

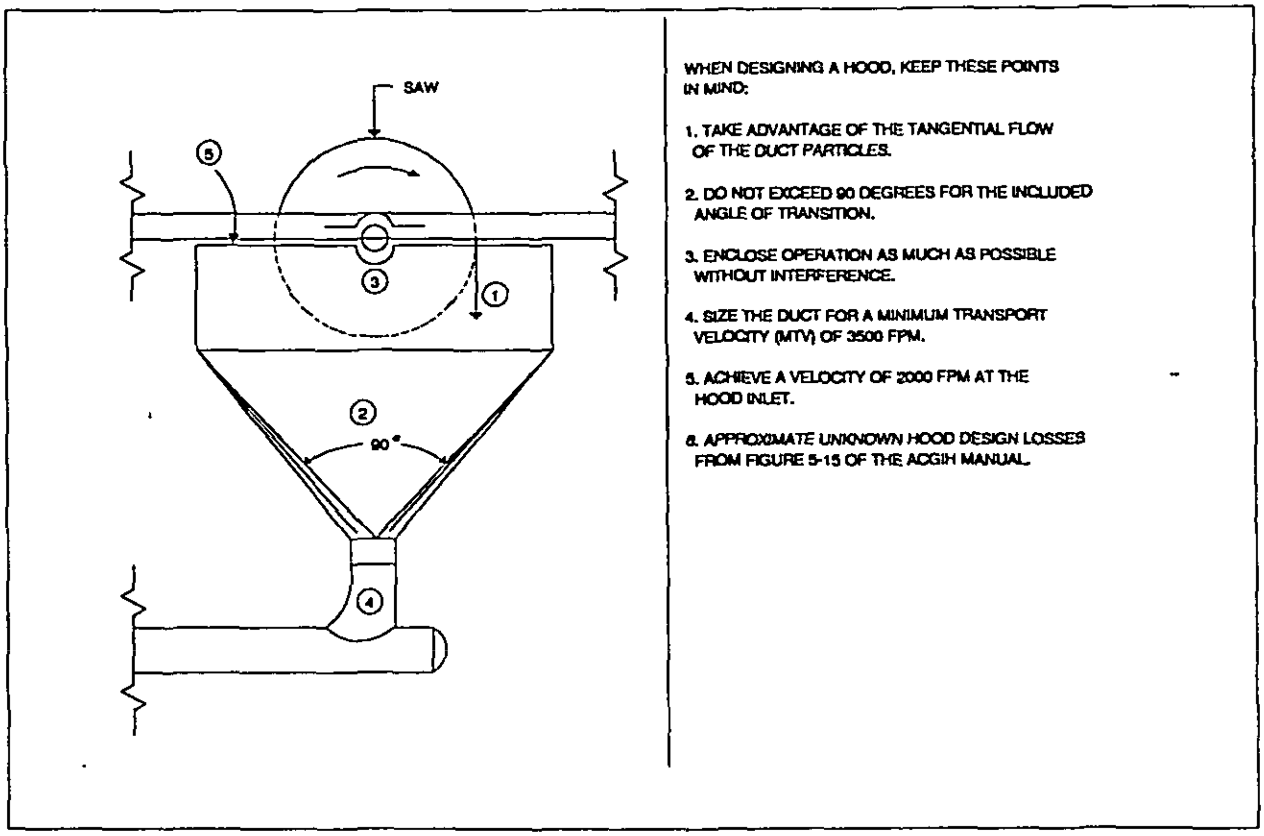


Figure 66
General Hood Design

10.4.3 Exhaust Air and Ductwork. Table 10-7.1 of the ACGIH manual gives exhaust volumes for specific wood shop machines. Size the ductwork to provide 3,500 fpm (17 m/s), the minimum transport velocity for wood dust. Refer to para. 2.1.3.1 of this manual for general ductwork design.

As stated earlier, the ductwork should complement the layout of the shop. In most cases ductwork should be located along the ceiling and walls. However, running ductwork under the floor of the shop may reduce duct lengths and leave more working space around machinery.

When ductwork is overhead, use duct hangers with sufficient strength to support a duct if it becomes half filled with material. To prevent build-up of dust, provide cleanout doors adjacent to every bend and vertical riser. Figure 8-4 in the ACGIH manual shows examples of cleanout door designs. Locate cleanout doors on the side or top of the duct. For ducts 12 in. (425 mm) or less, horizontal runs should have cleanout doors at least every 12 ft (3.7 m). Larger ducts should have a cleanout door at least every 20 ft (6.1 m).

10.4.4 Floor Sweeps. Place floor sweeps in the design to assist in house keeping. There should be one floor sweep for every 20 ft (6.1 m) of straight, horizontal duct. The sweeps shall exhaust between 800 and 1400 cfm (0.38 and 0.66 m^3/min.) depending on the size of the shop, and this exhaust should be included in design calculations. Figure 67 shows basic floor sweep design.

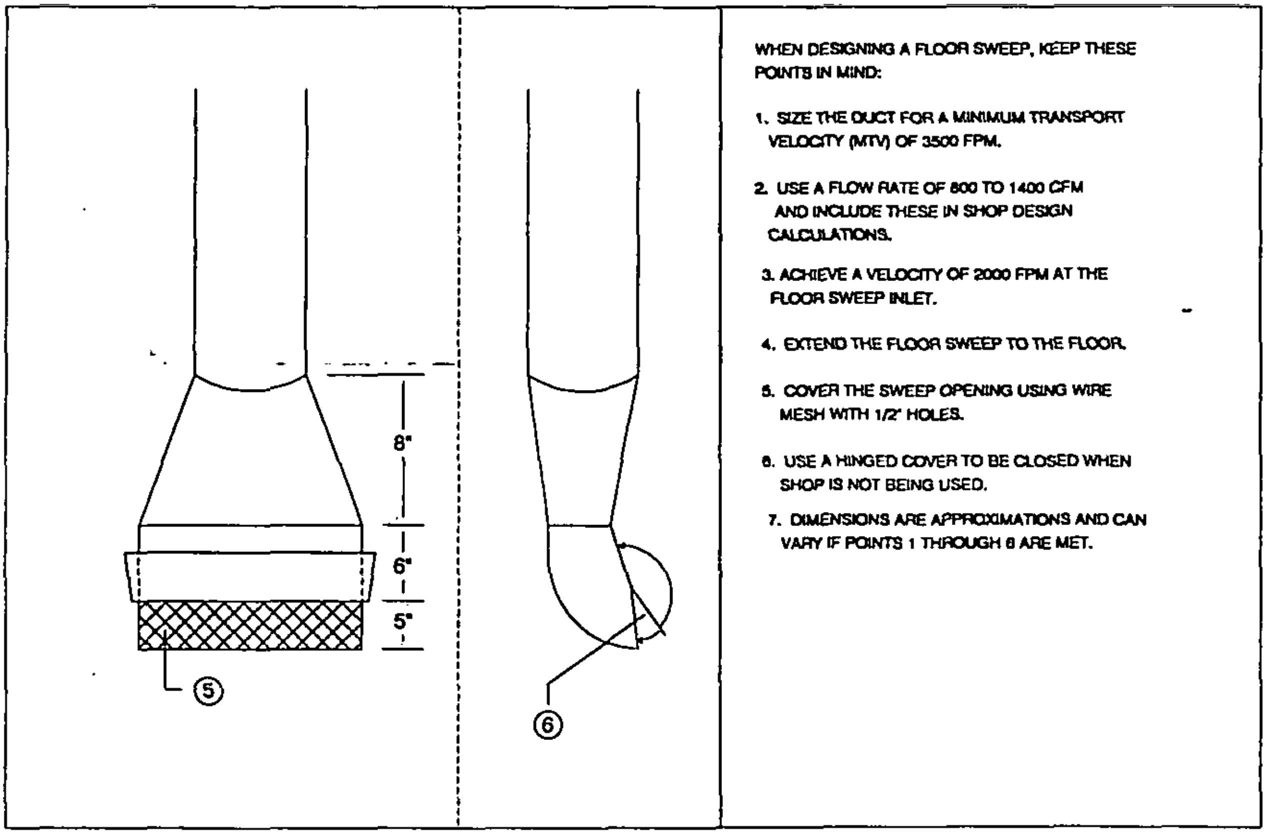


Figure 67
Floor Sweep

10.4.5 Fans. A centrifugal fan with backward inclined or backward curved airfoil blades is best suited for a wood shop. The fan should always be placed downstream of the air cleaning device. Specify a Class II construction fan.

A centrifugal fan with backward inclined/backward curved, single thickness blades is less efficient, but acceptable. Also, this fan is specifically designed for light dust applications. For more information on fan selection, refer to para. 2.1.3.2 of this handbook.

10.4.6 Air Cleaning Devices. High efficiency dust collectors with fabric filter media should be used for wood shops because they are effective in removing both large and microscopic dusts. The main parameters for selecting an air cleaning device are volume flow rate and particle size distribution. Particle size distributions can be obtained from either particle sampling methods or health research data.

10.4.7 Weather Stack Design and Location. A vertical discharge stack with a no-loss stackhead is recommended for wood shops facilities. At no time shall a horizontal discharge be used. Refer to para. 2.1.3.3 in this manual for more information on stack design.

10.5 Replacement Air. Design replacement air systems that modulate inlet dampers to maintain a negative pressure (relative to the atmosphere) ranging from -0.05 to -0.10 in. wc (-12.4 to -24.8 Pa) in the dirty spaces. For replacement air system criteria, refer to para. 2.1.3.4 in this manual.

10.5.1 Quantity and Distribution. Distribute air to produce a laminar flow of air from supply to exhaust. The vertical supply method is preferred to the horizontal supply method.

10.5.2 Recirculated Air Replacement System. Recirculated air replacement systems are not recommended for wood shop facilities.

10.5.3 Heating and Air Conditioning. Design the heating and cooling systems in accordance with NAVFAC DM-3.03.

10.6 System Controls. Design system controls in accordance with para. 2.1.3.5 and the following criteria. Position an annunciator panel at the entrance to the shop so the operators can monitor the operation of the replacement air system, and the exhaust air system. Provide differential pressure sensors across the air cleaning device, the replacement air filters, and at the exhaust fan inlet. Mark the gauges with acceptable operating ranges.

10.7 Safety and Health Items. Because wood dust is listed as an explosion hazard, design the facility in accordance with NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities.

For personal protective equipment, refer to section 9.4 of ANSI 01.1. If a respirator is needed, ANSI Z88.2 gives guidelines on practices for respiratory protection.

APPENDIX A

DESIGN CALCULATION EXAMPLES FOR REPRESENTATIVE METAL CLEANING AND ELECTROPLATING HOODS

Design Calculation Example I: Lateral Exhaust Hood
Design Calculation Example II: Push-Pull Exhaust Hood, Method 2
Design Calculation Example III: Enclosing-Type Exhaust Hood

DESIGN CALCULATION EXAMPLE I: LATERAL EXHAUST HOOD

Given: Chrome plating tank (6 x 2.5 ft) free standing in room, with side baffles. No crossdrafts, and adequately distributed replacement air. Referenced tables and figures are in MIL-HDBK-1003/17.

Volume Calculation for Good Conditions (No crossdraft, adequate and well-distributed replacement air):

1. The hazard classification for chromic acid used in hard chrome plating is A-1 (ACGIH Manual). Therefore, the minimum control velocity is 150 fpm (Table 2).

2. Select the cfm/ft^2 of tank dimensions, using the required control velocity of 150 fpm and tank width-to-length ratio. Since this tank has side baffles, use Table 4.

By using the exhaust hood illustrated in Figure 38, the hood plenum acts as a baffle. End baffles are necessary because the 30-in. tank width borders the requirement for slot hoods on both sides of the tank.

W = 2.5 ft
L = 6.0 ft
W/L = 0.42

3. Multiply tank surface area by value obtained from Table 4 to calculate required air volume.

Minimum exhaust rate = 225 cfm/ft^2 (from Table 4; baffled tank, W/L = 0.42)

Minimum exhaust volume = (225 cfm/ft^2)(15 ft^2) = 3,375 cfm

4. Determination of hood static pressure using Figure 38:

Design slot velocity is 2,000 fpm. Slot length (L_s) shall be 6 in. less than tank length and shall begin 3 in. from each end of the tank.

Slot area = Q/V = 3,375 cfm/2,000 fpm = 1.69 ft^2 (estimate)

Slot width = A/L_s = 1.69 ft^2/5.5 ft = 0.31 ft = 3.7 in. (estimate)

Use two 1.75 in. slots, spaced 3.00 in. apart. The value of 1.75 in. was chosen to obtain a reasonable dimension for construction and to keep slot velocity above 2,000 fpm.

Design slot velocity = Q/A
= 3,375 cfm/(2(1.75)(5.5 ft)(1 ft/12 in.))
= 2,058 fpm

Plenum depth = (2)(slot width) = (2)[(2)(1.75 in.)] = 7.00 in.

Duct area = Q/V = 3,375 cfm/2,500 fpm = 1.35 ft^2 (estimate)

A 15 in. duct has an area = 1.227 ft^2

Design duct velocity = Q/A = 3,375/1.227 = 2,751 fpm

Hood SP = entry loss + acceleration and

$VP = (V/4,005)^2 = 1.78\ VP_{slot} + 0.25\ VP_{duct} + 1.0\ VP_{duct}$
(See Sections 3 and 5, ACGIH Manual)

$VP = (V/4005)^2$ at standard temperature and pressure (STP)

Hood SP = (1.78)(0.28 in.) + (0.25)(0.47 in.) + (1)(0.47 in.) =
= 0.50 + 0.12 + 0.47

Hood SP = 1.09 in. wc at (STP)

DESIGN CALCULATION EXAMPLE II: PUSH-PULL HOOD, METHOD 2

Given: Chrome plating tank (8 x 3.5 ft)
Baffled tank, free standing in the shop
Adequate well distributed replacement air

<u>Exhaust (Pull) Flow Calculations</u>

1. The hazard classification for chromic acid is A-1. Therefore, the minimum control velocity is 150 fpm (Table 2).

2. Volume flow rate (Q_E) calculations are based on Table 4 with the following values:

L = 8 ft W/L=0.44 W = 3.5 ft. Q = 225 cfm/ft^2

The push-pull system allows 50% reduction in volume flow rate (Q) required for a lateral exhaust hood.

$(Q)(0.5) = Q_E = 112.5\ cfm/ft^2$
$QE = (112.5\ cfm/ft^2)(8\ ft)(3.5\ ft) = 3{,}150\ cfm$

3. Hood design calculations

Maintain slot velocity minimum of 2,000 fpm. Slot length (L_S) shall be less than the tank length and shall begin 3 in. from each end of the tank.

Slot area = Q/V = 3,150 cfm/2,000 fpm = 1.58 ft^2 (estimate)

Slot width = A/L_S = 1.58 ft^2/7.5 ft = 0.21 ft = 2.53 in. (estimate)

Therefore, specify two 1.25-in. slots spaced 3 in. apart. The value of 1.25 in. was chosen to obtain a reasonable dimension for construction and to keep slot velocity above 2,000 fpm.

Design slot velocity = Q/A
= 3,150 cfm/(2)(1.25 in.)(1 ft/12 in)(7.5ft)
= 2,016 fpm

Plenum depth = (2)(slot width) = (2)(2)(1.25 in.) = 5 in. (minimum)

4. Duct design calculations are based on a required minimum velocity of 2,500 fpm.

Duct area = Q/V = 3,150 cfm/2,500 fpm
= 1.26 ft^2 (estimate) V 2,500 fpm

Therefore, choose 15-in. duct to maintain the minimum transport velocity of 2,500 fpm. Area of 15-in. duct is 1.227 ft^2

Design Duct Velocity = Q/A = 3,150 cfm/1.227 ft^2 = 2,567 fpm

5. Exhaust Hood Static Pressure

Exhaust hood SP = entry loss + acceleration

Exhaust hood SP = 1.78 VP_{slot} + 0.25 VP_{duct} + 1.0 VP_{duct}
(Refer to Section 3 and 5, ACGIH Manual)

$VP = (V/4{,}005)^2$ at standard temperature and pressure (STP)

Exhaust hood SP = (1.78)(0.25) + (0.25)(0.41) + (1.0)(0.41)

Exhaust hood SP = 0.96 in. wc at STP

Push Flow Calculations

1. Push-jet volume flow rate is based on empirical data.

Q_j = 5 cfm/ft^2 of tank surface area
Q_j = (5 cfm/ft^2)(8 ft)(3.5 ft) = 140 cfm

Push-air plenum cross-sectional area shall be a minimum of 4 x total jet area.

2. Using nozzle manufacturers data, the jet is 17/32 in. inside diameter.

$A = (Pi/4)(17/32)^2 = 0.222\ in.^2$

Total jet area = (0.222 $in.^2$)(15 nozzles) = 3.3 $in.^2$

Plenum area = (Total jet area)(4) = 13.2 $in.^2$.

3. Using manufacturers data, push air plenum pressure is to be adjusted in the field and is designed for 2 to 4 in. wc

Approximate operating pressure is found empirically from manufacturer data.

Q_j/#nozzles = 140 cfm/15 nozzles = 9.3 cfm/nozzle

Manufacturers data indicates that the chosen nozzle at 9.3 cfm/nozzle gives a pressure of 4 in. wc.

Design plenum pressure is 4 in. wc

DESIGN CALCULATION EXAMPLE III: ENCLOSING-TYPE EXHAUST HOOD

Given: Chrome plating tank (8 x 3-1/2 ft)
Free standing in center of room, two opened sides
No crossdrafts, and adequate, well-distributed replacement air
Figure 45 - Outside monorails are more adaptable

Exhaust Volume Calculations

1. The hazard classification for chromic acid is A-1. Using Table 5, the minimum capture velocity is 150 fpm because two sides of the enclosures are open.

2. Area calculations are based on the following dimensions and equation:

H = 4 ft L = 8 ft W = 3.5 ft C = 1 ft

Area = area of opening + area of monorail slot

Area = 2 HW + CL

$$\text{Area} = (2)(4)(3.5) + (1)(8) = 36 \text{ ft}^2$$

3. Exhaust Volume Calculation is based on the equation:

$$Q = VA$$

$$Q = (150 \text{ fpm})(36 \text{ ft}^2) = 5{,}400 \text{ cfm}$$

Hood Design Calculations

1. Slot design criteria not applicable for enclosing hoods.

2. Plenum design criteria not applicable for enclosing hoods.

Duct Design Calculations

1. Duct design is based on the following criteria and calculations:

Duct velocity = 2,500 fpm

$Q = VA$,

$A = Pi(d^2)/4$ where d = duct diameter in feet

Duct area = Q/V = 5,400 cfm/2,000 fpm = 2.16 ft^2 (estimate)

Diameter = $(4A/Pi)^{.5} = [4(2.16)/Pi]^{.5}$ = 19.9 in (estimate)

Using 20-in. duct, A = 2.182 ft^2

Design duct velocity = Q/A = 5,400 cfm/2.182 ft^2 = 2,475 fpm

Hood Static Pressure Calculations

Using Sections 3 and 5 of the ACGIH Industrial Ventilation Manual, hood static pressure calculations are based on the following equations:

1. $V = 4{,}005\ VP$ at standard temperature and pressure (STP):

   V = highest velocity in the balanced system

   VP = velocity pressure in in. of water column (wc)

   $VP = (V/4{,}005)^2 = (2{,}475/4{,}005)^2 = 0.38$ in. wc @ STP

2. Hood Static Pressure = entry loss + acceleration

Entry loss factor (assuming 90° included angle hood is square or rectangular using figure 5-15 in the Industrial Ventilation Manual) is 0.25.

Acceleration factor = 1

Hood static pressure = $(.25)(VP_D) + (1.0)(VP_D)$

SPhood = (0.25)(0.38 in.) + (1)(0.38 in.) = 0.48 in. wc @ (STP)

APPENDIX B

CALCULATION FOR LOWER EXPLOSIVE LIMIT FOR GENERIC STYRENE

This calculation is valid if differential pressure in the room is greater than 10 in. wc.

CHARACTERISTICS:

Styrene at 14.7 psi (1 Atmosphere) 70 °F. (530 °R.)
Specific Gravity (SG) = 0.907 no units
Lower Explosive Limit (LEL) = 1.10 %
Molecular Weight (MW) = 104 lb/lb-mole

ASSUMPTIONS:

Operating Temperature in the Room is 85 °F. (545 °R.)
Operations use 7 gallons of Styrene per hour
Room dimensions are 20x10x15 feet for length, height and width, respectively.
Molar volume (MV) means 1 pound-mole of any gas or vapor occupies 387 cubic feet at 70 °F and 14.7 psi.

CALCULATIONS:

1) Adjust volume for temperature difference.

(MV)(Operating Temperature/Standard Temperature) = MVop
$(387\ ft^3/lb\text{-}mole)(545^o/530^o) = 398\ ft^3/lb\text{-}mole$

2) Determine Vapor Volume (VV).

(MVop)[(standard liquid density)(SG)]/MW = VV
$(398\ ft^3/lb\text{-}mole)(8.34\ lb/gal)(0.907)/(104\ lb/lb\text{-}mole) = 28.9\ ft^3/gal$

3) Determine Dilution Volume required per gallon of solvent.

[4(100-LEL)(VV)]/LEL = Vol
$[4(100\% - 1.1\%)(28.9\ ft^3/gal)]/1.1\% = 10{,}393\ ft^3/gal$

4) Determine Dilution Ventilation rate.

(Vol)(Actual gals/hr)(1hr/60 min) = Vol dil
$(10{,}393\ ft^3/gal)(7\ gal/hr)(1hr/60\ min) = 1{,}213\ ft^3/min$

5) Compare to ventilation rate required for health aspects. Assume cross ventilation with velocity equaling 100 fpm

(Velocity)(Width)(Height) = Volume Flow Rate
$(100\ ft/min)(10ft)(15\ ft) = 15{,}000\ ft^3/min$

REFERENCES

NOTE: Unless otherwise specified in the text, users of this handbook should utilize the latest revisions of the documents cited herein.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS AND NAVFAC GUIDE SPECIFICATIONS:

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise indicated, copies are available from Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

STANDARDS

MILITARY

MIL-STD 282, Notice 3 — Filter Units, Protective Clothing, Gas-Mask Components, and Related Products: Performance Test Methods

MIL-STD-1472C, Notice 3 — Human Engineering Design Criteria for Military Systems, Equipment, and Facilities

HANDBOOKS

MIL-HDBK 1004/6 — Lightning Protection (May 1988)

MIL-HDBK 1008 — Fire Protection for Facilities Engineering Design and Construction

MIL-HDBK 1028/3 — Maintenance Facilities for Ammunition, Explosives, and Toxics (December 1987)

MIL-HDBK 1190 — Protection Planning and Design Guide

NAVY MANUALS, P-PUBLICATIONS, AND MAINTENANCE OPERATING MANUALS:

Available from Commanding Officer, Naval Publications and Forms Center (NPFC), 5801 Tabor Avenue, Philadelphia, PA 19120-5099. To order these documents: Government agencies must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP); the private sector must write to NPFC, ATTENTION: Cash Sales, Code 1051, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

DM-1.03 — Architectural Acoustics (May 1985)

DM-3.03 — Heating, Ventilating, Air Conditioning, and Dehumidifying Systems (May 1986)

DM-3.05 — Compressed Air and Vacuum Systems (March 1983)

DM-3.10	Noise & Vibration Control of Mechanical Equipment (ARMY), (December 1983)
NAVMED P-5112	Navy Environmental Health Bulletins
P-970	Protection Planning in the Noise Environment (June 1978)
OP5, Vol. 1, Rev.4	Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping
S6340-AA-MMA-010	Otto Fuel II Safety, Storage, and Handling Instructions

NAVY DEPARTMENTAL INSTRUCTIONS: Available from Commanding Officer, Naval Publications and Forms Center, ATTENTION: Code 3015, 5801 Tabor Avenue, Philadelphia, PA 109120-5099.

NAVMEDCOMINST 6270.1	Health Hazards of Otto Fuel II
OPNAVINST 5100.23B	NAVY Occupational Safety and Health (NAVOSH) Program Manual

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

The following Governments documents and publications form a part of this document to the extent specified herein.

OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION (OSHA)

CFR 29-1910	Occupational Safety and Health Standards
OSHA 3048	Noise Control, A Guide for Workers and Employees

ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA-560-	A Guide to Respiratory Protection for the Asbestos
OPTS-86-001	Abatement Industry (September 1986)

(Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402).

NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY & HEALTH (NIOSH)

NIOSH Publication No. 79-117	Industrial Noise Control Manual-Revised Edition (December 1978)
NIOSH Research Report No. 75-108	Development of Design Criteria for Exhaust Systems for Open Surface Tanks (October 1974)

NIOSH Publication No. 85-116	Recommendations for Control of Occupational Safety and Health Hazards in Foundries (September 85)
NTIS Publication No. PB81-167710	Proceedings of the Symposium on Occupational Health Hazards Control Technology in the Foundry and Secondary Non-Ferrous Smelting Industries (June 1980)

(Available from National Technical Information Service (NTIS), 5255 Port Royal Road, Springfield, VA 22161.)

NON-GOVERNMENT PUBLICATIONS:

Air Movement and Control Association Inc., (AMCA), 30 West University Drive, Arlington Heights, IL 60004.

Publication 201-85	Fan Application Manual-Fans and Systems

American Conference of Governmental Industrial Hygienists (ACGIH), Bldg. D-7, 6500 Glenway, Cincinnati, OH 45211-4438.

ACGIH Manual	Industrial Ventilation, A Manual of Recommended Practice (20th Edition, 1988)

American Gas Association (AGA), 8501 E. Pleasant Valley Rd., Cleveland, OH 44131

Z21.47-87	Gas Fired Central Furnaces (Except Direct Vent Central Furnaces)

American National Standards Institute (ANSI) 1430 Broadway, New York, NY 10018.

Z9.1-77	Practices for Ventilation and Operation of Open-Surface Tanks
Z9.2-79	Fundamentals Governing the Design and Operation of Local Exhaust Systems
Z88.2-80	Practices for Respiratory Protection
Z358.1-81	Emergency Eyewash and Shower Equipment
01.1-75	Safety Requirements for Woodworking Machinery

American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle NE., Atlanta, GA 30329

ASHRAE Handbook, 1989 Fundamentals

ASHRAE Handbook, 1988 Equipment

ASHRAE 52-76 Method of Air Cleaning Devices used in General Ventilation for Removing Particulate Matter

Clarke, John H., "Air Flow Around Buildings", Heating, Piping and Air Conditioning, Vol. 39 May 1967, pp 145-154.

(Available from Penton Publishing Company, Inc., 1100 Superior Ave., Cleveland, OH 44144.)

National Fire Protection Association. Inc. (NFPA), Batterymarch Park, Quincy, MA 02269.

NFPA 33-85	Spray Applications Using Flammable and Combustible Materials
NFPA 34-87	Dipping and Coating Processes Using Flammable or Combustible Liquids
NFPA 68-88	Deflagration Venting
NFPA 91-83	Installation of Blower and Exhaust Systems for Dust, Stack, and Vapor Removal or Conveying
654-88	Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries
664-87	Prevention of fires and Explosions in Wood Processing and Woodworking Facilities

Sheet Metal and Air Conditioning Contractors National Association. Inc. (SMACNA), 8224 Old Courthouse Road, Vienna, VA 22180

Guide 15d	Accepted Industry Practice for Industrial Duct Construction
Guide 5d	Thermoplastic Duct Construction
	Guide for Steel Stack Design and Construction

Stephenson, Revis L. and Harold E. Nixon, "Design of Industrial Vacuum Cleaning Systems and High Velocity, Low Volume Dust Control", (1987) Publication AVS-809B.

(Available from Hoffman & Filtration Systems, P.O. Box 548, East Syracuse, NY 13057.)

Underwriters Laboratory, 333T Pfingsten Rd., Northbrook, IL 60062

Standard 1096	Electric Central Air Heating Equipment

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1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-HDBK-1003/17A	Industrial Ventilation Systems

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS (Street, City, State, ZIP Code)

4. TYPE OF ORGANIZATION (Mark one)

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