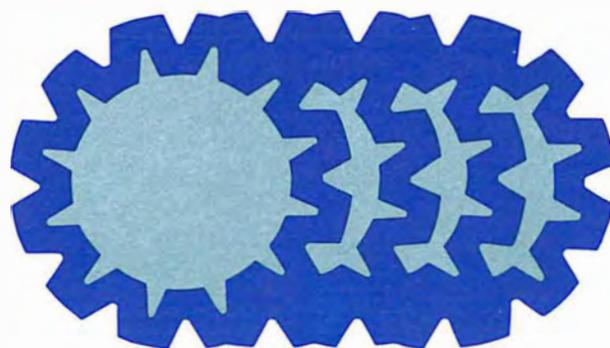


NIOSH

TECHNICAL INFORMATION

RECOMMENDED INDUSTRIAL VENTILATION GUIDELINES



**U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE / Public Health Service
Center For Disease Control / National Institute For Occupational Safety And Health**

RECOMMENDED INDUSTRIAL VENTILATION GUIDELINES

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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ABSTRACT

The Occupational Safety and Health Act of 1970 specifies that engineering controls be employed where feasible to maintain exposures to toxic materials below levels specified in 29 CFR 1910.1000. To facilitate the design of ventilation systems for compliance with this requirement, a program was conducted to compile and update existing ventilation guidelines and to consolidate them into a single document. The study was performed pursuant to Contract No. CDC-99-74-33 with the National Institute for Occupational Safety and Health (NIOSH) in conjunction with the Standards Completion Program being jointly conducted by NIOSH and the Occupational Safety and Health Administration (OSHA).

The processes and operations for which guidelines have been prepared are: abrasive-blasting; asbestos-textile manufacturing; ceramics manufacturing; cotton yarn manufacturing; foundry operations; grinding, polishing, and buffing; kitchen operations; laboratory operations; materials handling; metal machining and metal working; open-surface tank operations; service garage operations; spray-finishing; and welding. Each guideline is accompanied by a separate discussion and justification section.

These guidelines prescribe specific ventilation system design criteria. However, they do not preclude the use of alternative engineering controls which provide the control required by 29 CFR 1910.1000. Consequently, they are intended to be used as design guides and are not to be considered as containing mandatory requirements for the use of specific designs or controls.

Certain sections of 29 CFR 1910 contain requirements which affect the use of ventilation as an engineering control. Where such requirements exist, they are appropriately referenced in these recommended guidelines.

INTRODUCTION

Background

Gases, vapors, and finely divided particulate materials, released into workplace atmospheres, are undesirable but unavoidable byproducts of many processes and operations. When these materials are generated into the breathing zones of employees in excessive concentrations, they may impair the health of workers, sometimes permanently and seriously. When flammable, they may create the more obvious hazards of fire and explosion. Limitation of employee exposure to these materials is, therefore, an important aspect of occupational health and safety programs and is indeed required by the provisions of Title 29 of the Code of Federal Regulations, Part 1910.1000.

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have been actively participating in a joint program with the objective of developing more effective regulations for the control of safety and health hazards in occupational environments. This program, known as the Standards Completion Program (SCP), will result in regulations defining the methods and measures required for controlling employee exposures to harmful substances. They will specifically require that engineering and work practice controls be instituted to reduce air contaminant exposures to at or below exposure limits, except to the extent that such controls are not technically feasible. Where such controls are not sufficient alone or in combination, they will nonetheless be required to reduce exposures to the lowest levels feasible.

The primary engineering control for air contaminants is the use of ventilation, i.e. the utilization of controlled flows of air to capture or entrain air contaminants at their source and to convey them away from the workplace environment. The optimal design of a ventilation system which provides adequate contaminant control with the minimum expenditure of energy and materials is a complex process requiring an understanding of the phenomena by which air contaminants are generated and dispersed in air and of the principles for the design and operation of ventilation equipment.

Though numerous facilities will find it necessary to install and/or maintain such equipment in accordance with requirements in 29 CFR 1910, it cannot be expected that all owners or operators of facilities will have the expertise available to design an effective ventilation system for every operation or process for which one may be necessary. Consequently, NIOSH and OSHA, during the conceptualization of the SCP, perceived the need for a compilation of the currently available guidelines for controlling contaminants from industrial operations.

Objective of the Study

Ventilation system design guidelines for various processes and operations can be found in the ACGIH Industrial Ventilation Manual, ANSI standards, NIOSH research reports, trade association and professional society handbooks, textbooks, and technical papers published in various publications. Some of these sources treat numerous topics and types of processes and operations while others are limited in scope. Many of them overlap and present guidelines for similar operations, sometimes presenting significantly different approaches for controlling the same contaminant source. It was the objective of this program to review available literature pertaining to the chosen operational categories, and to select, update, and consolidate those guidelines which are considered to be most appropriate for general use.

Presentation of the Guidelines

The recommended ventilation guidelines developed from this program are presented in the following sections of this report for various operational categories. Each section in the main body of the report treats a particular category and is complete unto itself in terms of definitions, introductory and general statements, etc. for convenience of use. The appendix of the report contains an overall discussion and rationale for certain general sections found in the individual guidelines and a set of specific memoranda discussing and justifying the sources of information used in the development of each of the guidelines.

The text of the ventilation guidelines was prepared in a format similar to the standard prepared by the American National Standards Institute on Ventilation for Grinding, Polishing, and Buffing (ANSI Z43.1-1966). All figures presented are similar in style and data provided to those in the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists (ACGIH). Indeed, since many of the figures were abstracted from the ACGIH manual, the authors wish to gratefully acknowledge the permission of the ACGIH Committee on Industrial Ventilation for their use. Likewise, appropriate credit must be given to ANSI for use of certain drawings from its publications.

Contents and Applicability

These guidelines primarily contain exhaust hood designs and/or ventilation system performance criteria, the overall performance characteristics of a ventilation system which define the design requirements for the rest of the system. The general principles of ventilation, overall system design procedures, construction specification, fan selection, air cleaning device selection, etc. are topics well covered by the ACGIH Industrial Ventilation Manual and other texts.

Ventilation is prescribed in the guidelines whenever exposures of employees to air contaminants exceed the exposure limits specified in Title 29 of the Code of Federal Regulations, Part 1910.1000 (formerly 29 CFR 1910.93). While the various sections present specific ventilation system design criteria, they do not prohibit the use of other engineering controls which provide the control required by 29 CFR 1910.1000. They are provided as engineering controls known to be technically feasible and are not to be considered as containing mandatory requirements for the use of specific designs or controls.

Certain sections of 29 CFR 1910 contain requirements which affect the use of ventilation as an engineering control. Where such requirements exist, they are appropriately referenced in these guidelines.

RECOMMENDED VENTILATION GUIDELINES FOR
ABRASIVE-BLASTING OPERATIONS

1. Scope

These guidelines prescribe the use of exhaust hoods, local exhaust ventilation, and other methods for the control and removal of airborne contaminants generated by abrasive-blasting operations. Abrasive-blasting installations covered by these guidelines include abrasive-blasting rooms and chambers, rotary tables, barrels, and cabinets. The guidelines exclude ventilation requirements for portable blasting operations as used at open locations and elevations to clean buildings and other masonry and metallic surfaces. They also do not apply to steam blasting, steam or solvent cleaning, or hydraulic or solvent cleaning methods where work is done without the aid of abrasives, but do apply where abrasives are used in these operations.

2. Definitions

- a. Abrasive - A solid substance used in granular or particulate form as an abrasive-blasting agent.
- b. Abrasive-Blasting - The forcible application of an abrasive to a surface by pneumatic pressure, hydraulic pressure, or centrifugal force.
- c. Abrasive-Blasting Cabinet - An enclosure within which objects are placed for cleaning where the object is held in position by a mandrel or a rubber glove encased hand during the blasting operation and the operator stands outside the enclosure and operates the blasting nozzle through an opening or openings in the enclosure.
- d. Abrasive-Blasting Barrel - A complete enclosure which rotates on an axis, or which has an internal moving tread to tumble the parts, in order to expose various surfaces of the parts to the action of an automatic blast spray.
- e. Abrasive-Blasting Respirator - A continuous flow air-line respirator constructed so that it will cover the wearer's head, neck, and shoulders to protect him from rebounding abrasive.
- f. Abrasive-Blasting Room or Chamber - A complete enclosure in which blasting operations are performed and where the operator works inside of the room to operate the blasting nozzle and direct the flow of the abrasive material.
- g. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- h. Duct Velocity - The average air velocity in a duct of an exhaust system.
- i. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in

existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.

- j. Dust Collector - A device or combination of devices for separating dust from the air handled by an exhaust system.
- k. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- l. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- m. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- n. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- o. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- p. Particulate - Filter Respirator - An air purifying respirator, commonly referred to as a dust or fume respirator which removes most of the dust or fume from the air passing through the device.
- q. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.
- r. Rotary Blasting Table - An enclosure where the pieces to be cleaned are positioned on a rotating table and are passed automatically through a series of blast sprays.

3. Application

These guidelines shall apply to abrasive-blasting operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the maximum exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation and Abrasive-Blasting Equipment Design Requirements

4.1 General

4.1.1 Enclosures

All abrasive-blasting operations which may generate air contaminant concentrations in excess of exposure limits shall, where practical, be conducted within a ventilated enclosure.

4.1.2 Make-Up Air

Provision shall be made to supply clean make-up air to abrasive-blasting enclosures or the vicinity of their use to replace the air exhausted. When make-up air is supplied in the enclosure, the amount of make-up air provided shall be slightly lower than the amount of exhausted air to maintain a slightly negative pressure within the enclosure to ensure that door seals are tightly closed and that abrasive residue will not escape from any openings or leaks in the walls of the room or cabinet.

4.1.3 Baffles

All air inlets and access openings shall be baffled or so arranged that by the combination of inward airflow and baffling the escape of abrasive or dust particles into an adjacent work area will be minimized and visible spurts of dust will not be observed. Slit abrasive-resistant baffles shall be installed in multiple sets at all small access openings where dust might escape, and shall be inspected regularly and replaced when needed.

4.1.4 Observation Windows

Safety glass protected by screening shall be used in observation windows, where hard deep-cutting abrasives are used.

4.1.5 Combustible Organic Abrasives

Organic abrasives which are combustible shall be used only in automatic systems. Where flammable or explosive dust mixtures may be present, the construction of the equipment, including the exhaust system and all electric wiring, shall conform to the requirements of American National Standard Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal and Conveying, Z33.1-1961 (NFPA 91-1961), and the National Electric Code, NFPA 70-1971; ANSI C1-1971 (Rev. of C1-1968). The blast nozzle shall be bonded and grounded to prevent the build up of static charges. Where flammable or explosive dust mixtures may be present, the abrasive-blasting enclosure, the ducts, and the dust collector shall be constructed with loose panels or explosion venting

areas, located on sides away from any occupied area, to provide for pressure relief in case of explosion, following the principles set forth in the National Fire Protection Association Explosion Venting Guide, NFPA 68-1954.

4.2 Abrasive-Blasting Rooms or Chambers

Abrasive-blasting rooms or chambers within which one or more operators are employed shall fall into the following two categories or classifications. Enclosures within which silica sand is used as an abrasive or is contained in or coated on the material being blasted shall be categorized as Class I enclosures. Enclosures in which materials other than silica sand are used as an abrasive and the material being blasted is free of natural sand shall be categorized as Class II enclosures. Figure 1 illustrates an acceptable enclosure design for the control of air contaminants.

Doors of abrasive-blasting rooms and chambers shall be flanged and tight when closed. Doors on blast-cleaning rooms shall be operable from both inside and outside, except that where there is a small operator access door openable from inside and outside, the large work access door may be closed or opened from the outside only.

4.3 Rotary Abrasive-Blasting Tables

Figure 2 illustrates an acceptable enclosing hood design for rotary abrasive-blasting tables. Other designs which utilize protective curtains instead of a solid door are also acceptable.

4.4 Abrasive-Blasting Barrels

Abrasive-blasting barrels (tumble blast machines) shall be enclosed to the maximum extent practical. An acceptable enclosure design for such equipment is illustrated in Figure 3.

4.5 Abrasive-Blasting Cabinet

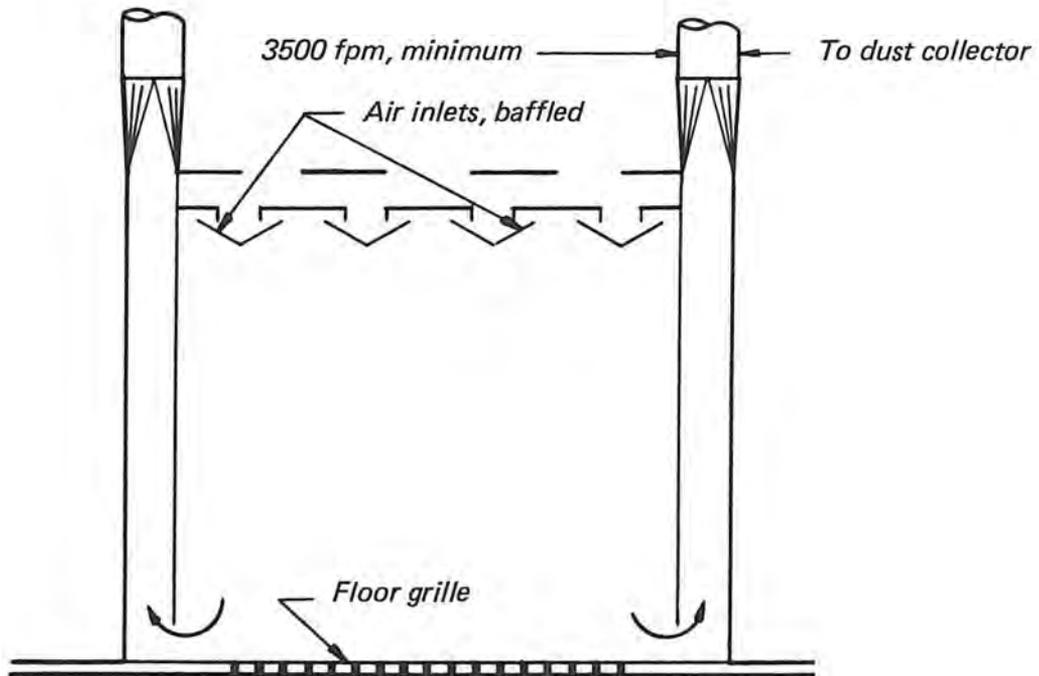
An example of an enclosure design for abrasive-blasting cabinets is shown in Figure 4.

5. Ventilation Requirements

5.1 General

5.1.1 Maintenance

The static pressure drop at the exhaust ducts leading from the equipment shall be checked when the installation is completed and periodically thereafter to assure continued satisfactory operation. Whenever an appreciable change in the pressure drop indicates a partial blockage, slipping fan belt, or other system malfunction, the system



SECTION THRU TYPICAL ROOM

ROOM LENGTH-TO-WIDTH RATIO OF 2 TO 1 OR LESS: Provide minimum downdraft ventilation over entire projected floor area of 80 fpm for Class I enclosures; 60 fpm for Class II enclosures. Exhaust openings shall be along at least the two sides of the room. Lowest point of such openings may not be more than 10 inches above floor line.

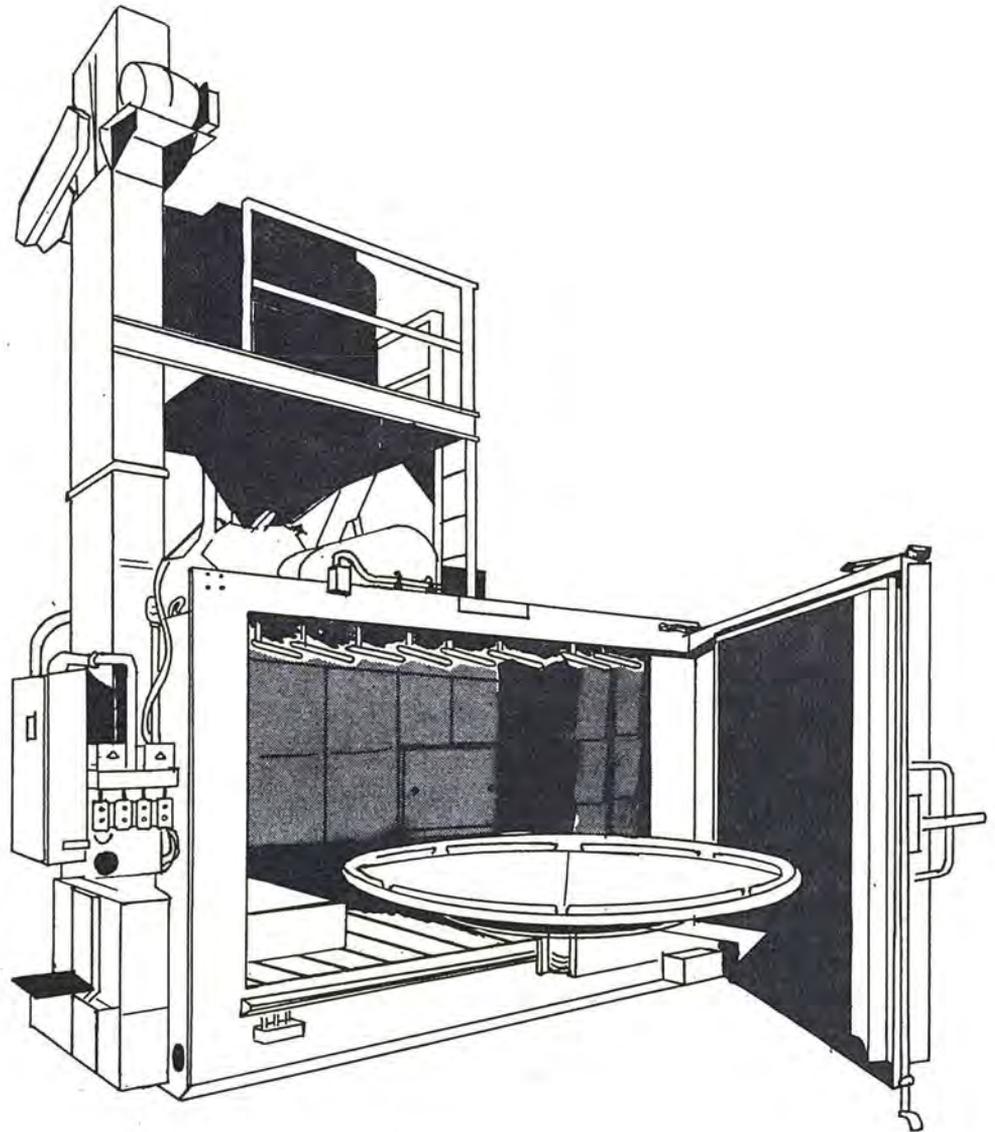
ROOM LENGTH-TO-WIDTH RATIO in EXCESS OF 2 TO 1: Provide ventilation as above or lateral ventilation not less than 100 fpm through cross-sectional area for Class I enclosures; not less than 75 fpm through cross-sectional area for Class II enclosures. Airflow in direction of largest dimension requires lower exhaust volume.

AIR INLETS: Provide 300 fpm minimum air velocity through baffled inlets.

DUCT VELOCITY = 3500 fpm minimum

ENTRY LOSS = 1 VP; or calculate from individual losses

FIGURE 1 ABRASIVE-BLASTING ROOM OR CHAMBER

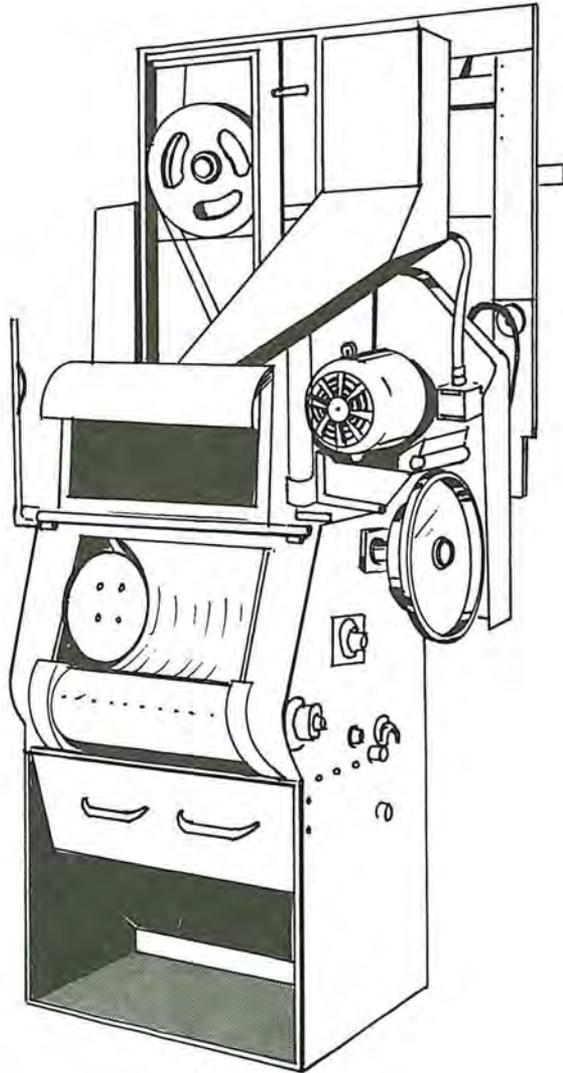


Q = minimum 500 cfm/sq ft of all openings with door closed, but not less than 200 cfm/sq ft of total openings (taken without curtains) where protective curtain utilized.

Duct velocity = 3500 fpm minimum

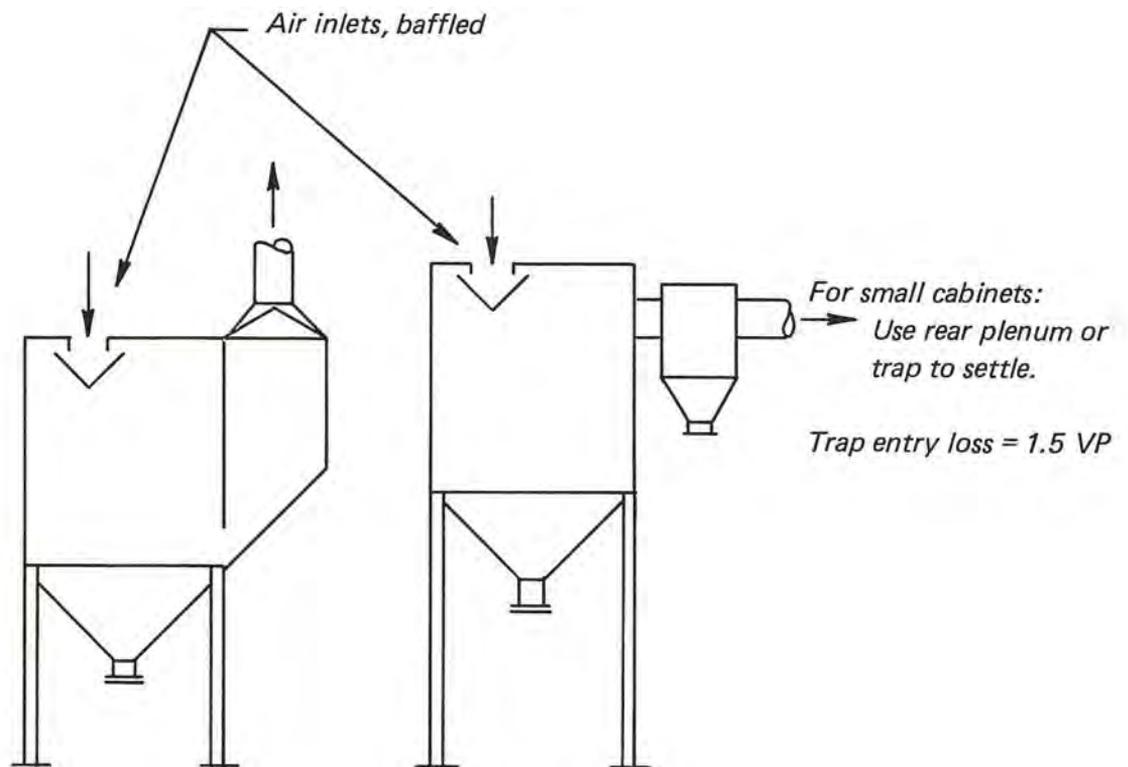
Consult manufacturer for entry loss.

FIGURE 2 ROTARY BLASTING TABLE



Q = minimum 500 cfm/sq ft of all openings with door closed
Duct velocity = 3500 fpm minimum
Consult manufacturer for entry loss.

FIGURE 3 ABRASIVE-BLASTING BARREL



Q = 20 air changes per minute minimum
Air inlets: Provide 500 fpm minimum air velocity through baffled inlets
Duct velocity = 3500 fpm minimum
Entry loss = 1 VP; or calculate from individual losses

FIGURE 4 ABRASIVE-BLASTING CABINETS

shall be cleaned and/or returned to normal operation conditions as appropriate.

5.1.2 Abrasive Recirculation

In installations where the abrasive is recirculated, the exhaust ventilation system for the blasting enclosure shall not be relied upon for the removal of fines from the spent abrasive. An abrasive separator shall be provided for the purpose.

5.1.3 Dust Collectors

The air exhausted from blast-cleaning equipment shall be discharged through dust collecting equipment. Dust collectors shall be set up so that the accumulated dust can be emptied and removed without contaminating other working areas.

5.1.4 Operational Procedures and General Safety

Before an enclosure is opened, the blast shall be turned off and the exhaust system shall be run for a sufficient period of time to remove the dusty air within the enclosure. Dust shall not be permitted to accumulate on the floor or on ledges outside of an abrasive-blasting enclosure, and dust spills shall be cleaned up promptly. Aisles and walkways shall be kept clear of steel shot or similar abrasive which may create a slipping hazard.

5.1.5 Electrical and Mechanical Interlocks

Abrasive-blasting installations shall be provided an electrical or mechanical interlock system which prevents the operation of abrasive-blasting unless the exhaust system is operating.

5.2 Class I Abrasive-Blasting Rooms or Chambers

Class I blasting rooms or chambers having a length to width ratio of 2 to 1 or less shall be provided with downdraft ventilation of not less than 80 fpm velocity over the entire projected floor area of the room. Such rooms having a ratio of length to width ratios in excess of 2 to 1 shall be ventilated either as above or by means of lateral ventilation of not less than 100 fpm through the cross-sectional area of the room. All openings into the enclosure shall be provided an indraft air velocity of at least 300 fpm.

5.3 Class II Abrasive-Blasting Rooms or Chambers

Class II blasting rooms or chambers having a length to width ratio of 2 to 1 or less shall be provided with downdraft ventilation of not less than 60 fpm velocity over the entire projected floor area of the

room. Such rooms having a length to width ratio in excess of 2 to 1 shall be ventilated either as above or by means of lateral ventilation of not less than 75 fpm through the cross-sectional area of the room. All openings into the enclosure shall be provided an indraft air velocity of at least 300 fpm.

5.4 Abrasive-Blasting Rotary Tables, Barrels, and Cabinets

An indraft air velocity of a minimum of 500 fpm shall be provided through all operating openings in the enclosures for rotary abrasive-blasting tables, abrasive-blasting barrels, and abrasive-blasting cabinets. Where protective curtains are utilized for rotary abrasive-blasting table enclosures, the minimum exhaust volume shall be 200 cfm/sq ft of total openings without curtains. The minimum exhaust volume to be provided an abrasive-blasting cabinet shall be at least equivalent to 20 air changes per minute.

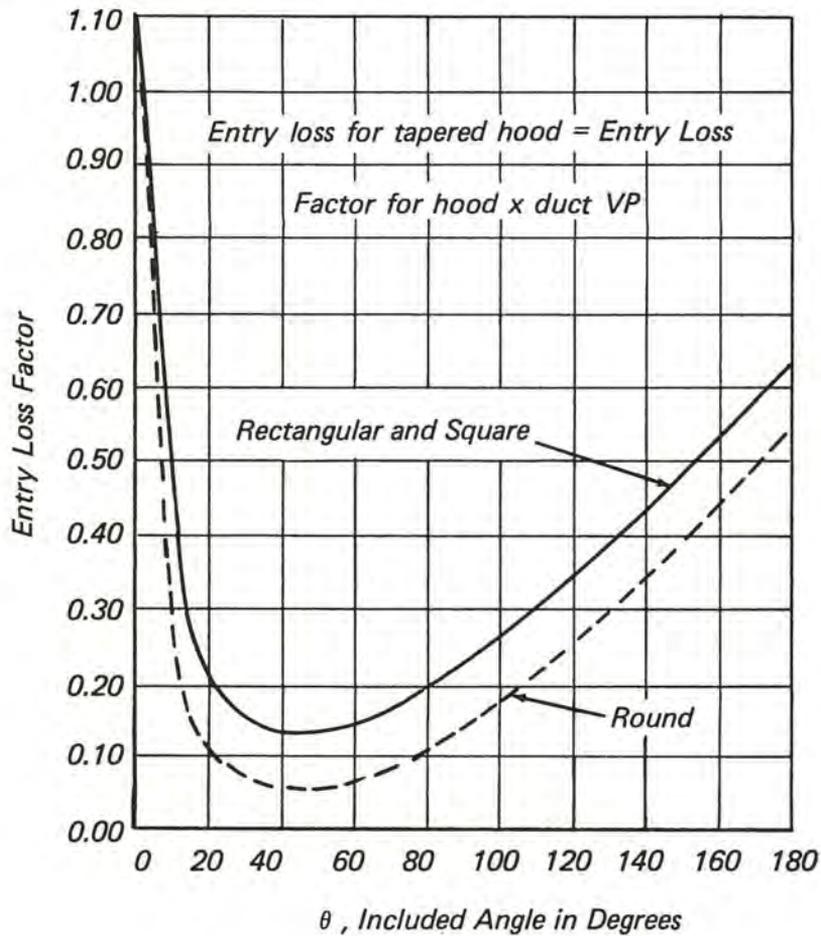
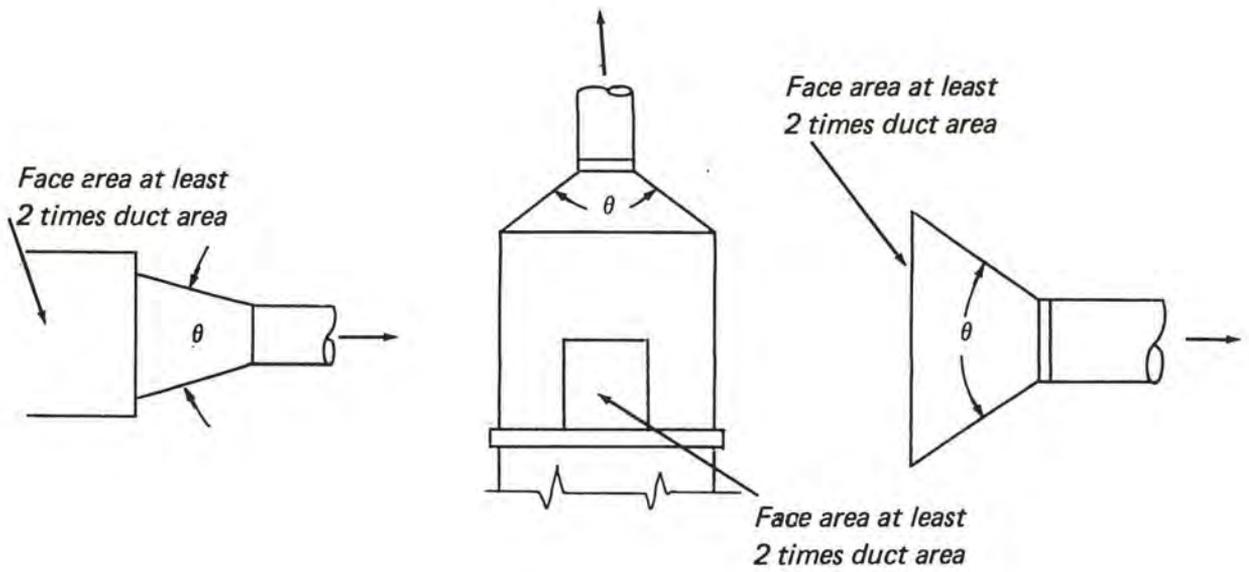
RECOMMENDED VENTILATION GUIDELINES FOR
ASBESTOS TEXTILE MANUFACTURING OPERATIONS

1. Scope

These guidelines prescribe the use of exhaust hoods and enclosures for the control and removal of air contaminants generated by asbestos textile manufacturing operations, including the manufacturing of asbestos and asbestos-bearing yarn, cord, thread, cloth, roving, lap, wick, rope, tape, felt, and carded fibers. Operations covered by these guidelines include bag-opening, blending, conveying, carding, felting, spinning, twisting, winding, weaving, and braiding. The guidelines do not cover asbestos mining or milling operations or manufacturing of asbestos products other than textiles.

2. Definitions

- a. Bag-Opening- An operation in which bags of asbestos fibers are opened and fibers are separated from the bag and fed into fiber processing equipment.
- b. Blending - The combining of asbestos fibers of different types, grades or staple length, and possibly other fibrous materials, prior to spinning.
- c. Braid - A narrow textile band formed by plaiting together several strands of asbestos yarn.
- d. Carding - A process of opening and cleaning textile fibers which separates them from each other, lays them parallel, makes them into a thin web, and condenses them into a continuous, unbursted strand of fibers called a sliver.
- e. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- f. Duct Velocity - The average velocity in a duct of an exhaust system.
- g. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.
- h. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- i. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- j. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- k. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- l. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- m. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- n. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.



Tapered Hoods

Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- o. Felt (Non-Woven) - An asbestos product in sheet form produced by carding or other fiber orientation processes.
- p. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- q. Spinning - The process of drawing and twisting fibers to produce thread or yarn.
- r. Twisting - The process of twisting threads to produce yarn.
- s. Weaving - The process of forming a fabric by means of a loom.
- t. Winding - The process of winding a thread or yarn on a spool.

3. Application

These guidelines shall apply to all asbestos textile manufacturing operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000a. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood and enclosure designs described in these guidelines have been found to reduce air contaminant concentrations when applied to asbestos textile manufacturing operations. The airflow requirements, however, are based on very limited data, and should be considered only as minimum requirements. Other designs which provide adequate performance are acceptable. Where the specified ventilation requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation Requirements

4.1 General Requirements

4.1.1 Hood and Enclosure Design

Every operation involved in the manufacturing of asbestos textiles shall be enclosed to the maximum extent possible and exhaust ventilated to control the escape of asbestos fibers from the operation. With operations which require access by employees, exhaust hoods shall be used and located so as to convey contaminated air away from employees' breathing zones. Protective barriers shall be used to the maximum extent possible along with the exhaust hoods to prevent the flow of contaminated air into breathing zones.

4.1.2 Exhaust Flow Rates

Except where higher exhaust flow rates are specified for specific operations, air shall be exhausted from each operation at a rate sufficient to maintain air velocities into all enclosure openings of 50 fpm or greater.

4.1.3 Make-Up Air

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue. Duct velocities in all exhaust ducts shall be maintained at or above 3000 fpm.

4.2 Requirements for Specific Operations

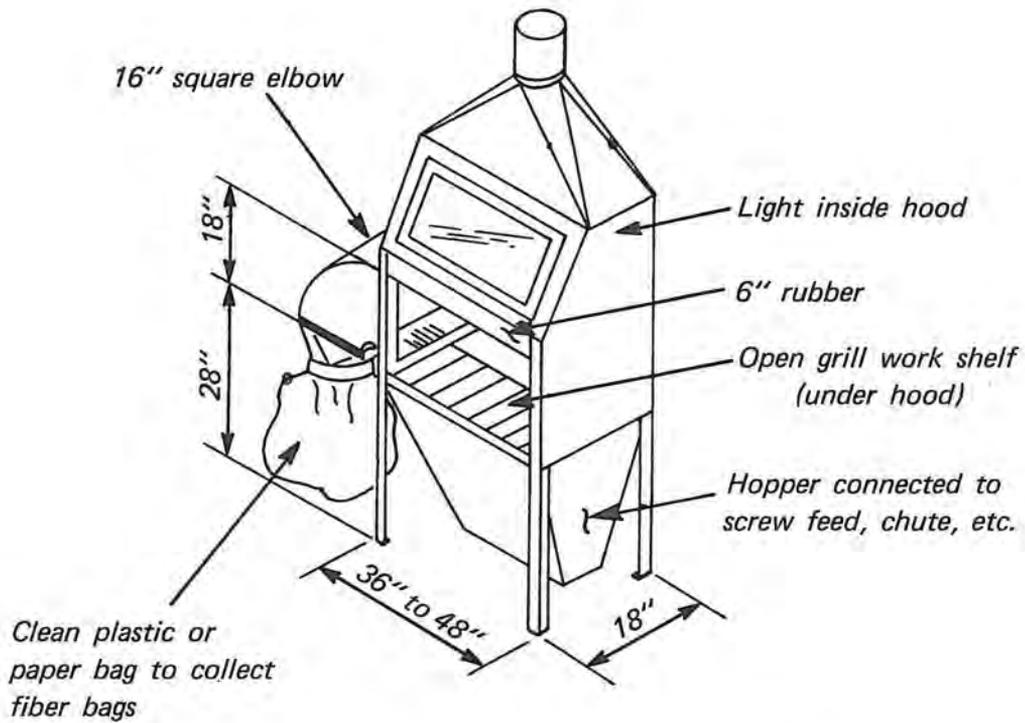
4.2.1 Asbestos Fiber Bag-Opening

Asbestos fiber bag-opening operations shall be conducted in complete enclosures. An acceptable design of a bag-opening enclosure is shown in Figure 2. A minimum exhaust flow rate of 200 cfm per sq ft of open area shall be maintained during bag-opening operations. This flow rate shall be based on open area measured with the bag feed door open.

The opened bags shall be disposed of in a manner which does not result in exposures of employees to asbestos fibers. An acceptable method of opened bag disposal is to discharge the opened bag into a clean plastic bag through a discharge chute as shown in Figure 2.

4.2.2 Asbestos Fiber Storage and Handling Operations

Asbestos fiber handling, conveying, transporting, and loading operations shall be conducted in complete enclosures. Accumulation of asbestos fibers in the enclosures shall be prevented by scrapers, brushes, exhaust ducts, or other means. Each enclosure shall be exhaust ventilated with a minimum air velocity of 50 fpm into all open areas. Higher air velocities shall be maintained as necessary to prevent escape of asbestos fibers from locations where the material is agitated such as loading and transfer points. An acceptable design of an enclosure for asbestos fiber handling equipment is shown in Figure 3.

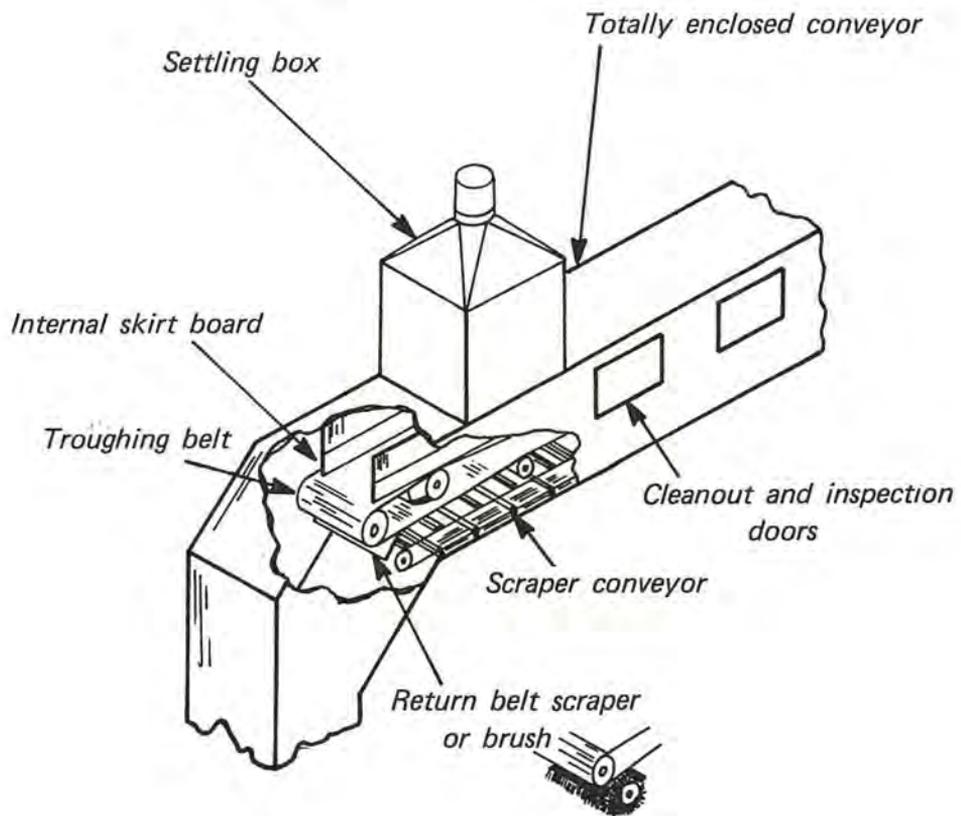


$Q = \text{minimum } 200 \text{ cfm/sq ft of open area with door open}$

$\text{Duct velocity} = 3000 \text{ fpm minimum}$

$\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

FIGURE 2 ENCLOSURE FOR ASBESTOS FIBER BAG-OPENING OPERATION



$Q = 50 \text{ cfm/sq ft of open areas}$
 Duct velocity = 3000 fpm minimum
 Entry loss = 0.5 duct VP

FIGURE 3 ENCLOSURE FOR ASBESTOS FIBER CONVEYING OPERATION

4.2.3 Asbestos Fiber Carding Operations

Asbestos fiber carding operations shall be conducted in complete enclosures. The enclosures shall be exhaust ventilated with a minimum air velocity of 50 fpm into all enclosure openings, except that a minimum air velocity of 200 fpm shall be maintained into feed box openings during fiber feeding operations. An acceptable design of an enclosure for a carding machine and feed box is shown in Figure 4.

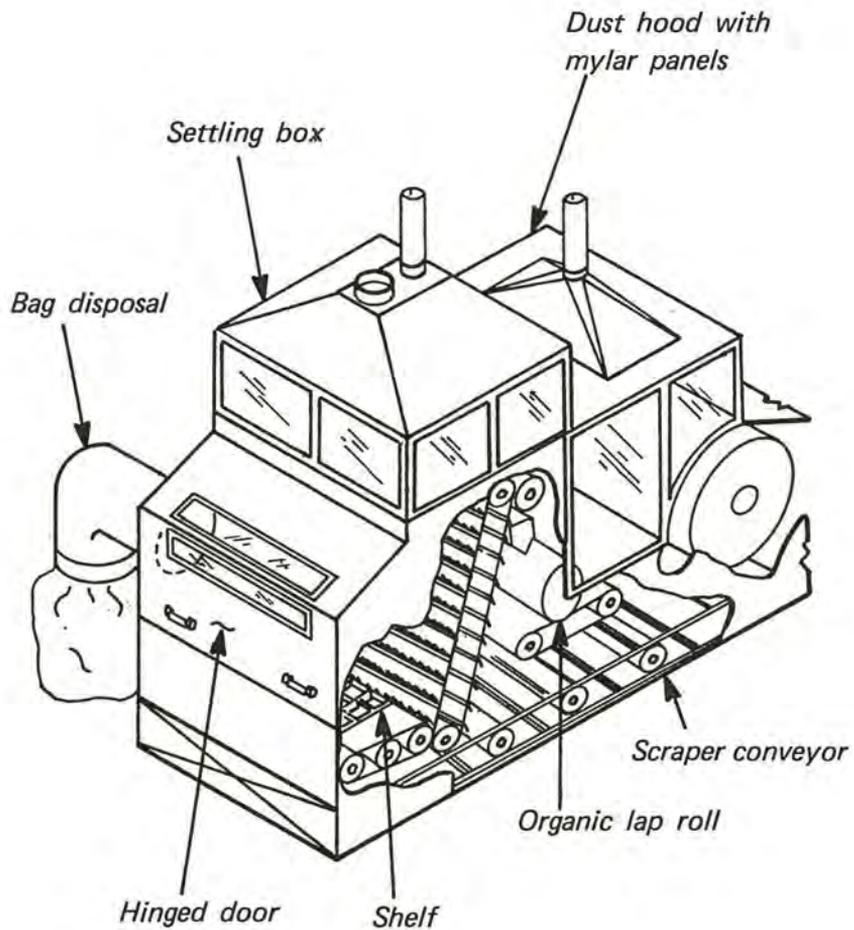
The exhaust flow take-off ducts should be located within the carding machine enclosure so as to collect airborne asbestos fiber and to prevent the accumulation of fiber within the enclosure. These take-off ducts should be located above or below the points in the carding machine where asbestos fibers become airborne.

4.2.4 Spinning, Twisting, Braiding, and Winding Operations

Spinning, twisting, braiding, and winding of asbestos yarn shall be conducted in partial enclosures with open areas provided only as necessary to allow access by employees for operation and maintenance of machinery. Transparent barriers shall be provided between the machinery and the operators' breathing zones. Enclosures shall be exhaust ventilated from the back or bottom with exhaust air take-offs distributed so as to maintain a uniform air velocity into all open areas. A minimum air velocity of 50 fpm shall be maintained into all enclosure openings.

4.2.5 Weaving Operations

Asbestos textile weaving operations shall be conducted under canopy hoods with baffles which enclose the operations to the maximum extent possible. Baffles shall remain in their closed positions while weaving operations are in progress, and the operations shall be exhaust ventilated with an exhaust flow rate sufficient to maintain minimum air velocities of 50 fpm into all openings to the baffled space.



*Q = minimum 200 cfm/sq ft of feed box openings
during fiber feeding operations
= minimum 50 cfm/sq ft of enclosure openings
during carding operations*

Duct velocity = 3000 fpm minimum

*Entry loss = 0.5 duct VP with door closed
= entry loss factor for tapered hood x
duct VP with door open*

FIGURE 4 ENCLOSURE AND FEED BOX FOR TEXTILE CARDING MACHINE

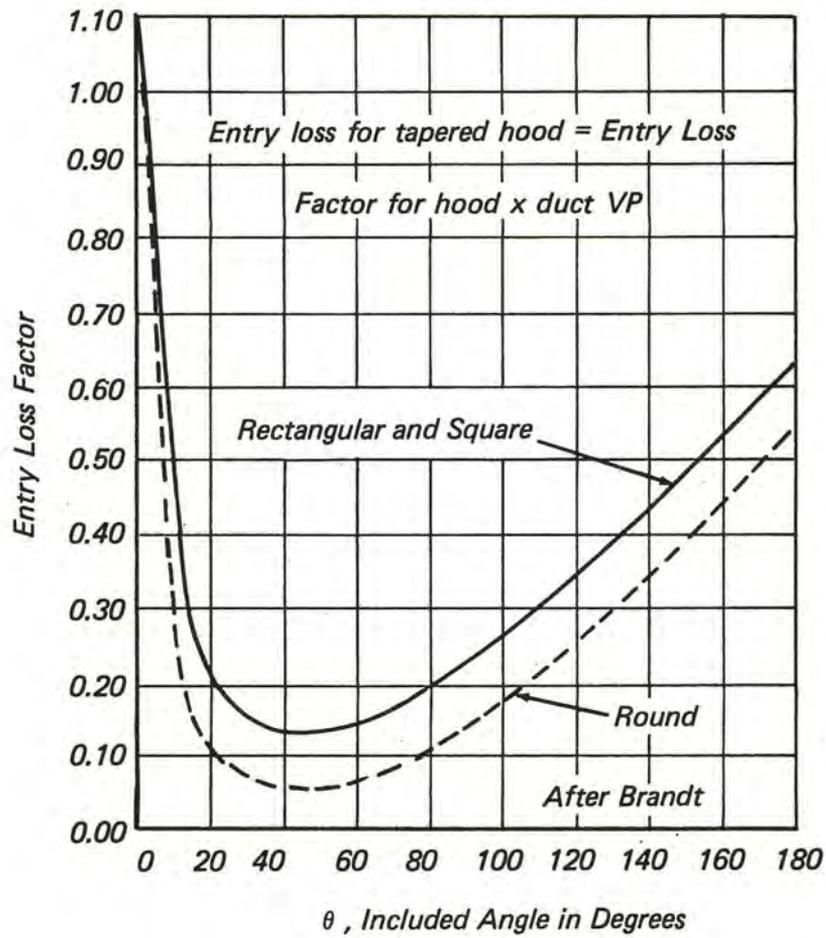
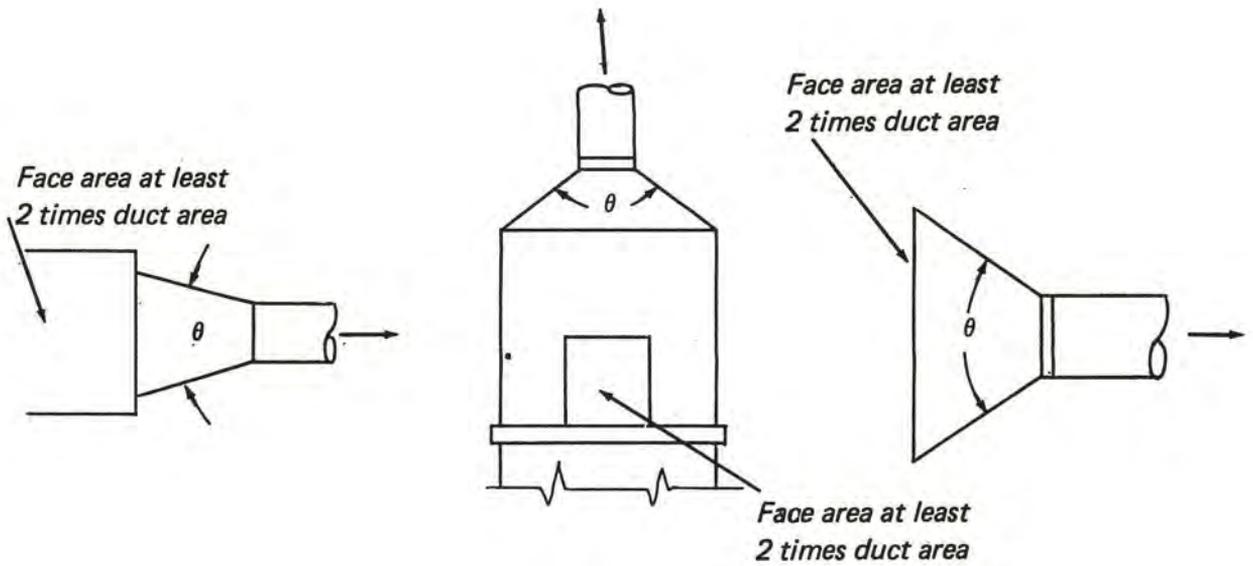
RECOMMENDED VENTILATION GUIDELINES FOR CERAMICS OPERATIONS

1. Scope

These guidelines prescribe the use of exhaust hoods and exhaust systems for the control and removal of airborne contaminants generated by certain ceramics operations. Ceramics operations covered by these guidelines include screening, mixing, mulling, non-aqueous slip casting, injection molding, dry pressing, finishing (pre-firing), and finishing (post-firing). The operations of dry batching, packaging (especially bag filling), grinding, spray painting, and spray glazing are covered by other ventilation guidelines and are referenced as being such.

2. Definitions

- a. Batching - The weighing, formulation and, in general, the movement of predetermined amounts of raw materials. These operations usually precede mixing and mulling operations.
- b. Capture Velocity - The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- c. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- d. Dry Pressing - The forming of ceramic ware by compacting powder containing less than fifteen (15) percent water by weight. The compaction is usually carried out in a metallic die under high pressure.
- e. Duct Velocity - The average air velocity in a duct of an exhaust system.
- f. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- g. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.
- h. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- i. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- j. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- k. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.



Tapered Hoods

*Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.*

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- l. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- m. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- n. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- o. Finishing (Post-Firing) - Those secondary shaping or finishing operations such as grinding and turning that are carried out on formed ware that has been fired.
- p. Finishing (Pre-Firing) - Those secondary shaping or finishing operations such as grinding, turning, fettling, trowing, scalloping, or sanding that are carried out on formed ware that has not been fired.
- q. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- r. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- s. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- t. Injection Molding - The forming of ware by the injection under pressure of ceramic raw materials containing organic binders into a mold. The ware is usually given some treatment at elevated temperatures prior to firing.
- u. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- v. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- w. Make-up Air - Air supplied to a building or space to replace air exhausted.
- x. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- y. Mixing - The process whereby raw materials for the ceramics product (e.g., clay, sand, crushed stone, etc.) are mixed together.
- z. Mulling - The process whereby raw materials for the ceramic product (e.g., clay, sand, crushed stone, etc.) are ground and mixed.
- aa. Non-Aqueous Slip Casting - The forming of ceramic ware by pouring a liquid suspension of the desired raw materials where

- aa. Non-Aqueous Slip Casting - The forming of ceramic ware by pouring a liquid suspension of the desired raw materials where the liquid involved is not water. The use of methanol as the carrying liquid is specifically included in this definition.
- bb. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- cc. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity, usually expressed in inches of water gauge.
- dd. Screening - The process whereby raw materials for the ceramics product (e.g., clay, sand, crushed stone, etc.) are sized by passing them through one or more screens.
- ee. Spray Drying - A process for drying a slip or suspension of ceramic raw materials inside a drying chamber and involving the use of an atomizing nozzle, rotating disc, or similar device to spray the material into a drying chamber which is filled with heated gases.
- ff. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all ceramic operations connected with the traditional ceramics industry in the manufacture of whitewares, structural (heavy) clay products, refractories, and technical ceramics, which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists. These guidelines do not cover operations in the manufacture of glass, mineral wool, cement, lime, gypsum, or abrasives.

The guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood designs illustrated or described in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation Requirements for Ceramics Operations

4.1 General

A hood used for the control of air contaminants generated from ceramics operations shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that contaminants are projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

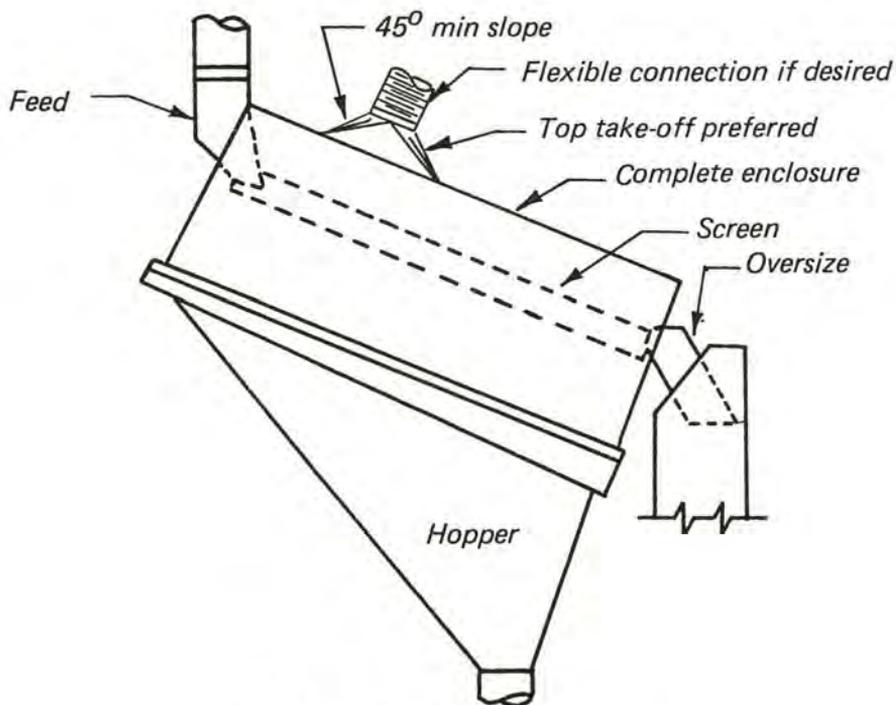
When the material being handled in a ceramics operation is a flammable or combustible liquid or dust, and the operation is exhaust ventilated, the minimum exhaust volume, where practical, shall be sufficient for dilution of air contaminant concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being handled, the fan rotating element shall be of nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

4.2 Screening Operations

Equipment used in screening operations, including any magnetic separation equipment, shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. Figure 2 illustrates acceptable hood designs for screening equipment. Minimum air volumes exhausted shall be in accordance with those given in the figure. Duct velocity shall be a minimum of 3500 fpm.

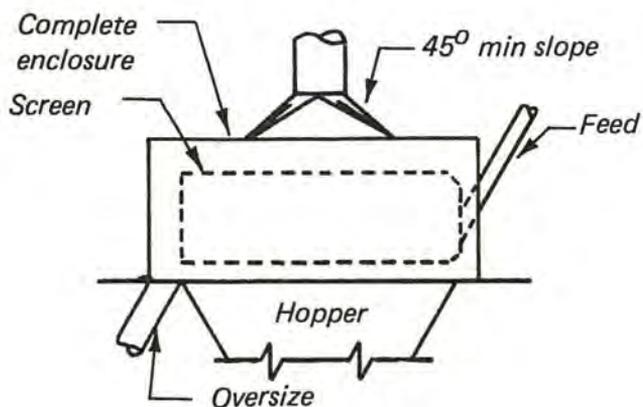
4.3 Mixing and Mulling Operations

Equipment used in mixing and mulling operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. Acceptable hood designs for such equipment are illustrated in Figures 3 and 4. Minimum air volumes exhausted shall be in accordance with those given in the figures. Duct velocity shall be a minimum of 3500 fpm.



FLAT DECK SCREEN

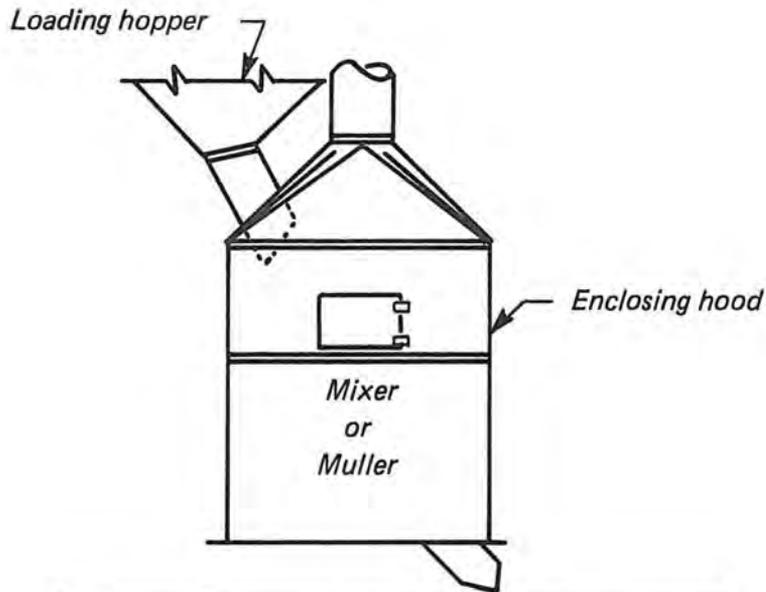
$Q = 200 \text{ cfm/sq ft}$ through hood openings, but not less than 50 cfm/sq ft screen area. No increase for multiple decks
 Duct velocity = 3500 fpm minimum
 Entry loss = 0.50 VP



CYLINDRICAL SCREEN

$Q = 100 \text{ cfm/sq ft}$ circular cross section of screen; at least 400 cfm/sq ft of enclosure opening
 Duct velocity = 3500 fpm minimum
 Entry loss = 0.50 VP

FIGURE 2 SCREENING OPERATION VENTILATION



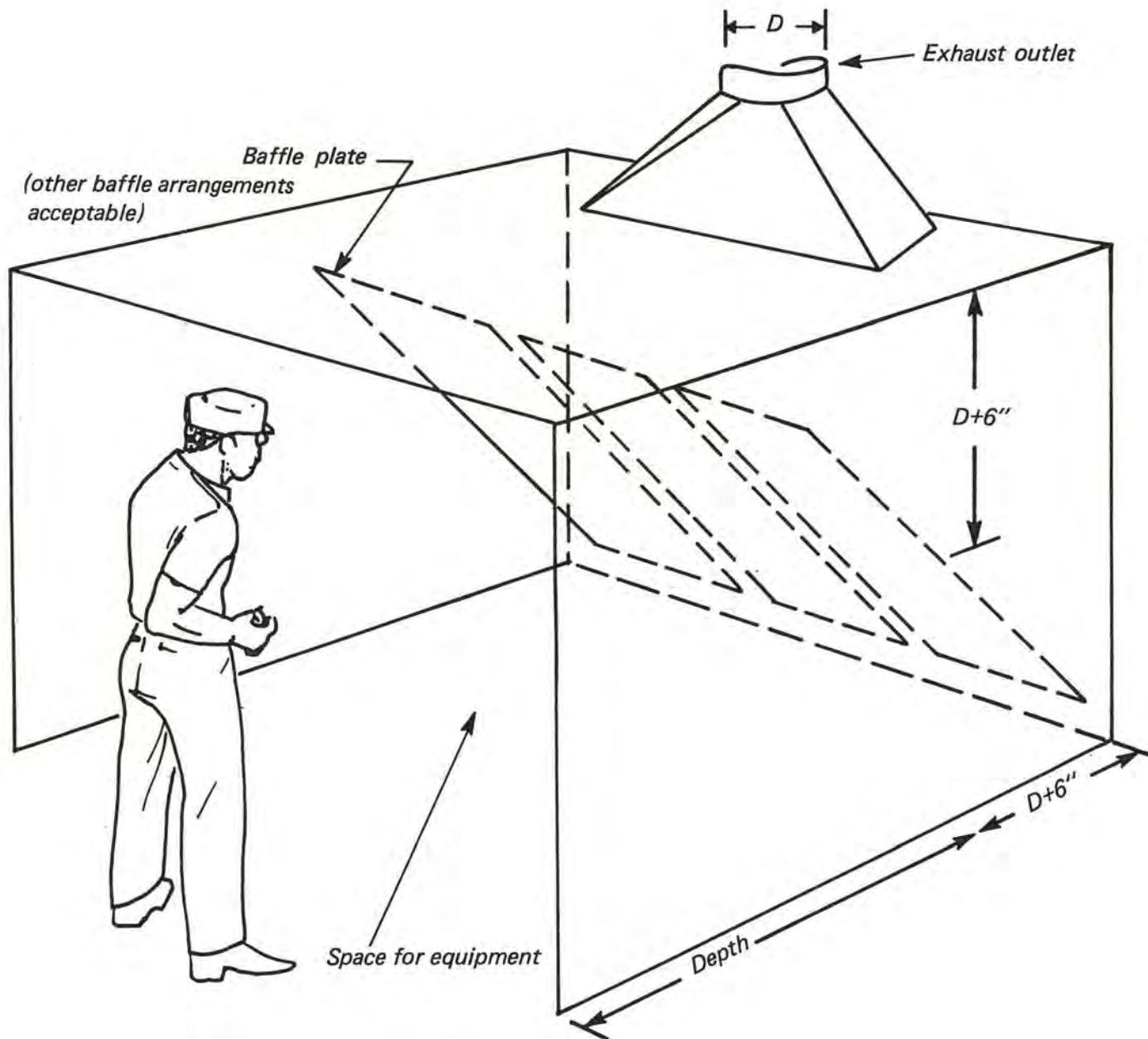
<i>Minimum Exhaust Volumes for Mixers and Mullers</i>	
<i>Mixer/Muller Diameter (feet)</i>	<i>Minimum Exhaust (cfm)</i>
<i>< 4</i>	<i>600</i>
<i>4</i>	<i>750</i>
<i>6</i>	<i>900</i>
<i>7</i>	<i>1050</i>
<i>8</i>	<i>1200</i>
<i>10</i>	<i>1575</i>

Q = 150 cfm/sq ft through all openings, but not less than the table values

Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood X duct VP

FIGURE 3 ENCLOSING HOOD FOR MIXER OR MULLER



Walk-in booth (shown)

$$Q = WHV$$

= required exhaust volume, cfm

Width (W) = equipment width + 6', feet

Height (H) = equipment height + 3' (min. = 7'), feet

Depth = equipment depth + 6', feet

Baffle area = 0.40 WH, sq ft

Small booth

$$Q = WHV$$

= required exhaust volume, cfm

Width (W) = equipment width + 1', feet

Height (H) = equipment height + 1', feet

Depth = 0.75 W or H, whichever is larger, feet

Baffle area = 0.60 WH, sq ft

V = adequate face velocity for contaminant and process type, fpm

Entry loss for tapered takeoff (shown)

plus baffles = 1.78 slot. VP

plus entry loss factor for tapered hood X duct VP

Entry loss for plain duct end takeoff plus baffles =

1.78 slot VP + 0.50 duct VP

FIGURE 4 BOOTH ENCLOSURES

4.4 Non-Aqueous Slip Casting Operations

Non-aqueous slip casting operations (e.g., mixing, storing, forming, drying) shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

Figures 3 to 7 illustrate acceptable hood designs, if properly applied, for equipment used in the mixing of non-aqueous substances for slip casting operations.

Acceptable hood designs for equipment used to form the mixtures used in non-aqueous slip casting are illustrated in Figures 6 and 7. The capture velocity (V) provided shall be a minimum of 100 fpm at the source of contaminant generation farthest from the hood face.

Equipment used to dry non-aqueous slip cast forms shall be enclosed and provided an air velocity of a minimum of 100 fpm through all openings in the hood.

4.5 Injection Molding Operations

Injection molding equipment (e.g., a mixer, a molding machine, or a dryer) shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. Hood designs illustrated in Figures 3 to 7 shall be considered acceptable if properly applied to the operations of injection molding.

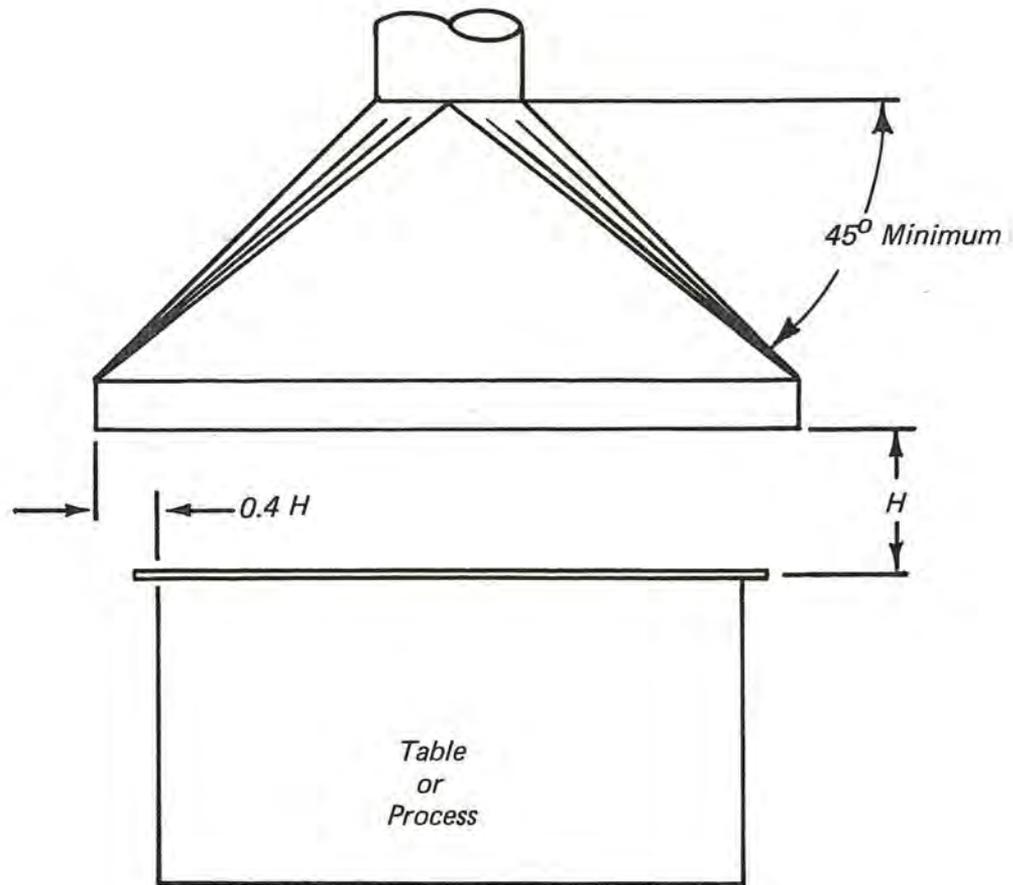
4.6 Dry Pressing Operations

Equipment used to form ceramic ware by dry pressing shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. Figure 6 illustrates acceptable open hood designs for use with this equipment. Where used, such a hood shall be placed as close as practical to the die and press parts and positioned to draw contaminated air away from the breathing zones of employees. Where operations permit, the hood shall be shaped to partially enclose the die and press area. The capture velocity provided an open hood for such applications shall be a minimum of 100 fpm in the air contaminant-generating area. Enclosing hoods utilized shall be provided a minimum face velocity of 100 fpm.

4.7 Finishing (Pre-Firing and Post-Firing)

Equipment or operations for the finishing of formed ceramic ware before or after firing shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. The finishing operations covered shall include, but not be limited to, grinding, turning, fettling, scalloping, or sanding.

For grinding, buffing, and polishing type operations, the hood designs and associated exhaust volumes or air velocities given in the ventilation guidelines for grinding, polishing, and buffing are acceptable for use. For other machine-finishing operations, either an enclosing hood with a face velocity of at least 200 fpm or an open hood with a capture velocity of at least 200 fpm at the point farthest from the hood face at which contaminants are generated shall be provided.



Not to be used when worker must bend over process. Hood shall be curtained or baffled as necessary to ensure that cross-drafts do not cause spillage of contaminants from the canopy.

$Q =$ minimum exhaust volume, cfm

$= 1.4 PHV$ for open type canopy.

$P =$ perimeter of tank, feet.

$H =$ distance from lower edge of canopy to lowest top of table or process, feet

$V =$ adequate air velocity for contaminant and process type, fpm

$Q =$ for two sides enclosed.

$(W+L) HV$ W & L are open sides of hood, feet

$V =$ adequate air velocity for contaminant and process type, fpm

$Q = WHV$ or for three sides enclosed. (booth)

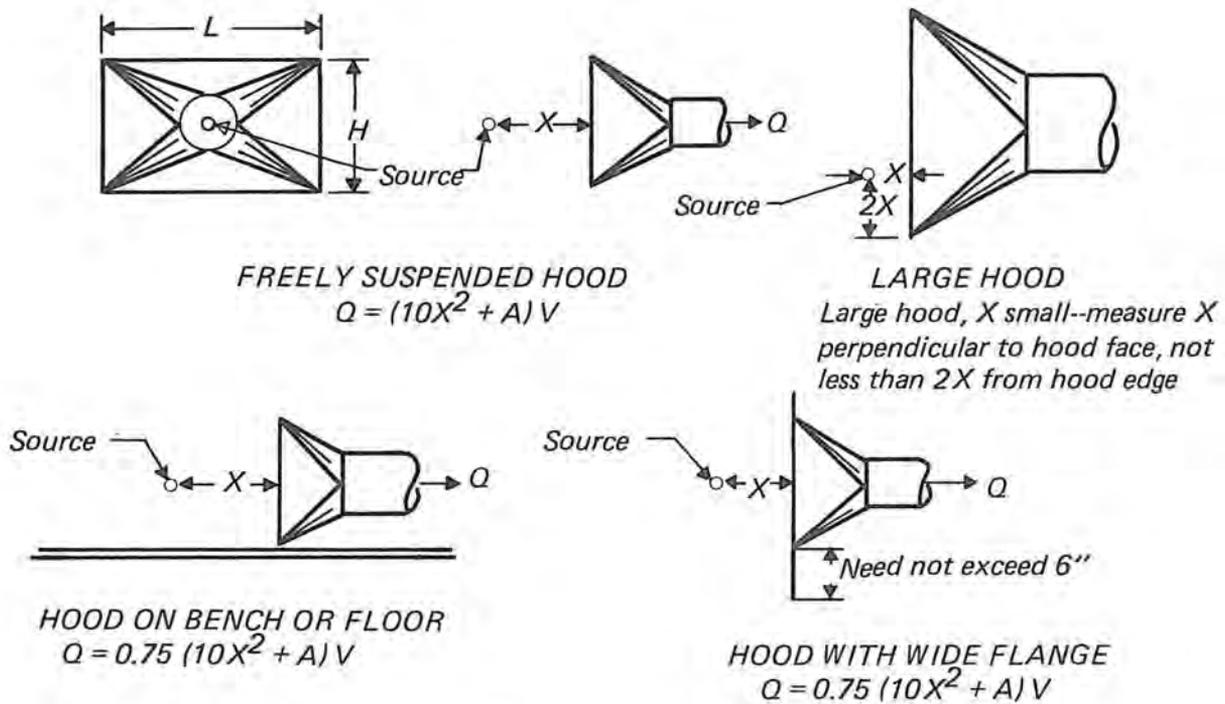
LHV $V =$ adequate air velocity for contaminant and process type, fpm

Duct velocity = 1000 fpm minimum for vapors and fumes.

= 2000 fpm minimum for dusts and powders

Entry loss = entry loss factor for tapered hood X duct VP

FIGURE 5 CANOPY HOOD



Q = exhaust volume, cfm

X = distance from hood face to farthest point of contaminant release, feet.

A = hood face area, sq ft, equals LH

L = length of hood, feet

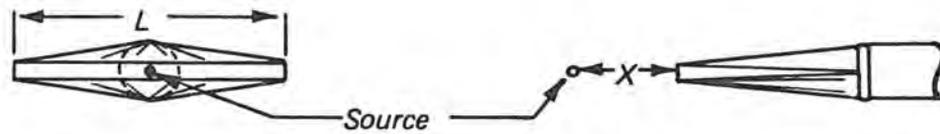
H = height of hood, feet

V = adequate capture velocity for contaminant and process type at source of contaminant generation, fpm, at distance X

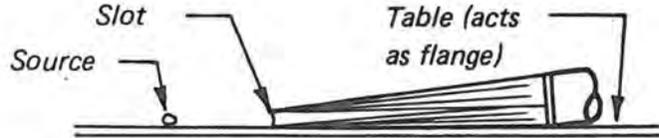
Entry loss = entry loss factor for tapered hood X duct VP

Note: Air volume must increase as the square of distance of the source from the hood. Baffling by flanging or by placing on bench, floor, etc. has a beneficial effect.

FIGURE 6 OPEN HOODS

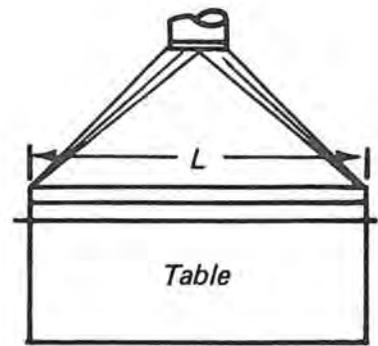


FREELY SUSPENDED SLOT
 $Q = 3.7 LXV$

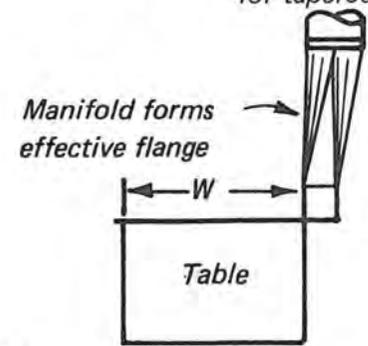


SLOT ON TABLE OR BENCH
 $Q = 2.8 LXV$

Q = exhaust volume, cfm
 X = distance, feet, hood face to farthest point of source (usually on centerline of hood)
 V = adequate capture velocity for contaminant and process type at source of contaminant generation, fpm, at distance X .
 L = length, feet, of hood
 W = width, feet, of table
 Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP



FLANGED SLOT
 $Q = CLW$



$(C = \text{constant from } 50\text{--}500; \text{ usual choice is } 150\text{--}250)$

Exhaust volume formulae above applicable when $X/L < 0.3$. When $X/L > 0.3$, use open hood formulae in Figure 6.

FIGURE 7 SLOT HOOD

For hand-finishing operations, either a booth-type working enclosure such as the acceptable design shown in Figure 4 or an open hood with a capture velocity of at least 100 fpm at the point farthest from the hood face at which contaminants are generated shall be provided.

4.8 Other Operations

Spray glazing, spray painting, and similar operations shall be enclosed and exhaust ventilated in accordance with the ventilation guidelines for spray-finishing operations.

Materials handling operations such as batching, conveyor transport of material, bag and drum filling, hopper and bin loading, etc. shall be enclosed and exhaust ventilated in accordance with the ventilation guidelines for materials handling operations.

RECOMMENDED VENTILATION GUIDELINES FOR COTTON YARN MANUFACTURING OPERATIONS

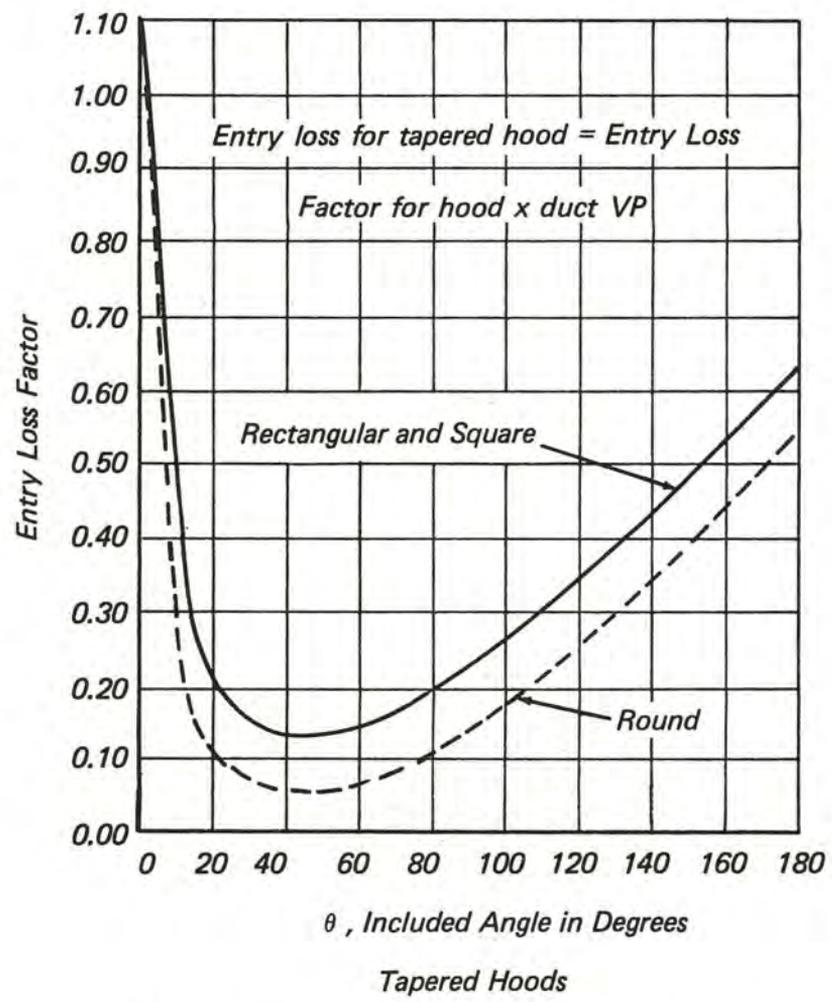
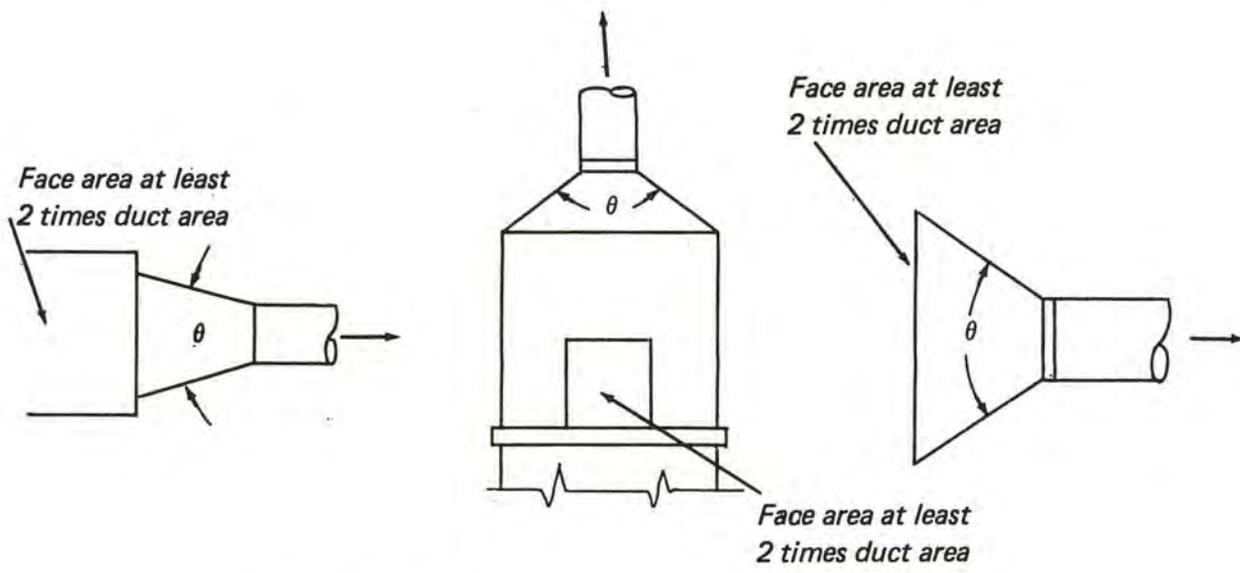
1. Scope

These guidelines prescribe the use of exhaust hoods and enclosures for the control and removal of cotton dust generated by cotton yarn manufacturing operations.

These guidelines cover operations involved in the manufacturing of yarn from raw cotton and blends of raw cotton with other fibers. Operations covered by the guidelines include opening, picking, carding, drawing, and combing. The guidelines do not cover operations preceding delivery of the raw cotton to the yarn manufacturer, roving or spinning operations, or operations subsequent to spinning.

2. Definitions

- a. Carding - A brushing action in which cotton fibers are worked by a series of wire teeth to remove impurities and short fibers and to arrange remaining fibers into a sliver.
- b. Combing - A process following drawing to further clean the fibers and arrange them in a parallel order.
- c. Cotton Dust - Dust generated into the atmosphere as a result of the processing of cotton fibers combined with any naturally occurring materials such as stems, leaves, bracts, and inorganic matter which may have accumulated on the cotton fibers during the growing or harvesting period.
- d. Drawing - A process following carding to improve the uniformity of the sliver and to arrange the fibers in a more nearly parallel order.
- e. Duct Velocity - The average velocity in a duct of an exhaust system.
- f. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.
- g. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- h. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- i. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- j. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- k. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- l. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.



Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- m. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- n. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- o. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- p. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- q. Opening - A series of processes in the preliminary treatment of raw cotton to separate compressed and matted masses of cotton into loose tufts and to remove heavy and bulky impurities. Opening processes include bale breaking, feeding, separating, opening, and conveying.
- r. Picking - A process following opening to further clean and open the cotton fiber and to form a continuous mat (lap) for use on a card.
- s. Roving - A process following drawing or combing to further attenuate the fibers (drafting), to improve the uniformity of the sliver, and to insert some twist.
- t. Shaped Hood - An exhaust hood shaped to conform to the source of air contaminants.
- u. Sliver - A thin, light, elongated assemblage of cotton fibers resembling an untwisted rope.
- v. Spinning - The final process in cotton yarn manufacturing, following roving, in which the stock is drafted to the required yarn size, twisted, and wound into a package suitable for the next process.
- w. Yarn - A twisted strand of fibers suitable for weaving, knitting, or thread-making.

3. Application

These guidelines shall apply to all cotton yarn manufacturing operations except roving and spinning which generate cotton dust into the breathing zones of employees in excess of the exposure limits specified in 29 CFR 1910.1000. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while cotton dust-generating operations are in progress and at all other times when the potential for employee exposure to excessive dust concentrations exists.

These guidelines define minimum ventilation requirements for cotton dust control. The exhaust hood designs illustrated or described in these guidelines are representative of common usage when applied to cotton yarn manufacturing operations. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain cotton dust concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse conditions or circumstances, different or more stringent control measures shall be provided as necessary to maintain dust concentrations at or below exposure limits.

4. Ventilation Requirements

4.1 General

An exhaust hood used for the control of cotton dust shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that the cotton dust is projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

The minimum exhaust volume from a cotton textile manufacturing operation, where practical, shall be sufficient for dilution of cotton dust concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the dust under all operating conditions. Where a fan is located in ductwork and the concentration of the cotton dust is greater than 25 percent of its lower explosive limit, the fan rotating element shall be of nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

4.2 Opening and Picking Operations

Equipment used in opening and picking operations, including hoppers, feeders, pickers, openers, rake distributors, and conveyors, shall be ventilated by means of open hoods, shaped hoods, or enclosing hoods, and by direct connection of fan exhausts to ventilation systems. Acceptable designs of exhaust hoods for opening and picking equipment are shown in Figures 2 through 9.

Typical exhaust airflow rates for opening and picking equipment are listed below:

$Q = 50-75 \text{ cfm/sq ft of open area}$
 $\text{Duct velocity} = 2500-3000 \text{ fpm}$
 $\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

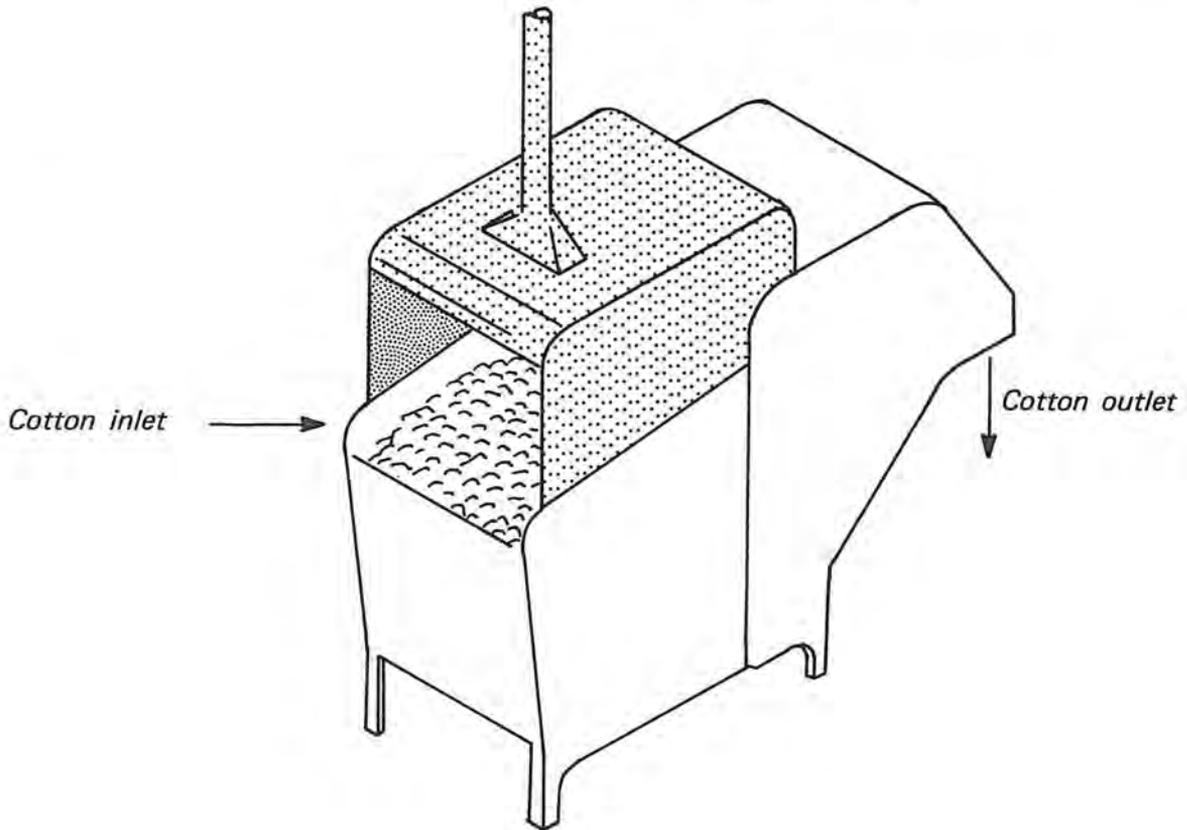


FIGURE 2 ENCLOSING HOOD FOR FEEDER

$Q = 50-75 \text{ cfm/sq ft of open area}$
 $\text{Duct velocity} = 2500-3000 \text{ fpm}$
 $\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

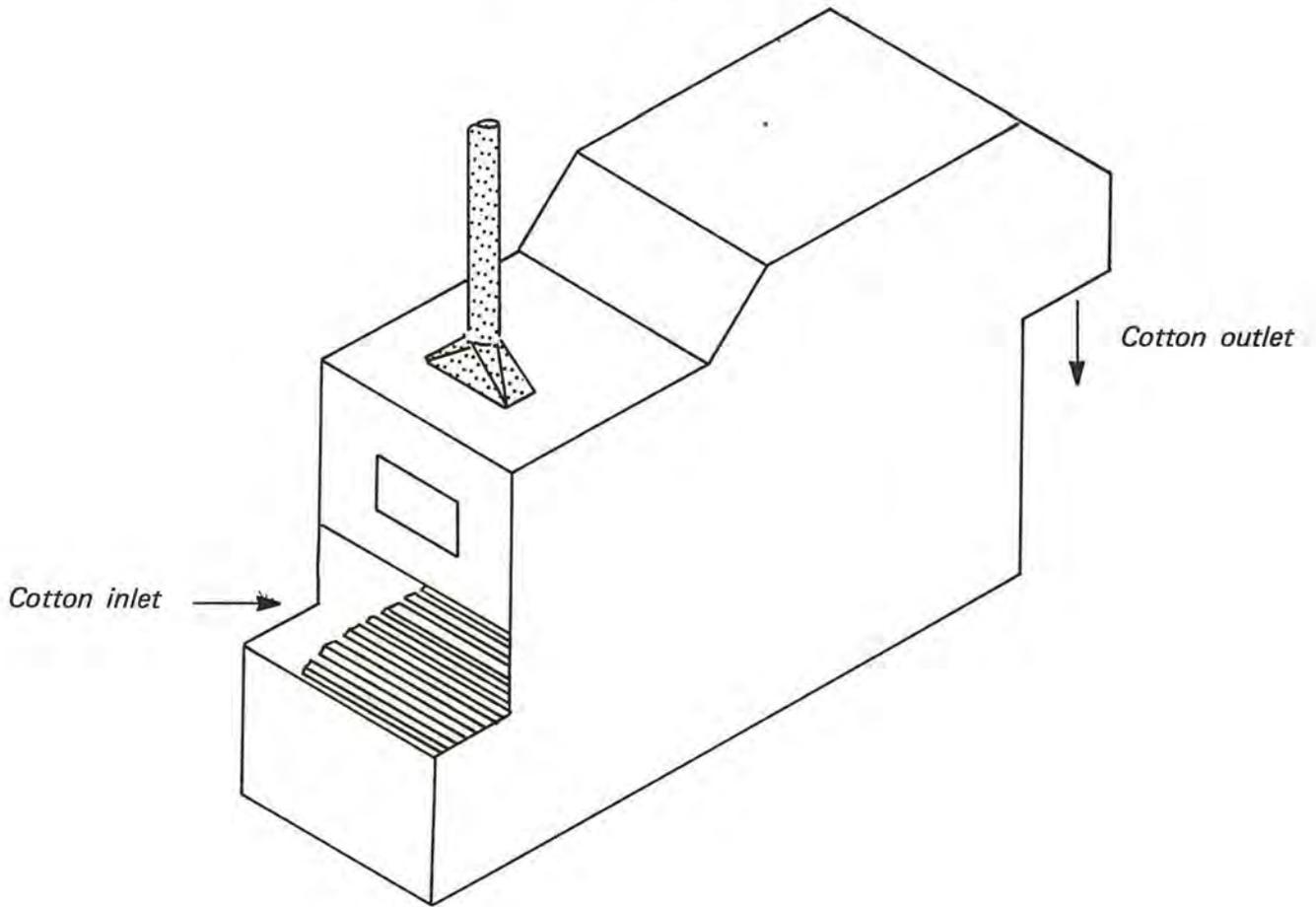


FIGURE 3 ENCLOSING HOOD FOR CLEANING AND BLENDING FEEDER

$Q = 50-75 \text{ cfm/sq ft of open area}$
 $\text{Duct velocity} = 2500-3000 \text{ fpm}$
 $\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

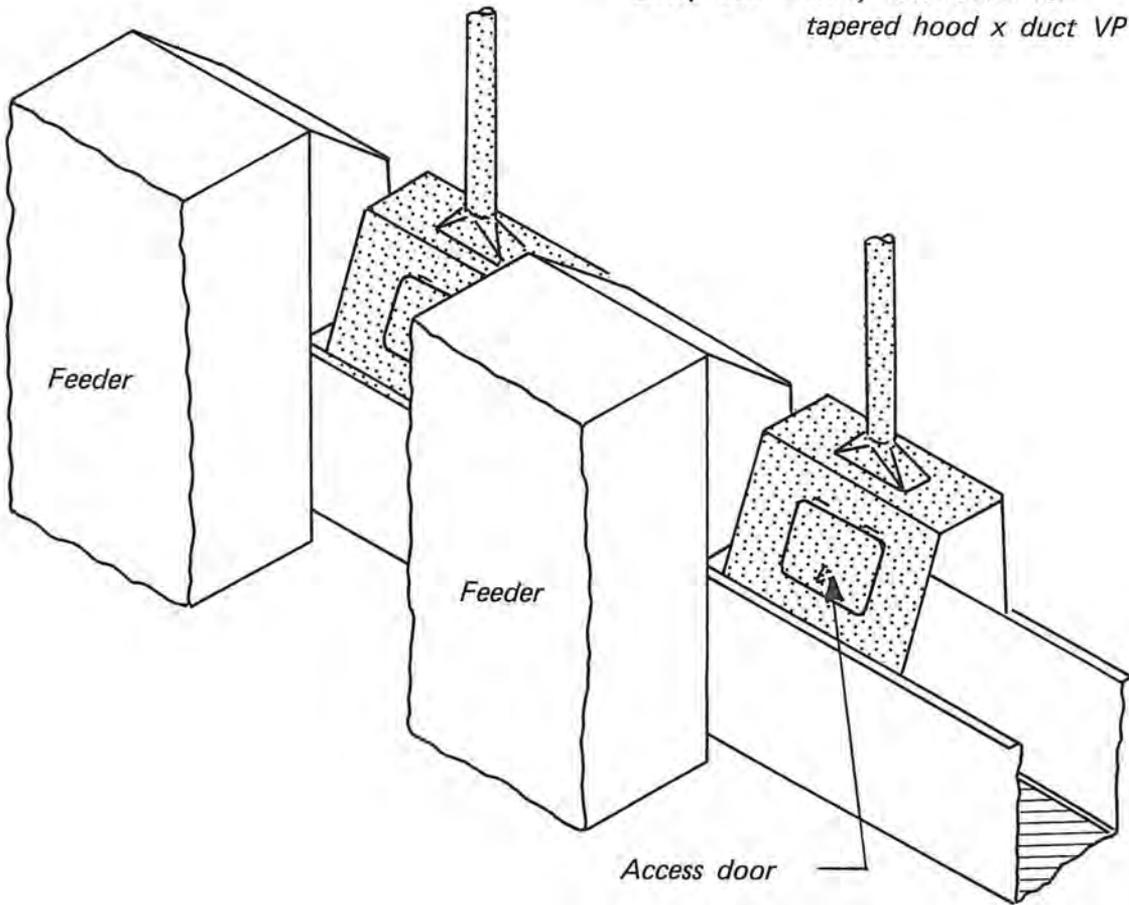


FIGURE 4 FEED TABLE HOODS

$Q = 50-75 \text{ cfm/sq ft of open area}$
 $\text{Duct velocity} = 2500-3000 \text{ fpm}$
 $\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

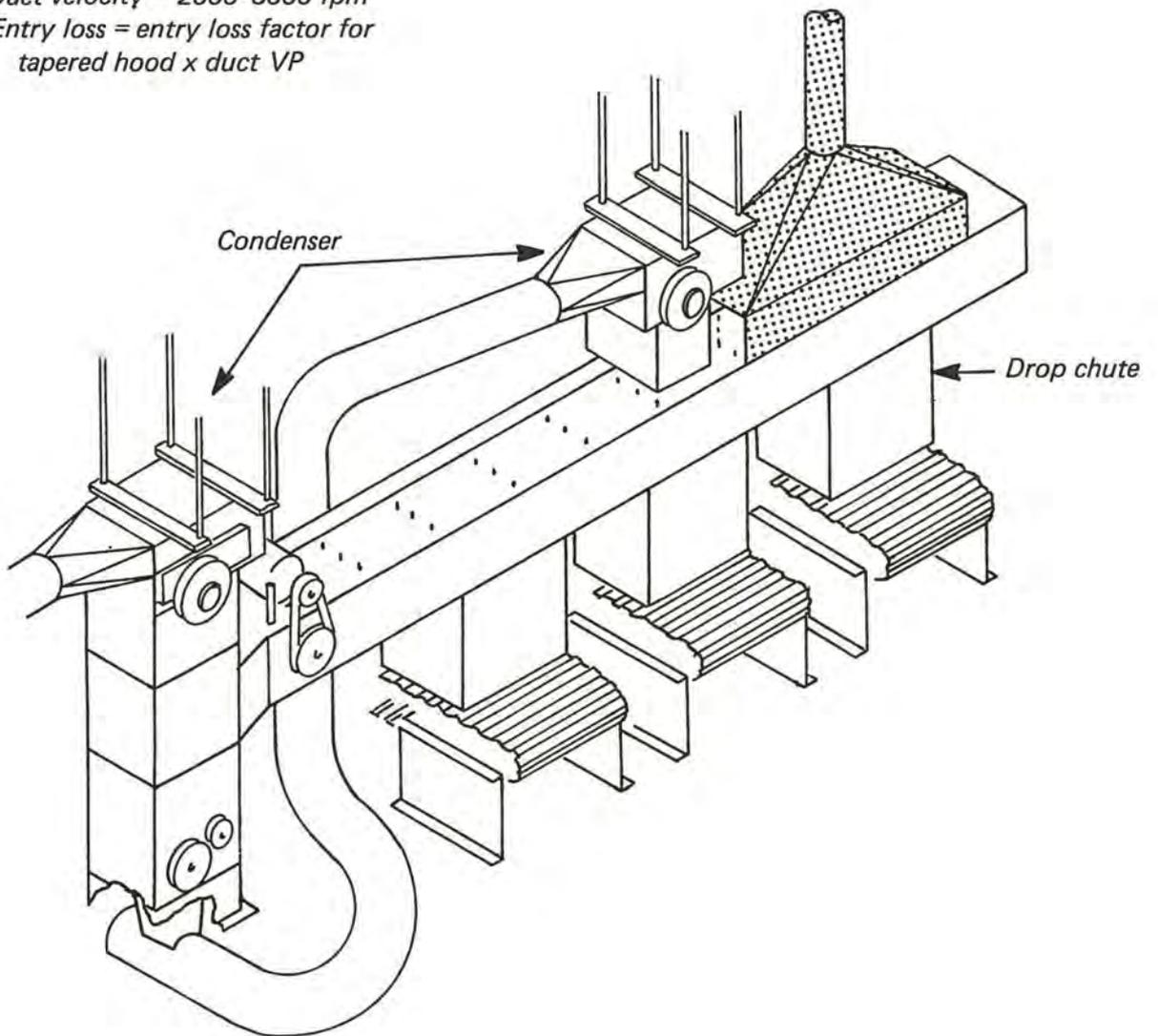


FIGURE 5 ENCLOSING HOOD FOR RAKE DISTRIBUTOR

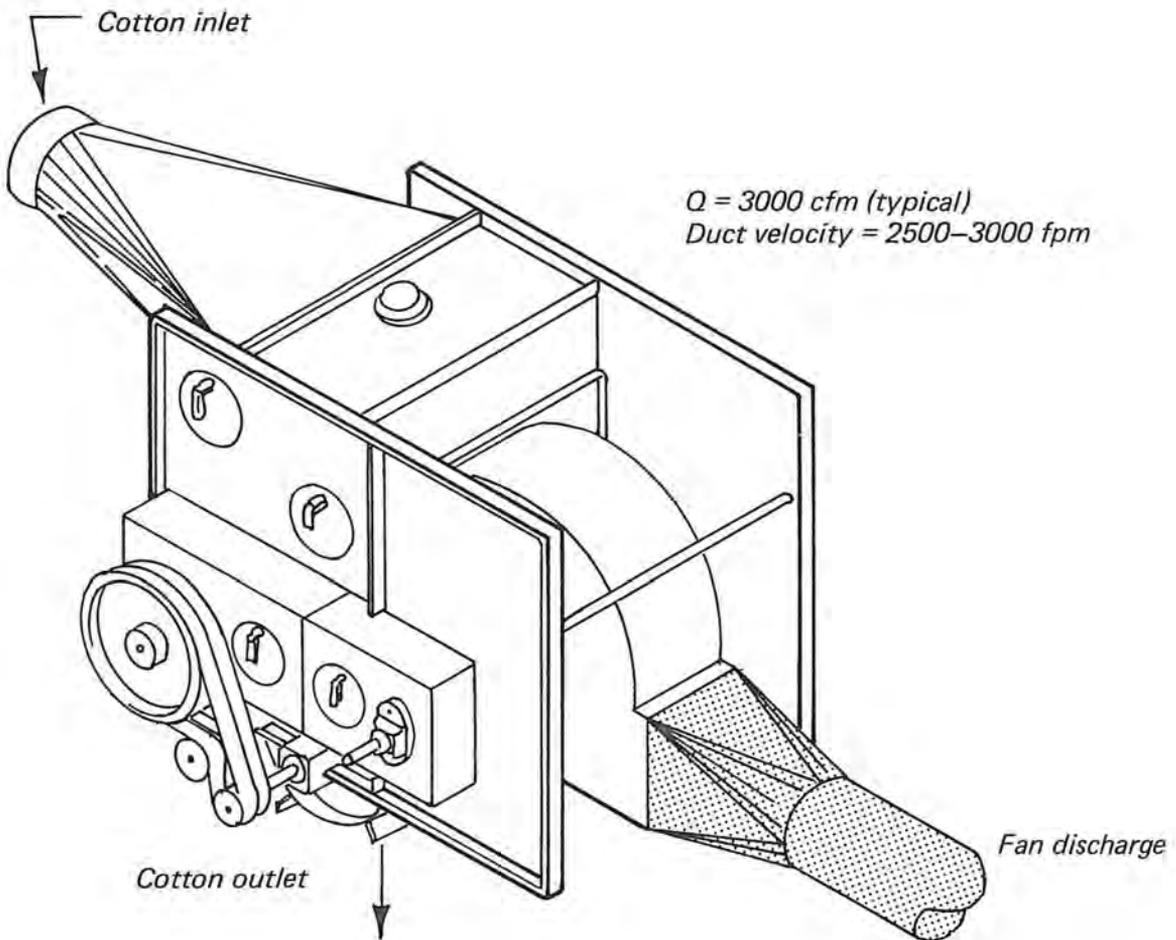


FIGURE 6 DUST AND WASTE EXTRACTOR (CONDENSER)
DIRECT CONNECTED TO VENTILATION SYSTEM

$Q = 3000 \text{ cfm (typical)}$
Duct velocity = 2500-3000 fpm

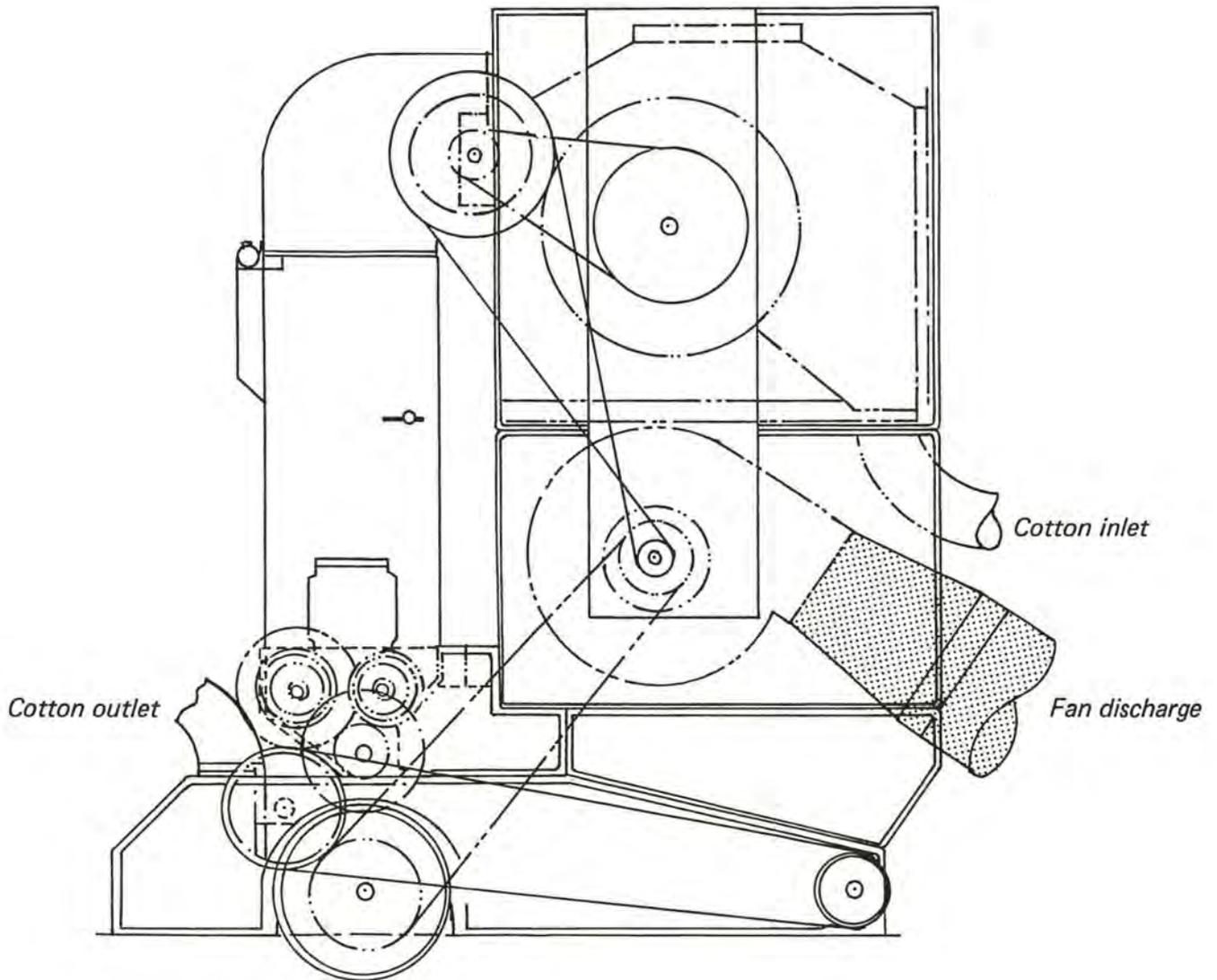


FIGURE 7 LATTICE OPENER WITH DUST AND WASTE EXTRACTOR (CONDENSER) DIRECT CONNECTED TO VENTILATION SYSTEM

$Q = 1500 \text{ cfm/ aspirator (typical)}$
 $\text{Duct velocity} = 2500\text{--}3000 \text{ fpm}$

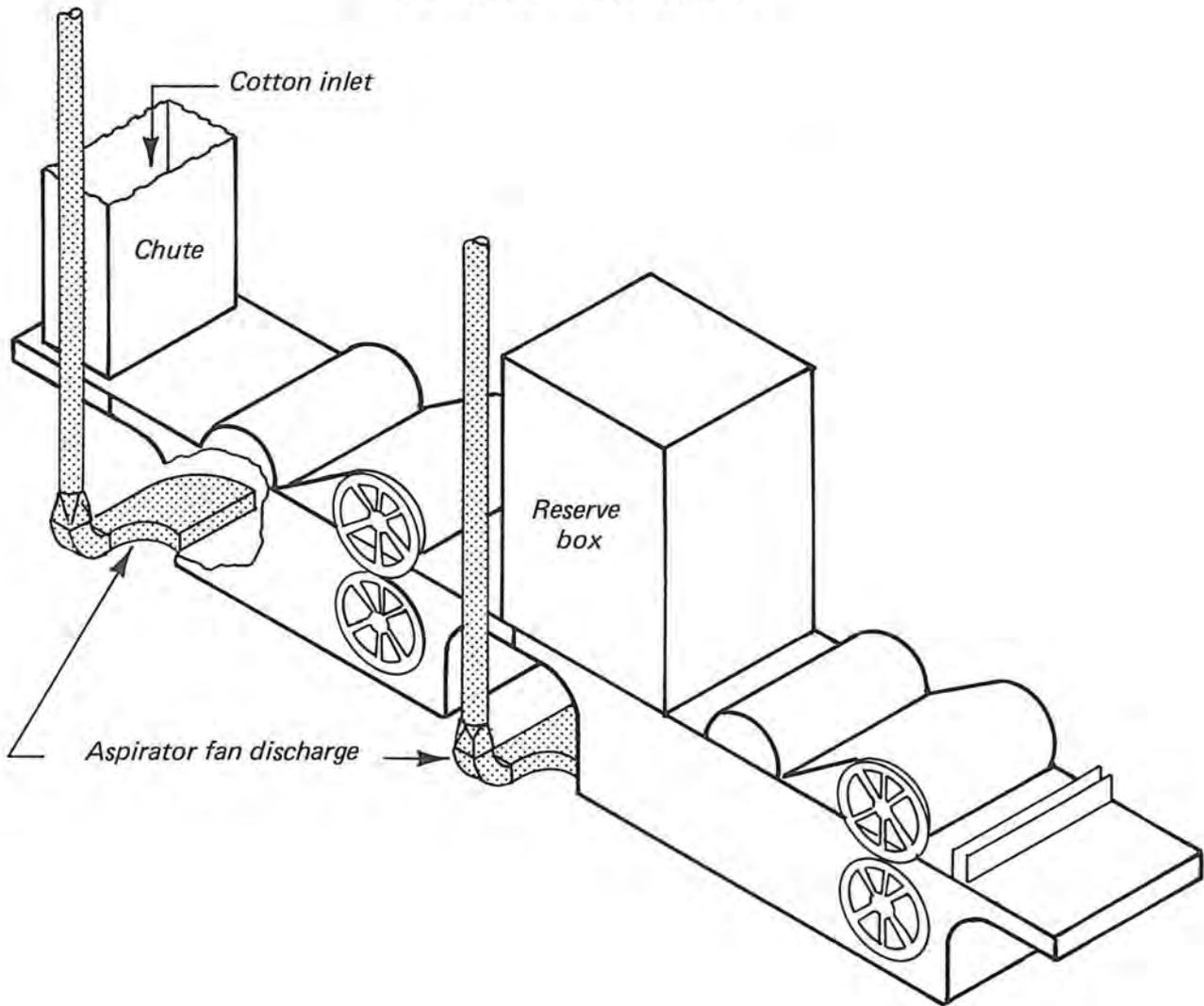


FIGURE 8 OPEN HOODS FOR TWO-BEATER PICKER

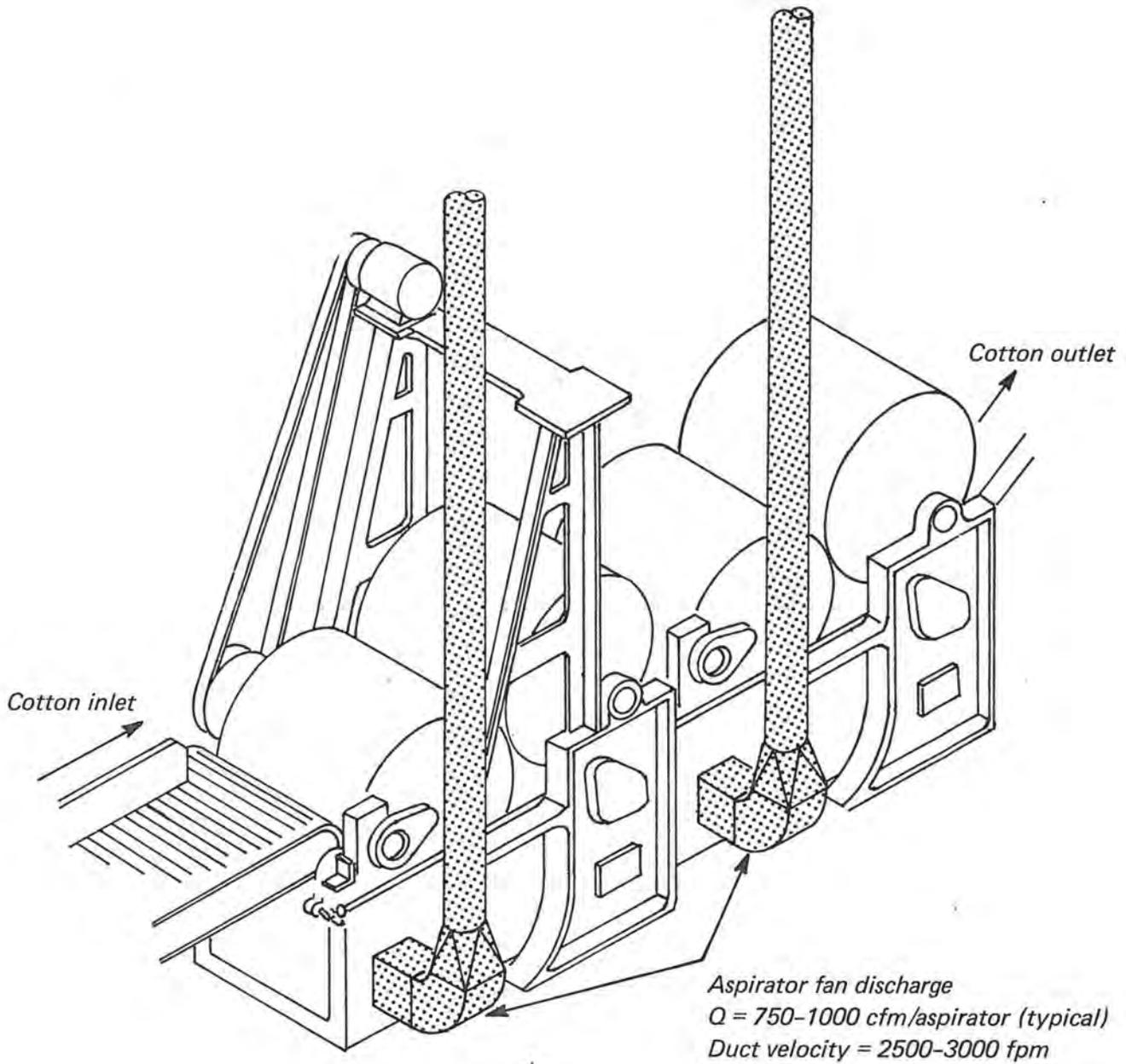


FIGURE 9 WASTE OPENER ASPIRATOR FANS
 DIRECT CONNECTED TO VENTILATION
 SYSTEM

EQUIPMENT TYPE	CFM EACH
Feeder Hopper Hoods	500
Feed Table Hoods	500
Condenser Fans	3,000
Reserve-Hopper Hoods	500+
Picker-Beater Fans	1,500
Waste Hopper Hoods	500
Waste Grinder Aspirator Fans	750-1,000
Fiber Transport (depending on size and system arrangement)	3,000-15,000

These flow rates are provided only for guidance in the planning of ventilation systems. Actual flow rate requirements will vary with size and type of equipment.

4.3 Carding Operations

Carding equipment shall be ventilated by means of enclosing or shaped exhaust hoods with supplementary open exhaust hoods used to control cotton dust at isolated sources such as coiler trumpets. Acceptable designs of exhaust hoods for carding equipment are shown in Figures 10 through 12. Typical exhaust flow rates required with exhaust hoods for carding machines producing less than 40 lb/hr are as follows:

HOOD LOCATION	EXHAUST FLOW RATE (CFM)
Doffer Cylinder	370
Lickerin Cylinder	400
Coiler Trumpet	30/coiler

These typical flow rates are provided only for guidance in planning of ventilation systems. Actual flow rate requirements will vary with type and size of equipment.

The carding machine exhaust ventilation system may also include a provision for undercard cleaning. A design of an undercard cleaning system is shown in Figure 13. The exhaust flow rate requirement for the system shown is 400 cfm.

4.4 Drawing Operations

Drawing equipment shall be exhaust ventilated by means of open hoods. Exhaust hoods shall be used to capture effluent flows from draw frame dust collectors, and to control dust generated by draw frame creels.

Acceptable designs of exhaust hoods for capturing dust collector effluent flows are shown in Figures 14, 15, and 16. Exhaust flow rate requirements for this application will vary between 900 and 1600 cfm depending upon equipment type.

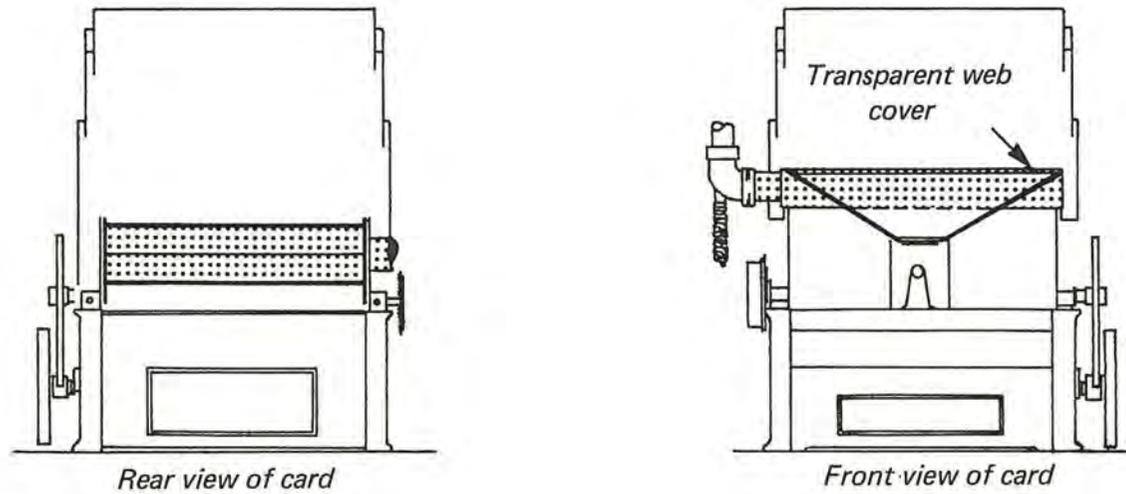
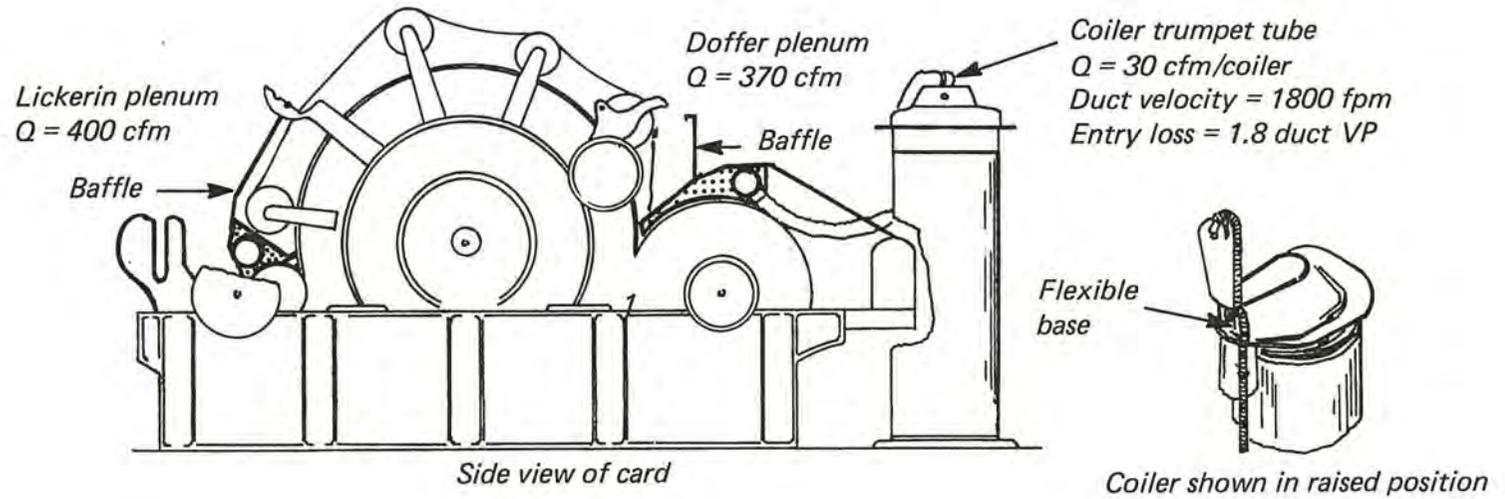


FIGURE 10 EXHAUST HOOD LOCATIONS ON A CARDING MACHINE

$Q = 370 \text{ cfm}$
Slot velocity = 700 fpm
Duct velocity = 4000 fpm
Entry loss = 1.78 slot VP + 0.5 duct VP

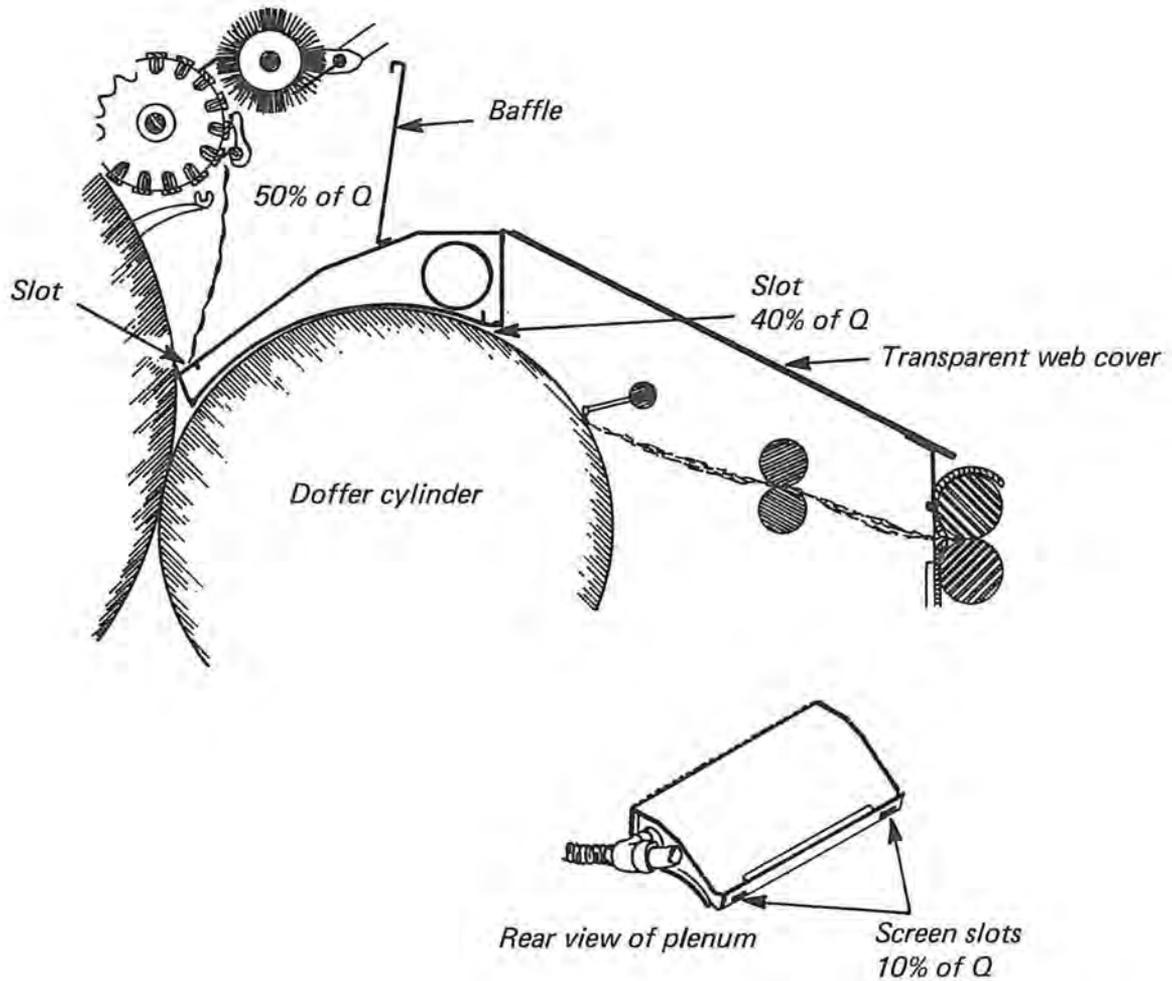


FIGURE 11 SHAPED HOOD AT DOFFER CYLINDER

$Q = 400 \text{ cfm}$
Slot velocity = 1400 fpm
Duct velocity = 4000 fpm
Entry loss = 1.78 slot VP + 0.5
duct VP

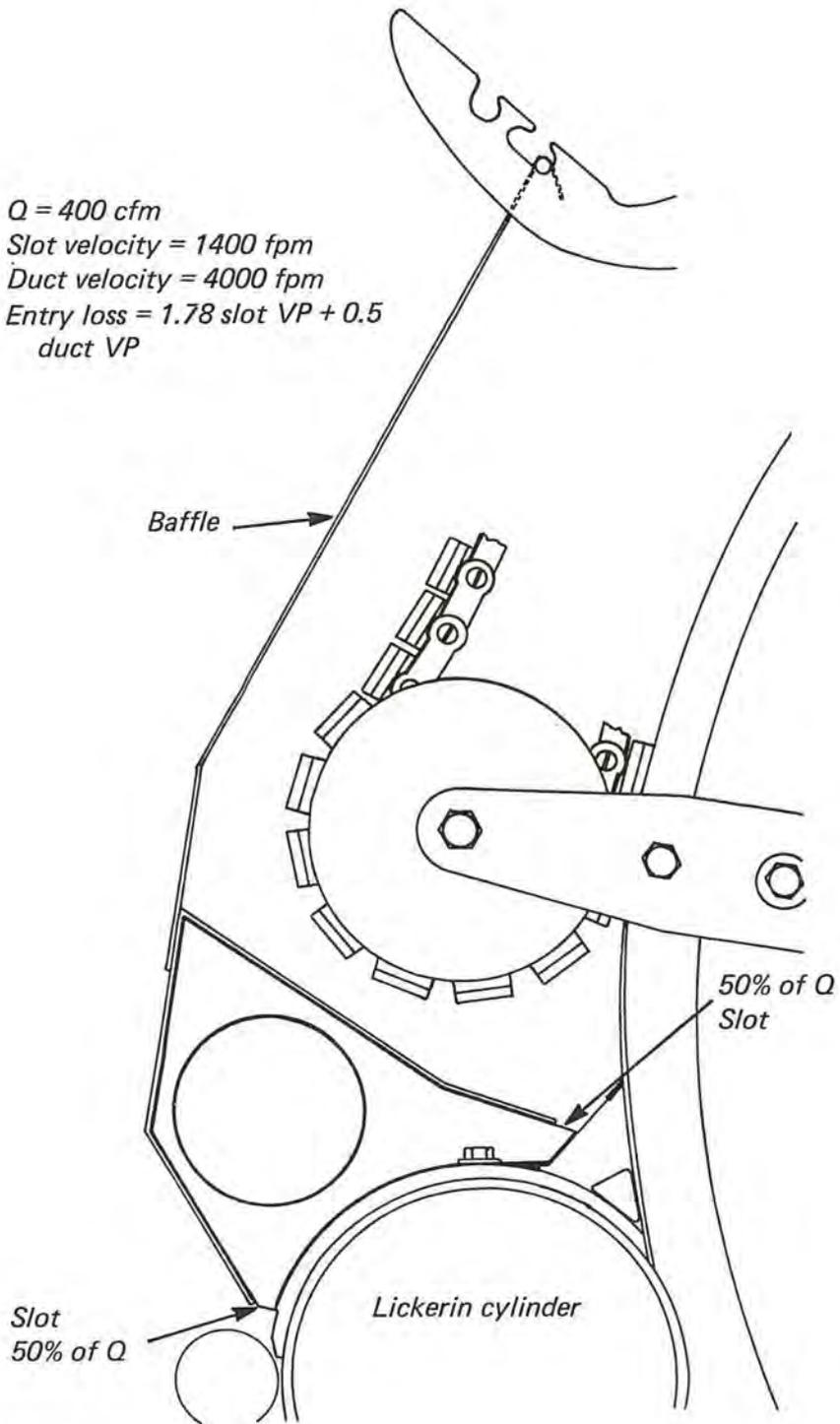


FIGURE 12 SHAPED HOOD AT LICKERIN CYLINDER

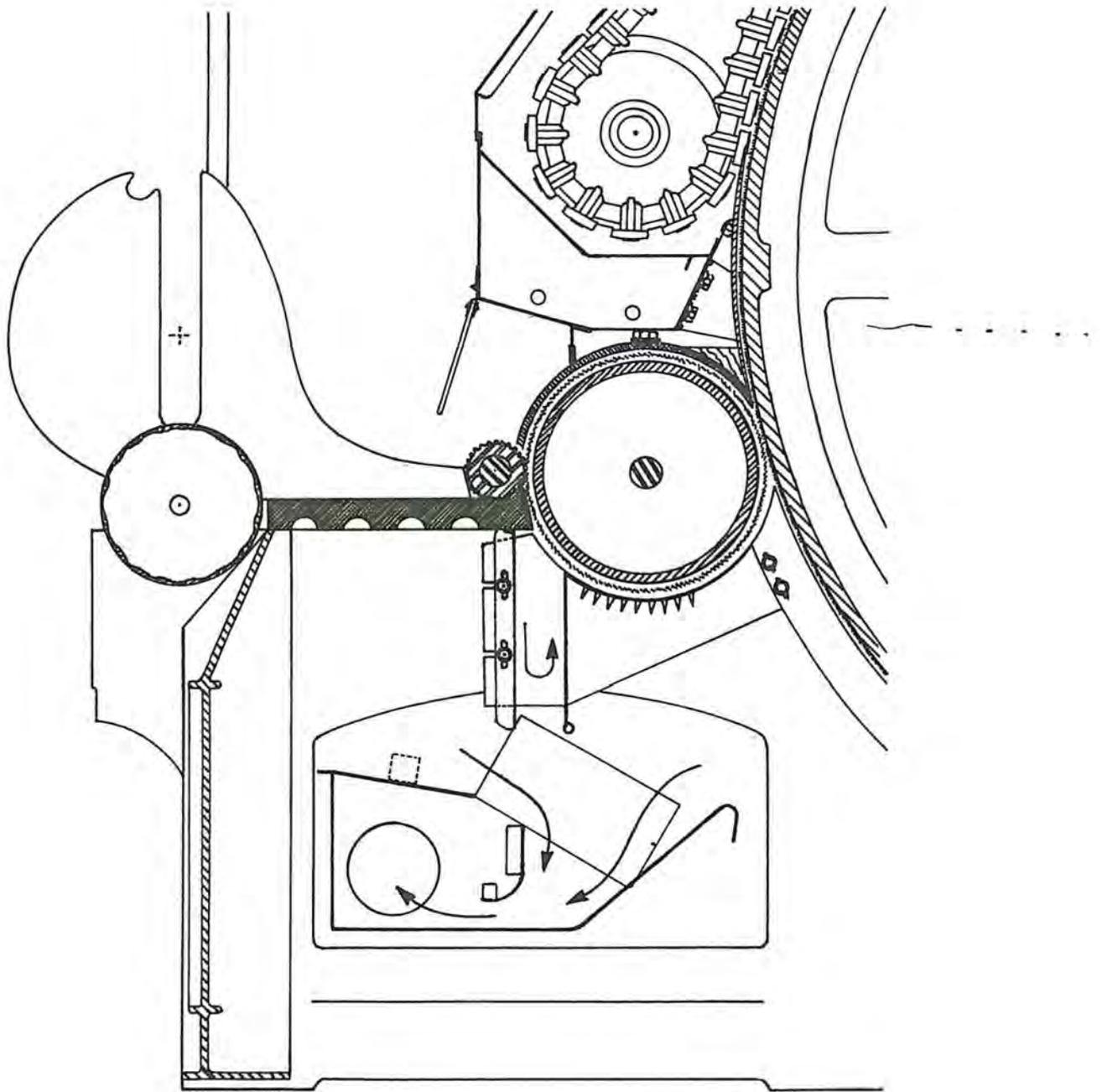


FIGURE 13 UNDERCARD CLEANING SYSTEM

$Q = 975-1635 \text{ cfm}$
Entry loss = entry loss factor for tapered hood x duct VP
Duct velocity = 2500-3000 fpm

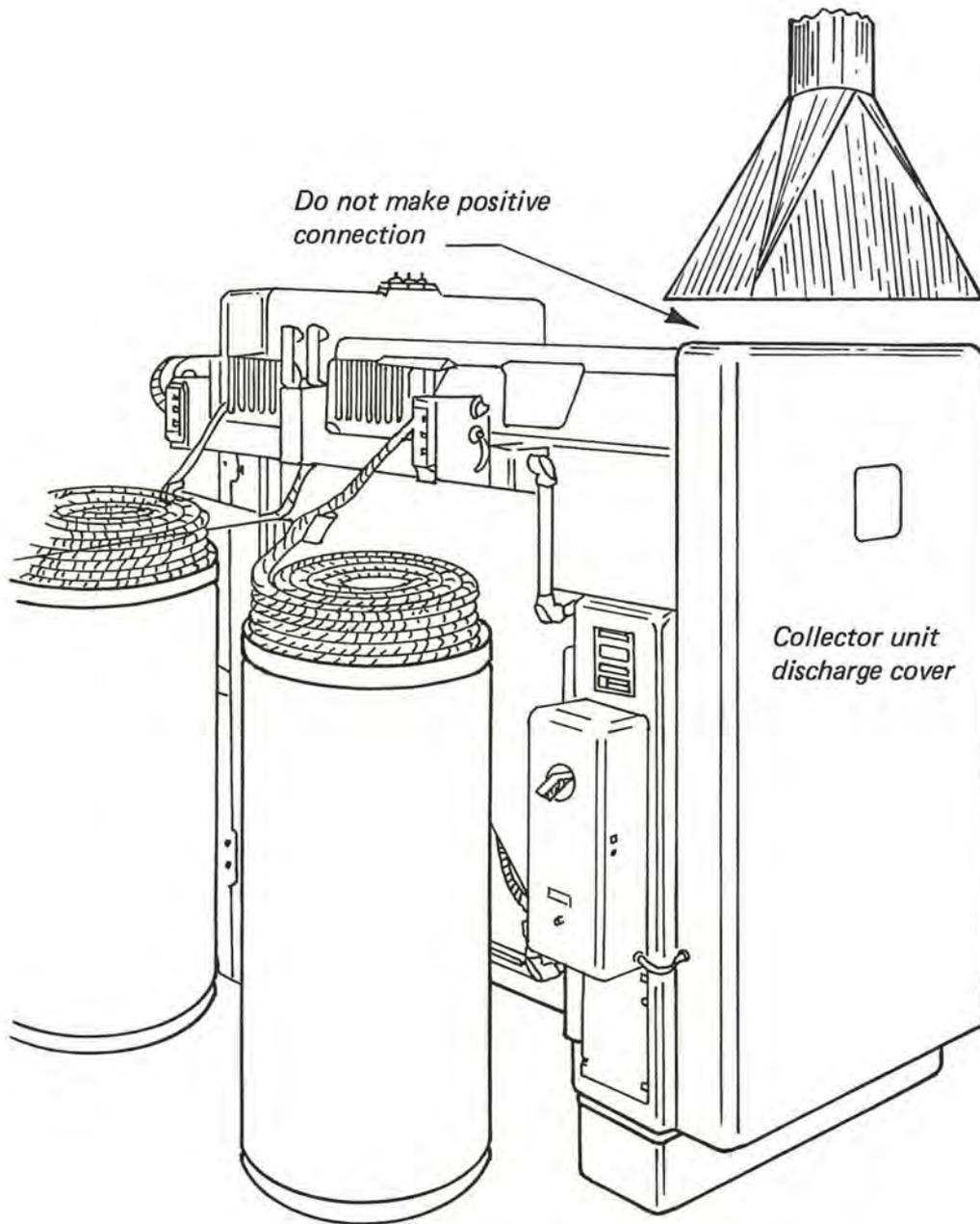


FIGURE 14 DUST COLLECTOR EFFLUENT HOOD FOR DRAW FRAME WITH TOP DISCHARGE

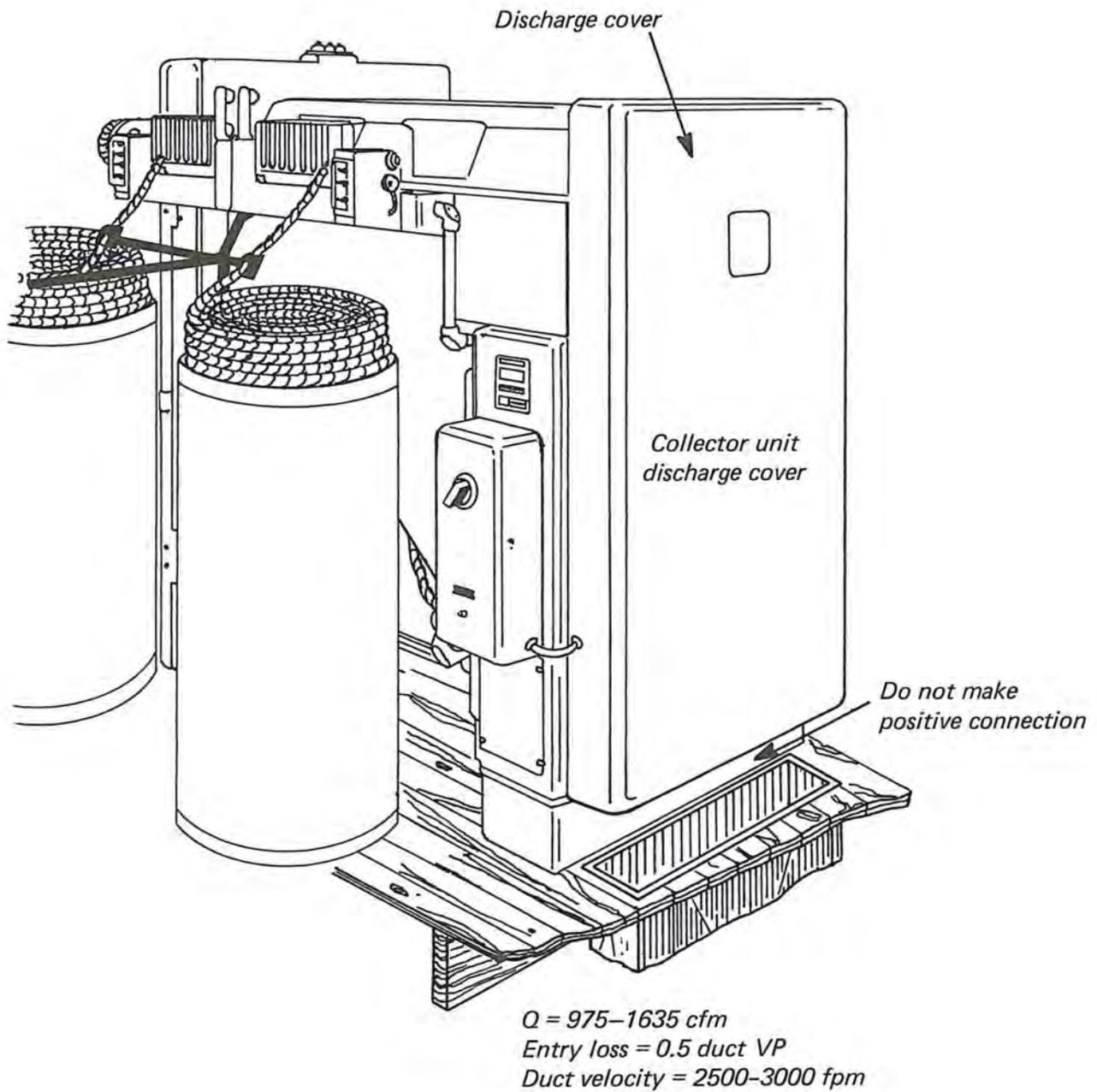


FIGURE 15 DUST COLLECTOR EFFLUENT HOOD FOR DRAW FRAME WITH BOTTOM DISCHARGE

Collector unit discharge
 $Q = 900 \text{ cfm (typical)}$

Creel hood
 $Q = 75\text{--}150 \text{ cfm/sq ft of open area}$

Entry loss = entry loss factor for tapered hood x duct VP
Duct velocity = 2500–3000 fpm

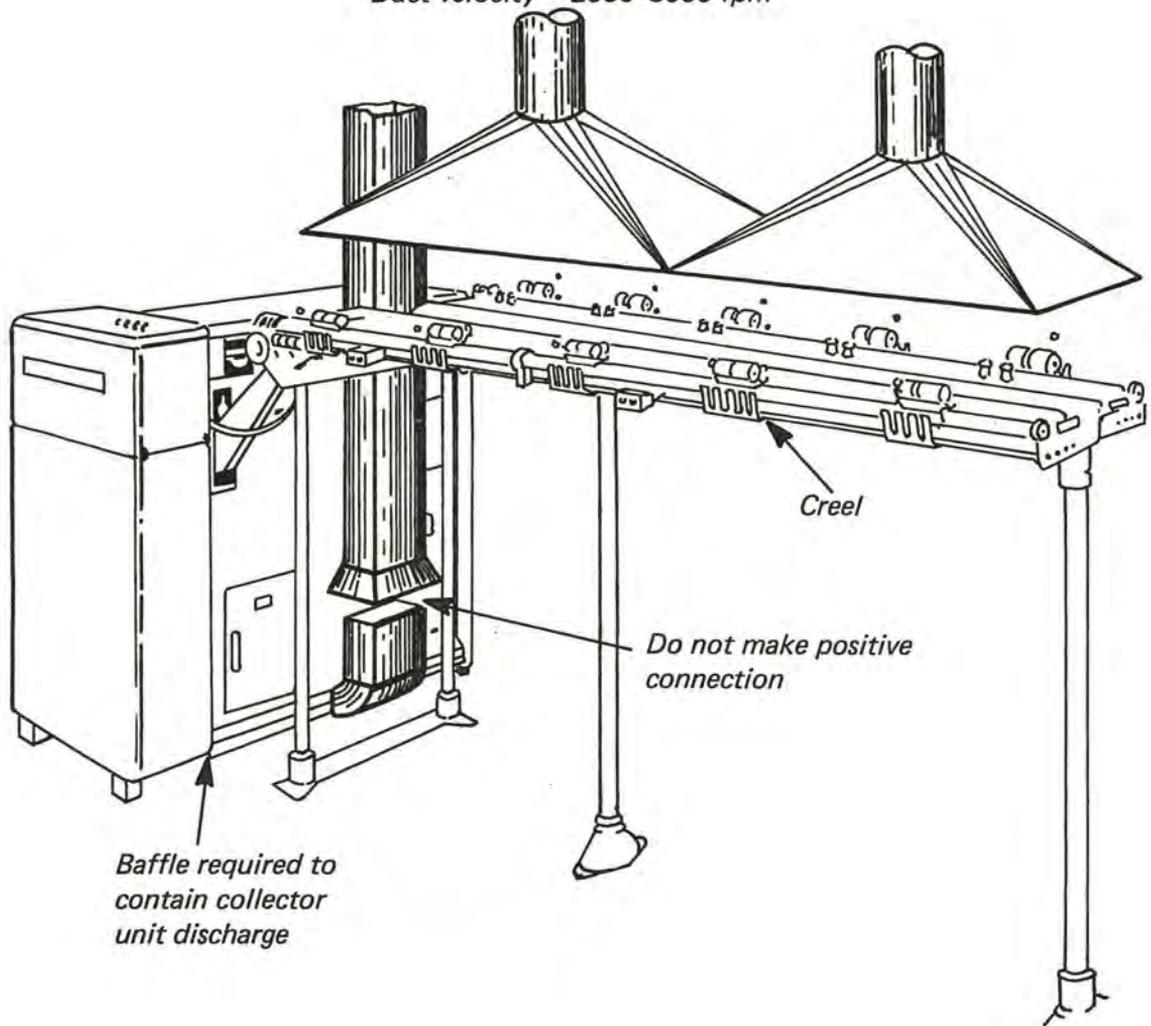


FIGURE 16 DUST COLLECTOR EFFLUENT HOOD AND CREEL HOOD FOR DRAW FRAME

An acceptable design of an exhaust hood for control of dust generated by a draw frame creel is shown in Figure 16. The exhaust flow rate requirement for this application will vary between 75 and 150 cfm per sq ft of open area depending upon equipment type and hood location.

4.5 Combing Operations

Combing equipment shall be exhaust ventilated by means of open exhaust hoods and by direct connection of aspirator fan exhausts to ventilation systems. Placement of exhaust hoods of acceptable design on a typical comber is indicated in Figure 17, and the designs and exhaust flow rate requirements of these hoods are shown in Figures 18 and 19. These designs and flow rate requirements are presented for purposes of planning ventilation systems. Actual design and flow rate requirements will vary with equipment design.

4.6 Dust and Lint Separators

Sections 4.1 through 4.4 describe the exhaust hoods required to capture and remove the cotton dust generated by the various operations into the work area. If the exhaust air is to be discharged to the outside air, a suitable dust and lint separation system shall be required to meet ambient air standards. If the air is to be returned to the workplace, dust and lint separators of suitable design and efficiency shall be required to maintain cotton dust concentrations at or below the exposure limit. Requirements for such dust and lint separation systems shall be established in conjunction with the exhaust hood capture efficiencies and the overall system configuration.

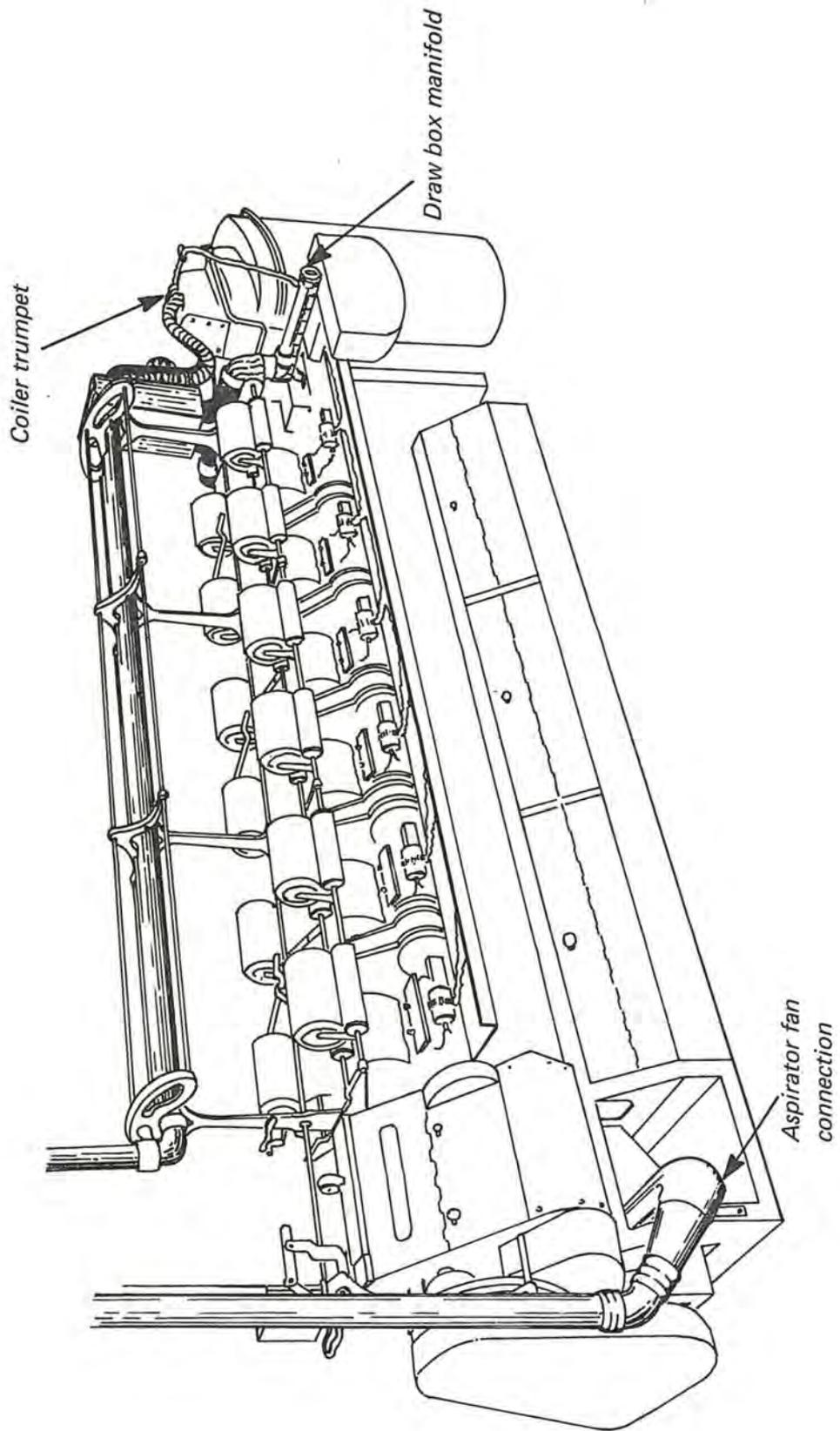


FIGURE 17 TYPICAL LOCATIONS OF EXHAUST HOODS FOR COMBING EQUIPMENT

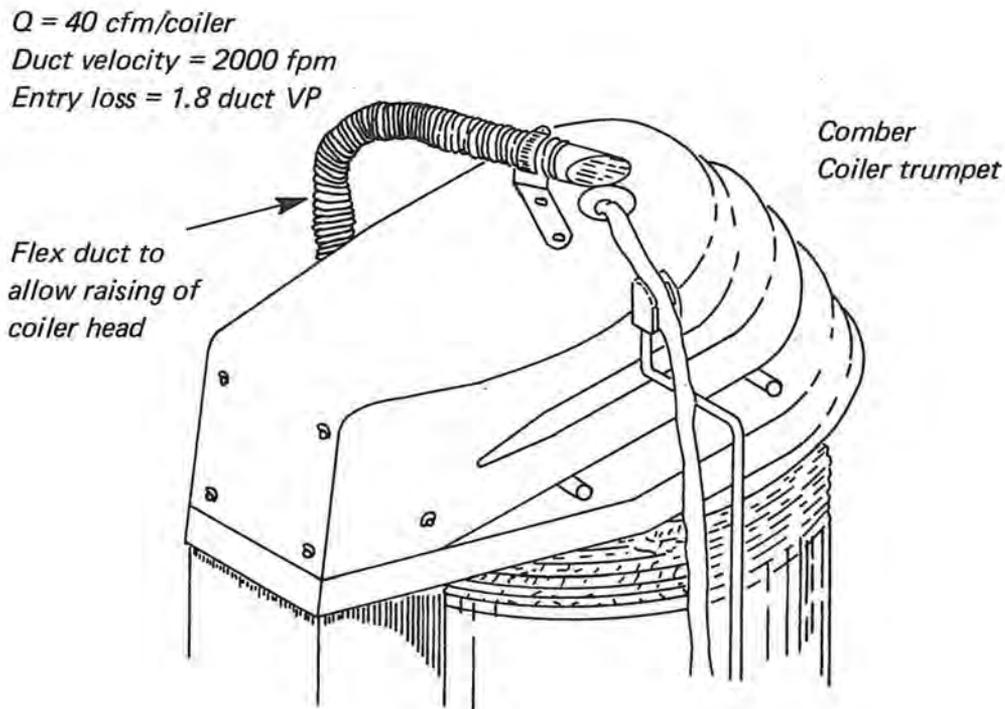
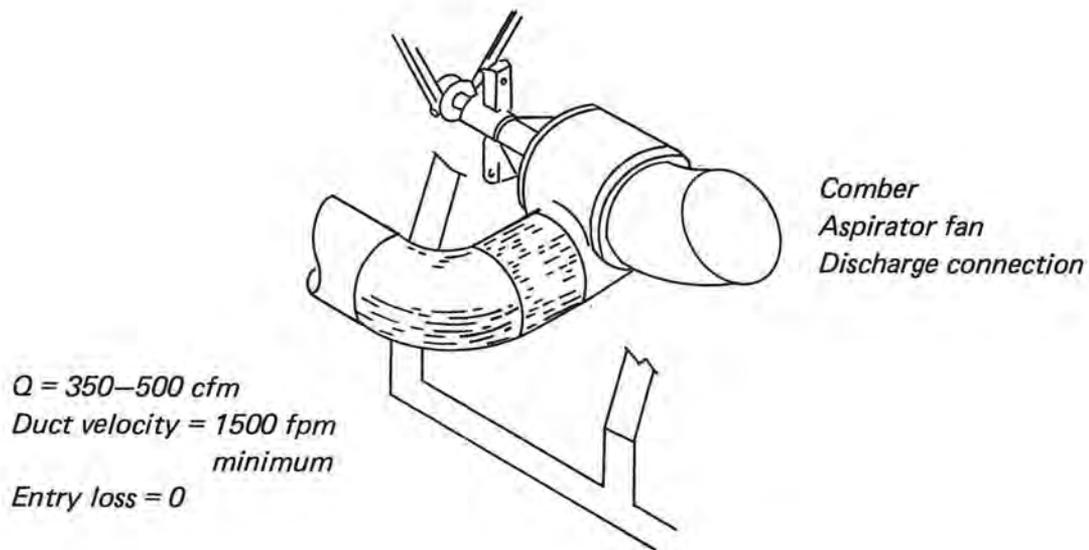


FIGURE 18 EXHAUST HOODS FOR COMBING EQUIPMENT

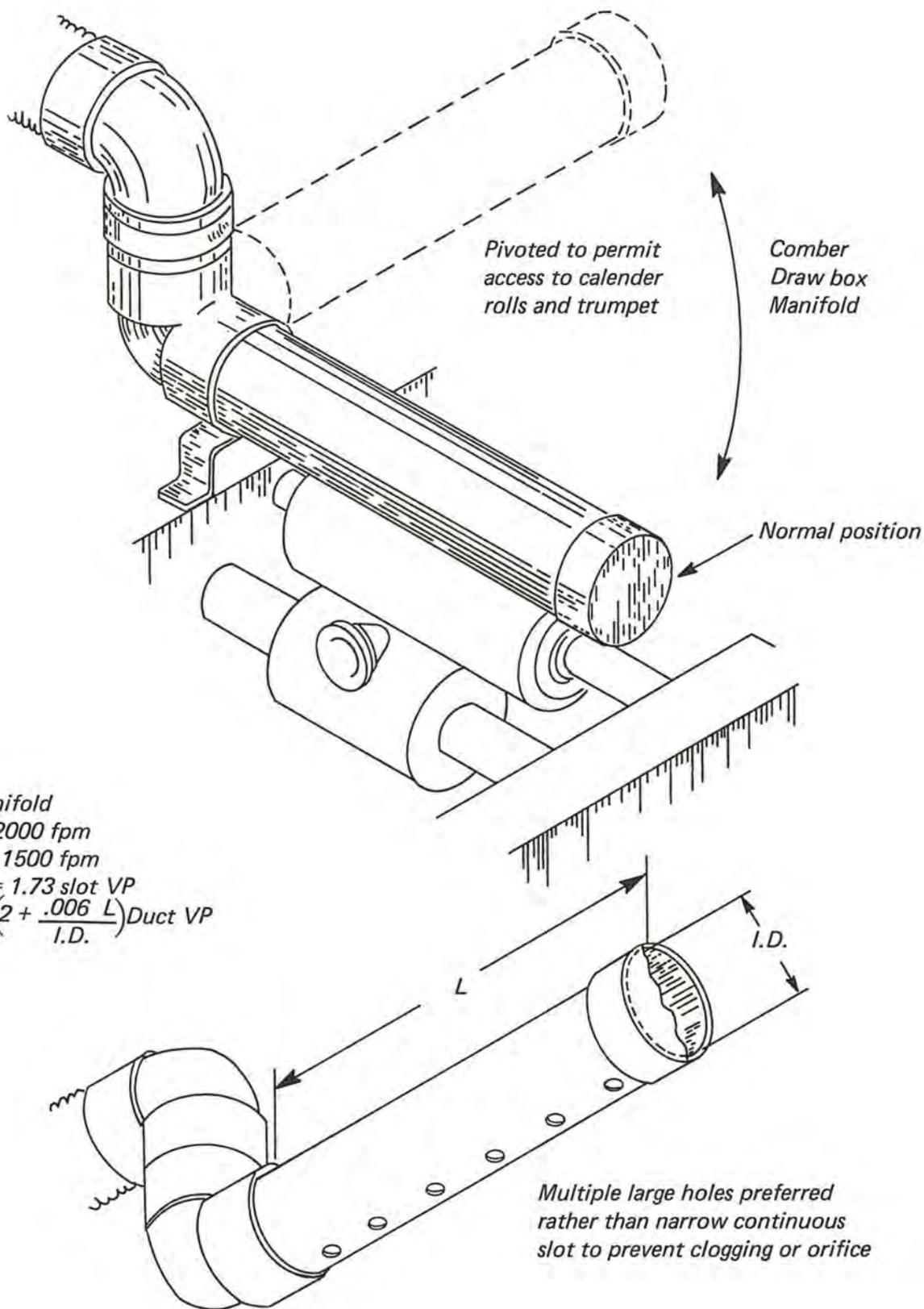


FIGURE 19 EXHAUST HOOD FOR COMBING EQUIPMENT

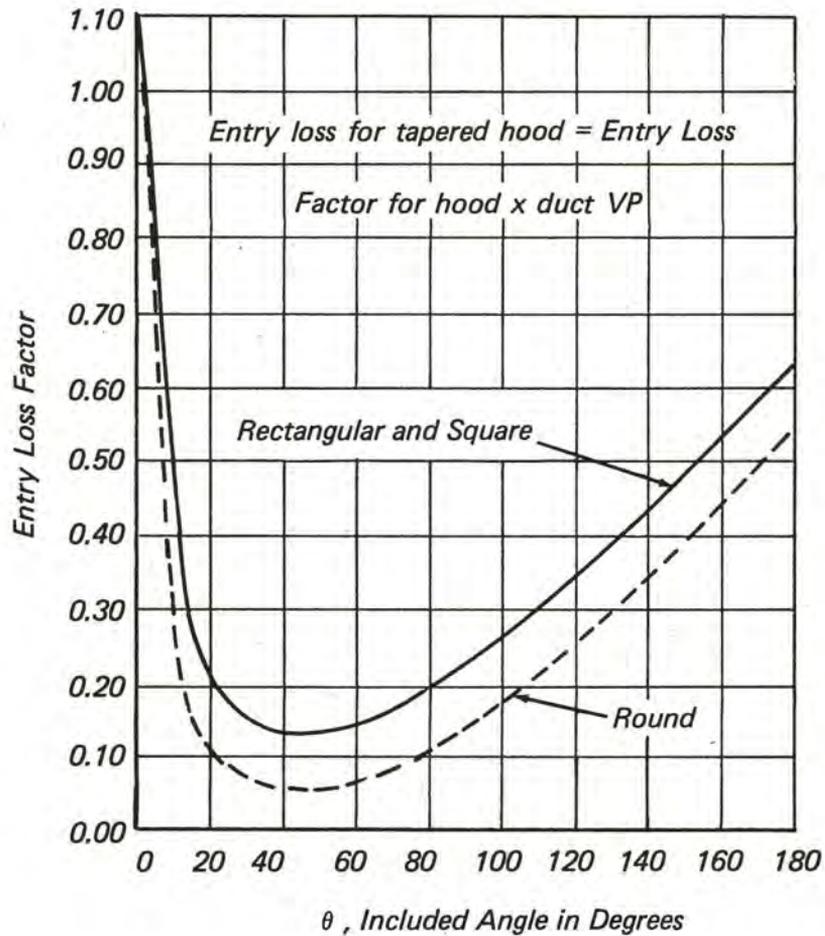
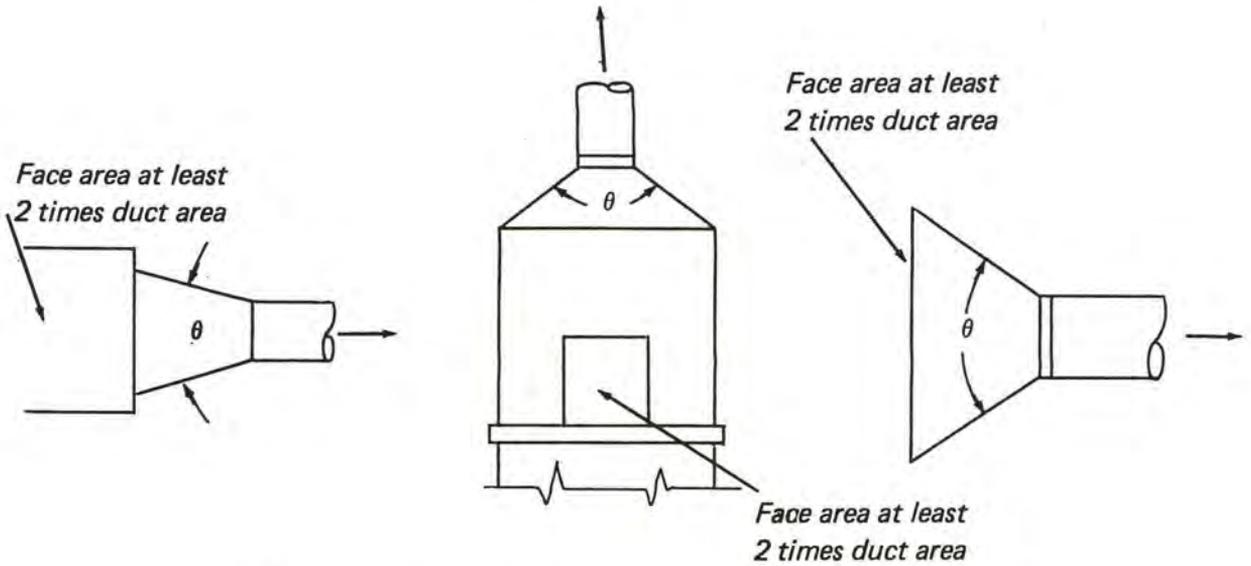
RECOMMENDED VENTILATION GUIDELINES FOR FOUNDRY OPERATIONS

1. Scope

These guidelines prescribe the use of exhaust hoods for the control and removal of air contaminants generated by foundry operations. Foundry operations covered by the guidelines include mulling and mixing; core making, core molding, core grinding, metal melting, molten metal transfer, metal pouring, die casting, hot mold transfer, and mold shakeout and tumbling.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.
- f. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- g. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- h. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- i. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- j. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- k. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- l. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- m. Fumes - Small solid particles formed by the condensation of vapors of solid materials.



Tapered Hoods

*Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.*

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- n. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- o. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- p. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- q. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- r. Make-up Air - Air supplied to a building or space to replace air exhausted.
- s. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- t. Natural Ventilation - Air movement through a space produced by either or both of two natural forces; wind forces and stack effects.
- u. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity, usually expressed in inches of water gauge.
- v. Transport Velocity - The minimum air velocity in a duct of an exhaust system necessary to assure that all particulates captured by the system will be conveyed through the duct.
- w. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all foundry operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall operate continuously while the contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which

provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Foundry Operations and Equipment

4.1 General

A hood used for the control of contaminants from foundry operations shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that the contaminants are projected into the hood in the direction of the exhaust airflow.

When the material being handled in a foundry operation is flammable or combustible when dispersed in air in a finely divided state, and the operation is exhaust ventilated, the minimum exhaust volume, where practical, shall be sufficient for dilution of air contaminant concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being handled, the fan rotating element shall be of nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

4.2 Mulling and Mixing Equipment

4.2.1 General

Equipment for the conditioning, mixing, or blending of sand with other materials in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.2.2 Non-Cooling Mullers

Non-cooling mullers which generate air contaminant concentrations in excess of exposure limits shall be provided an enclosing hood with a minimum exhaust volume of 150 cfm/sq ft through all openings but not less than the total volumes given in Figure 2 for various mixer diameters. Figure 2 illustrates an acceptable hood design for such a muller. Duct velocity shall be a minimum of 3500 fpm.

4.2.3 Cooling Mullers

Cooling mullers shall not require exhaust if maintained in a dust-tight condition sufficient to preclude generation of air contaminant concentrations in excess of exposure limits. Blow-through fans may not be operated during loading operations with such equipment. If the muller enclosure is not sufficiently dust-tight, an exhaust hood shall be provided which maintains a minimum 150 fpm air velocity through all openings into the muller hood in addition to the cooling air volume. Figure 2 illustrates acceptable hood designs for such equipment. Duct velocity shall be a minimum of 4500 fpm.

4.2.4 Batch Hoppers

Batch hoppers on mullers with blow-through cooling shall be provided with a separate exhaust hood having a minimum exhaust volume of 600 cfm, where use of the hopper results in the generation of air contaminant concentrations in excess of exposure limits. Separate exhaust shall not be required with other fan arrangement (i.e. muller under suction). Figure 2 illustrates an acceptable exhaust hood design for such hoppers.

4.2.5 Bond Hoppers

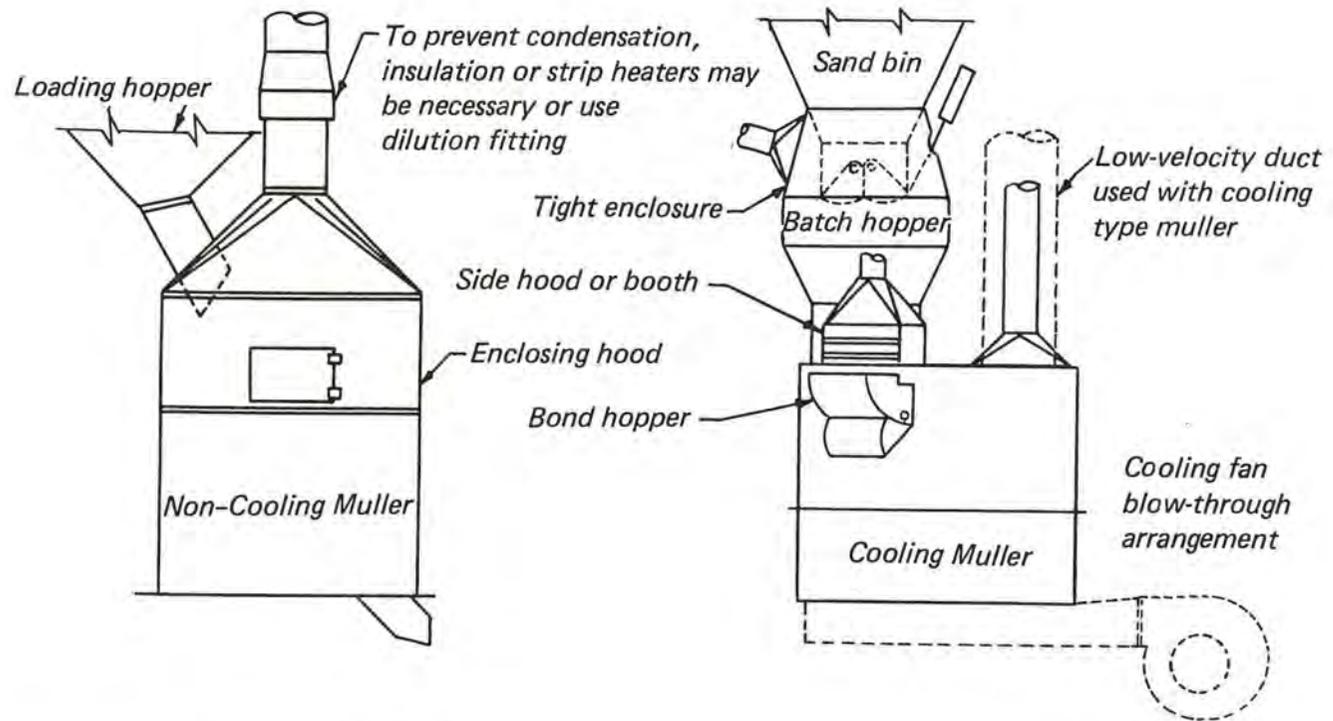
Where use of a bond hopper results in the generation of air contaminant concentrations in excess of exposure limits, the hopper shall be provided a side hood or booth with a minimum exhaust volume of 600 cfm. Figure 2 illustrates an acceptable hood design and location for such hoppers.

4.2.6 Other Mixing Equipment

Other types of mixers which generate air contaminant concentrations in excess of exposure limits and which are used for the conditioning, mixing, or blending of sand with other materials shall be enclosed to the degree the operation permits and shall be provided a minimum exhaust volume of 150 cfm/sq ft of remaining openings.

4.2.7 Skip Hoists

Where use of a skip hoist for loading mullers or other mixers in foundry operations results in the generation of air contaminant concentrations in excess of exposure limits, the skip hoist shall be fully



<i>Min. Exhaust Volume for Non-Cooling Mullers</i>	
<i>Mixer Diameter (feet)</i>	<i>Min. Exhaust (cfm)</i>
4	750
6	900
7	1050
8	1200
10	1575

$Q = 150 \text{ cfm/sq ft}$ through all openings, but not less than the table values for non-cooling mullers

Duct velocity for non-cooling muller = 3500 fpm minimum

Duct velocity for cooling muller = 4500 fpm minimum

Entry loss for tapered hood = entry loss factor for tapered hood X duct VP

Entry loss for slotted side draft hood = 1.78 slot VP plus entry loss factor for tapered hood X duct VP

Entry loss for round duct with flange = 0.49 duct VP

FIGURE 2 MIXER AND MULLER VENTILATION

enclosed or a hood shall be installed between the rails and behind the skip of the same length as the skip and with a minimum exhaust volume as given by the formula in Figure 3. Figure 3 also illustrates acceptable hood designs.

4.3 Core Molding, Making and Finishing Equipment

4.3.1 General

Equipment for the making, molding, grinding, or sanding of cores in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.3.2 Shell Core Molding Equipment

Shell core molding equipment which generates air contaminant concentrations in excess of exposure limits and which is of the type illustrated in Figure 4 shall be provided a minimum exhaust volume of 250 cfm/sq ft of the face of the canopy for a single unit and 150 cfm/sq ft of the face of the canopy for a double unit. Figure 4 illustrates an acceptable design for a slotted side-draft hood which shall be provided where necessary to remove smoke as hot cores emerge from the equipment. The minimum air volume exhausted from such a side-draft hood shall be as given by the formula in Figure 4. Duct velocities shall be sufficient to achieve transport velocity.

4.3.3 Core Making Machines - Small Roll Over Type

An exhaust hood shall be provided for core making machines of the small roll over type which generate air contaminant concentrations in excess of exposure limits. An acceptable hood design and minimum exhaust volume for such equipment is given in Figure 5. The minimum duct velocity provided shall be 3500 fpm.

4.3.4 Core Grinding Equipment

Core grinding equipment which generates air contaminant concentrations in excess of exposure limits and which is of the type illustrated in Figure 6 shall be provided an exhaust hood similar to the acceptable design shown in the figure and a minimum exhaust volume in accordance with the table in the figure. Other grinding equipment shall be provided exhaust ventilation in accordance with the ventilation guidelines for grinding, polishing, and buffing.

4.3.5 Core Sanding Operations Using Lathes

Where lathes are used to sand cores and the sanding operation results in the generation of air contaminant concentrations in excess of exposure limits, a downdraft hood shall be installed under the source of

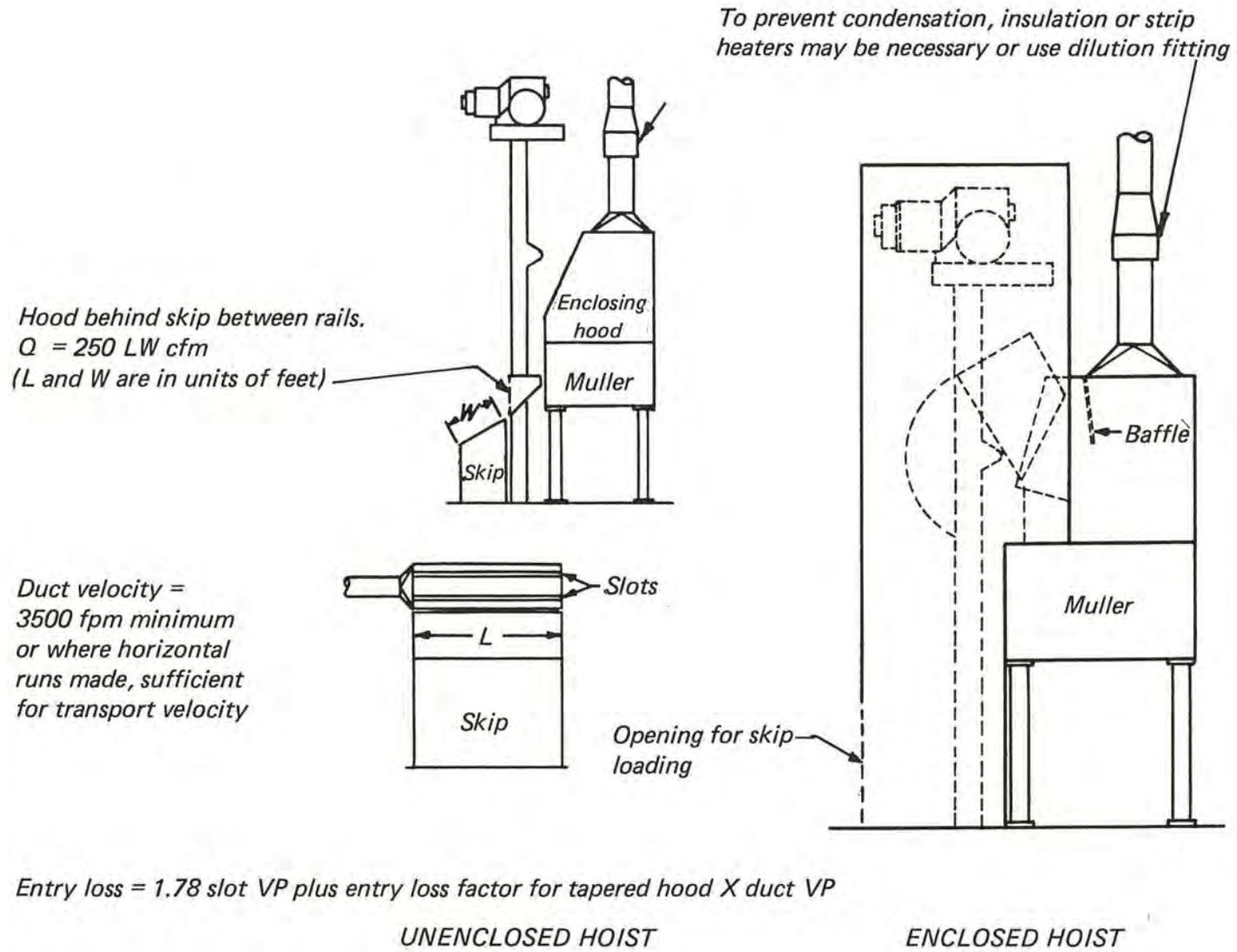
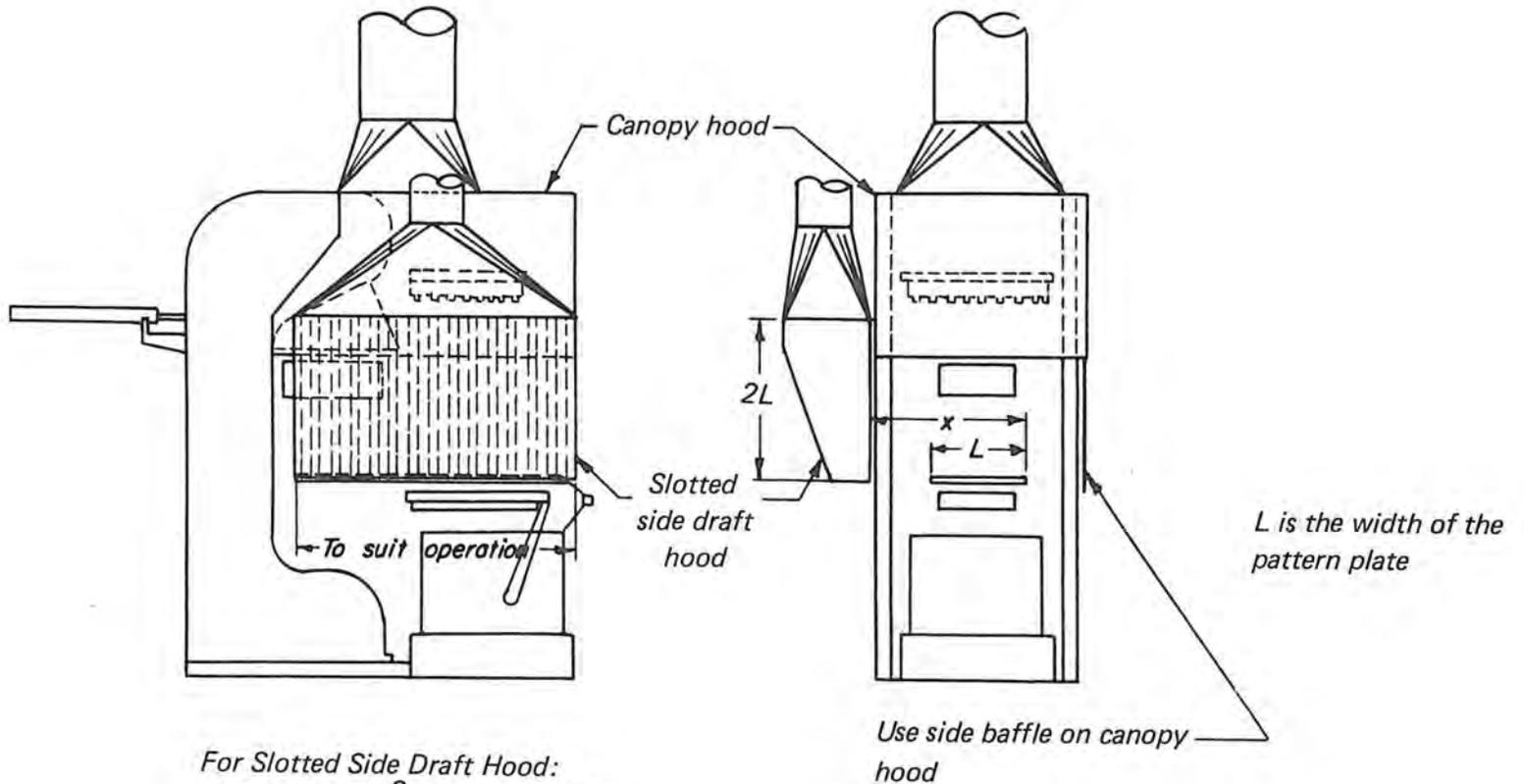


FIGURE 3 SKIP HOIST VENTILATION FOR MIXERS AND MULLERS



For Slotted Side Draft Hood:

$$Q = 75 (10x^2 + \text{hood area}) \text{ cfm}$$

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood X duct VP

For Canopy Units:

$$Q = 250 \text{ cfm/sq ft of the face of the canopy for single units}$$

$$= 150 \text{ cfm/sq ft of the face of the canopy for double units}$$

Entry loss = entry loss factor for tapered hood X duct VP

FIGURE 4 SHELL CORE MOLDING EQUIPMENT

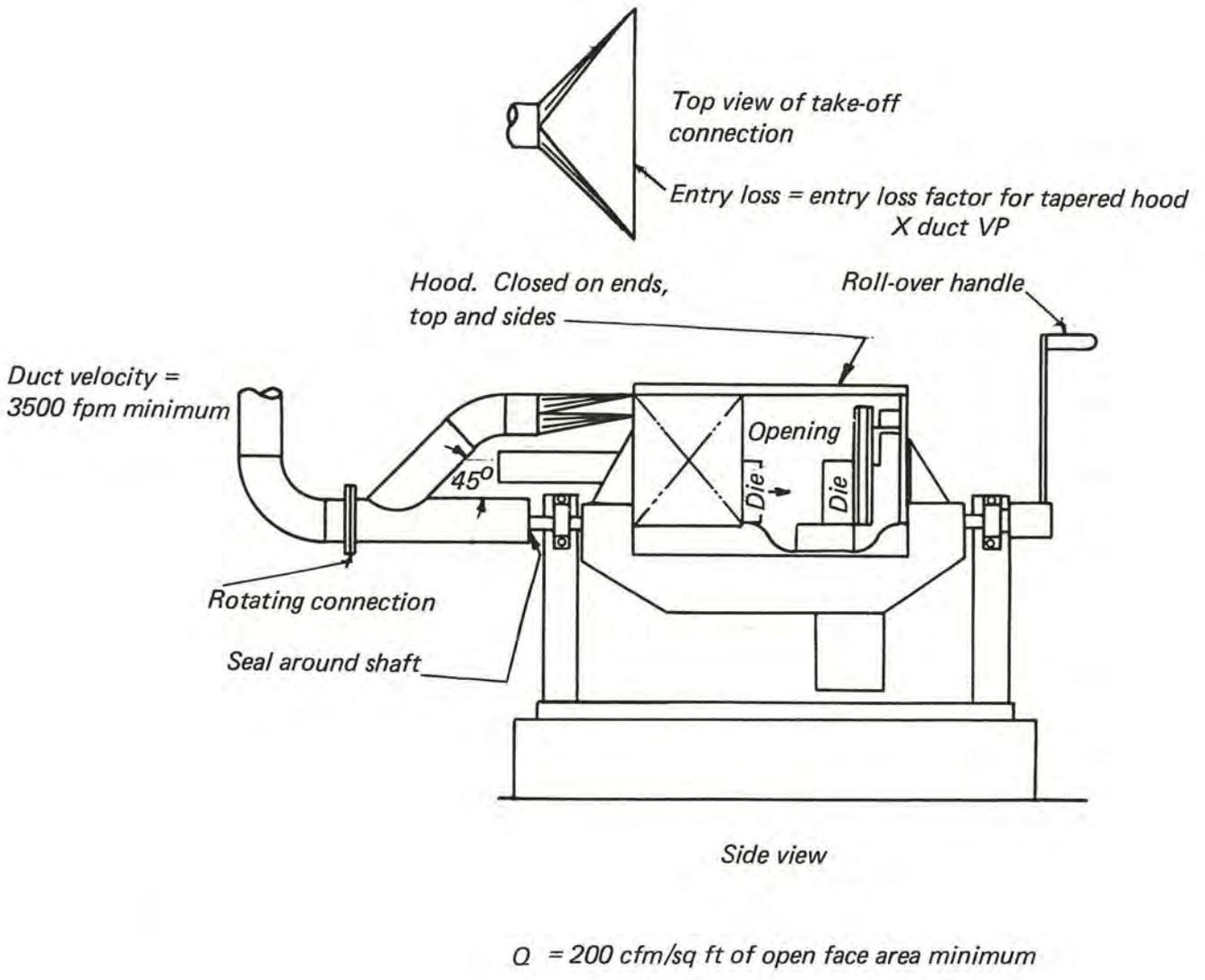
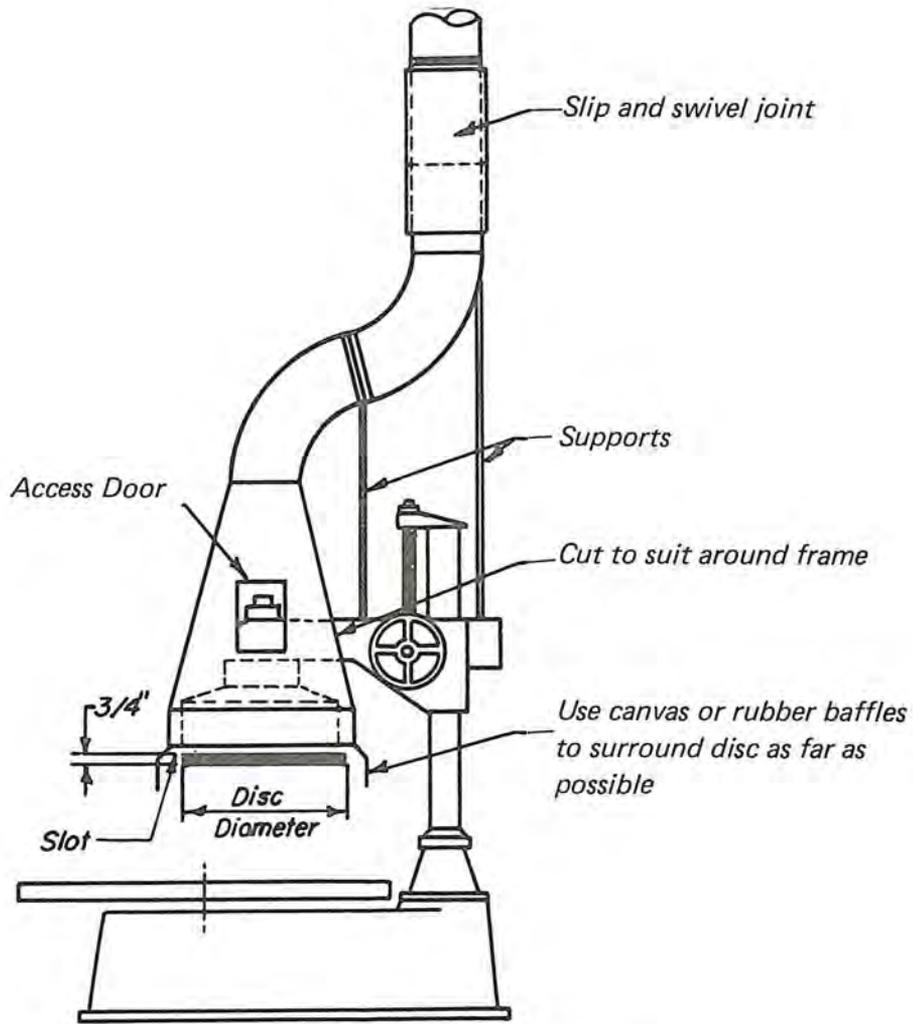


FIGURE 5 CORE MAKING MACHINE OF SMALL ROLL OVER TYPE



<i>Disc Diameter</i>	<i>Duct Diameter</i>	<i>min. cfm</i>
<i>Up to 20"</i>	<i>6"</i>	<i>900</i>
<i>Over 20" to 30"</i>	<i>8"</i>	<i>1600</i>
<i>Over 30" to 53"</i>	<i>12"</i>	<i>3500</i>
<i>Over 53" to 72"</i>	<i>16"</i>	<i>6300</i>

Minimum duct velocity = 3500 fpm

Minimum slot velocity = 2000 fpm

Entry loss = 1.0 slot velocity pressure plus 0.40 duct VP

FIGURE 6 CORE GRINDER

air contaminant generation which provides a capture velocity of 100 fpm at the source. The minimum duct velocity shall be 3500 fpm or, where horizontal runs are made, sufficient to achieve transport velocity.

4.4 Die Casting Equipment and Operations

4.4.1 General

Equipment and operations for die casting in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.4.2 Die Casting Operations

Die casting machines and operations which generate air contaminant concentrations in excess of exposure limits shall be provided exhaust hoods. Figures 7 and 8 illustrate acceptable hood designs and associated exhaust volumes for use with such machines and operations.

4.5 Metal Melting Furnaces and Operations

4.5.1 General

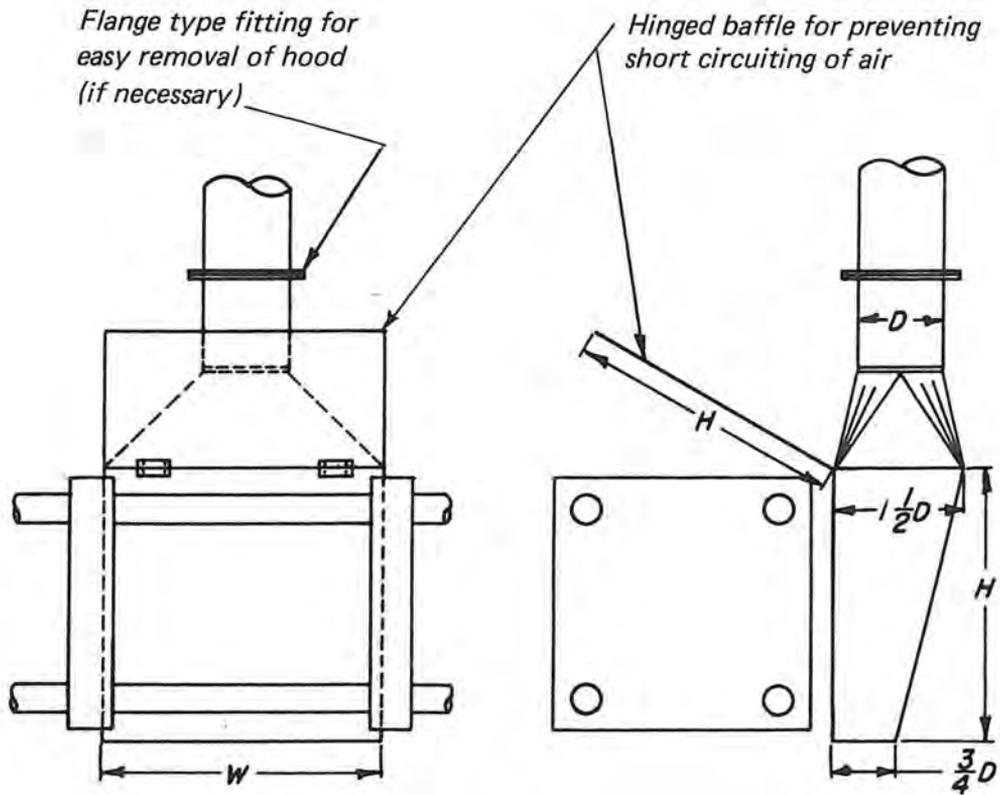
All furnaces for melting of metals in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.5.2 Crucible Melting Furnaces

Crucible non-tilt melting furnaces which generate air contaminant concentrations in excess of exposure limits shall be enclosed to the degree the operation permits and provided a minimum exhaust volume of 200 scfm/sq ft of openings plus the volume of the products of combustion corrected for temperature. Duct velocity shall be a minimum of 1000 fpm or, where horizontal runs are made, sufficient to achieve transport velocity. Figure 9 illustrates an acceptable enclosure design for such furnaces.

4.5.3 Electric Rocking Furnaces

Electric rocking furnaces which generate air contaminant concentrations in excess of exposure limits shall be enclosed to the degree the operation permits and provided a minimum exhaust volume of 400 cfm/sq ft of openings. Duct velocity shall be a minimum of 1000 fpm or, where horizontal runs are made, sufficient to achieve transport velocity. An acceptable exhaust hood design for an electric rocking furnace is illustrated in Figure 10.



Note: Place hood as close to machine as possible. If more than 4 inches from back of machine, hinged side baffles should be used.

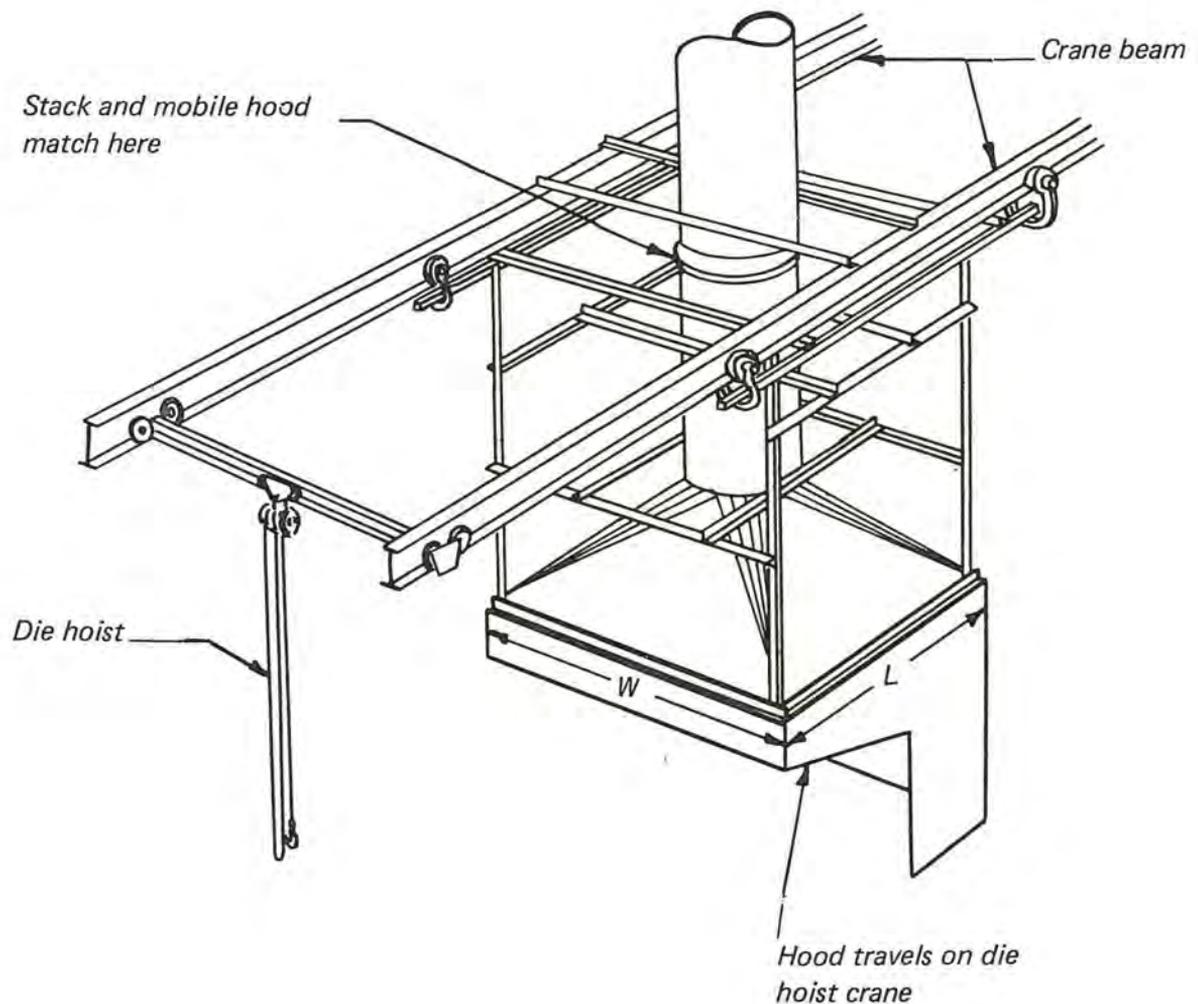
Note: Products of combustion require separate flue or may be vented into hood.

$Q = 300WH$ cfm minimum where W and H are in units of feet

Entry loss = entry loss factor for tapered hood X duct VP

Duct velocity = 2500 fpm minimum

FIGURE 7 DIE CASTING MACHINE HOOD



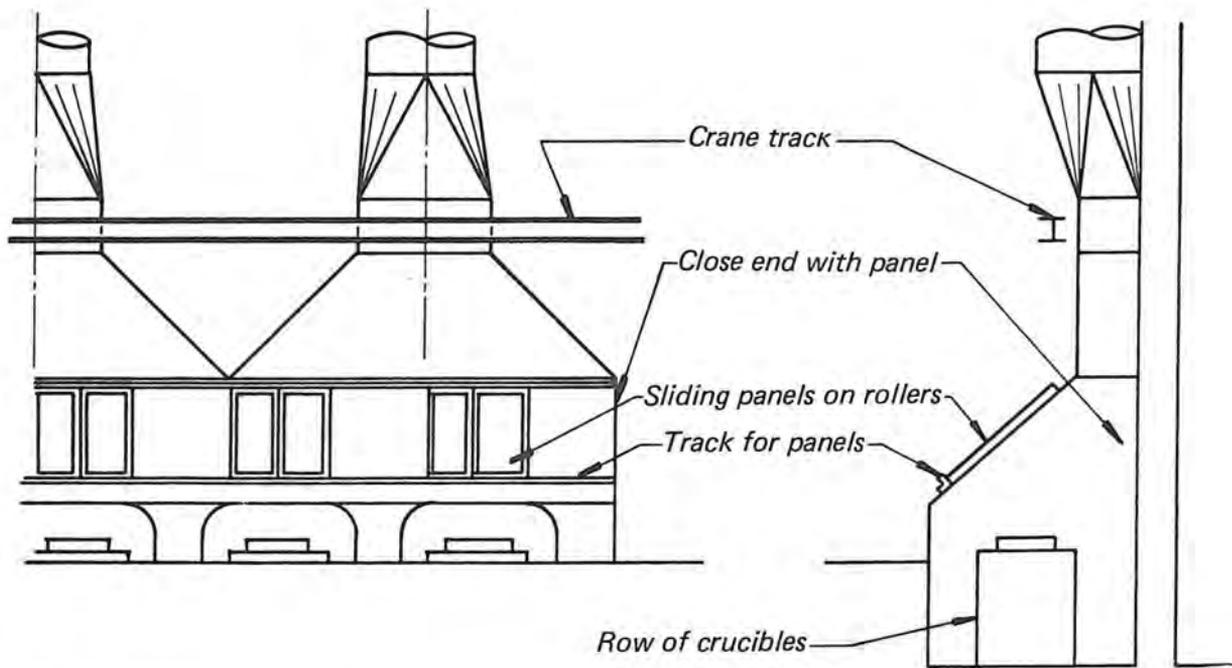
$$Q = 300 WL \text{ cfm}$$

Duct Velocity = 1000 fpm minimum

Entry loss = entry loss factor for tapered hood X duct VP

The dimensions L and W are in units of feet, W shall be a minimum of 1.4 times the projected width of the die. L shall be the minimum length necessary to provide adequate clearance from the die when the hood is in position.

FIGURE 8 DIE CASTING MACHINE OR MELTING FURNACE MOBILE HOOD



$Q = 200$ scfm/sq ft of opening including doors, plus products of combustion.*

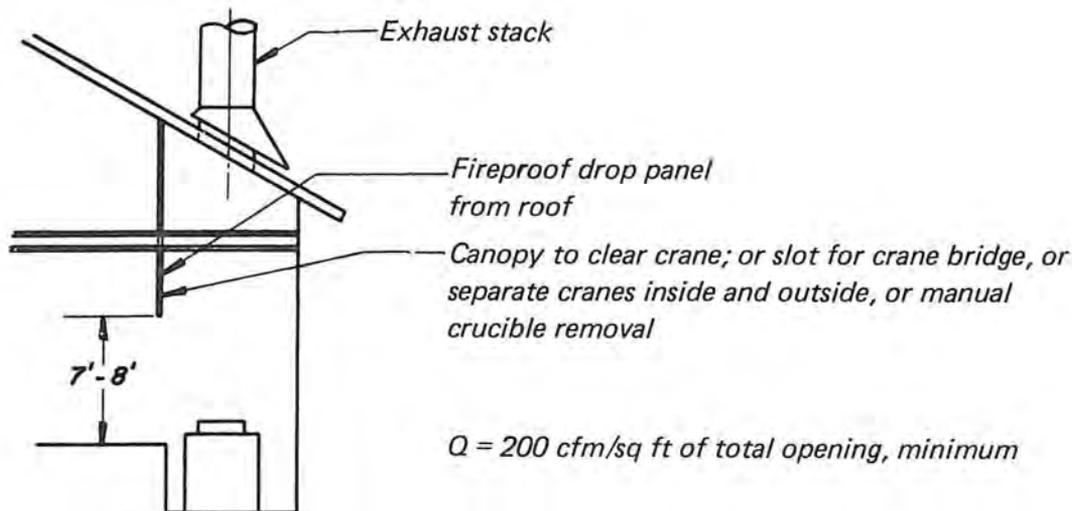
Entry loss = $0.5VP$

Minimum duct velocity = 1000^{**}

*Correct for temperature.

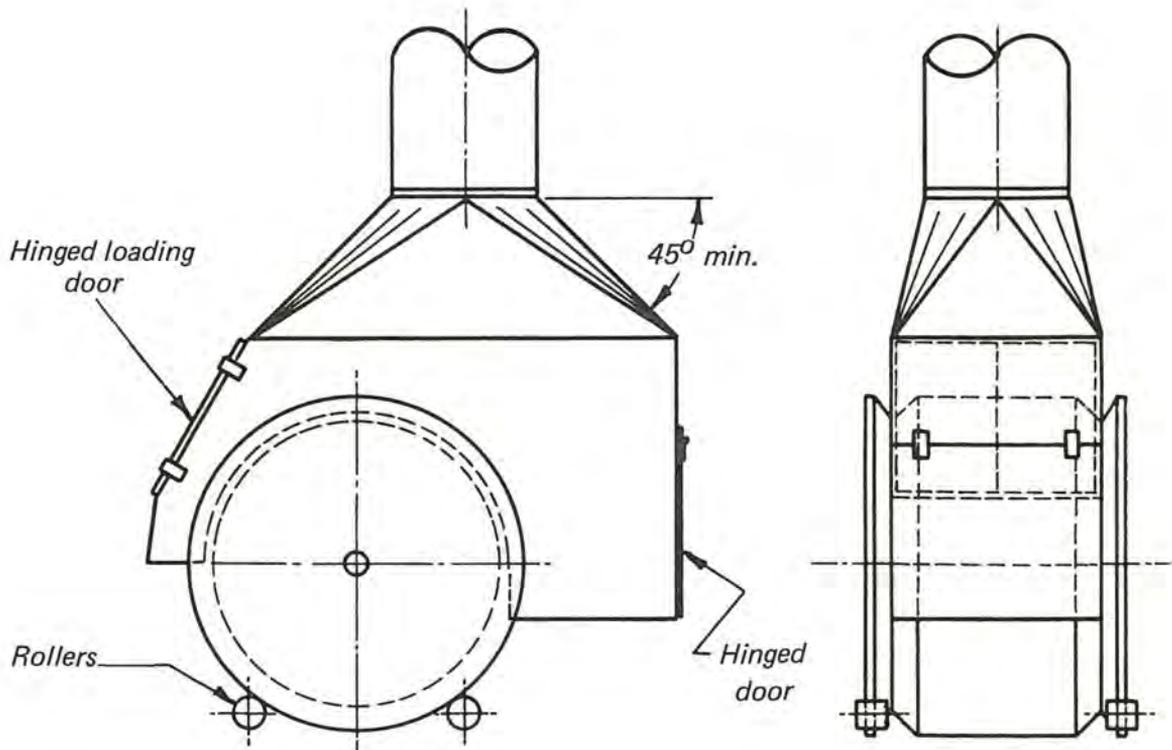
**For horizontal runs, transport velocity is necessary.

NOTE: Same principle of sliding or swinging doors is applied to individual furnace enclosures.



$Q = 200$ cfm/sq ft of total opening, minimum

FIGURE 9 NON-TILT CRUCIBLE MELTING FURNACE



$Q = 400 \text{ cfm/sq ft of opening}$

$\text{Duct velocity} = 1000 \text{ fpm minimum or transport velocity for horizontal runs}$

$\text{Entry loss} = 1.78 \text{ slot VP plus entry loss factor } \times \text{ duct VP}$

FIGURE 10 ELECTRIC ROCKING FURNACE

4.5.4 Top Electrode and Similar Melting Furnaces

Top electrode melting furnaces of the type illustrated in Figure 11 and furnaces of similar physical geometry without top electrodes which generate contaminant concentrations in excess of exposure limits shall be provided exhaust hoods similar to the acceptable design illustrated or exhaust systems utilizing direct furnace roof taps or canopy hoods. Any such engineering control provided shall be of adequate design and capacity to maintain air contaminant concentrations at or below exposure limits. Where canopy hoods are utilized, a minimum air velocity of 200 fpm through all open areas between the furnace and lower edge of canopy shall be maintained and the working area shall be curtained or baffled as necessary to ensure that cross-drafts do not cause spillage of contaminants from the hood and/or as necessary to direct contaminants away from the breathing zones of employees. Figure 12 illustrates an acceptable design for canopy hoods.

4.5.5 Tilting Melting Furnaces

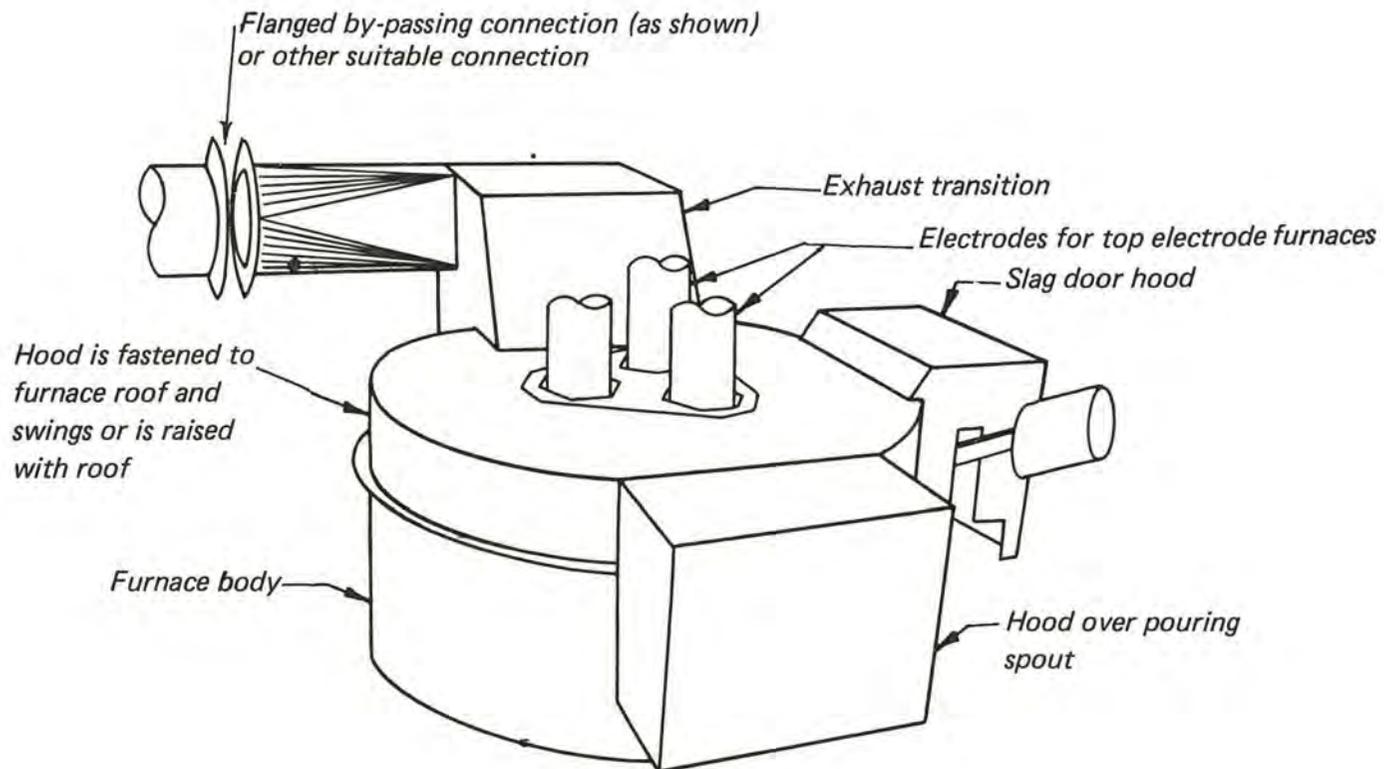
Tilting melting furnaces which generate contaminant concentrations in excess of exposure limits and which are of the type illustrated in Figure 13, or are kettle furnaces, shall be enclosed to the degree the operation permits. Additionally, such furnaces shall be provided a minimum exhaust volume of 200 cfm times the length and width of the furnace enclosure in units of feet but not less than 200 scfm/sq ft of all openings with doors open corrected for temperature and volume of combustion products. Duct velocity shall be a minimum of 1000 fpm, or where horizontal runs are made, sufficient to achieve transport velocity. An acceptable enclosure design for such furnace equipment is illustrated in Figure 13. The pouring spout of kettle furnaces shall be in an upright position during melting.

4.5.6 Cupola Furnaces

Cupola furnaces and the working areas about them shall be equipped as necessary with stacks and other exhaust systems which are designed and sized such that employees working in the vicinity of the furnace are not exposed to contaminant levels in excess of exposure limits. Specifically, the employer shall ensure that carbon monoxide levels on the charging floor as well as in overhead coke bins and the upper levels of the foundry where exposed crane operators may be working do not reach concentrations exceeding the exposure limit. Stack systems shall be designed to provide a minimum average air velocity of 250 fpm across the full open area of the charge opening.

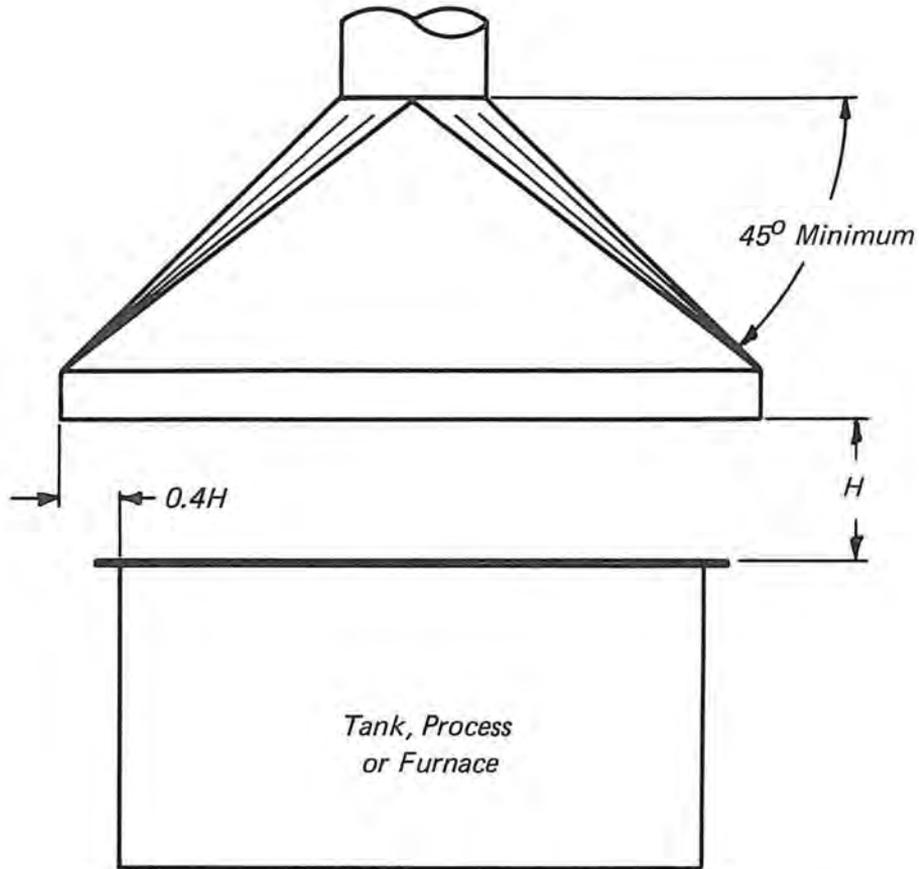
4.5.7 Non-Tilt Melting Pots and Furnaces

Non-tilt melting pots and furnaces which generate contaminant concentrations in excess of exposure limits shall be enclosed and provided a minimum exhaust volume of 150 scfm/sq ft of openings plus the volume of the products of combustion corrected for temperature. Duct velocity shall be a minimum of 2000 fpm or, where horizontal runs are



Consult manufacturer for Q, static pressure, and operating temperature.

FIGURE 11 HOOD FOR TOP ELECTRODE MELTING FURNACE



Not to be used where material is toxic and worker must bend over tank or process.

Q = Minimum exhaust volume, cfm

= $1.4 PHV$ for open type canopy.

P = perimeter of tank, feet

H = distance from lower edge of canopy to top of tank, process, or furnace, feet

V = minimum 200 fpm air velocity

= $(W+L)HV$ for two sides enclosed.

W & L are open sides of hood, feet

V = minimum 200 fpm air velocity

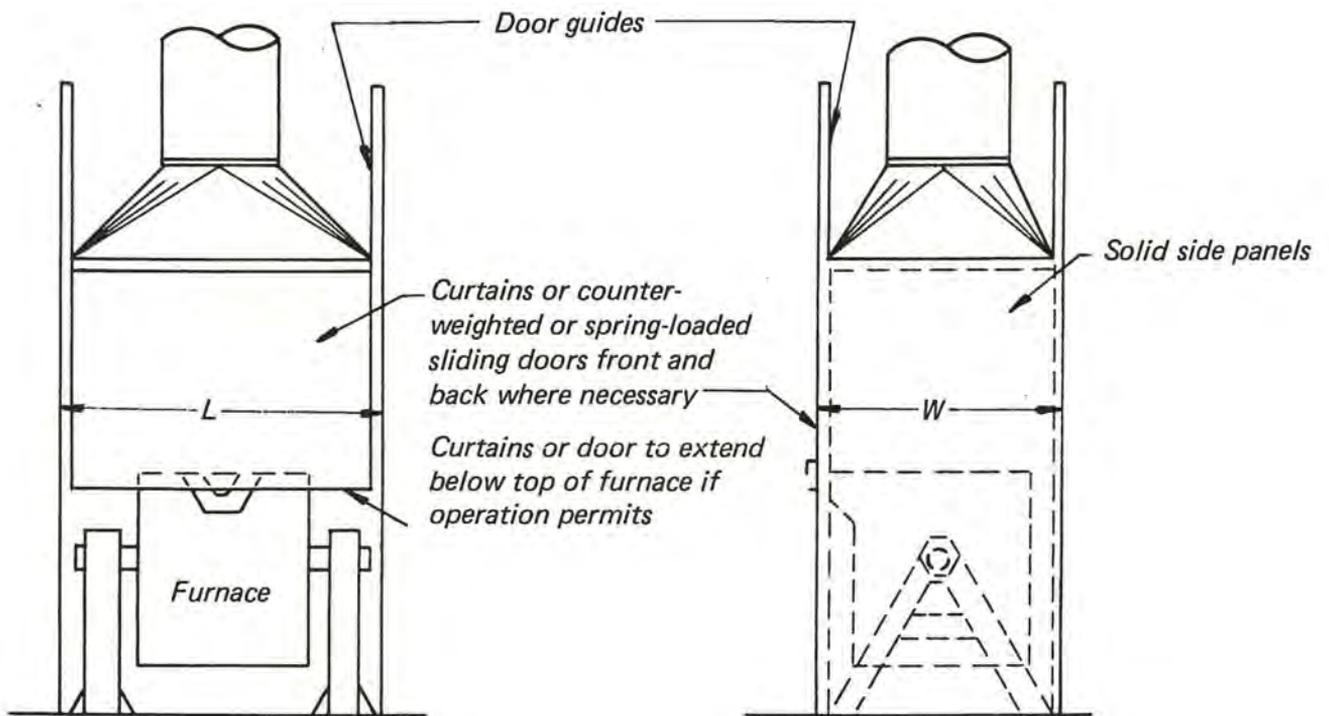
= WHV or LHV for three sides enclosed. (Booth)

V = minimum 200 fpm air velocity

Entry loss = Entry loss factor for tapered hood X duct VP

Duct velocity = 1000 fpm minimum

FIGURE 12 CANOPY HOOD



$Q = 200 LW$ cfm where L and W are in units of feet; but not less than 200 scfm/sq ft (corrected for temperature and combustion products) of all openings with doors open.

Duct velocity = 1000 fpm minimum or transport velocity for horizontal runs

Entry loss = entry loss factor for tapered hood X duct VP

FIGURE 13 TILTING MELTING FURNACES

made, sufficient to achieve transport velocity. Figure 14 illustrates an acceptable exhaust hood design for such equipment.

4.5.8 Furnace Charging

Where furnace charging practices in foundry operations are such that charges are made by opening normally enclosed and ventilated furnaces which already contain molten metal, the employer shall ensure that the dumping of loose scrap or the exposed surface of the molten metal does not generate contaminant concentrations in excess of exposure limits. Where natural ventilation and general mechanical ventilation are inadequate alone, either a canopy hood shall be provided over the furnace opening with a minimum air velocity of 200 fpm through all open areas between the furnace and lower edge of canopy or the area immediately around the furnace shall be curtained or baffled as necessary to divert contaminants from the breathing zones of employees and/or as necessary to ensure that cross-drafts may not cause spillage or air contaminants from the hood. An acceptable design for a canopy hood is illustrated in Figure 12.

4.5.9 Furnace Repair

Where cutoff saws are used for the shaping and sizing of refractory brick, and the saw generates contaminant concentrations in excess of exposure limits, the saw itself or the immediate area of its use shall be provided an exhaust system which reduces the contaminant concentration to a level at or below the exposure limit. An acceptable hood design is illustrated in Figure 15.

4.5.10 Ladle Preheating, Skimming, and Pyrometry Stations

Ladle preheating, skimming, and pyrometry stations which generate contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated as necessary to maintain contaminant concentrations at or below exposure limits. Acceptable hood designs and their associated exhaust volumes are shown in Figures 13 and 16.

4.6 Molten and Hot Metal Transfer Operations

4.6.1 General

Equipment for the pouring and transfer of molten metal in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain contaminant concentrations at or below the exposure limits.

To Fan

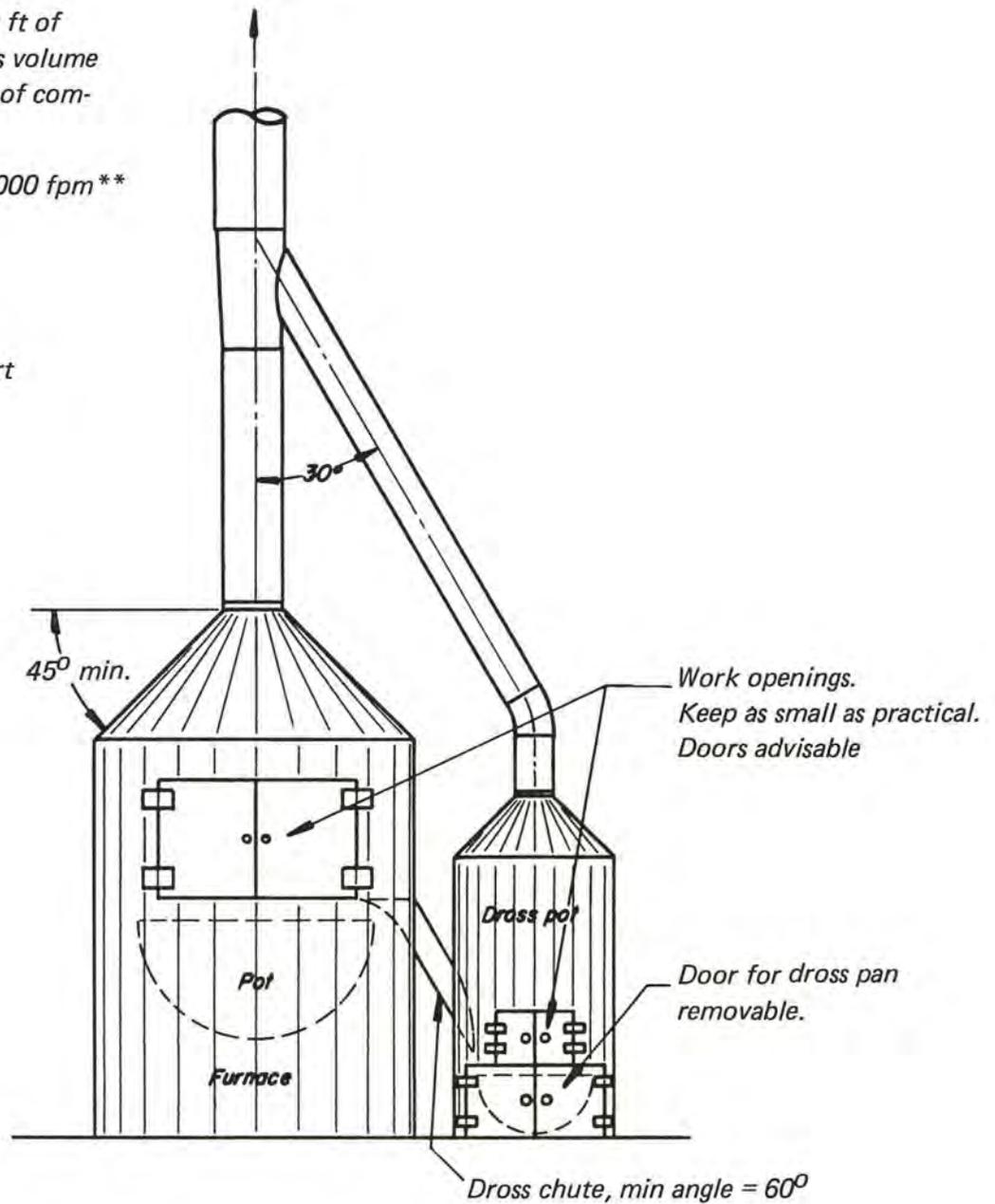
Minimum $Q = 150$ scfm/sq ft of opening plus volume of products of combustion*

Minimum duct velocity = 2000 fpm**

Entry loss = 0.50VP

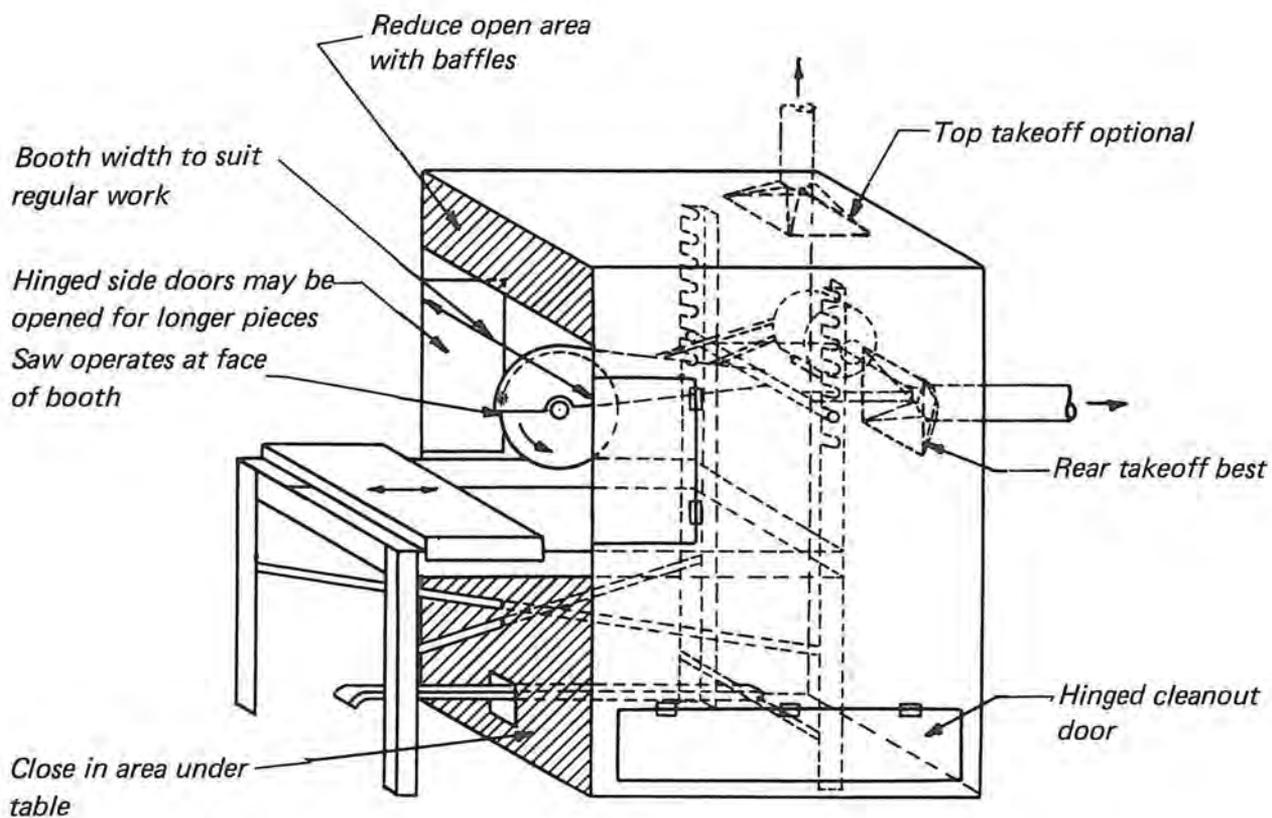
*Correct for temperature.

**For horizontal runs, transport velocity is necessary.



NOTE: Separate flue required if combustion gases are not vented through the hoods.

FIGURE 14 STATIONARY FURNACE OR MELTING POT (NON-TILT)



$Q = 250 \text{ cfm/sq ft of open face area}$

Duct velocity = 3500 fpm minimum

Entry loss for takeoff without taper = 0.50 duct VP

Entry loss for takeoff with taper = entry loss factor for tapered hood X duct VP

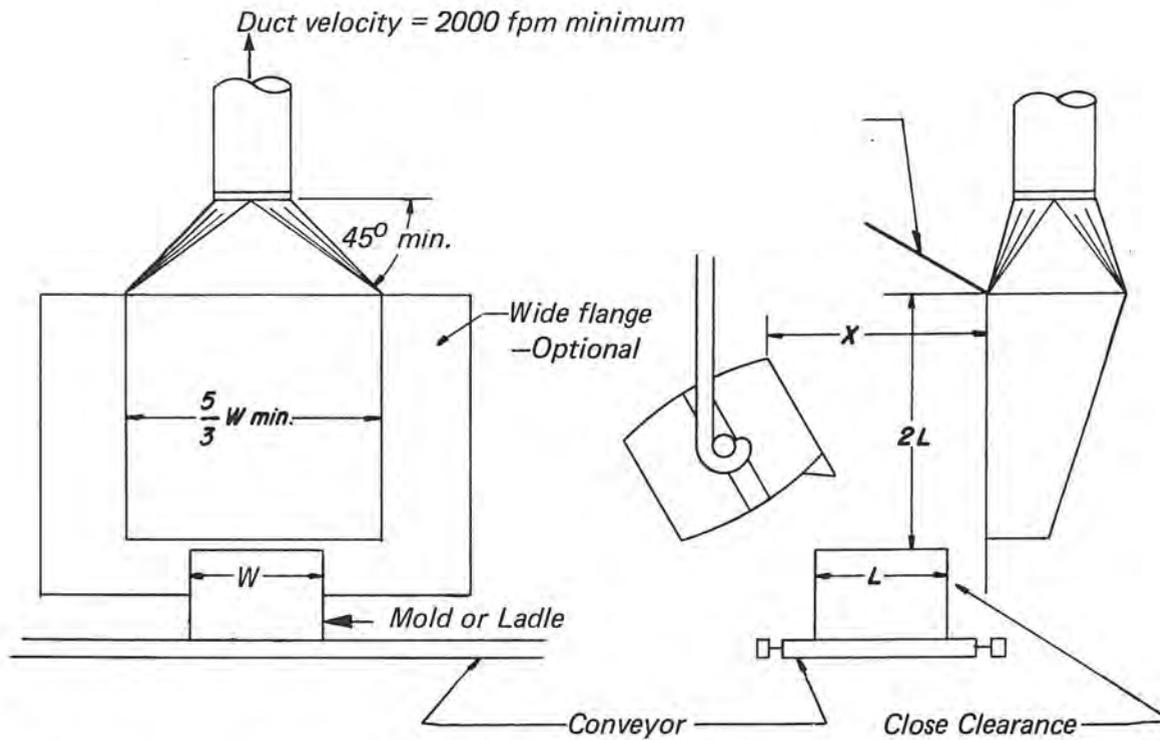
Stationary installation —

Indoor and outdoor: Connect to exhaust system and dust collector
Discharge outdoors

Portable use —

Indoor and outdoor: Use adequate unit collector and fan

FIGURE 15 ABRASIVE CUT-OFF SAW VENTILATION



Unflanged hood: $Q = 200 (10x^2 + \text{hood face area})$ cfm minimum

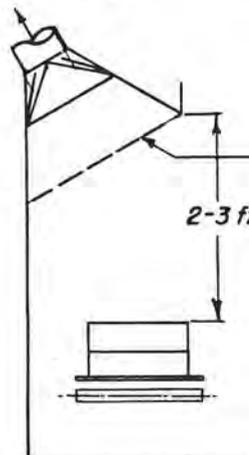
Flanged hood: $Q = 150 (10x^2 + \text{hood face area})$ cfm minimum

where $X, W,$ and L are in units of feet and the hood face area is in units of sq ft

Entry loss = entry loss factor for tapered hood \times duct VP

FLANGED OR UNFLANGED HOOD ARRANGEMENT

Duct velocity = 2000 fpm minimum



Use slots for distribution

Slot velocity = 1500 fpm minimum

Minimum $Q = 200$ cfm/lin ft of hood in direction of conveyor travel

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood \times duct VP

PARTIAL SIDE ENCLOSURE

FIGURE 16 POURING STATION – SMALL MOLDS OR FURNACE TAPS

4.6.2 Pouring Stations - Small Molds

Where molten metal is poured into a small mold and the pouring operation generates contaminant concentrations in excess of exposure limits, the pouring station shall be provided an exhaust hood. Acceptable designs for such hoods are illustrated in Figure 16. Where unflanged hoods are used, the minimum air volume exhausted shall be determined from the formula given for such hoods in Figure 16. Where flanged hoods are used, the minimum exhaust volume provided shall be 75% of that calculated for unflanged hoods. Pouring stations with partial side enclosures shall be provided a minimum exhaust volume of 200 cfm/linear ft of hood in the direction of conveyor travel. Slots sized for a minimum velocity of 1500 fpm shall be required for distribution purposes in such arrangements. Minimum duct velocities for any of the three designs shall be 2000 fpm.

4.6.3 Pouring Stations-Large Molds

Where molten metal is poured into a large mold and the pouring operation generates contaminant concentrations in excess of exposure limits, the pouring station shall be provided a side-draft hood similar to such hoods used in shakeout operations. The exhaust volume provided shall be a minimum of 400 cfm/sq ft of the working area where the working area shall be considered to be a minimum of LW where L and W are respectively the length and width of the mold in units of feet. The minimum duct velocity provided shall be 2000 fpm.

4.6.4 Pouring Stations - Furnace Taps

Where molten metal is poured into ladles from furnace taps and contaminant concentrations in excess of the exposure limits are generated, the location at which the pouring occurs shall be enclosed and exhaust ventilated as necessary to maintain contaminant concentrations at or below exposure limits.

4.6.5 Ladle Transfer Operations

Where lead, aluminum, zinc, or other easily volatized metals or alloys of these metals are transferred to pouring stations in ladles or other types of open containers, and contaminant concentrations in excess of the exposure limits are generated, the containers shall be covered during transfer (flux blankets shall be considered acceptable covers) and/or shall be exhaust ventilated using mobile hoods or other feasible engineering controls as necessary to maintain contaminant concentrations at or below exposure limits. Where a hood is used, the capture velocity provided shall be a minimum of 175 fpm at the furthest edge of the ladle in its transfer position from the face of the hood. Duct velocities shall be a minimum of 2000 fpm.

4.6.6 Smoking or Cooling Tunnels

Where conveyors are used to transport freshly poured molds from pouring stations while the molds are generating contaminants at a rate which produces contaminant concentrations in excess of exposure limits, the conveyor shall be enclosed to the degree the operation permits and shall be provided a minimum exhaust volume of 150 cfm/sq ft of all openings including leakage at the floor. Other conveyor operations which are conducted in foundries and which generate air contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated in accordance with the ventilation guidelines for materials handling operations.

4.7 Foundry Shakeout, Mold Transfer, and Tumbling Mill Operations

4.7.1 General

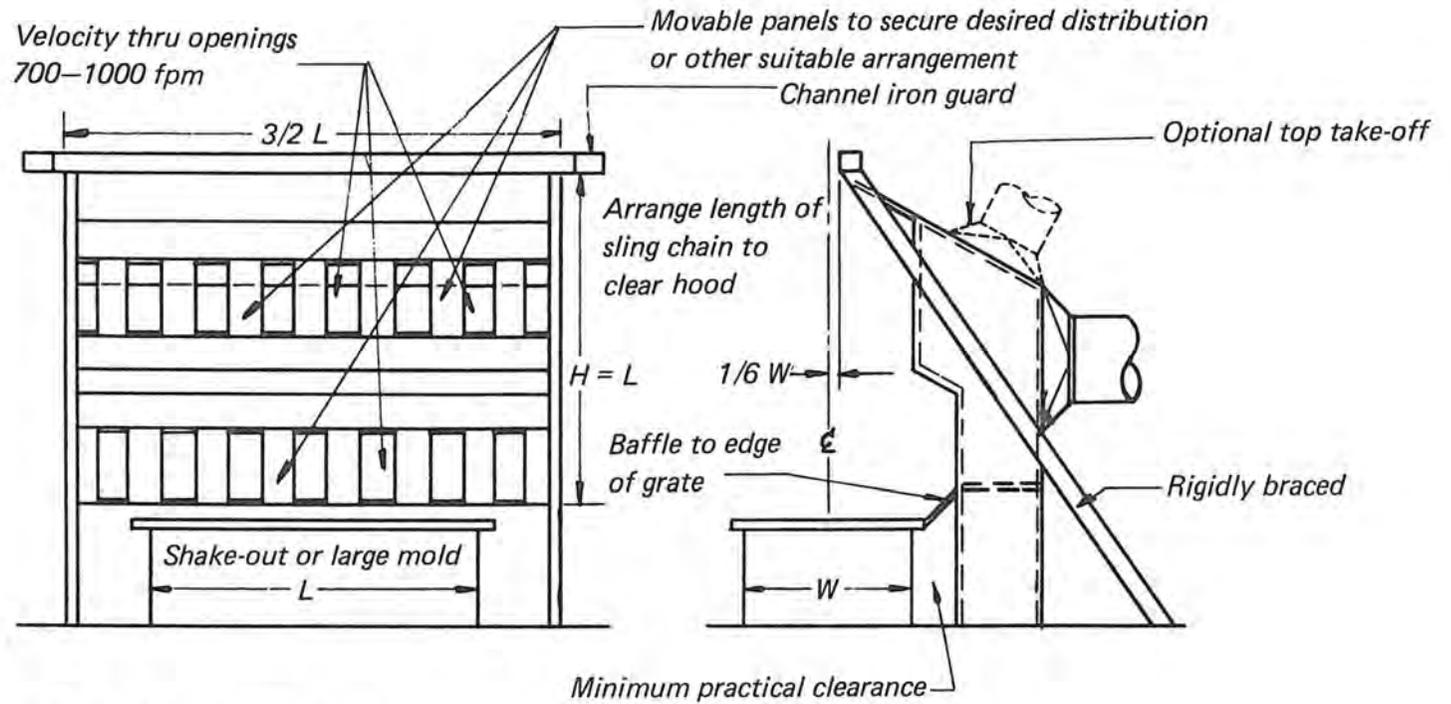
Where a shakeout operation is conducted which generates contaminant concentrations in excess of exposure limits, either a side-draft, enclosing, or downdraft hood or other feasible engineering control shall be provided as necessary to maintain contaminant concentrations at or below exposure limits. Equipment or operations for the transfer or tumbling of molds in foundry operations shall be enclosed and exhaust ventilated as necessary to maintain contaminant concentrations at or below exposure limits.

4.7.2 Single Side-Draft Hoods

Figure 17 illustrates an acceptable single side-draft hood design which may be used to control contaminant concentrations in accordance with paragraph 4.7.1 of these guidelines. The minimum exhaust volume provided such a hood shall be 400 cfm/sq ft of grate area for castings with surface temperatures greater than 100 degrees Fahrenheit or 350 cfm/sq ft of grate area for cooler castings. Duct velocity shall be a minimum of 3500 fpm. Shakeout hoppers shall be provided minimum exhaust volumes equivalent to 10 percent of the total exhaust volume of the side-draft hood.

4.7.3 Double Side-Draft Hoods

Figure 18 illustrates an acceptable double side-draft hood design which may be used to control contaminant concentrations in accordance with paragraph 4.7.1 of the guidelines. The minimum total exhaust volume provided for both hoods shall be 400 cfm/sq ft of grate area for castings with a surface temperature above 100 degrees Fahrenheit or 350 cfm/sq ft of grate area for cooler castings. Use of a blank wall opposite one side of a shakeout with a hood on the other side shall be permitted. Shakeout hoppers shall be provided minimum exhaust volumes equivalent to 10 percent of the total exhaust volume of the hoods. Duct velocity shall be a minimum of 3500 fpm.

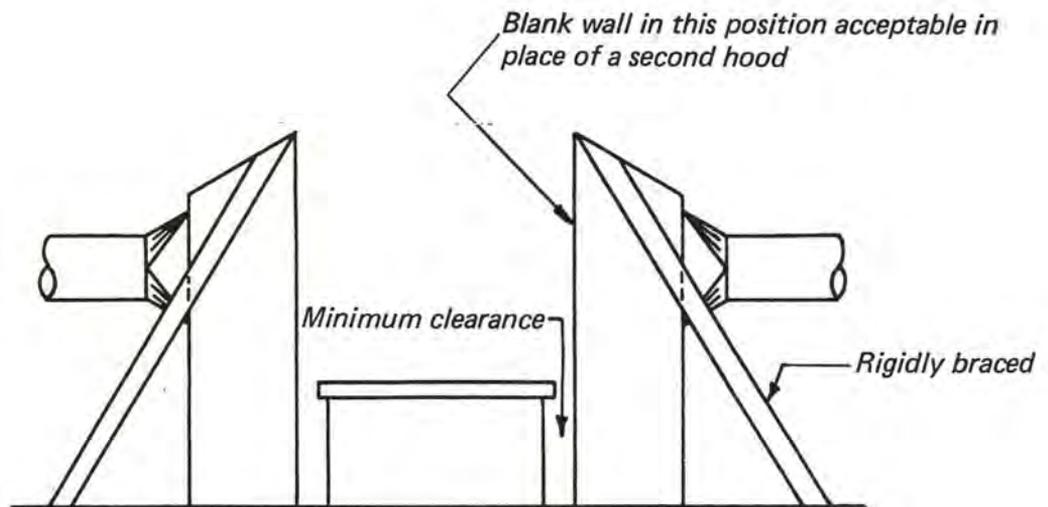


Q = minimum 400 cfm/sq ft grate area for castings with
surface temperature greater than 1000° ; minimum
350 cfm/sq ft grate area when cooler

Duct velocity = 3500 fpm minimum

Entry Loss = 1.78 slot VP plus entry loss factor for
tapered hood X duct VP

FIGURE 17 SIDE-DRAFT HOOD



Proportions same as single side-draft hood except for overhang.

Q = minimum 400 cfm/sq ft grate area for castings
with surface temperature greater than 100° ;
minimum 350 cfm/sq ft grate area when cooler

Duct velocity = 3500 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for
tapered hood \times duct VP

FIGURE 18 DOUBLE SIDE-DRAFT HOOD

4.7.4 Enclosing Hoods

Figure 19 illustrates an acceptable enclosing hood design which may be used to control contaminant concentrations in accordance with paragraph 4.7.1 of these guidelines. The minimum exhaust volume provided such a hood shall be 200 cfm/sq ft of the grate area for castings with a surface temperature greater than 100 degrees Fahrenheit or 150 cfm/sq ft of the grate area for cooler castings. Duct velocity provided shall be a minimum of 3500 fpm. Shakeout hoppers shall be provided minimum exhaust volumes equivalent to 10 percent of the total exhaust volume of the enclosing hood.

4.7.5 Hoods with Two Sides and 1/3 Top Enclosed

Where a hood which encloses two sides and 1/3 the top of the shakeout grate area is used to control contaminant concentrations in accordance with paragraph 4.7.1 of these guidelines, the hood shall be provided a minimum exhaust volume of 300 cfm/sq ft of grate area for castings with a surface temperature greater than 100 degrees Fahrenheit or 275 cfm/sq ft of grate area for cooler castings. Duct velocity shall be a minimum of 3500 fpm. Shakeout hoppers shall be provided minimum exhaust volumes equivalent to 10 percent of the total exhaust volume of the hood.

4.7.6 Downdraft Hoods

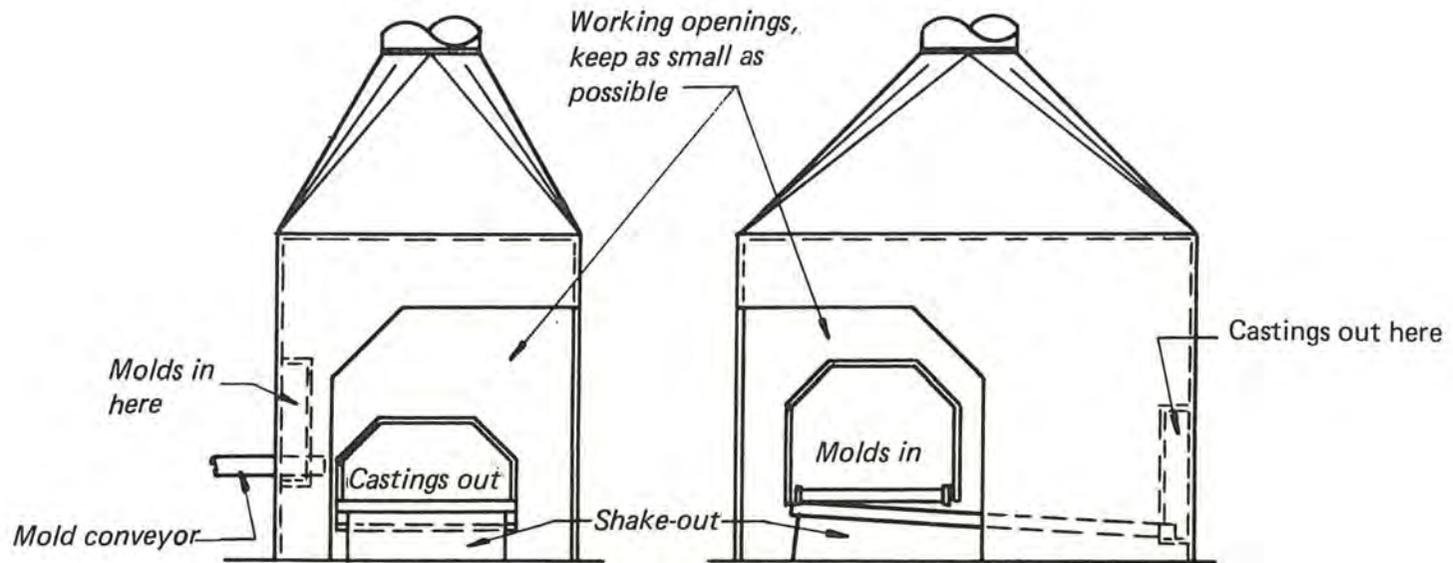
Figure 20 illustrates an acceptable downdraft hood design which may be used to control contaminant concentrations in accordance with paragraph 4.7.1 of these guidelines. Where used for castings with surface temperatures greater than 100 degrees Fahrenheit, the minimum exhaust volume provided such a hood shall be 600 cfm/sq ft of grate area. For cooler castings, the minimum exhaust volume provided shall be 200 cfm/sq ft of grate area. Since ventilation will not function if castings and sand completely cover the grate, the grate area shall be greater than the flask area. Slots for such hoods shall be sized for a minimum face velocity of 1500 fpm. Duct velocity shall be a minimum of 4000 fpm.

4.7.7 Shakeout Hoppers

Figure 21 illustrates an acceptable design for shakeout hopper exhaust for use with other than downdraft hoods. Duct velocity shall be a minimum of 3500 fpm or where horizontal runs are made, sufficient to achieve transport velocity.

4.7.8 Other Shakeout Operations

Where molds are overturned on the floor, gate and riser knockoff is attempted, or manual core knockout operations are conducted in a manner that contaminant concentrations in excess of exposure limits are

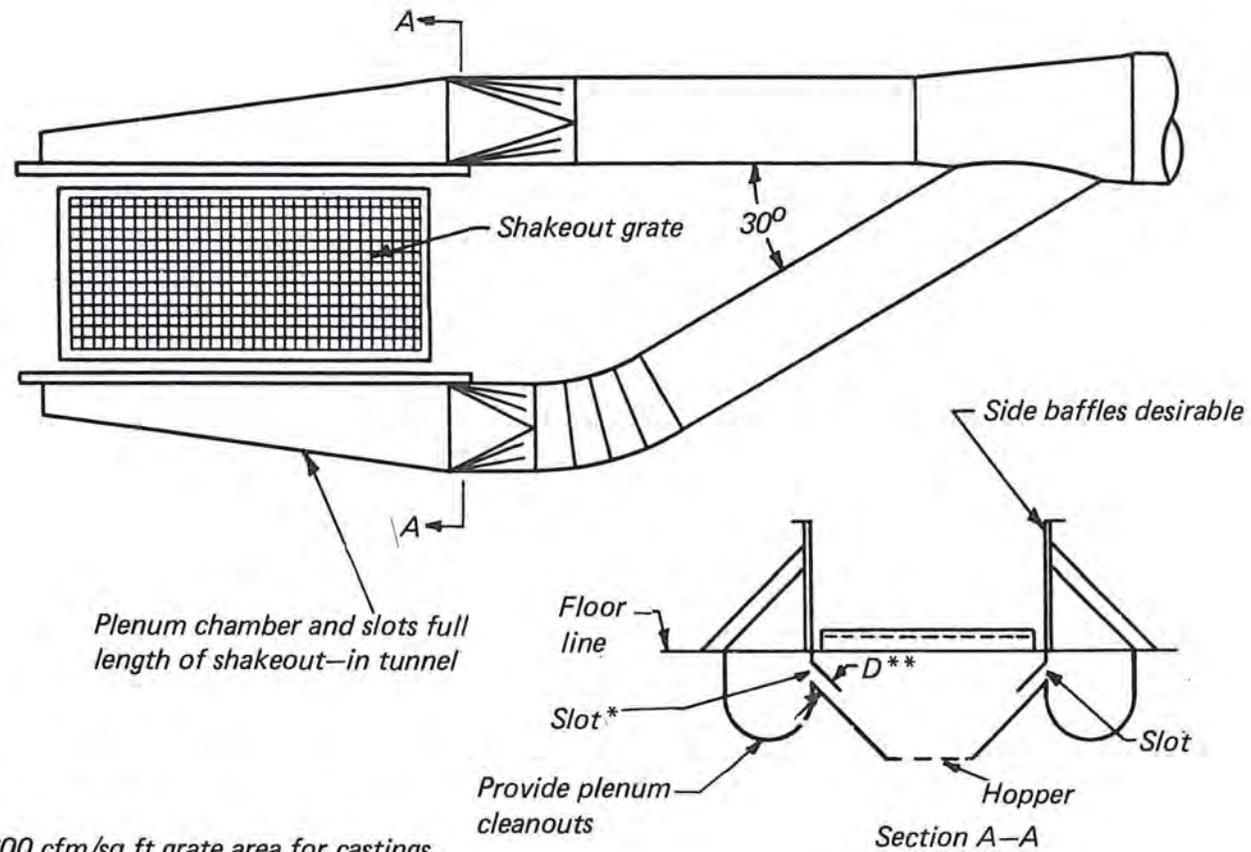


$Q = \text{minimum } 200 \text{ cfm/sq ft grate area for castings with surface temperature above } 100^{\circ}; \text{ minimum } 150 \text{ cfm/sq ft grate area when cooler}$

$\text{Duct velocity} = 3500 \text{ fpm minimum}$

$\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

FIGURE 19 ENCLOSING HOOD



$Q =$ minimum 600 cfm/sq ft grate area for castings with surface temperature above 100°; minimum 200 cfm/sq ft grate area when cooler

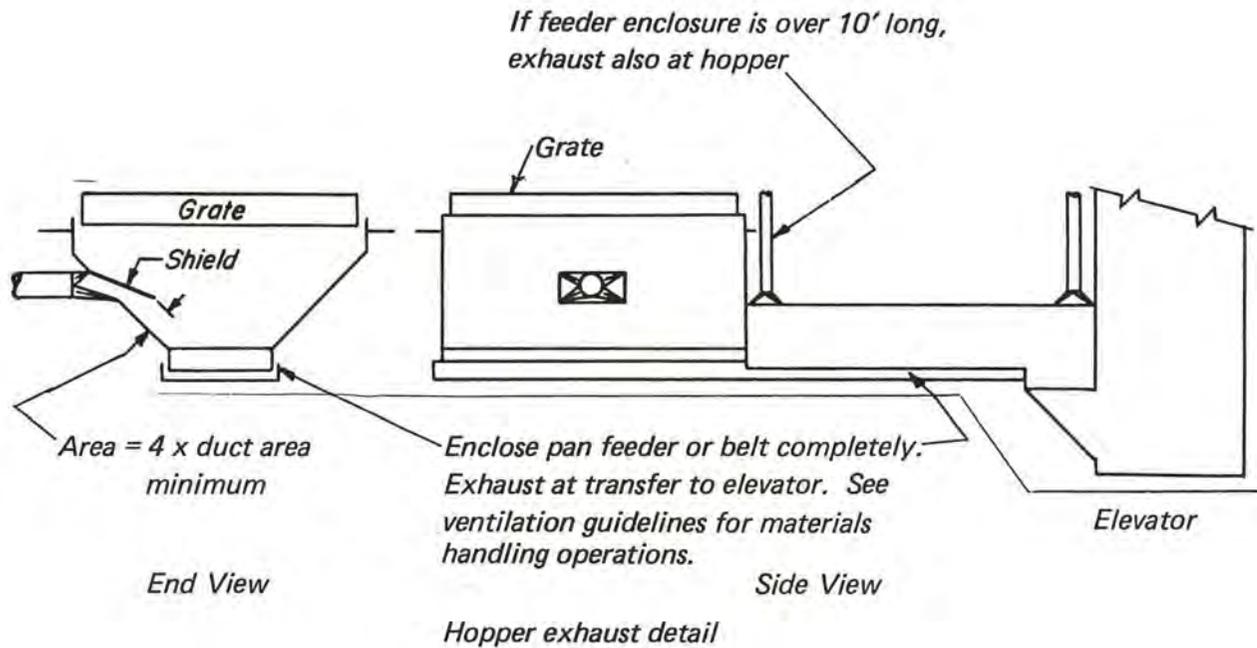
Duct velocity = 4000 fpm minimum

Entry loss = 1.78 slot VP plus fittings

*Size slots for 1500–2000 fpm

**Size D for 1000 fpm or less

FIGURE 20 DOWNDRAFT HOOD



Q = minimum of 10% of total exhaust volume
of side-draft or enclosing hood

Duct velocity = 3500 fpm minimum

FIGURE 21 SHAKEOUT HOPPER EXHAUST

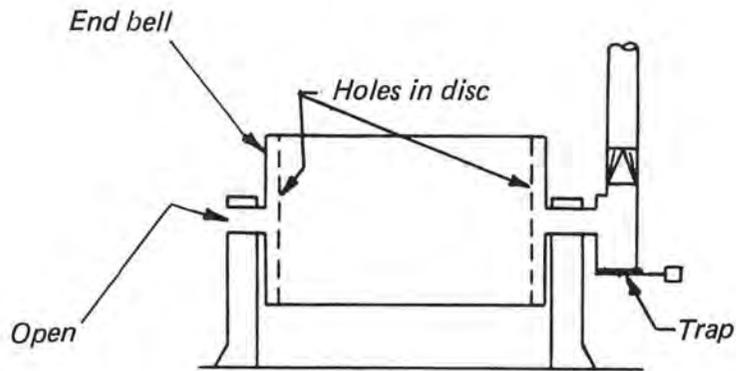
generated, a side-draft or semi-booth exhaust hood shall be installed as close to the contaminant source as operations permit. The exhaust system shall be designed to provide a minimum exhaust volume of 200 cfm/sq ft of dust-producing working area. Duct velocity shall be a minimum of 3500 fpm or, where horizontal runs are made, sufficient to achieve transport velocity.

4.7.9 Mold and Casting Transfer Operations

Where molds or dirty castings are transferred from one conveyor to another or from conveyor to tote box or some other similar transfer operation is conducted which generates contaminant concentrations in excess of exposure limits, the transfer point shall be enclosed to the degree the operation permits and shall be exhaust ventilated. A minimum exhaust volume of 200 cfm/sq ft of all openings shall be provided when the surface temperature of the casting is above 100 degrees Fahrenheit. A minimum exhaust volume of 150 cfm/sq ft of all openings shall be provided for cooler castings. Duct velocity shall be a minimum of 3500 fpm or, where horizontal runs are made, sufficient to achieve transport velocity.

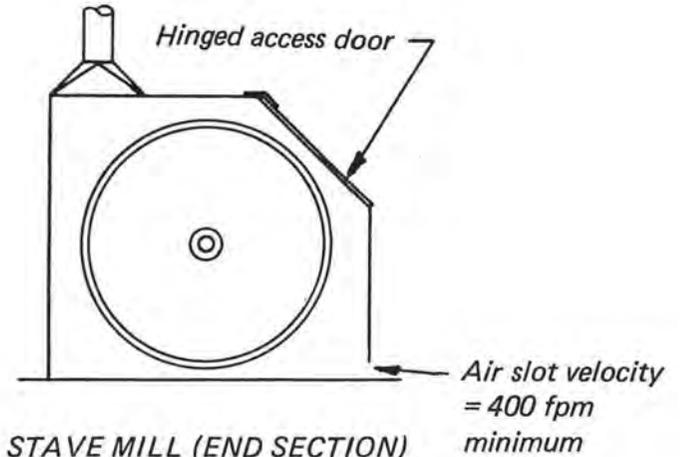
4.7.10 Tumbling Mills

Figure 22 illustrates acceptable designs and associated exhaust volumes for tumbling mills which generate contaminant concentrations in excess of exposure limits.



**SECTION THRU HOLLOW TRUNNION
TUMBLER**

*Duct velocity = 5000 fpm minimum
Entry loss = 3.25''–8.25'' H₂O (depends on design *)*



STAVE MILL (END SECTION)

*Duct velocity = 3500 fpm minimum
Entry loss = entry loss factor for tapered
hood X duct VP*

MINIMUM EXHAUST VOLUMES

Square mill side diam in.	Round mill I.D. in inches	cfm **	
		Trunnion	Stave
	Up to 24 incl.	430	800
Up to 24 incl.	24 – 30	680	900
25 – 30	31 – 36	980	980
31 – 36	37 – 42	1330	1330
37 – 42	43 – 48	1750	1750
43 – 48	49 – 54	2200	2200
49 – 54	55 – 60	2730	2730
55 – 60	61 – 66	3300	3300
61 – 66	67 – 72	3920	3920
67 – 72		4600	4600

**Low-loss designs have large air inlet openings in end bell.
Holes in end discs are sized for velocities of 1250–1800 fpm*

***For lengths over 70'', increase cfm proportionately to length*

FIGURE 22 TUMBLING MILLS

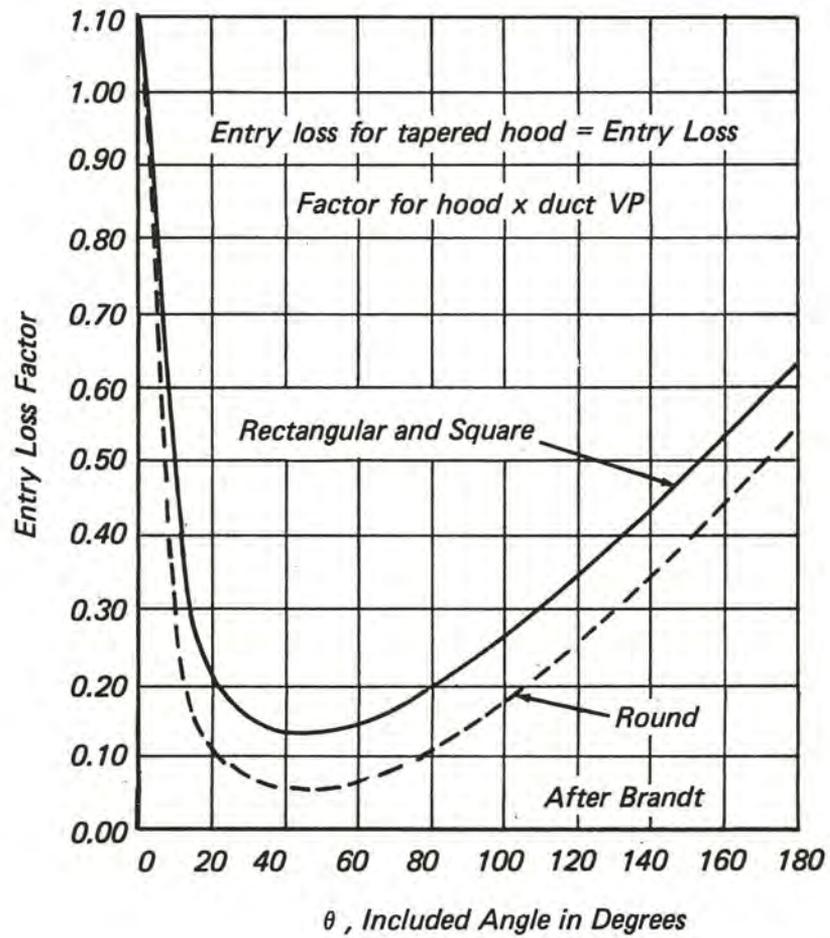
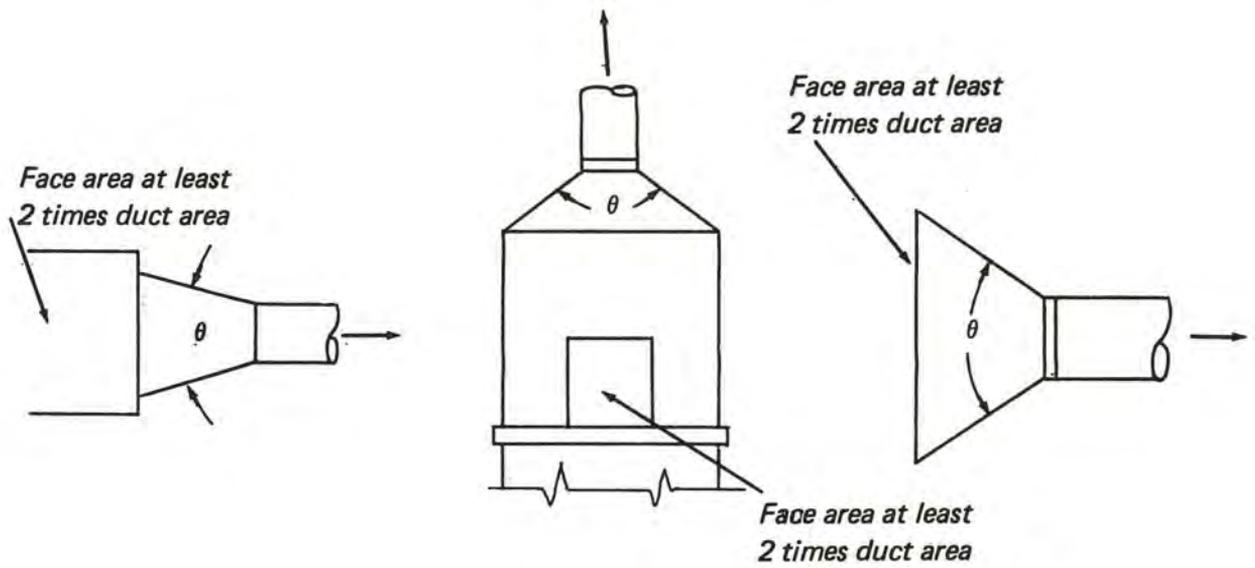
RECOMMENDED VENTILATION GUIDELINES FOR GRINDING, POLISHING, AND BUFFING OPERATIONS

1. Scope

These guidelines prescribe the use of local exhaust ventilation for the control and removal of airborne contaminants generated by grinding, polishing, and buffing operations. Grinding operations covered by the guidelines include all operations conducted with bonded abrasive wheels, otherwise known as "hardwheel grinding." Polishing operations covered by the guidelines include all operations conducted with abrasive-coated fabric or paper in the form of belts, discs, or wheels otherwise known as coated-abrasive operations. Buffing operations covered by the guidelines include all operations conducted with circular buffs of fabric to which buffing compounds containing abrasive materials are applied. Ventilation requirements prescribed in these guidelines are based on the control of air contaminants from grinding, polishing, and buffing of metals.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Downdraft Table - An open hood incorporated in the surface of a workbench or table for the control of air contaminants generated by operations conducted on the workbench or table.
- d. Duct Velocity - The average air velocity in a duct of an exhaust system.
- e. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- f. Enclosing Hood - An exhaust hood which partially or totally encloses a contaminant-producing operation; also booth or enclosure.
- g. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- h. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- i. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.



Tapered Hoods
 Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- j. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- k. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- l. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- m. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- n. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- o. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- p. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- q. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- r. Low-Volume-High-Velocity Hood - An open or shaped hood of small size designed to be operated in close proximity to the point of contaminant generation and to produce high capture velocities at that point.
- s. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- t. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- u. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- v. Pressure, Static - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse a pipe.)
- w. Pressure, Total - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).
- x. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches water gauge.
- y. Shaped Hood - An exhaust hood which is shaped to conform to the configuration of the contaminant source and which

- partially encloses the source. A protective guard or housing may serve as a shaped hood if connected to an exhaust system.
- z. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all operations involving grinding, polishing, or buffing of metals which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while the contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists. These guidelines shall apply to all contaminants generated by grinding, polishing, and buffing operations including workpiece materials, abrasive materials, and abrasive bonding, support, and carrier materials.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in the guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation Equipment Design Requirements

4.1 General

Grinding, polishing, or buffing operations which generate air contaminant concentrations in excess of exposure limits into the breathing zones of employees shall be hooded and exhaust ventilated as necessary to maintain air contaminant concentrations to levels at or below exposure limits. A hood used for the control of contaminants from a grinding, polishing, or buffing operation shall be connected to an exhaust system which draws air through the hood to capture air contaminated by the operation and to convey the contaminated air through the exhaust system.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust

ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

4.2 Exhaust Hood Types

Four general classes of exhaust hoods are applicable to the control of air contaminants from grinding, polishing, and buffing operations:

1. Open hoods;
2. Low-volume-high-velocity hoods;
3. Shaped hoods; and
4. Enclosing hoods.

The applicability of each hood class to specific operations and its operational requirements are indicated in Section 5.

4.3 Conformity with other Regulations

Grinding machines are required to be fitted with protective guards in accordance with 29 CFR 1910.215 and 1910.243. These protective guards may be used as exhaust hoods provided that such use does not result in nonconformity with the protective guard requirements.

4.4 Fire Prevention

When the material being ground, polished, or buffed is flammable or combustible when dispersed in air in a finely divided state and the grinding, polishing, or buffing operation is exhaust ventilated, the minimum exhaust volume where practical, shall be sufficient for dilution of air contaminant concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being handled, the fan rotating element shall be nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall also be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact. Furthermore, under such circumstances, an automatic fire detection and extinguishing system shall be installed in the exhaust system.

Certain metallic dusts in a finely divided state if allowed to accumulate in hoods, ducts, or dust collectors may cause spontaneous combustion. The most notable of these materials is magnesium dust. Ventilation systems for magnesium dusts and particles should be preferably of the high velocity types, and duct velocities must be maintained at high levels to prevent accumulation of dust in exhaust ducts. To reduce the danger of fire in the dust collector, the wet type collector should be used.

5. Ventilation Equipment Applicability and Operational Requirements

5.1 General

Types and subtypes of grinding, polishing, and buffing equipment are classified in Table 1. Contaminant materials are classified in Table 2 according to their exposure limits. The applicability and exhaust flow requirements for each hood type are summarized in Table 3 for each equipment-type and contaminant class combination.

Where an enclosing hood or booth is used for the control of air contaminants from a grinding, polishing, or buffing operation and it is necessary for an employee to be inside the hood or booth during operations, the employee shall be protected against excessive exposure to contaminants by ensuring that he remain between the contaminant source and hood face or the open end of the booth. This shall be allowed only if there is a directed airflow through the hood or booth with average velocity equal to or greater than the minimum required face velocity and no Class II or III contaminants are generated by the operation.

5.2 Specific Operations

5.2.1 Surface-Type Grinders

An open hood may be used with a surface-type grinder for the control of Class I air contaminants. Figure 2 illustrates an acceptable design for such a hood. The hood shall be located as close as possible to the grinding wheel and as low as possible so that the swarf flow from the grinding operation flows into the hood face. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in Figure 2.

A low-volume-high-velocity hood may be used with a surface-type grinder for the control of Class I air contaminants. Figure 3 illustrates an acceptable design for such a hood. The exhaust flow required to control air contaminant exposures shall be determined by tests under actual grinding operations, and the exhaust flow so determined shall be maintained at all times while grinding operations are in progress. The exhaust flow range contained in Figure 3 is provided only as a guide to the probable exhaust flow requirement.

Table 1
Types of Grinding, Polishing
and Buffing Equipment

Equipment Types	Equipment Subtypes
1. Surface-Type Grinders	Surface Grinders Roll Grinders Snaggers Slab and Billet Grinders Swing Grinders
2. Pedestal-Type Grinders	Pedestal Grinders Bench Grinders Floorstand Grinders Tool Grinders
3. Disc Grinders and Polishers	Single Spindle Disc Grinders Double Spindle Disc Grinders Disc Polishers
4. Internal Grinders	Internal Grinders
5. Abrasive Cutting-Off Machines	Abrasive Cutting-Off Machines
6. Pedestal-Type Polishers and Buffers	Wheel and Drum Polishers Backstand Idler Polishers Buffing Lathes
7. Belt Polishers	Belt Grinders and Polishers (using flat belt surface)
8. Portable Grinders, Polishers, and Buffers	Portable Grinders Portable Polishers Portable Buffers
9. Multiple Polishers and Buffers	Multiple-Belt Polishers Multiple-Head Buffers

TABLE 2

Classification of Contaminant Materials from
Grinding, Polishing, and Buffing

Contaminant Class	Classification Criteria	Example Materials
I	Dusts, fumes, and mists with exposure limits of 10 mg/M ³ and above; gases and vapors with exposure limits of 100 ppm and above.	Nuisance dusts (Iron, Steel, Aluminum, etc.)
II	Dusts, fumes, and mists with exposure limits of 1 mg/M ³ and above (up to 10 mg/M ³); gases and vapors with exposure limits of 1 ppm and above (up to 100 ppm).	Chromium Copper Nickel
III	Dusts, fumes, and mists with exposure limits below 1 mg/M ³ ; gases and vapors with exposure limits below 1 ppm.	Beryllium Cobalt Lead Silica Silver

TABLE 3

Summary of Minimum Ventilation Requirements for
Grinding, Polishing, and Buffing Operations
Ventilation Methods and Exhaust Flow Requirements

<u>Equipment Class</u>	<u>Open Hoods</u>	<u>Low-Volume High-Velocity Hoods</u>	<u>Shaped Hoods</u>	<u>Enclosing Hoods</u>
Surface-Type Grinders	Class I: $Q = 0.0003 V_s(10x^2 + A)$. Classes II & III: Not applicable. See Note 1.	Class I: $Q = KD$ where $K = 100-500$. Classes II & III: Not applicable. See Note 4.	Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Pedestal-Type Grinders	Class I: $Q = 0.0003 V_s(10x^2 + A)$. Classes II & III: Not applicable. See Note 2.	Class I: $Q = KD$ where $K = 100-500$. Classes II & III: Not applicable. See Note 4.	Class I: $Q = 0.0003 V_s D^2$ Classes II & III: Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Disc Grinders and Polishers	Not applicable.	Not applicable.	Class I: $Q = 200-6000$ cfm. (See Section 5.2.3). Classes II & III: Not applicable. See Note 4.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Internal Grinders	Not applicable.	Classes I & II: $Q = KD$ where $K = 100-500$. Class III: Not applicable. See Note 4.	Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Abrasive Cutting-Off Machines	Class I: $Q = 0.0003 V_s(10x^2 + A)$. Classes II & III: Not applicable. See Note 1.	Not applicable.	Class I: $Q = 0.0005 V_s D^2$ Classes II & III: Not applicable.	Classes I & II: 250 fpm face velocity. Class III: 400 fpm face velocity.

Table 3 Continued

Summary of Minimum Ventilation Requirements for
Grinding, Polishing, and Buffing Operations

Ventilation Methods and Exhaust Flow Requirements

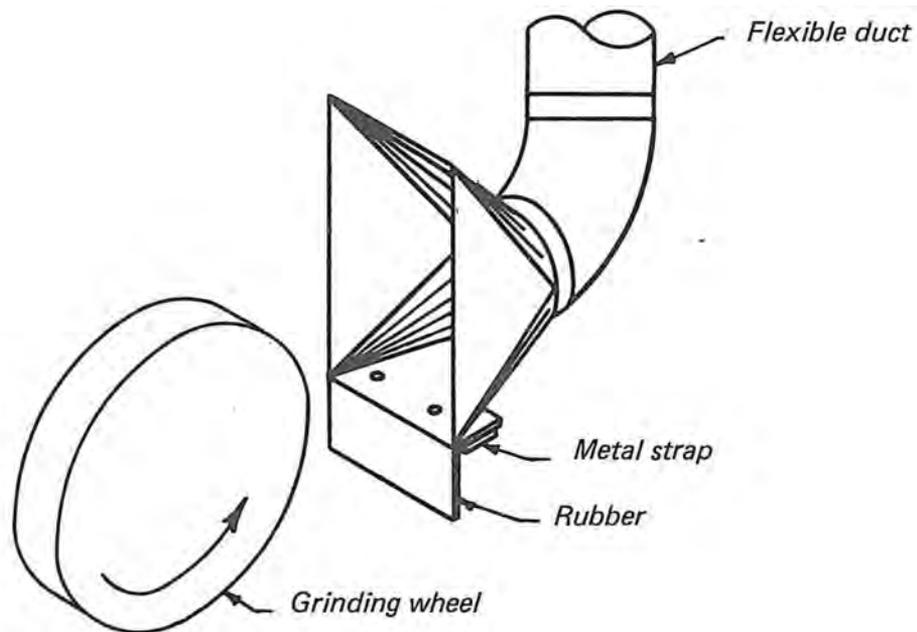
<u>Equipment Class</u>	<u>Open Hoods</u>	<u>Low Volume High-Velocity Hoods</u>	<u>Shaped Hoods</u>	<u>Enclosing Hoods</u>
Pedestal-Type Polishers and Buffers	Classes I & II: $Q = 0.0003 V_s (10x^2 + A)$. Class III; Not applicable. See Note 2.	Not applicable	Classes I & II: $Q = 0.0003 V_s D^2$ Class III: Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Belt Polishers	Not applicable.	Not applicable.	Class I: $Q = 0.00035V WL$. Classes II & III: Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Portable Grinders, Polishers and Buffers	Class I: Downdraft Table with 150 fpm face velocity. Classes II & III: Not applicable. See Note 3.	Classes I & II: Q dependent on machine configuration. (See Section 5.2.8). Class III: Not applicable.	Classes I & II: Q dependent on machine configuration. (See Section 5.2.8). Class III: Not applicable.	Class I: 100 fpm face velocity. Class II: 200 fpm face velocity. Class III: 400 fpm face velocity.
Multiple Polishers and Buffers	Classes I & II: $Q = 0.0003 V_s (10x^2 + A)$. for each polishing belt or buffing head. Class III: Not applicable.	Not applicable.	Classes I & II: $Q = 0.0003 V_s D^2$ for each polishing belt or buffing head. Class III: Not applicable.	Classes I & II: 250 fpm face velocity. Class III: 400 fpm face velocity.

Notes

- Hood should be located so that swarf flow from grinder is directed into hood face.
- Hood shall be located so that contaminated air is not drawn into operator's breathing zone.
- Operations shall be conducted so that flow of contaminants is toward hood and away from operator.
- Exhaust flow required shall be determined by test under grinding conditions. Range shown is a guide to probable requirement.

Nomenclature

- Q = Minimum exhaust flow; cfm
 V_s = Surface velocity of wheel, belt, or buff; fpm
X = Distance from hood face to nearest point on wheel, belt, or buff; in.
A = Hood face area; in.²
D = Diameter of wheel or buff, in.
W = Width of belt; in.
L = Belt polisher roller spacing; in.



Locate hood as close as possible to wheel and low enough to intercept swarf flow.

$$Q = 0.0003 V_s (10X^2 + A) \text{ but not less than } 100 \text{ cfm}$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

X = hood-wheel distance, in*

A = hood face area, sq in

Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x duct VP

**X measured from center of hood face to nearest point on wheel surface.*

FIGURE 2 SURFACE-TYPE GRINDER WITH OPEN HOOD

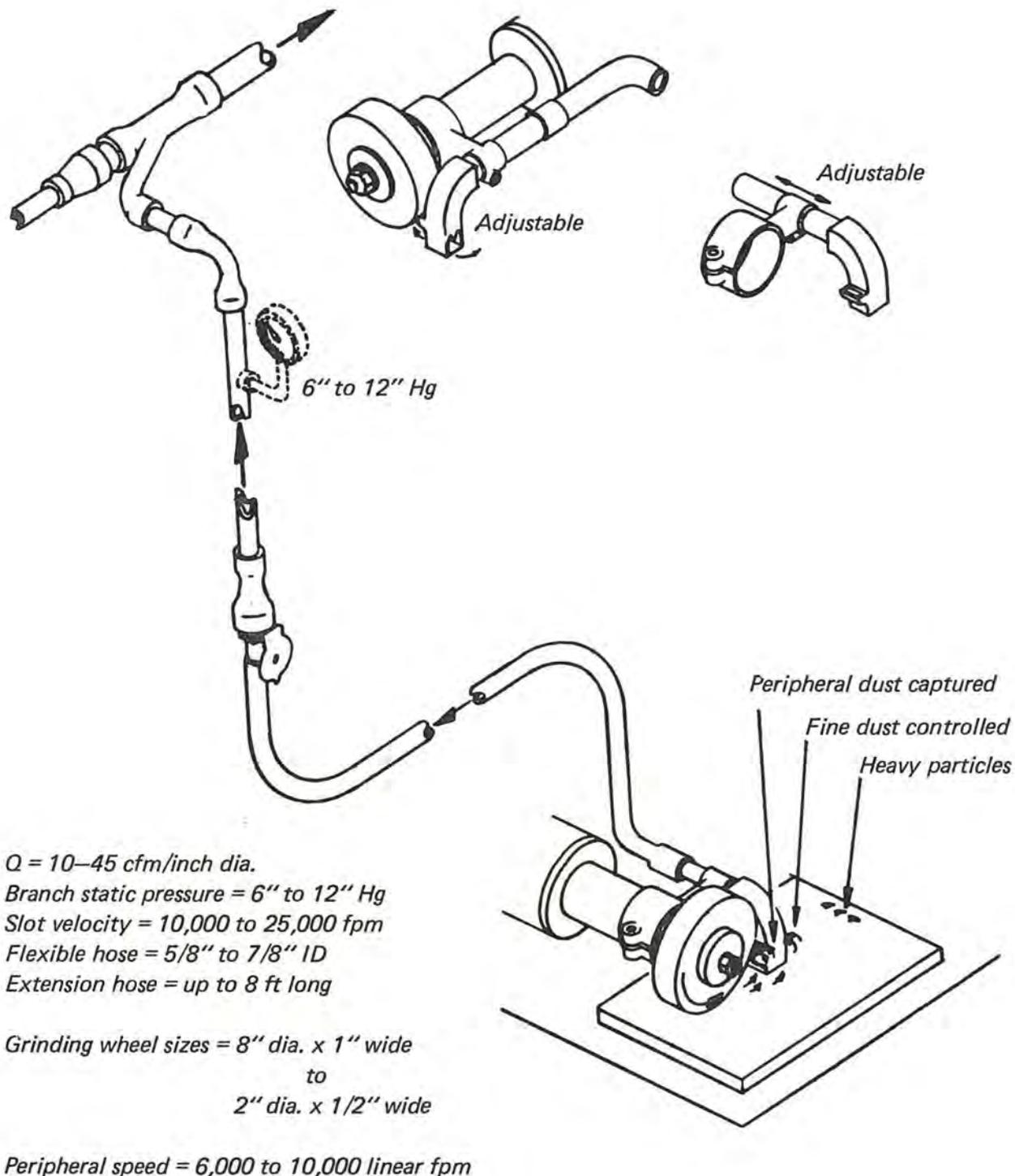


FIGURE 3 SURFACE-TYPE GRINDER WITH LOW-VOLUME-HIGH-VELOCITY HOOD

An enclosing hood may be used with a surface-type grinder for the control of Class I contaminants and shall be used for the control of Class II and Class III contaminants. Figure 4 illustrates an acceptable design and location for such a hood. The grinder shall be operated so that the flow of swarf from the grinding operation is directed toward the back of the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 4.

5.2.2 Pedestal-Type Grinders

An open hood may be used with a pedestal-type grinder for the control of Class I contaminants. Figure 5 illustrates acceptable designs and locations for such a hood. The hood shall not be located in a position which would cause contaminated air to flow into the breathing zone of the grinder operator. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in Figure 5.

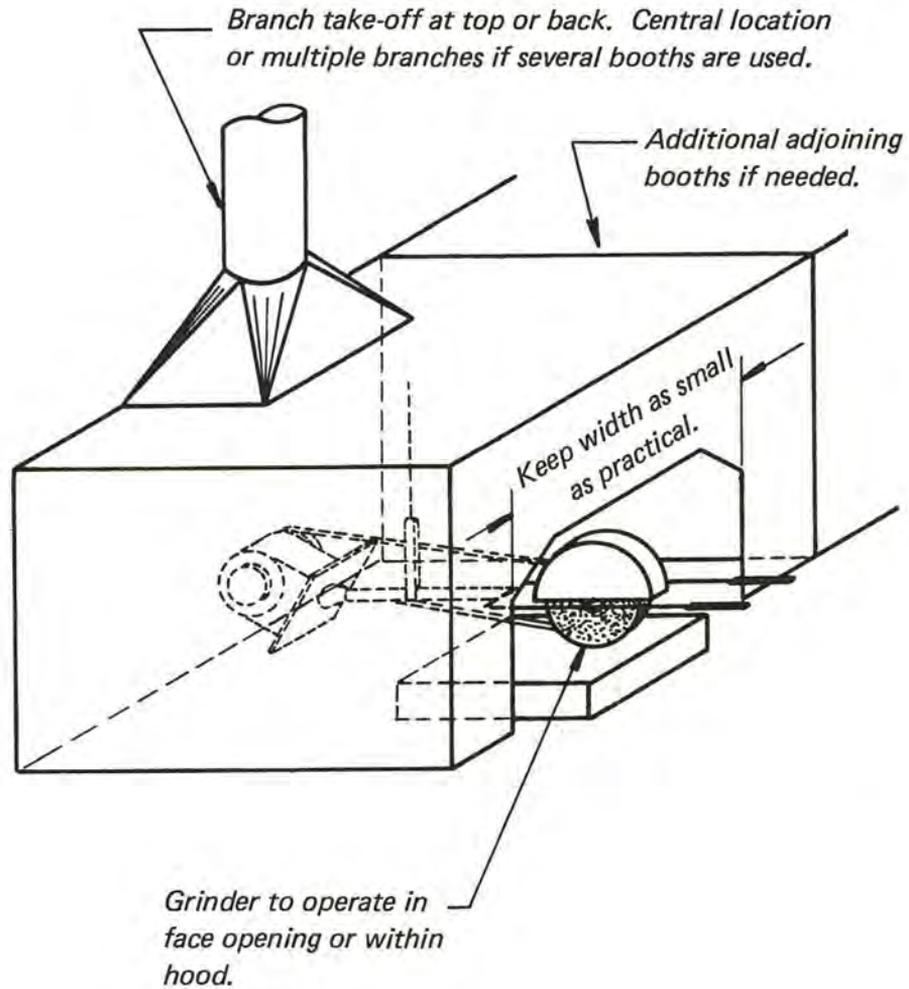
A low-volume-high-velocity hood may be used with a pedestal-type grinder for the control of Class I air contaminants. Figure 6 illustrates an acceptable design and location for such a hood. The exhaust flow required to control air contaminant exposures shall be determined by tests under actual grinding operations, and the exhaust flow so determined shall be maintained at all times while grinding operations are in progress. The exhaust flow range specified in Figure 6 is provided only as a guide to the probable exhaust flow requirement.

A shaped hood may be used with a pedestal-type grinder for the control of Class I contaminants. Figure 7 illustrates an acceptable design for such a hood. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in the figure. An open hood or a low-volume-high-velocity hood may be used in conjunction with a shaped hood to obtain more effective control of air contaminants.

An enclosing hood may be used with a pedestal-type grinder for the control of Class I contaminants and shall be used for the control of Class II and Class III contaminants. An acceptable design for the hood is shown in Figure 4. The grinder shall be located entirely within such a hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in the figure.

5.2.3 Disc Grinders and Polishers

A shaped hood may be used with a disc grinder or polisher for the control of Class I contaminants. An existing grinder housing may be used as a hood or a housing designed specifically for contaminant control may be used. Examples of shaped hoods used with disc grinders are shown in Figures 8, 9, and 10. The exhaust flow required to control air contaminant exposures shall be determined by test under actual grinding or polishing operations and the exhaust flow so determined shall be maintained at all times while grinding or polishing operations



EXHAUST FLOW REQUIREMENTS

Class I contaminants: Hood face velocity 100 fpm minimum

Class II contaminants: Hood face velocity 200 fpm minimum

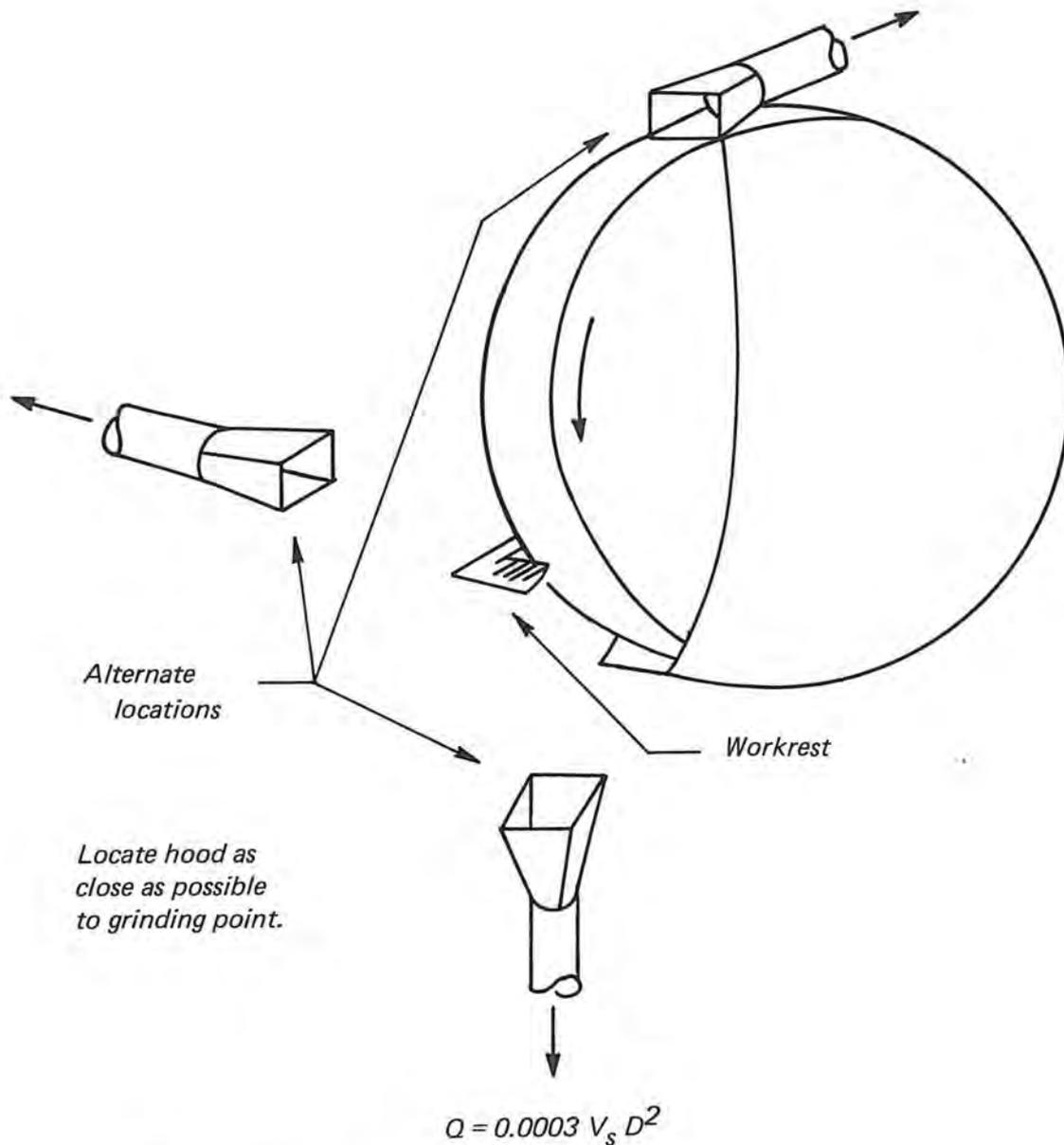
Class III contaminants: Hood face velocity 400 fpm minimum

Duct velocity = 3000 fpm minimum

Entry loss when face area less than 2 times duct area = 0.50 duct VP

Entry loss when face area at least 2 times duct area = entry loss factor for tapered hood X duct VP

FIGURE 4 SURFACE-TYPE GRINDER WITH ENCLOSING HOOD



Q = minimum exhaust volume, cfm

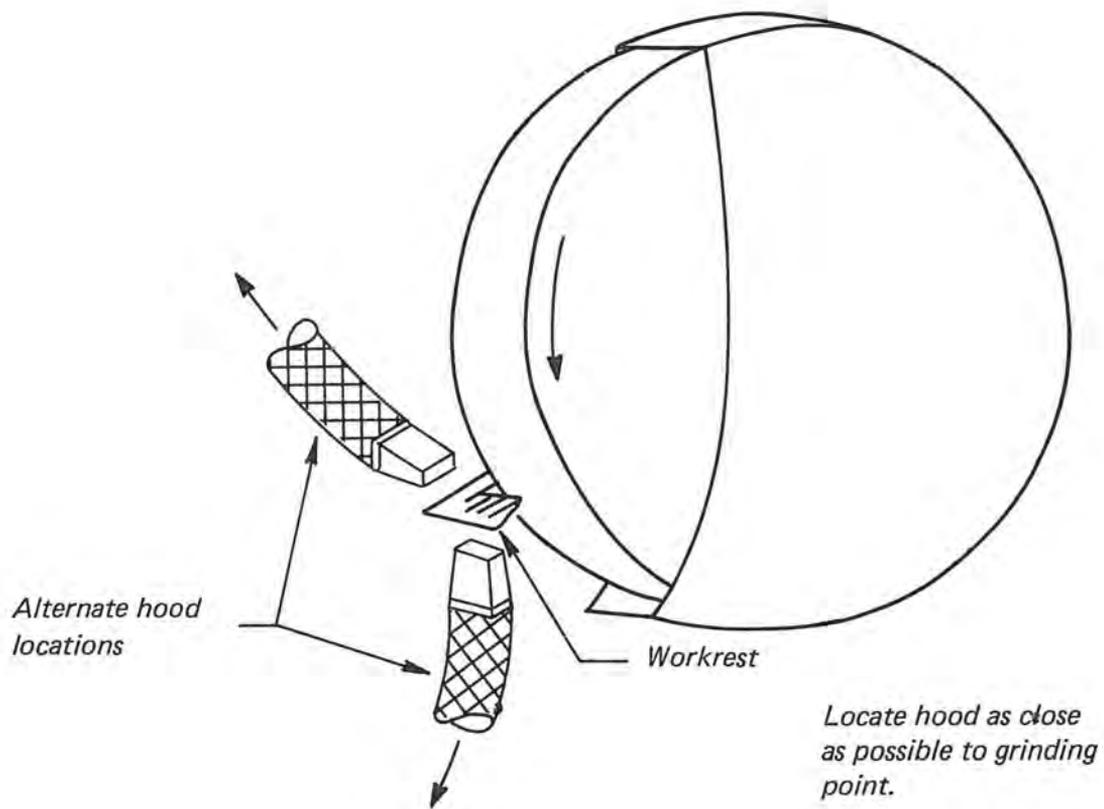
V_s = wheel surface speed, fpm

D = maximum wheel diameter, in

Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood X duct VP

FIGURE 5 PEDESTAL-TYPE GRINDER WITH OPEN HOOD

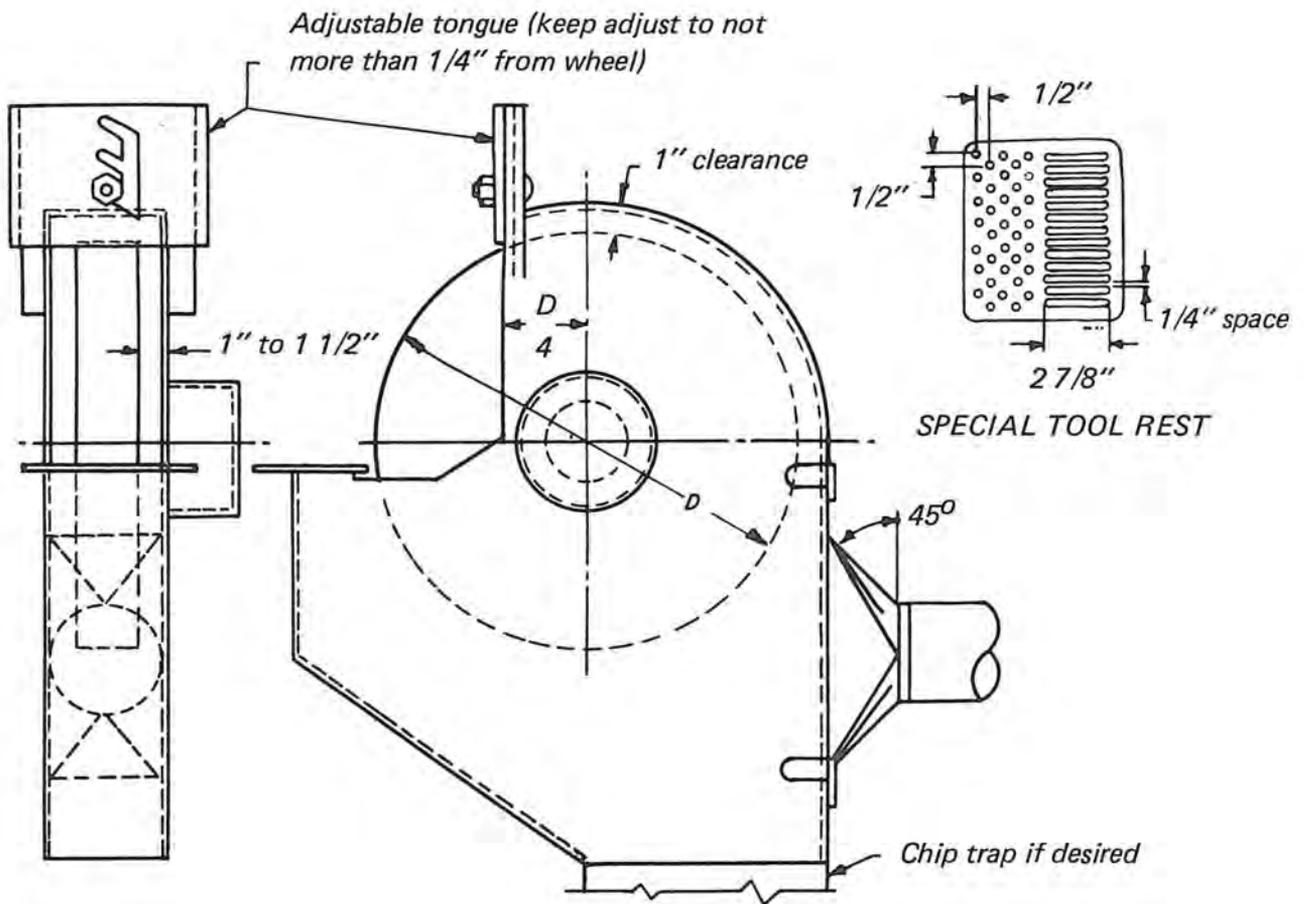


$Q = 10 \text{ to } 40 \text{ cfm/in of wheel diameter}$

Hood slot velocity = 10,000 to 25,000 fpm

(must exceed wheel surface speed)

FIGURE 6 PEDESTAL-TYPE GRINDER WITH LOW-VOLUME-HIGH-VELOCITY HOOD



$$Q = 0.0003 V_s D^2$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

D = maximum wheel diameter, in

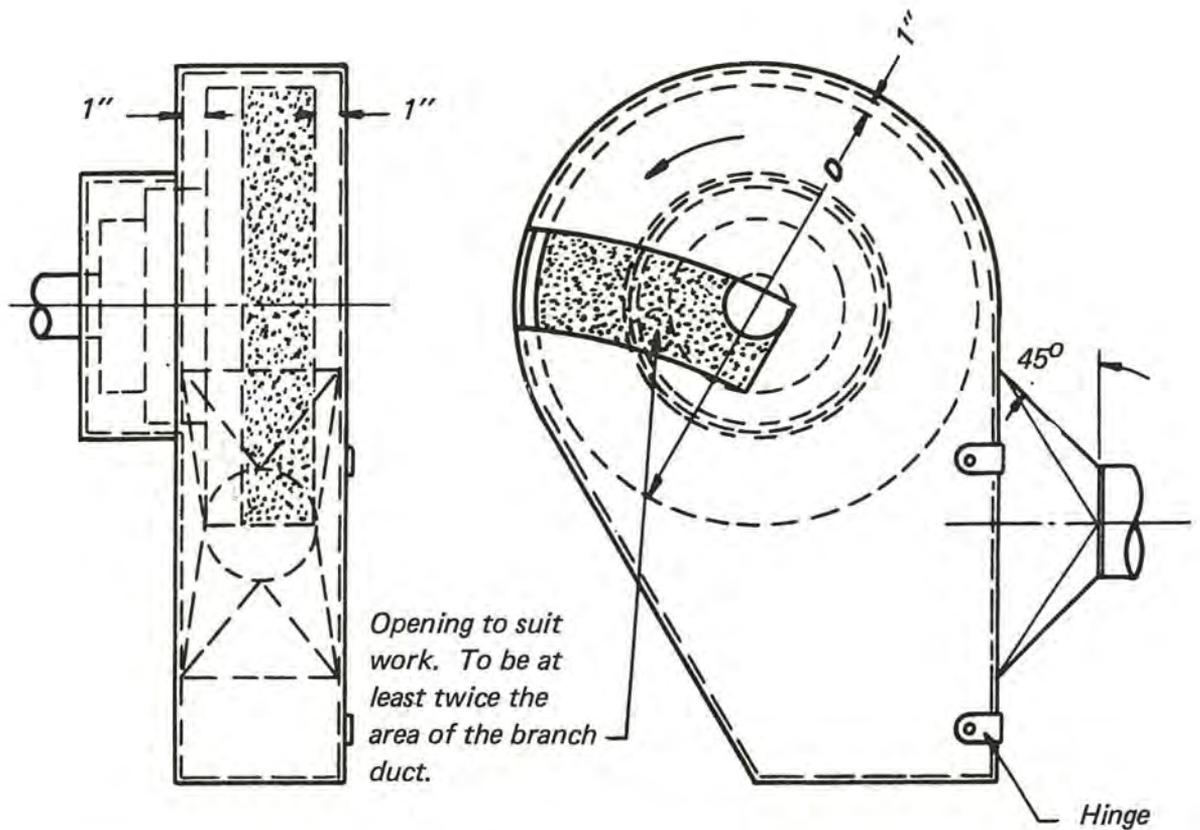
Duct velocity = 4500 fpm minimum in branch

= 3500 fpm minimum in main

Entry loss = 0.65 VP for straight takeoff

= 0.40 VP for tapered takeoff

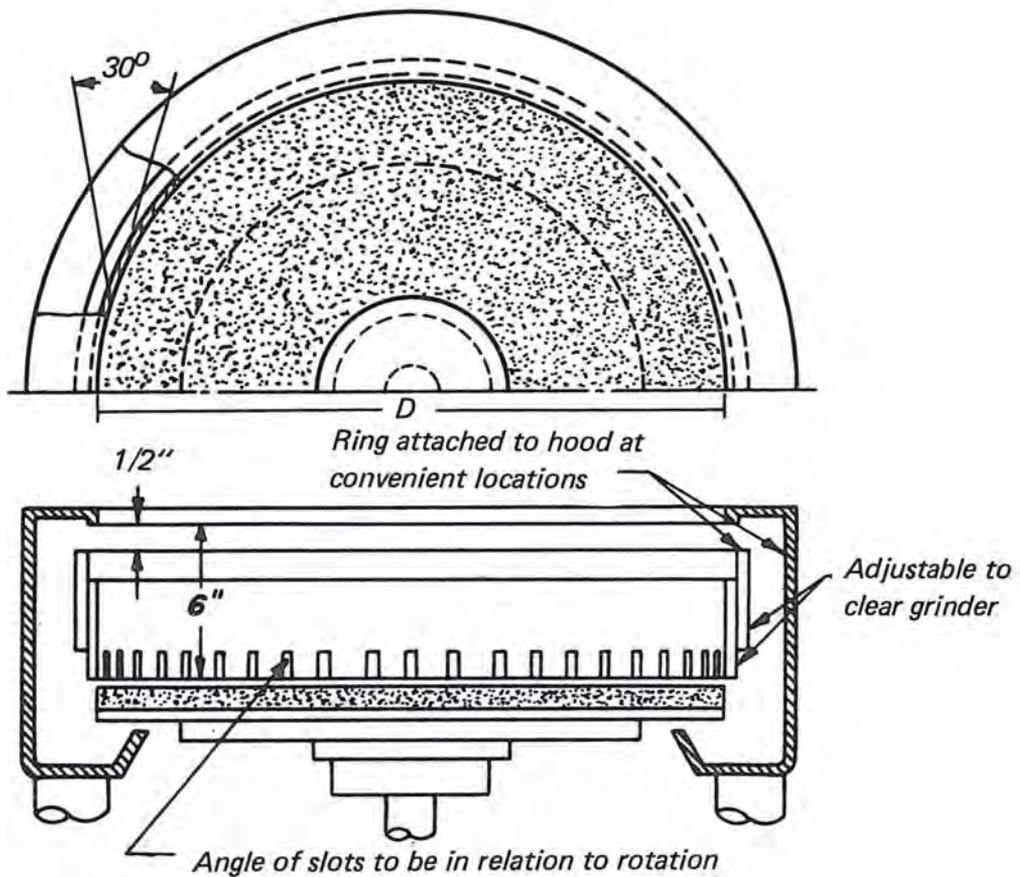
FIGURE 7 PEDESTAL-TYPE GRINDER WITH SHAPED HOOD



<i>Disc diam., inches</i>	<i>Min. exhaust volume, cfm</i>
<i>up to 12</i>	<i>220</i>
<i>over 12 to 19</i>	<i>390</i>
<i>over 19 to 30</i>	<i>610</i>
<i>over 30 to 36</i>	<i>880</i>

Duct velocity = 4500 fpm minimum in branch
= 3500 fpm minimum in main
Entry loss = 0.65 VP for straight takeoff
= 0.45 VP for tapered takeoff

FIGURE 8 HORIZONTAL SINGLE-SPINDLE DISC GRINDER WITH SHAPED HOOD

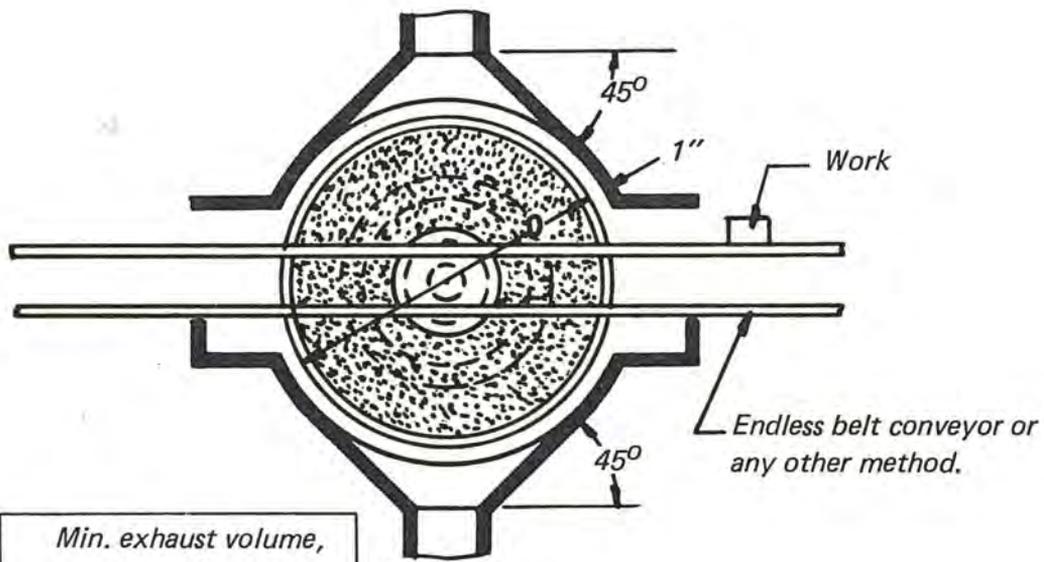
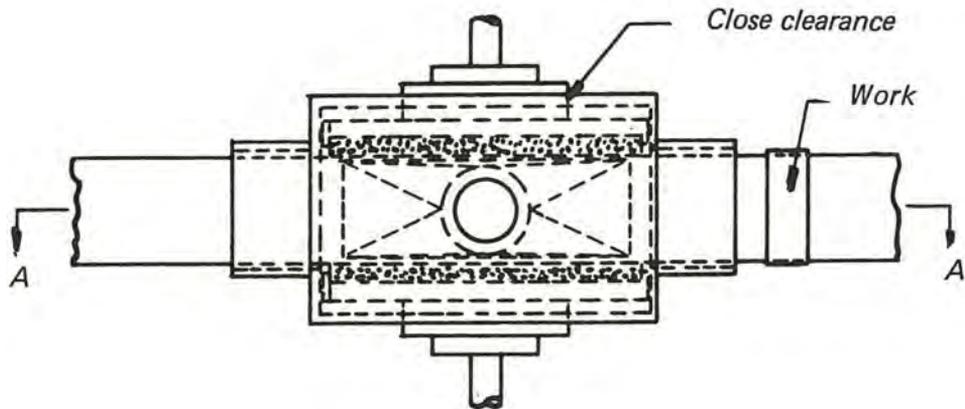


Disc diam., inches	1/2 or more of disc covered		Disc not covered	
	No. *	Min. exhaust, cfm	No. *	Min. exhaust, cfm
up to 20	1	500	2	780
over 20 to 30	2	780	2	1480
over 30 to 53	2	1770	4	3530
over 53 to 72	2	3140	5	6010

*Number of exhaust outlets around periphery of hood; or equal distribution provided by other means.

Duct velocity = 4500 minimum in branch
= 3500 minimum in main
Slot velocity = 2000 fpm minimum
Entry loss = 1.0 slot VP + 0.5 branch duct VP

FIGURE 9 VERTICAL SPINDLE DISC GRINDER WITH SHAPED HOOD



Section A-A

Disc diam., inches	Min. exhaust volume, cfm
up to 19	610
over 19 to 25	880
over 25 to 30	1200
over 30 to 53	1990
over 53 to 72	6280

Note: Practically complete enclosure of discs with machine housing and exhaust from the housing is acceptable.

Duct velocity = 4500 fpm minimum in branch
 = 3500 fpm minimum in main
 Entry loss = 0.65 VP for straight takeoff
 = 0.45 VP for tapered takeoff

FIGURE 10 HORIZONTAL DOUBLE-SPINDLE DISC GRINDER WITH SHAPED HOOD

are in progress. The exhaust flows indicated in Figures 8, 9, and 10 are appropriate only for the grinder-hood combinations shown but can be used as guides for establishing approximate flow requirements for similar equipment.

An enclosing hood may be used with a disc grinder or polisher for the control of Class I contaminants and shall be used for the control of Class II and Class III contaminants. An acceptable design for such a hood is illustrated in Figure 4. The grinder shall be located entirely within the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 4.

5.2.4 Internal Grinders

A low-volume-high-velocity hood may be used with an internal grinder for the control of Class I and Class II contaminants. An example of a design for such a hood is illustrated in Figure 11. The exhaust flow required to control air contaminant exposures shall be determined by test under actual grinding operations and the exhaust flow so determined shall be maintained at all times while grinding operations are in progress. The exhaust flow range specified in Figure 11 is provided only as a guide to the probable exhaust flow requirement.

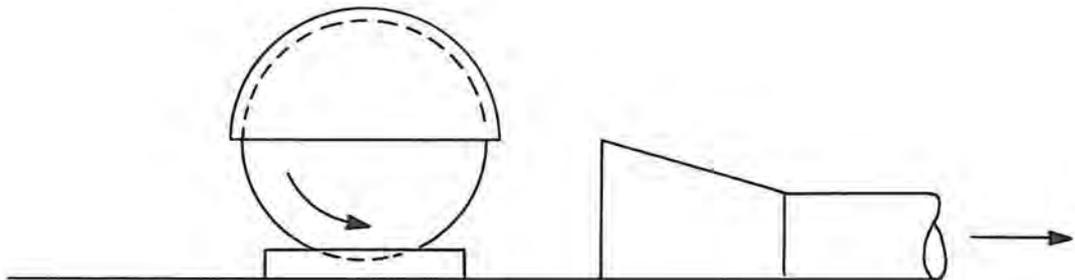
An enclosing hood may be used with an internal grinder for the control of Class I and Class II contaminants and shall be used for the control of Class III contaminants. Figure 4 illustrates an acceptable design for such a hood. The grinder shall be located entirely within the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 4.

5.2.5 Abrasive Cutting-Off Machines

An open hood may be used with an abrasive cutting-off machine for the control of Class I air contaminants. An acceptable design for such a hood is illustrated in Figure 12. The hood shall be located so that the swarf flow from the cutting-off operation flows into the hood face and the hood face shall be of sufficient size to intercept the swarf flow at all positions of the cutting-off wheel. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in Figure 12.

A shaped hood may be used with an abrasive cutting-off machine for the control of Class I air contaminants. An example of such a hood is illustrated in Figure 13. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in the figure.

An enclosing hood may be used with an abrasive cutting-off machine for the control of Class I contaminants and shall be used for the control of Class II and Class III contaminants. An acceptable design and location for such a hood is illustrated in Figure 14. The machine shall be operated so that the flow of swarf from the operation is directed toward the back of the hood. The exhaust flow shall be



$$Q = 0.0003 V_s (10X^2 + A)$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

X = hood-wheel distance, in

A = hood face area, sq in

X measured from center of hood face to nearest point on wheel surface.

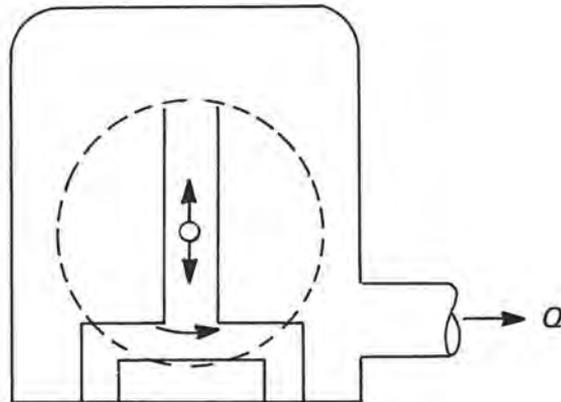
Hood face height shall be greater than effective wheel cutting depth.

Locate hood as close as possible to wheel and
in a position to intercept swarf flow.

Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x duct VP

FIGURE 12 ABRASIVE CUTTING-OFF MACHINE WITH OPEN HOOD



$$Q = 0.0005 V_s D^2$$

Q = minimum exhaust volume, cfm

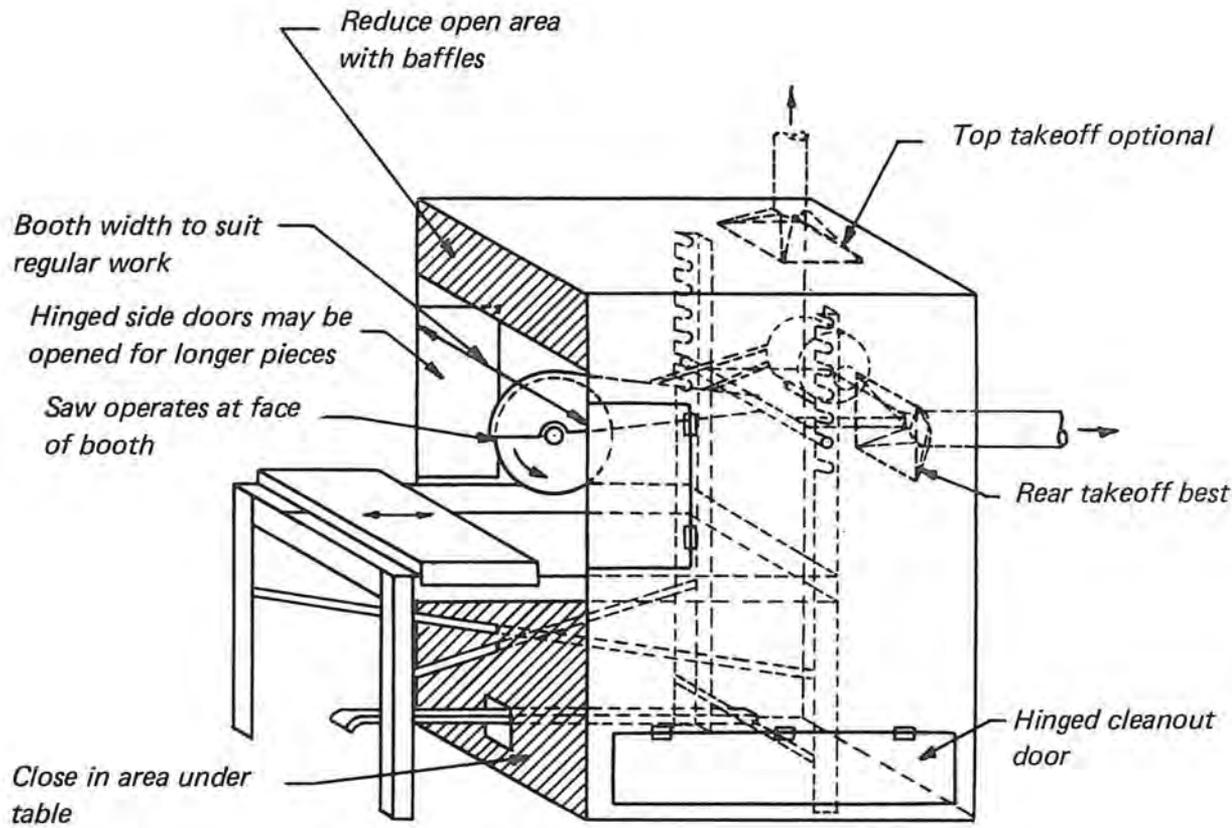
V_s = wheel surface velocity, fpm

D = wheel diameter, in

Duct velocity = 3500 fpm minimum

Entry loss = 0.50 duct VP

FIGURE 13 ABRASIVE CUTTING-OFF MACHINE WITH SHAPED HOOD



$Q = \text{minimum } 250 \text{ cfm/sq ft of open area for Class I and Class II contaminants}$
 $= \text{minimum } 400 \text{ cfm/sq ft of open area for Class III contaminants}$
 Duct velocity = 3500 fpm minimum
 Entry loss for takeoff without taper = 0.50 duct VP
 Entry loss for takeoff with taper = entry loss factor for tapered hood X duct VP

FIGURE 14 ABRASIVE CUTTING-OFF MACHINE WITH ENCLOSING HOOD

maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 14.

5.2.6 Pedestal-Type Polishers and Buffers

An open hood may be used with a pedestal-type polisher or buffer for the control of Class I and Class II contaminants. Figure 15 illustrates an acceptable design and location for such a hood. The hood shall not be located in a position which would cause contaminated air to flow into the breathing zone of the machine operator. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in Figure 15.

A shaped hood may be used with a pedestal-type polisher or buffer for the control of Class I and Class II contaminants. The hood shall be designed generally as shown in Figure 16, 17, or 18, and the minimum exhaust flow through the hood shall be maintained in accordance with the appropriate formula contained in the figures.

An enclosing hood may be used with a pedestal-type polisher or buffer for the control of Class I and Class II contaminants and shall be used for the control of Class III contaminants. Figure 4 illustrates an acceptable design for such a hood. The machine shall be located entirely within the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 4.

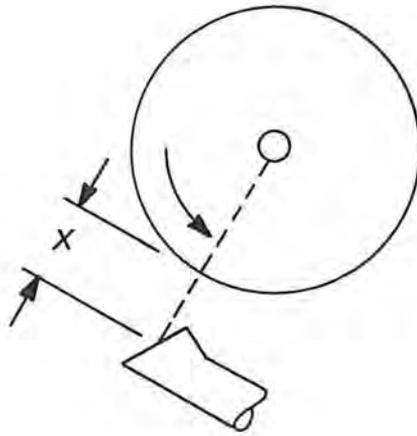
5.2.7 Belt Polishers

A shaped hood may be used with a belt polisher for the control of Class I contaminants. An acceptable design for such a hood is illustrated in Figure 19. The minimum exhaust flow through the hood shall be maintained in accordance with the formula contained in the figure.

An enclosing hood may be used with a belt polisher for the control of Class I contaminants and shall be used for the control of Class II and Class III contaminants. Figure 4 illustrates an acceptable design for such a hood. The polisher shall be located entirely within the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 4.

5.2.8 Portable Grinders, Polishers, and Buffers

A downdraft table may be used with portable grinders, polishers, and buffers for the control of Class I contaminants. Acceptable designs for such tables are illustrated in Figures 20 and 21. Operations shall be conducted above the table top and with the flow of contaminants directed away from the operator and toward the table. The exhaust flow through the table shall be sufficient to establish a face velocity at the table surface of 150 fpm or greater.



$$Q = 0.0003 V_s (10X^2 + A)$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

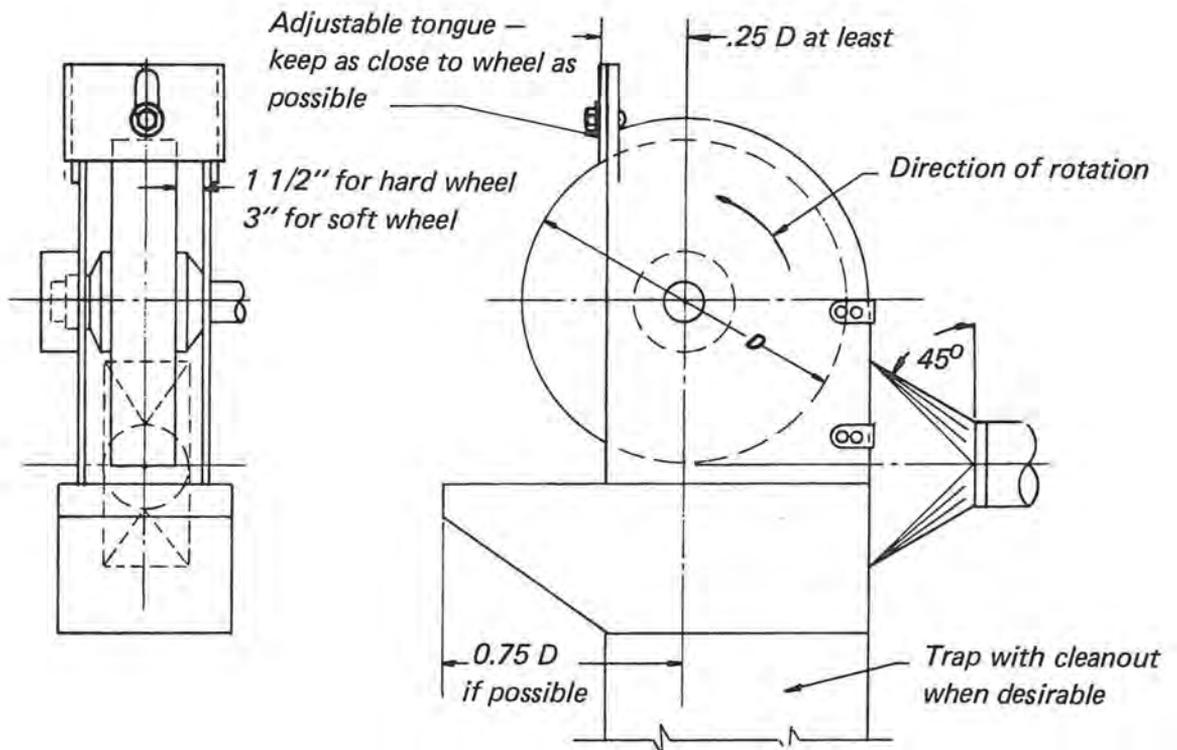
X = hood-wheel distance, in

A = hood face area, sq in

Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x
duct VP

FIGURE 15 PEDESTAL-TYPE POLISHER OR BUFFER WITH OPEN HOOD



$$Q = 0.0003 V_s D^2$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

D = maximum wheel diameter, in

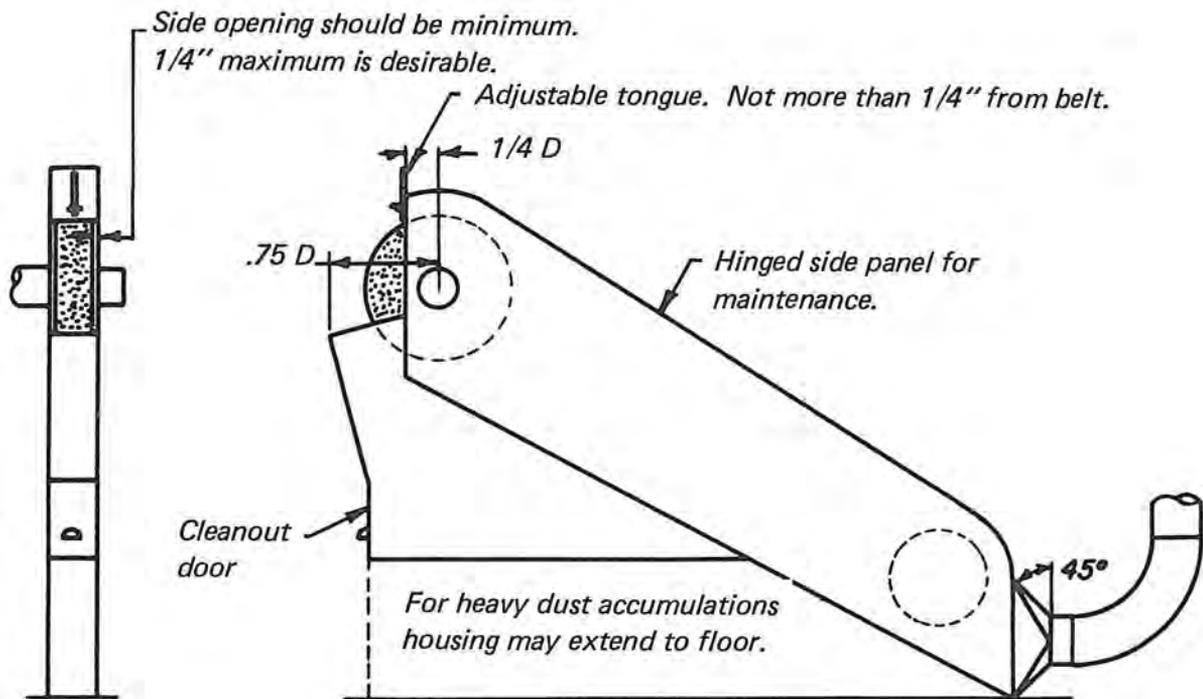
In cases of extra wide wheels (W greater than $\frac{D}{4}$),
increase Q by factor equal to $\frac{4W}{D}$. (W = wheel width, in)

Duct velocity = 3500 fpm minimum

Entry loss = 0.65 duct VP for straight takeoff

= 0.40 duct VP for tapered takeoff

FIGURE 16 PEDESTAL-TYPE POLISHER OR BUFFER WITH SHAPED HOOD



$$Q = 0.0003 V_s D^2$$

where Q = minimum exhaust volume, cfm

V_s = belt surface speed, fpm

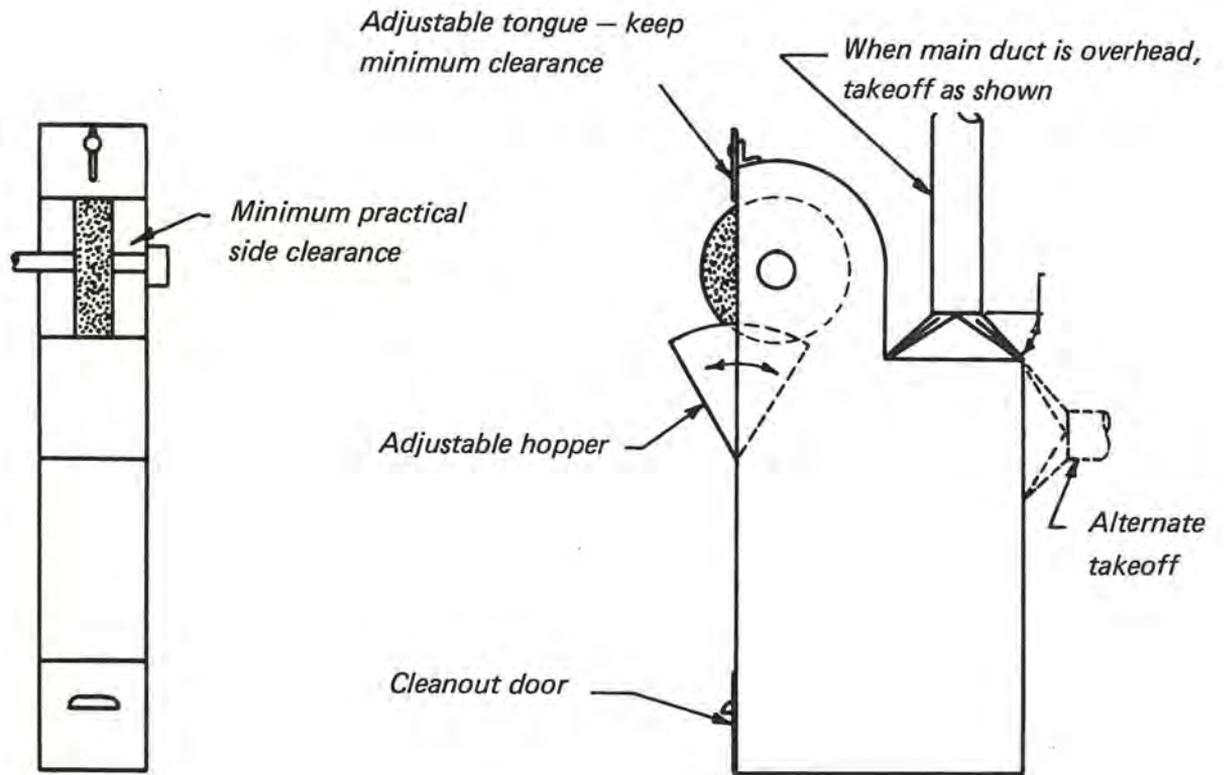
D = contact wheel diameter, in

Duct velocity = 3500 fpm minimum

Entry loss = 0.65 duct VP for straight takeoff

= 0.40 duct VP for tapered takeoff

FIGURE 17 BACKSTAND IDLER POLISHER WITH SHAPED HOOD



$$Q = 0.0003 V_s D^2$$

where Q = minimum exhaust volume, cfm

V_s = wheel surface speed, fpm

D = maximum wheel diameter, in

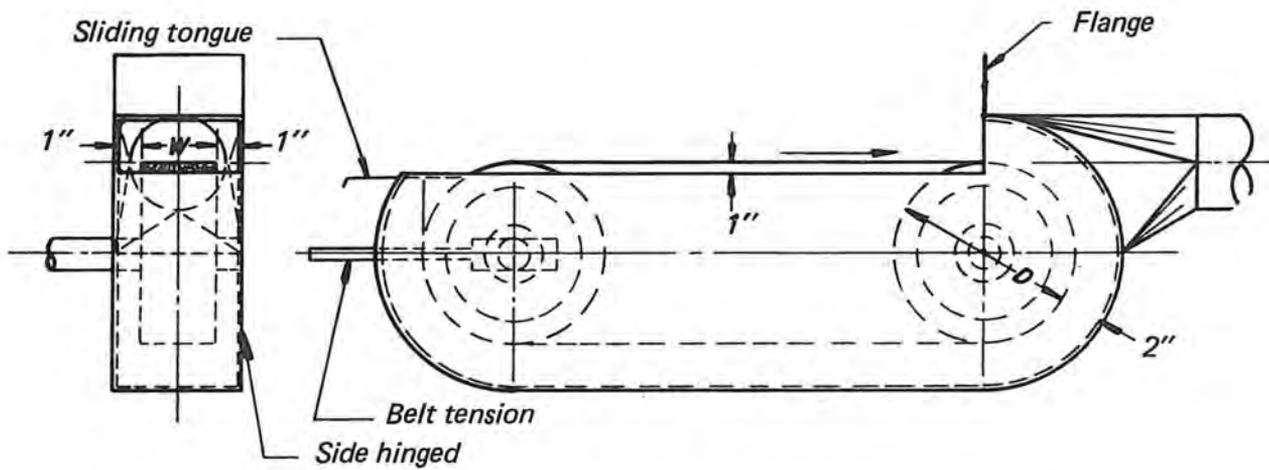
In cases of extra wide wheels (W greater than $\frac{D}{4}$),
increase Q by factor equal to $\frac{4W}{D}$. (W = wheel width, in)

Duct velocity = 3500 fpm minimum

Entry loss = 0.65 duct VP for straight takeoff

= 0.40 duct VP for tapered takeoff

FIGURE 18 BUFFING LATHE WITH SHAPED HOOD



$$Q = 0.00035 V_s W L$$

where Q = minimum exhaust volume, cfm

V_s = belt surface speed, fpm

L = roller spacing, in

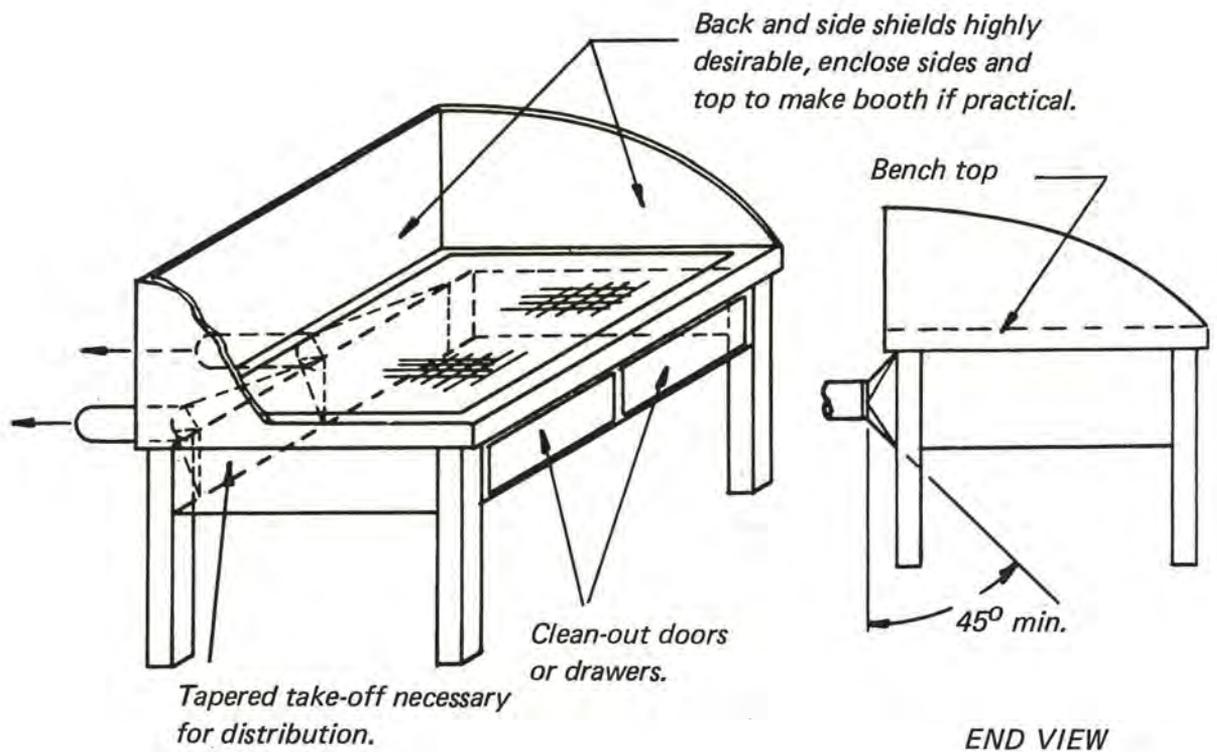
W = belt width, in

Duct velocity = 3500 fpm minimum

Entry loss = 0.65 duct VP for straight takeoff

= 0.40 duct VP for tapered takeoff

FIGURE 19 BELT POLISHER WITH SHAPED HOOD

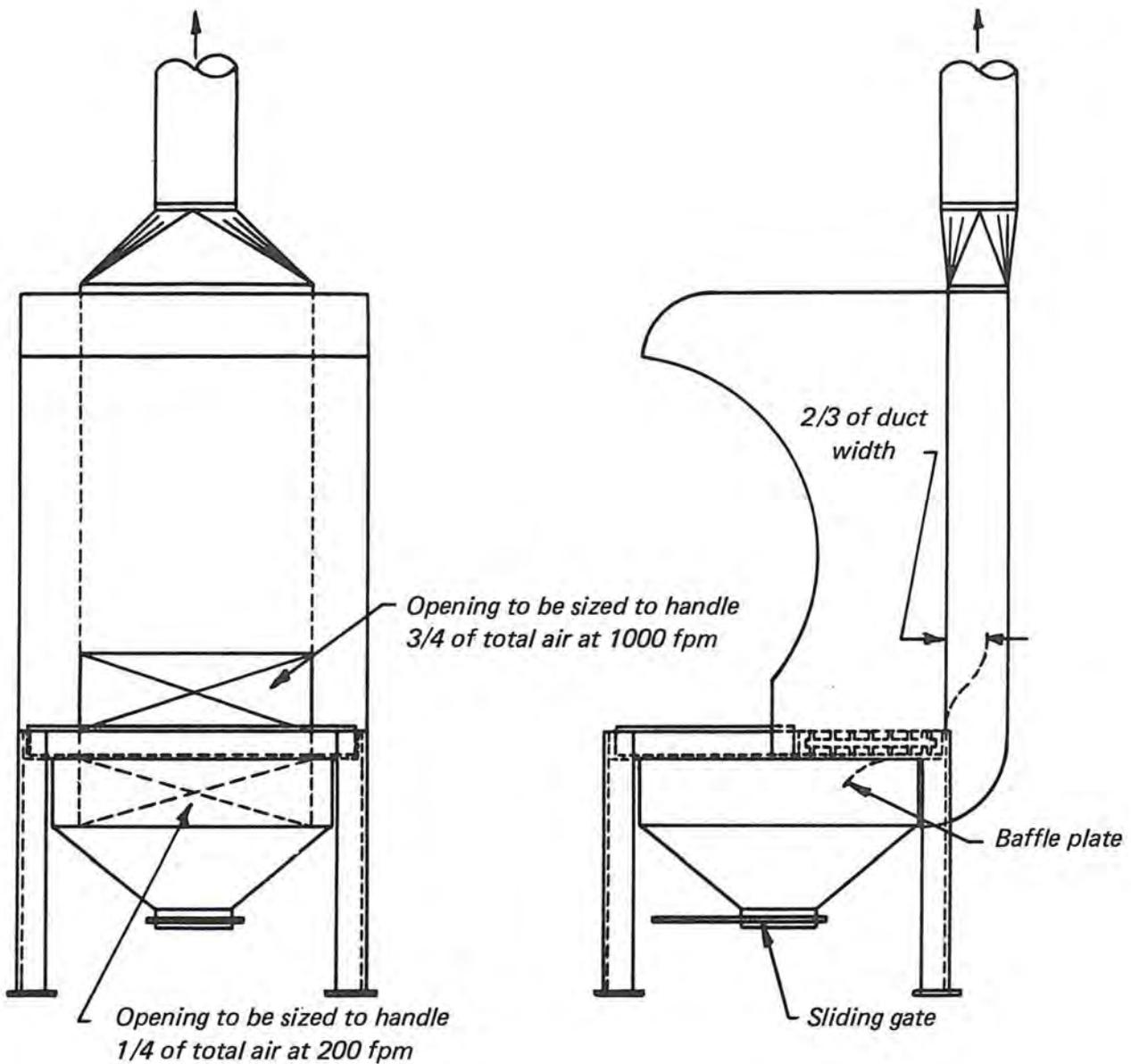


$Q = \text{minimum } 150 \text{ cfm/sq ft of table area}$

$\text{Duct velocity} = 3500 \text{ fpm minimum}$

$\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

FIGURE 20 DOWNDRAFT TABLE FOR PORTABLE GRINDING, POLISHING, OR BUFFING OPERATIONS



$Q = \text{minimum } 150 \text{ cfm/sq ft of hood face}$

$\text{Duct velocity} = 3500 \text{ fpm}$

$\text{Entry loss} = \text{entry loss factor for tapered hood} \times \text{duct VP}$

FIGURE 21 CROSSDRAFT TABLE FOR PORTABLE GRINDING,
POLISHING, OR BUFFING OPERATIONS

A low-volume-high-velocity hood may be used with a portable grinder or polisher for the control of Class I and Class II contaminants. Examples of low volume-high-velocity hood designs are shown in Figures 22 and 23. The exhaust flow required to control air contaminant exposures shall be determined under actual grinding or polishing conditions for each machine-hood combination, and the exhaust flow so determined shall be maintained at all times while grinding or polishing operations are in progress. The exhaust flow ranges indicated in Figures 22 and 23 are provided only as guides to probable exhaust flow requirements.

A shaped hood may be used with a portable grinder for the control of Class I and Class II contaminants. An example of a shaped hood is shown in Figure 24. The exhaust flow required to control air contaminant exposures shall be determined by test under actual grinding operations for each machine-hood combination, and the exhaust flow so determined shall be maintained at all times while grinding operations are in progress. The exhaust flow range indicated in Figure 24 is provided only as a guide to the probable exhaust flow requirement.

An enclosing hood may be used with a portable grinding, polishing, or buffing machine for the control of Class I and Class II contaminants and shall be used for the control of Class III contaminants. An acceptable design for such a hood is illustrated in Figure 25. The machine shall be located entirely within the hood. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 25.

5.2.9 Multiple Polishers and Buffers

Open or shaped hoods may be used with multiple polishers and buffers for the control of Class I contaminants. A separate hood shall be installed for each polishing belt or buffing head conforming with the design and operational requirements specified in Section 5.2.6.

An enclosing hood may be used with a multiple polishing or buffing machine for the control of Class I contaminants and shall be used for the control of Class II or Class III contaminants. Examples of enclosing hood designs for multiple polishers and buffers are shown in Figures 26 and 27. The exhaust flow shall be maintained at a rate sufficient to establish the appropriate hood face velocity specified in Figure 26 and 27.

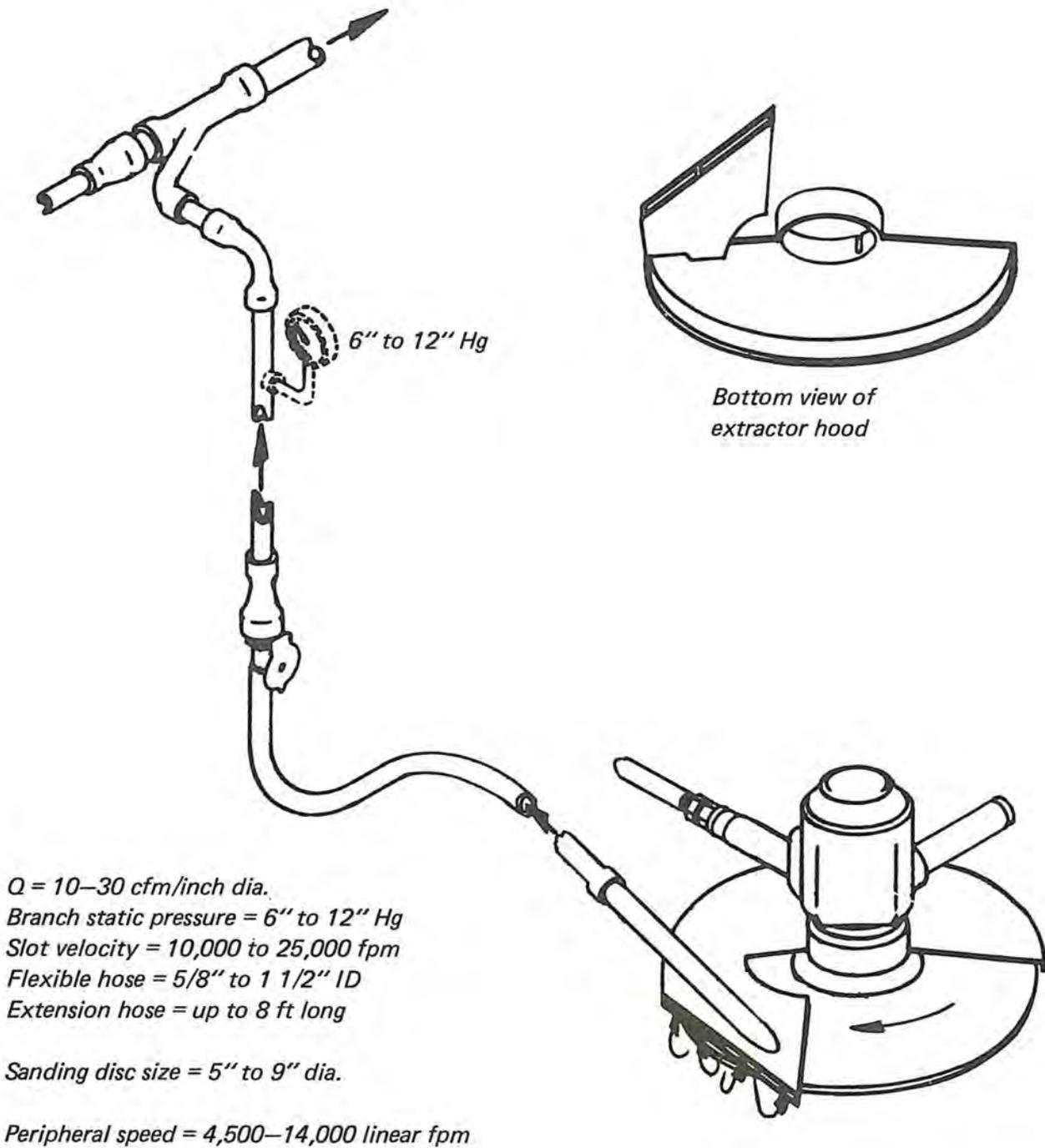


FIGURE 22 DISC POLISHER WITH LOW-VOLUME-HIGH-VELOCITY HOOD

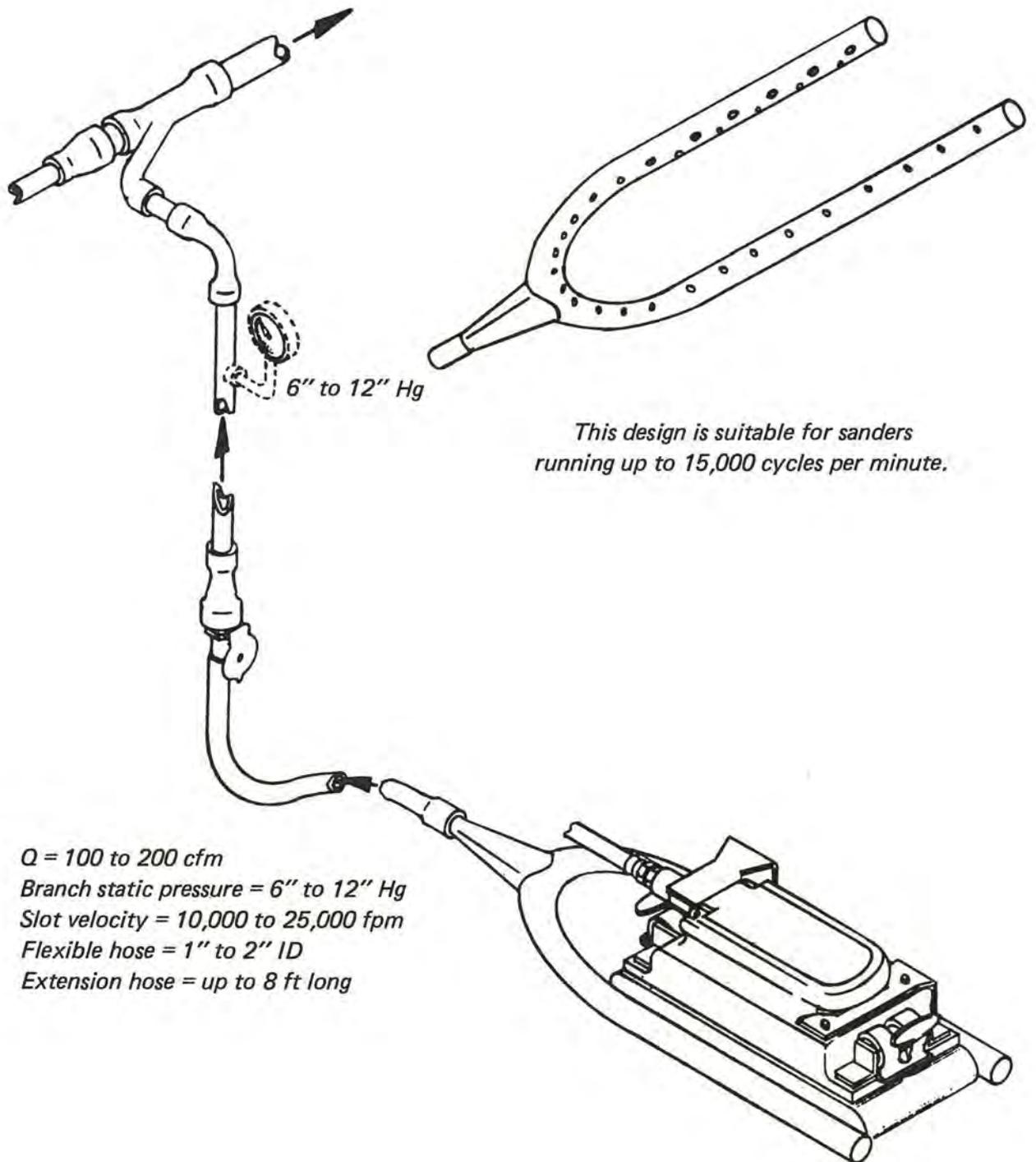


FIGURE 23 VIBRATORY POLISHER WITH LOW-VOLUME-HIGH-VELOCITY HOOD

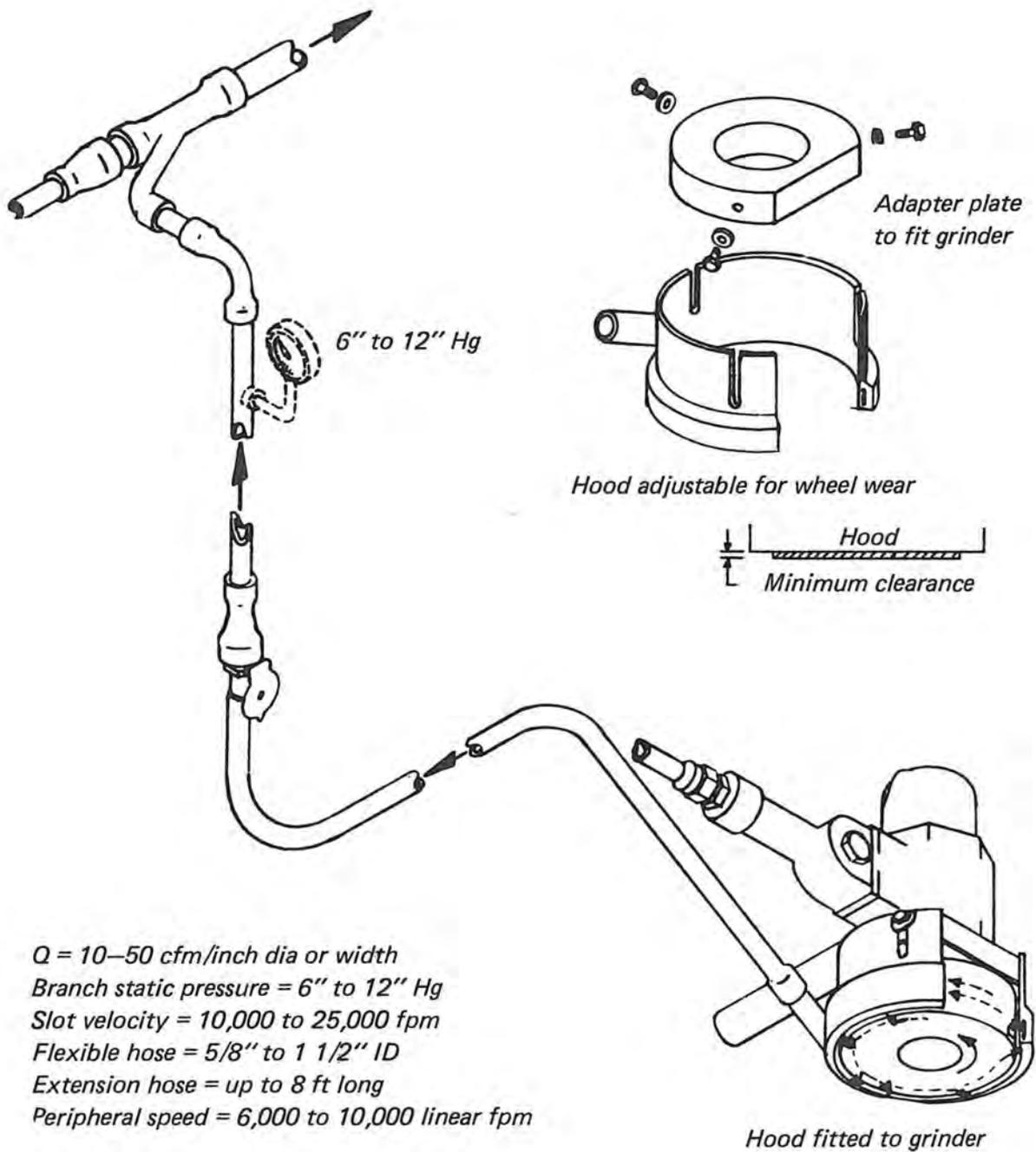
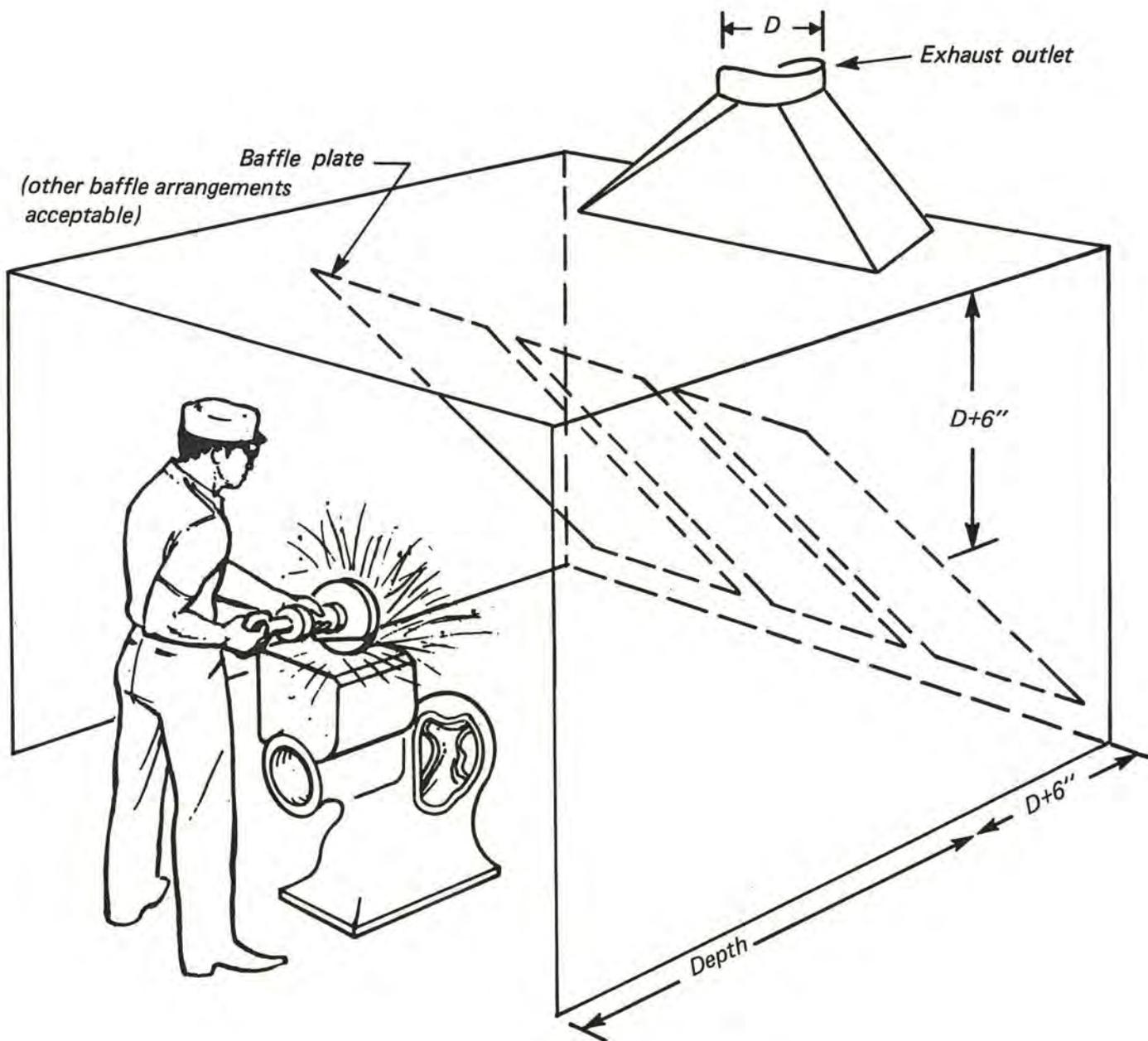


FIGURE 24 PORTABLE GRINDER WITH SHAPED HOOD



$$Q = WHV$$

= required exhaust volume, cfm

Width (W) = equipment width + 6', feet

Height (H) = equipment height + 3' (min. = 7'), feet

Depth = equipment depth + 6', feet

Baffle area = 0.40 WH, sq ft

Face velocity (V) = 100 fpm minimum for Class I contaminants

= 200 fpm minimum for Class II contaminants

= 400 fpm minimum for Class III contaminants

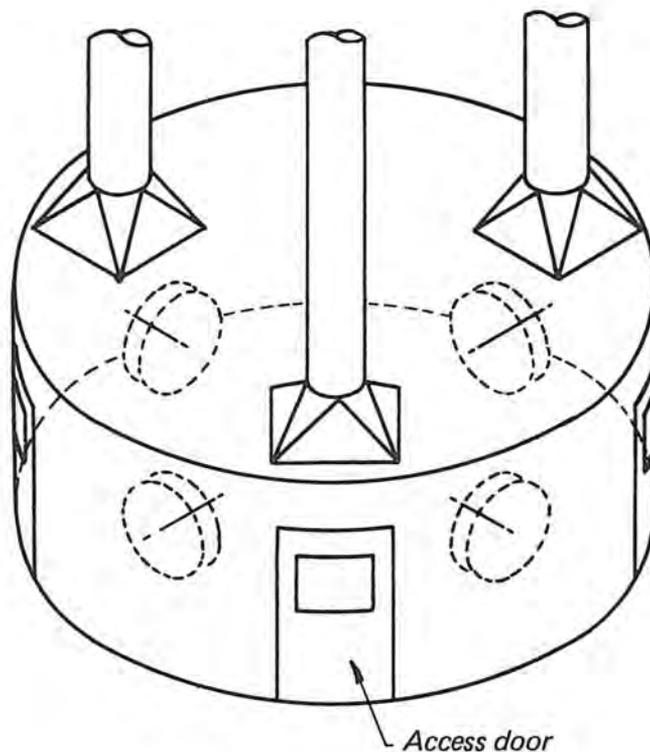
Entry loss for tapered takeoff (shown) plus baffles = 1.78 slot VP

plus entry loss factor for tapered hood X duct VP

Entry loss for plain duct end takeoff plus baffles =

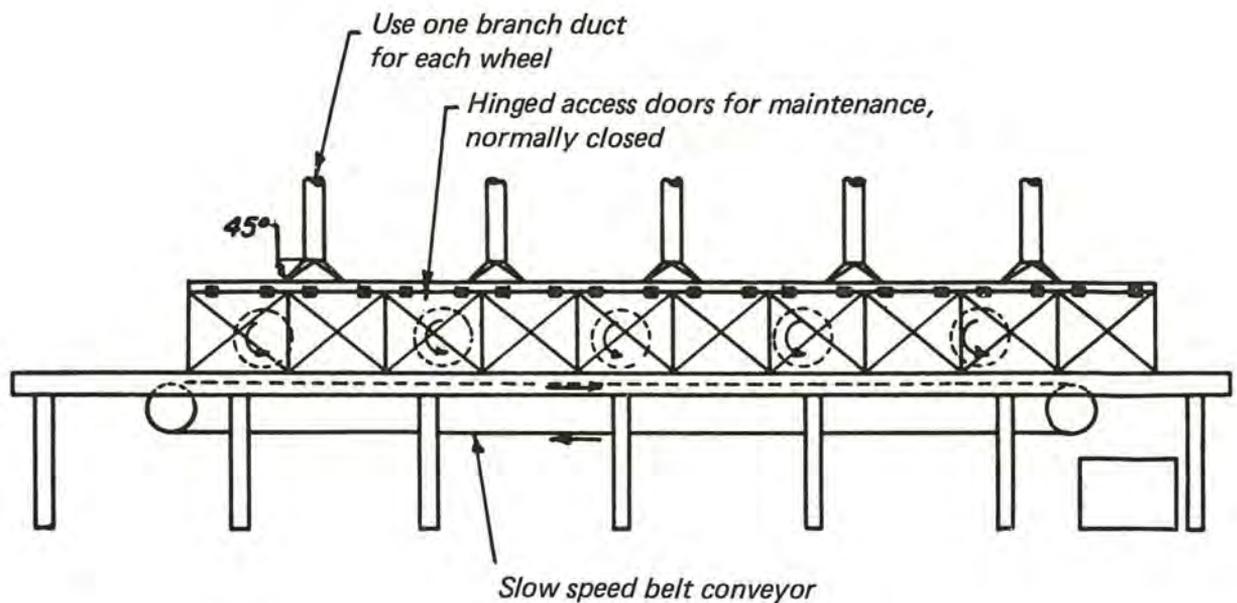
1.78 slot VP + 0.50 duct VP

FIGURE 25 ENCLOSING HOOD FOR PORTABLE GRINDING, POLISHING, OR BUFFING OPERATIONS



Q = minimum 250 cfm/sq ft of open area for Class I or Class II contaminants
 For Class III contaminants hood shall be fully enclosed with negative internal static pressure of 0.1 in water gauge
 Duct velocity = 3500 fpm minimum
 Entry loss when open area less than 2 times duct area = 0.50 duct VP
 Entry loss when open area at least 2 times duct area = entry loss factor for tapered hood X duct VP

FIGURE 26 ENCLOSING HOOD FOR CIRCULAR MULTIPLE BUFFERS



Q = minimum 250 cfm/sq ft of open area for Class I or Class II contaminants
 For Class III contaminants hood shall be fully enclosed with negative internal static pressure of 0.1 in water gauge.

Duct velocity = 3500 fpm minimum

Entry loss when open area less than 2 times duct area = 0.50 duct VP

Entry loss when open area at least 2 times duct area = entry loss factor for tapered hood X duct VP

FIGURE 27 ENCLOSING HOOD FOR LINEAR MULTIPLE BUFFERS

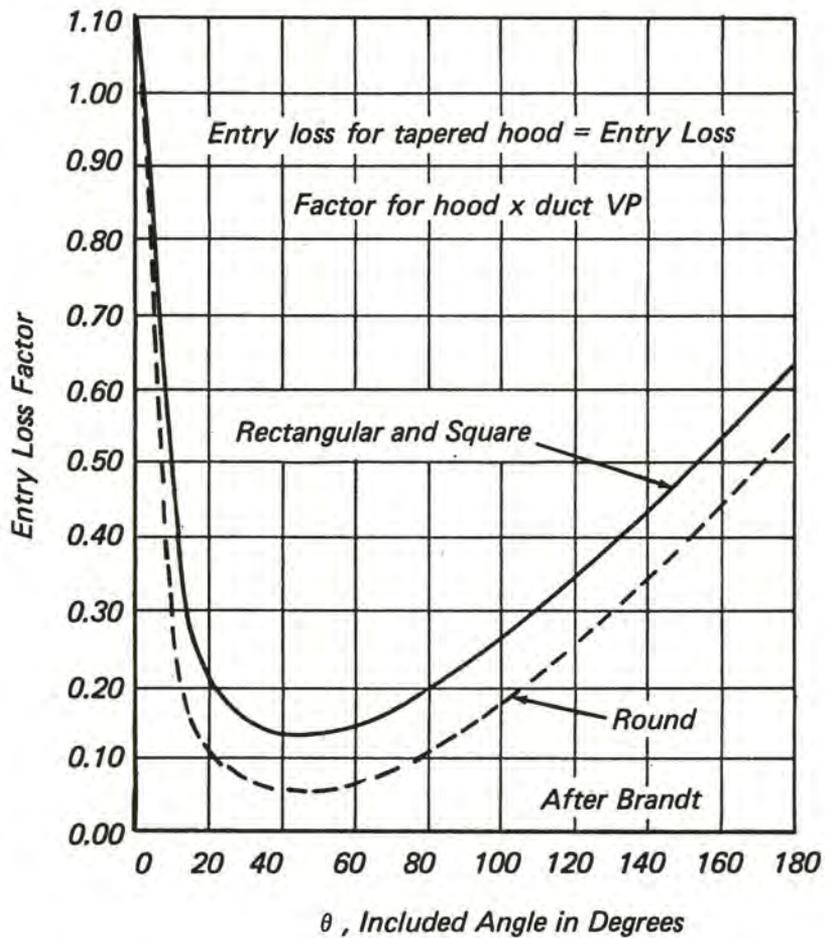
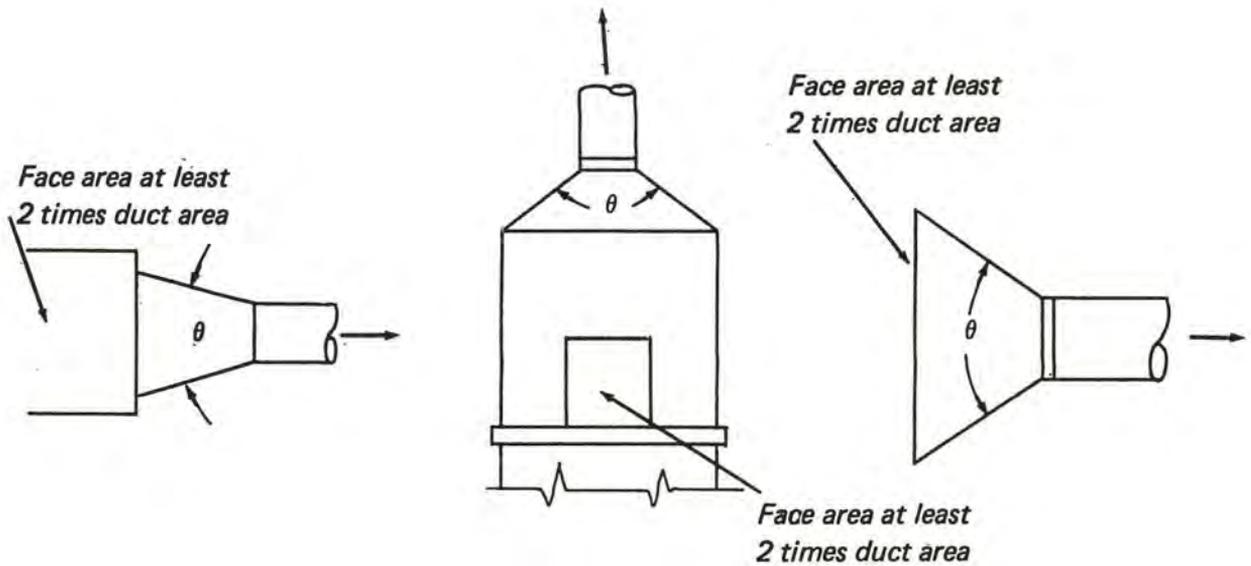
RECOMMENDED VENTILATION GUIDELINES FOR KITCHEN OPERATIONS

1. Scope

These guidelines prescribe the use of general ventilation and local exhaust ventilation for the control and removal of heat, water vapor and airborne contaminants generated by kitchen operations. Kitchen operations covered by these guidelines include the use of ranges, baking ovens, dishwashing equipment, kettles, top heat broilers, barbecue pits, steam pressure cookers and other similar cooking equipment used in commercial, industrial or institutional applications. The guidelines do not apply to installations for normal residential use.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.
- f. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- g. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure] as a function of the included or major angle of the hood.
- h. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- i. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- j. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- k. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- l. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.



Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- m. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- n. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- o. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- p. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- q. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- r. Make-up Air - Air supplied to a building or space to replace air exhausted.
- s. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- t. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.

3. Application

These guidelines shall apply to all commercial, industrial, institutional or similar kitchen operations which generate air contaminants into the breathing zones of employees in concentrations in excess of permissible exposure limits and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse conditions or circumstances, different or more stringent control measures shall be provided as necessary to maintain contaminant concentrations at or below exposure limits.

4. Ventilation Equipment Design Requirements

4.1 Exhaust Hoods

4.1.1 General

A hood used for the control of air contaminants from kitchen operations shall be provided with suitable ductwork for conveying away the contaminated air, a grease removal device (where required), a fan for providing air movement and an outside discharge stack.

Where large quantities of exhaust air may cause negative pressures which reduce the effectiveness of exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating or cooking devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems and combustion processes in the workplace without restricting the performance of any hood, system, or flue. The supply of make-up air shall not be dependent upon the opening of windows, doors, etc.

4.1.2 Canopy and Island Hoods

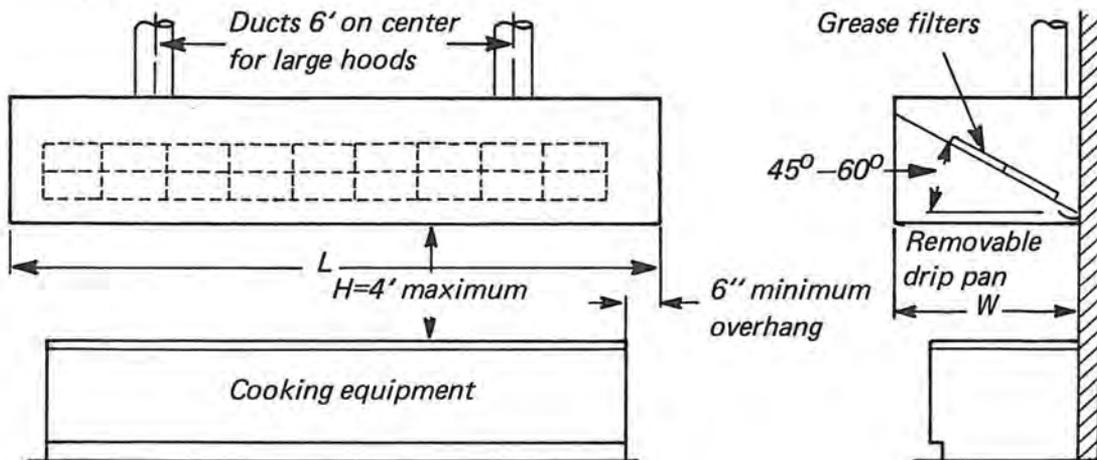
Figures 2 and 3 illustrate acceptable designs for canopy (against wall) and canopy island hoods used for other than dishwashing operations. Exhaust air volumes for such hoods shall be determined from the hood dimensions and the appropriate formula shown in the figures. Such hoods installed in kitchens shall be constructed from metal or other non-combustible materials and shall have grease removal devices which conform with section 4.2 of these guidelines.

4.1.3 Back Shelf or Low Sidewall Hoods

Figure 4 illustrates an acceptable design for a back shelf or low sidewall hood. Exhaust air volumes for such hoods shall be determined by the hood length and the formula shown in Figure 4. Back shelf or low sidewall hoods installed in kitchens shall be constructed from metal or other non-combustible materials and shall have grease removal devices which conform with section 4.2 of these guidelines.

4.1.4 Enclosing Hoods

Figures 5 and 6 illustrate acceptable designs for enclosing hoods. Exhaust air volumes for such hoods shall be determined by the appropriate formula shown in the figures. Enclosing hoods installed in kitchens shall be constructed from metal and other non-combustible materials and shall have grease removal devices which conform with section 4.2 of these guidelines.



$$Q = WL V \text{ cfm but not less than } 50 PH \text{ cfm}$$

where:

Q = exhaust volume, cfm

V = minimum 80 fpm face velocity

W = width of hood, ft

L = length of hood, ft

P = perimeter of hood, ft

$$= 2W + L$$

H = distance of hood from cooking equipment, ft

Duct velocity = 1000 fpm minimum

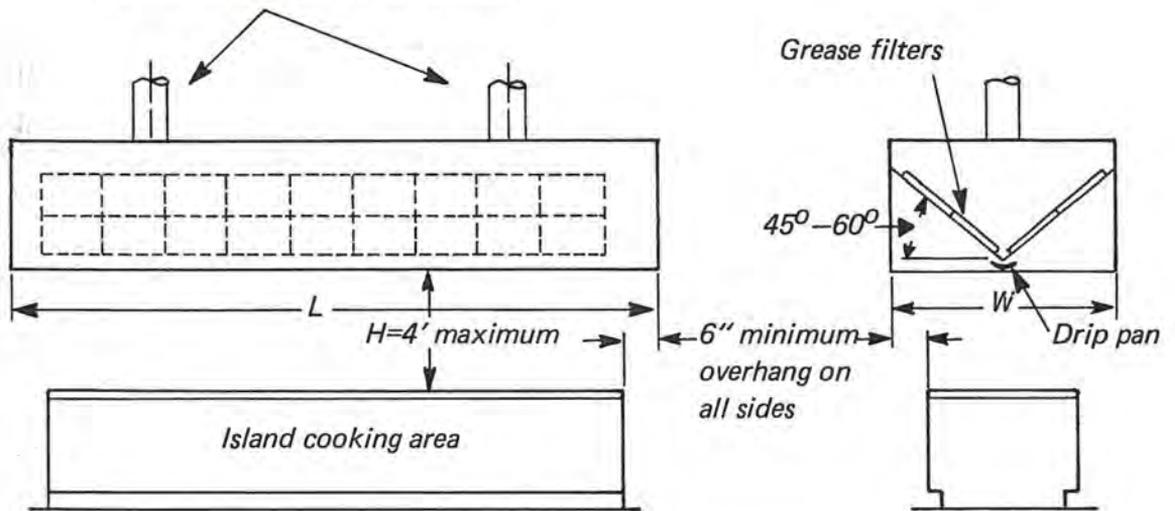
Entry loss = filter resistance + 0.5 duct VP

Filter resistance = clean filter resistance + 0.1"

Consult manufacturer for clean filter resistance.

FIGURE 2 CANOPY HOOD (AGAINST WALL)

If hood is more than 12 feet long, use multiple takeoffs 6 feet on center.



$$Q = WL V \text{ cfm but not less than } 50 PH \text{ cfm}$$

where:

Q = exhaust volume, cfm

V = minimum 125 fpm face velocity

W = width of hood, ft

L = length of hood, ft

P = perimeter of hood, ft
 $= 2W + 2L$

H = distance of hood from cooking equipment, ft

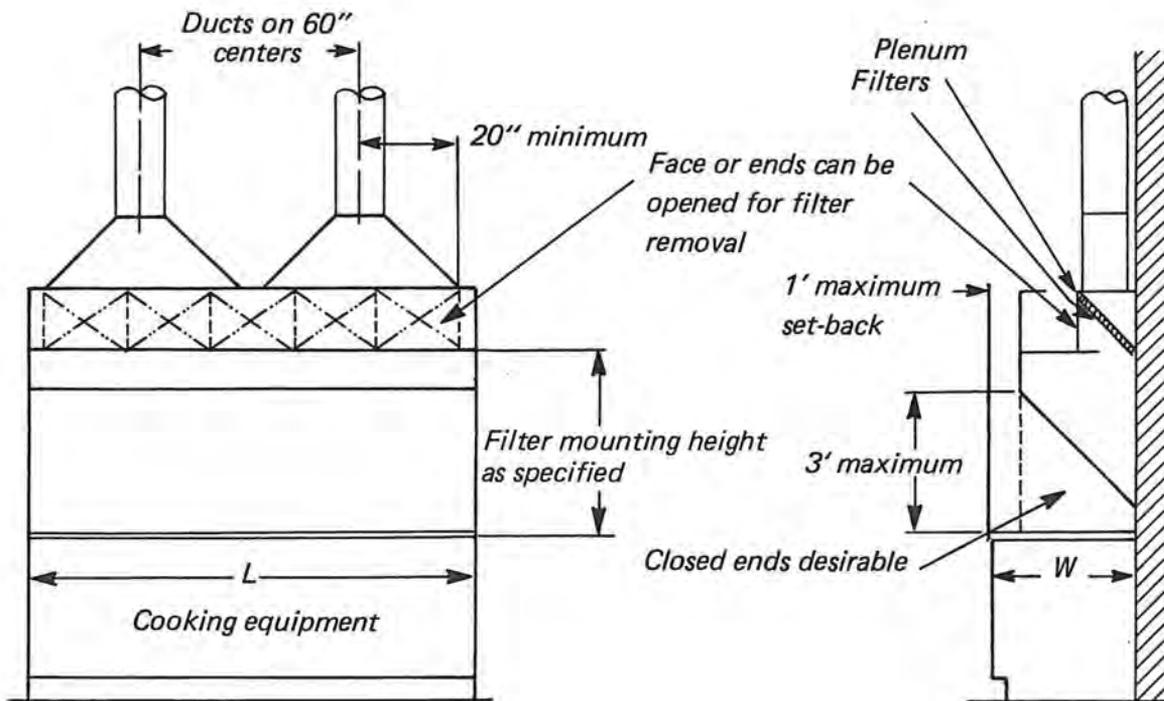
Duct velocity = 1000 fpm minimum

Entry loss = filter resistance + 0.5 duct VP

Filter resistance = clean filter resistance + 0.1"

Consult manufacturer for clean filter resistance.

FIGURE 3 CANOPY ISLAND HOOD



$$Q = Q_f L \text{ cfm}$$

where:

Q = exhaust volume, cfm

Q_f = minimum 200 cfm/linear foot of hood length

W = width of hood, ft

L = length of hood, ft

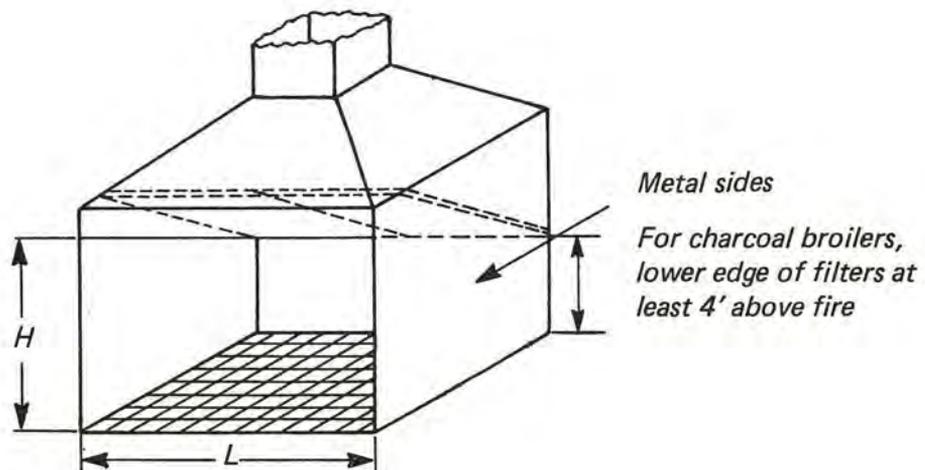
Duct velocity = 1000 fpm minimum

Entry loss = filter resistance + entry loss factor for tapered hood x duct VP

Filter resistance = clean filter resistance + 0.1"

Consult manufacturer for clean filter resistance.

FIGURE 4 BACK SHELF OR LOW SIDEWALL HOOD



$$Q = VLH \text{ cfm}$$

where:

Q = exhaust volume, cfm

V = minimum 75 fpm face velocity for Class II operations or
minimum 100 fpm face velocity for Class III operations

W = width of hood open face, ft

L = length of hood open face, ft

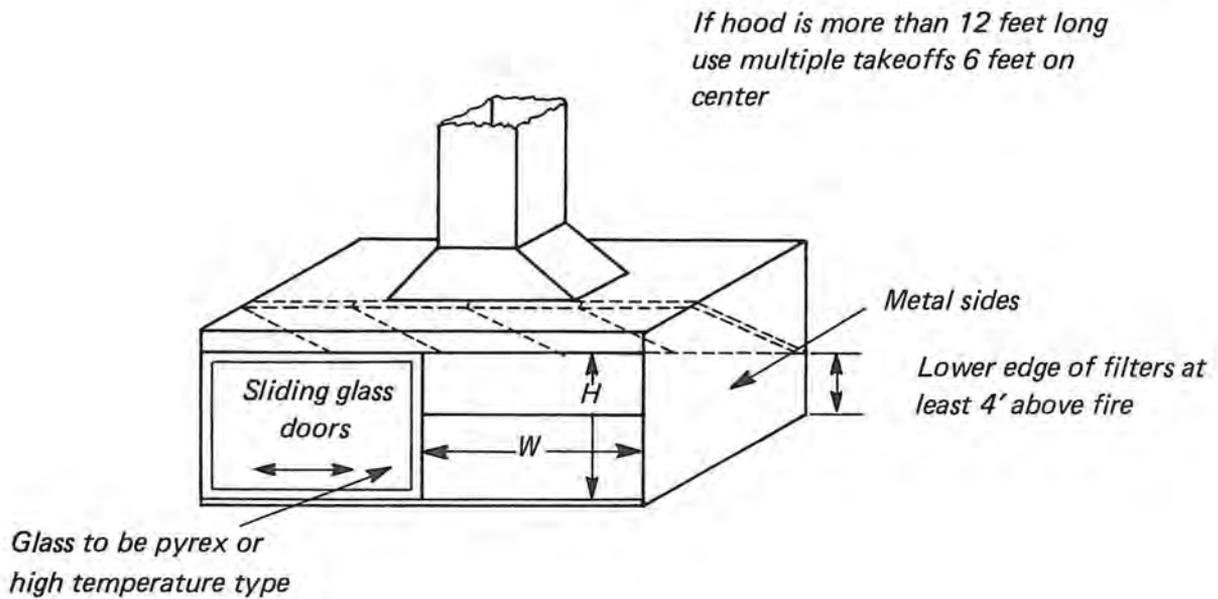
Duct velocity = 1000 fpm minimum

Entry loss = filter resistance + entry loss factor for tapered hood x duct VP

Filter Resistance = clean filter resistance + 0.1"

Consult manufacturer for clean filter resistance.

FIGURE 5 ENCLOSING HOOD



$$Q = VWH \text{ cfm}$$

where:

Q = exhaust volume, cfm

V = minimum 75 fpm face velocity for Class II operations or
minimum 100 fpm face velocity for Class III operations

W = width of maximum door opening, ft

H = height of open face, ft

Duct velocity = 1000 fpm minimum

Entry loss = filter resistance + entry loss factor for tapered hood x duct VP

Filter resistance = clean filter resistance + 0.1"

Consult manufacturer for clean filter resistance.

FIGURE 6 ENCLOSING HOOD

4.1.5 Dishwasher Ventilation

Figure 7 illustrates acceptable designs for a canopy hood, slot hood, and exhausted vestibule for use in dishwasher ventilation. Exhaust air volumes for these hoods shall be determined from the appropriate formula in Figure 7.

4.2 Grease Removal Devices

4.2.1 General

Grease removal devices shall include grease filter units, grease extractors and separators. Grease removal devices, where required by this standard, shall meet the performance requirements of nationally accepted testing procedures (e.g. those of the National Sanitation Foundation).

4.2.2 Materials

Grease filters (including frames) and other grease removal devices shall be constructed of non-combustible materials.

4.2.3 Installation of Grease Filters

Grease filters shall be tight fitting and firmly held in place yet be easily accessible and removable for cleaning. Grease filters shall be installed at an angle between 45 and 60 degrees to the horizontal. The lowest edge of the filter shall be at least 1 - 1/4 ft above the cooking surface if the filter is not exposed to a cooking flame or at least 4 ft above the cooking surface if the filter is exposed to a cooking flame (as in a charcoal broiler). Filters shall be shielded from direct radiant heat. A removable grease drip pan shall be provided.

4.2.4 Inspection and Maintenance

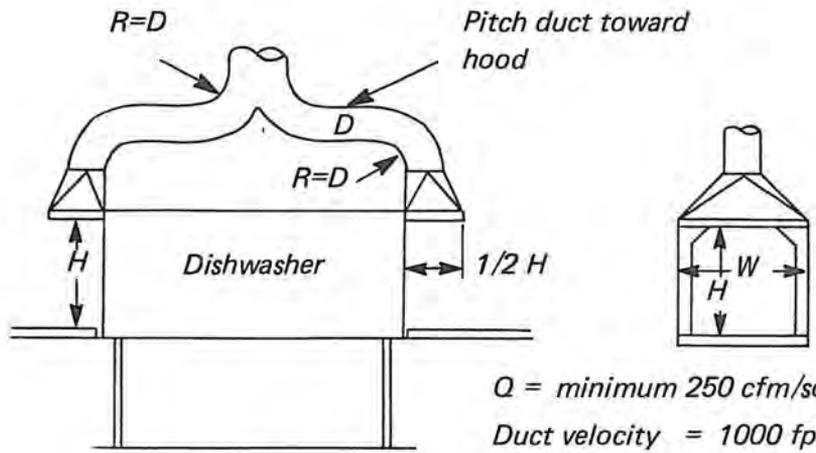
Grease removal devices shall be cleaned at frequent intervals prior to surfaces becoming heavily contaminated with grease or oily sludge. Cleaning of grease extractors should be in accordance with nationally accepted procedures (e.g. those of the National Sanitation Foundation) and the manufacturer's instructions. Clean-out openings or a split sleeve connection shall be provided at the fan inlet for inspection and cleaning.

5. Ventilation Requirements

5.1 Classification of Operations

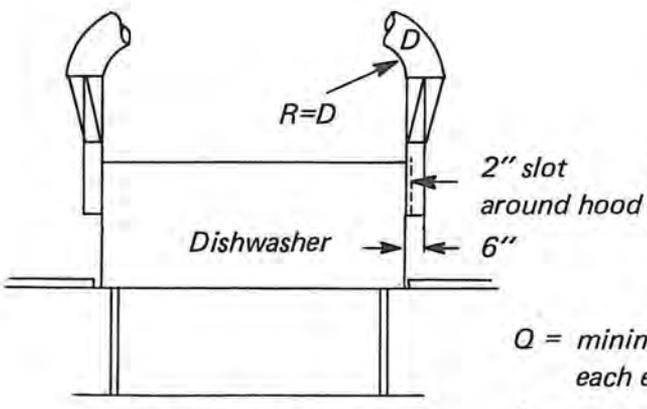
For the purposes of these guidelines kitchen operations shall be classified into four classes:

Class I shall include operations which result in the emission of steam and heat with trace amounts of grease and/or particulates. In-



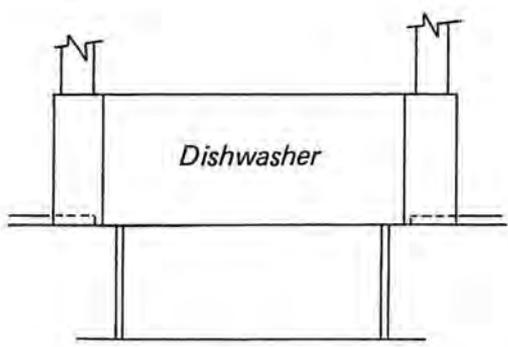
CANOPY HOODS

$Q = \text{minimum } 250 \text{ cfm/sq ft of face area} - \text{each end}$
 Duct velocity = 1000 fpm minimum
 Entry loss = entry loss factor for tapered hood x duct VP



SLOT HOODS

$Q = \text{minimum } 150 \text{ cfm/sq. ft of door area } (150WH) - \text{each end}$
 Duct velocity = 1000 fpm minimum
 Entry loss = 1.00 slot VP + entry loss factor for tapered hood x duct VP



EXHAUSTED VESTIBULES

$Q = \text{minimum } 150 \text{ cfm/sq ft of entrance and exit area}$
 Duct velocity = 1000 fpm minimum
 Entry loss = 0.50 duct VP for round duct takeoff

FIGURE 7 DISHWASHER VENTILATION

cluded in this category are range top operations and the use of toasting and baking equipment, steamers, and similar kitchen equipment.

Class II shall include operations which may result in the emission of moderate amounts of grease mists, particulates, heat and/or steam. Included in this category are the use of kettles, top-heat broilers, deep-fat and pressure fryers, cooking grills, pizza ovens, roasting ovens, and similar kitchen equipment.

Class III shall include operations which may result in the emission of large volumes of particulates and grease mists or aerosols as well as, in some cases, large amounts of air contaminants resulting from the incomplete combustion of fuels. Included in this category are charcoal broilers, barbecue pits, and similar kitchen equipment when used indoors.

Class IV shall include dishwashing equipment that releases steam to the ambient environment during its operation.

5.2 Airflow and Hood Applicability Requirements

General mechanical ventilation at a minimum rate of 4 cubic feet per minute of air per square foot of floor area shall be provided wherever Class I operations are performed. Air exhausted by hoods required to ventilate Class II operations may be counted toward satisfying this requirement.

Canopy (against wall) or canopy island hoods, back shelf or low sidewall hoods or enclosing hoods shall be provided wherever Class II kitchen operations are performed.

Enclosing hoods as described in section 4.1.4 shall be provided wherever Class III kitchen operations are performed. Wherever a Class III kitchen operation is performed, ventilation shall be provided for that operation alone. Class III kitchen operation ventilation requirements shall not be met by employing an exhaust hood common to other operations.

Dishwasher ventilation as described in section 4.1.5 shall be provided wherever Class IV kitchen operations are performed.

The minimum ventilation rates to be provided the various hood designs for the classes of kitchen operations described shall be in accordance with Table 1.

TABLE 1

Summary of
Ventilation Requirements for Kitchen Operations

Ventilation Design	Illustration (Figure No.)	Minimum Ventilation Rates*			
		Class I	Class II	Class III	Class IV
General Ventilation (cfm/sq ft floor area)	-	4	NA	NA	NA
Canopy (Against wall) (fpm face velocity)	2	NR	80	NA	**
Canopy Island (fpm face velocity)	3	NR	125	NA	**
Back shelf (cfm/linear foot of hood)	4	NR	200	NA	**
Enclosing	5,6	NR	75	100	**

NR - Not required

NA - Not allowable as the sole method of ventilation

* - Units listed in "Ventilation Design" column

** - See Section 4.1.5 of these guidelines

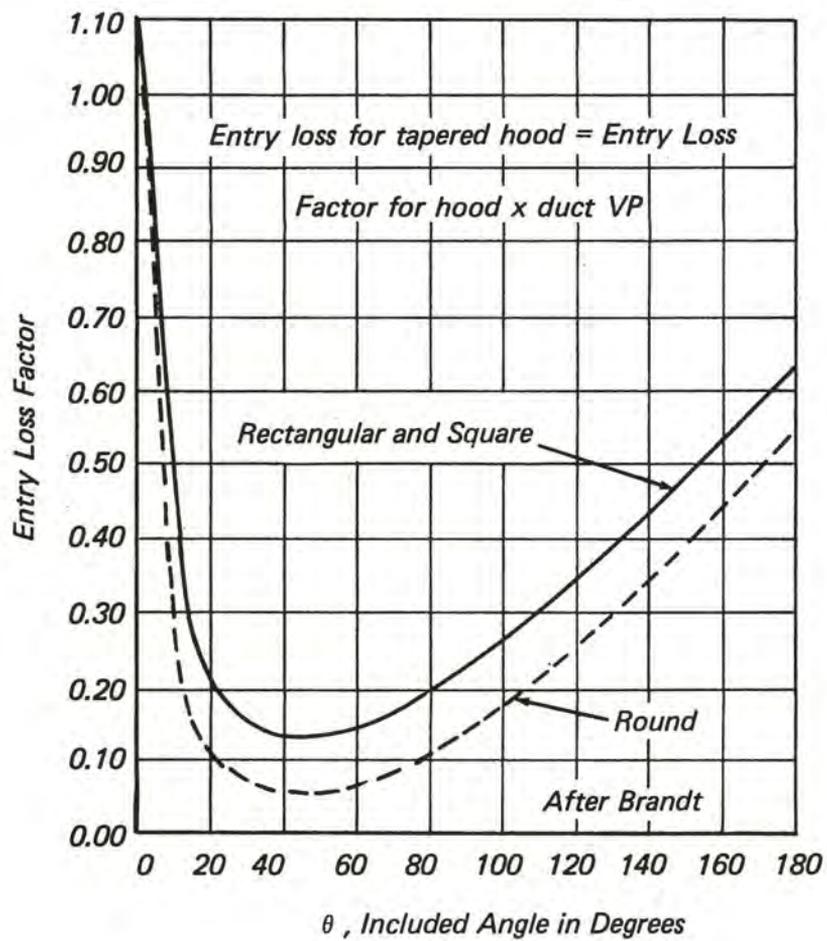
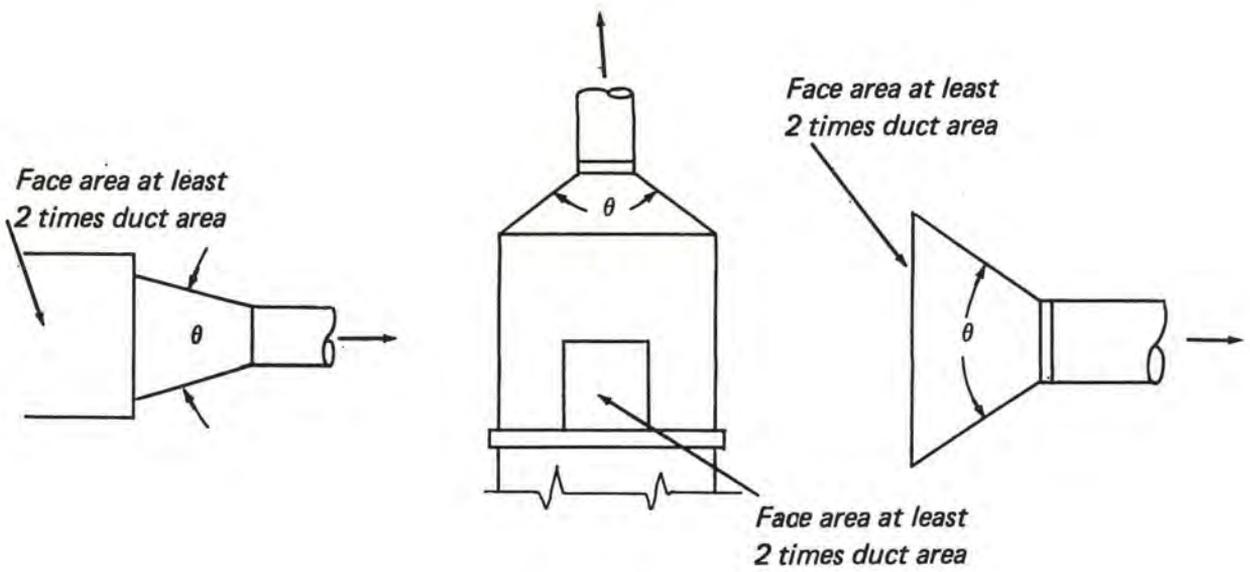
RECOMMENDED VENTILATION GUIDELINES FOR LABORATORY OPERATIONS

1. Scope

These guidelines prescribe the use of exhaust hoods for the control and removal of airborne contaminants, other than biological contaminants, generated by laboratory operations. The guidelines supplement (are in addition to) control measures prescribed in 29 CFR 1910.1000 for cancer-suspect agents.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- f. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- g. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- h. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- i. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- j. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- k. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- l. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- m. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- n. Glove Hood - An exhaust hood which totally encloses a contaminant-producing operation; also glove box.



Tapered Hoods

Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- o. Laboratory Hood - An exhaust hood which partially encloses a contaminant-producing operation; also fume hood.
- p. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster and stack for removing contaminated air from a space.
- q. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- r. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- s. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- t. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- u. Pressure, Static - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of water gauge when dealing with air. (The tendency to either burst or collapse a pipe.)
- v. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.
- w. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed in these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all laboratory operations involving radioactive, toxic, or carcinogenic substances capable of being dispersed as airborne contaminants. Ventilation equipment provided in accordance with the guidelines shall be operated continuously while the air contaminant generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations

at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

The guidelines do not apply to laboratory operations which generate biological contaminants.

4. Ventilation Equipment Design Requirements

4.1 General

Laboratory operations shall be provided exhaust hoods and shall be exhaust ventilated to ensure that air contaminant concentrations are maintained at or below exposure limits.

An exhaust hood used for the control of air contaminants from a laboratory operation shall be located away from external airflows, traffic lanes, or other external factors which could disrupt the exhaust airflow and contaminant control process wherever possible. Where a hood must be located near a door, a window which can be opened, or an air supply outlet, the exhaust volume shall be increased as necessary to assure control of contaminants.

When the material being handled in a laboratory operation is flammable or combustible when dispersed in air and the laboratory operation is exhaust ventilated, the minimum exhaust volume, where practical, shall be sufficient for dilution of air contaminant concentrations in the hood and exhaust system to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being handled, the fan rotating element shall be nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

Provision shall be made for make-up air to be supplied to the space in which a laboratory hood is operated to replace the exhausted air. The make-up air supply shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

Sections 4.2 through 4.5 of these guidelines describe acceptable hood designs for the control of air contaminants from laboratory operations. Selection of the type of hood design to be used for a particular laboratory operation shall be in accordance with the provisions of Section 5 of these guidelines.

4.2 Glove Hood (Glove Box)

4.2.1 Basic Design

A glove hood can be used for preventing escape of air contaminants from a laboratory process with the minimum requirement for exhaust air. A basic design for a glove hood is illustrated in Figure 2. A fixed window is provided for viewing processes within the hood, and arm length gloves sealed in glove port rings provide means for manual operation of equipment in the hood. One or more locks are provided for transferring items to and from the hood. All facilities are totally enclosed in the hood with external controls preferable.

4.2.2 Contaminant Control

Where a glove hood is used for contaminant control, air shall be exhausted from the hood to maintain a negative pressure inside when the hood is closed and to maintain a minimum flow velocity into openings when the hood is open. If flames are operated in the hood, airflow through the hood shall be sufficient to provide combustion air for the flames.

Filters shall be installed in hood openings if continuous flow of air into the hood is required. Strippable plastic may be applied to interior surfaces to facilitate decontamination of the hood.

4.3 Laboratory Hood (Fume Hood)

4.3.1 Basic Design

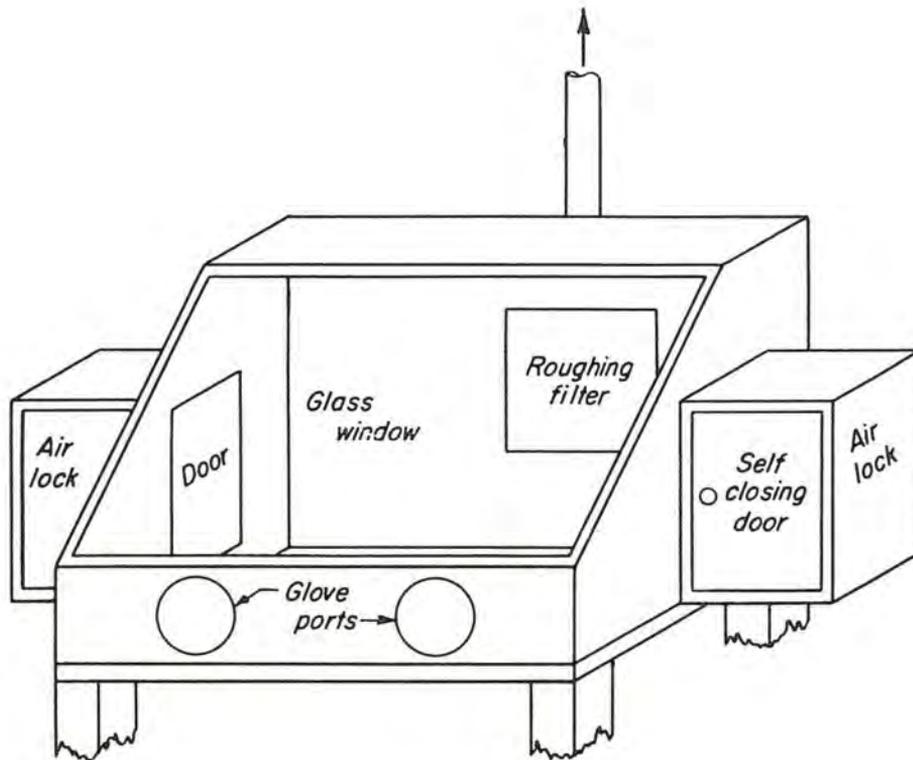
A laboratory hood can be used for preventing escape of air contaminants from a laboratory operation but with a greater exhaust air requirement than with a glove hood. A basic design for a laboratory hood is illustrated in Figure 3. The design shown is a bench-top hood. However, this guideline also applies to floor-mounted or "walk-in" hoods. The operation is conducted within the hood with access directly through the front or "face". Air is exhausted from the hood through an array of slots or other openings which cause air to flow inward through the face with a uniform velocity over the face area. The uniform face velocity and a smooth flow of air through the hood are necessary for effective control of air contaminants from the operation in the hood.

4.3.2 Jam and Sill Design

As an additional means of achieving a uniform face velocity the jams and sill of the laboratory hood can be specially designed to prevent flow eddies at the edges of the hood face. Eddies can be prevented by rounding or bevelling of the jams and sill as illustrated in Figure 4. Most effective control of airflow around jams and sill can be achieved by the use of raised airfoils also illustrated in Figure 4.

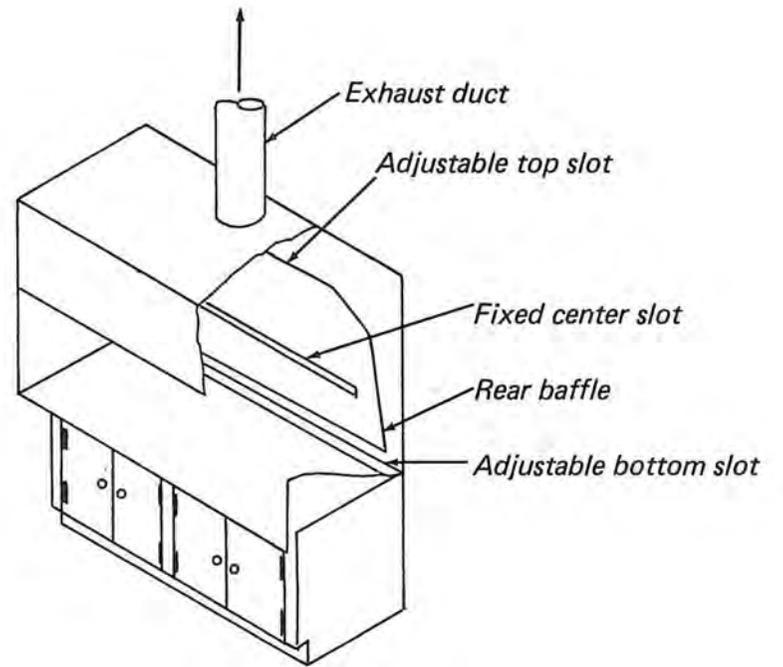
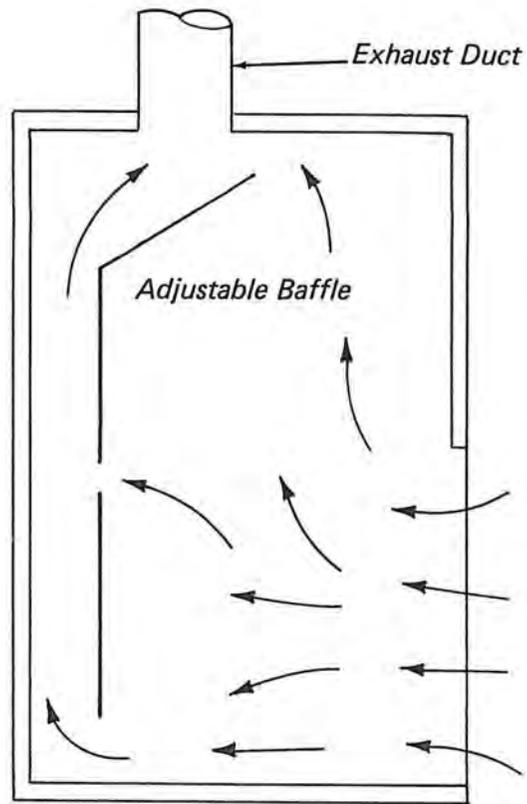
4.3.3 Sash Design

A vertical sash can be used, as illustrated in Figure 5, to partially or completely close the face of the hood to provide more



$Q = \text{minimum } 50 \text{ cfm/sq ft of open door area; sufficient to maintain}$
 $0.3 \text{ in } H_2O \text{ static pressure when doors closed}$
 $\text{Entry loss} = 0.5 \text{ duct VP}$
 $\text{Duct velocity} = 2000 \text{ fpm minimum}$

FIGURE 2 GLOVE HOOD



Entry loss = 0.5 duct VP
Duct velocity = 2000 fpm minimum

FIGURE 3 LABORATORY HOOD

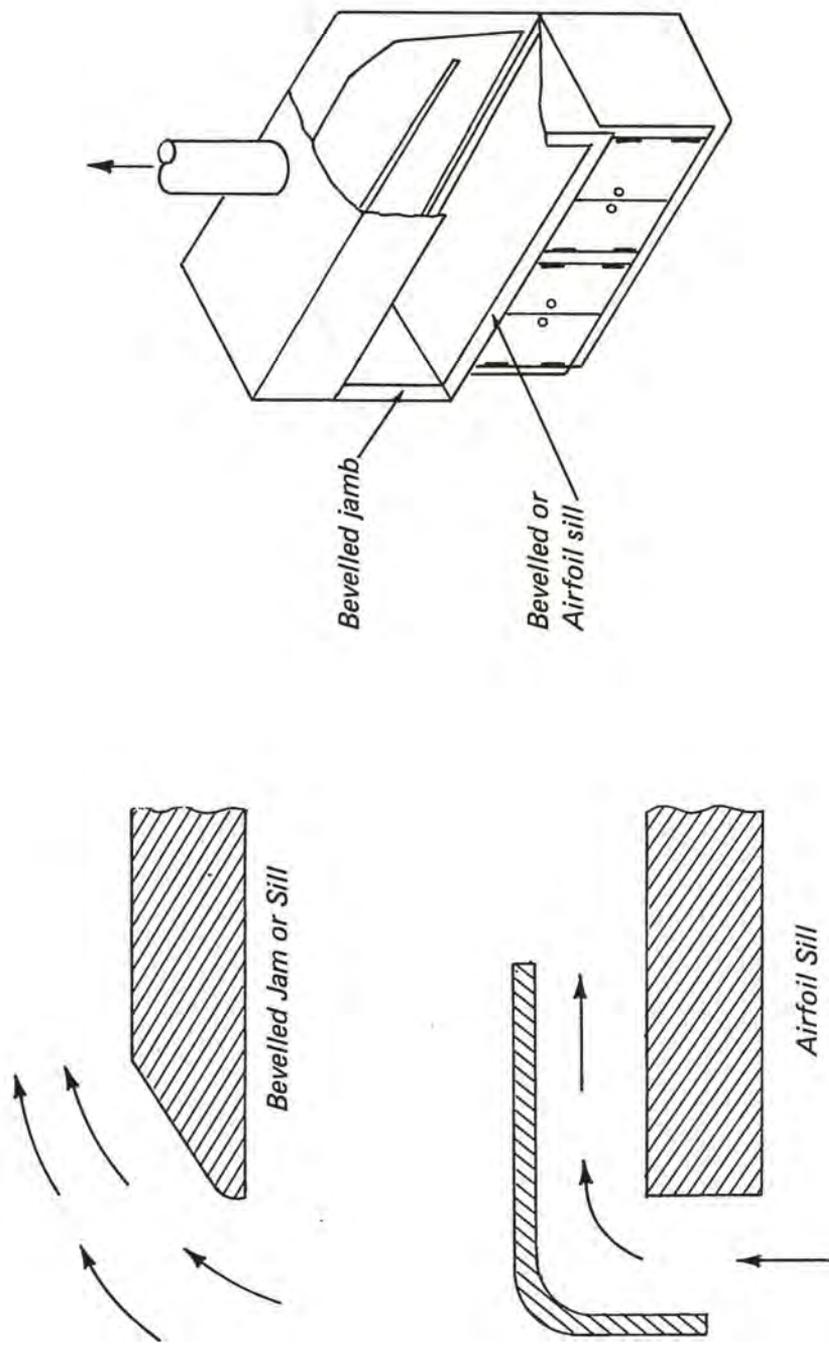


FIGURE 4 JAM AND SILL DESIGNS FOR LABORATORY HOODS

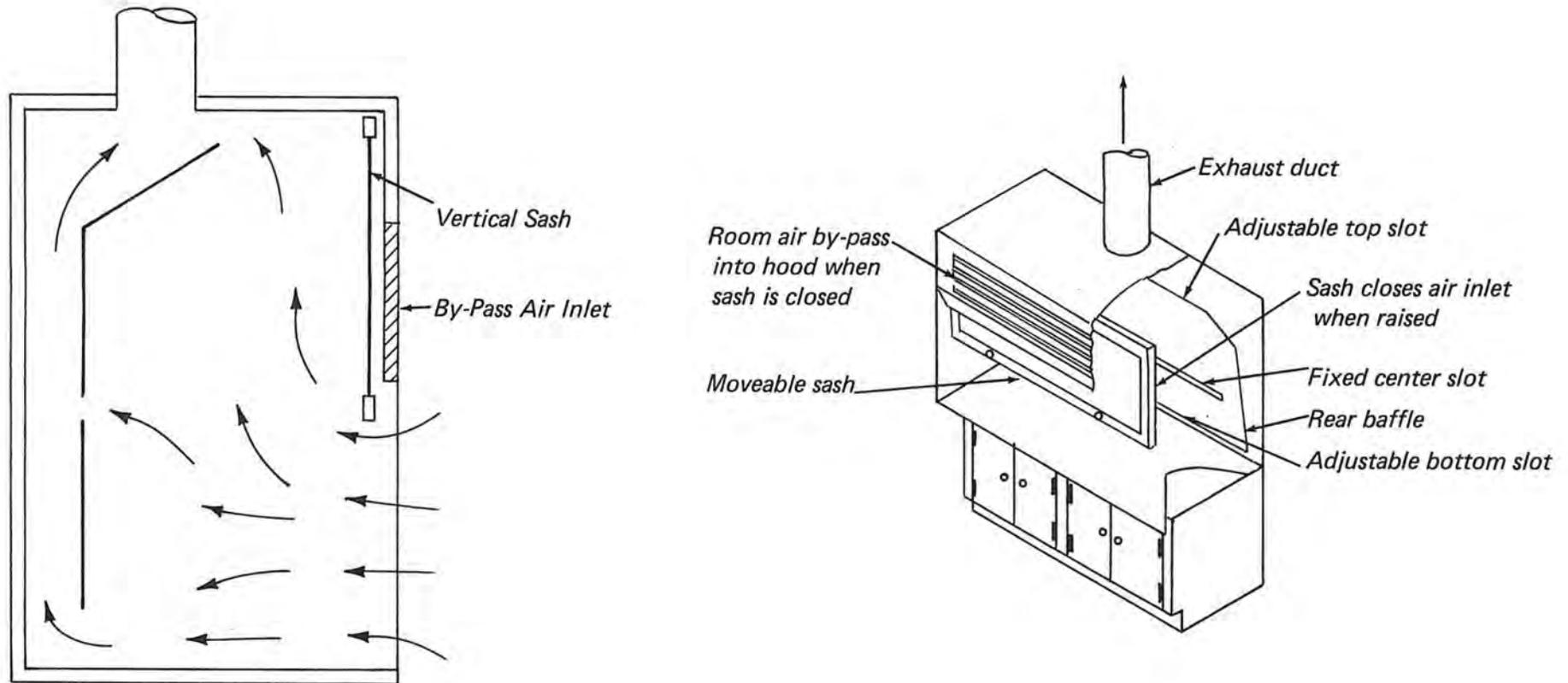


FIGURE 5 LABORATORY HOOD WITH VERTICAL SASH AND BY-PASS AIR INLET

effective contaminant control, to protect the worker, or to conserve air. If a sash is used, provision shall be made to avoid excessive air velocities at the hood face as the face area is reduced. Face velocity control can be maintained by a room-air by-pass or by an automatic control feature which reduces the exhaust airflow rate in proportion to the reduction in face area. If a by-pass is used, the by-pass openings shall be covered with a grille or equivalent structure which effectively protects the worker against material fragments which might be projected from the operation in the enclosure.

Horizontal sashes may be used on large laboratory hoods for contaminant control or air conservation. When horizontal sashes are used, excessive hood face velocities shall be prevented by the use of by-pass openings or automatic exhaust volume controls.

4.3.4 Auxiliary Air Supply

An auxiliary air supply may be used to reduce the amount of room air exhausted through a laboratory hood. The auxiliary air supply shall be mounted outside the hood as illustrated in Figure 6 so that the auxiliary airflow is induced through the face opening by the exhaust system. The auxiliary air supply shall be designed, installed, and operated so that the auxiliary airflow does not disrupt the uniform flow velocity through the face of the hood and the smooth flow of air through the hood.

4.4 Open Hood

An open exhaust hood can be used to capture air contaminants from a laboratory process when the sites from which the contaminants are generated are clearly defined and the contaminants leave the process at low velocity. The hood shall be mounted such that air contaminants from the process are emitted into an exhaust flow field which effectively entrains the contaminants and draws them into the hood without allowing excessive concentrations in the breathing zones of laboratory workers. Acceptable designs and operational requirements for open hoods are illustrated in Figures 7 and 8. Examples of specialized open hood designs developed for specific laboratory operations are shown in Figure 9.

4.5 Perchloric Acid Hood

Processes involving the use of perchloric acid shall be conducted within a laboratory hood specifically designed for perchloric acid use and used exclusively for that purpose. The following design features shall be incorporated in a perchloric acid hood:

- a. The hood and its ductwork shall be constructed of non-reactive, acid resistant, impervious materials.
- b. The hood and exhaust duct shall be designed to facilitate cleaning of internal surfaces.

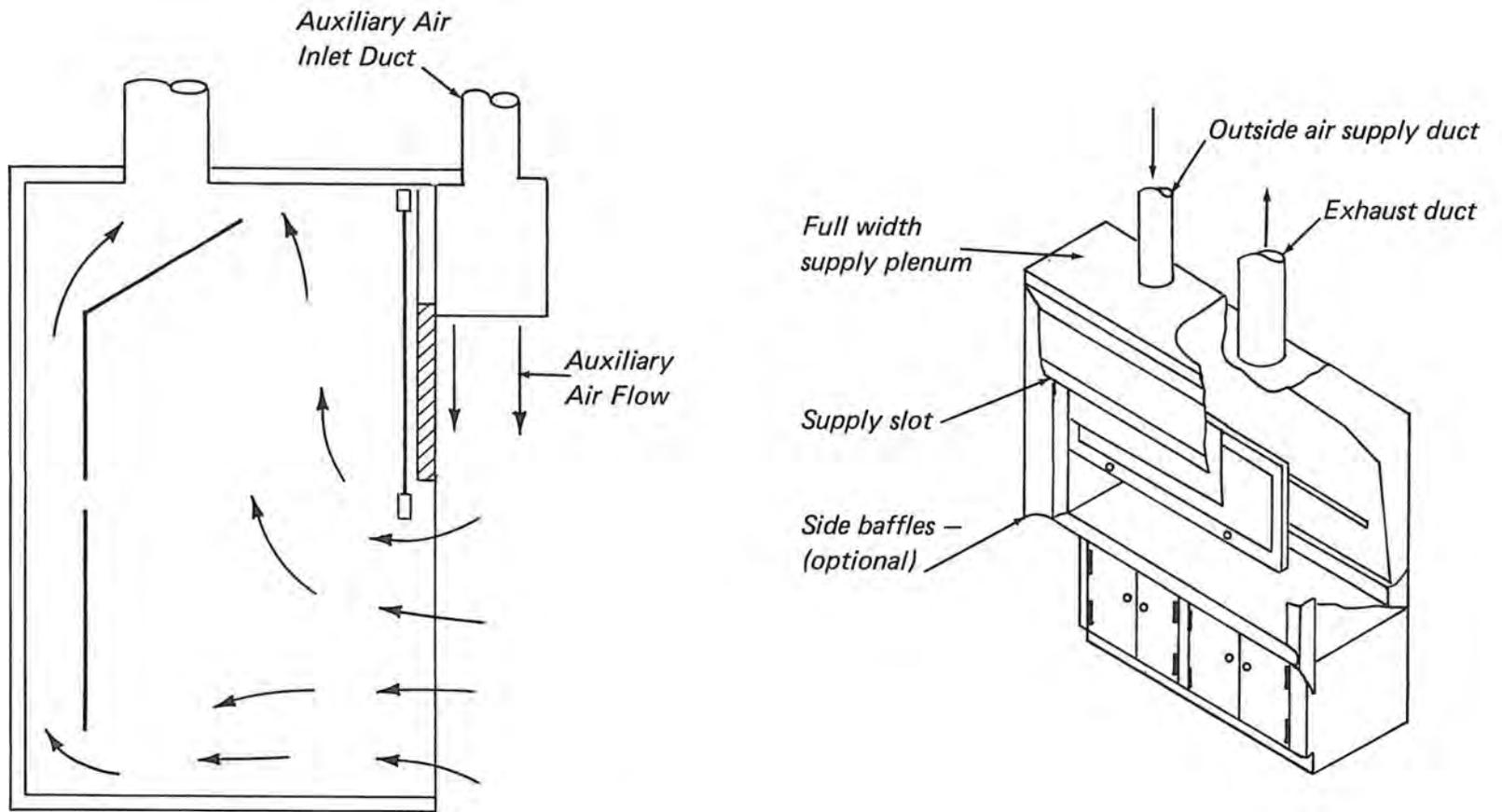
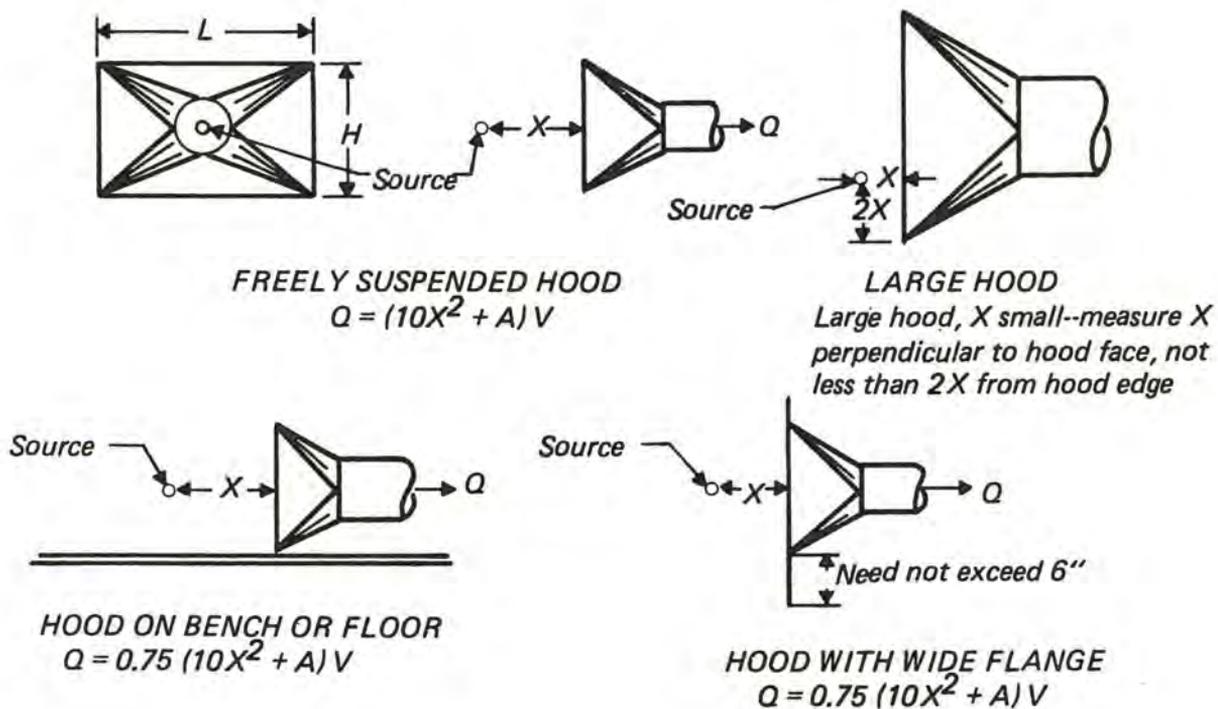


FIGURE 6 LABORATORY HOOD WITH AUXILIARY AIR SUPPLY



Q = exhaust volume, cfm

X = distance from hood face to farthest point of contaminant release, feet.

A = hood face area, sq ft, equals LH

L = length of hood, feet

H = height of hood, feet

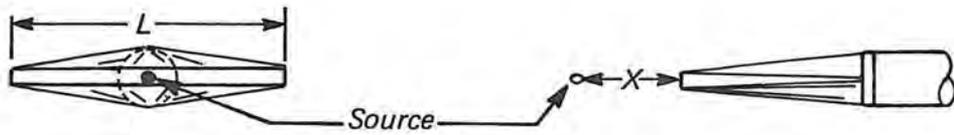
V = minimum capture velocity, fpm, at distance X

Entry loss = entry loss factor for tapered hood X duct VP

Duct velocity = 2000 fpm minimum

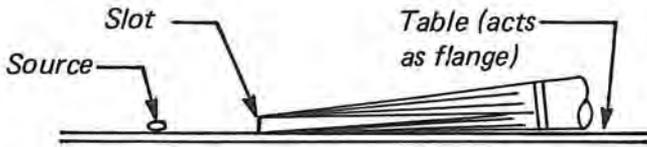
Note: Air volume must increase as the square of distance of the source from the hood.
 Baffling by flanging or by placing on bench, floor, etc. has a beneficial effect.

FIGURE 7 OPEN HOODS

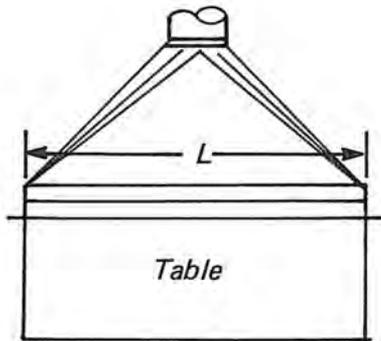


FREELY SUSPENDED SLOT
 $Q = 3.7 LXV$

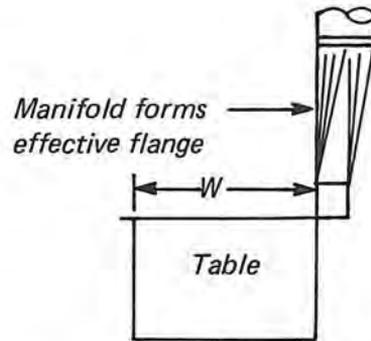
- Q = exhaust volume, cfm
- X = distance, feet, hood face to farthest point of source (usually on centerline of hood)
- V = minimum capture velocity of 100 fpm at source of contaminant generation, at distance X (for Class I contaminants only)
- L = length, feet, of hood
- W = width, feet, of table



SLOT ON TABLE OR BENCH
 $Q = 2.8 LXV$



FLANGED SLOT
 $Q = CLW$



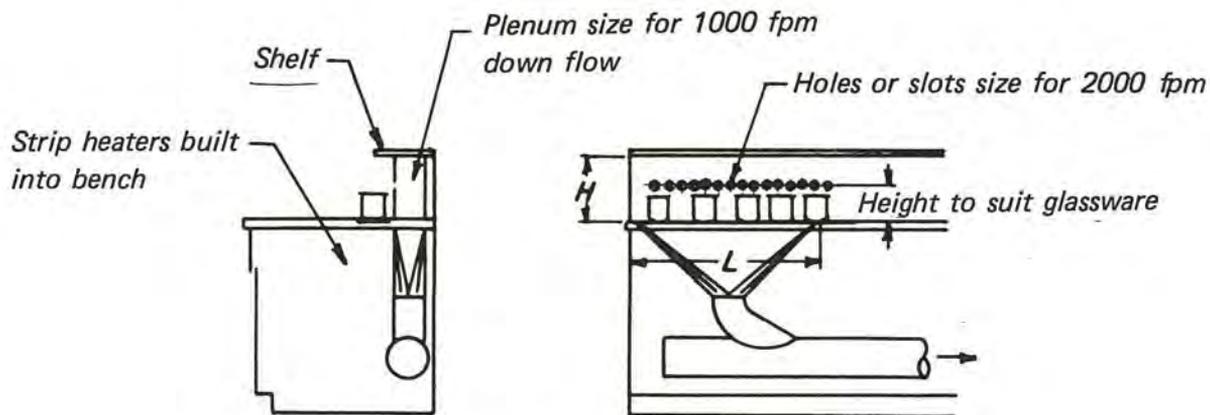
(C = constant from 50–500; usual choice is 150–250)

Duct velocity = 2000 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood
 \times duct VP

Exhaust volume formulae above applicable when $X/L < 0.3$. When $X/L > 0.3$, use open hood formulae in Figure 7.

FIGURE 8 SLOT HOOD

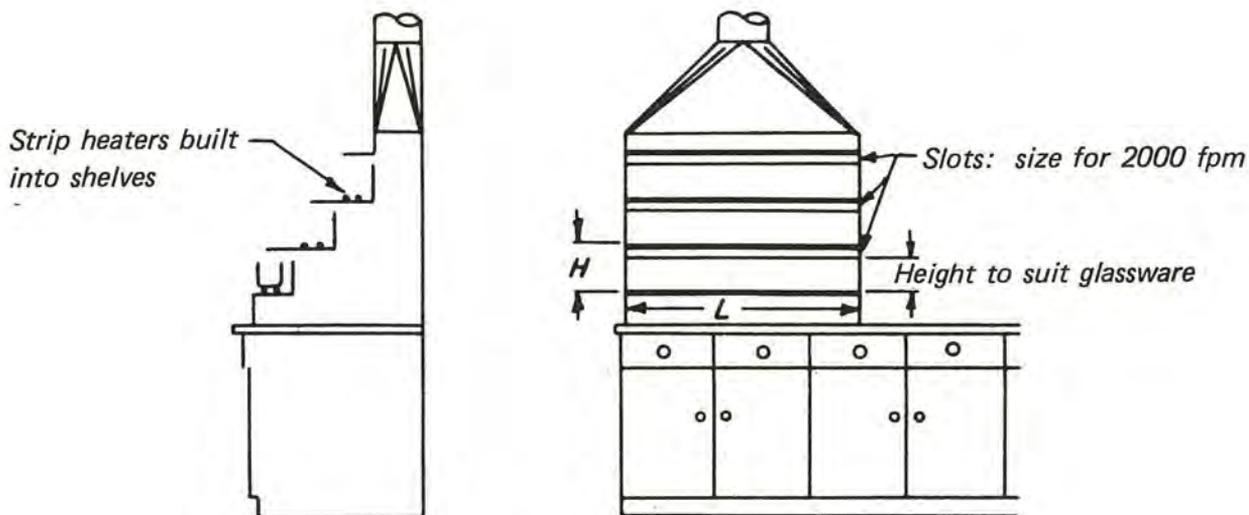


EVAPORATION BENCH

$Q = 20 \text{ cfm/lineal foot of hood or } 50 \text{ HL cfm}$

Duct velocity = 2000 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP



EVAPORATION HOOD

$Q = 20 \text{ cfm/lineal foot of shelf or } 50 \text{ HL cfm for each shelf}$

Duct velocity = 2000 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP

FIGURE 9 SPECIALIZED OPEN HOOD DESIGNS

- c. Utility controls shall be located outside the hood.
- d. A hood used for perchloric acid shall be identified with large warning signs.

For further information regarding the proper design of perchloric acid hoods, see the ACGIH Industrial Ventilation Manual.

5. Hood Operational Requirements

5.1 Hood Applications and Exhaust Flow Requirements for Radioactive and Toxic Substances

An exhaust hood shall be used in accordance with these guidelines in conjunction with any laboratory operation involving the use, transfer, preparation, or generation of any radioactive or toxic substances in a form capable of being dispersed as an airborne contaminant. Specific criteria governing the applicability of this requirement for different forms of substances are as follows:

Gases or Vapors - An exhaust hood shall always be used with an operation involving a radioactive or toxic substance in gaseous or vapor form.

Liquids - An exhaust hood shall be used with an operation involving a radioactive or toxic substance in liquid form if the saturated vapor concentration of the liquid exceeds the exposure limit for the substance. The applicable saturated vapor concentration shall be that concentration corresponding to the ambient temperature or the liquid temperature, whichever is higher. An exhaust hood also shall be used if suspended droplets or mists of the liquid could be generated by the operation either purposely or accidentally.

Solids - An exhaust hood shall be used with an operation involving a radioactive or toxic substance in solid form if the substance is finely divided or if fine particles of the substance could be generated in the operation.

The application of hood types to laboratory operations and hood exhaust volume requirements are governed by the exposure limits of the substances involved in the operations. Except for perchloric acid use, hood applications and exhaust volume requirements are listed in Table 1 for three classes of substances. These substance classes are defined in Table 2. The hood type utilized for a particular laboratory operation and the minimum exhaust volume requirement for the hood shall be in accordance with the provisions of Table 1 for the particular substance class being used.

TABLE 1

Hood Applications and Minimum Exhaust Volume Requirements*

Contaminant Class	Glove Hood	Laboratory Hood	Open Hood
I	50 cfm/sq ft open door area; 0.3 in H ₂ O static pressure closed	Face velocity: 100 fpm avg. 50 fpm min.	Capture velocity: 100 fpm
II	(same as for Class I)	Face velocity: 100 fpm avg. 75 fpm min.	Not allowed
III**	(same as for Class I)	Face velocity: 150 fpm avg. 125 fpm min.	Not allowed

* Minimum exhaust volumes or face velocities shall be based on the maximum hood face area.

** For cancer-suspect agents, these requirements supplement (are in addition to) control requirements prescribed for specific materials in 29 CFR 1910.1000.

TABLE 2

Classification of Contaminant Substances

Contaminant Class	Contaminant Substances	
	Gases & Vapors	Dusts, Fumes & Mists
I	Substances with exposure limits of 100 ppm and above	Substances with exposure limits of 10 mg/M ³ and above
II	Substances with exposure limits of 1 ppm and above (up to 100 ppm)	Substances with exposure limits of 0.1 mg/M ³ and above (up to 10 mg/M ³)
III	Substances with exposure limits below 1 ppm; also, radioisotopes, carcinogens, and cancer-suspect agents	Substances with exposure limits below 0.1 mg/M ³ ; also, radioisotopes, carcinogens, and cancer-suspect agents

Note : This classification does not include biological agents.

5.2 Operational Requirements for Perchloric Acid Use

Operations involving perchloric acid shall be conducted in a hood designed in accordance with Section 4.5 of these guidelines. Minimum exhaust volume through the hood shall be 150 cfm per sq ft of face area. If the hood is fitted with a sash or the face area is variable, the minimum exhaust volume shall be based on the maximum face area. The internal surfaces of the hood and exhaust duct shall be cleaned at least once daily when the hood is in use.

5.3 General Operational Requirements

No concurrent operations or procedures shall be permitted in a laboratory which adversely affect the performance of an exhaust hood used for the control of air contaminants. In particular, items or materials shall not be stored in a hood in a manner which disrupts the flow of air through the hood. The exhaust flow through a hood shall not be stopped or reduced while an operation involving radioactive or toxic substances is being controlled by the hood. The flow control features of a hood, including face opening, baffle configuration, or hood location, shall not be changed while the hood is in use. A hood shall be tested to establish that it conforms with this guideline prior to its first use, following any modification which affects the exhaust volume or flow pattern, and at periodic intervals during use, such intervals not to exceed 6 months in duration.

RECOMMENDED VENTILATION GUIDELINES FOR MATERIALS HANDLING

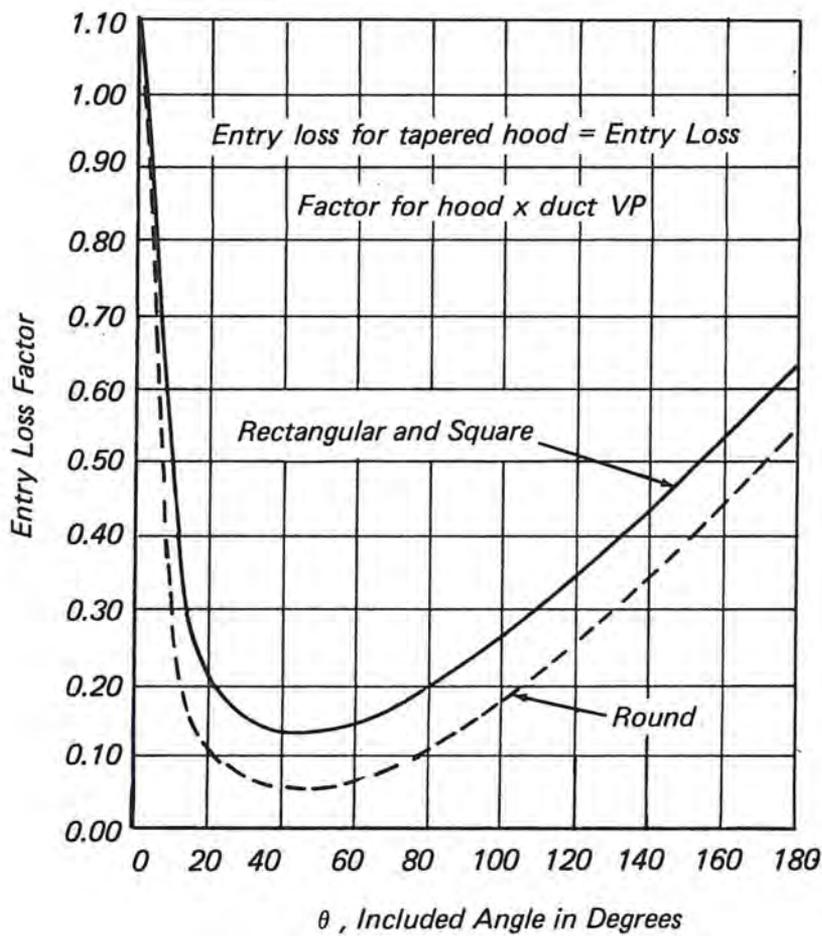
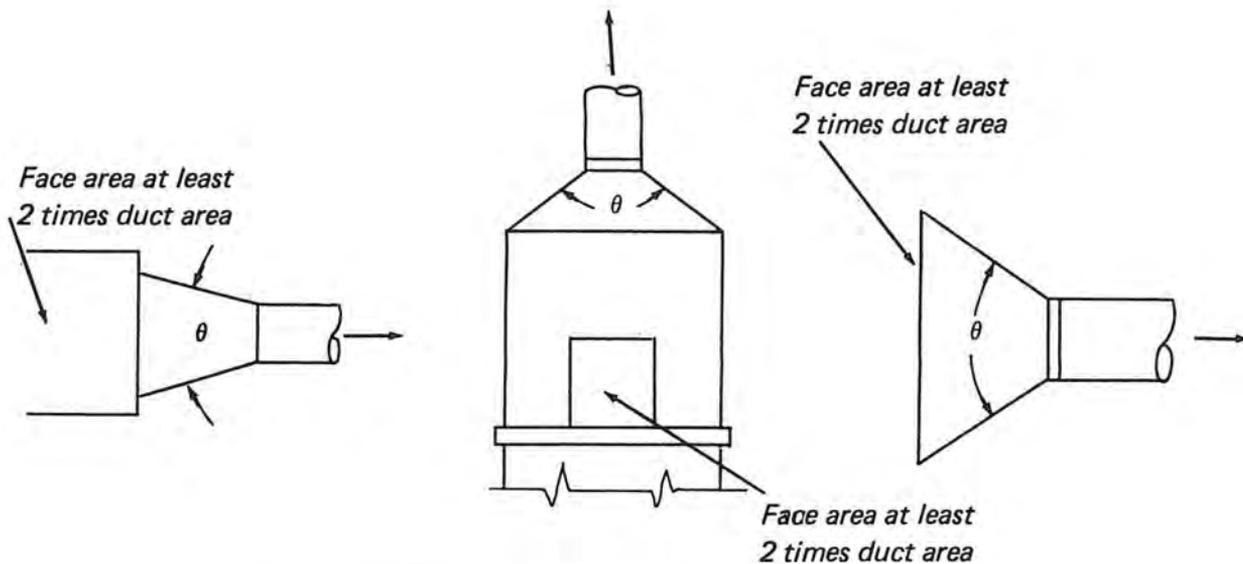
1. Scope

These guidelines prescribe the use of local exhaust ventilation for the control and removal of airborne contaminants generated by material handling operations. Material handling operations covered by these guidelines include, but are not limited to, various types of conveyor operations such as belt, boom, portable, apron, bucket, flight, drag chain, screw, oscillating, and vibrating conveyor operations; belt wiping; and bagging, drumming, and filling operations. Material handling equipment that is not covered includes such principally individual units as industrial trucks, tractors and trailers, tiering machines, cranes, monorails, hoists, power and hand shovels, power scoops, bucket drag lines, and highway or rail vehicles.

2. Definitions

- a. Belt Wiper - A device to clean or remove material which clings to a conveyor belt.
- b. Bin - A container for storing material.
- c. Bucket Elevator - A conveyor for carrying bulk materials in a vertical or inclined path consisting of an endless belt, chain, or chains, to which elevator buckets are attached, and the necessary head and boot terminal machinery and supporting frame or casing.
- d. Chute - A trough in which bulk materials or objects are lowered by gravity.
- e. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- f. Conveying Mechanism - This term in the standard refers to the mechanical device which is directly in contact with the material being handled and transmits the power necessary for movement of the material. For a belt conveyor, this device would be the belt. For a flight conveyor, it would be the flights etc.
- g. Conveyor - A horizontal, inclined, or vertical device for moving or transporting bulk material, packages, or objects in a path predetermined by the design of the device and having points of loading and discharge, fixed or selective.
- h. Duct Velocity - The average air velocity in a duct of an exhaust system.
- i. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- j. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants; also booth or enclosure.

- k. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- l. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- m. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- n. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- o. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- p. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- q. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- r. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- s. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- t. Hopper - A box having a funnel-shaped bottom, or a bottom reduced in size, narrow, or necked to receive material and direct it to a conveyor, feeder, or chute.
- u. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- v. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- w. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- x. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- y. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.
- z. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these



Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to materials handling operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while the air contaminant generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in the guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

Some materials handling operations are covered in the ventilation guidelines for specific industries (the ceramic industry, foundries, etc.). Where these guidelines contain requirements for a specific operation or piece of equipment for which different requirements exist in industry guidelines, the requirements in the industry guidelines shall be adhered to instead of the requirements given in these.

4. Material Handling Operations and Equipment

4.1 General

An exhaust hood used for the control of contaminants from material handling operations shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that the contaminants are projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

When the material being handled in a materials handling operation is flammable or combustible when dispersed in air in a finely divided state, and the handling operation is exhaust ventilated, the minimum exhaust volume, where practical, shall be sufficient for dilution of air contaminant concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being handled, the fan rotating element shall be of nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

4.2 Conveying Equipment

4.2.1 General

Equipment for the movement or transportation of bulk materials, packages, or objects in a path predetermined by the design of the device (i.e., various types of conveyors) shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.2.2 Conveyors

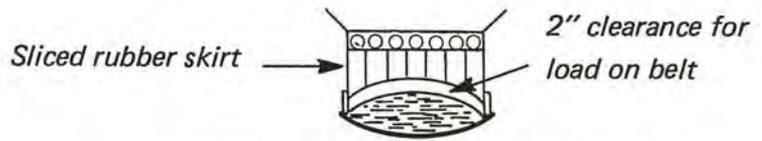
Belt conveyors which generate air contaminant concentrations in excess of exposure limits due to dusting off the top of their loads shall be enclosed and provided a minimum exhaust volume of 350 cfm per ft of the width of the belt at points separated by no more than 30 feet along their length. Figure 2 illustrates an acceptable design and arrangement for the ventilation equipment in such a case.

Where a contaminant is generated in excessive concentrations as a result of material falling from the return strand of a belt and not from dusting off the top of the load, and an effective belt wiper cannot be installed, the entire conveyor run shall be enclosed, using hopper bottoms if practical.

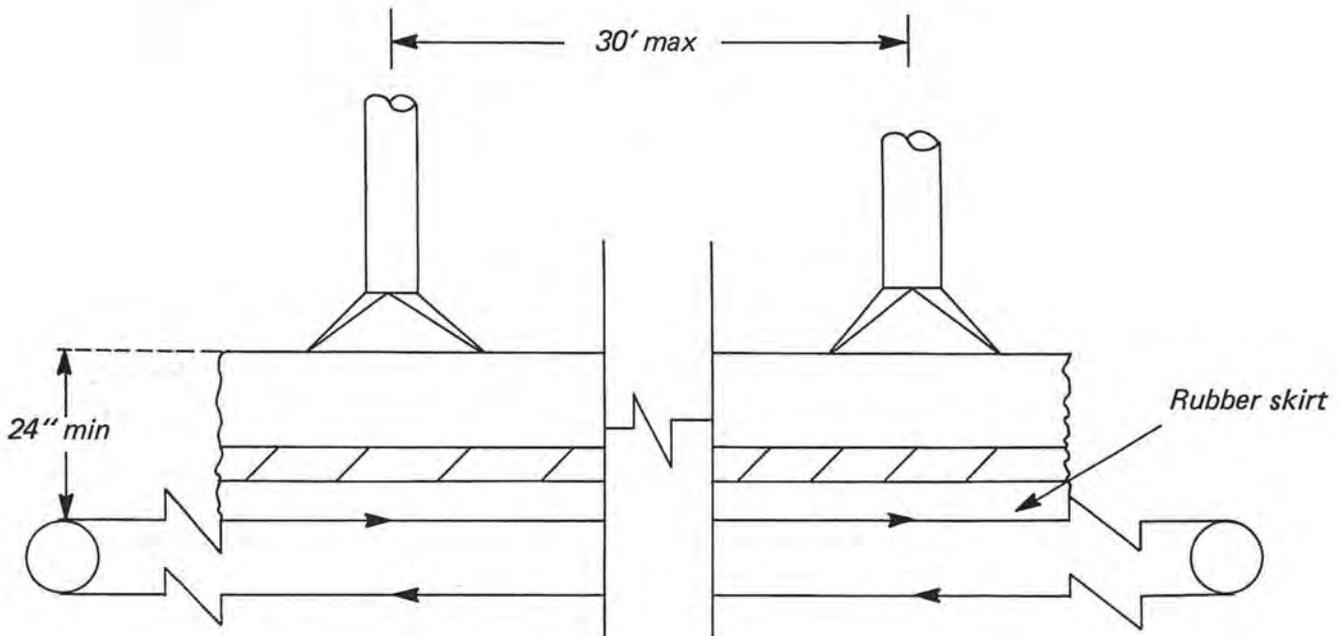
Where the contaminant being generated is a vapor or component of "smoke" being generated from a hot material, the conveyor shall be enclosed and provided a minimum exhaust volume of 150 cfm/sq ft of all openings including leakage at the floor.

4.2.3 Bucket Elevators

Bucket elevators which generate air contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated. Figure 3 illustrates an acceptable design and arrangement for the ventilation equipment. The casing of such bucket elevators shall be exhausted at a minimum rate of 100 cfm per sq ft of cross-sectional

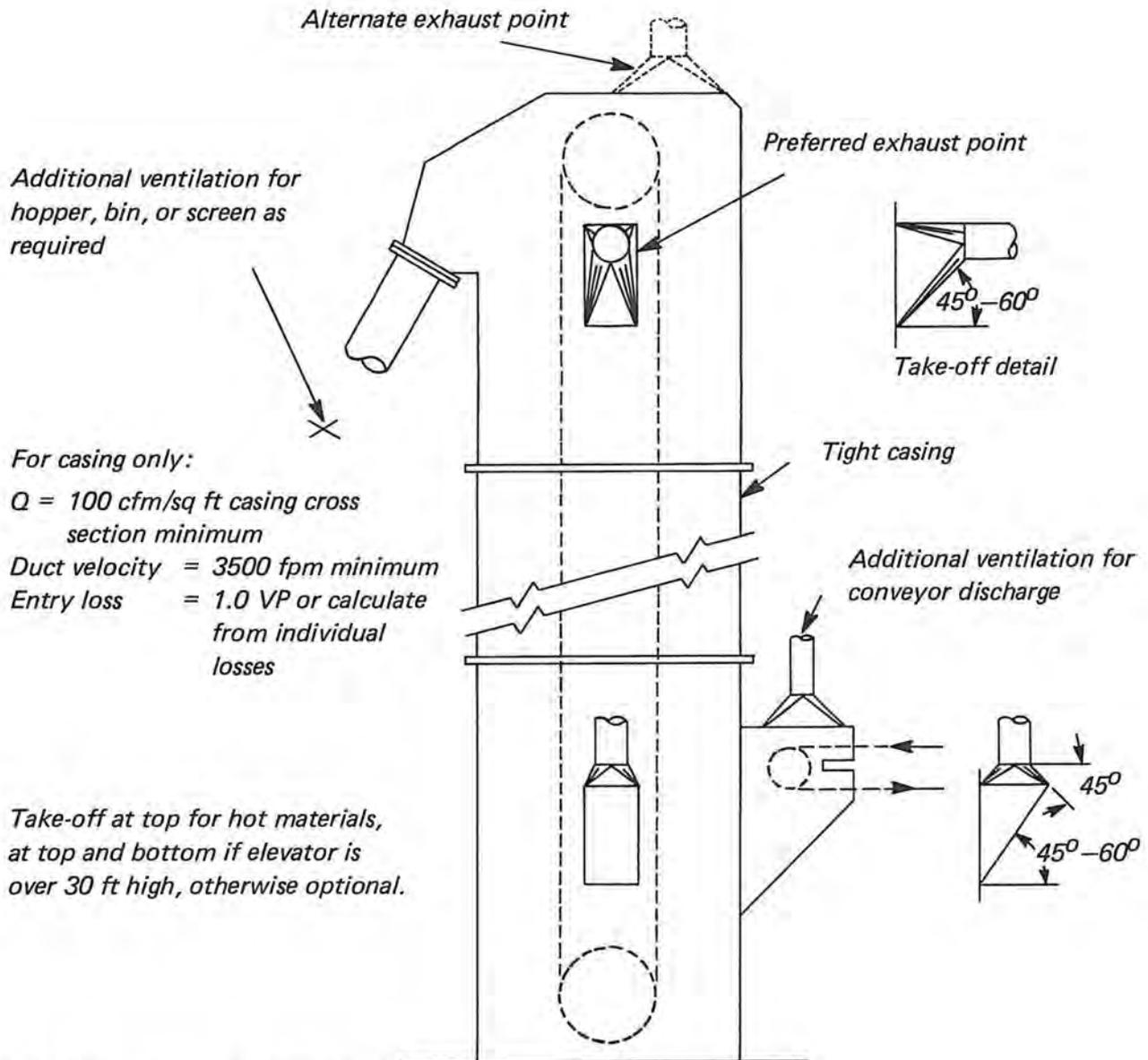


Detail of belt openings for this and other figures showing conveyors



Cover conveyor between transfer points
 Exhaust at transfer points as required
 Exhaust minimum additional 350 cfm/ft of
 belt width at a maximum of 30 ft intervals
 Entry loss = entry loss factor for tapered hood x duct VP
 Duct velocity = 3500 fpm minimum

FIGURE 2 BELT CONVEYOR VENTILATION



For belt conveyor discharge point ventilation:

<i>Belt Speed</i>	<i>Volume</i>
<i>Less than 200 fpm</i>	<i>minimum 350 cfm/ft of belt width but not less than 150 cfm/sq ft of openings</i>
<i>Over 200 fpm</i>	<i>minimum 500 cfm/ft of belt width but not less than 200 cfm/sq ft of openings</i>

For discharge point of other conveyor types provide minimum 150 cfm/sq ft of openings

FIGURE 3 BUCKET ELEVATOR VENTILATION

area. The bucket elevator loading point shall also be enclosed in a manner similar to that shown in Figure 3 for bucket elevators without a magnetic separator, and to that shown in Figure 4 for elevators with a magnetic separator. Where a belt conveyor is used for loading the elevator, the belt speed is less than 200 fpm and a magnetic separator is not utilized, an additional exhaust volume of a minimum of 350 cfm per ft of belt width, but not less than 150 cfm per sq ft of all openings in the enclosing hood, shall be provided. Where the belt speed is over 200 fpm, or where a magnetic separator is utilized, an additional exhaust volume of 500 cfm per ft of belt width, but not less than 200 cfm per sq ft of all openings in the enclosing hood shall be provided. Where another type of conveying mechanism is used, the minimum exhaust volume shall be 150 cfm per sq ft of all openings in the enclosure.

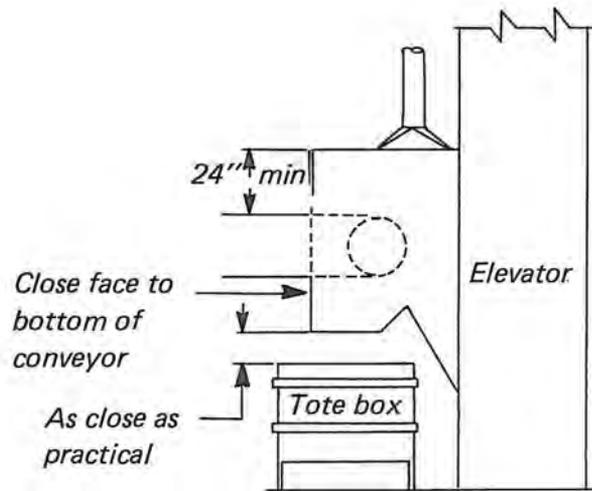
4.2.4 Conveyor to Conveyor and Chute to Conveyor Transfer Points

Where the transfer of a material or objects from one conveyor to another or from a chute to a conveyor generates air contaminant concentrations in excess of exposure limits, the transfer point shall be enclosed and exhaust ventilated. Figure 5 illustrates acceptable designs and arrangements for the ventilation equipment. Where a belt is used and the belt speed is less than 200 fpm, such transfer points shall be exhausted at a minimum rate of 350 cfm per ft of belt width, but not less than 150 cfm per sq ft of all openings in the enclosure. For belt speeds greater than 200 fpm, the minimum exhaust volume shall be 500 cfm per ft of belt width, but not less than 200 cfm per sq ft of all openings. Other types of conveying mechanisms shall be provided a minimum exhaust volume of 150 cfm per sq ft of all openings in the enclosure.

When the distance through which a conveyed material falls from one conveyor to another or from a chute to a conveyor exceeds 3 ft, additional control measures may be necessary to maintain air contaminant concentrations at or below exposure limits. One method which is usually effective involves extension of the belt loading skirt as illustrated in Figure 5. Alternatively, an open hood may be installed at the position marked "A" on Figure 5. For belt or other conveying mechanism widths of 1 to 3 ft, the additional exhaust volume from this open hood shall be a minimum of 700 cfm. For widths greater than 3 ft, the exhaust volume shall be a minimum of 1000 cfm.

4.2.5 Belt Wipers

Where air contaminant concentrations in excess of exposure limits are generated due to material falling off the return strand of a belt, a belt wiper shall be installed, if practical. Figure 6 illustrates an acceptable design for a belt wiper. The minimum exhaust volume shall be 200 cfm per ft of belt width. The slot velocity shall be a minimum of 2000 fpm. Minimum duct velocity shall be 4000 fpm.

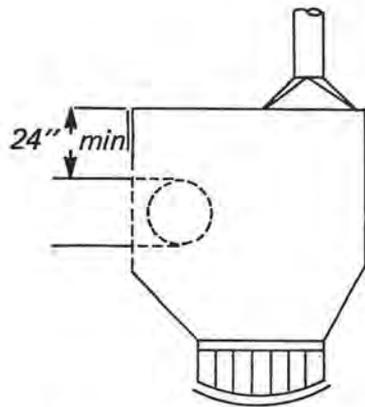


*Minimum Q = 500 cfm/ft of belt width but not less
 than 200 cfm/sq ft of all openings
 = 200 cfm/sq ft of all openings for conveying
 mechanisms other than belts*

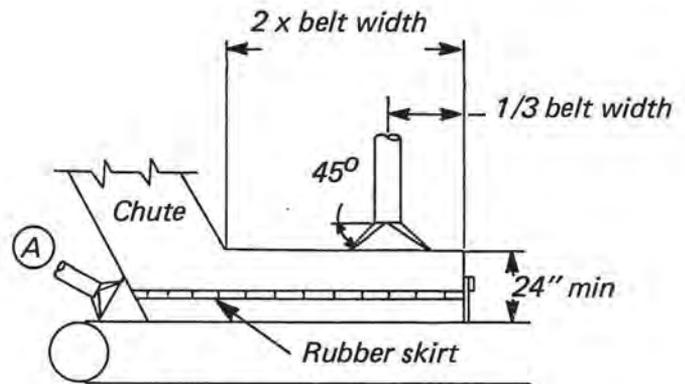
Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x duct VP

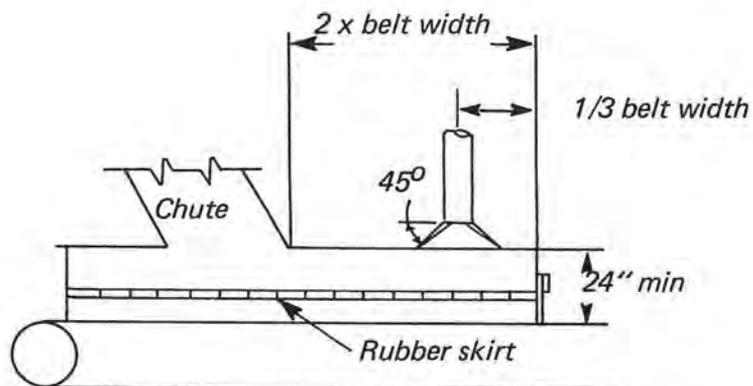
FIGURE 4 CONVEYOR TO ELEVATOR WITH MAGNETIC SEPARATOR



Conveyor to
conveyor transfer



Chute to conveyor transfer
with additional exhaust



Chute to conveyor transfer with extended skirt

- Minimum $Q = 350 \text{ cfm/ft}$ of belt width for speeds under 200 fpm but not less than 150 cfm/sq ft of all openings
- $= 500 \text{ cfm/ft}$ of belt width for speeds over 200 fpm but not less than 200 cfm/sq ft of all openings
- $= 150 \text{ cfm/sq ft}$ of all openings for conveying mechanisms other than belts

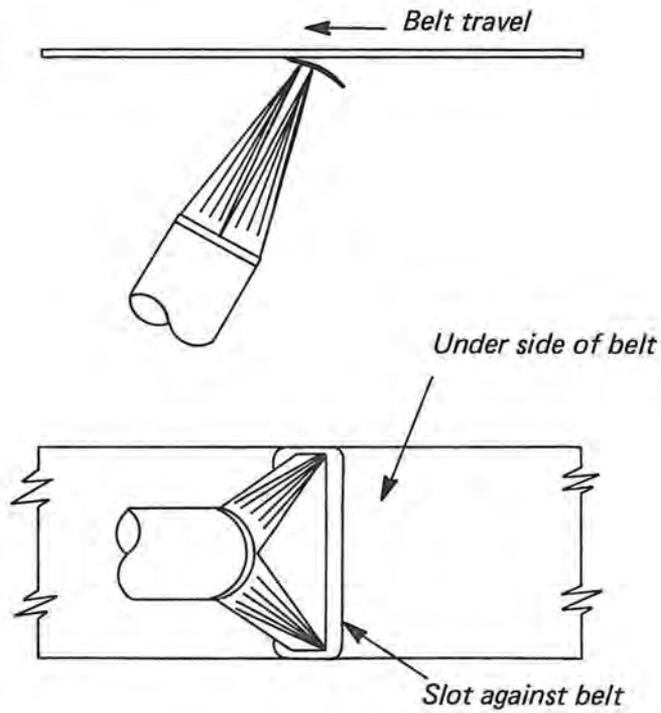
Duct velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x duct VP

Where material fall is greater than 3 ft, extend skirt or provide additional exhaust at A for dusty material as follows:

- Belt or other mechanism width 1-3 ft: $Q = 700 \text{ cfm}$ minimum
- above 3 ft: $Q = 1000 \text{ cfm}$ minimum

FIGURE 5 CONVEYOR OR CHUTE TO CONVEYOR TRANSFER



$Q = \text{minimum } 200 \text{ cfm/ft of belt width}$

$\text{Slot velocity} = 2000 \text{ fpm minimum}$

$\text{Duct velocity} = 4000 \text{ fpm minimum}$

$\text{Entry loss} = 1.78 \text{ slot VP}$

Not recommended for wet belts as in ore conveying.

FIGURE 6 BELT WIPER

4.3 Bins and Hoppers

4.3.1 General

Bin and hopper loading operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.3.2 Conveyor or Chute Loading

Where a bin or hopper is loaded by means of a chute or conveyor and the loading operation generates air contaminant concentrations in excess of exposure limits, the hopper and bin shall be enclosed and exhaust ventilated. Figure 7 illustrates acceptable designs and arrangements for the ventilation equipment. Where a belt conveyor is used and the belt speed is less than 200 fpm, an exhaust volume of a minimum of 350 cfm per ft of belt width, but not less than 150 cfm per sq ft of all openings in the hood shall be exhausted. For belt speeds greater than 200 fpm, the exhaust volume shall be a minimum of 500 cfm per ft of belt width but not less than 200 cfm per sq ft of all openings. Where another type of conveying mechanism is used, the minimum exhaust volume shall be 150 cfm per sq ft of all openings. Where a chute is used, minimum exhaust volume shall be 200 cfm per sq ft of all openings. In all cases, duct velocity shall be a minimum of 3500 fpm.

4.3.3 Loading By Other Means

Where a hopper is loaded by means other than with a conveyor or chute (e.g., by dumping the contents of a barrel or bag, by transfer utilizing a scoop or shovel, by use of a front end loader, etc.) and the loading operation generates air contaminant concentrations in excess of exposure limits, the hopper shall be provided an enclosing hood and shall be exhaust ventilated. Figure 8 illustrates an acceptable design and arrangement for the ventilation equipment. The exhaust hood provided shall be exhausted at a minimum rate of 150 cfm per sq ft of hood face. Duct velocity shall be a minimum of 3500 fpm.

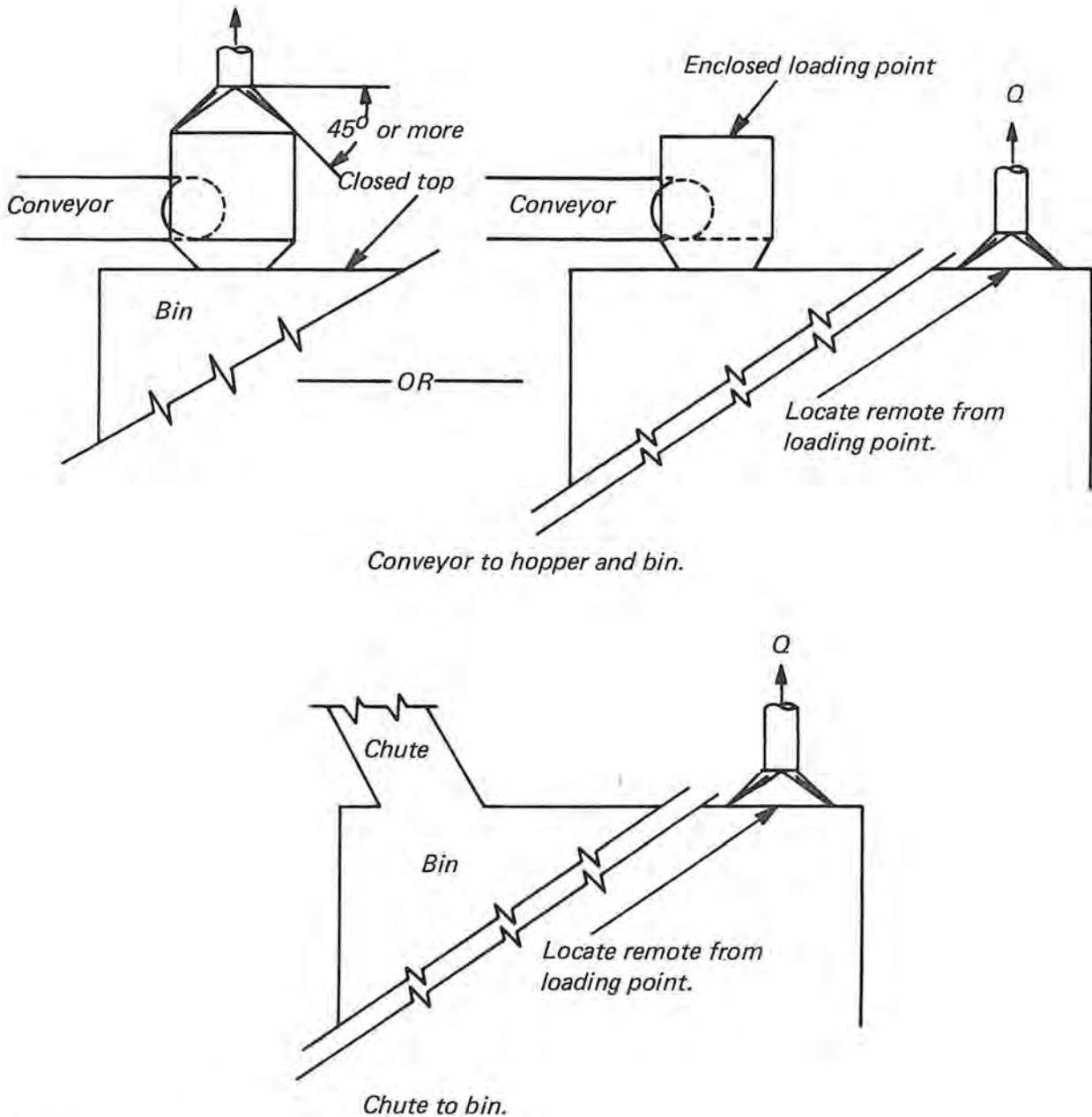
4.4 Filling and Packaging Operations

4.4.1 General

Filling and packaging operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.4.2 Bag Filling

Bag filling operations which generate air contaminant concentrations in excess of exposure limits shall be provided an exhaust hood and shall be exhaust ventilated. Figure 9 illustrates an



For conveyor to hopper and bin:

*Minimum Q = 350 cfm/ft of belt width but not less than 150 cfm/sq ft of openings
= 50 cfm/ft of belt width but not less than 200 cfm/sq ft of openings
= 150 cfm/sq ft of openings for conveying mechanisms other than belts*

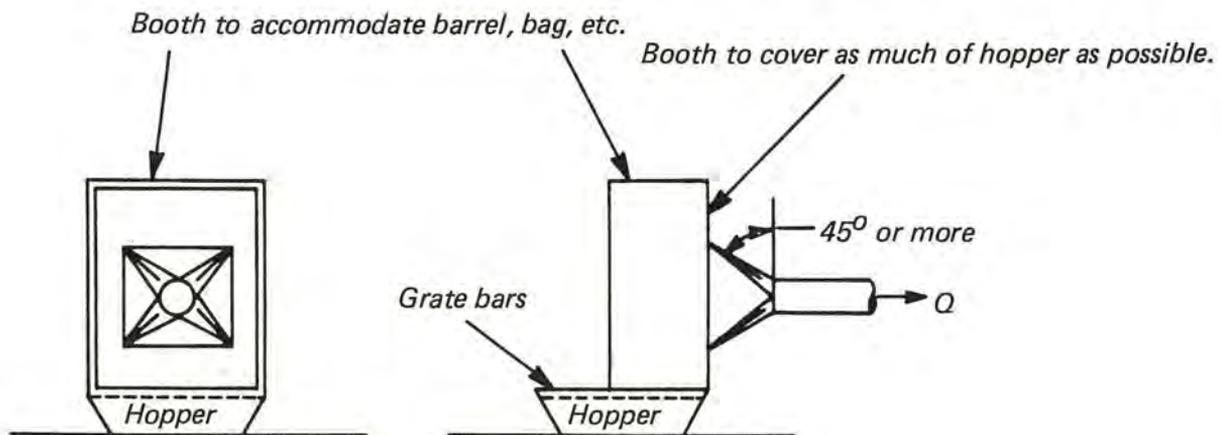
For chute to bin:

Minimum Q = 150 cfm/sq ft of openings in bin

For both:

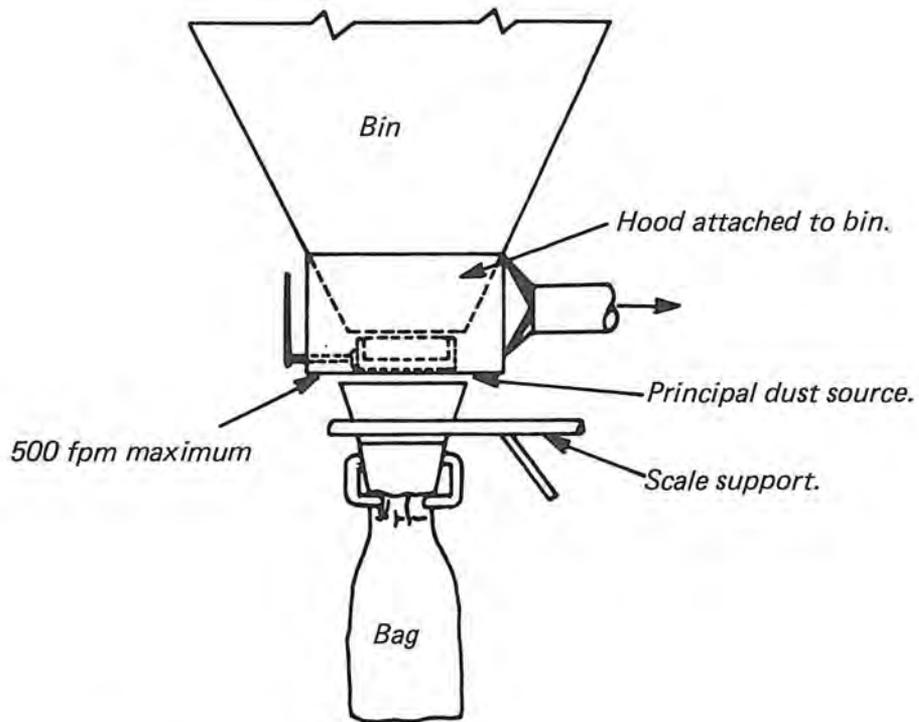
Duct velocity = 3500 fpm minimum

FIGURE 7 CHUTE AND CONVEYOR LOADING OF HOPPERS AND BINS



$Q = \text{minimum } 150 \text{ cfm/sq ft of hood face}$
 Entry loss = entry loss factor for tapered hood x duct VP
 Duct velocity = 3500 fpm minimum

FIGURE 8 ENCLOSING HOOD FOR HOPPERS



*Minimum Q = 400 cfm for non-toxic, nuisance dust
 = 1000 cfm for toxic dust*

Dust velocity = 3500 fpm minimum

Entry loss = entry loss factor for tapered hood x duct VP

FIGURE 9 BAG FILLING

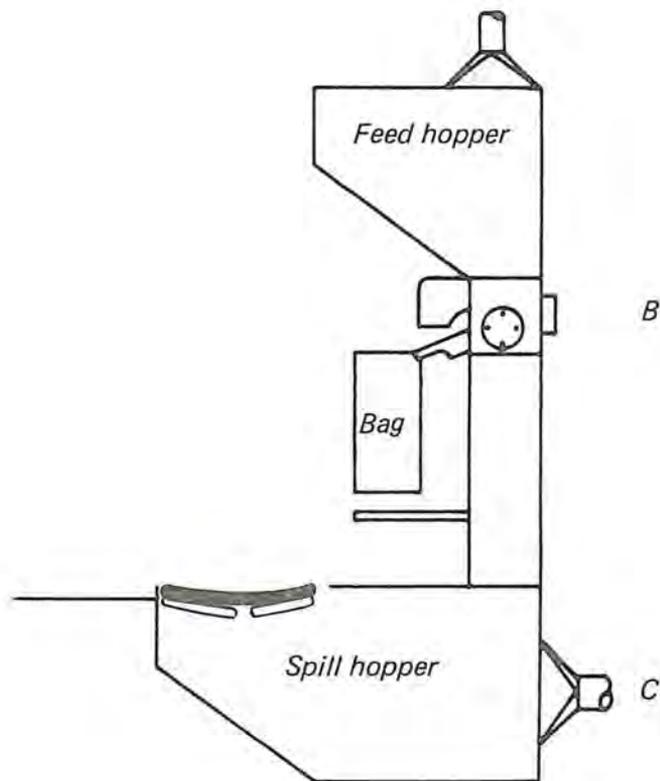
acceptable design and arrangement for the ventilation equipment. When a material considered to be a nuisance dust by 29 CFR 1910.1000 is handled in such an operation, a minimum exhaust volume of 400 cfm shall be provided. When a material which is considered to be toxic by 29 CFR 1910.1000 is handled in such an operation, the minimum exhaust volume shall be 1000 cfm. The minimum duct velocity shall be 3500 fpm.

4.4.3 Bag Tube Packing Machines

Bag tube packing machines which generate air contaminant concentrations in excess of exposure limits shall be provided an exhaust hood and shall be exhaust ventilated. Figure 10 illustrates an acceptable design and arrangement for the ventilation equipment. A minimum exhaust volume of 500 cfm shall be provided such machines at each filling tube. Additionally, minimum exhaust volumes of 500 cfm shall be provided at the feed hopper and 950 cfm at the spill hopper. Duct velocity shall be a minimum of 3500 fpm.

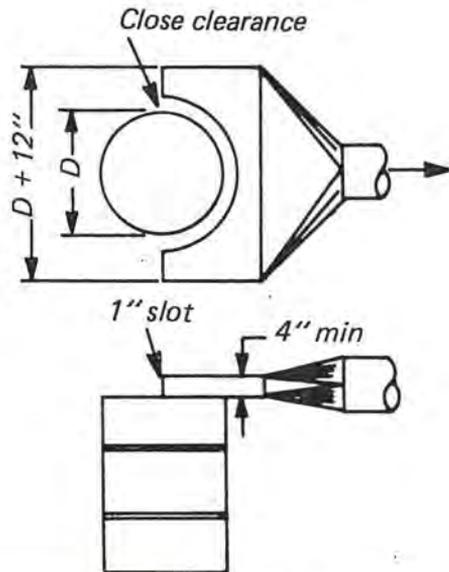
4.4.4 Barrel and Drum Filling

Barrel and drum filling operations which generate air contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations to levels at or below exposure limits. Figure 11 illustrates acceptable hood designs and associated exhaust volumes for such operations.

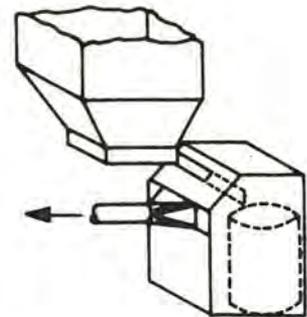


Minimum Q = 500 cfm/filling tube
= 500 cfm at feed hopper
= 950 cfm at spill hopper
Duct velocity = 3500 fpm minimum
Branch entry loss = entry loss factor for tapered hood x duct
VP at A & C
= 1.00 VP at open end at B

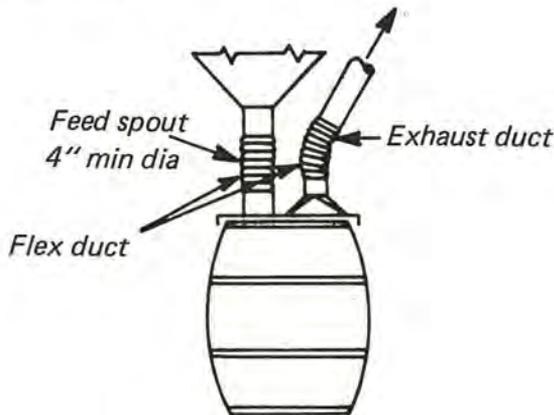
FIGURE 10 BAG TUBE PACKING MACHINE



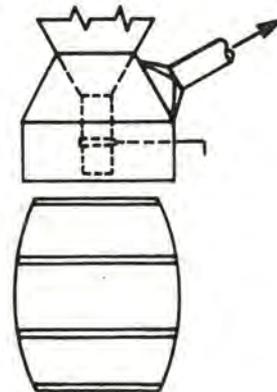
Minimum Q = 100 cfm/sq ft barrel top min
Duct velocity = 3500 minimum
Entry loss = 1.78 slot VP + entry loss factor
for tapered hood x duct VP
Manual loading only.



Minimum Q = 150 cfm/sq ft open face area
Duct velocity = 3500 fpm minimum
Entry loss = entry loss factor for tapered hood
x duct VP



Minimum Q = 50 cfm x drum dia (ft) for weighted lid
= 150 cfm x drum dia (ft) for loose lid
Duct velocity = 3500 fpm minimum
Entry loss = entry loss factor for tapered hood x duct VP



Minimum Q = 300 cfm
Duct velocity = 3500 fpm minimum
Entry loss = entry loss factor for tapered hood
x duct VP

FIGURE 11 BARREL AND DRUM FILLING

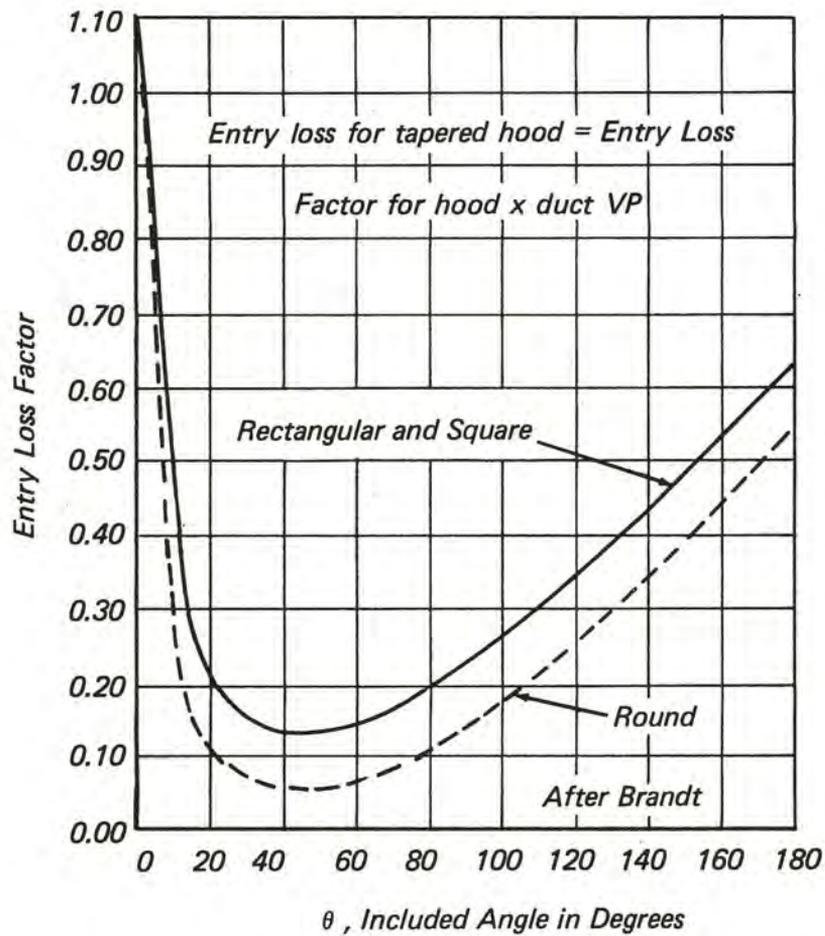
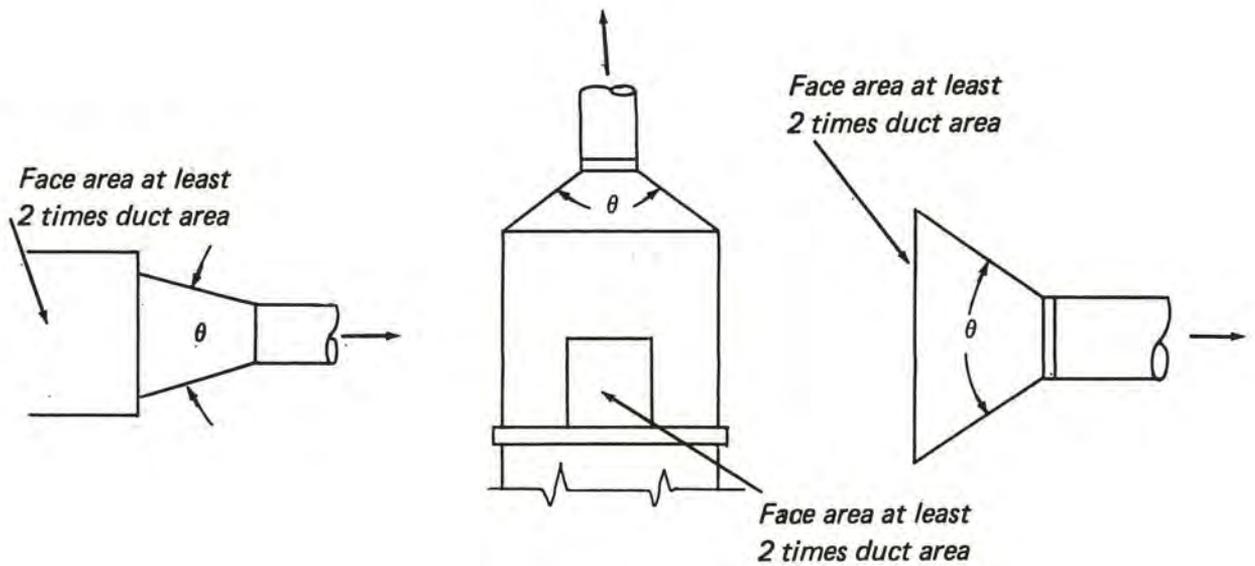
RECOMMENDED VENTILATION GUIDELINES FOR METAL MACHINING
AND METAL WORKING OPERATIONS

1. Scope

These guidelines prescribe the use of local exhaust ventilation for the control and removal of airborne contaminants generated by metal machining and metal working operations. Metal machining operations covered by these guidelines include turning, drilling, boring, reaming, broaching, shaping, planing, milling, and sawing. Metal working operations covered by the guidelines include cold and hot working. These guidelines do not cover metal grinding, polishing, and buffing operations or welding and thermal spraying operations. These latter operations are covered by other ventilation guidelines.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Enclosing Hood - An exhaust hood which partially or totally encloses a contaminant-producing operation; also booth or enclosure.
- f. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- g. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- h. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- i. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- j. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- k. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.



Tapered Hoods

*Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.*

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- l. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- m. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- n. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- o. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- p. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- q. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- r. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- s. Pressure, Static - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of water gauge when dealing with air. (The tendency to either burst or collapse a pipe.)
- t. Pressure, Total - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).
- u. Pressure, Velocity - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.

3. Application

These guidelines shall apply to all metal machining and metal working operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines.

Ventilation equipment provided in accordance with these guidelines shall be operated continuously while air contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists. These guidelines shall apply to contaminants generated directly or indirectly by metal machining and metal working operations including dusts and fumes from workpiece materials and workpiece surface coatings; dusts, mists, and vapors from lubricants and cutting fluids; and gases (e.g., ozone or nitrogen dioxide) generated by the interaction of high temperature machining processes with air.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions,

different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation System Design Requirements

4.1 General

Metal machining and metal working operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

A hood used for the control of contaminants from metal machining and metal working operations shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that the contaminants are projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

When the material being machined or worked upon in a metal machining or metal working operation is flammable or combustible when dispersed in air in a finely divided state, and the operation is exhaust ventilated, the minimum exhaust volume, where practical, shall be sufficient for dilution of air contaminant concentrations in the exhaust duct to a level at or below 25 percent of the lower explosive limit of the material under all operating conditions. Where a fan is located in the ductwork and the concentration of the air contaminant is greater than 25 percent of the lower explosive limit of the material being machined or worked upon, the fan rotating element shall be of nonsparking material or the casing shall consist of or be lined with nonsparking material. There shall be sufficient clearance between the fan rotating element and the fan casing so as to prevent contact.

Certain metallic dusts in a finely divided state if allowed to accumulate in hoods, ducts, or dust collectors may cause spontaneous combustion. The most notable of these materials is magnesium dust. Ventilation for magnesium dusts and particles should be preferably of the high velocity type. To reduce the danger of fire in the dust collector, a wet type collector should be used.

Design requirements for exhaust hoods applicable to and acceptable for the control of air contaminants from metal machining and metal working operations are specified in this section. The hood type to be used for a particular metal machining or metal working operation and the minimum exhaust flow to be provided the hood shall be in accordance with the provisions of Section 5 of these guidelines.

4.2 Non-Enclosing Hoods

4.2.1 Open Hoods

Figure 2 illustrates an acceptable freely suspended open hood design for the control of contaminated air from a metal machining or metal working operation. The hood face may be round, square, or rectangular in shape. The minimum exhaust volume through the hood shall be determined by the appropriate formula in Figure 2, using the capture velocity (V) specified for the operation in Section 5. Typical applications of open hoods to metal machining operations are illustrated in Figure 3. The hood which partially encloses the source of contaminants provides more effective contaminant control than the completely open hood.

In cases where an elongated hood face is required, a slot hood shall be used. Figure 4 illustrates acceptable designs for such hoods. The minimum exhaust volume through the hood shall be determined by the appropriate formula in the figure using the capture velocity (V) specified for the operation in Section 5. An example of a slot hood designed for use with a specific machine tool is shown in Figure 5.

If an open hood of a different design is used, it shall provide a capture velocity at the farthest point of contaminant release from the hood face equal to or greater than that specified in Section 5.

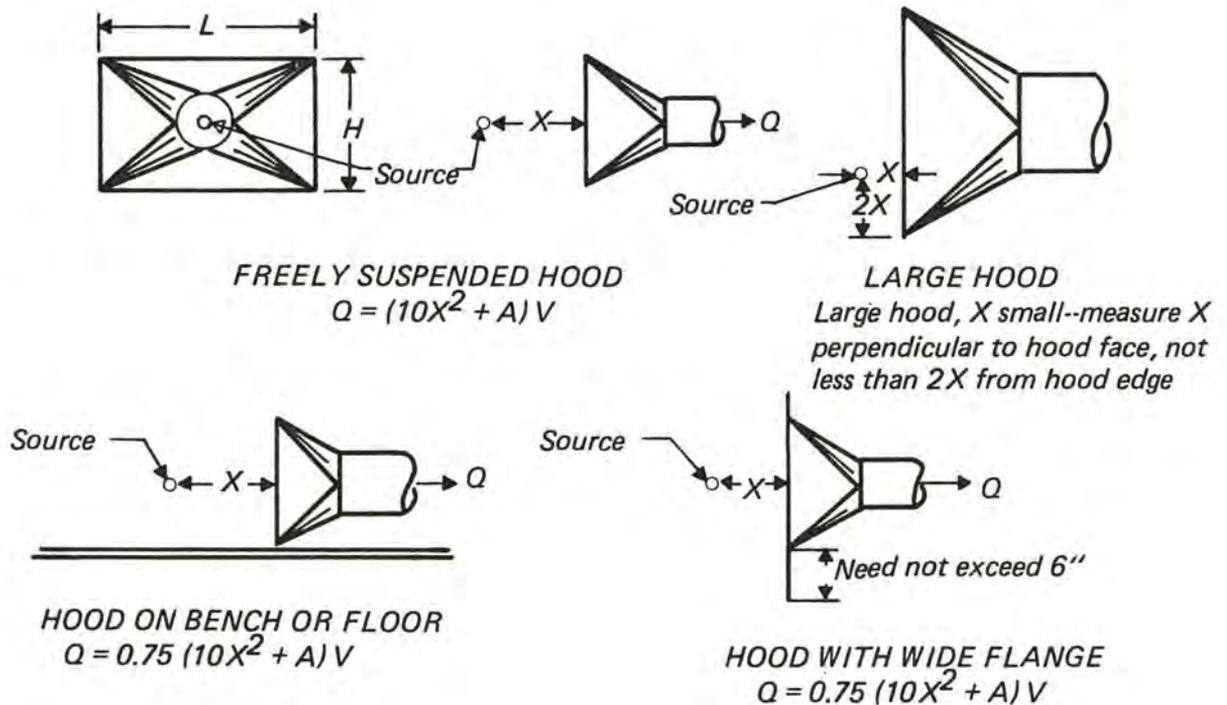
4.2.2 Low-Volume High-Velocity Open Hoods

A low-volume high-velocity open hood is a hood designed and operated to produce high capture velocities at points of contaminant release. Low-volume high-velocity hoods may be used to achieve greater effectiveness in contaminant control or to control contaminants released with high initial velocities. Low-volume high-velocity hoods generally are designed to be small in size and to be located in close proximity to the contaminant release point. Hoods of this type require relatively small exhaust volumes to achieve contaminant control. An example of an acceptable low-volume high-velocity hood design is shown in Figure 6.

Low-volume high-velocity hoods generally must produce capture velocities exceeding the contaminant release velocity. When a low-volume high-velocity hood is used with a metal machining or metal working operation, the minimum exhaust flow requirement necessary to prevent employee exposure to air contaminant concentrations in excess of exposure limits shall be determined by measurement of employee exposure for each hood design and operation.

4.3 Enclosing Hoods

An enclosing hood used with a metal machining or metal working operation shall be designed to prevent the projection of contaminants outward through hood openings. The principle of an enclosing hood is illustrated in Figure 7. Examples of enclosing hoods designed for use with specific types of machine tools are shown in Figures 8, 9, and 10.



Q = exhaust volume, cfm

X = distance from hood face to farthest point of contaminant release, feet.

A = hood face area, sq ft, equals LH

L = length of hood, feet

H = height of hood, feet

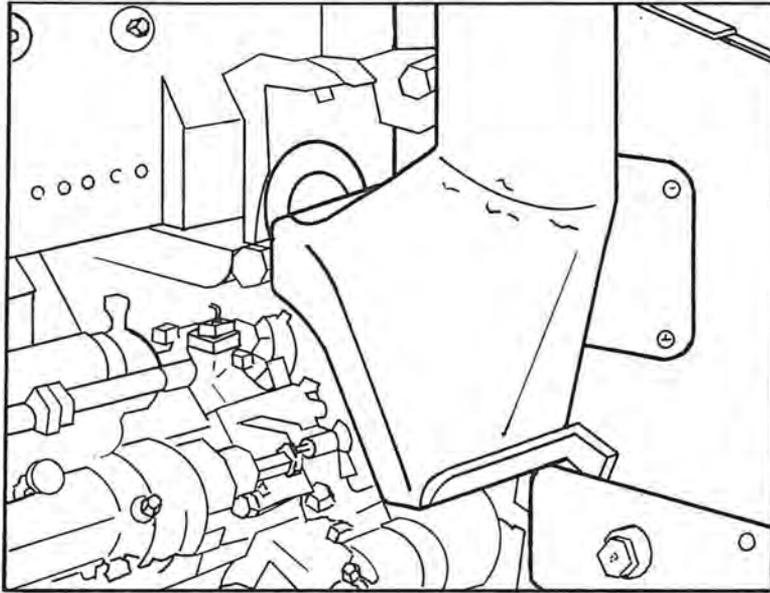
V = minimum capture velocity, fpm, at distance X

Entry loss = entry factor for tapered hood X duct VP

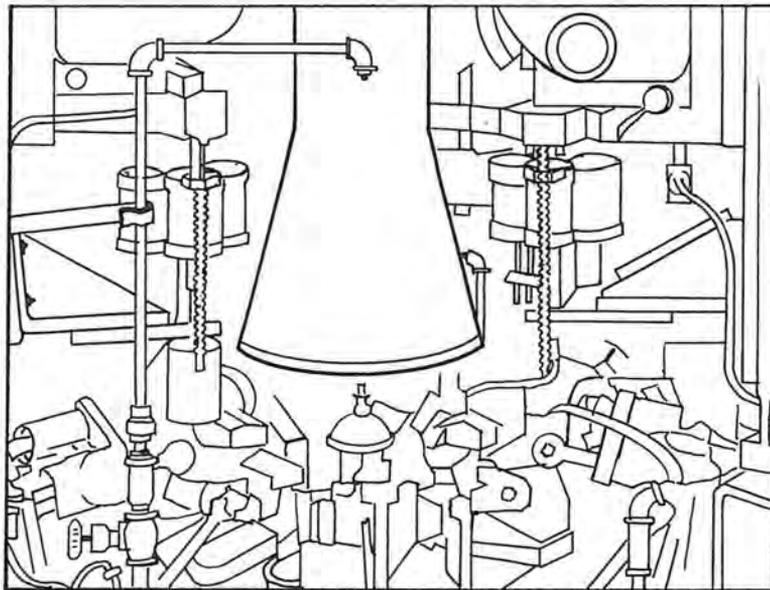
Duct velocity = 2000 fpm minimum

Note: Air volume must increase as the square of distance of the source from the hood.
Baffling by flanging or by placing on bench, floor, etc. has a beneficial effect.

FIGURE 2 OPEN HOODS

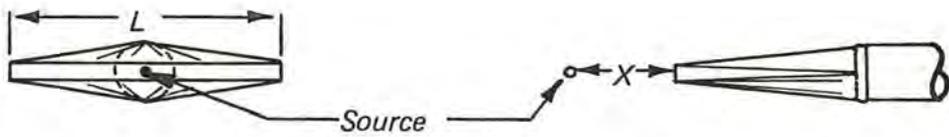


Open Hood with Partial Enclosure



Open Hood

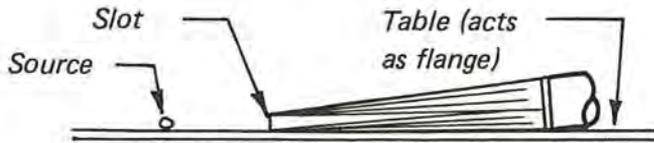
FIGURE 3 TYPICAL APPLICATIONS OF OPEN HOODS TO METAL MACHINING OPERATIONS



FREELY SUSPENDED SLOT

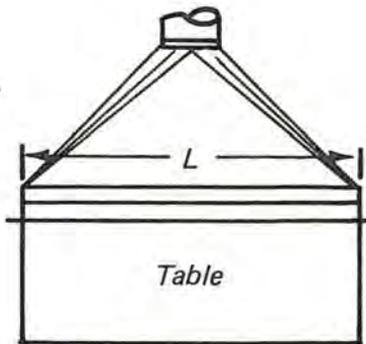
$Q = 3.7 LXV$

- Q = exhaust volume, cfm
- X = distance, feet, hood face to farthest point of source (usually on centerline of hood)
- V = minimum capture velocity, fpm, at distance X
- L = length, feet, of hood
- W = width, feet, of table
- Duct velocity = 2000 fpm minimum
- Entry loss = 1.78 slot VP plus entry loss factor for tapered hood X duct VP



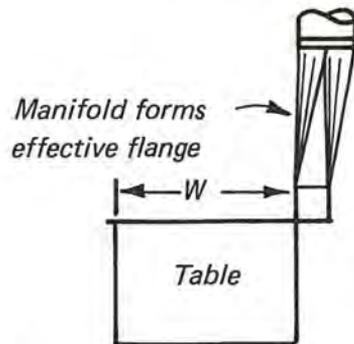
SLOT ON TABLE OR BENCH

$Q = 2.8 LXV$



FLANGED SLOT

$Q = CLW$



(C = constant from 50–500; usual choice is 150–250)

Exhaust volume formulae above applicable when $X/L < 0.3$. When $X/L > 0.3$, use open hood formulae in Figure 3.

FIGURE 4 SLOT HOOD

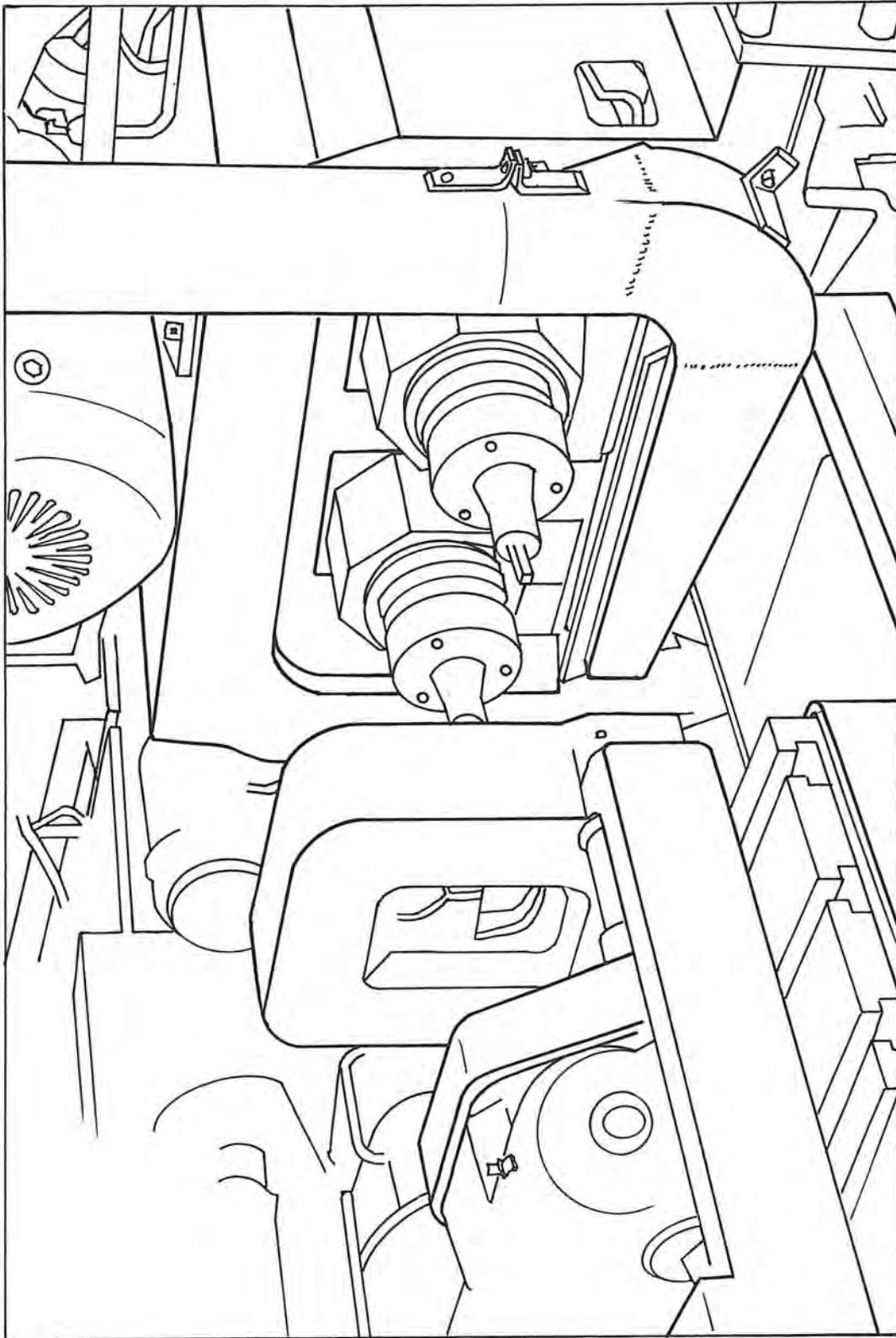


FIGURE 5 TYPICAL APPLICATION OF A SLOT HOOD TO A METAL MACHINING OPERATION (Boring Machine)

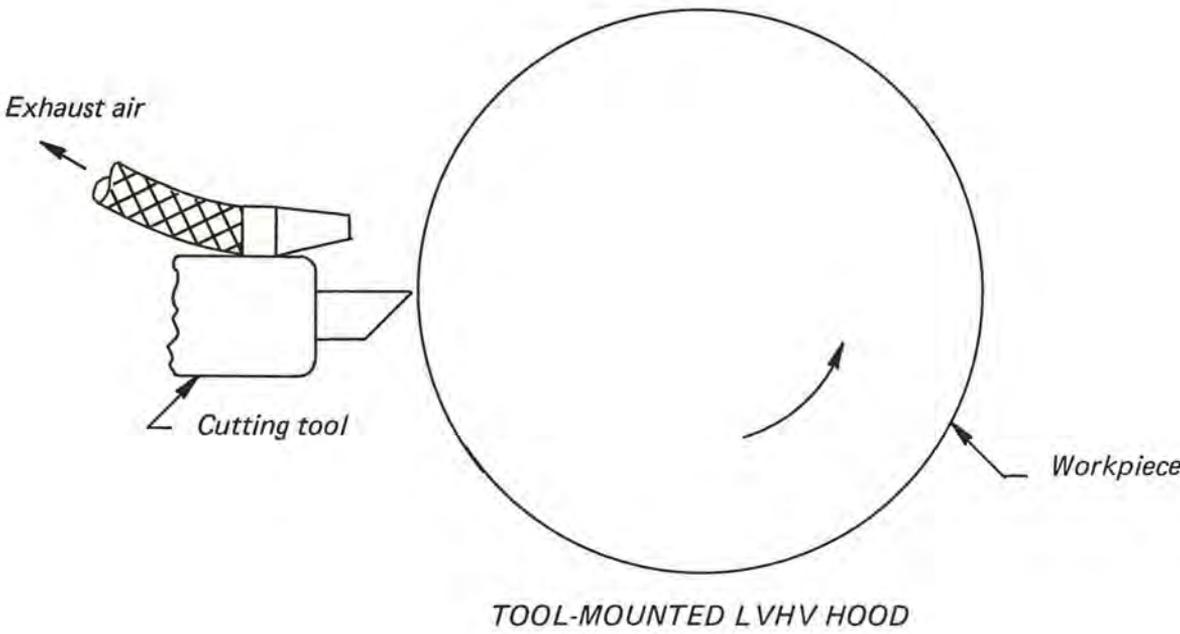
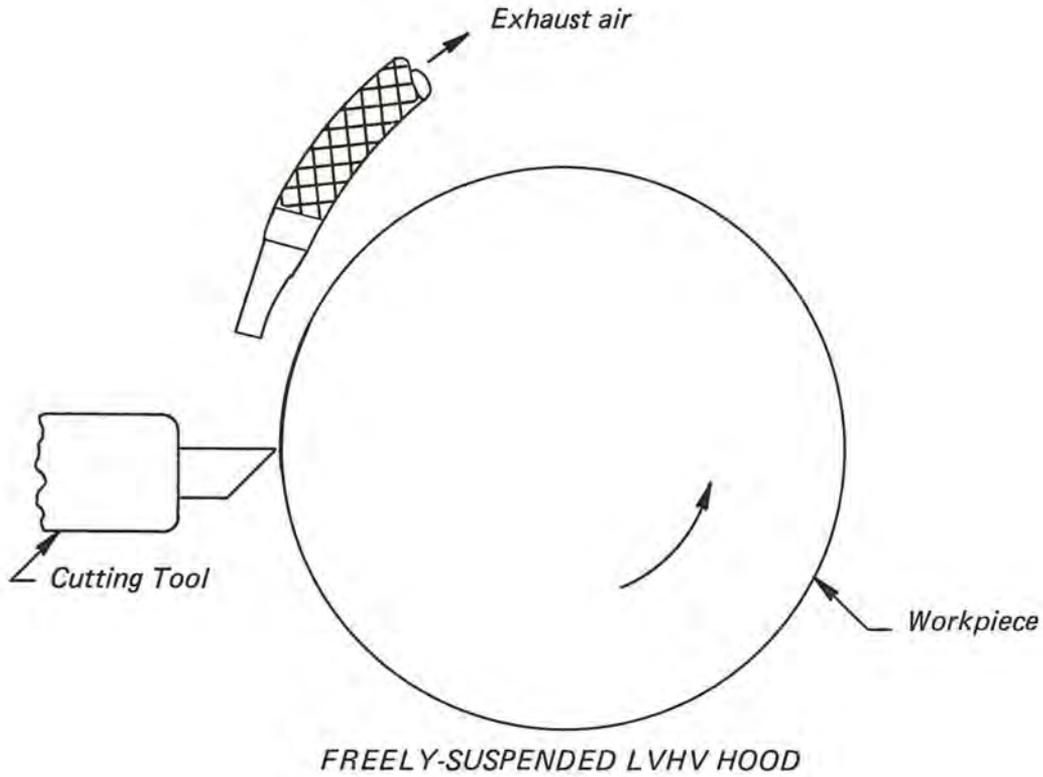


FIGURE 6 TYPICAL APPLICATIONS OF LOW-VOLUME-HIGH-VELOCITY HOODS TO METAL MACHINING OPERATIONS

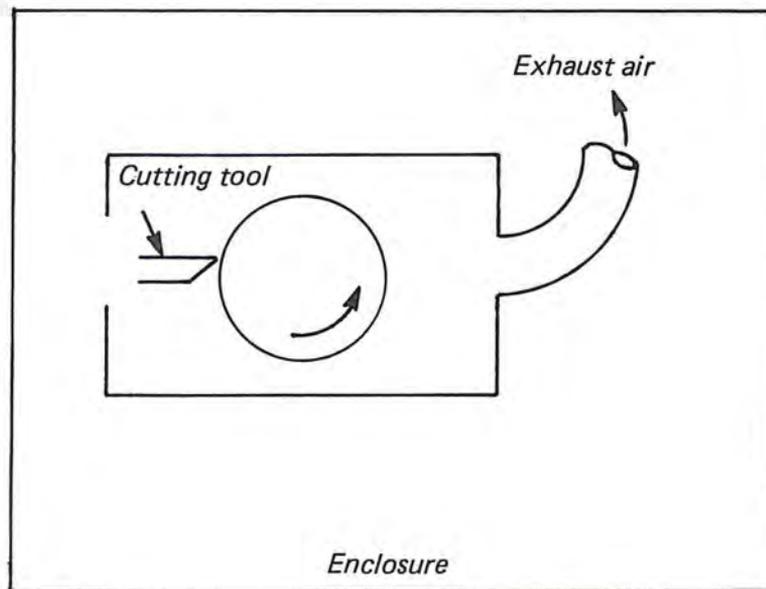


FIGURE 7 PRINCIPLE OF OPERATION OF ENCLOSING HOODS

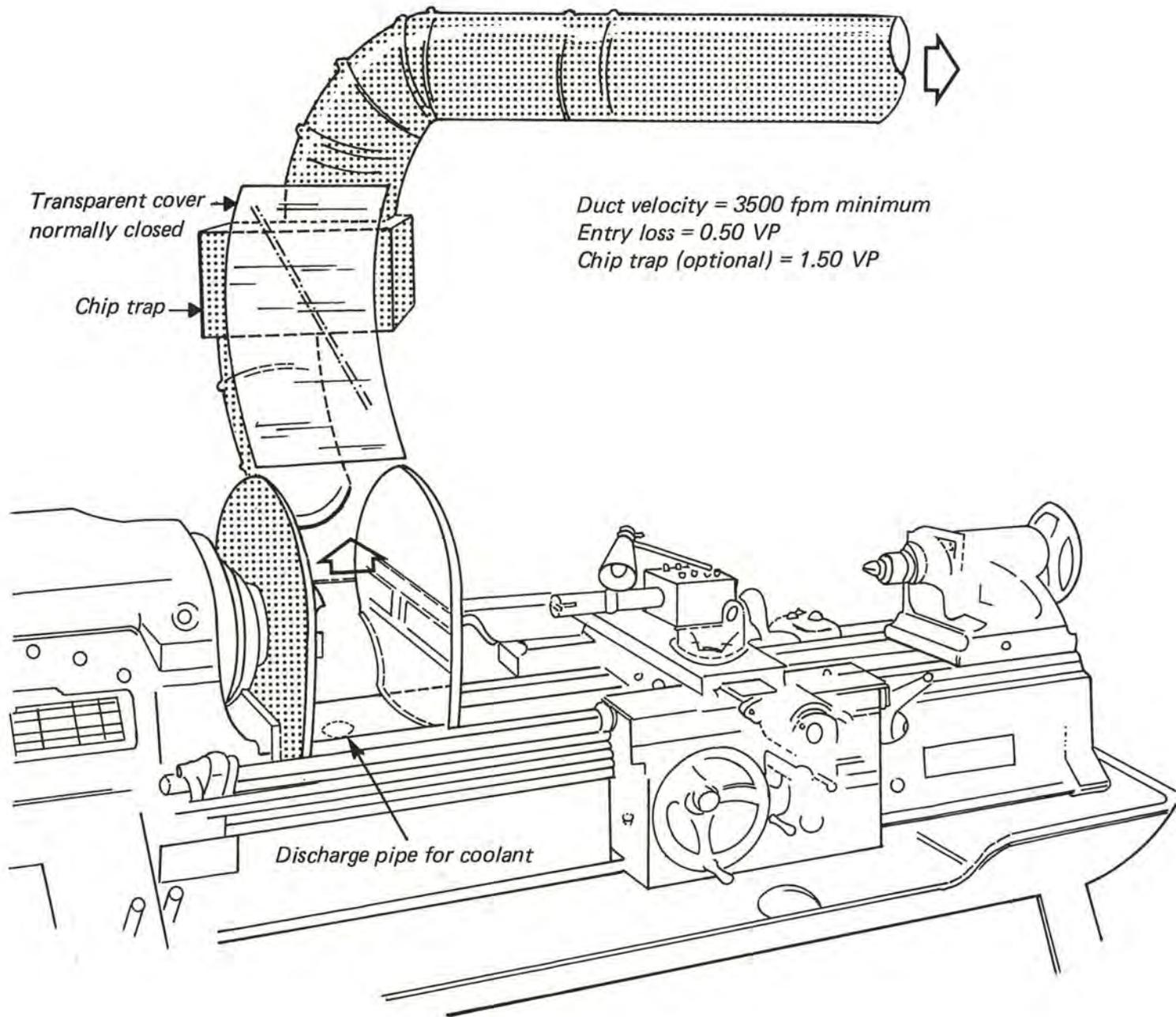
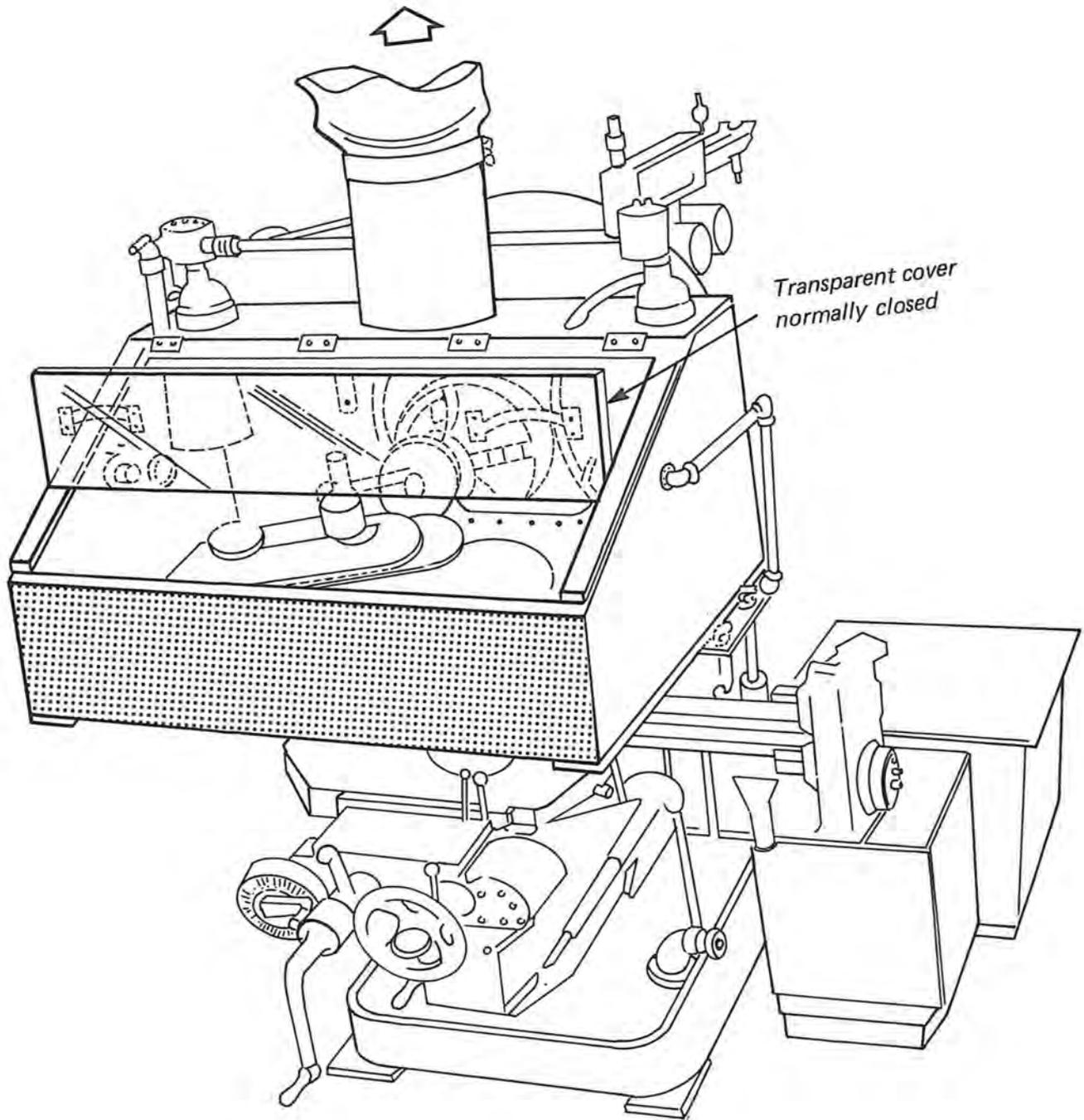
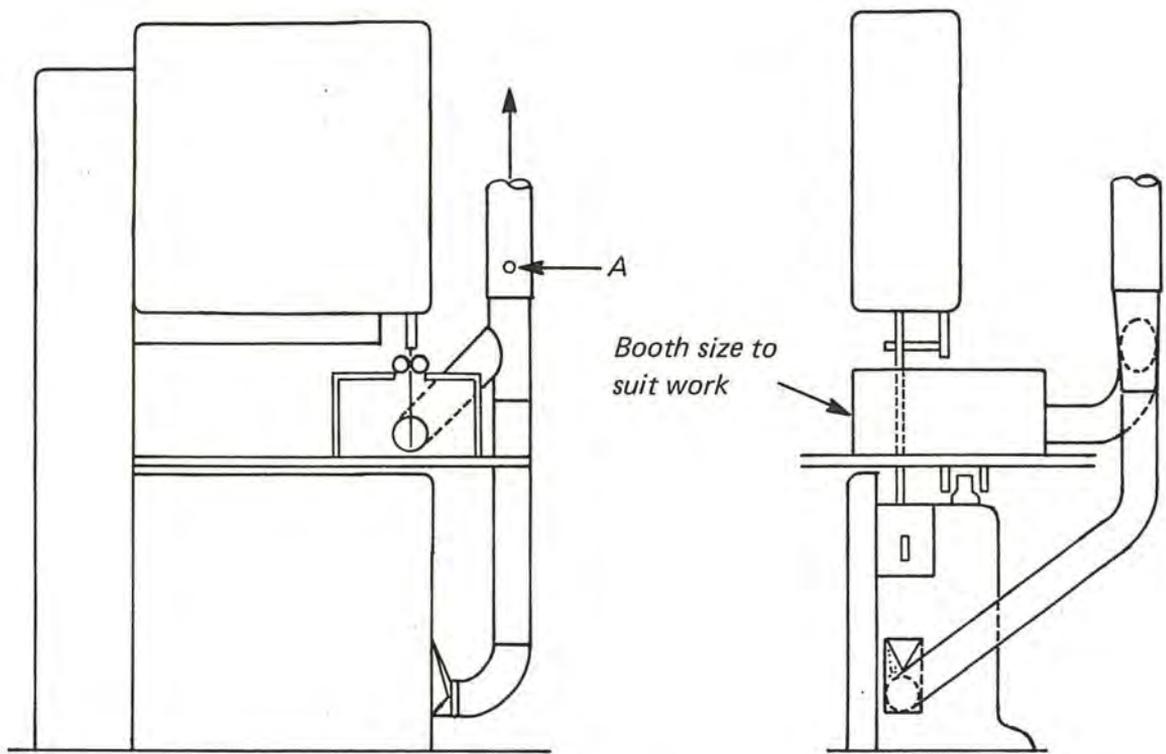


FIGURE 8 TYPICAL APPLICATION OF AN ENCLOSING HOOD TO A METAL MACHINING OPERATION (LATHE)



Duct velocity = 3500 fpm minimum
Entry loss = 0.35 VP

FIGURE 9 TYPICAL APPLICATION OF AN ENCLOSING HOOD TO A METAL MACHINING OPERATION (MILLING MACHINE)



Duct velocity = 4000 fpm minimum
Entry loss = 1.75 VP in riser (point A)

FIGURE 10 TYPICAL APPLICATION OF ENCLOSING HOODS
 TO A METAL MACHINING OPERATION (BAND SAW)

Minimum exhaust flow requirements for enclosing hoods are specified in Section 5.

5. Ventilation System Applicability and Operational Requirements

5.1 Applicability

Classes of contaminant materials, defined on the basis of exposure limits, are listed in Table 1. Types of hoods applicable to and acceptable for the control of each contaminant class are indicated in the table. If an operation results in exposure of an employee to excessive concentrations of contaminant materials of two or more classes, selection of a hood type shall be based on the highest applicable contaminant class.

5.2 Exhaust Flow Requirements

Minimum exhaust flow requirements for combinations of various hood types and contaminant classes are listed in Table 2.

TABLE 1

Classification of Contaminant Materials

Contaminant Class	Classification Criteria	Example Materials	Applicable Hood Types
I	Dusts, fumes, and mists with exposure limits of 10 mg/M ³ and above; gases and vapors with exposure limits of 100 ppm and above.	Nuisance Dust Iron Iron Oxide Steel Aluminum Zinc	Open hoods, enclosing hoods
II	Dusts, fumes, and mists with exposure limits of 0.1 mg/M ³ and above (up to 10 mg/M ³); gases and vapors with exposure limits of 1 ppm and above (up to 100 ppm).	Cadmium Chromium Cobalt Copper Lead Nickel Nitrogen Dioxide Oil Mist Ozone	Open hoods, enclosing hoods
III	Dusts, fumes, and mists with exposure limits below 0.1 mg/M ³ ; gases and vapors with exposure limits below 1 ppm.	Beryllium Mercury Uranium	Enclosing hoods, High-Velocity Open Hoods

TABLE 2

Minimum Exhaust Flow Requirements

Contaminant Class	Open Hood	Enclosing Hood
I	Capture Velocity; 100 fpm min.	100 cfm/sq ft of open area
II	Capture Velocity; 200 fpm min.	200 cfm/sq ft of open area
III	Capture Velocity; 500 fpm min.	300 cfm/sq ft of open area

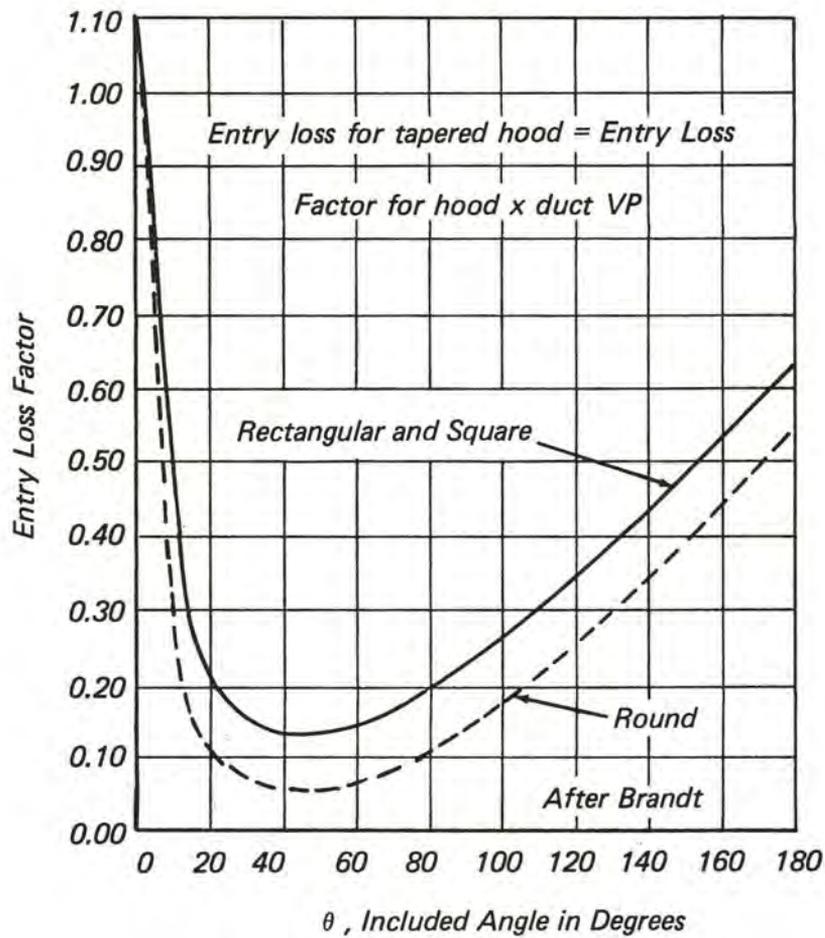
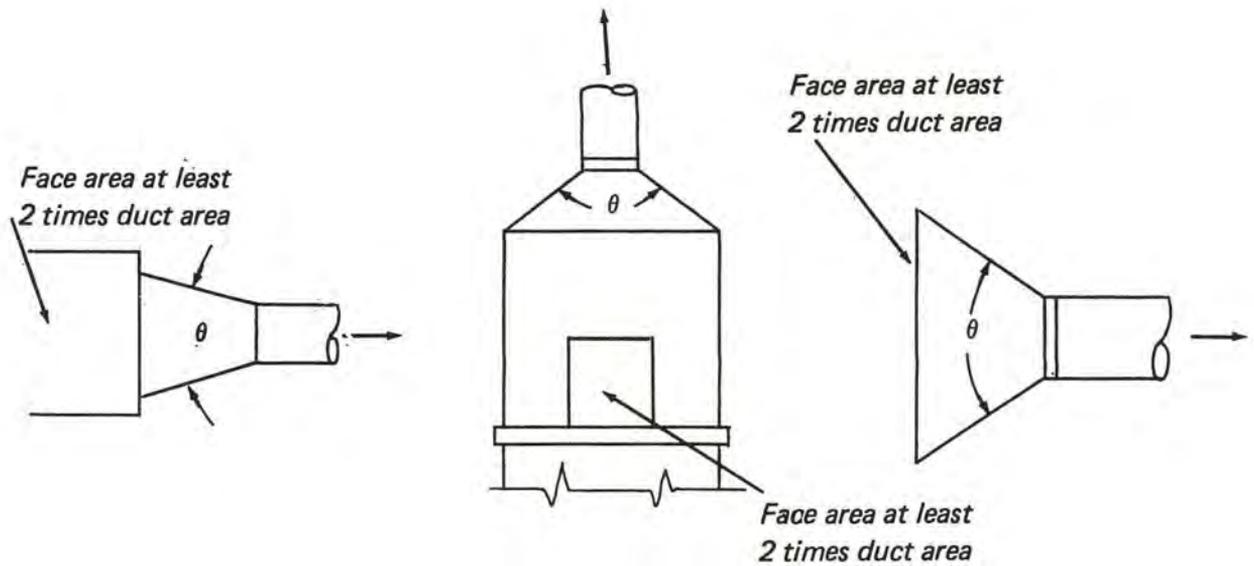
RECOMMENDED VENTILATION GUIDELINES FOR OPEN-SURFACE TANK OPERATIONS

1. Scope

These guidelines prescribe the use of general ventilation and local exhaust ventilation for the control and removal of airborne contaminants generated by open-surface tank operations. Open-surface tank operations covered by these guidelines include vapor degreasing, solvent degreasing, emulsion degreasing, electroplating, anodizing, pickling, quenching, dyeing, dipping, tanning, metal stripping, rust-proofing, rinsing, digesting and all other operations involving the immersion of materials in liquids, or in the vapors of liquids contained in pots, tanks, vats or similar containers. These guidelines do not apply to operations involving molten metals, to surface-coating operations, or to the draining or drying of material subsequent to immersion in open-surface tanks.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Enclosing Hood - An exhaust hood which partially or fully encloses the source of contaminants.
- f. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- g. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- h. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- i. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- j. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.



Tapered Hoods

Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- k. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- l. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- m. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- n. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- o. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- p. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
- q. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- r. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- s. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.

3. Application

These guidelines shall apply to all open-surface tank operations (as described in Scope) which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while the contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive concentrations exists.

These guidelines define minimum requirements for air contaminant control. The exhaust hood designs illustrated in the guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as

necessary to maintain contaminant levels at or below exposure limits. In cases where control means other than ventilation (such as surface-active agents, tank covers, or foams, beads, chips or other material floated on the tank surface) are employed, ventilation measures less stringent than those described in these guidelines may be utilized if contaminant concentrations can be maintained below the exposure limits.

4. Classification of Open-Surface Tank Operations

Open-surface tank operations shall be classified into 16 classes, numbered A-1 to D-4, inclusive. Class is determined by two factors, hazard potential designated by a letter from A to D, inclusive, and rate of gas, vapor, or mist evolution designated by a number from 1 to 4, inclusive (for example, B-3).

4.1 Hazard Potential

4.1.1 General

Hazard potential is an index, on a scale from A to D, inclusive, of the severity of the hazard associated with the substance contained in the tank because of the toxic, flammable, or explosive nature of the vapor, gas, or mist produced therefrom.

The toxic hazard is determined from the permissible exposure concentration, measured in parts per million parts of contaminated air (ppm), or in milligrams per cubic meter of air (mg/M³), as specified in 29 CFR 1910.1000. The relative fire or explosion hazard is measured in degrees Fahrenheit in terms of the closed-cup flash point of the substance in the tank.

4.1.2 Determination of Hazard Potential

Hazard potential shall be determined from Table 1, with the value indicating greater hazard being used. For example, when the hazardous material may be either a vapor with an exposure limit (TLV) in ppm or a mist with a TLV in mg/M³, the TLV indicating the greater hazard shall be used. (A takes precedence over B; B over C; C over D.)

Where the tank contains a mixture of liquids (other than organic solvents whose effects are additive), the hygienic standard of the most toxic component (for example, the one having the lowest ppm or mg/M³) shall be used, except where such substance constitutes an insignificantly small fraction of the mixture. For mixtures of organic solvents, their combined effect, rather than that of any individual component, shall determine the hazard potential. In the absence of information to the contrary, the effects shall be considered as additive. The TLV of an additive mixture shall be calculated from the following formula:

TABLE 1

Determination of Hazard Potential

Hazard Potential	Toxicity Group		Flash Point
	Gas or Vapor (ppm)	Mist (mg/M3)	
A	0-10	0-.1	-
B	11-100	0.11-1.0	Under 100°F
C	101-500	1.1-10	100-200°F
D	Over 500	Over 10	Over 200°F

$$\frac{\frac{c(1)}{TLV(1)} + \frac{c(2)}{TLV(2)} + \dots + \frac{c(n)}{TLV(n)}}{1} = \text{TLV of the mixture}$$

where:

$c(n)$ = concentration measured at the operation of component n .
 If the sum of the ratios of the airborne concentrations of each contaminant to the toxic concentration of that contaminant exceeds unity, i.e., if

$$\frac{c(1)}{TLV(1)} + \frac{c(2)}{TLV(2)} + \frac{c(3)}{TLV(3)} + \dots + \frac{c(n)}{TLV(n)} \text{ is greater than } 1$$

then the TLV of the mixture shall be considered as being exceeded.

4.2 Rate of Contaminant Evolution

4.2.1 General

Rate of gas, vapor, or mist evolution is a numerical index on a scale of from 1 to 4, inclusive, both of the relative capacity of the tank to produce gas, vapor, or mist and of the relative energy with which it is projected or carried upwards from the tank. Rate is evaluated in terms of:

- a. The temperature of the liquid in the tank in degrees Fahrenheit;
- b. The number of degrees Fahrenheit that this temperature is below the boiling point of the liquid in degrees Fahrenheit.
- c. The relative evaporation of the liquid in still air at room temperature in an arbitrary scale -- fast, medium, slow, or nil; and
- d. The extent that the tank gasses or produces mist in an arbitrary scale -- high, medium, low, and nil.

4.2.2 Determination of Rate of Contaminant Evolution

Rate of contaminant evolution shall be determined from Table 2. Where liquid temperature, degrees below boiling point, relative evaporation rate and gassing yield different numerical values, the lowest numerical value shall be used.

5. Ventilation Equipment Design Requirements

TABLE 2

Determination of Rate of Contaminant Evolution

Rate	Liquid Temperature, °F	Degrees Below Boiling Point	Relative Evaporation (Note 2)	Gassing (Note 3)
1	over 200	0-20	Fast	High
2	150-200	21-50	Medium	Medium
3	94-149	51-100	Slow	Low
4	under 94	over 100	Nil	Nil

NOTES:

1. In certain classes of equipment, specifically vapor degreasers, an internal condenser or vapor level thermostat is used to prevent the vapor from leaving the tank during normal operation. In such cases, rate of vapor evolution from the tank into the workroom is not dependent upon the factors listed in the table, but rather upon abnormalities of operating procedure, such as carryout of vapors from excessively fast action, dragout of liquid by entrainment in parts, contamination of solvent by water and other materials, or improper heat balance. When operating procedure is excellent, effective rate of evolution may be taken as 4. When operating procedure is average, the effective rate of evolution may be taken as 3. When operation is poor, a rate of 2 or 1 is indicated, depending upon observed conditions.

2. Relative evaporation rate is determined according to the method described by A. K. Doolittle in Industrial and Engineering Chemistry, vol. 27, p 1169, where time for 100-percent evaporation is as follows: Fast: 0-3 hours; Medium: 3-12 hours; Slow: 12-50 hours; Nil: more than 50 hours. For classification of specific contaminants, see 29 CFR 1910.1000.

3. Gassing means the formation by chemical or electrochemical action of minute bubbles of gas under the surface of the liquid in the tank and is generally limited to aqueous solutions. Gassing rates for some typical operations are estimated in Appendix A of ANSI Standard Z9.1.

5.1 Enclosing Hoods

An enclosing hood shall:

- a. Project over the entire tank,
- b. Be designed such that normal work procedures do not require the worker's head to be within the enclosure,
- c. Be enclosed on at least two sides and the top.

Acceptable enclosing hood designs are depicted in Figure 2. The quantity of air in cubic feet per minute necessary to be exhausted through an enclosing hood shall be not less than the product of the face velocity times the net area of all openings in the enclosure through which air can flow into the hood.

5.2 Lateral Hoods

5.2.1 General

Hoods which do not project over the entire tank, and in which the direction of air movement into the hood or hoods is substantially horizontal, shall be considered to be lateral exhaust hoods. Acceptable lateral hood designs are depicted in Figures 3, 4, and 5. The quantity of air in cubic feet per minute necessary to be laterally exhausted per square foot of tank area in order to maintain the required capture velocity shall be determined from Table 4 for all variations in ratio of tank width (W) to tank length (L). The total quantity of air in cubic feet per minute required to be exhausted per tank shall be not less than the product of the area of tank surface times the cubic feet per minute per square foot of tank area, determined from Table 4. Open-surface tanks with lateral exhaust are vulnerable to crossdrafts, and for effective control with the airflows given in Table 4, crossdrafts must be kept at a minimum.

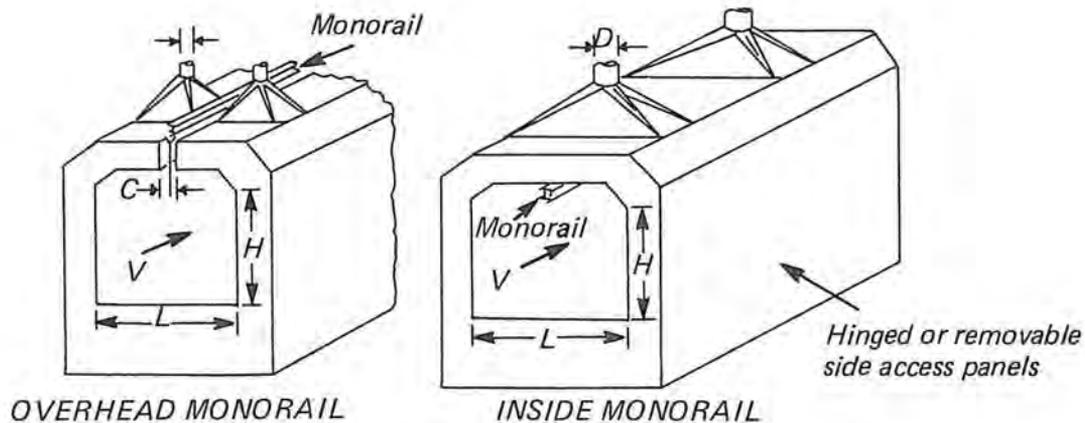
5.2.2 Push-Pull Hoods

Lateral exhaust hoods shall be considered push-pull hoods when air-supply slots or orifices are provided along the side or center of the tank opposite from the exhaust slots. An acceptable push-pull lateral exhaust hood design is shown in Figure 6.

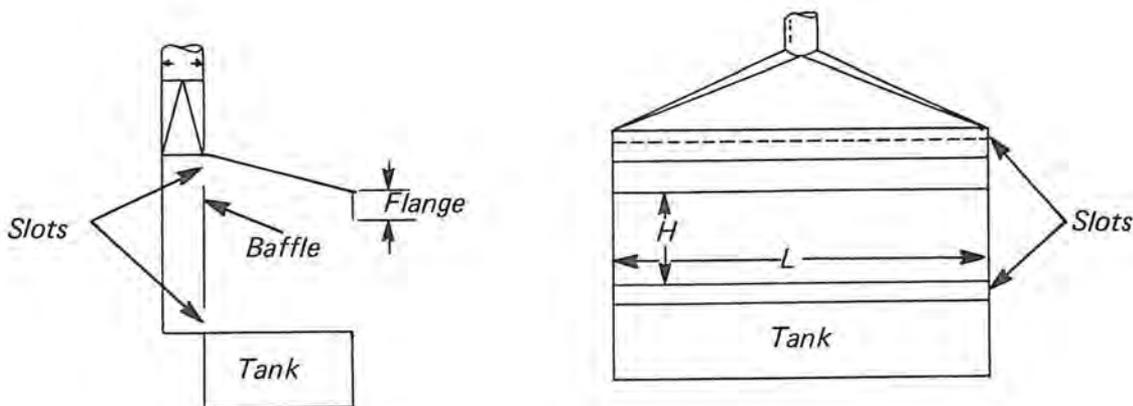
The supply air volume of a push-pull hood plus the entrained air shall not exceed 50 percent of the exhaust volume. The velocity of the supply air-stream as it reaches the effective control area of the exhaust slot shall be less than the effective velocity over the exhaust slot area. The supply air-stream shall not be allowed to impinge on obstructions between it and the exhaust slot in such a manner as to significantly interfere with the performance of the exhaust hood.

5.3 Canopy Hoods

All tanks exhausted by means of hoods which project over the entire tank, and which do not conform to the definition of enclosing hoods,



Q = exhaust volume, cfm, equals AV
 H = height of rectangular opening, feet
 L = length of opening, feet
 A = area of openings in enclosure
 = $2HL + \text{area of monorail slot}$
 V = minimum face velocity, fpm (see Table 3)
 Duct velocity = 1500 fpm minimum
 Entry loss = entry loss factor for tapered hood x duct VP
 Make C , L , and H only large enough to pass work and hanger



Q = exhaust volume, cfm, equals AV
 H = height of open area, feet
 L = length of open area, feet
 A = area of openings in enclosure, sq ft, equals LH
 V = minimum face velocity, fpm (see Table 3)
 Duct velocity = 1500 fpm minimum
 Slot velocity = 2000 fpm minimum
 Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP

FIGURE 2 ENCLOSING HOODS

TABLE 3

Ventilation Requirements for Open-Surface Tank Operations

Class (See Section 2 and Tables 1 and 2)	Enclosing Hood (see 5.1)		Lateral Exhaust (Note 1) Capture Velocity (see 5.2) (fpm)	Canopy Hood (Note 2) Capture Velocity (see 5.3)	
	One Open Side (fpm)	Two Open Sides (fpm)		Three Open Sides (fpm)	Four Open Sides (fpm)
A-1, and A-2	100	150	150	Do not use	Do not use
A-3 (Note 2), B-1, B-2, and C-1	75	100	100	125	175
B-3, C-2, and D-1 (Note 3)	65	90	75	100	150
A-4 (Note 2), C-3, and D-2 (Note 3)	50	75	50	75	125
B-4, C-4, D-3 (Note 3), and D-4	General room ventilation required (See 5.4)				

NOTES:

1. See Table 4 for computation of ventilation rate.
2. Do not use canopy hood for hazard potential A processes.
3. Where complete control of hot water is desired, design as next highest class.
4. Proper solvent vapor degreaser ventilation should be designed to provide just enough ventilation to control vapor to a safe concentration that would escape from an unventilated tank. Excessive ventilation increases solvent loss by drawing the vapor (the degreasing media) which should be retained in the tank into the ventilating system. A slide damper should be provided in the air duct, the degreaser should be checked with an instrument for determining vapor concentration, and the airflow should be regulated with the damper to the minimum airflow that will give proper control. This will help control high solvent loss.

Q = exhaust volume, cfm, equals qLW

L = tank length, feet

W = tank width, feet

q = cfm/sq ft tank area from Table 4 to maintain minimum capture velocity specified in Table 3.

Duct velocity = 1500 fpm minimum

Slot velocity = 2000 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP

W/L not over 2 to 1.

Maximum length of transition piece = 4 ft.

Use more than one for longer hoods.

Hood may be raised 6 inches to allow for pipes over edge of tank. Gap should be baffled.

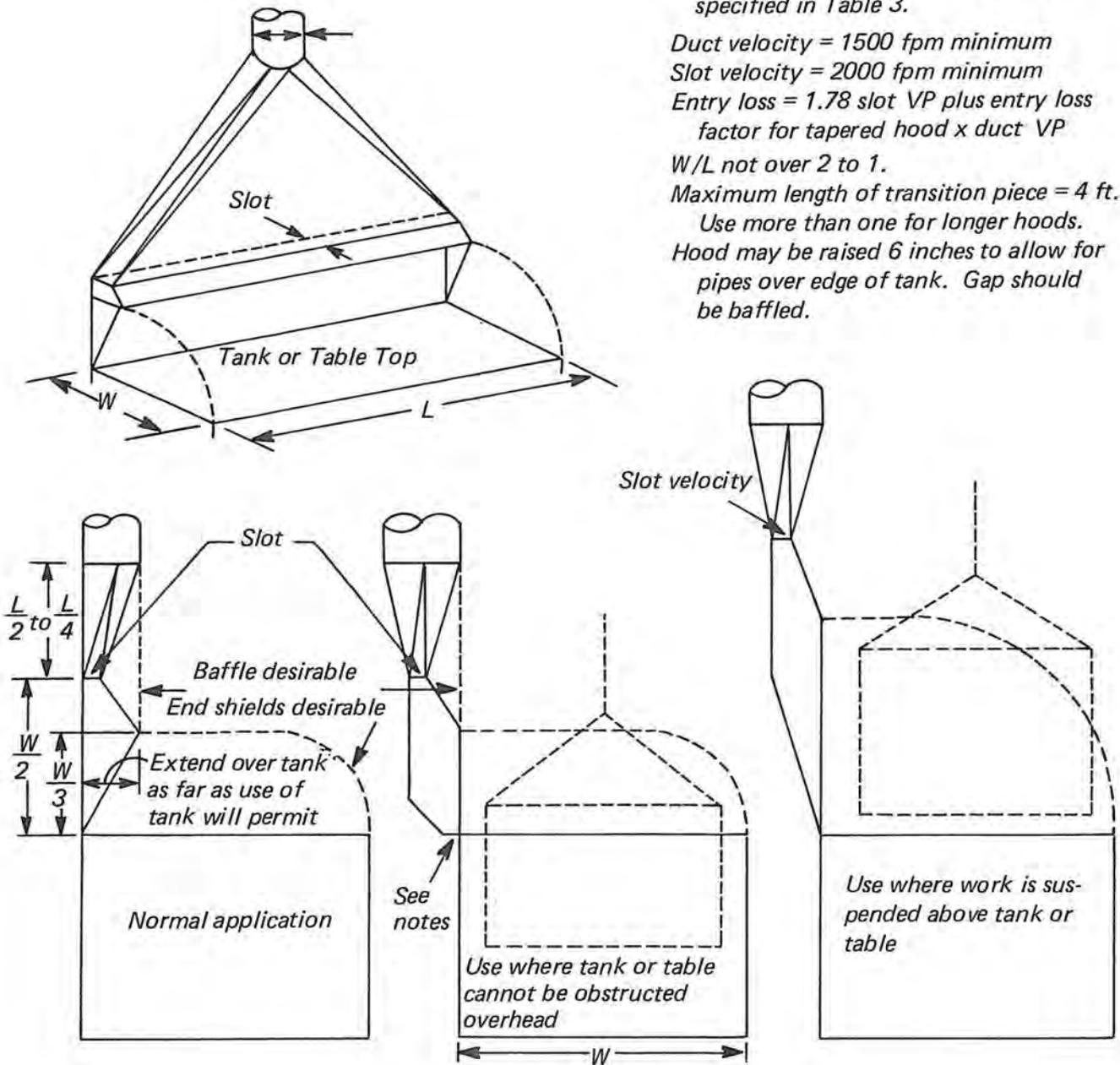
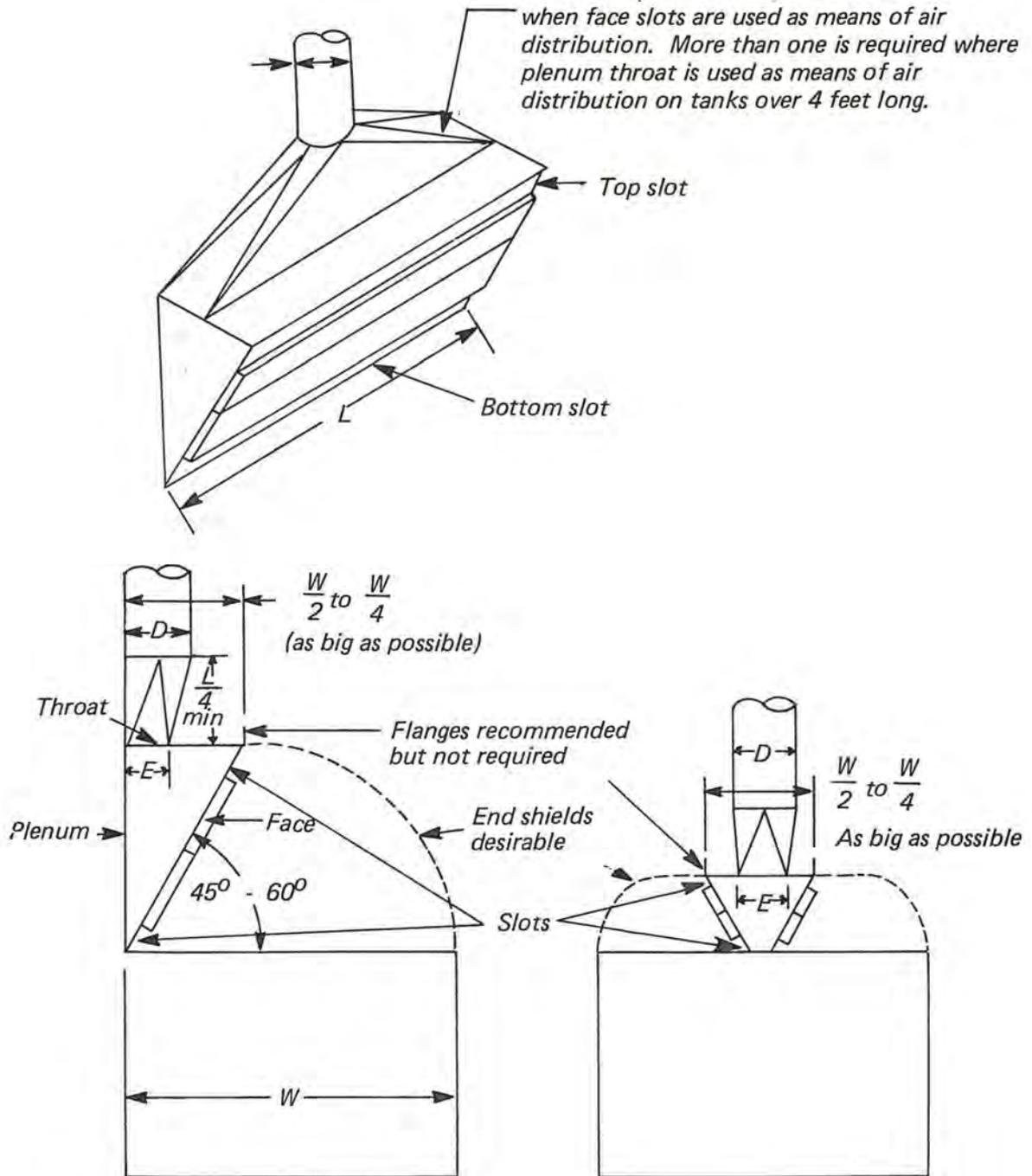


FIGURE 3 LATERAL EXHAUST HOOD



Q = exhaust volume, cfm, equals qLW

L = tank length, feet

W = tank width, feet

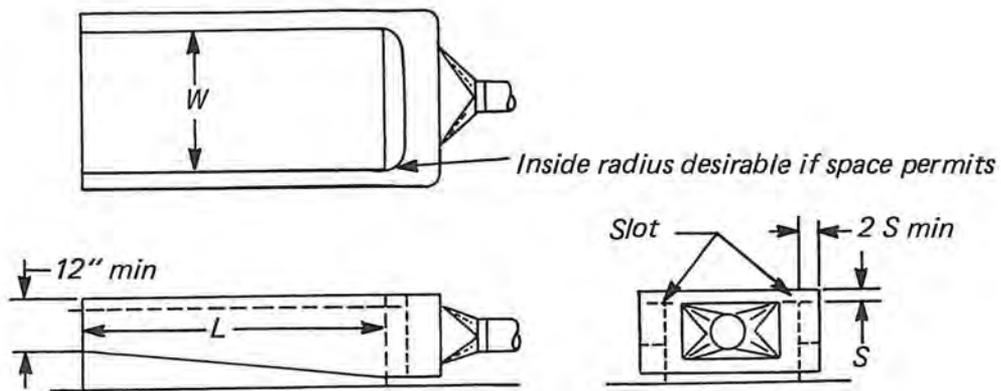
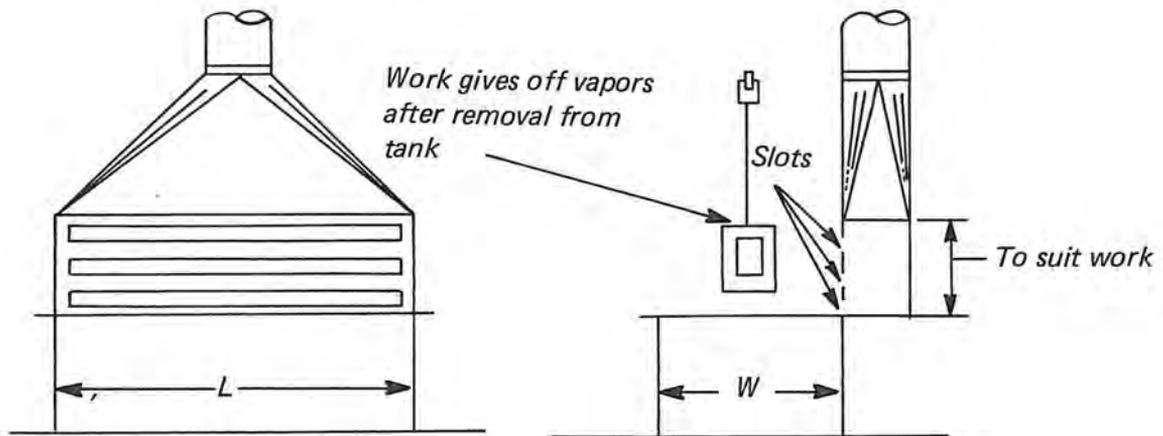
q = cfm/sq ft tank area from Table 4 to maintain minimum capture velocity specified in Table 3

Duct velocity = 1500 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP

Distribution obtained by either designing throat (E) for velocity of 2000–3000 ft/min or designing face slots for velocity of 2000 ft/min. If liquid pick-up is expected, air distribution by throat velocity should be used. Liquid level should be kept 6 inches below top edge of tank.

FIGURE 4 LATERAL EXHAUST HOOD



Q = exhaust volume, cfm, equals qLW

L = tank length, feet

W = tank width, feet

q = cfm/sq ft tank area from Table 4 to maintain minimum capture velocity specified in Table 3

Duct velocity = 1500 fpm minimum

Slot velocity = 2000 fpm minimum

Entry loss = 1.78 slot VP plus entry loss factor for tapered hood x duct VP

FIGURE 5 LATERAL EXHAUST HOOD

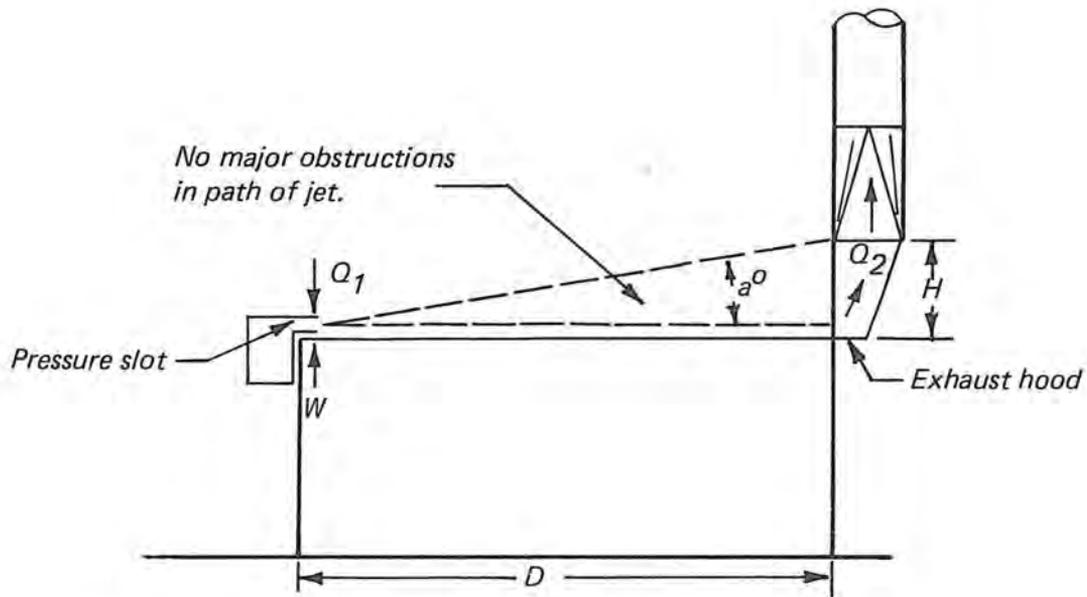
TABLE 4

Minimum Ventilation Rate in Cubic Feet of Air per Minute
per Square Foot of Tank Area for Lateral Exhaust

Required Minimum Capture Velocity Feet per Minute (from Table 3)	Cubic feet per minute per square foot to maintain required minimum velocities at following tank width (W)/tank length (L) ratios. (Notes 1 and 2)				
	0.0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0
Hood along one side or two parallel sides of tank when one hood is against a wall or baffle (Note 2). Also for a manifold along tank centerline (Note 3).					
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	260	300
Hood along one side or two parallel sides of free standing tank not against wall or baffle. (See Note 3)					
50	75	90	100	110	125
75	110	130	150	170	190
100	150	175	200	225	250
150	225	260	300	340	375

NOTES:

1. It is not practicable to ventilate across the long dimension of a tank whose ratio W/L exceeds 2.0. It is undesirable to do so when W/L exceeds 1.0. For circular tanks with lateral exhaust along up to 1/2 the circumference, use W/L = 1.0; for over 1/2 the circumference use W/L = 0.5.
2. Baffle is a vertical plate the same length as the tank with the top of the plate as high as the tank is wide. If the exhaust hood is on the side of a tank against a building wall or close to it, it is perfectly baffled.
3. Use W/2 as tank width in computing when manifold is along centerline, or when hoods are used on two parallel sides of a tank.
4. Tank width (W) means the effective width over which the hood must pull air to operate (for example, where the hood face is set back from the edge of the tank, this set back must be added in measuring tank width). The surface area of tanks can frequently be reduced, and better control obtained (particularly on conveyerized systems) by using covers extending from the upper edges of the slots toward the center of the tank.



Exhaust Hood
Quantity of air exhausted
 $Q_2 = 100 - 150$ cfm/sq ft
tank area

Pressure Slot
Quantity of air supplied,
 $Q_1 = \frac{1}{D \times E} \times Q_2$
where; D = length of throw, feet
 E = entrainment factor.

Hood height (H) should be $\geq 0.2 D$

$$\frac{H}{D} = \tan a$$

$$\text{for } \frac{H}{D} = 0.2, a = 11^\circ$$

Throw length, D , feet	Entrainment factor, E
0-8	2.0
8-16	1.4
16-24	1.0
over 24	0.7

Slot velocity = 2000 fpm

Duct velocity = 1500 fpm minimum

Design such systems so they can be easily modified or adjusted to obtain desired results and can be fixed or locked to retain desired adjustments and settings.

FIGURE 6 PUSH-PULL HOOD

shall be considered to be overhead canopy hoods. An acceptable canopy hood design is shown in Figure 7.

5.4 General Mechanical Room Ventilation

General mechanical room ventilation (dilution ventilation) may be utilized to control contaminants produced by tanks classified as B-4, C-4, D-3, and D-4. When dilution ventilation is utilized to control contaminants, the clean airflow shall be directed to pass over the worker and then intermix with the effluent from the tanks. Figure 8 illustrates the relative effectiveness of various air distribution designs.

6. Ventilation Requirements

6.1 General

Ventilation methods and exhaust flow requirements are prescribed in Table 3 for the sixteen classes of open-surface tank operations. Minimum exhaust rates for lateral exhaust hoods are prescribed in Table 4.

The ventilation requirements in Tables 3 and 4 apply to all cases where the flow of air past the breathing or working zone of the operator and into the hoods is undisturbed by local environmental conditions such as open windows, wall fans, unit heaters, or moving machinery. Where such disturbances to airflow occur, efforts shall be made to eliminate or minimize them, and the hood should be so designed as to eliminate or minimize their influence.

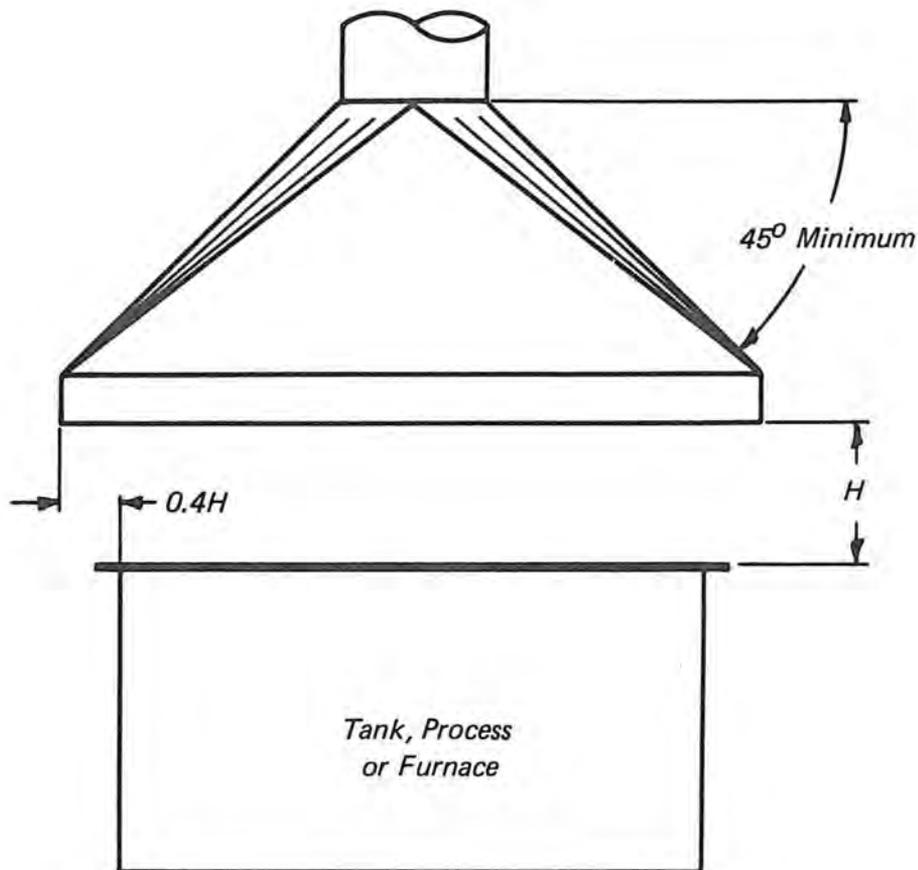
When applying the ventilation requirements contained in these guidelines, the rate of vapor evolution (including steam or products of combustion) from the process shall be estimated. If the rate of vapor evolution is equal to or greater than 10 percent of the calculated exhaust volume requirement, then the total exhaust volume requirement shall be increased by an amount equal to the rate of vapor evolution.

6.2 Airborne Spray

Wherever spraying or other mechanical means are used to disperse a liquid above an open-surface tank, control must be provided for the airborne spray. Such operations shall be enclosed as completely as practical. The inward air velocity into the enclosure shall be sufficient to prevent the discharge of spray into the workroom. Mechanical baffles may be used to help prevent the discharge of spray.

6.3 Make-Up Air

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the



Not to be used for Class A operations. Hood shall be curtained or baffled as necessary to ensure that crossdrafts do not cause excessive spillage of contaminants from canopy.

Q = exhaust volume, cfm

= $1.4 PHV$ for open type canopy.

P = perimeter of tank, feet

H = distance from lower edge of canopy to top of tank or process, feet

V = minimum capture velocity, fpm

(See Table 3)

$Q = (P_o)HV$ for three sides open

P_o = length of open sides of hood, feet

= $2L+W$ or $2W+L$

W & L are open sides of hood, feet

V = minimum capture velocity, fpm (See Table 3)

Entry loss = entry loss factor for tapered hood X duct VP

Duct velocity = 1500 fpm minimum

FIGURE 7 CANOPY HOOD

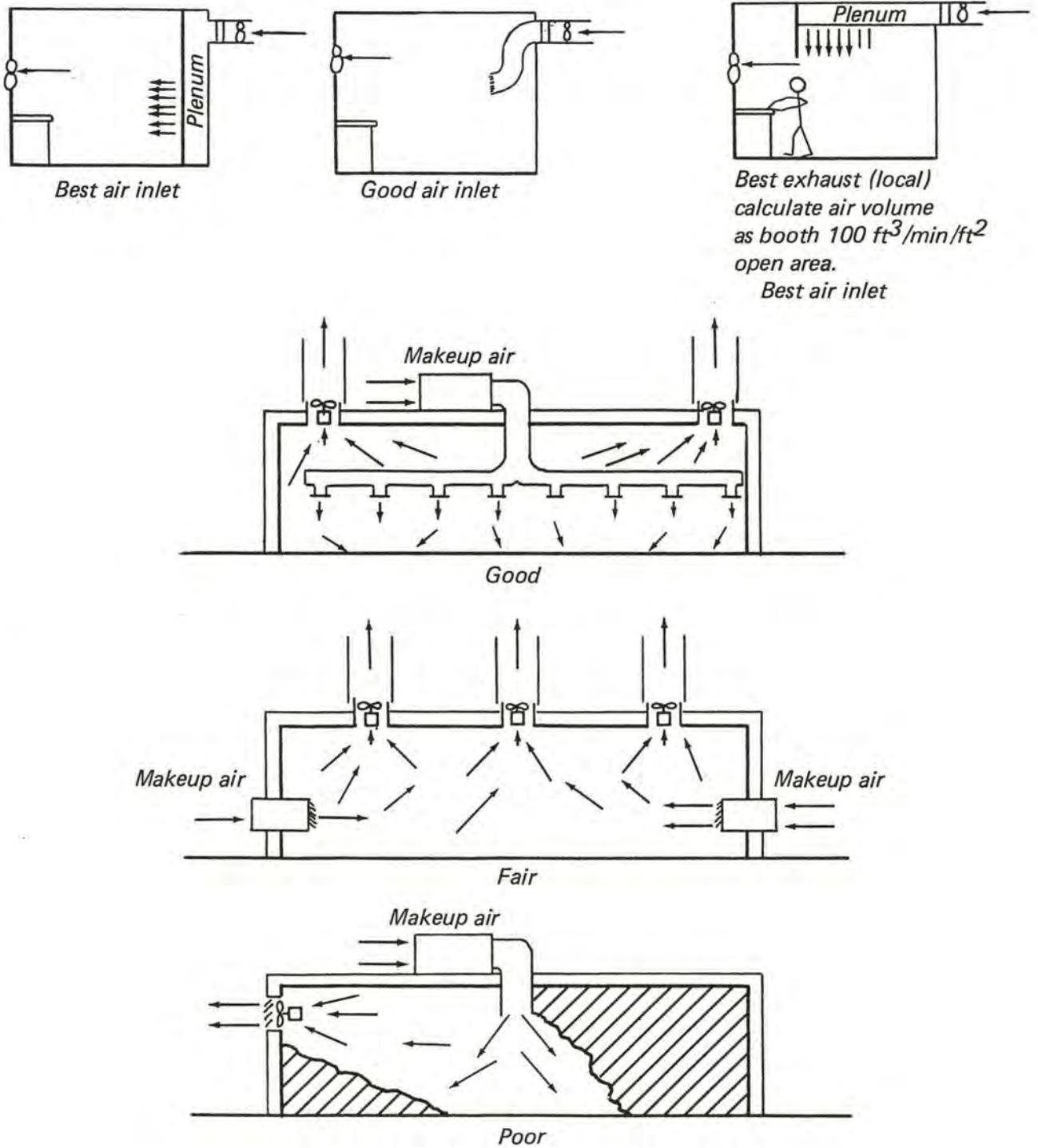


FIGURE 8 GENERAL MECHANICAL VENTILATION – AIR DISTRIBUTION DESIGNS

exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue. The airflow of the make-up air system shall be measured on installation. Periodically, thereafter, the airflow should be remeasured, and corrective action shall be taken when the airflow is below that required.

RECOMMENDED VENTILATION GUIDELINES FOR SERVICE GARAGES

1. Scope

These guidelines prescribe the use of general and local exhaust systems for the control and removal of air contaminants generated by service garage operations. Operations covered by these guidelines include vehicle movement, dead engine servicing or storage, no-load engine servicing, dynamometer servicing, body repair, and degreasing operations.

2. Definitions

- a. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- b. Duct Velocity - The average velocity in a duct of an exhaust system.
- c. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- d. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- e. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- f. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- g. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- h. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- i. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- j. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- k. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- l. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air cleaning equipment, exhauster, and stack for removing contaminated air from a space.
- m. Make-Up Air - Air supplied to a building or space to replace air exhausted.
- n. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- o. Natural-Flow Ventilation - This term in the context of this standard refers to air movement caused not by a fan in an

exhaust system but as the direct result of operation of a vehicles engine.

- p. Natural Ventilation - Air movement through a space produced by either or both of two natural forces; wind forces and stack effects.
- q. Vapors - the gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all service garage operations which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall be operated continuously while contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust system designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of special-purpose engines (e.g. large displacement racing engines without emission controls), unique or novel fuels, crowded or unusual working conditions, or other adverse circumstances, different or more stringent control measures shall be provided as necessary to maintain contaminant concentrations at or below exposure limits.

4. Service Garage Operations and Equipment

4.1 General

A hood used for the control of contaminants from service garage operations shall be connected to an exhaust system. With operations with which contaminants are released with an initial velocity, the hood shall be designed and located, where practical, such that the contaminants are projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust flows of all exhaust ventilation systems, process systems, and combustion processes in the

workplace without restricting the performance of any hood, system, or flue.

4.2 No-Load Engine Servicing Operations

4.2.1 General

Vehicles in service garages where repair procedures are conducted which necessitate engine operation under no-load conditions (i.e. tune-ups, valve adjustments, leak detection, etc.) shall be exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.2.2 Engine Exhaust Ventilation

4.2.2.1 Mechanical Ventilation

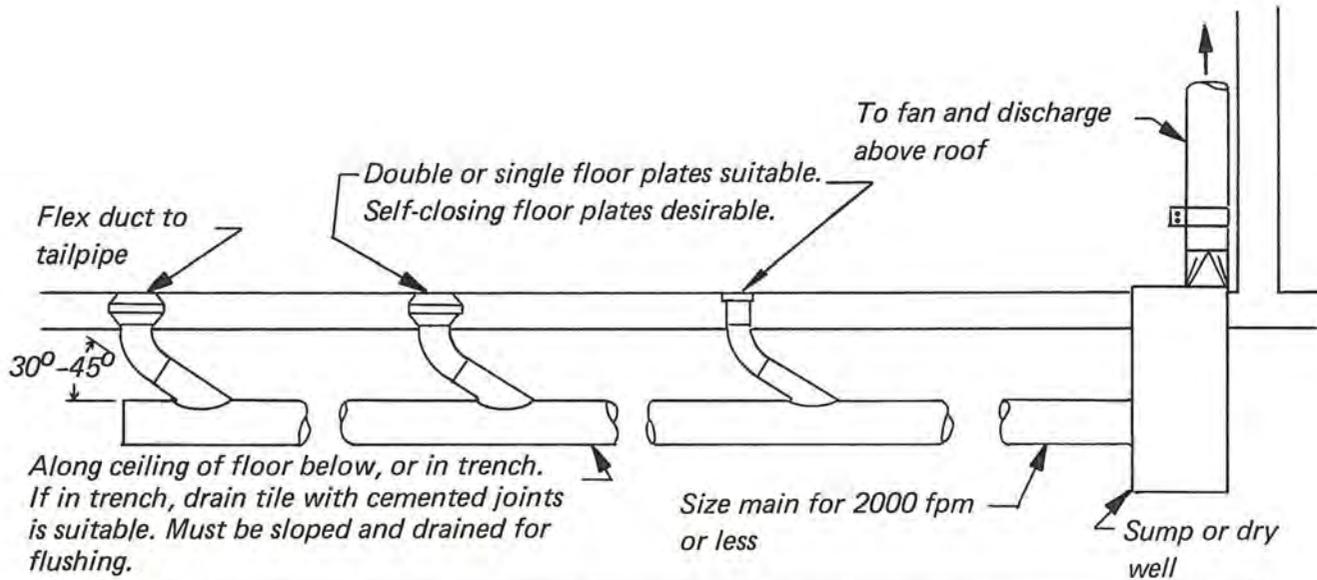
With the exception given in paragraph 4.2.2.2, any vehicle upon which a no-load engine servicing operation is being conducted in a service garage and which generates excessive air contaminant concentrations shall have its engine exhaust outlet(s) suitably and snugly attached to an exhaust system. Figure 1 illustrates an acceptable design for an underfloor system. An acceptable design for an overhead system is illustrated in Figure 2.

4.2.2.2 Natural-Flow Ventilation

In service garages designed such that a vehicle having a no-load engine servicing operation conducted upon it is located within close proximity to a wall or door separating the vehicle from the outdoors, it shall be permitted, as an alternative to a mechanical system, that the vehicle have its engine exhaust outlet(s) snugly attached to a flexible duct or hose which contains and directs the engine exhaust through the wall or door to the outdoors. Where this is done, the vehicle shall be so arranged relative to the door or wall opening that the flexible duct can be used in a straight line arrangement without sharp bends and so that no more than 6 feet of flexible duct is required. The minimum diameter of the duct or hose, exclusive of the adaptor necessary to snugly fit it to the engine exhaust outlet(s), shall comply with Table 1. The air contaminants shall be discharged from the building in such a manner that they do not increase air contaminant concentrations within the building to excessive levels by re-entering through open doors or other openings.

4.3 Dynamometer Servicing Operations

4.3.1 General



UNDER FLOOR SYSTEM EXHAUST REQUIREMENTS		
Engine type	cfm per vehicle (min.)	Flex duct ID (min.)
Automobiles and trucks up to 285 CID*	100	3"
Automobiles and trucks over 285 CID*	200	4"***
Diesel	400	4 1/2"

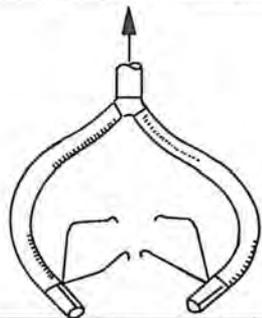
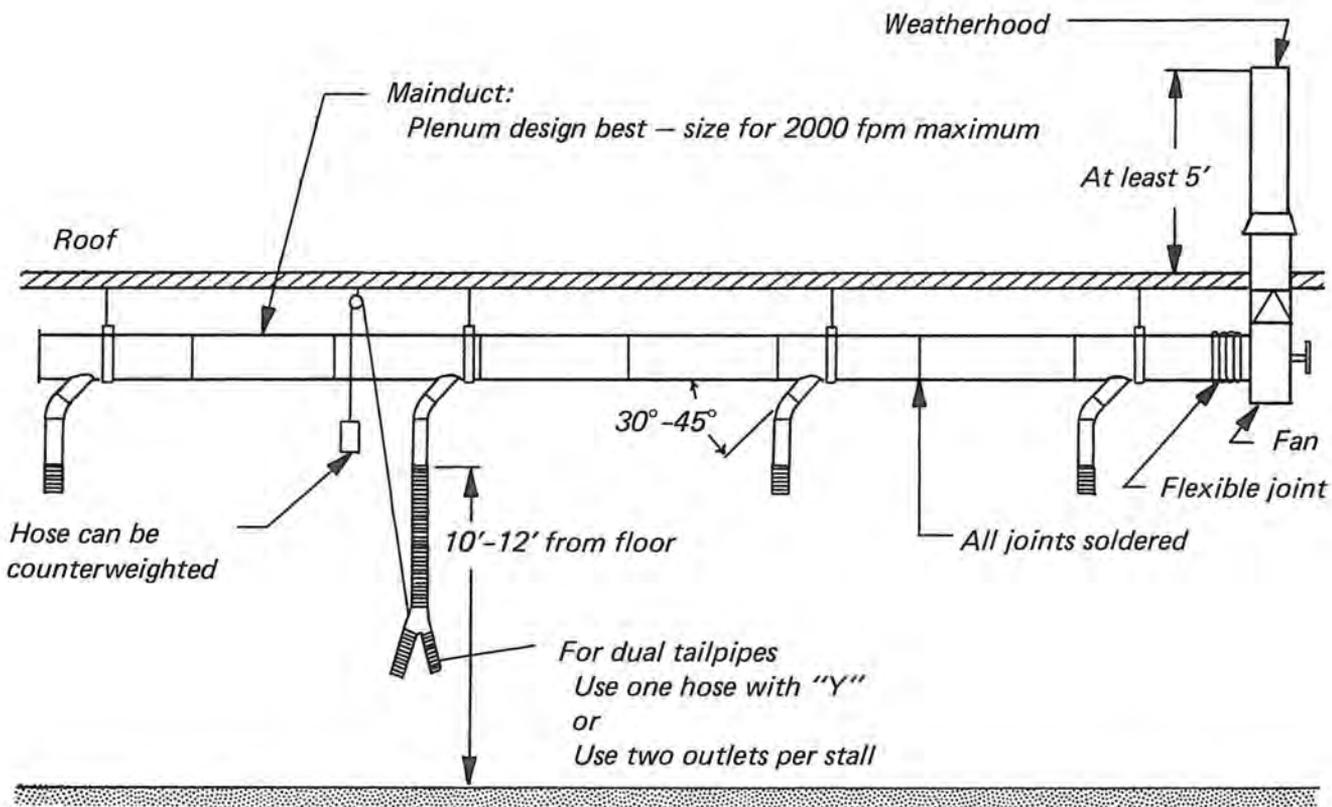
CID = cubic inch displacement of engine

*Gasoline fueled engines

**3" dia. permissible for short runs with proper fan.

For friction loss of flexible duct; consult manufacturers' data.

FIGURE 1 UNDERFLOOR SERVICE GARAGE VENTILATION



Use adapters on dual exhausts and special tailpipes for snug fit.



OVERHEAD SYSTEM EXHAUST REQUIREMENTS			
Engine type	cfm/vehicle (min.)	Flexible duct diam (min.)	Branch connection (min.)
Up to 285 CID*	100	3"	4"
Over 285 CID*	200	4"	4"
Diesel	400	4 1/2"	6"

For friction loss of flexible duct; consult manufacturers' data
CID = cubic inch displacement of engine

*Gasoline fueled engines

FIGURE 2 OVERHEAD SERVICE GARAGE VENTILATION

TABLE 1

Minimum Flexible Hose or Duct Sizes
For Various Engine Sizes and Types
For No-Load Servicing Operations

TYPE	FLEX DUCT ID (Min)
Gasoline Engines:	
Up to 285 cu. in displacement	3"
Over 285 cu. in. displacement	4"
Diesel Engines:	4-1/2"

TABLE 2

Ventilation Rates for Dynamometer Pits
and Sumps when in Service*

TYPE	MINIMUM EXHAUST RATE (cfm)
Gasoline	300
Diesel engine	
Up to 300 hp	500
300-700 hp	600
Turbocharged diesel engine	
Up to 500 hp	800

These areas shall be considered as "below grade" areas when not in service. See Paragraph 4.4.3.

Dynamometer service equipment and the vehicles which are being serviced by use of this equipment shall be exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.3.2 Dynamometer Pits and Sumps

Pits or sumps located underneath dynamometer servicing equipment shall be exhaust ventilated in accordance with Table 2. An acceptable design for the exhaust system for such pits and sumps is illustrated in Figure 3.

4.3.3 Vehicle Engine Exhaust Removal

A vehicle being dynamometer serviced shall have its engine exhaust outlet(s) suitably attached to a mechanical exhaust system similar to one of the acceptable designs illustrated in Figures 1 and 2. The use of a single exhaust system for dynamometer pit or sump ventilation and vehicle engine exhaust removal shall be acceptable only where the different static pressure requirements of the separate branches can be properly balanced. The system design utilized for vehicle engine exhaust removal shall be designed to provide an exhaust volume per vehicle which is in accordance with Table 3. Table 3 also lists the minimum duct or hose sizes which shall be provided for engine exhaust outlets. The air contaminants removed shall be discharged from the building in such a manner that they do not increase air contaminant concentrations within the building to excessive levels by re-entering through open doors or other openings.

4.4 Vehicle Movement, Storage, and Dead Engine Servicing Operations

4.4.1 General

Service garages in which fueled vehicles are moved, stored, or have dead engine servicing operations conducted upon them (i.e. lubrication, brake repairs, muffler installation, tire changes, etc.) shall be exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.4.2 General Ventilation Requirements

Service garages shall be provided minimum general room ventilation rates in accordance with Table 4. These rates shall be maintained using natural ventilation and/or general mechanical ventilation systems as necessary.

4.4.3 Below Grade Areas

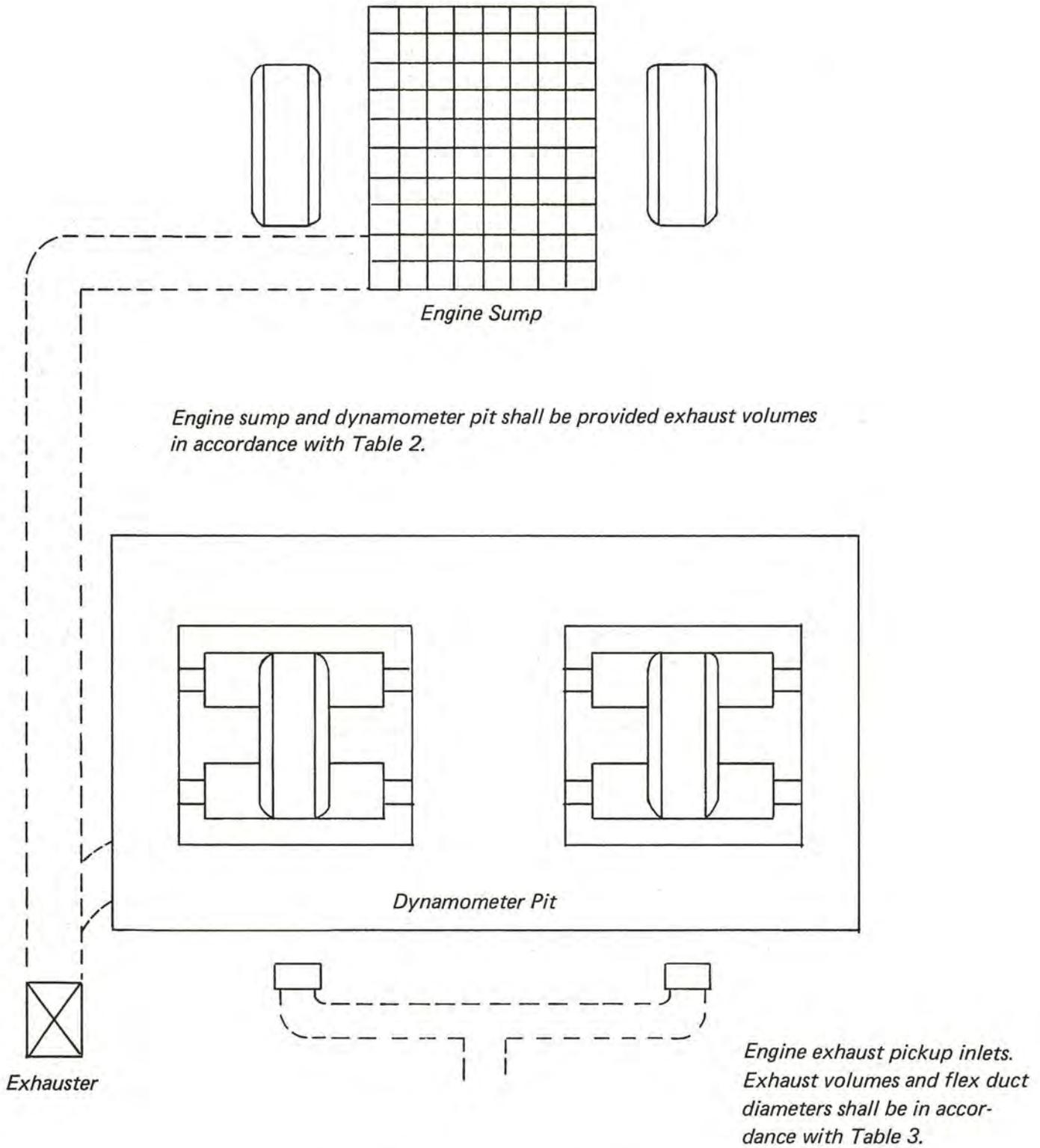


FIGURE 3 DYNAMOMETER VENTILATION

TABLE 3

Minimum Exhaust Flow and Flexible
Hose or Duct Sizes for Engines Being
Dynamometer Serviced

ENGINE TYPE	MIN. FLEX DUCT ID (inches)	MIN. FLOW PER VEHICLE (cfm)
Gasoline		
Up to 285 cu. in. displacement	3-1/2	200
Over 285 cu. in. displacement	4-1/2	400
Diesel:		
Up to 300 hp	6	750
300-700 hp	7	1000
Turbocharged Diesel		
Up to 500 hp	8	1400

TABLE 4

Minimum General Ventilation
Rates for Service Garages

Vehicle Type Serviced	Min. Ventilation Rate (cfm per service stall or vehicle capacity)
Gasoline-Powered Vehicles:	
Light-Duty (<6000 lb GVW*)	400
Heavy-Duty (>6000 lb GVW)	800
Diesel-Powered Vehicles:	
Light-Duty (<6000 lb GVW)	400
Heavy-Duty (>6000 lb GVW)	1200

*
GVW = Gross Vehicle Weight

Below grade areas other than repair pits shall be provided continuous mechanical ventilation at a rate of 0.75 cfm/sq ft of floor area.

4.4.4 Repair Pits

Repair pits shall be provided an exhaust system which completely changes the air in the pit at least once every five minutes. Air shall be removed from a point near the pit floor.

4.5 Other Operations

4.5.1 General

Other service garage operations not covered in these guidelines but which generate air contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

4.5.2 Body Repair Operations

Spray painting; abrasive blasting; grinding, buffing and polishing of metals; and cutting and welding operations which generate air contaminant concentrations in excess of exposure limits shall be enclosed and exhaust ventilated in accordance with applicable ventilation guidelines.

4.5.3 Solvent Spray Degreasing Operations

Solvent spray degreasing operations of vehicles or in-place components which are conducted indoors and which generate air contaminant concentrations in excess of exposure limits shall be conducted in spray booths similar to booths utilized in spray painting operations and described in the ventilation guidelines for such operations. Solvent spray degreasing operations of individual components which generate air contaminant concentrations in excess of exposure limits shall be conducted in a small spray booth similar to such booths utilized in spray painting operations and described in the ventilation guidelines for such operations. The minimum face velocity to be provided for such a small booth shall be 100 fpm.

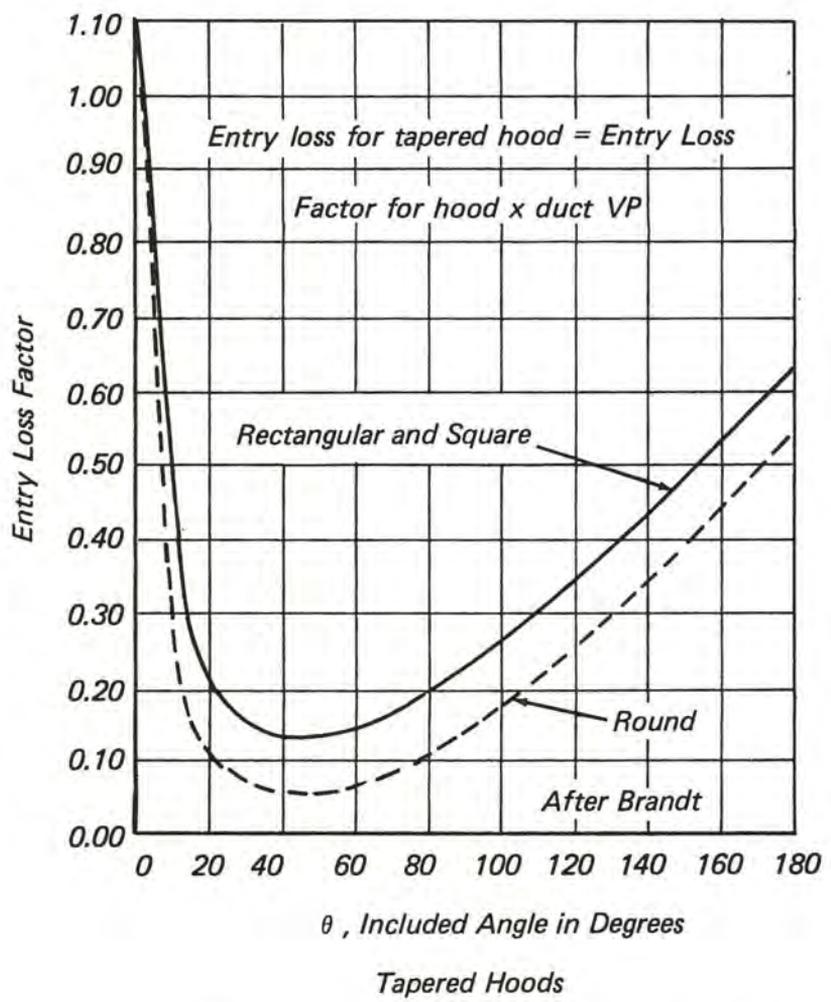
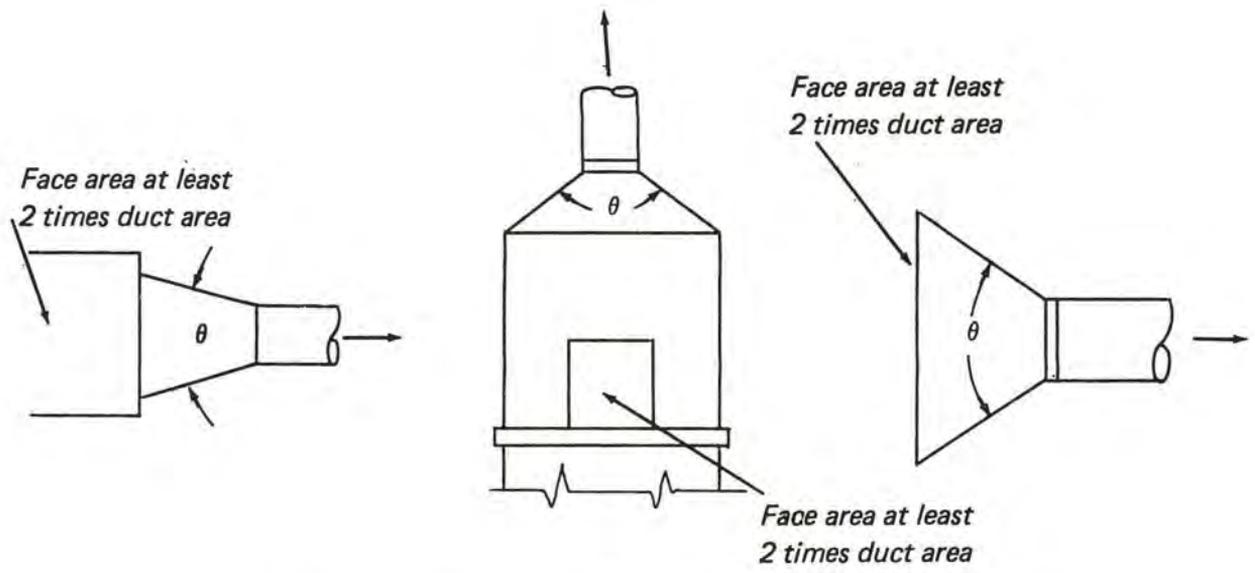
RECOMMENDED VENTILATION GUIDELINES FOR SPRAY FINISHING OPERATIONS

1. Scope

These guidelines prescribe the use of local exhaust ventilation for the control and removal of air contaminants generated by spray-finishing operations and by the use of ovens for the drying or baking of spray work. The guidelines do not prescribe the use of ventilation for the spraying of large structures such as bridges, the exteriors of buildings, large storage tanks, ships or similar structures, nor to small portable spraying apparatus not used repeatedly in the same location.

2. Definitions

- a. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- b. Dry Spray Booth - A spray booth not equipped with a water washing system. A dry spray booth may be equipped with (1) distribution or baffle plates to promote an even flow of air through the booth or cause the deposit of overspray before it enters the exhaust duct; or (2) overspray dry filters to minimize dusts or mists; or (3) overspray dry filters to minimize dusts or residues entering exhaust ducts; or (4) overspray dry filter rolls designed to minimize dusts or residues entering exhaust ducts; or (5) where dry powders are being sprayed, with powder collection systems so arranged in the exhaust to capture oversprayed material.
- c. Duct Velocity - The average air velocity in a duct of an exhaust system.
- d. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- e. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- f. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- g. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- h. Exhaust Volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.
- i. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as



Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- specified by 29 CFR 1910.1000.
- j. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
 - k. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
 - l. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
 - m. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
 - n. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
 - o. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air cleaning equipment, exhauster, and stack for removing contaminated air from a space.
 - p. Lower Explosive Limit - For a gas or vapor, the lower limit of explosibility at ordinary ambient temperature expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 deg. F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility of a gas or vapor increases with higher temperatures. For dusts, the lower limit of explosibility is the minimum concentration of dust in air necessary for sustained flame propagation. The concentration is usually expressed in grams per liter or milligrams per cubic meter of the dust in air.
 - q. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
 - r. Overspray - That portion of the substance being sprayed that misses or does not adhere to the object being spray-finished.
 - s. Pressure, Static - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of water gauge when dealing with air. (The tendency to either burst or collapse a pipe).
 - t. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.
 - u. Spray Booth - A power-ventilated structure provided to enclose or accommodate a spraying operation to confine and limit the escape of spray, vapor, and residue, and to safely conduct or direct them to an exhaust system.
 - v. Spray-finishing Operations - Methods by which organic or inorganic materials in mist or droplet form are projected and thereby deposited onto surfaces to be coated, treated, or solvent cleaned. In the context of this standard, such methods do not include metal spraying or metallizing, operations abrasive-blasting operations, or spray washing and

- degreasing as conducted in self-contained washing and degreasing machines or systems.
- w. Spray Room - A spray room is a ventilated room in which spray-finishing operations not conducted in a spray booth are performed separately from other areas.
 - x. Vapor - The gaseous form of substances which are normally in a solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.
 - y. Water Wash Spray Booth - A spray booth equipped with a water washing system designed to minimize dusts or residues entering exhaust ducts and to permit the recovery of overspray-finishing material.

3. Application

These guidelines shall apply to those spray-finishing operations described herein which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with the guidelines shall be operated continuously while the contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials, or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation Equipment Design Requirements

4.1 General

A hood used for the control of contaminants from spray-finishing operations shall be connected to an exhaust system. With processes in which contaminants are released with an initial velocity, the hood shall be designed, located, and operated in such a manner that the contaminants are projected into the hood in the direction of the exhaust airflow.

4.2 Make-up Air

4.2.1 Supply

Clean fresh air, free of contamination from adjacent industrial exhaust systems, chimneys, stacks, or vents, shall be supplied to a spray booth or room in quantities essentially equal to the volume of air exhausted through the spray booth or room. Except where adequate and safe means of radiant heating for all operating personnel is provided, the make-up air system shall include a heater, and thermostat or ductstat controls.

Where a spray booth or room receives make-up air through self-closing doors, dampers, or louvers, they shall be fully open at all times when the booth or room is in use for spraying.

4.2.2 Filters

Where the air supply to a spray booth or room is filtered, the fan static pressure shall be calculated on the assumption that the filters clogged to the extent that they require cleaning or replacement.

The rating of filters shall be governed by test data supplied by the manufacturer of the filter. A pressure gage shall be installed to show the pressure drop across the filters. This gage shall be marked to show the pressure drop at which filters require cleaning or replacement. Filters shall be replaced or cleaned whenever the pressure drop across them becomes excessive (a satisfactory limit for disposable filters is a pressure drop of 0.25 inches water gauge) or whenever the airflow through the face of the booth falls below specified velocities.

4.3 Construction and Location of Equipment

4.3.1 Spray Booths

Spray-finishing operations shall be located as provided in sections 201 through 206 of the Standard for Spray Finishing Using Flammable and Combustible Materials, NFPA No. 33-1969.

Spray booths and the equipment, materials, and procedures utilized in spray-finishing operations shall conform to the requirements of 29 CFR 1910.107.

4.3.2 Means of Egress

Unobstructed walkways shall not be less than 6-1/2 feet high and shall be maintained clear of obstruction from any work location in a spray booth to a booth exit or open booth front. In booths where the open front is the only exit, such exits shall be not less than 3 feet wide. In booths having multiple exits, such exits shall not be less than 2 feet wide, provided that the maximum distance from the work location to the exit is 25 feet or less. Where booth exits are provided with doors, such doors shall open outward from the booth.

4.3.3 Washing Chambers

For wet or water wash spray booths, the water-chamber enclosure, within which intimate contact of contaminated air and cleaning water or other cleaning medium is maintained, if made of steel, shall be 18 gage or heavier and adequately protected against corrosion.

Chambers may include scrubber spray nozzles, headers, troughs, or other devices. Chambers shall be provided with adequate means for creating and maintaining scrubbing action for removal of particulate matter from the exhaust air stream.

4.3.4 Collecting Tanks

Collecting tanks shall be of welded steel construction or other suitable non-combustible material. If pits are used as collecting tanks, they shall be concrete, masonry, or other material having similar properties.

Tanks shall be provided with weirs, skimmer plates, or screens to prevent sludge and floating paint from entering the pump suction box. Means for automatically maintaining the proper water level shall also be provided. Fresh water inlets shall not be submerged. They shall terminate at least one pipe diameter above the safety overflow level of the tank.

Tanks shall be so constructed as to discourage accumulation of hazardous deposits.

4.3.5 Pump Manifolds, Risers, and Headers

Pump manifolds, risers, and headers shall be adequately sized to insure sufficient water flow to provide efficient operation of water chambers.

4.3.6 Overspray Filters

Overspray filters which are installed and maintained in accordance with the requirements of 29 CFR 1910.107 (b) (5) shall only be in a location easily accessible for inspection, cleaning, or replacement. However, where effective means, independent of the overspray filters, are installed which will result in the required air distribution across the booth cross section, it is permissible to operate the booth without the filters in place.

4.3.7 Drying and Baking Ovens

Ovens used for baking or drying sprayed work shall conform to NFPA No. 86A, Class A Ovens and Furnaces, and sections 1101 through 1104 of the Standard for Spray Finishing Using Flammable and Combustible Materials, NFPA No. 33-1969.

4.4 Ventilation Requirements

4.4.1 General

Spray booths or spray rooms shall be used, where practical, to enclose all spray-finishing operations which generate air contaminant concentrations in excess of exposure limits. Where used, spray rooms for production spray-finishing operations shall conform to the requirements for spray booths.

Spray booths and rooms shall be provided ventilation in accordance with the provisions of 29 CFR 1910.107 (d) and the provisions of these guidelines. The total air volume exhausted through a spray booth or room shall be such as to dilute any solvent vapor to a concentration no more than 25 percent of the lower explosive limit of the solvent under all operating conditions.

To reduce the potential hazards of backlash of overspray, the object being sprayed shall be placed completely within and as deeply as practical within a spray booth. In the case of downdraft booths, the object shall be positioned as to ensure uniform exhaust airflow around the object.

Where a spray booth or room has an air replacement system, the system shall be designed to introduce replacement air upstream or above the object being sprayed and such that the airflow in the booth or spraying area cross section is in accordance with the exhaust volumes and airflow velocities specified in these guidelines when measured upstream or above the object being sprayed.

4.4.2 Small Spray Booths

Figure 2 illustrates acceptable designs for small dry spray booths (e.g. bench type spray booths). Where a small spray booth is used, the minimum air volume exhausted from the booth shall be in accordance with the requirements given in Figure 2.

4.4.3 Large Spray Booths

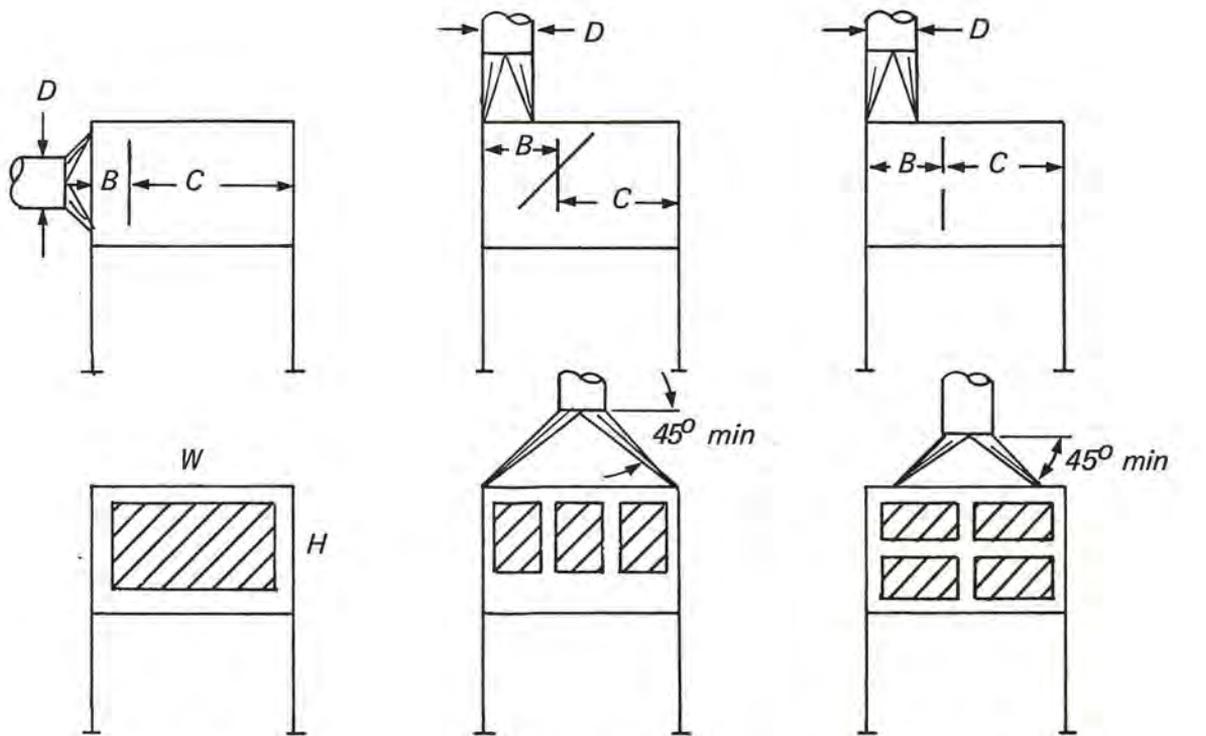
Figure 3 illustrates acceptable designs for large dry spray booths. Where a large spray booth is used, the minimum air volume exhausted from the booth shall be in accordance with the requirements given in the figure.

Figure 4 illustrates an acceptable general design for a tunnel water wash booth. Figure 5 illustrates an acceptable general design for a water wash booth exhausted from two sides. The minimum air volume to be exhausted from such booths shall be in accordance with the requirements given in the appropriate figure. Figure 6 illustrates typical air distribution and air cleaning sections for these booths.

Where downdraft booths are provided with doors, such doors shall be closed when spray-finishing operations are conducted.

4.4.4 Vehicle Spray Paint Booths

Where a spray painting operation is conducted on an automobile, truck, or similar vehicles exterior, and the operation generates air contaminant concentrations in excess of exposure limits, the spray



1. Solid Baffle

$B = 0.75D$

Baffle area = $0.60WH$

2. Angular Baffle

$B = D + 6''$

Baffle area = $0.60WH$

3. Split Baffle or Filters

$B = D + 6''$

Baffles or filters = $0.75WH$

Filter combustibility

Class 2 or better

Any combination of branch ducts and baffles may be used.

Air spray operations

$Q =$ minimum 200 cfm/sq ft ($200WH$) – for face area up to 4 sq ft

= minimum 150 cfm/sq ft – for face area over 4 sq ft

$W =$ work size + 1', ft

$H =$ work size + 1', ft

$C = 0.75 W$ or H , whichever is larger, ft

Airless and electrostatic spray operations

$Q =$ minimum 125 cfm/sq ft ($125WH$) – for face area up to 4 sq ft

= minimum 100 cfm/sq ft – for face area over 4 sq ft

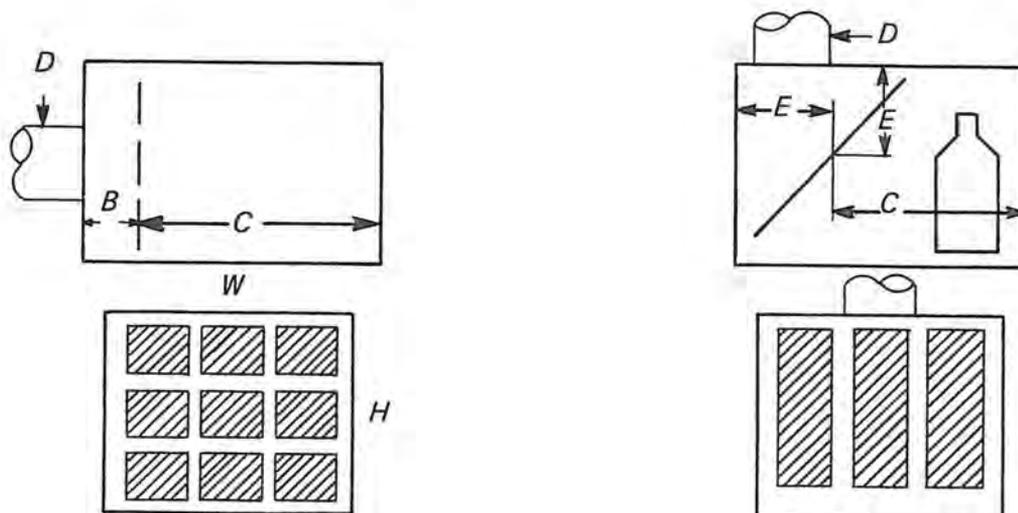
Duct velocity = 1000 fpm minimum

Entry loss = Baffles: 1.78 slot VP + 0.50 duct VP

= Filters: Dirty filter resistance + 0.50 duct VP

Spray booths having a frontal area larger than 9 square feet require 2-1/2 inches deep metal deflector or curtain at upper outer edge of the booth over the opening

FIGURE 2 SMALL SPRAY BOOTH



1. Split Baffle or Filters

$B = 0.75D$

Baffle or filter area = $0.75WH$

Filter combustibility Class 2 or better

2. Angular Baffle

$E = D + 6''$

Baffle area = $0.40WH$

Air spray operations

Any combination of duct connections and baffles may be used. Large, deep booths do not require baffles.

Walk-in booth

$Q =$ minimum 100 cfm/sq ft booth cross-section; may be 75 cfm/sq ft for very large, deep booth.

$W =$ work size + 6', ft

$H =$ work size + 3' (minimum = 7'), ft

$C =$ work size + 6', ft

Operator outside booth

$Q =$ minimum 100 cfm/sq ft of open area, including conveyor openings.

$W =$ work size + 2', ft

$H =$ work size + 2', ft

$C = 0.75 \times$ larger front dimension, ft

Airless and electrostatic spray operations

$Q =$ minimum 60 cfm/sq ft booth cross-section, walk-in booth

= minimum 60 cfm/sq ft of total open area, operator outside of booth

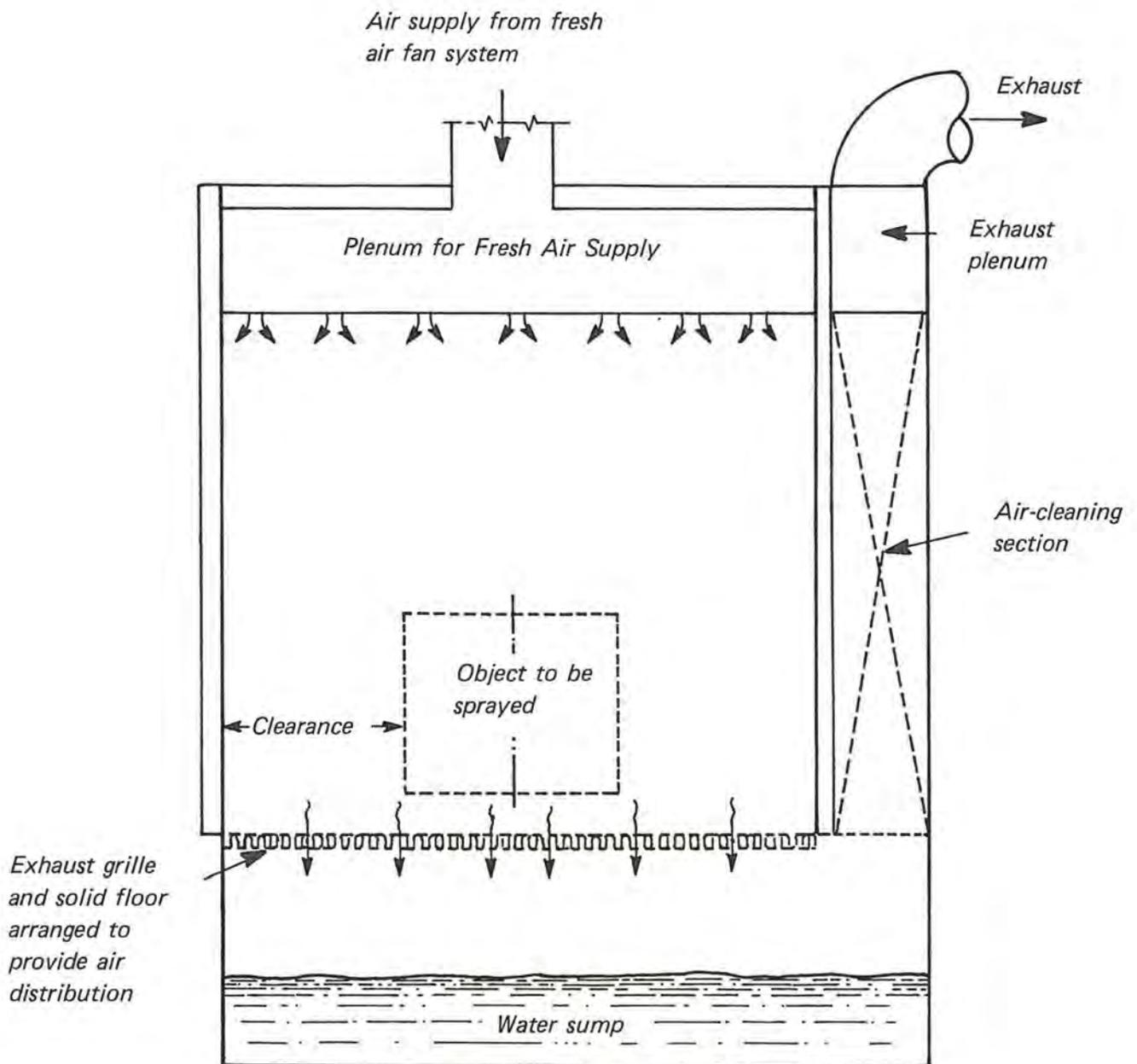
Duct velocity = 1000 fpm minimum

Entry loss = Baffles: 1.78 slot VP + 0.50 duct VP

= Filters: Dirty filter resistance + 0.50 duct VP

Spray booths having a frontal area larger than 9 square feet require 2-1/2 inches deep metal deflector or curtain at upper outer edge of the booth over the opening.

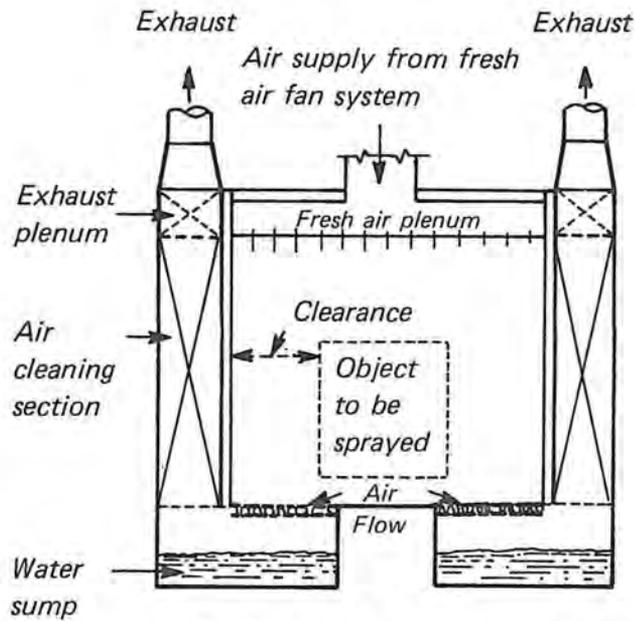
FIGURE 3 LARGE SPRAY BOOTH



Exhaust from both sides of booth, as in Figure 5, is required for wide booths. The water level shall be sufficiently below the booth floor to allow proper air distribution.

- $Q = \text{minimum } 100 \text{ cfm/sq ft horizontal cross-section for air spray operations}$
- $= \text{minimum } 60 \text{ cfm/sq ft horizontal cross-section for airless spray operations}$
- Duct velocity = 1000 fpm minimum
- Entry loss = 1.78 slot VP when floor is thin grille with sharp-edged openings
- $= 0.5 \text{ slot VP when openings are of some thickness in vertical direction}$

FIGURE 4 TUNNEL WATER WASH BOOTH



- $Q = \text{minimum } 100 \text{ cfm/sq ft horizontal cross-section for air spray operations}$
- $= \text{minimum } 60 \text{ cfm/sq ft horizontal cross-section for airless spray operations}$
- $\text{Duct velocity} = 1000 \text{ fpm minimum}$
- $\text{Entry loss} = 1.78 \text{ slot VP when floor is thin grille with sharp-edged openings}$
- $= 0.5 \text{ slot VP when openings are of some thickness in vertical direction}$

FIGURE 5 WATER WASH BOOTH

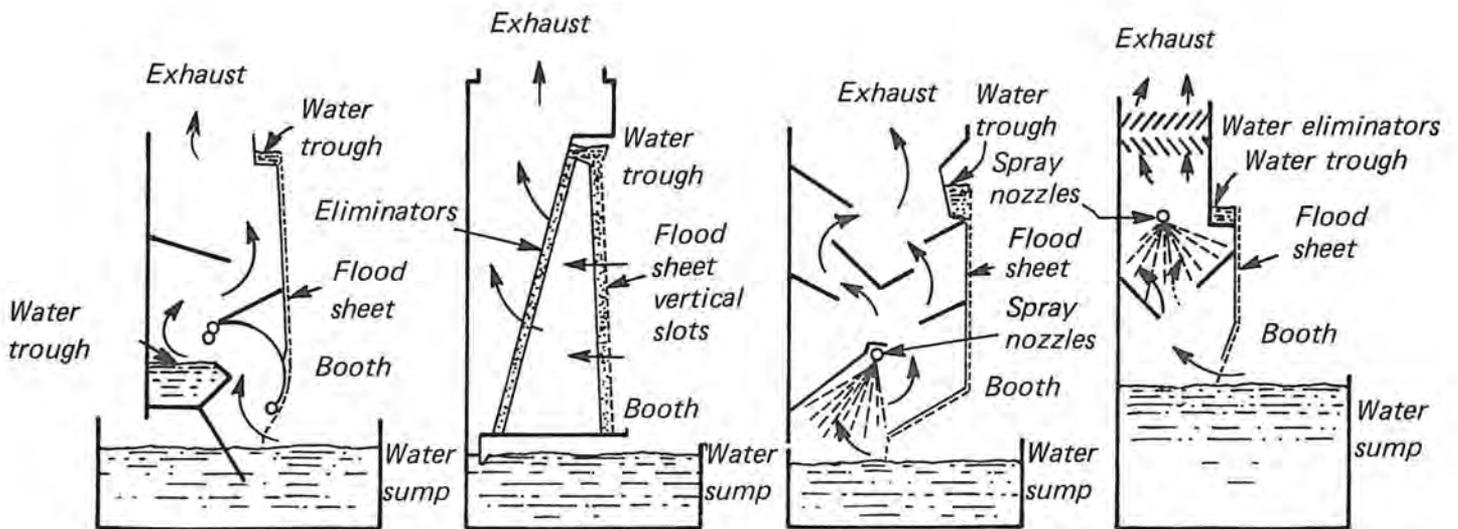


FIGURE 6 TYPICAL AIR DISTRIBUTION AND AIR CLEANING SECTIONS FOR WATER WASH SPRAY BOOTHS

painting operation shall be conducted in a spray booth. Figure 7 illustrates an acceptable design for a booth having a single entrance. Figure 8 illustrates an acceptable design for a drive-through booth. The minimum air volume to be exhausted from such booths shall be in accordance with requirements given in the appropriate figure.

4.4.5 Trailer Interior Spray Painting

Figure 9 illustrates an acceptable arrangement for ventilation of trailers which are being internally spray-finished. Where such an arrangement is used, a minimum air volume of 50 cfm per sq ft of the cross-sectional area of the trailer shall be exhausted and the operator shall be provided and shall wear an air-supplied respirator approved by MESA and NIOSH.

4.4.6 Drying or Baking Ovens

Where an oven is used for drying or baking sprayed work, the oven shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits and/or to prevent a fire or explosion hazard.

Figure 10 illustrates acceptable hood designs to prevent the escape of air contaminants from door openings of drying or baking ovens. The minimum air volumes exhausted through such hoods shall be in accordance with the requirements given in the figure.

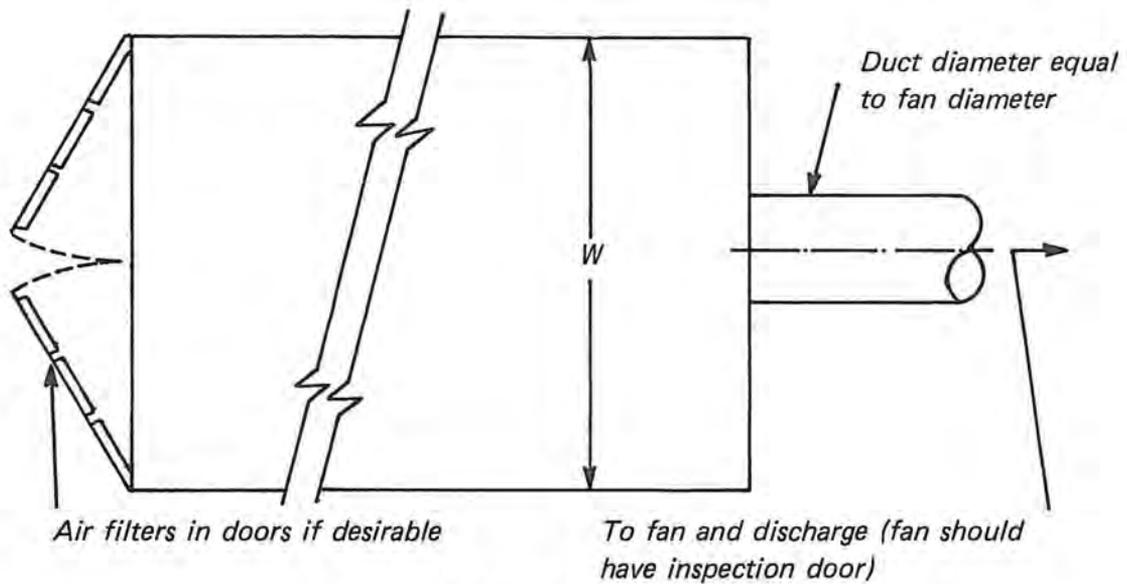
Ovens shall be structurally separate from all spray booths and the air drawn into any fixed oven for ventilation or combustion shall not be from any spray booth nor disturb the airflow into any spray room.

Enclosed spaces within baking or drying ovens shall be ventilated as necessary to prevent contaminant concentrations which can present a fire or explosion hazard. The ventilation rate to be provided such ovens shall be determined from the following formula:

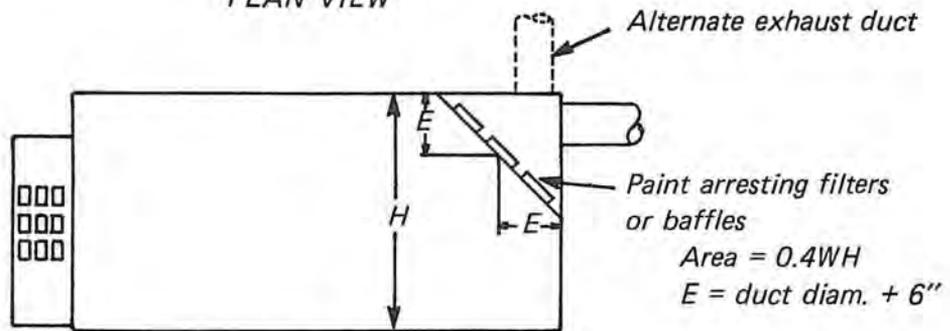
$$\text{cfm per pint of solvent evaporated = } \frac{(403) (\text{Sp. gr. liquid}) (100) (C)}{\text{per minute} \quad (\text{M. W. liquid}) (\text{LEL}) (B)}$$

were:

- LEL= lower explosive limit of a gas or vapor expressed in percent in air by volume.
- C = safety factor which depends on percentage of LEL necessary for safe conditions; for maintenance of vapor concentrations to not more than 25% LEL in properly ventilated continuous ovens, C=4. In batch ovens with good air distribution, the existence of peak drying rates requires a C factor of 10 or 12. In improperly ventilated batch ovens, larger C factors are necessary.
- B = a constant which takes into account the fact that the LEL of a solvent vapor-air mixture decreases at elevated temperatures.



PLAN VIEW



ELEVATION

Typical filter installation

Air spray operations

Q = minimum 100 cfm/sq ft of cross-sectional area

Airless spray operations

Q = minimum 60 cfm/sq ft of cross-sectional area

Entry loss = 0.50 VP plus resistance of each filter bank when dirty

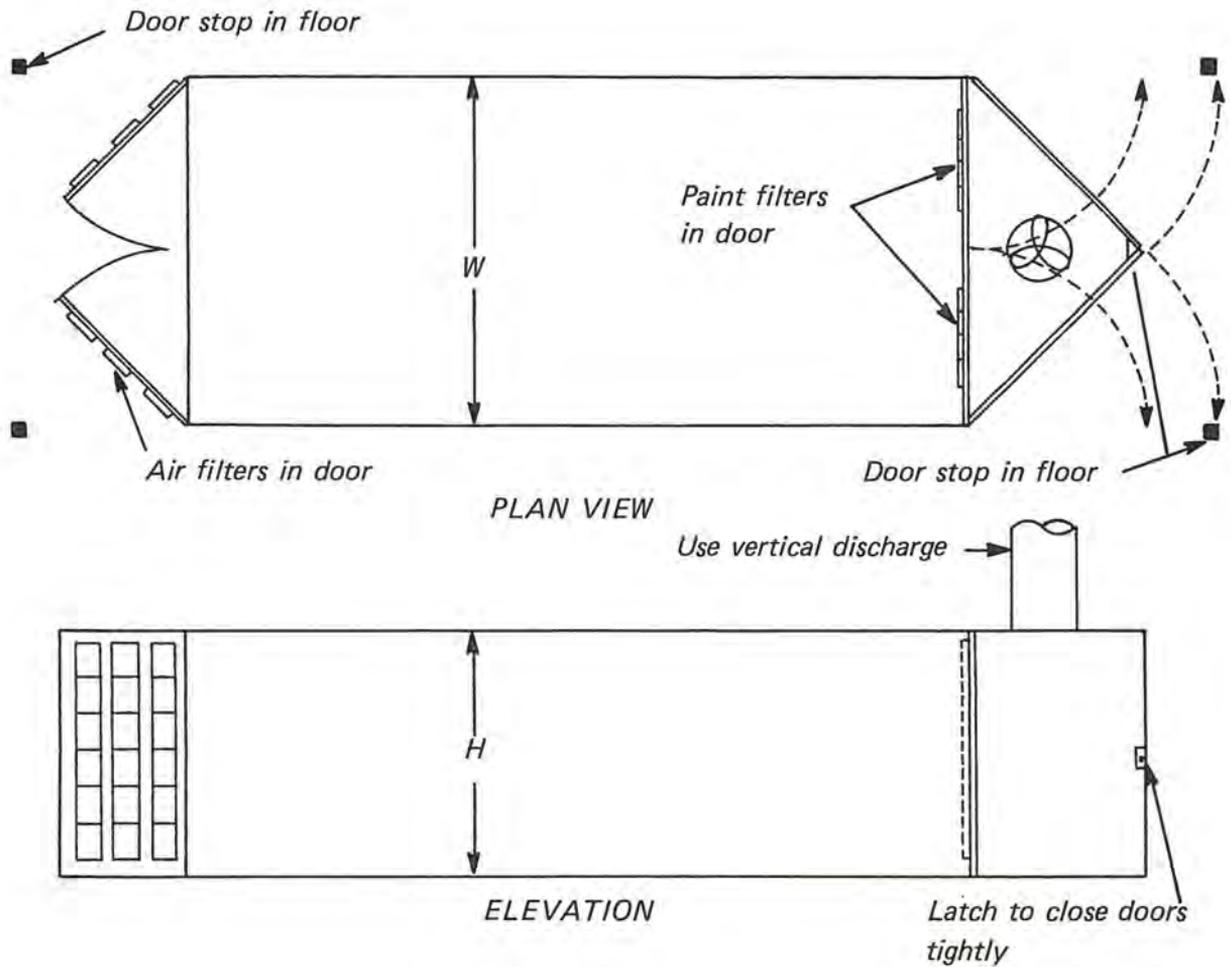
Duct velocity = 1000 fpm minimum

Air filters to be sized for 275 cfm/sq ft of filter

Paint filters: Combustibility Class 2 or better

size and number of filters for minimum area shown

FIGURE 7 AUTO SPRAY PAINT BOOTH



Q = minimum 50 cfm/sq ft of cross-sectional area
 (when $W \times H$ is greater than 150 sq ft)

Entry loss = 0.50 VP plus resistance of each filter bank when dirty

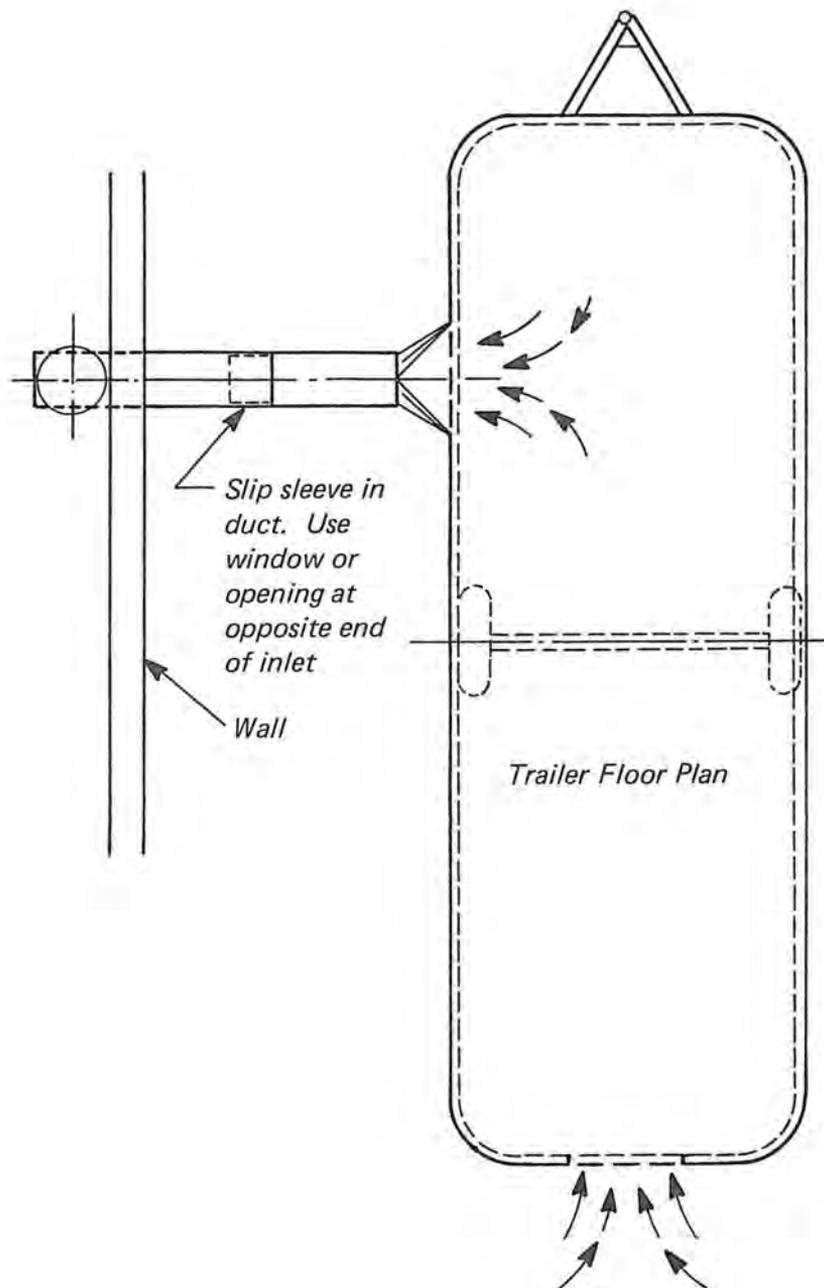
Duct velocity = 1000 fpm minimum

Air filters: Size for 275 cfm/sq ft of filters

Paint filters: Combustibility Class 2 or better, consult manufacturer
 for size and number

Note: Fan interlock with make-air supply and compressed air to spray
 gun is desirable.

FIGURE 8 LARGE DRIVE-THROUGH SPRAY PAINT BOOTH



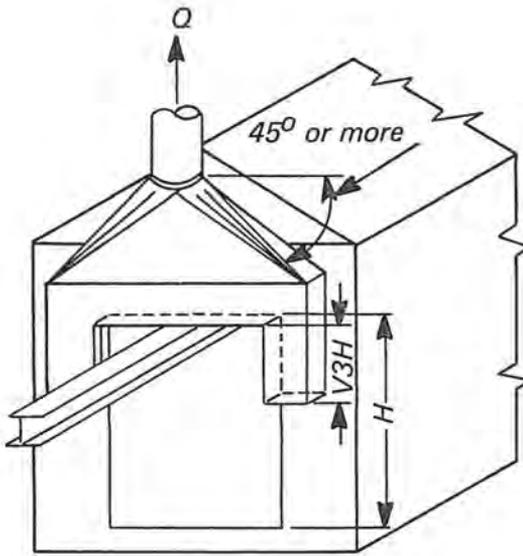
Q = minimum 50 cfm/sq ft of cross-sectional trailer area
 Entry loss = entry loss factor for tapered hood x duct VP
 Duct velocity = 1000 fpm minimum

Note: Operator must wear an air-supplied respirator approved by NIOSH and MESA

FIGURE 9 TRAILER INTERIOR SPRAY PAINTING

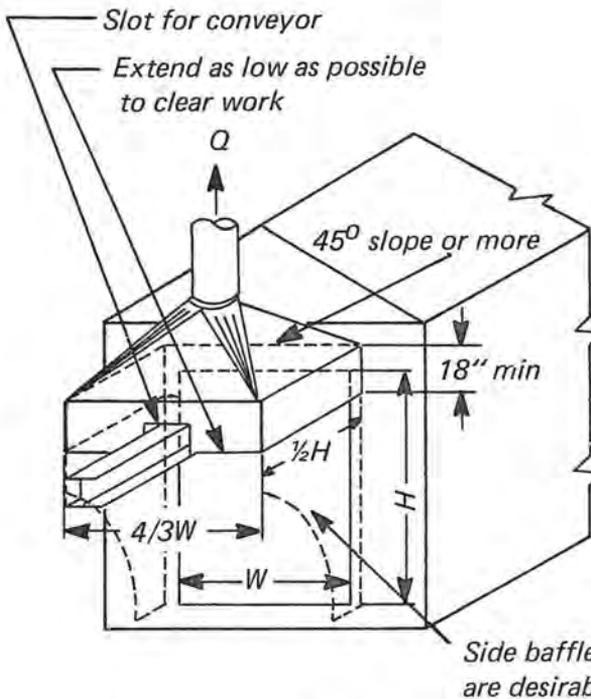
SLOT TYPE

$Q = \text{minimum } 100 \text{ cfm/sq ft door plus } \frac{1}{2} \text{ products of combustion}$
 Entry loss = 1.0 slot VP plus entry loss factor for tapered hood x duct VP
 Duct velocity = 1000 fpm minimum



Size plenum for 500 fpm maximum

Slot on three sides size for 1000 fpm
 Locate on inside or outside of door



CANOPY TYPE

$Q = \text{minimum } 200 \text{ cfm/sq ft of hood face plus } \frac{1}{2} \text{ products of combustion}$
 Entry loss = entry loss factor for tapered hood x duct VP
 Duct velocity = 1000 fpm minimum

Note: For dryers, include volume of water vapor liberated

Note: Hoods at each end of oven. Reduce size of doors as much as possible. Separate vent must be added for products of combustion.

FIGURE 10 DRYING OR BAKING OVEN VENTILATION

B= for temperatures up to 250 deg. F; B=0.7 for temperatures above 250 deg. F.

The above formula is correct for air at 70 deg. F. Temperature correction is necessary for operating temperatures in excess of 100 deg. F. The formula for such corrections is as follows:

cfm at operating conditions =

$$\frac{(\text{cfm at 70 deg. F.}) (460 + \text{operating temperature})}{(460 + 70)}$$

4.4.7 Mixing Rooms

Rooms for the mixing of paints and other materials used in spray-finishing operations shall be ventilated as necessary to maintain air contaminant concentrations at or below exposure limits. Control is usually achieved in such rooms by the covering of mixers and the provision of ventilation by floor exhaust openings. Exhaust volumes shown to be successful are usually on the order of 12 to 20 air changes per hour.

4.4.8 Ventilation of Freshly Sprayed Material

Where freshly spray-finished objects are conveyed to drying or baking ovens or are air dried, ventilation shall be provided as necessary to maintain air contaminant concentrations in the breathing zones of employees to levels at or below exposure limits. Control may be achieved through the use of general mechanical ventilation at an adequate rate or through the use of exhausted conveying or drying tunnels with a minimum air velocity through all openings of 100 fpm.

4.4.9 Spray Rooms

Spray rooms within which spray-finishing operations are conducted which generate air contaminant concentrations in excess of exposure limits shall be ventilated as necessary to maintain contaminant concentrations at or below exposure limits. Where air spray operations are conducted, a minimum general mechanical ventilation rate of 15,000 cfm shall be provided for the first gun being used and an additional 5000 cfm for each additional gun. Where airless spray operations are conducted, the minimum exhaust volume shall be 9,000 cfm for the first gun and an additional 3,000 cfm for each additional gun.

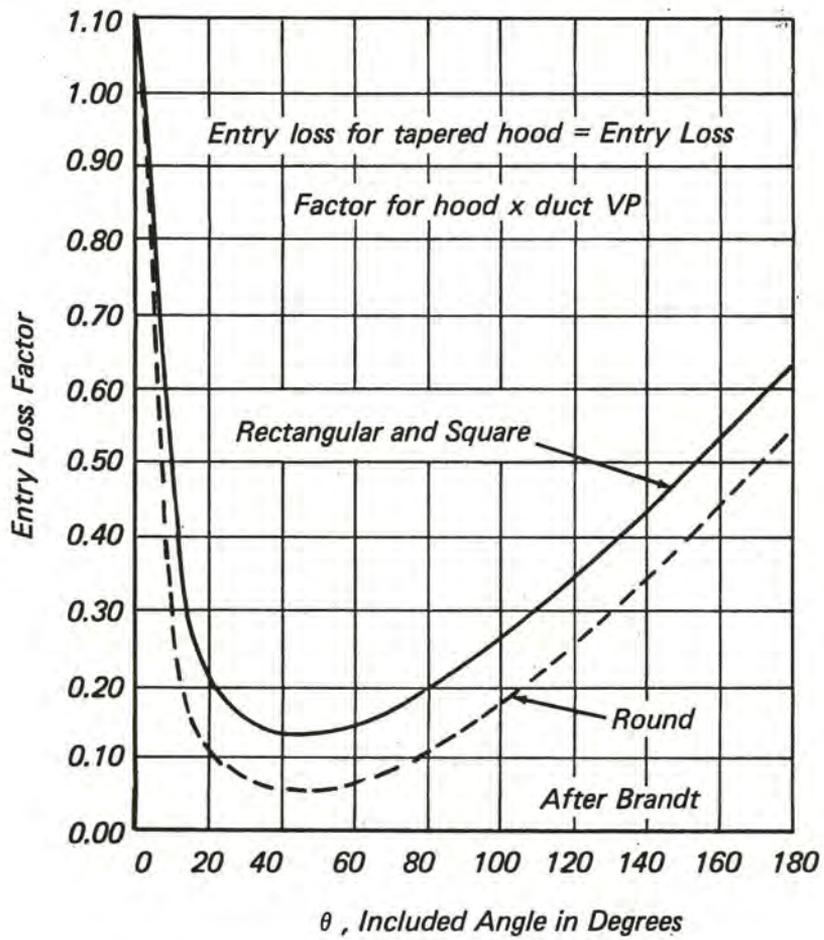
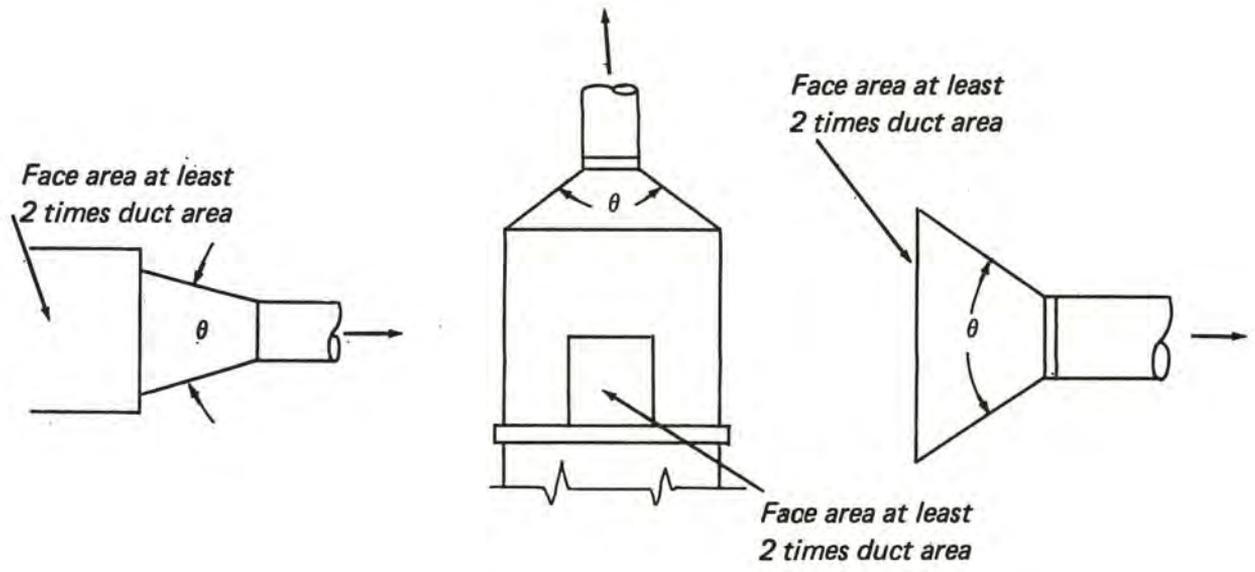
RECOMMENDED GUIDELINES FOR WELDING OPERATIONS

1. Scope

These guidelines prescribe the use of general ventilation and local exhaust ventilation for the control and removal of airborne contaminants generated by welding operations. Welding operations covered by these guidelines include joining and surfacing of metals by welding, brazing, and soldering; severing and gouging of metals by flame and arc cutting; and the coating of metals by thermal spraying.

2. Definitions

- a. Capture Velocity - The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
- b. Confined Space - An enclosed space in which welding operations are conducted with a volume of less than 10,000 cubic feet per welder, a ceiling height of less than 16 feet, or where the welding space contains partitions, balconies, or other structural barriers to the extent that they significantly obstruct ventilation.
- c. Contaminant - A substance (dust, fume, mist, vapor, or gas) whose presence in air is harmful, hazardous, or undesirable.
- d. Duct Velocity - The average air velocity in a duct of an exhaust system.
- e. Dust - Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.
- f. Enclosed Space - A building, room, or area which is completely enclosed except for doors, passageways and ventilation openings.
- g. Enclosing Hood - An exhaust hood which partially or totally encloses the source of contaminants; also booth or enclosure.
- h. Entry Loss - Loss in pressure caused by air flowing into a duct or hood, usually expressed in inches of water gauge.
- i. Entry Loss Factor - A factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss in inches of water gauge. The entry loss factors for tapered hoods are given by the graph in Figure 1 as a function of the included or major angle of the hood.
- j. Exhaust Hood - A shaped inlet designed to capture contaminated air and conduct it into an exhaust duct.
- k. Exhaust volume or Flow Rate (Q) - Volume rate of flow exhausted from an exhaust hood.



Tapered Hoods

*Flanged or unflanged; round, square, or rectangular.
 θ is the major angle on rectangular hoods.*

FIGURE 1 ENTRY LOSS FACTOR FOR TAPERED HOODS

- l. Exposure Limit - Maximum allowable concentration of an airborne contaminant to which a worker may be exposed as specified by 29 CFR 1910.1000.
- m. Face - The opening in an exhaust hood or enclosure through which the exhaust flow enters.
- n. Face Velocity - The average exhaust flow velocity at the face of an exhaust hood or enclosure.
- o. Fumes - Small solid particles formed by the condensation of vapors of solid materials.
- p. Gases - Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
- q. General Mechanical Ventilation - The process of supplying air to or removing air from a space by mechanical means.
- r. General Ventilation - Removal and replacement of air from an enclosed space in a non-localized manner for the purpose of controlling concentrations of air contaminants.
- s. Local Exhaust System - A system consisting of exhaust hoods, ductwork, air-cleaning equipment, exhauster, and stack, for removing contaminated air from a space.
- t. Make-up Air - Air supplied to a building or space to replace air exhausted.
- u. Mists - Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
- v. Natural Ventilation - Air movement through a space produced by either or both of two natural forces; wind forces and stack effects.
- w. Open Hood - An exhaust hood which does not enclose the source of contaminants.
- x. Pressure, Static - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse a pipe).
- y. Pressure, Total - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).
- z. Pressure, Velocity (VP) - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.
- aa. Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

3. Application

These guidelines shall apply to all welding operations, including welding, brazing, soldering, surfacing, cutting, gouging, and thermal spraying, which generate air contaminants into the breathing zones of employees in concentrations in excess of the exposure limits specified

in 29 CFR 1910.1000 and which are not specifically covered by other ventilation guidelines. Ventilation equipment provided in accordance with these guidelines shall operate continuously while the contaminant-generating operations are in progress and at all other times when the potential for employee exposure to excessive contaminant concentrations exists.

These guidelines define minimum ventilation requirements for air contaminant control. The exhaust hood designs illustrated in these guidelines are representative of common usage. Other designs which provide equivalent or improved performance are acceptable. Where the specified requirements are insufficient to maintain air contaminant concentrations at or below exposure limits because of unique, peculiar, or novel processes or materials or other adverse circumstances or conditions, different or more stringent control measures shall be provided as necessary to maintain contaminant levels at or below exposure limits.

4. Ventilation Equipment Design Requirements

4.1 General

Welding operations shall be enclosed and exhaust ventilated as necessary to maintain air contaminant concentrations at or below exposure limits.

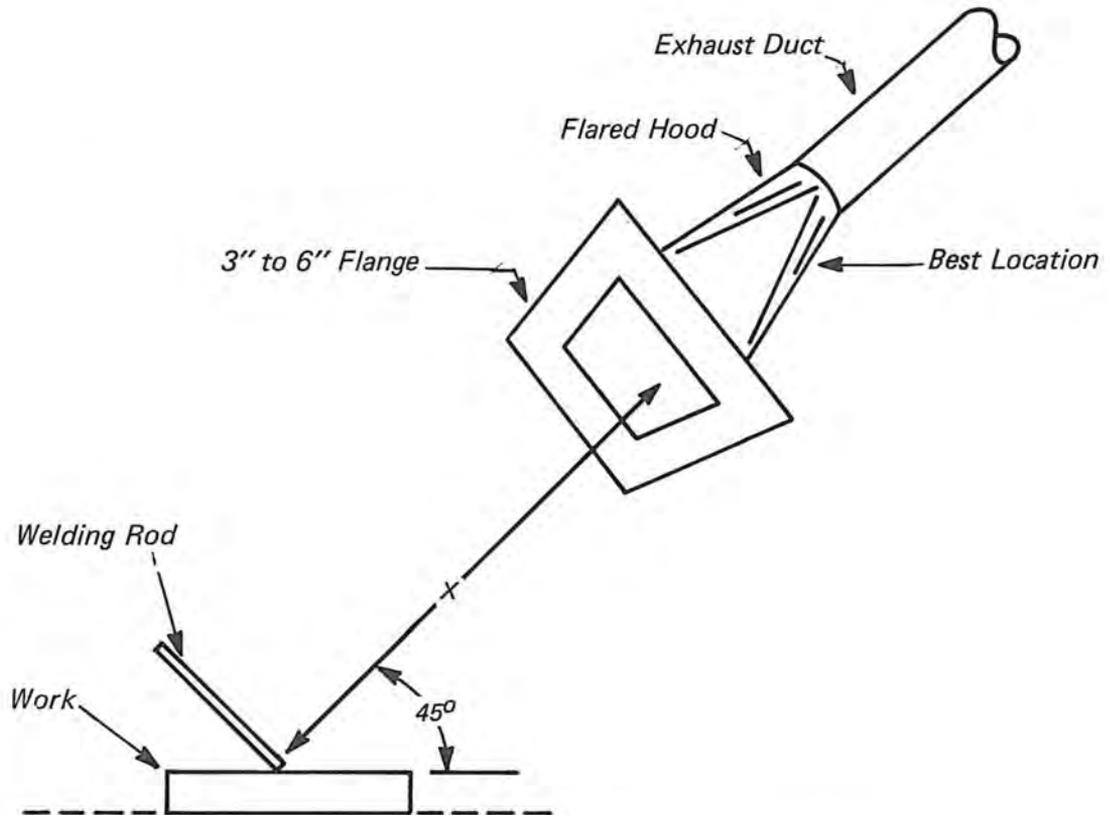
A hood used for the control of contaminants from a welding operation shall be connected to an exhaust system. With operations in which contaminants are released with a significant initial velocity such as thermal spraying or oxygen cutting, the hood shall be designed and located such that the contaminants are projected into the hood in the direction of the exhaust airflow.

Where large quantities of exhaust air cause negative pressures which reduce the effectiveness of process exhaust systems or cause a carbon monoxide hazard due to back-drafting of flues of heating devices, provision shall be made to supply clean make-up air to replace the exhausted air. The make-up air supply, where necessary, shall be adequate to provide for the combined exhaust ventilation systems, process systems, and combustion processes in the workplace without restricting the performance of any hood, system, or flue.

Sections 4.2 through 4.6 of these guidelines describe acceptable designs for the control of air contaminants from welding operations. Selection of the hood design to be used for a particular welding operation shall be in accordance with the provisions of Section 5 of these guidelines.

4.2 Freely Suspended Open Hood

Figure 2 illustrates an acceptable freely suspended open hood design and location for the control of contaminated air from a welding operation. The hood face may be round, square, or rectangular in shape. The minimum exhaust volume through the hood shall be calculated by the



$$Q = K(10 X^2 + A)V_x$$

- Q = exhaust volume, cfm
 X = distance from center of hood face to farthest point of contaminant release, ft
 A = hood face area (not including flange), sq ft
 V_x = minimum capture velocity, fpm
 K = 1.0 for unflanged hood; 0.75 for flanged hood
 Entry loss = entry loss factor for tapered hood X duct VP
 Duct velocity = 2000 fpm minimum

FIGURE 2 FREELY-SUSPENDED OPEN HOOD

formula included in the figure using the capture velocity (V) specified for the welding operation in Section 5. If an open hood of a different design is used, it shall provide a capture velocity at the farthest point of contaminant release from the hood face equal to or greater than that specified in Section 5.

An open hood also may be used with a contaminant-generating operation conducted at the face of the hood as shown in Figure 3. The minimum flow rate through the hood shall be that necessary to establish the hood face velocity specified in Section 5.

4.3 Crossdraft Table

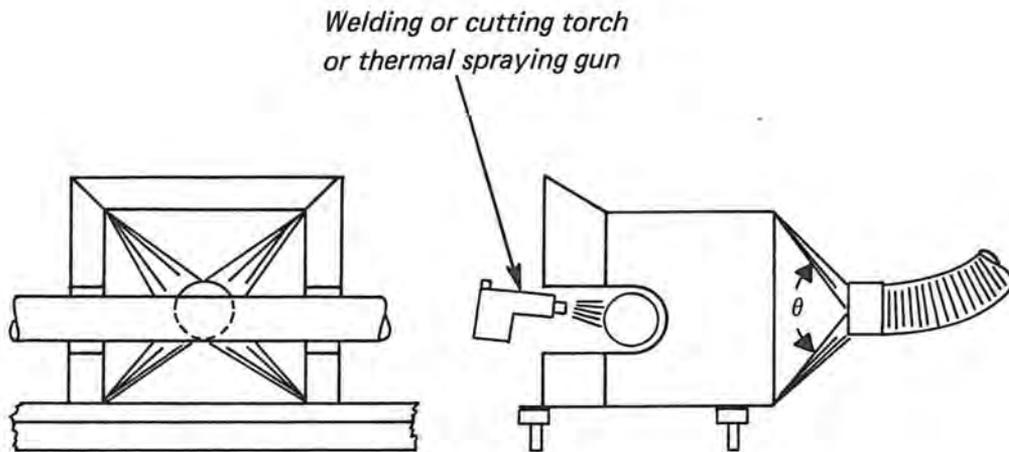
A crossdraft table is an open hood used in conjunction with a welding table for the control of contaminated air from a welding operation. Figure 4 illustrates an acceptable design for a crossdraft table. The minimum exhaust volume through the hood shall be maintained in accordance with the formula in Figure 4 and the capture velocity specified for the welding operation in Section 5. If a hood of a different design is used, it shall provide a capture velocity at the farthest point of contaminant release from the hood face equal to or greater than that specified in Section 5.

4.4 Downdraft Table

A downdraft table is an exhaust hood formed by drawing air through the open top of a table or workbench for the control of contaminated air from a welding operation. Figure 5 illustrates an acceptable design for a downdraft table. The exhaust volume through the table shall be sufficient to maintain the minimum face velocity specified in Section 5. Welding operations shall be conducted such that the point of contaminant release is vertically above the table top and at a distance from the table top not exceeding 25 percent of the shortest dimension of the airflow opening in the table top. If a hood of a different design is used, it shall provide a face velocity at the table top equal to or greater than that specified in Section 5.

4.5 Gun-Mounted Exhaust Hood

A gun-mounted exhaust hood is a local exhaust hood incorporated directly in a welding gun as shown schematically in Figure 6. Designs of gun-mounted hoods vary and are constrained by the requirements for small size and conformity with the shape of the welding gun. Because gun-mounted hoods vary in design, a general formula for exhaust flow requirements cannot be defined. Prior to the use of a gun-mounted hood, the manufacturer or user shall establish the exhaust volumes necessary for the hood to prevent breathing zone contaminant concentrations which exceed exposure limits. Exhaust volume requirements shall be established separately for each welding operation for which the hood will be used, and the required exhaust volumes shall be maintained continuously during operations utilizing the gun-mounted hood.



$$Q = A V_f$$

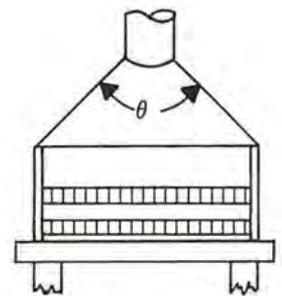
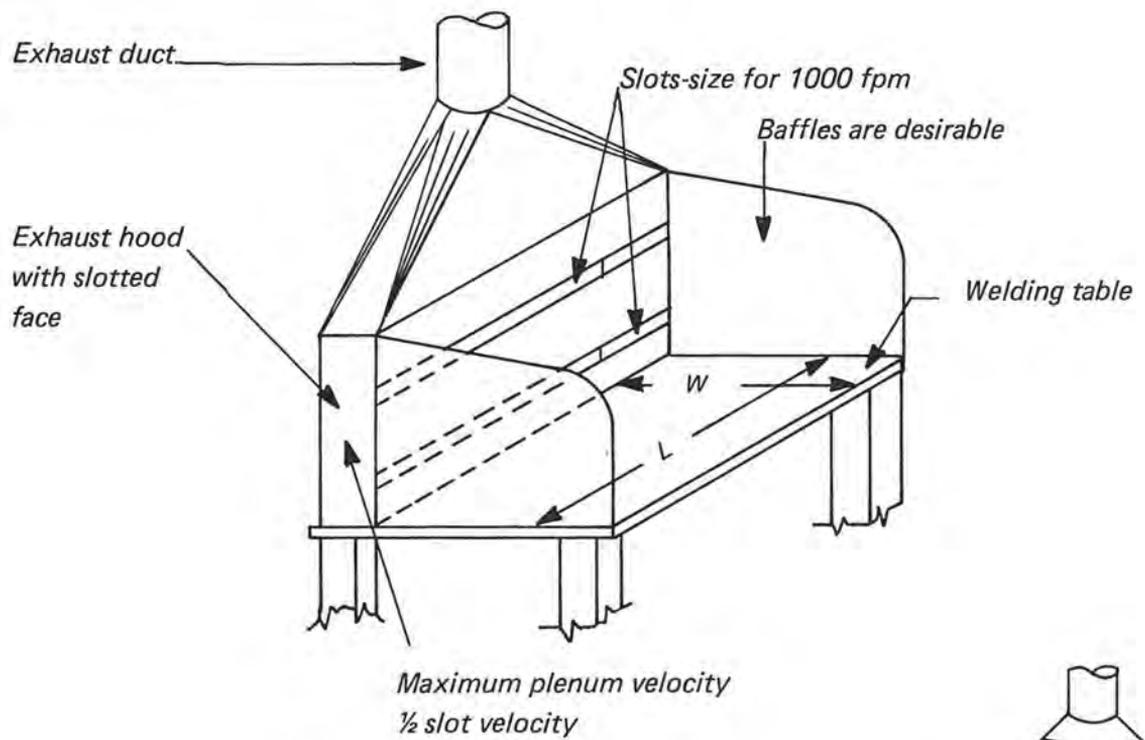
Q = exhaust volume, cfm

A = hood face area, sq ft

V_f = minimum face velocity, fpm

Entry loss = entry loss factor for tapered hood x duct VP

FIGURE 3 OPEN HOOD WITH WELDING OPERATION AT FACE



$$Q = KLWV_x$$

Q = exhaust volume, cfm

W = table width, ft (not to exceed 4 ft)

L = table length, ft

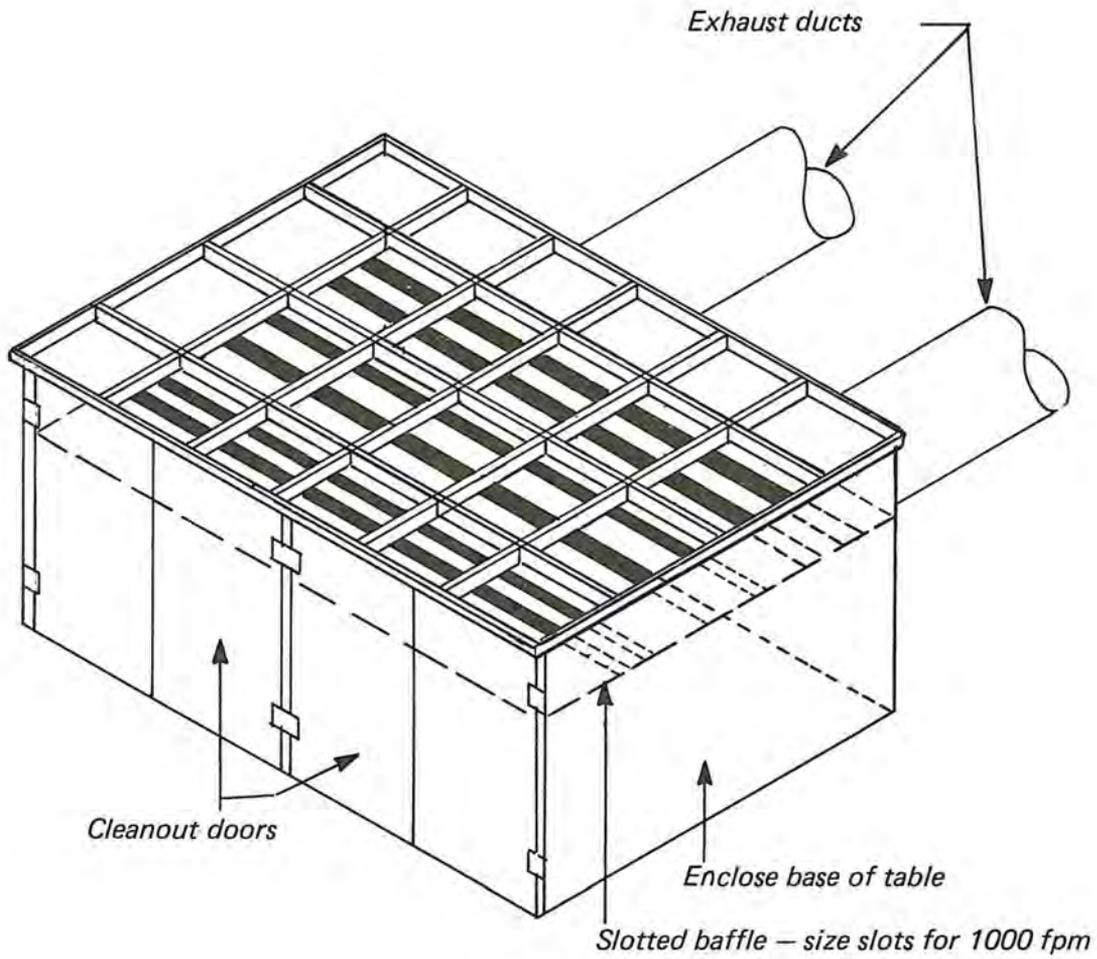
V_x = minimum capture velocity, fpm

K = 2.4 with baffles; 2.8 without baffles

Entry loss = 1.78 slot VP plus entry loss factor
for tapered hood x duct VP

Duct velocity = 2000 fpm minimum

FIGURE 4 CROSSDRAFT TABLE



$$Q = A V_f$$

Q = exhaust volume, cfm

A = table top area, sq ft

V_f = minimum face velocity, fpm

Entry loss = 1.78 slot VP plus entry loss factor
for tapered hood x duct VP

Duct velocity = 2000 fpm minimum

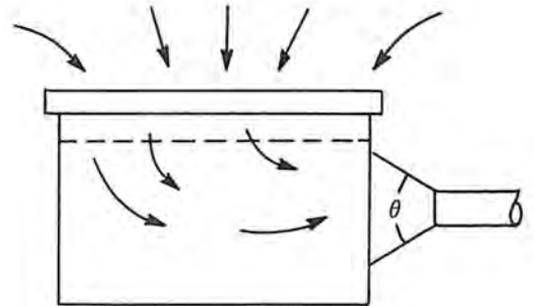
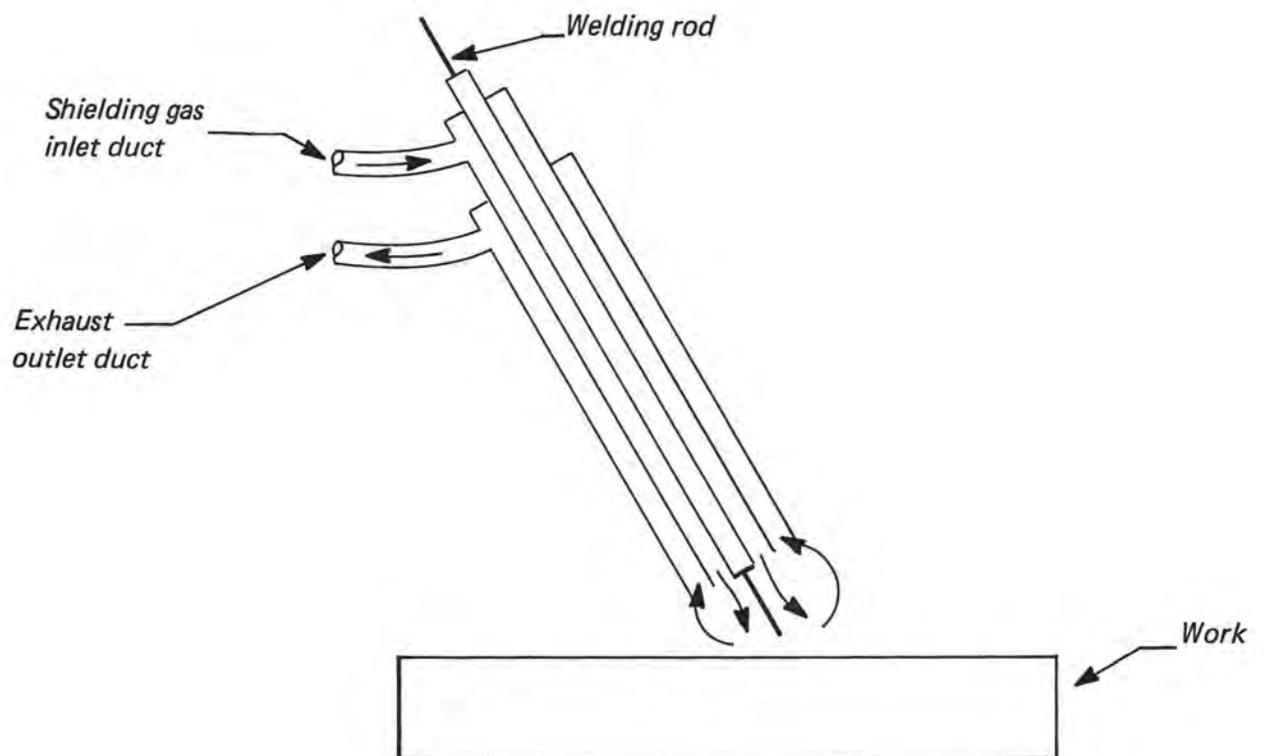


FIGURE 5 DOWNDRAFT TABLE



Exhaust flow requirements must be determined for each welding operation and welding gun configuration by experimental testing with air contaminant sampling and analysis.

FIGURE 6 WELDING GUN-MOUNTED EXHAUST HOOD

4.6 Enclosing Hood

Figure 7 illustrates an acceptable enclosing hood design for the control of contaminated air from a welding operation. The hood shall be of sufficient size for the welding operation to be located entirely within the hood. The welder shall operate such that the exhaust air flow causes contaminants from the operation to flow away from the welder's breathing zone. The exhaust volume through the hood shall be sufficient to establish the minimum face velocity specified for the operation in Section 5. If a hood of a different design is used, it shall provide a face velocity equal to or greater than that specified in Section 5.

5. Ventilation Requirements

5.1 General

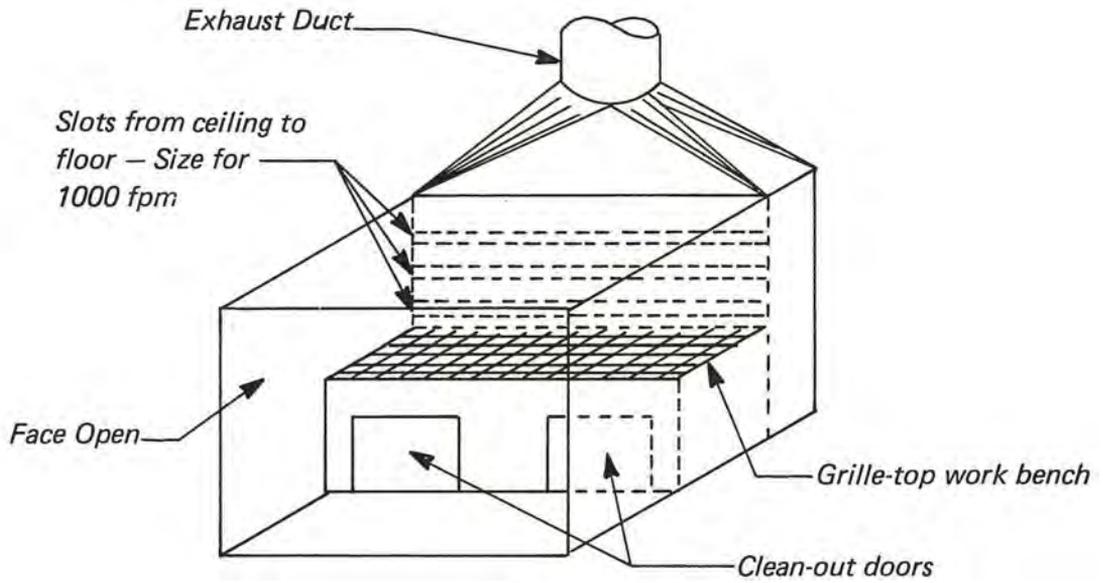
Ventilation methods and exhaust flow requirements are prescribed in this section for specific welding operations and contaminant materials. Contaminant materials are designated by classes based on exposure limits and are defined in Table 1. If a welding operation results in exposure of a worker to excessive concentrations of contaminant materials of two or more classes, the ventilation requirements for the highest class of contaminant material shall apply.

The ventilation requirements prescribed in the following paragraphs are summarized in Table 2. It will be noted that, for most operations, more than one ventilation method is allowable.

5.2 Gas Welding, Torch Brazing, and Torch Soldering

Ventilation for gas welding, torch brazing, or torch soldering operations shall be provided by one of the following methods:

- a. General mechanical ventilation at a minimum exhaust rate of 2000 cfm per welder. Applicable to operations in enclosed spaces which are confined or not confined and to Class I contaminants only.
- b. Freely suspended open hood or crossdraft table with minimum capture velocity of 100 fpm. Applicable to Class I and II contaminants only.
- c. Downdraft table with a minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- d. Enclosing hood with minimum face velocity of 100 fpm. Applicable to Class I and II contaminants only.
- e. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.



Work bench required for thermal spraying; optional for other welding operations.

$$Q = A V_f$$

Q = exhaust volume, cfm

A = hood face area, sq ft

V_f = minimum face velocity, fpm

Entry loss = 1.78 slot VP plus entry loss factor
for tapered hood x duct VP

Duct velocity = 3000 fpm minimum

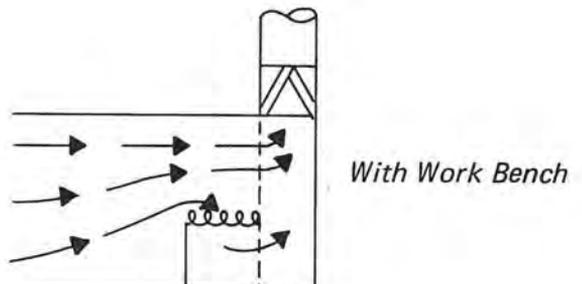
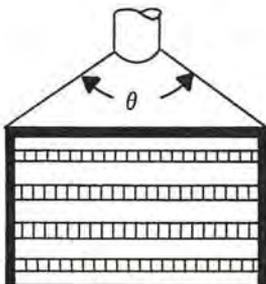
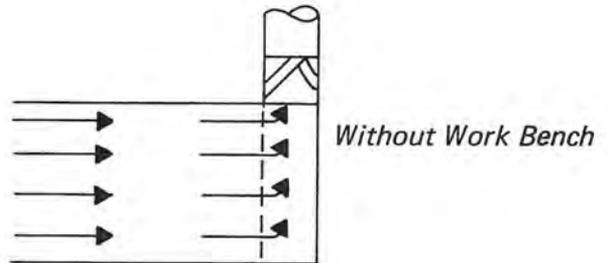


FIGURE 7 ENCLOSING HOOD

TABLE 1

CLASSIFICATION OF CONTAMINANT MATERIALS FROM WELDING OPERATIONS

Contaminant Class	Classification Criteria	Example Materials
I	Dusts, fumes, and mists with exposure limits of 10 mg/M ³ and above; gases and vapors with exposure limits of 100 ppm and above.	Inert dust Iron Oxide
II	Dusts, fumes, and mists with exposure limits of 0.1 mg/M ³ and above (up to 10 mg/M ³); gases and vapors with exposure limits of 1 ppm and above (up to 100 ppm)	Cadmium Cobalt Fluoride Lead Carbon Monoxide Nitrogen Dioxide Ozone
III	Dusts, fumes, and mists with exposure limits below 0.1 mg/M ³ ; gases and vapors with exposure limits below 1 ppm.	Beryllium Mercury

TABLE 2
SUMMARY OF MINIMUM VENTILATION REQUIREMENTS FOR WELDING OPERATIONS
VENTILATION METHODS AND EXHAUST FLOW REQUIREMENTS

<u>Operation</u>	<u>General Mechanical Ventilation</u>	<u>Freely-Suspended Open Hood</u>	<u>Crossdraft Table</u>	<u>Downdraft Table</u>	<u>Gun-Mounted Open Hood</u>	<u>Enclosing Hood</u>
Gas Welding	Class I - 2000 cfm per welder in any enclosed space. Classes II & III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Torch Brazing and Soldering	Class I - 2000 cfm per welder in any enclosed space. Classes II & III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Shielded Metal-Arc Welding	Class I - 2000 cfm per welder with electrodes 3/16 in dia. or less; 4500 cfm per welder with electrodes greater than 3/16 in dia. Not allowed in confined space. Classes II & III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Plasma Arc Welding	Class I - 2000 cfm per welder. Not allowed in confined space. Classes II & III - not allowed.	Classes I and II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Submerged Arc Welding	Class I - 2000 cfm per welder. Not allowed in confined space. Classes II & III - not allowed.	Classes I and II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Gas Shielded-Arc Welding	Class I - 2000 cfm per welder. Not allowed in unconfined space. Classes II & III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Classes I & II - Exhaust rate to be determined by manufacturer or user. Class III - not allowed.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Flux Cored Arc Welding	Class I - 4500 cfm per welder. Not allowed in confined space. Classes II & III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 100 fpm capture velocity. Class III - not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Classes I & II - Exhaust rate to be determined by manufacturer or user. Class III - not allowed.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Oxygen Cutting and Gouging	Class I - 2000 cfm per welder in any enclosed space. Classes II & III - not allowed.	Not allowed.	Not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Arc Cutting and Gouging	Class I - 2000 cfm per welder. Not allowed in confined space. Classes II & III - not allowed.	Not allowed.	Not allowed.	Classes I & II - 150 fpm face velocity. Class III - not allowed.	Not applicable.	Classes I & II - 100 fpm face velocity. Class III - 150 fpm face velocity.
Thermal Spraying	Not allowed.	Class I - 200 fpm face velocity with operation at face of hood. Classes II & III - not allowed.	Not allowed.	Not allowed.	Not applicable.	Class I - 125 fpm face velocity. Classes II & III - 200 fpm face velocity.

5.3 Shielded Metal-Arc Welding with Electrode of
3/16-inch Diameter or Less, Plasma Arc Welding,
and Submerged Arc Welding

Ventilation for shielded metal-arc welding (with electrodes of 3/16-inch diameter or less), plasma arc welding, and submerged arc welding operations shall be provided by one of the following methods:

- a. General mechanical ventilation at a minimum exhaust rate of 2000 cfm per welder. Applicable to operations in enclosed spaces which are not confined and to Class I contaminants only.
- b. Freely suspended open hood or crossdraft table with minimum capture velocity of 100 fpm. Applicable to Class I and II contaminants only.
- c. Downdraft table with a minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- d. Enclosing hood with minimum face velocity of 100 fpm. Applicable to Class I and II contaminants only.
- e. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.4 Shielded Metal-Arc Welding with Electrodes Greater
than 3/16-inch in Diameter

Ventilation for shielded metal-arc welding operations (with electrodes greater than 3/16-inch in diameter) shall be provided by one of the following methods:

- a. General ventilation at a minimum exhaust rate of 4500 cfm per welder. Applicable to operations in enclosed spaces which are not confined and to Class I contaminants only.
- b. Freely suspended open hood or crossdraft table with minimum capture velocity of 100 fpm. Applicable to Class I and II contaminants only.
- c. Downdraft table with minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- d. Gun-mounted open hood with minimum exhaust flow in accordance with requirements established for the particular hood design and welding operation as prescribed in Section 4.2.5. Applicable to Class I and II contaminants only.
- e. Enclosing hood with minimum face velocity of 100 fpm. Applicable to Class I and II contaminants only.
- f. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.5 Gas Shielded-Arc Welding

Ventilation for gas shielded-arc welding operations shall be provided by one of the following methods:

- a. General mechanical ventilation with a minimum exhaust rate of 2000 cfm per welder. Applicable to operations in enclosed spaces which are not confined and to Class I contaminants only.
- b. Freely-suspended open hood or crossdraft table with minimum capture velocity of 100 fpm. Applicable to Class I and II contaminants only.
- c. Downdraft table with minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- d. Gun-mounted open hood with minimum exhaust flow in accordance with exhaust flow requirements established for the particular hood design and welding operation as prescribed in Section 4.2.5. Applicable to Class I and II contaminants only.
- e. Enclosure with minimum face velocity of 100 fpm. Applicable to Class I and II contaminants only.
- f. Enclosure with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.6 Flux Cored Arc Welding

Ventilation for flux cored arc welding operations shall be provided by one of the following methods:

- a. General mechanical ventilation with a minimum exhaust rate of 4500 fpm per welder. Applicable to operations in enclosed spaces which are not confined and to Class I contaminants only.
- b. Freely suspended open hood or crossdraft table with minimum capture velocity of 100 fpm. Applicable to Class I and II contaminants only.
- c. Downdraft table with minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- d. Gun-mounted open hood with minimum exhaust flow in accordance with requirements established for the particular hood design and welding operation as prescribed in Section 4.2.5. Applicable to Class I and II contaminants only.
- f. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.7 Oxygen Cutting and Gouging

Ventilation for oxygen cutting and gouging operations shall be provided by one of the following methods:

- a. General mechanical ventilation at a minimum exhaust rate of 2000 cfm per welder. Applicable to operations in enclosed spaces which are confined or not confined and to Class I contaminants only.
- b. Downdraft table with a minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- c. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.8 Arc Cutting and Gouging

Ventilation for arc cutting and gouging operations shall be provided by one of the following methods:

- a. General ventilation at a minimum exhaust rate of 2000 cfm per welder. Applicable to operations in enclosed spaces which are not confined and to Class I contaminants only.
- b. Downdraft table with a minimum face velocity of 150 fpm. Applicable to Class I and II contaminants only.
- c. Enclosing hood with minimum face velocity of 100 fpm. Applicable to Class I and II contaminants only.
- d. Enclosing hood with minimum face velocity of 150 fpm. Applicable to Class I, II, and III contaminants.

5.9 Thermal Spraying

Ventilation for thermal spraying operations shall be provided by one of the following methods:

- a. Freely suspended open hood with operation conducted at face of hood and with minimum face velocity of 200 fpm. Applicable to Class I contaminants only.
- b. Enclosing hood with minimum face velocity of 125 fpm. Applicable to Class I contaminants only.
- c. Enclosing hood with minimum face velocity of 200 fpm. Applicable to Class I, II, and III contaminants.

5.10 Other Welding Operations

Ventilation shall be provided for the control of contaminants from other welding operations not specifically identified in these guidelines if such operations result in exposures of workers to contaminant concentrations in excess of exposure limits. Ventilation shall be provided by a method specified below for the class of contaminant generated by the operation.

Contaminant	Ventilation
Class	Method
I	General ventilation, open hood, or enclosing hood
II	Open hood or enclosing hood
III	Enclosing hood

Exhaust flow rates required to prevent excessive contaminant exposures shall be determined by measurements of contaminant levels, and these flow rates shall be maintained continuously while the operation is conducted.

APPENDICES

RATIONALE FOR GENERAL REQUIREMENTS

1. Introduction

There are certain statements included in some sections of the guidelines which are not discussed within the rationale memorandum for any particular guideline and the purpose of which are not completely self-evident. These are described and discussed below.

2. "Application" Section

With the single exception of the Ventilation Guidelines for Laboratory Operations, the "Application" paragraphs of the guidelines state that they only apply to operations or processes which generate air contaminants into the breathing zone of employees in concentrations in excess of exposure limits specified by the Code of Federal Regulations in Title 29, Part 1910.1000. This statement is significant in that it points out to an employer that, though he may be conducting or performing an operation or process for which ventilation guidelines have been prepared, the particular nature of his equipment, their location and the materials utilized may not result in excessive airborne contaminant concentrations. Under such circumstances the employer is not in violation of mandatory requirements and has no obligation to provide control measures other than those he may currently be using to maintain concentrations at or below exposure limits.

The reason that the Ventilation Guidelines for Laboratory Operations state that control measures should always be instituted is because the variability of laboratory work does not allow a priori knowledge of whether an exposure limit will or will not be exceeded during any particular operation. Avoidance of violations in these circumstances requires that control measures be available and working before the operation is initiated.

The statement is also made in the Application paragraphs that hood designs and airflow requirements are presented which are representative of common usage but which should be considered as defining minimum control requirements. It is to be realized that, though there is appreciable confidence that use of the design parameters as given will result in adequate control, it cannot be guaranteed that they will always do so, especially where the process or operation being conducted is unusual in some aspect.

3. Make-Up Air

Make-up air -- air supplied to a building or space to replace exhausted air -- is essential to ensure that exhaust hoods operate properly, to eliminate high velocity cross drafts through windows and doors, to ensure operation of natural draft stacks such as combustion flues, to eliminate cold drafts on workers, to eliminate differential

pressure on doors, and even to conserve fuel. Although the paragraphs concerning these topics do not address all of the reasons for which a controlled supply of such air is more often than not necessary, they do require at a minimum that air be supplied to eliminate the carbon monoxide hazard due to back-drafting of flues of heating devices and to ensure that a properly designed local exhaust system will operate as desired when activated.

4. Fire and Explosion Prevention

The guidelines for processes or operations which may involve substances which are flammable, combustible, or explosive when dispersed in air contain the requirements that either the concentration of the contaminant in the exhaust duct be maintained to a level at or below 25 percent of its lower explosive limit or the fan and ductwork be constructed to minimize the possibility of ignition. These requirements are derived from the mandatory requirements which are scheduled to be promulgated by the Standards Completion Program and which will be found in the individual standards for flammable or combustible substances. Since the substances covered do not include all such substances used in industry, and since the purpose of such requirements are to protect both workers and facilities from fires or explosions, universally unwanted occurrences, they are included in these guidelines also.

RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR ABRASIVE-BLASTING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for abrasive-blasting operations. The guidelines have been developed as a revision of the existing standard (Reference 1). Revisions have been made on the basis of current guides to industrial ventilation practice (Reference 2) and certain regulations promulgated by the State of New York Department of Labor (Reference 3). The purpose of the guidelines is to provide specific enclosure design and exhaust system airflow requirements in place of the presently included general statement in 29 CFR 1910.94(a) that "The rate of exhaust shall be sufficient to provide prompt clearance of the dust-laden air within the enclosure after the cessation of blasting."

2. Scope and Application

The scope and application of the guidelines are based on abrasive-blasting operations as defined and described in References 1-5. The guidelines are directed towards abrasive-blasting operations conducted within enclosures. Portable blasting operations as used at varying locations and elevations to clean buildings and other masonry and metallic surfaces are excluded from ventilation requirements. Furthermore, these guidelines, as the standard in 29 CFR 1910.94a, do not apply to steam blasting, steam or solvent cleaning, or hydraulic or solvent cleaning methods where work is done without the aid of abrasives.

The guidelines are applicable to the following abrasive-blasting systems:

- Abrasive-blasting rooms and chambers
- Abrasive-blasting cabinets
- Rotary abrasive-blasting tables
- Abrasive-blasting barrels

3. Definitions

The definitions provided in the guidelines relating to exhaust system designs and equipment are consistent with those used in relevant ventilation guides. Definitions of abrasive-blasting systems and associated materials and devices are primarily from the standard in 29 CFR 1910.94(a). Only minor modifications in terminology have been made for the sake of clarity and consistency.

4. Ventilation and Abrasive-Blasting Equipment Design Requirements

4.1 General

The requirements given in this section for enclosures and make-up air are general requirements whose purpose is self-evident. The requirements for baffles, observation windows, and combustible organic abrasives are taken directly from the standard in 29 CFR 1910.94(a).

4.2 Abrasive-Blasting Rooms and Chambers

NIOSH investigations into abrasive-blasting operations have conclusively indicated that the use of silica sand as an abrasive material develops extensive industrial health problems that exceed the hazards resulting from the use of other inorganic and organic abrasives. Indeed, this problem has been recognized to the extent that a number of nations have forbidden the use of silica sand for blast cleaning operations. Consequently, it is imperative for the health and safety of blast cleaning operators that ventilation requirements for systems using silica sand in any form be more stringent than the requirements for other abrasives, especially in situations where the operator works inside the enclosure where the blasting operations are taking place. The guidelines take this into consideration in section 4.2 by categorizing rooms and chambers within which operators work into two classes. Class I enclosures are those within which silica sand is used, Class II enclosures those within which other materials are used.

The enclosure design given in Figure 1 of the guidelines is taken from Print VS-101 of the ACGIH manual. The requirement that the lowest point of such openings be not more than 10 inches above the floor line is derived from Reference 3.

The requirements concerning doors to such rooms and chambers are from the current standard.

4.3 Rotary Abrasive-Blasting Tables and Abrasive-Blasting Barrels

Figures 2 and 3 of the guidelines simply illustrate common designs for these devices.

4.4 Abrasive-Blasting Cabinets

Figure 4 in the guidelines is derived from Print VS-101 of the ACGIH manual.

5. Ventilation Requirements

5.1 General

The requirements for maintenance, abrasive recirculation, dust collectors, operational procedures and general safety are taken almost verbatim from 29 CFR 1910.94(a). The requirement for an electrical or mechanical interlock helps ensure the protection of employees by

lessening the probability that blasting will be carried out in enclosures which are not properly safeguarded.

5.2 Class I Abrasive-Blasting Rooms or Chambers

The airflow requirements specified are taken from the State of New York regulation, the only state which appears to have taken into special consideration the industrial health hazards of the use of silica sand. The airflows are comparable with those recommended in the ACGIH manual. The ACGIH gives a downdraft air velocity range of 60-100 fpm with 80 fpm being given as the usual choice while the New York standard gives 80 fpm as a minimum velocity in such applications. The 100 fpm crossdraft figure is the same in both sources but New York only allows crossdraft ventilation when the length to width ratio of the room or chamber is in excess of 2 to 1. The ACGIH makes no such distinction based on room dimensions. The 300 fpm minimum indraft velocity through air inlets is solely from the New York standard and is felt to be a reasonable specification for the prevention of contamination of air outside the enclosure.

5.3 Class II Abrasive-Blasting Rooms and Chambers

For materials other than silica, the New York standard specifies, as above, that a 300 fpm minimum indraft velocity is to be maintained through air inlets. This requirement is therefore utilized for Class II enclosures. The downdraft and lateral ventilation rates, with the same qualifications on use given for Class I enclosures, are specified as 40 fpm and 50 fpm respectively. These figures were felt to be somewhat low for the capture of contaminants, regardless of the fact that the contaminants to which they are applied are nowhere nearly as toxic as silica sand (see Table 1 for a list of commonly used abrasives). Consequently, the lowest figure given by the ACGIH was used for downdraft ventilation, i.e. 60 fpm, and a crossdraft rate of 75 fpm was selected as a minimum. The crossdraft rate specified is 50 percent greater than the rate specified by the New York standard, just as 60 fpm is 50 percent greater than 40 fpm.

5.4 Rotary Abrasive-Blasting Tables, Abrasive-Blasting Barrels, and Abrasive-Blasting Cabinets

The requirement of a minimum indraft velocity of 500 fpm at all openings of rotary blasting tables and blasting barrels is from the New York standard. The 200 cfm per sq ft of total openings (taken without curtains) figure was recommended by the ACGIH for rotary tables with protective curtains. The blasting cabinet requirements of a 20 air change per minute exhaust volume with at least a 500 fpm inward velocity at all operating openings is also from the ACGIH manual.

Exhaust volume requirements for rotary blasting tables and blasting barrels are not given because these requirements were found to be a function of the object being cleaned, the cubic feet of internal

TABLE 1

Abrasives Commonly Used *

Abrasive	Number Reported	Percent of Total
Sand	115	44.7
Steel Shot	43	16.7
Steel Grit	25	9.7
Alumina	24	9.3
Flint/Garnet	18	7.0
Glass Beads	12	4.6
Carbides	9	3.5
Slag	8	3.1
Organics (Cobs, Pecan Shells, etc.)	3	1.1
TOTAL	257	

* Based on survey results given in Reference 5.

cleaning space, the number of blast cleaning nozzles or wheels, and the horsepower of the wheels. Given the detail with which other exhaust system design parameters are specified, it can be expected that manufacturers will determine and recommend the proper exhaust volume to be provided for their particular equipment designs.

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1. 29 CFR 1910.94(a), Ventilation for Abrasive-Blasting.
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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR
ASBESTOS TEXTILE MANUFACTURING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of ventilation guidelines for asbestos textile manufacturing operations. The guidelines have been developed to supplement the existing standard on environmental control of asbestos published in 29 CFR 1910.1000 and in no way change or eliminate the requirements of the existing standard. They have been developed as a result of a review of current practices and health hazards in asbestos textile manufacturing operations (References 1-8) and a review of current guides to industrial ventilation practice (Reference 9).

2. Scope and Application

These ventilation guidelines are limited to operations involving the processing of asbestos fibers subsequent to mining and milling operations, these latter operations being under the jurisdiction of MESA. The guidelines are further limited to processing operations involved in the manufacture of textile products consisting partially or totally of asbestos fibers. This category of operations is performed by a well-defined segment of the asbestos product manufacturing industry and a reasonably well-developed set of ventilation guidelines exists for these operations.

3. Definitions

The definitions included in the guidelines are consistent with those used in relevant ventilation guides and in textile manufacturing practice.

4. Ventilation Requirements

The ventilation requirements specified in the guidelines are based on what appears to be a near consensus with regard to the desirability of enclosing asbestos textile manufacturing operations (e.g. References 5 and 7). The basic minimum exhaust rate requirements corresponding to a face velocity of 50 fpm is taken from the airflow specification for weaving operations in Reference 9. The 200 fpm face velocity requirement for bag-opening operations is specified in Reference 7.

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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR CERAMICS OPERATIONS

1. Introduction and Scope

This memorandum sets forth the rationale for the development of ventilation guidelines for the ceramics industry.

1.1 Industry Coverage

The ceramics industry is here taken to include only the traditional ceramics industry primarily engaged in the manufacture of whitewares, structural (heavy) clay products, refractories, and technical ceramics. These industries would be generally classified in Standard Industrial Classifications 325 (Structural Clay Products) and 326 (Pottery and Related Products) (Reference 1). The manufacture of glass, mineral wool, cement, gypsum, lime and abrasives, also "ceramics" by modern definition, is not intended to be covered by these guidelines since the materials and operations utilized differ considerably.

1.2 Health Hazards

The principal health hazard in the traditional ceramics industry has been and remains today, pneumoconiosis, which results from the prolonged inhalation of siliceous dust within the respirable size range (References 2 and 3). Varying amounts of free silica are found in two basic raw materials -- sand and clay -- used in the industry.

In addition to siliceous dust and various nuisance dusts that are generated in many ceramics operations, other inorganic compounds of varying toxicity are used as additives, as raw materials for the ware, or as components of the glazes used. Typical examples include compounds of antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, gold, lead, lithium, magnesium, manganese, nickel, potassium, silver tin, titanium, vanadium, zinc, and zirconium. Lead poisoning (from the lead in glazes) and mercury poisoning (from the preparation of gilding compounds), two notable past health hazards, are no longer common.

Additionally, various organic chemicals are used in non-aqueous slip casting (methanol), as binders in injection molding and some dry pressing (resins and other organic chemicals), and as solvents in some decorating and glazing operations. The vapors from these chemicals produce varying degrees of hazards to workers' health.

1.3 Ceramics Operations Coverage

The ceramics operations for which ventilation guidelines are prescribed were chosen after a thorough review of operations within the industry. They are considered to account for a large majority of the hazards to the health of ceramics workers (excluding accidents). It is realized that some of the operations covered by these guidelines,

especially non-aqueous slip casting, are carried out by a minority of ceramics establishments.

The fact that a particular ceramics operation is not covered by a guideline does not remove the possibility that ventilation may be desirable or necessary to protect the workers' health. One obvious example is the use of kilns and ovens used for firing the ceramics ware. Ventilation requirements for these pieces of equipment have not been included in the guidelines as the design of an exhaust ventilation system is intimately connected with, and indeed a part of, the design of a kiln or oven.

2. Definitions

The definitions included on ventilation terminology in the guidelines are consistent with those used in relevant ventilation guides (References 4 and 5).

The definitions of industry operations are included to define more precisely the operations that are covered by the ventilation guidelines and thus avoid misunderstandings.

The water content of materials used in dry processing generally ranges from 5 to 15% water (by weight) for most ceramics except technical ceramics where a lower water content would generally be implied by the use of the word "dry".

3. Ventilation Requirements for Ceramics Operations

3.1 General

There exist few data sources for ventilation guidelines in the ceramics industry. To the extent possible, the recommendations of references 4 and 5 were followed whenever it was felt that a recommended design was applicable to a particular ceramics operation; a good example of an instance in which this was the case is in dry screening operations. Additionally, the few comments on recommended ventilation for ceramics operations given in references 2 and 3 were considered when appropriate. The comments in reference 2 essentially recommend an airflow of 300 fpm for severe dust generating operations. Reference 3 includes the statement "Where local exhaust ventilation is applied, there should be the maximum degree of enclosure to prevent the escape of dust; for hand operations, the air velocity would be of the order of 50 m/min., but a higher air velocity is needed if dust is propelled against the airflow."

Because of the lack of specific information in the literature regarding control of air contaminants from this industry and the variability in contaminant-generation rates from one establishment to another conducting a particular type of operation (caused by differing material formulations, operational procedures, production rates, etc), it was found necessary in the guidelines to sometimes specify only general hood designs (i.e., booths, canopy hoods, and open hoods) which can

provide adequate contaminant control if properly applied to the subject operation.

3.2 Screening Operations

The hood designs and airflow requirements given in print VS-307 of the ACGIH manual are considered to be directly applicable for screening operations. Consequently, they have been listed and shown in Figure 2 of the guidelines as acceptable designs.

3.3 Mixing and Mulling Operations

Figure 3 of the guidelines, an enclosing hood design and its associated exhaust volumes for mixers and mullers, was derived from print VS-108 of the ACGIH manual. Prints VS-604 and VS-605 of the ACGIH manual, together with Figure 4 of Reference 6, provided the basis for the booth design illustrated in Figure 4 of the guidelines. Of particular note is that though the illustration itself is similar to the one in Reference 6, the baffle arrangement was modified to make it consistent with those shown in the ACGIH manual.

3.4 Non-Aqueous Slip Casting Operations

Though non-aqueous slip casting is conducted by few establishments, the need for ventilation of the operation is clear. The guidelines have been written to cover the use of any non-aqueous liquid in a slip casting operation even though methanol is the liquid commonly used.

Acceptable hood designs illustrated for these operations include enclosing hoods, booths, canopy hoods, open hoods, and slot hoods. The origins of Figures 3 and 4, an enclosing hood for mixers and mullers and a booth design respectively, were discussed previously. The open and slot hood designs in Figures 6 and 7 of these guidelines were derived from Figures 4-14 and 4-15 of the ACGIH manual. The design of the canopy hood shown in Figure 5 is from Print VS-903 of this manual.

3.5 Injection Molding Operations

Significant variations in the size and shape of equipment and in production rates does not allow recommendation of specific exhaust hood designs for these operations. Consequently, only the general designs given in Figures 3 to 7 of the guidelines were specified as being acceptable.

3.6 Finishing Operations

Secondary shaping operations carried out before firing, referred to as finishing (pre-firing) operations, can generate significant amounts of dust. Finishing operations carried out after firing, finishing (post-firing) operations, do not, in general, remove as much material

but can under some circumstances produce air contaminated beyond exposure limits.

The guidelines reference the ventilation guidelines for grinding, polishing, and buffing operations as providing acceptable hood designs and airflow requirements. Though those guidelines were developed primarily for metals, their recommendations are applicable for operations conducted on ceramic materials.

The recommendation for the use of an enclosing or open hood with a minimum face or capture velocity respectively of 200 fpm is consistent with the recommendations of the grinding, polishing, and buffing guidelines for the types of materials utilized in the ceramics industry. The use of an open hood or booth with a minimum capture or face velocity of 100 fpm should be adequate for capturing respirable dust particles not released with a significant initial velocity.

3.7 Other Operations

Spray glazing and painting and materials handling operations conducted in ceramics establishments are covered by other ventilation guidelines. The applicable guidelines are referenced.

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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR COTTON YARN MANUFACTURING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of ventilation guidelines for cotton yarn manufacturing operations. The need for the guidelines has been demonstrated by investigations of cotton dust exposures in cotton yarn manufacturing facilities (References 2 - 5).

2. Scope and Application

These ventilation guidelines cover all operations except roving and spinning subsequent to delivery of raw cotton to the yarn manufacturing facility and prior to utilization of the manufactured yarn in weaving or knitting. The manufacturing operations covered fall into the sub-categories of opening, picking, carding, and drawing. The guidelines cover all operations within these sub-categories as well as transfer processes between categories. Such operations are performed by a well-defined segment of the cotton industry and a well-developed set of ventilation guidelines (Reference 1) exists for these operations.

3. Definitions

The definitions of ventilation equipment and processes are consistent with those used in relevant ventilation guidelines (Reference 6). The definitions of yarn manufacturing equipment and processes are taken from Reference 1. The definitions of "cotton dust" is from the NIOSH criteria document for this substance (Reference 5).

4. Ventilation Requirements

The ventilation requirements specified in the guidelines for opening, picking, carding, drawing, and combing operations have been taken directly from Reference 1. No ventilation guidelines have been found for roving and spinning operations so the operator must rely on general ventilation guidelines for controlling cotton dust from these operations.

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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR FOUNDRY OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of ventilation guidelines for foundry operations. The guidelines were developed as a result of a literature review of practices and health hazards in foundry operations (References 1 - 13), and a review of current guides to industrial ventilation practice (References 13 - 17).

2. Scope and Application

The scope and application of these guidelines are based on foundry operations as defined and described in various sources (References 1-13). The guidelines are directed toward all foundry operations which have been noted in any of the sources as producing air contaminant concentrations which can be hazardous to health and which are not covered in other guidelines (e.g., materials handling). The major operations which are specifically covered by the guidelines include, but are not limited to:

- Mulling and mixing
- Core making and molding
- Die casting
- Core grinding and sanding
- Metal melting
- Metal pouring
- Molten metal transfer
- Hot mold transfer
- Shakeout and tumbling

3. Definitions

The definitions included in the guidelines are consistent with those used in relevant ventilation guides.

4. Ventilation and Enclosure Requirements

4.1 Mulling and Mixing Equipment

All ventilation requirements for mixing and mulling operations are from the ACGIH Industrial Ventilation Manual (Reference 14). Print VS-107 is the basis for skip hoist hoods and exhaust volumes and Print VS-108 for mixer and muller hoods.

4.2 Core Making and Finishing Equipment

All requirements were derived from the ACGIH manual. Prints VS-102, 114, and 115 and Table 5-9-2 were utilized.

4.3 Die Casting Equipment and Operations

Requirements were essentially derived from Prints VS-904 and 905 of the ACGIH manual. In Print VS-905 the length of the hood was related to the size of the die by requiring that it be 1.4 times the length of the die. The 1.4 figure was recommended by the expert reviewer of the guidelines (Reference 18), and was agreed with as providing adequate overhang for contaminant capture.

4.4 Melting Furnace Equipment

Requirements for melting furnaces were basically derived from Prints VS-103, 104, 105, 106, and 903 of the ACGIH manual. However, based upon observations made that cupola furnaces have a particular problem with carbon monoxide generation (References 5, 7), a requirement was added that such emissions be controlled and that the air velocity be a minimum of 250 fpm across the open face of the charging door (Reference 16). Other observations (References 1, 7, 16) led to requirements for furnace charging and repair operations. Print VS-401 from the ACGIH manual was used for controlling emissions from cut-off saws.

A major revision to the requirements of the ACGIH manual concerned the extension of the specifications for top electrode melting furnaces to furnaces of similar physical geometry. Reference 16 clearly demonstrated that the hood and enclosure designs shown in the manual for this type of furnace are applicable to and used for similar furnaces. No attempt was made to specify minimum air velocities because review of the literature indicated that the range of velocities necessary to control emissions could vary widely depending upon a variety of factors (References 5, 16).

4.5 Molten and Hot Metal Transfer Operations

The potential necessity for ventilation of ladle preheating, skimming, and pyrometry stations was discussed in the AFS manual (Reference 13). Because of the similarity between equipment and operations, the controls specified in the guidelines are analogous to the controls specified for tilting furnaces and molten metal pouring stations.

Requirements for pouring stations for small molds were derived from Print VS-109 of the ACGIH manual. As recommended in this manual, the requirements for large molds are similar to the side-draft hood requirements for shakeout operations. The exhaust volume is based upon the contaminant-producing work area. In the case of shakeout, this was defined as the shakeout grate area. For pouring of large molds, it is based upon the horizontal cross-sectional area of the mold.

Because of observations which have been made, general requirements are given for ventilation of metal pouring from furnace taps (References 1, 13, 16) and for covering or ventilation of ladles when easily volatilized metals are transferred (References 1, 13). Requirements for cooling tunnels are from the AFS manual.

4.6 Shakeout and Tumbling Mill Operations

Specifications for the various shakeout hood types, tumbling mills, and shakeout hoppers were derived from Prints VS-110, 111, 112, and 113 and Table 5-9-2 of the ACGIH manual. To clarify what is meant by a "hot" casting and a "cool" casting in the requirements for shakeout hoods, a temperature of 100°F was chosen as the dividing line. Choice of this value was based on a comment in the AFS manual that exhaust volumes require temperature corrections when the contaminated air temperature exceeds 100°F.

The recommendations for manual core knockout ventilation was extended to all similar shakeout type operations which can be considered to be manual operations. An analogy between dirty casting transfer points and shakeout operations resulted in the guideline for casting transfer operations.

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RATIONALE FOR VENTILATION GUIDELINES FOR GRINDING, POLISHING, AND BUFFING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for grinding, polishing, and buffing operations. These guidelines have been developed as a revision of the existing standard (Reference 1). Revisions have been made on the basis of current guides to industrial ventilation practice (References 2, 3, and 4) and the results of research on ventilation requirements (Reference 5).

Requirements for ventilation of grinding, polishing, and buffing operations stem from the nature of these operations which involve the generation of particulate materials by abrasive action between tools and workpiece materials. Particulates are formed primarily from the workpiece, from the abrasive, and from materials used to support the abrasive. Other sources of particulates are surface coatings and contaminants on the workpiece. The particulate materials generated by grinding, polishing, and buffing operations generally become airborne as they are generated as a result of the high surface velocities of the abrasive tools. The need for control of air contaminants from grinding, polishing, and buffing operations is recognized in industries where these operations are used extensively (Reference 6), and the potential of these operations for producing excessive air contaminant exposures has been demonstrated by experimental measurements of breathing zone dust concentrations (Reference 5).

2. Scope and Application

The guidelines prescribe ventilation equipment and operational requirements appropriate to grinding, polishing, and buffing metals. The ventilation system performance data on which the guidelines are based were obtained from metal processing operations. It is likely that the same ventilation methods are applicable to the processing of nonmetals. However, no source of ventilation performance data for processing nonmetals are available.

3. Definitions

The definitions which are given in these guidelines are consistent with those used in relevant ventilation guides (References 2, 3, and 4). The only new concept introduced in the guidelines is found in the term

"shaped hood" which is used to designate a class of exhaust hoods. This term refers to machine guards or housings which are also used as exhaust hoods. This type of hood also has been referred to as a "shaped collector" (Reference 5). Hoods of this class require special designation and separate treatment because their exhaust flow requirements are different from those of other classes of hoods.

4. Ventilation Equipment Requirements

This section of the guidelines is designed to inform the operator of grinding, polishing, and buffing machines of the various requirements for protective equipment which exist. These requirements include equipment or provisions for:

- Exhaust ventilation
- Make-up air
- Machine guarding
- Fire protection

Three classes of exhaust hoods considered to be applicable to grinding, polishing, and buffing operations are identified here: open hoods, shaped hoods, and enclosing hoods. The low-volume-high-velocity hood is considered to be a subclass of open hoods.

5. Ventilation System Design and Operational Requirements

The operations covered by these guidelines include wide varieties of machine tools and contaminant materials. To provide a framework for the development of a finite number of ventilation requirements, machines and contaminants are divided into classes. The machine classification method and the contaminant classification method are taken from Reference 5. The machine classification groups machines according to characteristics which affect the applicability of various exhaust hood types. Each machine class contains machines for which the same ventilation methods are applicable. A "declassifying" table is included for relating the machine classes to the machine designations used in the machine tool industry.

The primary source of ventilation system performance data which can be used to specify exhaust hood flow rates is Reference 5. The data in this report are predominantly from tests with open hoods and shaped hoods. The data indicate that these hoods are capable in general of controlling breathing zone dust concentrations to within the range of 1 to 10 mg/M³. These results indicate that these hood types are suitable for the control of inert or Class I contaminants from all operations and Class II contaminants from selected operations. Consequently, the use of enclosing hoods is prescribed for the control of Class III contaminants from all operations and Class II contaminants from some operations. If a Class II contaminant is generated in low

concentrations because it is present in a low concentration in the workpiece or because of a low percentage duty cycle for the machine, the contaminant could possibly be controlled effectively by an open or shaped hood. This option is open to the machine operator.

Ventilation system performance data have been used in formulating exhaust hood design and operational requirements for the following machine-hood combinations generating Class I contaminants:

Machine-Hood	Data Source
Surface-type grinder with open hood	Reference 5
Surface-type grinder with LVHV hood	Reference 2
Surface-type grinder with enclosing hood	Reference 2
Pedestal-type grinder with open hood	Reference 5
Pedestal-type grinder with shaped hood	Reference 5
Disc grinder with internal hood	Reference 2
Internal grinder with LVHV hood	Reference 2
Cutting-off machine with shaped hood	Reference 5
Cutting-off machine with enclosing hood	Reference 2
Belt polisher with shaped hood	Reference 5
Portable machines with open hoods	Reference 2
Portable machines with LVHV hoods	Reference 2
Portable machines with shaped hoods	Reference 2
Portable machines with enclosing hoods	Reference 3
Multiple machines with enclosing hoods	Reference 2

Ventilation requirements specified for other machine-hood combinations generating Class I contaminants are extensions of the above data to other combinations. Requirements specified for control of Class II and Class III contaminants for all machine-hood combinations are based on the judgment of the developers of these guidelines.

REFERENCES

1. 29 CFR 1910.94, Ventilation; (b) Grinding, Polishing, and Buffing operations.
2. Industrial Ventilation: A Manual of Recommended Practice, 13th Edition, Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists, Lansing, Michigan, 1974.
3. "Ventilation Control of Grinding, Polishing, and Buffing Operations," American National Standard Z43.1-1966. American National Standards Institute, New York, 1966.
4. "Fundamentals Governing the Design and Operation of Local Exhaust Systems." American National Standard Z9.2-1971, American National Standards Institute, New York, 1971.
5. E. K. Bastress, et al., "Ventilation Requirements for Grinding, Buffing, and Polishing Operations," Report No. 0213, IKOR Incorporated, Burlington, Massachusetts, June 1973.
6. A J. Breslin and W. B. Harris, "Health Protection in Beryllium Facilities; Summary of Ten years of Experience", Health and Safety Laboratory, U.S. Atomic Energy Commission, May 1, 1958.
7. "Foundry Environmental Control," American Foundrymen's Society, Des Plaines, Illinois, 1972.

RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR KITCHEN OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for kitchen operations. Requirements contained in these guidelines are based on current guides to industrial ventilation practice.

2. Scope and Application

Operations covered by these guidelines are the common kitchen operations conducted in commercial, industrial, or institutional kitchens which are likely to result in the release of heat, steam, particulates, vapors, mists and/or aerosols into the workplace air. Ventilation methods specified in the guidelines include canopy (against wall), canopy island, back shelf (low sidewall), and enclosing hoods as well as special application canopy and slot hoods and exhausting vestibules for dishwashers.

The guidelines are restricted to the recommendation of ventilation systems for the control of air contaminants. They do not directly address the related problem of fire safety in kitchens. However, minimum requirements for the installation and maintenance of grease removal equipment are included. Other aspects of fire safety including fixed fire extinguishing and alarm systems, interlocks, and equipment cleaning are addressed under 29 CFR 1910 Subpart L-Fire Protection, and are therefore not included in these guidelines.

The Application of these guidelines does not cite the permissible exposure limits of section 1910.1000 since the most common contaminants at which the guidelines are directed (mainly grease and steam) do not have exposure limits specified in section 1910.1000.

3. Definitions

Definitions included in the guidelines are consistent with those used in relevant ventilation guides (Refs. 1 and 2).

4. Ventilation Equipment Design Requirements

4.1 Exhaust Hoods

The guidelines prescribe design requirements for the types of exhaust hoods most commonly used in kitchen operations. These designs are based on recommendations made in References 1 and 2. Exhaust flow rates prescribed are dependent on the operation as described in section 5 of this rationale document.

4.2 Grease Removal Devices

Minimum requirements, from recommendations contained in References 3 and 4, are prescribed for the installation and maintenance of grease removal devices. Filter mounting height specifications are based on these references rather than on Reference 1.

5. Ventilation Requirements

5.1 Classification of Operations

To simplify the specification of ventilation requirements, kitchen operations are classified into four groups. This classification is based on the type and amount of contaminant produced by each process.

5.2 Ventilation Required for Class I Operations

Class I operations as described in the guidelines produce a minimal amount of contaminant and heat which can be controlled with general ventilation (Ref. 5). The airflow prescribed is based upon the experience of our expert reviewer.

5.3 Ventilation Required for Class II Operations

Class II operations as described in the guidelines will obviously produce more severe air contaminant problems than Class I operations. Ventilation systems for these operations are therefore required to control and remove fat breakdown products from fryers, aerosols produced during the blowdown of pressure fryers, and similar contaminants.

Two sources of information on kitchen ventilation, References 1 and 3, differed on recommended exhaust volumes. It was found that the exhaust requirements specified in Reference 3 are based on an older (1964) edition of the ACGIH Ventilation Manual. The ACGIH has reduced ventilation requirements in recent years and found lower exhaust volumes to be effective (Ref. 5). Consequently, the exhaust requirements contained in Reference 1 have been adopted for Class II operations with the following modification. Enclosing hood exhaust requirements in Reference 1 are based only on Class III-type operations. Enclosing hoods can, however, be used over Class II operations with lower airflows. Consequently, these types of hoods are allowed for use with this class of operation with a lower airflow requirement as recommended by the reviewer of these guidelines (Ref. 5). Figures 2 and 3 are derived from Print VS-910 of the ACGIH manual. Figure 4 is derived from Print VS-911.

5.4 Ventilation Required for Class III Operations

The ventilation requirements for Class III operations are taken without change from the ACGIH Ventilation Manual. Figures 5 and 6 of the guidelines are adopted from Print VS-913 of the manual.

5.5 Ventilation Required for Class IV Operations

These requirements are also taken without change from the ACGIH manual. Figure 7 of the guidelines corresponds to Print VS-912 of the manual.

REFERENCES

1. "Industrial Ventilation: A Manual of Recommended Practice," 13th edition, Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists, Lansing, Michigan, 1974.
2. "Fundamentals Governing the Design and Operation of Local Exhaust Systems," American National Standard A9.2-1971, American National Standards Institute, New York, 1971.
3. "Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment," Standard No. 96-1973, National Fire Protection Association, Boston, Massachusetts, 1973.
4. "Commercial Cooking Equipment Exhaust Systems," Standard No. 33, National Sanitation Foundation.
5. Hama, George, "Review and Suggested Modifications of Draft Ventilation Standard for Kitchen Operations," Personal Communication, February, 1975.

RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR LABORATORY OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for laboratory operations. Requirements contained in the guidelines are based on current guides to industrial ventilation practice and the results of research on ventilation requirements.

2. Scope and Application

The guidelines have been developed for application to operations involving toxic, radioactive, and carcinogenic substances since the technology of control of these substances is sufficiently developed to provide a basis for guidelines. Biological agents are not covered by the guidelines since the technology for their control is not well developed.

Specific operations are not identified in the guidelines since laboratory operations are numerous and highly variable. Instead, ventilation methods are prescribed generally for all operations involving substances capable of becoming airborne in concentrations which exceed the exposure limits.

The ventilation requirements prescribed by the guidelines should be mandatory for all operations with the potential for causing excessive contaminant exposures. These guidelines cannot be made contingent upon the occurrence of excessive exposures because of the variability of laboratory operations. The exposure caused by an operation cannot be predicted in advance, and it would not be practical to require a measurement of the exposure resulting from each operation. Hence, the only practical approach remaining is to provide ventilation in conjunction with all operations which have the potential to cause excessive exposures.

Ventilation methods specified in the guidelines include the full range of local ventilation systems, including glove hoods, laboratory hoods, and open exhaust hoods. General or dilution ventilation is not specified as a ventilation method since it is not regarded as a reliable method of contaminant control (Reference 1). General ventilation is desirable when contaminant exposure limits are not exceeded, but a requirement for general ventilation for this condition is not appropriate as a part of the guidelines.

3. Definition

The definitions included in these guidelines have been taken from or are consistent with those in relevant ventilation guides (References 1 and 2).

4. Ventilation Equipment Design Requirements

4.1 General

Section 4.1 of the guidelines contains general provisions applicable to all the hood designs and airflow requirements given in the rest of the guidelines. Proper location of hoods is important for the avoidance of airflow disturbances. The requirement that contaminant concentrations be kept below 25 percent of the lower explosive limit is important for obvious reasons. Provision for make-up air must be specified to ensure that a hood will draw its intended flow rate under all laboratory operating conditions.

4.2 Glove Hood

The glove hood design specification is taken from Reference 1 without change.

4.3 Laboratory Hood

Laboratory hoods are represented as a class of ventilation equipment with a single basic design with three optional, add-on features: (1) rounded or airfoil jams and sill, (2) a sash and by-pass, and (3) an auxiliary air supply. A room-air by-pass (or equivalent method of face velocity control) is required in conjunction with a sash since, without a by-pass, a worker often will turn off the exhaust blower when the sash is lowered to prevent disturbance of his experiment by the high airflow velocity. Consequently, the lack of a by-pass is a health hazard.

With regard to auxiliary air supplies, a number of industrial hygienists recommend that the air supply be located outside the hood (e.g., References 3, 4, 5, and 6). The argument that an internal air supply can lead to a reversal of air velocity at the face is a valid basis for requiring that only external air supplies be used. Many existing hoods will not meet these guidelines. However, these hoods can be modified to meet them.

A maximum auxiliary airflow rate has not been specified since an excessive flow rate does not constitute a health hazard even though it may adversely affect the performance of the building air conditioning system. Protection against adverse effects on hood performance are covered by the face velocity requirements in the guidelines.

4.4 Open Hood

Figures from Reference 2 have been selected as representations of good practice in the application of open hoods.

4.5 Perchloric Acid Hood

Requirements specific to perchloric acid processes have been taken directly from Reference 1. This material is considered to be unique and deserves specific treatment. Other oxidizing agents, such as nitric acid, do not present the same hazards as perchloric acid.

5. Hood Operational Requirements

5.1 Hood Applications and Exhaust Flow Requirements for Radioactive and Toxic Substances

The classification of contaminant substances which has been used elsewhere in these ventilation guidelines (see welding) has been provided as a basis for prescribing hood types and exhaust volumes. Additionally, radioactive substances have been classified uniformly as Class III contaminants since the exposure limits for undiluted (100 percent specific activity) radioisotopes, when converted to mass concentrations, fall within the range specified for Class III contaminants. Carcinogens must be classified as Class III contaminants for these guidelines to be consistent with other control requirements specified in 29 CFR 1910.1000.

The exhaust flow requirements for glove hoods and laboratory hoods have been taken directly from References 1 and 4 and are supported by recommendations in References 5, 6, 7, 8, and 9. The exhaust flow requirement for local exhaust hoods is based on capture velocities required for contaminants released with low velocity into still air. This requirement is adequate to control materials of low toxicity for which an occasional escape from the hood can be tolerated.

5.2 Operational Requirements for Perchloric Acid Use

The exhaust volume requirement for perchloric acid use was taken from Reference 1.

5.3 General Operational Requirements

These general operational requirements are redundant with the specific operational requirements prescribed above. However, the general requirements serve to identify the need for vigilance in maintaining the performance of ventilation systems in the face of conflicting considerations in a laboratory environment.

REFERENCES

1. "Industrial Ventilation: A Manual of Recommended Practice," 13th Edition, Committee on Industrial Ventilation, American Conference of Governmental Hygienists, Lansing, Michigan, 1974.
2. "Fundamentals Governing the Design and Operation of Local Exhaust Systems," American National Standard Z9.2-1971, American National Standards Institute, New York, 1971.
3. J. R. Lynch, "Study Shows How to Select Lab Hoods to Cut Cooling Costs," Heating, Piping and Air Conditioning, January 1967, pp. 133-138.
4. R. S. Brief, et. al., "Design and Selection of Laboratory Hoods," Air Engineering, October, 1963.
5. T. Ruys, "Re: Fume Hoods," Chemtech, November 1972, pp. 701-703.
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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR MATERIALS HANDLING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for materials handling operations. The guidelines were developed as a result of a literature review of materials handling operations and practices within industry and a review of literature and guides pertaining to the control of air contaminants from such operations.

2. Scope and Application

The scope and application of the guidelines are based upon materials handling operations as defined and described in various sources (References 1-4). The guidelines are directed specifically towards those operations which are known to be potential sources of air contaminants, have commonly been controlled by means of ventilation, have had specific exhaust ventilation requirements recommended for them, and which are not covered in other ventilation guidelines in this document.

The major equipment types and operations covered by the guidelines include, but are not limited to:

Conveying Equipment

- Horizontal or inclined conveyors
- Bucket elevators
- Conveyor transfer points
- Belt wipers

Bins and Hoppers

- Conveyor and chute loading operations
- Other (i.e. manual or mechanically aided) bin or hopper loading operations

Filling and Packaging Operations

- Bag filling
- Bag tube packing machines
- Barrel and drum filling

Materials handling equipment such as principally individual units as industrial trucks, tractors and trailers, tiering machines, cranes, monorails, or rail vehicles are specifically excluded from consideration. These equipment types, per se, do not generate air contaminants in a manner which reasonably warrants treatment within these guidelines. Also noted is the fact that other ventilation standards concerning specific industries may include ventilation requirements for a specific operation or equipment type which is also covered by these guidelines.

In such cases it is stated that the other guidelines should be adhered to. This statement was felt necessary to allow development of guidelines for particular industries that are based upon the particular processes and materials utilized in that industry and to account for any contradictions which might otherwise arise.

3. Definitions

The definitions relating to exhaust system designs and equipment are consistent with those used in relevant ventilation guides. Definitions of specific equipment and operations are provided for clarification of the applicability of requirements.

4. Ventilation and Enclosure Requirements

4.1 General

The literature survey conducted during the development of the guidelines revealed that there has been little attention paid in general to control of air contaminants from materials handling equipment except by the ACGIH (Reference 3). All other information sources looked at either presented verbatim the recommendations of the ACGIH Ventilation Manual, presented slightly modified versions of them, or consisted of rather dated material. For this reason, it was concluded that only the ACGIH has directed any considerable effort towards contaminant control from these operations and that their manual is the only complete, up-to-date source of such information. Consequently, the recommendations of the ACGIH manual, with some clarifications and modifications, are the basis of virtually all of these guidelines.

Table 5-9-1 of the ACGIH manual describes ventilation requirements for equipment used in grain elevators, feed mills, and flour mills and notes that "ventilation control is desirable for these operations to minimize the explosive characteristics of grain dusts and to preserve plant housekeeping standards." Some of the equipment listed is the same as equipment covered by these guidelines, but the air volume requirements given are considerably lower or presented in a different manner (see requirements for belt discharge and bins). Reference 5 indicates that some dusts, specifically castor bean dust, can have extremely toxic effects by inhalation. Also noted and supported is that "the high incidence of respiratory disease among millers, bakers, grain elevator workers, and dock workers, who are often subject to breathing air of high grain dust concentrations, is well known. Evidence is available which indicates that insects, molds, and fungi associated with grain and feed handling can also cause respiratory ailments." These latter data indicate that enclosure and ventilation of operations is desirable not only because of housekeeping and explosion prevention considerations but also for employee health reasons. Though the ACGIH manual very probably does take health hazards into consideration in this matter, the facts that health hazards are not specifically noted as having been taken into account, less stringent requirements are in some case given in the table

than in other parts of the manual for similar operations, and the information source for the table is incorrectly referenced led to the conclusion that separate requirements for grain handling operations are not warranted without further study.

4.2 Conveying Equipment

The requirements for belt conveyors which generate excessive air contaminant concentrations due to dusting off the top of their loads are from Print VS-306 of the ACGIH manual.

The requirement that the entire conveyor be enclosed when excessive contaminant concentrations are caused by material dropping from the return strand of the belt and an effective belt wiper cannot be installed was suggested by the expert reviewer of the guidelines (Reference 6).

The enclosure and ventilation requirements for conveyors handling materials which generate vapors or smoke are derived from Reference 4. These specifications are given in this source for cooling or "smoking" tunnels in foundries. Since the expert reviewer of the guidelines (Reference 6) indicated that conveyors utilizing mechanisms other than belts to transport materials usually handle hot, "smoking" materials, the requirements of Reference 4 were concluded to be directly applicable.

In Figure 2 and in subsequent figures, recommendations for single specific hood taper angles were deleted as has been done for other guidelines. Reference 4, for example, illustrates several similar hood designs based on 30 degree hood tapers instead of the 45 degree ones shown throughout the ACGIH manual.

Bucket elevator requirements are from print VS-305 for elevators without magnetic separators and from VS-306 for elevators with them. Figures 3 and 4 are derived from the above prints respectively.

Conveyor or chute to conveyor transfer point requirements and Figure 5 of the guidelines are mostly derived from Print VS-304 of the ACGIH manual. Based on the experience of the reviewer of the guidelines (Reference 6), an additional method of controlling chute to conveyor transfer operations is presented which has been shown to be "usually" more effective than the method given in the manual. This method concerns extension of the belt loading skirt back from the point where the handled material drops onto the conveyor.

Where conveying mechanisms other than belts are utilized and excessive contaminant concentrations are generated during transfer operations, it is specified that a minimum exhaust volume of 150 cfm per sq ft of openings in the enclosure be maintained. This air volume is the minimum recommended by the ACGIH manual for belt conveyors which have a speed less than 200 fpm and should be appropriate for other conveying mechanisms in view of the fact that it is the impact of the falling material with the lower conveyor which is the primary cause of contaminant generation where conveyor speeds are low.

Figure 6 and belt wiper requirements are from Print VS-308 of the ACGIH manual.

4.3 Bins and Hoppers

Print VS-304 of the ACGIH manual is the basis for Figure 7 and the requirements for bin and hopper loading operations utilizing conveyors or chutes. As previously, the minimum exhaust volume for belt conveyors with speeds less than 200 fpm is specified for conveying mechanisms other than belts. This exhaust volume, 150 cfm per sq ft of openings in the enclosure, is also used for chute to bin loading operations.

The lower half of print VS-304 in the manual provides the basis for Figure 8 and the requirements for "manual" loading operations. Since the booth design shown is applicable not only to loading operations involving an employee dumping a bag or barrel into the hopper, but also where a front end loader or some other such machine is utilized, the text of the guidelines replaces the term "manual" with "by means other than with a conveyor or chute."

4.4 Filling and Packaging Operations

The requirements for bag filling operations and Figure 9 are from print VS-301 of the ACGIH manual. Those for bag tube packing machines and Figure 10 are from print VS-302. Barrel and drum filling requirements and Figure 11 are from print VS-303.

REFERENCES

1. Perry, R. H., et al, "Chemical Engineers' Handbook," 4th Edition, McGraw-Hill Book Co., Inc., New York, 1963.
2. Baumeister, T., Ed., "Standard Handbook for Mechanical Engineers," 7th Edition, McGraw-Hill Book Co., Inc., New York, 1967.
3. "Industrial Ventilation: A Manual of Recommended Practice," 13th Edition, Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists, Lansing, Michigan, 1974.
4. "Foundry Environmental Control", Volume 1, American Foundrymen's Society, Des Plaines, Illinois, 1972.
5. Shannon, L. J., et al, "Emissions Control in the Grain and Feed Industry Volume 1 - Engineering and Cost Study," EPA Report No. EPA-450/3-73-003A, December 1973.
6. Review of Materials Handling Ventilation Standard by Knowlton J. Caplan, Personal Communication, June 1975.

RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR METAL MACHINING AND METAL WORKING OPERATIONS

1. Scope and Application

These guidelines cover a very broad range of operations and contaminant materials. They cover all types of metal machining and working operations, except for grinding, polishing, and buffing operations which are covered by separate guidelines. A wide variety of metal machining and working operations occur in industry, and new types of operations appear each year. Consequently, opportunities for exposures of employees to air contaminants are numerous and varied.

Most metal machining operations do not generally cause excessive exposures to air contaminants and, therefore, do not require exhaust ventilation. However, ventilation is required in dry machining of brittle materials such as cast iron and toxic materials such as cobalt and beryllium. Ventilation also is required for the control of oil mist and toxic gases in certain operations where these contaminants are generated.

Metal working operations can cause excessive exposures of air contaminants consisting of dusts and fumes from metal surface coatings and mists and vapors from lubricants used on surfaces of metal working dies. However, as with metal machining operations, air contaminant control is not a universal problem.

2. Definitions

The definitions used in the guidelines are taken directly from References 1 and 2.

3. Ventilation System Design and Operational Requirements

Existing guidelines for ventilation of metal machining and working operations are directed primarily toward processing of high toxicity materials (Reference 1). No guidelines have been found for ventilation of machining and working operations with materials of low toxicity. However, references have been found in instances where ventilation is required, indicating that excessive air contaminant exposures can occur under some circumstances (References 3-5). Consequently, development of guidelines covering machining and working metals of both high and low toxicity appears to be warranted.

The classification of contaminant materials used in the ventilation guidelines for welding operations has been used here as a basis for formulating these general guidelines for metal machining and working operations. With three contaminant classes and two basic hood types - open and enclosing - six hood-contaminant combinations are defined. Exhaust flow requirements are prescribed for each combination with no distinction between specific operations. This lack of specificity does not mean that all machine tools require similar ventilation methods. It is not possible to specify ventilation requirements for specific tools

because of a lack of data on contaminant generation and ventilation system performance.

The exhaust flow requirement for Class III contaminants controlled with an enclosing hood is based on guidelines in Prints VS-207 and VS-209 in Reference 1. All other requirements are based on ventilation methods used with other categories of operations. These requirements are considered to be minimal and may be inadequate in cases where contaminants are released at high velocity, as with band saws and broaches. In these cases, higher exhaust flow rates may be required than those specified to provide effective control of contaminants. Since the relationships between tool or workpiece speed, contaminant velocity, and exhaust flow rate are not known at the present time, no attempt was made to specify more stringent requirements in these cases.

REFERENCES

1. "Industrial Ventilation: A Manual of Recommended Practice," 13th edition, Committee on Industrial Ventilation, American Conference of Governmental Hygienists, Lansing, Michigan, 1974.
2. "Fundamentals Governing the Design and Operation of Local Exhaust Systems," American National Standard Z9.2-1971, American National Standards Institute, New York, 1971.
3. Anonymous, "GE vs. Iron Chips: Removal is a 'Breeze'," Modern Materials Handling, October, 1967, pp. 54-55.
4. F. T. McDermott, "Dust in the Cemented Carbide Industry," AIHA Journal, March 1971, pp. 188-193.
5. Anonymous, "Oily Haze and Smoke in Plants Cleared Up with Precipitators," Metal Progress, July, 1974, p. 90.

RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES
FOR OPEN-SURFACE TANK OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for open-surface tank operations. The guidelines have been developed as a revision of the existing standard in 29 CFR 1910.94 (Reference 1). Revisions have been made on the basis of current guides to industrial ventilation practice to achieve consistency of format and content with the other ventilation guidelines developed in this program.

2. Scope and Application

The scope of these guidelines has been modified slightly to limit coverage to operations that actually involve open-surface tanks and to more precisely define the operations to which the guidelines apply. The scope of the existing standard, which was taken from ANSI Z9.1 (Reference 2), is so general that a broad range of processes and operations are covered. Since control measures other than ventilation can be beneficial for use with open-surface tank operations- the guidelines note that lower airflows than those specified are acceptable where other controls are used in conjunction with ventilation, and exposure limits are not exceeded.

3. Definitions

The definitions included in these guidelines are consistent with those used in relevant ventilation guides (References 2 and 3).

4. Required Ventilation and Classification of Operations

In order to assess the adequacy of the existing ventilation standard for open-surface tank operations, several ventilation guides and research reports were reviewed. This review led to the conclusion that while the existing standard is far from perfect, current knowledge does not permit any improvement within the framework of practical ventilation guidelines.

The ventilation rates required by the existing standard have been shown to result in many cases of overdesign (Reference 4). Flanigan et al. conclude in their report on this work that although the "tiered" system of classifying operations often results in overdesign, the ventilation rates suggested in Reference 4 are based on laboratory conditions and have not been proven under actual use conditions. In the

absence of changes that have been shown to work in industry, the existing ventilation rates have been retained in these guidelines.

Another weakness of the existing standard is its lack of specific guidance on the extent to which good operating practice and ancillary control measures reduce required ventilation rates. Esman and Clearwater (Reference 5) have shown that the use of tank covers can significantly reduce contaminant emissions, Hama et al. have investigated surface-active agents, and Flanigan et al. have demonstrated the effectiveness of floating plastic balls as a control measure. However, there is no technique available to predict the extent to which these control measures can permit a reduction in ventilation since operations vary greatly in tank size, content, room air currents, operating temperature, etc.

The requirements of the existing standard have generally been retained in these guidelines without change. The following sections discuss the modifications that have been made.

4.1 Classification of Open-Surface Tank Operations

The technical intent of the open-surface tank classification system is unchanged, but editorial improvements have been made to clarify this section of the guidelines. No change in technical intent has been suggested because, in the absence of some alternative system that has demonstrated benefits in practical use, it is considered undesirable to propose changes to methods that have been in use for several years. A revision of these guidelines will be required when further research and development provides data to permit the assessment of contaminant generation rates.

4.2 Ventilation Equipment Design Requirements

In section 5 of these guidelines, acceptable hood designs have been provided. Diagrams provided are based on information in References 2 and 3. Design data on Figure 4 (Push-Pull Hoods) are based on information from Reference 13 which indicates that a minimum hood height of 0.2 times the tank length should be used.

4.3 Ventilation Requirements

The ventilation requirements suggested in existing standards and ventilation guides (References 1 - 3) have been utilized in these guidelines. There is no indication that these ventilation rates have been shown to be deficient under actual use conditions.

4.3 Personal Protection, and Inspection and Maintenance

These sections, found in the existing standard, have been deleted from these guidelines. New mandatory standards being developed for the Standards Completion Program will address these and other aspects of safety and health.

REFERENCES

1. General Industry Safety and Health Regulations; Part 1910; U.S. Dept. of Labor, OSHA 2206, June 1974, pg. 23593
2. "American National Standard Practices for Ventilation and Operation of Open-Surface Tanks;" American National Standards Institute, Inc., N. Y., ANSI Z9.1-1971.
3. "Industrial Ventilation: A Manual of Recommended Practice," 13th Edition, Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists, Lansing, Michigan, 1974.
4. Flanigan, L. J.; Kim, B. C.; Semones, D. E.; Talbert, S. G.; Development of Design Criteria for Exhaust Systems for Open-Surface Tanks. Research Report Battelle Laboratories, February 1974, pg. 7-8.
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10. Kirk, R. E., Othmer, D. F.; Encyclopedia of Chemical Technology, volumes 7 and 8, Interstate Encyclopedia, Inc., N. Y.
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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR SERVICE GARAGES

1. Introduction

This memorandum describes the rationale followed in the development of guidelines concerning ventilation requirements for service garage operations. The guidelines were developed as a result of a literature review of practices and health hazards in service garages and a review of guides to ventilation practices and published technical work on the subject (References 1-11).

2. Scope and Application

The scope and application of the guidelines are based on service garage operations as defined and described in the various sources reviewed. The guidelines are directed toward service garage operations which have been noted in any of the sources as producing air contaminant concentrations which can be hazardous to health and which would not be covered in other guidelines (i.e., spray-finishing, welding, etc.). The operations which are specifically covered include:

- o No-Load Engine Servicing Operations;
- o Dynamometer Servicing Operations;
- o Vehicle Movement Within Enclosed Areas;
- o Vehicle Storage;
- o Dead Engine Servicing Operations;
- o Body Repair Operations; and
- o Solvent Degreasing Operations.

3. Definitions

The definitions included in the guidelines are consistent with those used in relevant ventilation guides, except for the term "natural-flow ventilation" which was specially defined for use.

4. Ventilation and Enclosure Requirements

4.1 No-Load Engine Servicing Operations

The types of repair procedures referred to in this category include those which require continuous or periodic engine operation with the transmission placed in neutral (i.e., tuneups, valve adjustments, leak detection, etc.). The source of air contaminants from such an operation can primarily be considered to be the engine exhaust outlet(s) (i.e., tailpipe(s)) of the vehicle being serviced. Essentially three types of ventilation practices or systems are commonly utilized to reduce contaminants from this source. The simplest consists strictly of natural "open door" air circulation. The next approach consists of attaching the exhaust outlet(s) to flexible ducts or hoses which contain and direct the volume of contaminants through a nearby door or wall to

the outdoors. The most sophisticated systems utilize ducting networks and fans.

Use of the first approach, natural ventilation, was not felt to constitute an acceptable means for engine exhaust removal for inclusion into the guidelines. Though the measure might be adequate in certain circumstances, these circumstances could not be defined in a precise, straightforward manner which would ensure that contaminants are sufficiently diluted. Too many variables are involved which must be given consideration (i.e., contaminant emission rate, distance of the source from an open door(s), floor area and volume of the garage, number and size of the open door(s), orientation of the door(s) in relation to wind direction, wind velocity, etc.) The use of the method, however, is not completely precluded since controls are required only where the vehicle being serviced generates contaminant concentrations in excess of exposure limits. The vehicle would not do this if natural ventilation alone was adequate.

The second approach described is very commonly utilized with success. Its continued use is therefore permitted with the stipulations that the hose(s) or duct(s) used be of sufficient diameter to permit unrestricted flow of contaminants and that the length of the hose or duct not be so long as to cause excessive back pressures.

Specification of the minimum internal diameters for these tubes presented a problem in that the data to be utilized, from prints VS-907 and -908 of the ACGIH Industrial Ventilation Manual (Reference 5), gave sizes as a function of engine horsepower and was dated January 1968. It is a well known fact that in 1971 the horsepower rating system for passenger cars was changed at the same time that compression ratios were lowered to conform with vehicle emission standards. Both these actions had the effect of substantially lowering advertised horsepower figures for particular size (i.e., displacement) engines. Since the displacement of a particular engine to a large extent controls the total volume of exhaust gases emitted, using the lower horsepower figures with the data given for a post-1971 vehicle might have produced undesirable results for many vehicles.

Engine displacement and horsepower data for typical 1965 passenger cars were taken from Reference 12 and plotted against each other as shown in Figure 1 of this document. As is evident, it is shown that a figure of 200 horsepower for a pre-1971 passenger car corresponds to an engine displacement of approximately 285 cubic inches. The 200 horsepower used by the ACGIH as the cutoff between the use of 3 or 4 inch diameter ducts was therefore replaced with a displacement figure of 285 cubic inches. The recommended duct diameter for diesel engines was left unchanged.

The restriction of the length of the flexible duct or hose to a maximum of 6 feet was based upon experimentation conducted by the principal author of References 4 and 6, the member of the ACGIH ventilation committee who initially reviewed these guidelines (Reference 14).

The illustrations for the mechanical systems in Figures 1 and 2 of the guidelines were taken from prints VS-907 and VS 908 of the Industrial

Data Source: Table 2, Section 9 (pg. 9-109) of Reference 12.

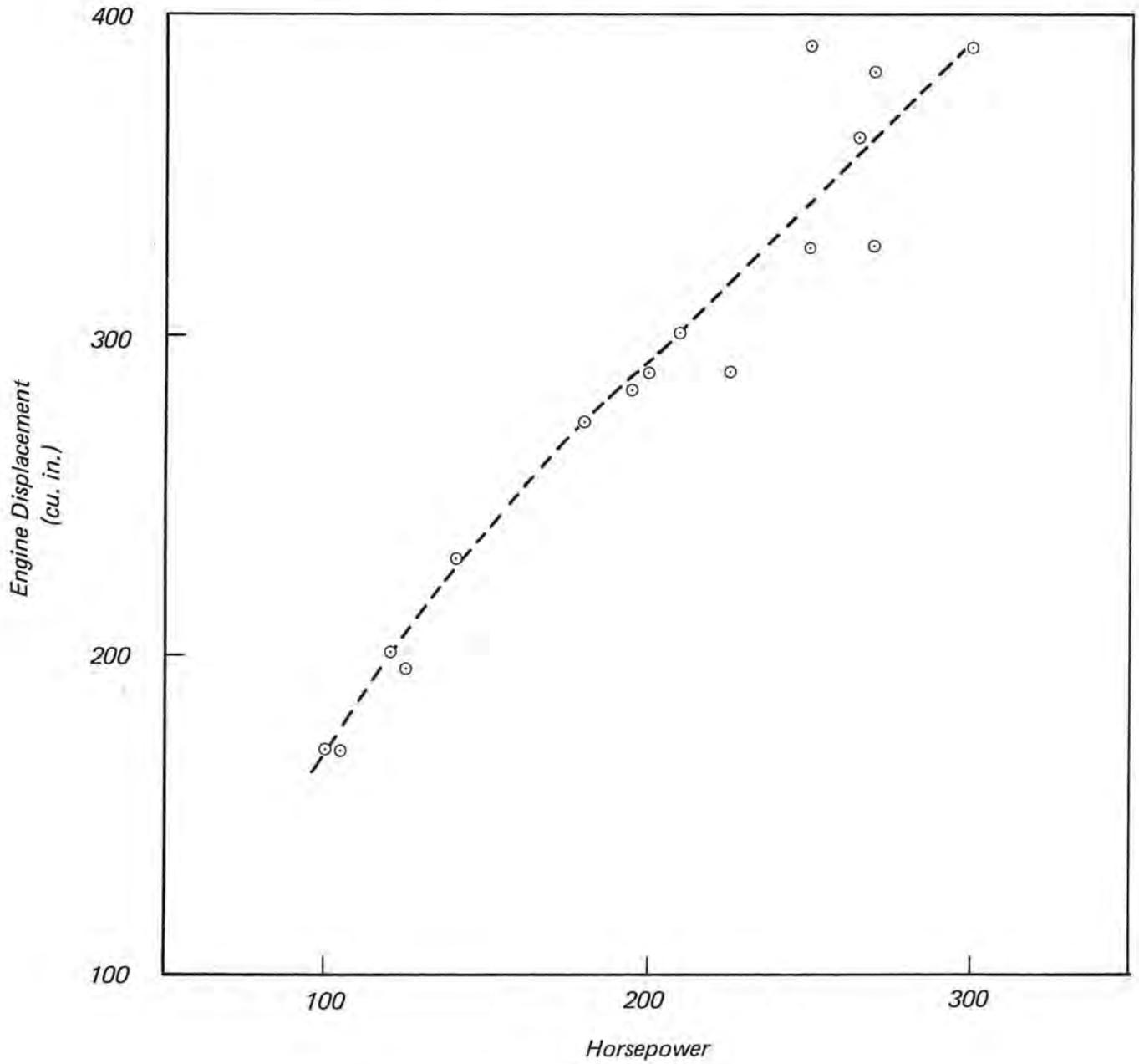


FIGURE 1 DISPLACEMENT VS HORSEPOWER CURVE FOR SELECTED 1965 U.S. AUTOMOBILE ENGINES

Ventilation Manual. As before, the 200 horsepower figure was replaced with a 285 cubic inch displacement figure.

4.2 Dynamometer Servicing Operations

The information concerning ventilation of dynamometer pits and sumps was taken directly from Reference 3.

The minimum flowrates per outlet or vehicle to be provided for gasoline-fueled vehicles were taken from the ACGIH Manual. The figures for diesel and turbocharged diesel engines are from Reference 3.

The minimum duct diameters specified for gasoline engines were derived by taking the flowrate figures and entering a table in Reference 3 which listed maximum recommended flowrates in various diameter ducts used for this purpose. The same table was also used to determine duct sizes for diesel engines.

Figure 3 in the guidelines is a slightly modified version of an illustration given in Reference 3. The modification primarily concerns the separation of the engine exhaust ventilation system from the dynamometer pit and sump exhaust system. This was done on the suggestion of the reviewer of the guidelines (reference 14) who felt that, because of the difference in static pressure requirements, it might be difficult for a contractor to balance out a single system. The illustration of a two-fan system should lead to a greater likelihood of satisfactory installation. The use of a single system is allowed, but only where "the different static pressure requirements of the separate branches can be properly balanced."

4.3 Vehicle Movement, Storage, and Dead Engine Servicing Operations

General ventilation is necessary to dilute exhaust gases from vehicles moving about a garage and vapors which evaporate from their fuel systems. The ASHRAE Handbook of Fundamentals (Reference 10) recommends a rate of 1 cfm per square foot of floor area. Ammerman in Reference 3 recommends six air changes per hour for large multi-bay shops. The ACGIH recommends 5000 cfm per running automobile, 10,000 cfm (or more) per truck and 100 cfm per horsepower per diesel engine.

In Reference 6 it is stated that "the figure of 5000 - 6000 cfm per car in operation has been used as a basis for design of garage ventilation. It is probable that this figure is not too accurate as it was based on some investigations made over 25 years ago on a car idling". Referring to the figures given in units of cfm per square foot, it is said "this method per se is not a sound basis for determining air flow rates for carbon monoxide control from motor vehicles because it does not base the air flow rate on the contaminant given off, but merely on a building dimension, the floor area. However, it is a more logical basis than the air change method because the floor area is related to the number of cars the garage will hold."

Reference 6 was primarily written as a guide to ventilation of parking garages. One of its conclusions is that garages of one level

require a total ventilation rate equal to the total vehicle capacity of the garage multiplied by 450 plus or minus 90 cfm. Reference 4 presents recommendations for automobile service garages and concludes that 500 cfm should be provided per car stall or garage capacity.

Inspection of Reference 4 reveals that its recommendation is based on the determination that 384 cfm plus or minus 108 cfm were required per car stall for adequate ventilation of the three service garages studied. Consequently, the upper figure ($384 + 108 = 492$) was chosen and rounded off to be presented as a design guideline for garages of 15 to 30 car capacity.

Based upon the above information, a figure of 400 cfm per car stall or car capacity was chosen as a reasonable minimum requirement for the near future.

This figure represents the mid-range of the various recommended figures and recognizes that all figures noted were developed using data from vehicles without sophisticated emission controls. Reference 13 indicates that average emission factors for 1972 light-duty gasoline-engined vehicles when compared to pre-1968 vehicles show estimated reductions of 68 - 78% in the amount of carbon monoxide emitted (depending on altitude) and an estimated 51 - 69% reduction in the amount of hydrocarbons. Nitrogen oxide emission factors are noted as having risen an estimated 63%. Nevertheless, overall figures show that the average pre-1968 vehicle of this type emitted about 121 grams per mile of contaminants versus an estimated 36 grams per mile for a 1972 vehicle. Crankcase and evaporative hydrocarbon emissions are shown as having dropped from 3.8 grams per mile for 1963 to 1967 vehicles to 0.2 gram per mile for 1972 vehicles. It can also be deduced from this source that at least 70% of the automobiles currently on-the-road have some degree of installed emission controls. These latter considerations suggest that the ventilation rate figure be periodically reevaluated as older vehicles are taken off the road.

ACGIH suggests a dilution rate of 10,000 cfm (or more) per running truck, a figure twice that recommended for automobiles. Reference 13 shows that heavy-duty gasoline-powered vehicles have demonstrated only slight reductions in emissions over the years that light-duty vehicles were controlled, and that such vehicles produce 1.5 to 2.0 times the emissions of pre-1968 automobiles. A figure of 800 cfm per service stall or vehicle capacity was therefore chosen as a reasonable minimum requirement.

For diesel-powered vehicles, ACGIH recommends a rate of 100 cfm per horsepower per running vehicle. Reference 13 shows that diesel-powered vehicles have had virtually unchanged emission characteristics since the advent of controls. A comparison of the emission factors of late model, light-duty gasoline-powered vehicles with light-duty diesel-powered vehicles demonstrates that the diesels emit less pollutants on the average. A similar comparison for heavy-duty vehicles also demonstrates less carbon monoxide and hydrocarbon emissions but substantially more (34 gm/mile vs. 9.2 gm/mile) nitrogen oxide emissions. Additionally shown are somewhat substantial sulfur oxide (2.4 gm/mile), aldehyde (0.2 gm/mile), and organic acid (0.2 gm/mile) emissions for the diesels.

Given the above information and the nuisance value which must be attached to the odor and visibility of diesel exhaust, it was decided that the same 400 cfm per service stall figure would be reasonable for light-duty diesel vehicles. For heavy-duty vehicles, a minimum rate of 1200 cfm per vehicle stall or capacity was chosen, a figure corresponding to 10% of the ACGIH recommended rate for a 120 horsepower engine. (NOTE: A typical diesel tractor engine is about 190 hp). It is noted that there is not as much confidence placed in the justification of this latter requirement as in other figures given.

Below grade areas other than repair pits require continuous ventilation to remove toxic or flammable vapors which might otherwise accumulate. The rate of 0.75 cfm per square foot of floor area is recommended by the National Fire Code (Reference 9).

Repair pits require ventilation for the same reasons as above. The same reference recommends an air change once every five minutes.

4.4 Other Operations

Body repair operations generally involve spray painting, grinding, buffing and polishing of metal, cutting and welding, and occasionally abrasive blasting operations. All of these operations are covered by other ventilation guidelines.

Degreasing operations fall into three general categories: solvent dip, solvent spray, and steam cleaning. Solvent dip operations usually are infrequent and utilize solvents of low volatility. Consequently, special ventilation requirements are not specified or needed for this class of operation (Reference 1).

Solvent spray cleaning involves the spray application of solvents. Though the solvents may be of low volatility, this method releases a fine aerosol mist of solvent into the air. Reference 1 suggests that such operations for individual vehicle components be done in a small booth having a face velocity of 100 fpm. This figure was utilized in the guidelines.

Solvent spray cleaning of vehicles and/or their larger components can potentially release large amounts of aerosol mist that would require a large spray booth similar to those used for painting automobiles. Consequently, this operation is considered equivalent to such a paint spray operation when the operation is to be conducted indoors. It is to be noted that this type of operation is best performed out-of-doors, if only because of the mess that it usually makes.

Steam cleaning is usually performed out-of-doors. Unlike solvent spray operations, there are no toxic or irritant aerosols created, and there is no special reason why the operation cannot be performed indoors.

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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR
SPRAY-FINISHING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for spray-finishing operations. The guidelines have been developed as a revision of the existing standard (Reference 1). Revisions primarily concern the addition of acceptable booth designs, addition of ventilation requirements for ovens used to dry or bake spray work, the rearrangement of the guidelines into the updated format, and the deletion of certain regulations felt to be redundant and/or not proper for inclusion.

2. Scope and Application

The scope of the guidelines is similar to the scope of the present standard but also includes the use of drying and baking ovens.

The Application of the guidelines requires exhaust ventilation when a spray-finishing operation generates air contaminant concentrations in excess of exposure limits into the breathing zones of employees. This is somewhat a relaxation of the present standard which makes ventilation mandatory under all circumstances. The relaxation is felt proper in that it makes the guidelines more consistent with the purpose of 29 CFR 1910.1000.

The guidelines specifically prescribe the use of:

- Small spray booths,
- Large spray booths and spray rooms,
- Vehicle spray paint booths,
- Ventilation for trailer interior painting, and
- Ventilation for drying and baking ovens.

As in the present standard, these guidelines do not prescribe ventilation for the spraying of large structures which cannot practically be placed in a booth.

3. Definitions

The definitions relating to exhaust system designs and equipment are consistent with those used in relevant ventilation guides. Definitions pertaining to spray-finishing operations are mostly taken verbatim from 29 CFR 1910.94 (c) and 29 CFR 1910.107. Only the definition of "overspray" was added for further clarification of the intent of the guidelines.

4. Ventilation Equipment Design Requirements

4.1 General

The present standard is derived completely from ANSI Z9.3 (Reference 2). This standard and other pertinent guidelines and literature (References 3-11) were reviewed and evaluated. This study determined that the enclosure and airflow requirements of the ACGIH Industrial Ventilation Manual (Reference 3) come from a great deal of experience and are adequate as given for the control of air contaminants. Indeed, any increase in airflow velocities could impair production procedures and result in an increase in overspray that could not be effectively handled by spray particle arresting filters and baffles. It is also doubtful if water wash cascade systems could operate efficiently under an increased airflow. Spray booth and oven ventilation designs were extracted from the ACGIH Industrial Ventilation Manual (Reference 3) and presented as representing acceptable designs.

The table of "minimum maintained velocities," Table G-10 of the present standard, was not utilized for these guidelines. This table is rather too generalized in that it notes that the effectiveness of a spray booth is dependent upon the relationship of the depth of the booth to its height and width and only gives ranges of acceptable airflow velocities.

To be noted is that these guidelines also do not include other portions of the present standard. These portions contained design and construction requirements for spray rooms, spray booths, and ductwork, and design requirements for make-up air systems. The design and construction requirements for spray booths and rooms which were deleted were redundant with requirements of 29 CFR 1910.107, and are thus given by reference in these guidelines.

The ductwork requirements and the make-up air system requirements were deleted because they are applicable not only for these particular guidelines but for all systems which handle similar substances. For similar reasons, the section showing an example of how to calculate air volumes necessary to dilute solvent concentrations to below 25 percent of lower explosive limits was deleted. These requirements and data are best suited for inclusion into separate guidelines giving such requirements for all exhaust and make-up air systems for the control of air contaminants.

4.2 Make-up Air

Requirements in the present standard which pertain to the volume of make-up air to be provided, to self-closing doors and dampers, and to air filters have been incorporated into these guidelines. As noted previously, detailed requirements in the present standard which are generally applicable to ventilation systems are not utilized. The guidelines do, however, require that means for tempering such air be provided.

4.3 Construction and Location of Equipment

Except for the requirement that drying and baking ovens shall conform with NFPA No. 86A, Class A Ovens and Furnaces, and sections 1101 through 1104 of the Standard for Spray-Finishing Using Flammable and Combustible Materials, NFPA No. 33-1969, all requirements are taken almost verbatim from the present standard.

4.4 Ventilation Requirements

Section 4.4.1 of these guidelines prescribe, in keeping with the application of the guidelines, that spray booths or rooms shall be used to enclose operations which generate air contaminant concentrations in excess of exposure limits. Additionally given are requirements, taken almost verbatim from the present standard, which are applicable to the proper operation of all spray booths and rooms.

Specific designs and minimum exhaust volumes recommended for small spray booths are taken from Print VS-604 of the ACGIH manual (Reference 3). Figure 2 of the guidelines is derived from this print.

Figure 3 of the guidelines and the specific designs for large spray booths are derived from Print VS-603 of the ACGIH manual. Figures 4, 5, and 6 are from NFPA No. 33-1969. The requirement that doors of downdraft booths be closed during operation of the booth is taken from the present standard.

Requirements for auto spray paint booths and large drive-through booths as well as the illustrations given in Figures 7 and 8 of the guidelines given are respectively from Prints VS-601 and VS-606 of the ACGIH manual.

Figure 9 and the requirements for the spray painting of trailer interiors are derived from Print VS-605.

Drying and baking oven requirements in Figure 10 are derived from Print VS-602 except that the requirement that ovens be structurally separate from all spray booths and that the air drawn into the oven for ventilation or combustion not be from any spray booth nor disturb the airflow into any spray room is taken from ANSI Z9.3. The equation for determination of exhaust volumes for enclosed spaces within ovens where flammable solvents are released comes from Reference 11.

The necessity for ventilation of mixing rooms and freshly sprayed objects was pointed out by the expert reviewer of the draft version of the guidelines (Reference 9). The rate of 2 to 20 air changes per hour is based upon his experience and is presented solely as a suggestion. The suggestion for the use of exhausted drying tunnels with an indraft velocity of 100 fpm through all openings is derived from Print VS-502 of the ACGIH manual.

The general mechanical ventilation rates for spray rooms in which air spray operations are conducted are also from the ACGIH manual. The rates for rooms in which airless spray operations are conducted were suggested in Reference 10.

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RATIONALE FOR RECOMMENDED VENTILATION GUIDELINES FOR WELDING OPERATIONS

1. Introduction

This memorandum describes the rationale followed in the development of guidelines on ventilation requirements for welding operations. These guidelines have been developed as a revision of the existing standard (Reference 1). Revisions have been made on the basis of current guides to industrial ventilation practice and the results of research on ventilation requirements.

2. Scope and Application

The scope of these guidelines is based on welding operations as defined by the American Welding Society (Reference 2). The guidelines are directed primarily toward those welding operations which are reported to produce air contaminants in sufficient quantities to create health hazards. These operations are:

Gas welding	Gas shielded-arc welding
Oxygen cutting and gouging	Plasma arc welding
Torch brazing and soldering	Submerged arc welding
Shielded metal-arc welding	Flux cored arc welding
Arc cutting and gouging	Thermal spraying

The welding operations not specifically covered by these guidelines include those which produce only small quantities of contaminants, such as resistance and induction welding, and those which are intermittent in nature, such as thermal welding.

3. Definitions

The definitions included in these guidelines are consistent with those used in relevant ventilation guides (References 3, 4, and 5), except for the definition of "confined space." The existing OSHA and ANSI welding ventilation standards (References 1 and 5) define three classes of work spaces as follows:

- a. Enclosed spaces with:
 - Volume greater than 10,000 cu. ft. per welder;
 - Ceiling height greater than 16 ft; and
 - No barriers to ventilation.
- b. Enclosed spaces not meeting requirements in (a);
- c. Confined spaces, such as boilers, tanks, and ship compartments.

The OSHA and ANSI standards prescribe different ventilation requirements for space classes a and b, but the requirements for classes b and c are not substantially different. Therefore, in these guidelines, the term "confined space" has been used to include both classes b and c, and the ventilation requirements are the same for all such spaces.

4. Ventilation Equipment Design Requirements

These guidelines prescribe various design requirements for general mechanical ventilation equipment and exhaust hoods of the types most commonly used with welding operations. Hood designs and exhaust flow rate formulas generally are based on guidelines contained in References 3 and 4. The design specified for a freely suspended open hood is based on the results of the investigation in Reference 6.

5. Ventilation Requirements

5.1 Contaminant Classification

The classification of contaminant materials is intended to provide a basis for specifying ventilation requirements in accordance with the toxicity levels of the contaminants to be controlled. For this purpose, three classes of materials have been defined which are considered to require different control methods.

Class I contaminants include inert and low toxicity materials for which general mechanical ventilation methods are prescribed.

Class II contaminants include materials of moderate toxicity for which open exhaust hoods are prescribed.

Class III contaminants include high toxicity materials for which enclosing hoods are prescribed.

There is a precedent for such a classification of contaminant materials and ventilation methods found in guidelines for ventilation of other industrial processes (Reference 3). However, no definitive basis exists for specifying the classification boundaries for welding processes. The classification of contaminants in these guidelines is based on the judgment of the authors and reviewers of the guidelines. The classification is consistent with limited data on ventilation requirements for specific contaminant materials such as zinc and lead (Reference 7).

5.2 Exhaust Flow Requirements

Exhaust flow requirements in these guidelines are based primarily on current ventilation guidelines (References 3 and 5). Evidence of the validity of these guidelines is not well documented except for a recent investigation of the effectiveness of two types of open hoods (Reference 6). Many investigations have been conducted of the types and quantities of air contaminants emitted by welding operations, and a survey of the results of these investigations is presented in Reference 7. These results clearly demonstrate the need for contaminant control for many types of operations. However, data on the performance of ventilation methods for welding operations generally are sparse.

5.3 General Mechanical Ventilation

General mechanical ventilation requirements specified in the new guidelines are based on guidelines contained in Reference 3. This basis, which is more conservative than the existing standard, was selected because it represents the most recent evaluation of ventilation requirements by the American Welding Society.

General mechanical ventilation is not allowed in the new guidelines for use with operations which release contaminants with high initial velocities. These operations include oxygen cutting and gouging, arc cutting and gouging, and thermal spraying. For these operations, open hoods or enclosures are specified which are effective in capturing high velocity contaminants and particles.

5.4 Open Hoods

Open exhaust hoods are prescribed within these guidelines for all welding operations generating Class II contaminant materials except thermal spraying. General mechanical ventilation is not considered adequate for the control of Class II contaminants since the flow of contaminants into the welder's breathing zone is not prevented. The use of open hoods with high velocity contaminants from thermal spraying operations is limited to Class I materials. This restriction is consistent with the guideline in Reference 3 for thermal spraying.

Capture velocities specified for open hoods are in accordance with guidelines in References 3 and 5. The effectiveness of these capture velocity requirements has been demonstrated for freely suspended hoods and crossdraft tables in the work described in reference 6.

5.5 Enclosing Hoods

Enclosing hoods are specified for use with all operations generating Class III contaminants to provide greater reliability in the control of these materials. Contaminant control by enclosing hoods is less subject to disruption by drafts and movements than is control by open hoods, and it is important that control of Class III contaminants be reliable and continuous.

Enclosing hoods are specified for use with thermal spraying operations generating either Class II or III contaminants because of the high velocities with which these contaminants are released.

The capture velocities specified with the use of enclosing hoods are consistent with the guidelines presented in References 3 and 5.

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