Oregon OSHA TECHNICAL MANUAL

Section III

(previously Section II of Oregon OSHA's Technical Manual)

<u>HEALTH HAZARDS</u>

*All information within this section and chapter has been reproduced from the Oregon OSHA Technical Manual (circa 1996) unless otherwise stated within the "**Chapter Revision Information**", located at the beginning of each chapter.*

SECTION III: CHAPTER 3

VENTILATION INVESTIGATIONS

Oregon OSHA TECHNICAL MANUAL

<u>Chapter Revision Information:</u>

- *This chapter was previously identified as Section II, Chapter 3 in Oregon OSHA's circa 1996* ***Technical Manual****. The section number was modified from Section II to Section III in May 2014 to provide uniformity with federal OSHA's Technical Manual (OTM).*
- *In May 2014, the chapter's multilevel listing format was modified from an alphanumeric system to a roman numeral system.*
- *In May 2014, several figures were updated for clarity. All content remains the same.*

SECTION III: CHAPTER 3

VENTILATION INVESTIGATION

TABLE OF CONTENTS

I. Introduction

Industrial ventilation generally involves the use of supply and exhaust ventilation to control emissions, exposures, and chemical hazards in the workplace. Traditionally, nonindustrial ventilation systems commonly known as heating, ventilating, and air-conditioning (HVAC) systems were built to control temperature, humidity, and odors.

Ventilation may be deficient in:

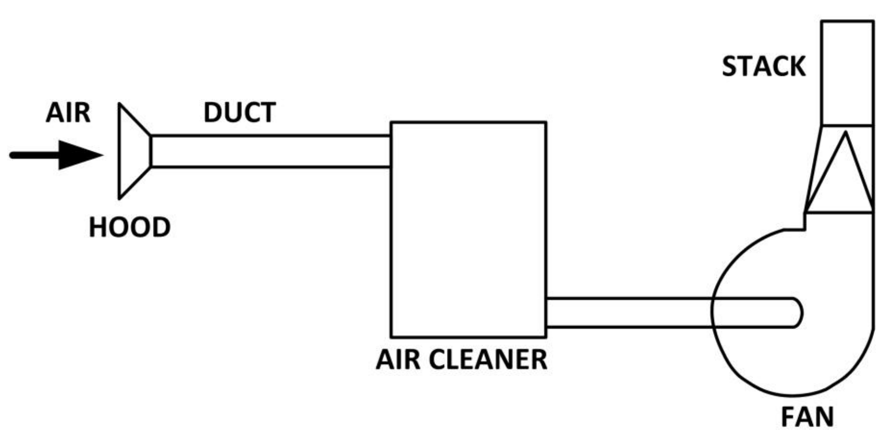
- confined spaces,
- facilities failing to provide adequate maintenance of ventilation equipment,
- facilities operated to maximize energy conservation,
- windowless areas, and
- areas with high occupant densities.

Any ventilation deficiency must be verified by measurement.

There are five basic types of ventilation systems:

- dilution and removal by general exhaust,
- local exhaust (see Figure III:3-1),
- makeup air (or replacement),
- HVAC (primarily for comfort), and
- recirculation systems.

Figure III:3-1. **Components of a Local Exhaust System**



Ventilation systems generally involve a combination of these types of systems. For example, a large local exhaust system may also serve as a dilution system, and the HVAC system may serve as a makeup air system (see Appendix III:3-1 for a primer and Appendix III:3-2 for an explanation of these terms).

II. Health Effects

Inadequate or improper ventilation is the cause of about half of all indoor air quality (IAQ) problems in nonindustrial workplaces (see Section III, Chapter 2, Indoor Air Quality). This section of the manual addresses ventilation in commercial buildings and industrial facilities.

A. Indoor Air Contaminants

Indoor air contaminants include but are not limited to particulates, pollen, microbial agents, and organic toxins. These can be transported by the ventilation system or originate in the following parts of the ventilation system:

- wet filters,
- wet insulation,
- wet undercoil pans,
- cooling towers, and
- evaporative humidifiers.

People exposed to these agents may develop signs and symptoms related to "humidifier fever," "humidifier lung," or "air conditioner lung." In some cases, indoor air quality contaminants cause clinically identifiable conditions such as occupational asthma, reversible airway disease, and hypersensitivity pneumonitis.

B. Volatile Organic and Reactive Chemicals

Volatile organic and reactive chemicals (for example, formaldehyde) often contribute to indoor air contamination. The facility's ventilation system may transport reactive chemicals from a source area to other parts of the building. Tobacco smoke contains a number of organic and reactive chemicals and is often carried this way. In some instances the contaminant source may be the outside air. Outside air for ventilation or makeup air for exhaust systems may bring contaminants into the workplace (e.g., vehicle exhaust, fugitive emissions from a neighboring smelter).

See Section III, Chapter 2, Indoor Air Quality, for a discussion of common indoor-air contaminants and their biological effects.

III. Standards and Codes

A. Consensus Standards

Appendix III:3-3 is a compilation of OSHA and industry consensus standards. Foremost are those recommended by the Air Movement and Control Association (AMCA), the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), the Sheet Metal and Air Conditioning Contractors National Association (SMACNA), the National Fire Protection Association (NFPA), and the American Conference of Governmental Industrial Hygienists (ACGIH). AMCA is a trade association that has developed standards and testing procedures for fans. ASHRAE is a society of heating and air conditioning engineers that has produced, through consensus, a number of standards related to indoor air quality, filter performance and testing, and HVAC systems. ANSI has produced several important standards on ventilation, including ventilation for paint-spray booths, grinding exhaust hoods, and open-surface tank exhausts. Four ANSI standards were adopted by OSHA in 1971 and are codified in 29 CFR 1910.94; these standards continue to be important as guides to design. ANSI has recently published a new standard for laboratory ventilation (ANSI Z9.5). SMACNA is an association representing sheet metal contractors and suppliers. It sets standards for ducts and duct installation. NFPA has produced a number of recommendations (which become requirements when adopted by local fire agencies), e.g., NFPA 45 lists a number of ventilation requirements for laboratory fume hood use. The ACGIH has published widely used guidelines for industrial ventilation.

B. OSHA Regulations

Ventilation criteria or standards are included in OSHA regulatory codes for job- or task-specific worker protection (see Appendix III:3-3). In addition, many OSHA health standards include ventilation requirements. The four standards in 29 CFR 1910.94 deal with local exhaust systems, and OSHA's construction standards (29 CFR 1926) contain ventilation standards for welding. OSHA's compliance policy regarding violation of ventilation standards is set forth in the *Field Inspection Reference Manual (FIRM)*.

IV. Investigation Guidelines

A. Investigation Phases

Workplace investigations of ventilation systems may be initiated by worker complaints of possible overexposures to air contaminants, possible risk of fire or explosion from flammable gas or vapor levels at or near the lower explosive limit (LEL), or indoor air quality complaints.
The second phase of the investigation involves an examination of the ventilation system's physical and operating characteristics.

B. Faulty Ventilation Conditions and Causes

Common faulty ventilation conditions and their probable causes are listed in Table III:3-1.

Specific points to consider during any investigation of a ventilation system include emission source, air behavior, and employee involvement. Points that should be included in a review of operational efficacy are shown in Table III:3-2. Appendix III:3-4 contains information on points to be checked in a troublesome exhaust system.

Table III:3-1. **Common Ventilation Conditions and Causes**

Condition	Possible cause(s)
Worker complaints, improper use of system, nonuse of system, alteration of system by employees.	The hood interferes with work. The hood provides poor control of contaminants.
Excessive employee exposures although flow volumes and capture velocities are at design levels.	Employee work practices need improvement. The ventilation system interferes with work or worker productivity and leads workers to bypass the system. Employee training is not adequate. Design of system is poor.
Constant plugging of duct.	Plugged ducts occur when transport velocity is inadequate or when vapor condenses in the duct, wets particles, and causes a build-up of materials. These problems are caused by poor design, open access doors close to the fan, fan problems, or other problems.
Reduced capture velocities or excessive fugitive emissions.	The cause of these conditions is usually reduced flow rate, unless the process itself has changed. Reduced flow rate occurs in the following situations: • plugged or dented ducts • slipping fan belts • open access doors • holes in ducts, elbows • closed blast gate to branch, or opened blast gates to other branches, or corroded and stuck blast gates • fan turning in reverse direction (This can occur when lead wires are reversed and cause the motor and fan to turn backwards. Centrifugal fans turning backwards may deliver up to only 50% of rated capacity.) • worn out fan blades • additional branches or hoods added to system since initial installation, or • clogged air cleaner.

Table III:3-2. **Problem Characterization**

Emission source

- Where are all emission sources or potential emission sources located?
- Which emission sources actually contribute to exposure?
- What is the relative contribution of each source to exposure?
- Characterization of each contributor:
  - chemical composition
  - temperature
  - rate of emission
  - direction of emission
  - initial emission velocity
  - pattern of emission (continuous or intermittent)
  - time intervals of emission
  - mass of emitted material

Air behavior

- Air temperature
- Air movement (direction, velocity)
- Mixing potential
- Supply and return flow conditions, to include pressure differences between space and surrounding areas
- Sources of tempered and untempered make-up air
- Air changes per hour
- Influence of existing HVAC systems
- Effects of wind speed and direction
- Effects of weather and season

Employee

- Worker interaction with emission source
- Worker exposure levels
- Worker location
- Worker education, training, cooperation

C. Basic Testing Equipment

Basic testing equipment might include:

- smoke tubes;
- velometers, anemometers;
  - swining vane anemometer,
  - thermal or hot-wire anemometer,
- pressure-sensing devices:
  - U-tube or electronic manometers,
  - Pitot tube,

- thermal (thermal and swinging vane instruments measure static pressure indirectly
- aneroid (“bellows”) gauges;

- noise-monitoring equipment;
- measuring tapes;
- other: rags, flashlight, mirror, tachometer ;
- combustible gas meter or oxygen meter; and
- tubes for CO, CO2 , formaldehyde, etc.

D. Documentation

The characteristics of the ventilation system that must be documented during an investigation include equipment operability, physical measurements of the system, and use practices.

E. Equipment Operability

Before taking velocity or pressure measurements, note and record the operating status of the equipment. For example, are filters loaded or clean? Are variable-flow devices like dampers, variable-frequency drives, or inlet vanes in use? Are make-up units operating? Are system blueprints available?

F. Measurements

1. DUCT DIAMETERS

Duct diameters are measured to calculate duct areas. Inside duct diameter is the most important measurement, but an outside measurement is often sufficient for a sheet metal duct. To measure the duct, the tape should be thrown around the duct to obtain the duct circumference, and the number should be divided by π (3.142) to obtain the diameter of the duct.

2. HOOD AND DUCT DIMENSIONS

Hood and duct dimensions can be estimated from plans, drawings, and specifications. Measurements can be made with measuring tape. If a duct is constructed of 2½ or 4-foot sections, the sections can be counted (elbows and tees should be included in the length).

3. HOOD-FACE VELOCITIES

Hood-face velocities outside the hood or at the hood face can be estimated with velometers, smoke tubes, and swinging-vane anemometers, all of which are portable, reliable, and require no batteries.

The minimum velocity that can be read by an anemometer is 50 feet per minute (fpm). The meter should always be read in the upright position, and only the tubing supplied with the equipment should be used.

Anemometers often cannot be used if the duct contains dust or mist because air must actually pass through the instrument for it to work.

The instrument requires periodic cleaning and calibration at least once per year.

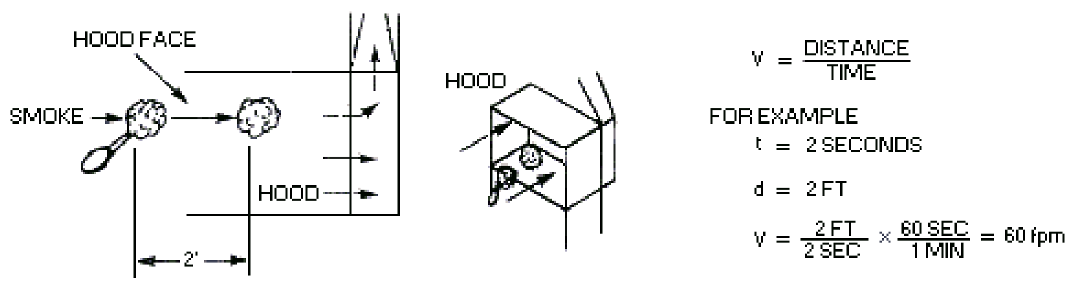
Hot-wire anemometers should not be used in airstreams containing aerosols.

Hood-face velocity measurement involves the following steps:

- mark off imaginary areas,
- measure velocity at center of each area, and
- average all measured velocities.

Smoke is useful for measuring face velocity (see Figure III:3-2) because it is visible. Nothing convinces management and employees more quickly that the ventilation is not functioning properly than to show smoke drifting away from the hood, escaping the hood, or traveling into the worker's breathing zone. Smoke can be used to provide a rough estimate of face velocity:

Figure III:3-2. **Use of Smoke to Demonstrate Air Flow**



Velocity = Distance/Time

or

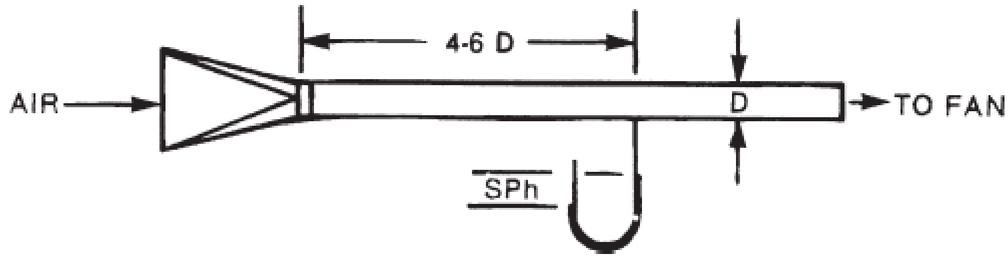
V = D/T

Squeeze off a quick burst of smoke. Time the smoke plume's travel over a two-foot distance. Calculate the velocity in feet per minute. For example, if it takes two seconds for the smoke to travel two feet, the velocity is 60 fpm.

4. HOOD STATIC PRESSURES (SPH)

Hood static pressures (SPH) should be measured about 4-6 duct diameters downstream in a straight section of the hood take-off duct. The measurement can be made with a pitot tube or by a static pressure tap into the duct sheet metal (see Figure III:3-3).

Figure III:3-3. **Use of Static Pressure Tap Into Duct to Measure Hood Static Pressure**



Pressure gauges come in a number of varieties, the simplest being the U-tube manometer.

Inclined manometers offer greater accuracy and greater sensitivity at low pressures than U-tube manometers. However, manometers rarely can be used for velocities less than 800 fpm (i.e., velocity pressures less than 0.05" w.g.). Aneroid-type manometers use a calibrated bellows to measure pressures. They are easy to read and portable but require regular calibration and maintenance.

5. DUCT VELOCITY MEASUREMENTS

Duct velocity measurements may be made directly (with velometers and anemometers) or indirectly (with manometers and pitot tubes) using duct velocity pressure.

Air flow in industrial ventilation ducts is almost always turbulent, with a small, nonmoving boundary layer at the surface of the duct.

Because velocity varies with distance from the edge of the duct, a single measurement may not be sufficient. However, if the measurement is taken in a straight length of round duct, 4-6 diameters downstream and 2-3 diameters upstream from obstructions or directional changes, then the average velocity can be estimated at 90% of the centerline velocity. (The average velocity pressure is about 81% of centerline velocity pressure.)

A more accurate method is the traverse method, which involves taking six or ten measurements on each of two or three passes across the duct, 90^o or 60^o opposed. Measurements are made in the center of concentric circles of equal area.

Density corrections (e.g., temperature) for instrument use should be made in accordance with the manufacturer's instrument instruction manual and calculation/correction formulas.

6. AIR CLEANER AND FAN CONDITIONS

Air cleaner and fan condition measurements can be made with a pitot tube and manometer.

G. Good Practices

1. HOOD PLACEMENT

Hood placement must be close to the emission source to be effective. Maximum distance from the emission source should not exceed 1.5 duct diameters.

The approximate relationship of capture velocity (Vc) to duct velocity (Vd) for a simple plain or narrow flanged hood is illustrated in Figure III:3-4. For example, if an emission source is one duct diameter in front of the hood and the duct velocity (Vd) = 3,000 feet per minute (fpm), then the expected capture velocity (Vc) is 300 fpm. At two duct diameters from the hood opening, capture velocity decreases by a factor of 10, to 30 fpm.

Figure III:3-4. **Relationship of Capture Velocity (Vc) to Duct Velocity (Vd)**

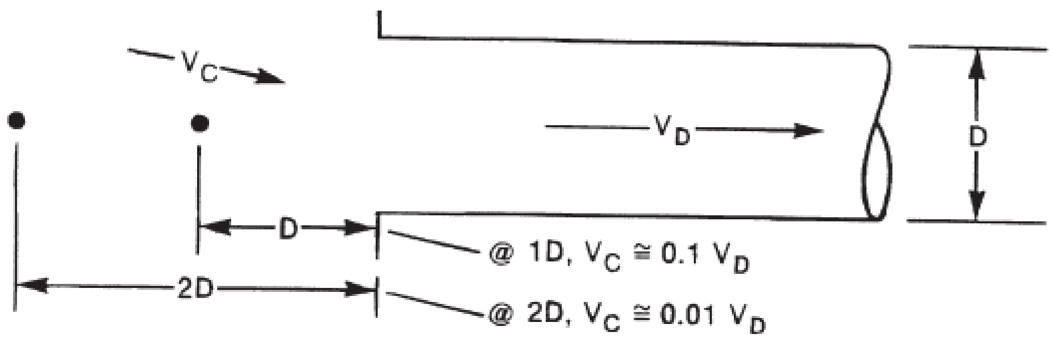


Figure III:3-5 shows a rule of thumb that can be used with simple capture hoods. If the duct diameter (D) is 6 inches, then the maximum distance of the emission source from the hood should not exceed 9 in. Similarly, the minimum capture velocity should not be less than 50 fpm.

Figure III:3-5. **Rule of Thumb for Simple Capture Hoods:**
Maximum Capture Distance Should Not Be More Than 1.5 Times the Duct Diameter

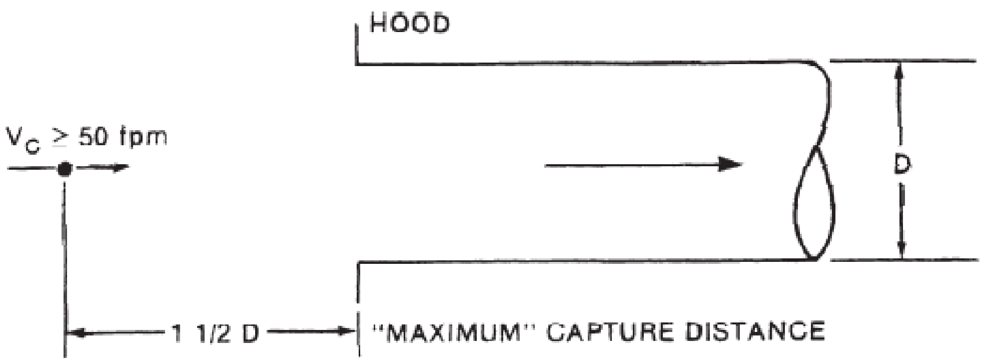
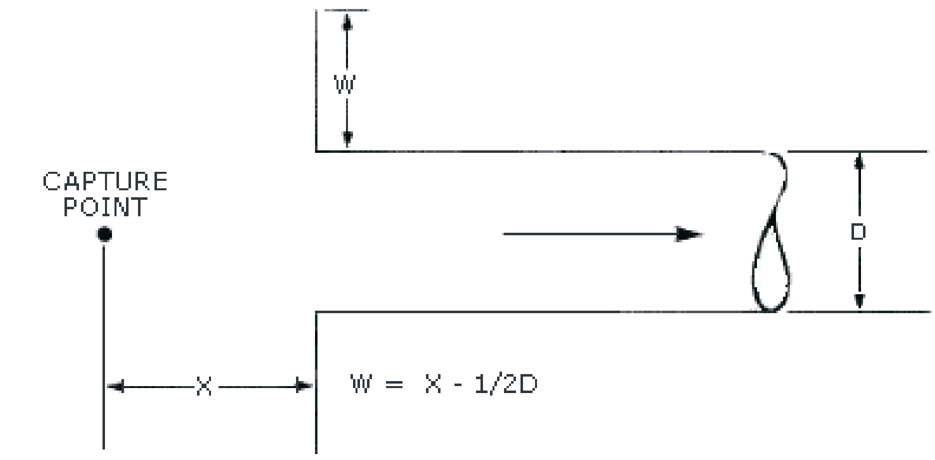


Figure III:3-6 provides a guide for determining an effective flange width.

Figure III:3-6. **Effective Flange Width (W)**

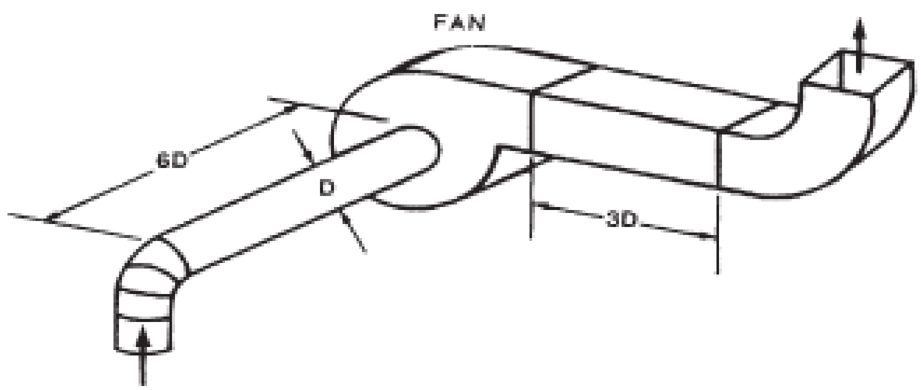


2. SYSTEM EFFECT LOSS

System effect loss, which occurs at the fan, can be avoided if the necessary ductwork is in place.

Use of the six-and-three rule ensures better design by providing for a minimum loss at six diameters of straight duct at the fan inlet and a minimum loss at three diameters of straight duct at the fan outlet (Figure III:3-7).

Figure III:3-7. **An Illustration of the Six-and-Three Rule**

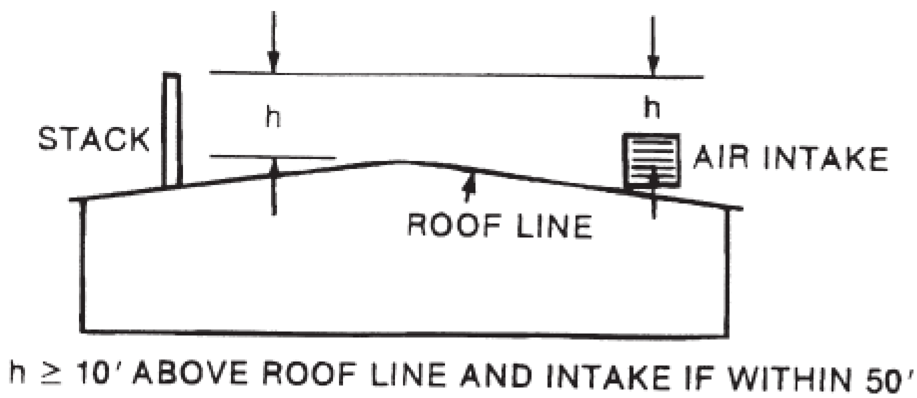


System effect loss is significant if any elbows are connected to the fan at inlet or outlet. For each 2½ diameters of straight duct between the fan inlet and any elbow, CFM loss will be 20%.

3. STACK HEIGHT

Stack height should be 10 ft higher than any roof line or air intake located within 50 ft of the stack (Figure III:3-8). For example, a stack placed 30 ft away from an air intake should be at least 10 ft higher than the center of the intake.

Figure III:3-8. **Minimum Stack Height in Relation to Immediate Roof Line or Center of Any Air Intake on the Same Roof.**



4. VENTILATION SYSTEM DRAWINGS AND SPECIFICATIONS

Ventilation system drawings and specifications usually follow standard forms and symbols, e.g., as described in the Uniform Construction Index (UCI).

Plan sections include electrical, plumbing, structural, or mechanical drawings (UCI, Section 15). The drawings come in several views: plan (top), elevation (side and front), isometric, or section.

Elevations (side and front views) give the most detail. An isometric drawing is one that illustrates the system in three dimensions. A sectional drawing provides duct or component detail by showing a cross-section of the component.

Drawings are usually drawn to scale. (Check dimensions and lengths with a ruler or a scale to be sure that this is the case. For example, 1/8 inch on the sheet may represent one foot on the ground.) Good practices to follow when reviewing plans and specifications are listed in Table III:3-3.

Table III:3-3. **Good Practices for Reviewing Plans and Specifications**

- Investigate the background and objectives of the project.
- Understand the scope of the project. What is to be included and why?
- Look for conciseness and precision. Mark ambiguous phrases, "legalese," and repetition.
- Do the specifications spell out exactly what is wanted? What is expected?
- Do plans and specifications adhere to appropriate codes, standards, requirements, policies, and do they recommend good practice as established by the industry?
- Will the designer be able to design, or the contractor to build, the system from the plans and specifications?
- Will the project meet OSHA requirements if it is built as proposed?

V. Prevention And Control

A well-designed system and a continuing preventive maintenance program are key elements in the prevention and control of ventilation system problems.

A. Elements of a Good Maintenance Program

PUT IT ON PAPER

Establish a safe place to file drawings, specifications, fan curves, operating instructions, and other papers generated during design, construction, and testing.

Establish a program of periodic inspection. The types and frequencies of inspections depend on the operation of the system and other factors.

- **Daily:** Visual inspection of hoods, ductwork, access and clean-out doors, blast gate positions, hood static pressure, pressure drop across air cleaner, and verbal contact with users. ("How is the system performing today?")
- **Weekly:** Air cleaner capacity, fan housing, pulley belts.
- **Monthly:** Air cleaner components.

A quick way to check for settled material in a duct is to take a broomstick and tap the underside of all horizontal ducts. If the tapping produces a "clean" sheet metal sound, the duct is clear. If the tapping produces heavy, thudding sounds and no sheet metal vibration, liquids or settled dust may be in the duct.

Establish a preventive maintenance program. Certain elements of any ventilation system should be checked on a regular schedule and replaced if found to be defective.

Provide worker training. Workers need to be trained in the purpose and functions of the ventilation system. For example, they need to know how to work safely and how best to utilize the ventilation system. Exhaust hoods do little good if the welder does not know that the hood must be positioned close to the work.

Keep written records. Maintain written documentation not only of original installations but also of all modifications as well as problems and their resolution.

B. Dealing with Micro-Organisms

If you suspect microbial agents, check for stagnant water in the ventilation system.

The presence of mold or slime is a possible sign of trouble. Table III:3-4 lists preventive measures for controlling microbial problems in ventilation systems.

Table III:3-4. **Preventive Measures for Reducing Microbial Problems in Buildings**

- Prevent buildup of moisture in occupied spaces (relative humidity of 60% or less).
- Prevent moisture collection in HVAC components.
- Remove stagnant water and slime from mechanical equipment.
- Use steam for humidifying.
- Avoid use of water sprays in HVAC systems.
- Use filters with a 50-70% collection efficiency rating.
- Find and discard microbe-damaged furnishings and equipment.
- Provide regular preventive maintenance.

C. Volatile Organic or Reactive Chemicals

If an organic or reactive chemical (e.g., formaldehyde) is believed to be the primary agent in an IAQ problem, potential controls to consider include additional dilution ventilation, removal or isolation of the offending material, and the transfer of sensitized employees.

D. Tobacco Smoke in Air

OSHA has published a proposed rule for IAQ (including tobacco smoke in the workplace), and this rulemaking is likely to be completed in the near future. Smoking policies should include provisions for dedicated smoking areas. Dedicated smoking areas should be configured so that migration of smoke into nonsmoking areas will not occur. Such areas should:

- have floor-to-ceiling walls of tight construction;
- be under negative pressure relative to adjacent areas;
- be exhausted outside the building and not recirculated.

For more information on investigation of complaints, CSHOs should consult the NIOSH Guidance for Indoor Air Quality Investigation and the EPA guide, Building Air Quality (1991).

VI. Bibliography

American Conference of Governmental Industrial Hygienists (ACGIH). 1988. *Industrial Ventilation, a Manual of Recommended Practice.* 20th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Air Movement and Control Association (AMCA). 1988. *AMCA Publication One.* Arlington Heights, IL: Air Movement and Control Association.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). *Handbooks and Standards.* Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). *SMACNA Publications.* Arlington, VA: Sheet Metal and Air Conditioning Contractors National Sssociation.

American National Standards Institute (ANSI) Standards:

Z9.1 - *Open Surface Tanks--Operation*
Z9.2 - *Fundamentals Covering the Design and Operation of Local Exhaust Systems*
Z9.3 - *Design, Construction, and Ventilation of Spray Finishing Operations*
Z9.4 - *Ventilation and Safe Practice of Abrasive Blasting Operations*
Z9.5 - *Laboratory Ventilation. Fairfax, VA: American Industrial Hygiene Association.*

Burgess, W. A. et al. 1989. *Ventilation and Control of the Work Environment.* New York: Wiley Interscience.

Burton, D. J. 1989. *Industrial Ventilation Workbook.* Salt Lake City, UT: IVE, Inc.

Burton, D. J. 1990. *Indoor Air Quality Workbook.* Salt Lake City, UT: IVE, Inc.

Jorgensen, R. et al. 1983. *Fan Engineering.* 8th ed. Buffalo, NY: Buffalo Forge Co.

Homeon, W. C. L. 1963. *Plant and Process Ventilation.* New York: Industrial Press.

National Institute for Occupational Safety and Health (NIOSH). 1987. *Guidance for Indoor Air Quality Investigations.* Cincinnati: NIOSH.

OSHA *Field Operations Manual.* 1992. OSHA Instruction CPL 2.45B. Washington, D.C.: U.S. Government Printing Office.

U.S. Environmental Protection Agency (EPA). 1991. *Building Air Quality.*

APPENDIX III:3-1. Ventilation Primer

Selection

Before an appropriate ventilation system can be selected, the employer should study emission sources, worker behavior, and air movement in the area. In some cases the employer may wish to seek the services of an experienced professional ventilation engineer to assist in the data gathering. Table III:3-5 shows factors to consider when selecting a ventilation system. Combinations of controls are often employed for HVAC purposes.

Table III:3-5. **Selection Criteria for General and Local Exhaust Systems**

General exhaust ventilation (dilution ventilation) is appropriate when:

- Emission sources contain materials of relatively low hazard. (The degree of hazard is related to toxicity, dose rate, and individual susceptibility);
- Emission sources are primarily vapors or gases, or small, respirable-size aerosols (those not likely to settle);
- Emissions occur uniformly;
- Emissions are widely dispersed;
- Moderate climatic conditions prevail;
- Heat is to be removed from the space by flushing it with outside air;
- Concentrations of vapors are to be reduced in an enclosure; and
- Portable or mobile emission sources are to be controlled.

Local exhaust ventilating is appropriate when:

- Emission sources contain materials of relatively high hazard;
- Emitted materials are primarily larger-diameter particulates (likely to settle);
- Emissions vary over time;
- Emission sources consist of point sources;
- Employees work in the immediate vicinity of the emission source;
- The plant is located in a severe climate; and
- Minimizing air turnover is necessary.

General Exhaust (Dilution) Ventilation Systems

General exhaust ventilation, also called dilution ventilation, is different from local exhaust ventilation because instead of capturing emissions at their source and removing them from the air, general exhaust ventilation allows the contaminant to be emitted into the workplace air and then dilutes the concentration of the contaminant to an acceptable level (e.g., to the PEL or below). Dilution systems are often used to control evaporated liquids.

To determine the correct volume flow rate for dilution (Q_d), it is necessary to estimate the evaporation rate of the contaminant (q_d) according to the following equation:

$$\mathbf{q_d = \frac{(387)\ (\mathit{lbs})}{(\mathit{MW})(min)(\mathit{d})}}$$

where:
- **q_d** = evaporation rate in acfm
- **387** = volume in cubic feet formed by the evaporation of one lb-mole of a substance, e.g., a solvent
- **MW** = molecular weight of emitted material
- **lbs** = lbs of material evaporated
- **min** = time of evaporation
- **d** = density correction factor

The appropriate dilution volume flow rate for toxics is:

$$Q_d = \frac{q_d)(K_m)(10^6)}{C_a}$$

where:
- **Q_d** = volume flow rate of air, in acfm
- **q_d** = evaporation rate, in acfm
- **K_m** = mixing factor to account for poor or random mixing (Note: K_m = 2 to 5; K_m = 2 is optimum)
- **C_a** = acceptable airborne concentration of the material (typically half of the PEL).

The number of air changes per hour is the number of times one volume of air is replaced in the space per hour. In practice, replacement depends on mixing efficiency. When using dilution ventilation:

- position exhausts as close to emission sources as possible,
- use auxiliary fans for mixing,
- make sure employees are upwind of the dilution zone, and

- add make-up air where it will be most effective.

Local Exhaust Ventilation Systems

A typical local exhaust ventilation system is composed of five parts: fans, hoods, ducts, air cleaners, and stacks. Local exhaust ventilation is designed to capture an emitted contaminant at or near its source, before the contaminant has a chance to disperse into the workplace air.

FAN SELECTION

To choose the proper fan for a ventilation system, this information must be known:

- air volume to be moved;
- fan static pressure;
- type and concentration of contaminants in the air (because this affects the fan type and materials of construction); and
- the importance of noise as a limiting factor.

Once this information is available, the type of fan best suited for the system can be chosen. Many different fans are available, although they all fall into one of two classes: axial flow fans and centrifugal fans. For a detailed explanation of fans, see the ACGIH *Industrial Ventilation Manual.*

HOODS

The hood captures, contains, or receives contaminants generated at an emission source. The hood converts duct static pressure to velocity pressure and hood entry losses (e.g., slot and duct entry losses).

Hood entry loss (H_e) is calculated according to the following equation:

$$H_e = (K)(VP) = |SP_h| = VP$$

where:

K = loss factor

VP = velocity pressure in duct

$|SP_h|$ = absolute static pressure about 5 duct diameters down the duct from the hood.

A hood's ability to convert static pressure to velocity pressure is given by the coefficient of entry (C_e), as follows:

$$C_e = \frac{Q_{ideal}}{Q_{actual}} = \sqrt{\frac{VP}{SP_h}} = \sqrt{\frac{1}{1 + K}}$$

where: **K** = loss factor

VP = velocity pressure in duct

$\mathbf{SP_h}$ = Static pressure

To minimize air-flow requirements, the operation should be enclosed as much as possible, either with a ventilated enclosure, side baffles, or curtains. This helps both to contain the material and to minimize the effect of room air.

When using a capture or receiving hood, the hood should be located as close to the contaminant source as possible. Reducing the amount of contaminants generated or released from the process reduces ventilation requirements.

The hood should be designed to achieve good air distribution into the hood openings so that all the air drawn into the hood helps to control contaminants. Avoid designs that require that the velocities through some openings be very high in order to develop the minimum acceptable velocity through other openings or parts of the hood.

The purpose of most ventilation systems is to prevent worker inhalation of contaminants. For this reason, the hood should be located so that contaminants are not drawn through the worker's breathing zone. This is especially important where workers lean over an operation such as an open-surface tank or welding bench.

Hoods must meet the design criteria in the ACGIH *Industrial Ventilation Manual* or applicable OSHA standards. Most hood design recommendations account for cross-drafts that interfere with hood operation. Strong cross-drafts can easily reduce a hood's effectiveness by 75%. Standard hood designs may not be adequate to contain highly toxic materials.

The hood should be designed to cause minimum interference with the performance of work. Positioning access doors inside an enclosure that must be opened and closed often means that in practice the doors will be left open, and locating capture hoods too close to the process for the worker's convenience often means that the hood will be disassembled and removed. Hoods should never increase the likelihood of mechanical injury by interfering with a worker's freedom to move around machinery.

Two common misconceptions about hoods that are a part of local exhaust systems are:

- *Hoods draw air from a significant distance away from the hood opening, and therefore they can control contaminants released some distance away.* It is easy to confuse a fan's ability to blow a jet of air with its ability to draw air into a hood. Hoods must be close to the source of contamination to be effective.
- *Heavier-than-air vapors tend to settle to the workroom floor and therefore can be collected by a hood located there.* A small amount of contaminant in the air (1,000 ppm means 1,000 parts of contaminant plus 999,000 parts of air) has a resulting density close to that of air, and random air currents will disperse the material throughout the room

DUCTS

Air flows turbulently through ducts at between 2000-6000 feet per minute (fpm). Ducts can be made of galvanized metal, fiberglass, plastic, and concrete. Friction losses vary according to ductwork type, length of duct, velocity of air, duct area, density of air, and duct diameter.

AIR CLEANERS

The design of the air cleaner depends on the degree of cleaning required. Regular maintenance of air cleaners increases their efficiency and minimizes worker exposure. Different types of air cleaners are made to remove:

- particulates (e.g., precipitators, cyclones, etc.); and
- gases and vapors (e.g., scrubbers).

STACKS

Stacks disperse exhaust air into the ambient environment. The amount of re-entrainment depends on exhaust volume, wind speed and direction, temperature, location of intakes and exhausts, etc. When installing stacks:

- provide ample stack height (a minimum of 10 ft above adjacent rooflines or air intakes);
- place stack downwind of air intakes;
- provide a stack velocity of a minimum of 1.4 times the wind velocity;
- place the stack as far from the intake as possible (50 ft is recommended);
- place the stack at least 10 ft high on most roofs to avoid recirculation; and
- avoid rain caps if the air intake is within 50 ft of the stack.

Make-Up Air Systems

Exhaust ventilation systems require the replacement of exhausted air. Replacement air is often called make-up air. Replacement air can be supplied naturally by atmospheric pressure through open doors, windows, wall louvers, and adjacent spaces (acceptable), as well as through cracks in walls and windows, beneath doors, and through roof vents (unacceptable). Make-up air can also be provided through dedicated replacement air systems. Generally, exhaust systems are interlocked with a dedicated make-up air system.

Other reasons for designing and providing dedicated make-up air systems are that they:

- avoid high-velocity drafts through cracks in walls, under doors, and through windows;
- avoid differential pressures on doors, exits, and windows; and
- provide an opportunity to temper the replacement air.

If make-up air is not provided, a slight negative pressure will be created in the room and air flow through the exhaust system will be reduced.

HVAC

HVAC (heating, ventilating, and air-conditioning) is a common term that can also include cooling, humidifying or dehumidifying, or otherwise conditioning air for comfort and health. HVAC also is used for odor control and the maintenance of acceptable concentrations of carbon dioxide.

Air-conditioning has come to include any process that modifies the air for a work or living space: heating or cooling, humidity control, and air cleaning. Historically, air-conditioning has been used in industry to improve or protect machinery, products, and processes. The conditioning of air for humans has become normal and expected. Although the initial costs of air conditioning are high, annual costs may account only for about 1% to 5% of total annual operating expenses. Improved human productivity, lower absenteeism, better health, and reduced housekeeping and maintenance almost always make air-conditioning cost effective.

Mechanical air-handling systems can range from simple to complex. All distribute air in a manner designed to meet ventilation, temperature, humidity, and air-quality requirements established by the user. Individual units may be installed in the space they serve, or central units can serve multiple areas.

HVAC engineers refer to the areas served by an air handling system as **zones**. The smaller the zone, the greater the likelihood that good control will be achieved; however, equipment and maintenance costs are directly related to the number of zones. Some systems are designed to provide individual control of rooms in a multiple-zone system.

Both the provision and distribution of make-up air are important to the proper functioning of the system. The correct amount of air should be supplied to the space. Supply registers should be positioned to avoid disruption of emission and exposure controls and to aid dilution efforts.

Considerations in designing an air-handling system include volume flow rate, temperature, humidity, and air quality. Equipment selected must be properly sized and may include:

- outdoor air plenums or ducts;
- filters;
- supply fans and supply air systems;
- heating and cooling coils;
- humidity control equipment;
- supply ducts;
- distribution ducts, boxes, plenums, and registers;
- dampers;
- return air plenums;
- exhaust air provisions;
- return fans; and
- controls and instrumentation.

Recirculation

Although not generally recommended, recirculation is an alternative to air exchanging. Where used, recirculation should incorporate air cleaners, a by-pass or auxiliary exhaust system, regular maintenance and inspection, and devices to monitor system performance. Key points to consider in the use of recirculation are shown in Table III:3-6.

Table III:3-6. **Recirculation Criteria**

- Protection of employees must be the primary design consideration.
- The system should remove as much of the contaminant as can economically be separated from exhaust air.
- The system should not be designed simply to achieve PEL levels of exposure.
- The system should never allow recirculation to significantly increase existing exposures.
- Recirculation should not be used if a carcinogen is present.
- The system should have fail-safe features, e.g., warning devices on critical parts, back-up systems.
- Cleaning and filtering devices that ensure continuous and reliable collection of the contaminant should be used.
- The system should provide a by-pass or auxiliary exhaust system for use during system failure.
- The system should include feedback devices that monitor system performance, e.g., static pressure taps, particulate counters, amperage monitors.
- The system should be designed not to recirculate air during equipment malfunction.
- The employer should train employees in the use and operation of the system.

APPENDIX III:3-2. Glossary

Acfm: Actual cubic feet per minute of gas flowing at existing temperature and pressure. (See also scfm.)

ACH, AC/H (air changes per hour): The number of times air is replaced in an hour.

AIR DENSITY: The weight of air in lbs per cubic foot. Dry standard air at T=68° F (20° C) and BP = 29.92 in Hg (760 mm Hg) has a density of 0.075 lb/cu ft.

ANIOMETER: A device that measures the velocity of air. Common types include the swinging vane and the hot-wire anemometer.

AREA (A): The cross-sectional area through which air moves. Area may refer to the cross-sectional area of a duct, a window, a door, or any space through which air moves.

ATMOSPHERIC PRESSURE: The pressure exerted in all directions by the atmosphere. At sea level, mean atmospheric pressure is 29.92 in Hg, 14.7 psi, 407 in w.g., or 760 mm Hg.

BRAKE HORSEPOWER (bhp): The actual horsepower required to move air through a ventilation system against a fixed total pressure plus the losses in the fan. bhp=ahp × 1/eff, where eff is fan mechanical efficiency.

BRANCH: In a junction of two ducts, the branch is the duct with the lowest volume flow rate. The branch usually enters the main at an angle of less than 90.

CANOPY HOOD (Receiving Hood): A one- or two-sided overhead hood that receives rising hot air or gas.

CAPTURE VELOCITY: The velocity of air induced by a hood to capture emitted contaminants external to the hood.

COEFFICIENT OF ENTRY (C_e): A measure of the efficiency of a hood's ability to convert static pressure to velocity pressure; the ratio of actual flow to ideal flow.

DENSITY CORRECTION FACTOR: A factor applied to correct or convert dry air density of any temperature to velocity pressure; the ratio of actual flow to ideal flow.

DILUTION VENTILATION (General Exhaust Ventilation): A form of exposure control that involves providing enough air in the workplace to dilute the concentration of airborne contaminants to acceptable levels.

ENTRY LOSS” See Hood Entry Loss or Branch Entry Loss.

EVASE (pronounced eh-va-say): A cone-shaped exhaust stack that recaptures static pressure from velocity pressure.

FAN: A mechanical device that moves air and creates static pressure.

FAN LAWS: Relationships that describe theoretical, mutual performance changes in pressure, flow rate, rpm of the fan, horsepower, density of air, fan size, and sound power.

FAN CURVE: A curve relating pressure and volume flow rate of a given fan at a fixed fan speed (rpm).

FRICTION LOSS: The static pressure loss in a system caused by friction between moving air and the duct wall, expressed as in w.g./100 ft, or fractions of VP per 100 ft of duct (mm w.g./m; Kpa/m).

GAUGE PRESSURE: The difference between two absolute pressures, one of which is usually atmospheric pressure.

GENERAL EXHAUST: See Dilution Ventilation.

HEAD: Pressure, e.g. "The head is 1 in w.g."

HOOD: A device that encloses, captures, or receives emitted contaminants.

HOOD ENTRY LOSS (H_e): The static pressure lost (in inches of water) when air enters a duct through a hood. The majority of the loss usually is associated with a vena contracta formed in the duct.

HOOD STATIC PRESSURE (SP_h): The sum of the duct velocity pressure and the hood entry loss; hood static pressure is the static pressure required to accelerate air at rest outside the hood into the duct at velocity.

HVAC (HEATING, VENTILATION, AND AIR CONDITIONING) SYSTEMS: Ventilating systems designed primarily to control temperature, humidity, odors, and air quality.

INDOOR AIR QUALITY (IAQ), SICK-BUILDING SYNDROME, TIGHT-BUILDING SYNDROME: The study, examination, and control of air quality related to temperature, humidity, and airborne contaminants.

in. w.g. (inches of water): A unit of pressure. One inch of water is equal to 0.0735 in. of mercury, or 0.036 psi. Atmospheric pressure at standard conditions is 407 in. w.g.

INDUSTRIAL VENTILATION (IV): The equipment or operation associated with the supply or exhaust of air by natural or mechanical means to control occupational hazards in the industrial setting.

LAMINAR FLOW (also Streamline Flow): Air flow in which air molecules travel parallel to all other molecules; laminar flow is characterized by the absence of turbulence.

LOCAL EXHAUST VENTILATION: An industrial ventilation system that captures and removes emitted contaminants before dilution into the ambient air of the workplace.

LOSS: Usually refers to the conversion of static pressure to heat in components of the ventilation system, e.g., "the hood entry loss."

MAKE-UP AIR: See Replacement and Compensating Air.

MANOMETER: A device that measures pressure difference; usually a U-shaped glass tube containing water or mercury.

MINIMUM TRANSPORT VELOCITY (MTV): The minimum velocity that will transport particles in a duct with little settling; MTV varies with air density, particulate loading, and other factors.

OUTDOOR AIR (OA): Outdoor air is the "fresh" air mixed with return air (RA) to dilute contaminants in the supply air.

PITOT TUBE: A device used to measure total and static pressures in an airstream.

PLENUM: A low-velocity chamber used to distribute static pressure throughout its interior.

PRESSURE DROP: The loss of static pressure across a point; for example, "the pressure drop across an orifice is 2.0 in. w.g."

REPLACEMENT AIR (also, Compensating Air, Make-Up Air): Air supplied to a space to replace exhausted air.

RETURN AIR: Air that is returned from the primary space to the fan for recirculation.

scfm: Standard cubic feet per minute. A measure of air flow at standard conditions, i.e., dry air at 29.92 in. Hg (760 mm Hg) (gauge), 68° F (20° C).

SLOT VELOCITY: The average velocity of air through a slot. Slot velocity is calculated by dividing the total volume flow rate by the slot area (usually, $V_s = 2{,}000$ fpm).

STACK: A device on the end of a ventilation system that disperses exhaust contaminants for dilution by the atmosphere.

STANDARD AIR, STANDARD CONDITIONS: Dry air at 68° F (20° C), 29.92 in Hg (760 mm Hg).

STATIC PRESSURE (SP): The pressure developed in a duct by a fan; the force in inches of water measured perpendicular to flow at the wall of the duct; the difference in pressure between atmospheric pressure and the absolute pressure inside a duct, cleaner, or other equipment; SP exerts influence in all directions.

SUCTION PRESSURE: (See Static Pressure.) An archaic term that refers to static pressure on the upstream side of the fan.

TOTAL PRESSURE (TP): The pressure exerted in a duct, i.e., the sum of the static pressure and the velocity pressure; also called Impact Pressure, Dynamic Pressure.

TRANSPORT VELOCITY: See Minimum Transport Velocity.

TURBULENT FLOW: Air flow characterized by transverse velocity components as well as velocity in the primary direction of flow in a duct; mixing velocities.

VELOCITY (V): The time rate of movement of air; usually expressed as feet per minute.

VELOCITY PRESSURE (VP): The pressure attributed to the velocity of air.

VOLUME FLOW RATE (Q): Quantity of air flow in cfm, scfm, or acfm.

APPENDIX III:3-3. OSHA and Consensus Standards

1. OSHA STANDARDS

A. Health-Related Ventilation Standards

This list includes some, but not necessarily all, OSHA standards that address the control of employee exposure to recognized contaminants.

General Industry

29 CFR 1910.94(a)	Abrasive blasting
29 CFR 1910.94(b)	Grinding, polishing and buffing operations
29 CFR 1910.94(d)	Open surface tanks
29 CFR 1910.252(c)(2)(i)(a) and (b); (c)(2)(ii)	Ventilation for general welding and cutting--General
29 CFR 1910.252(c)(3)	Local exhaust hoods and booths
29 CFR 1910.252(c)(5)(ii)	Fluorine compounds--Maximum allowable concentration
29 CFR 1910.252(c)(12)	Cutting of stainless steels
29 CFR 1910.1003 to .1016	Carcinogens
29 CFR 1910.1025(e)(5)	Lead
29 CFR 1910.1027(f)(3)	Cadmium

Construction

29 CFR 1926.57(a)	Ventilation--General
29 CFR 1926.62(e)(3)	Lead
29 CFR 1926.63(f)(4)	Cadmium
29 CFR 1926.154(a)(1)	Temporary heating devices--Ventilation
29 CFR 1926.353(e)(1)	Ventilation and protection in welding, cutting and heating--General welding, cutting, and heating

Maritime

29 CFR 1915.32(a)(2)	Toxic cleaning solvents
29 CFR 1915.51(f)(1)	Ventilation and protection in welding, cutting and heating--General welding, cutting, and heating
29 CFR 1918.93(a)(1)(iii)	Ventilation and atmospheric conditions

B. Health-Related Ventilation Standards Other Than Airflow

This list includes some, but not necessarily all, OSHA standards that do not contain airflow requirements but are located in the health-related ventilation standards.

General Industry

29 CFR 1910.94(a)(3)(i)(d)	Abrasive blasting--Blasting cleaning
29 CFR 1910.94(a)(5)	Abrasive blasting--Personal protective equipment
29 CFR 1910.94(a)(6)	Abrasive blasting--Air supply and air compressors
29 CFR 1910.94(a)(7)	Abrasive blasting--Operational procedures and general safety
29 CFR 1910.94(d)(9)	Open surface tanks--Personal protection
29 CFR 1910.94(d)(10)	Open surface tanks--Special precautions for cyanide
29 CFR 1910.94(d)(11)	Open surface tanks--Inspection, installation and maintenance
29 CFR 1910.94(d)(12)	Open surface tanks--Vapor degreasing tanks

C. Fire and Explosion-Related Ventilation Standards

This list includes some, but not necessarily all, OSHA standards that are intended to prevent fire and explosions.

General Industry

29 CFR 1910.94(c)	Ventilation--Spray finishing operations
29 CFR 1910.103(b)(3)(ii)(b)	Hydrogen--Gaseous hydrogen systems--Separate buildings
29 CFR 1910.103(b)(3)(iii)(b)	Hydrogen--Gaseous hydrogen systems--Special rooms
29 CFR 1910.103(c)(3)(ii)(b)	Hydrogen--Liquid hydrogen systems--Separate buildings
29 CFR 1910.103(c)(3)(iii)(b)	Hydrogen--Liquid hydrogen systems--Special rooms
29 CFR 1910.104(b)(3)(xii)	Oxygen--Bulk oxygen systems--Ventilation
29 CFR 1910.104(b)(8)(vii)	Oxygen--Bulk oxygen systems--Venting
29 CFR 1910.106(d)(4)(iv)	Flammable and combustible liquids--Container and portable tank storage--Design and construction of inside storage room--Ventilation
29 CFR 1910.106(e)(3)(v)	Flammable and combustible liquids--Industrial plants--Unit physical operations--Ventilation

29 CFR 1910.106(f)(2)(iii)(a)	Flammable and combustible liquids--Bulk plants--Building--Ventilation
29 CFR 1910.106(h)(3)(iii)	Flammable and combustible liquids--Processing plants--Processing building--Ventilation
29 CFR 1910.107(b)(5)(i)	Spray finishing using flammable and combustible materials--Spray booths--Dry type overspray collectors
29 CFR 1910.107(d)(1) and (2)	Spray finishing using flammable and combustible materials--Ventilation--Conformance--General
29 CFR 1910.107(i)(9)	Spray finishing using flammable and combustible materials--Electrostatic hand spraying equipment--Ventilation
29 CFR 1910.108(b)(1) and (2)	Dip tanks containing flammable combustible liquids--Ventilation--Ventilation combined with drying
29 CFR 1910.307	Hazardous (classified) locations

D. Exceptions to 25% of the LEL for Fire and Explosion-Related Standards

This list includes but is not limited to OSHA standards that allow concentrations of flammable materials no greater than 10% of the LEL.

Maritime

29 CFR 1915.12(a)(2)	Precautions before entering--Flammable atmospheres and residues
29 CFR 1915.13(a)(2)	Cleaning and other cold work (flammable vapors)
29 CFR 1915.35(b)(1), (2), (3)	Painting--Paints and tanks coatings dissolved in highly volatile, toxic and/or flammable solvents
29 CFR 1915.36(a)(2)	Flammable liquids ventilation

Construction

29 CFR 1926.803(i)(2)	Compressed Air--Ventilation and air quality--(Tunnels)

E. Special Conditions Standards

This list includes some but not necessarily all OSHA standards that involve confined space operations and/or high- hazard contaminants specifically designated in the standard.

General Industry

29 CFR 1910.252(c)(2)(i)(c)	Welding, cutting and brazing--Health protection and ventilating--Ventilation for general welding and cutting--General
29 CFR 1910.252(c)(4)	Welding, cutting and brazing--Health protection and ventilating--Ventilation in confined spaces
29 CFR 1910.252(c)(5)(i)	Welding, cutting and brazing--Fluorine compounds
29 CFR 1910.252(c)(6)(i)	Welding, cutting and brazing--Zinc--Confined spaces
29 CFR 1910.252(c)(7)(i)	Welding, cutting and brazing--Lead--Confined spaces
29 CFR 1910.252(c)(8)	Welding, cutting and brazing--Beryllium
29 CFR 1910.252(c)(9)	Welding, cutting and brazing--Cadmium
29 CFR 1910.252(c)(10)	Welding, cutting and brazing--Mercury

Construction

29 CFR 1926.154(a)(2)	Temporary heating devices--Ventilation
29 CFR 1926.353(b)(1)	Ventilation and protection in welding, cutting and heating--Welding, cutting and heating in confined spaces
29 CFR 1926.353(c)(1) and (2)	Ventilation and protection in welding, cutting and heating--Welding, cutting or heating of metals of toxic significance
29 CFR 1926.800(k)	Tunnels and shafts--Air quality and ventilation

Maritime

29 CFR 1915.12(b)(2)	Precautions before entering--Toxic atmospheres and residues
29 CFR 1915.12(c)(2)	Precautions before entering--Oxygen deficient atmospheres
29 CFR 1915.12(d)	Precautions before entering--Exceptions
29 CFR 1915.34(a)(4)	Mechanical paint removers--Power tools--(paint dust)
29 CFR 1915.51(c)(3)	Ventilation and protection in welding, cutting and heating--Welding, cutting and heating confined spaces
29 CFR 1915.51(d)(1) and (2)	Ventilation and protection in welding, cutting and heating--cutting or heating of metals of toxic significance.

2. CONSENSUS STANDARDS

Standard	*Source*	*Title*
Air filters		
ASHRAE 52-76	ASHRAE	Methods of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
Exhaust systems		
ANSI Z33.1-1982 NFPA 91-1983	NFPA	Installation of Blower and Exhaust Systems for Dust, Stock, Vapor Removal or Conveying (1983)
ANSI Z9.2-1979	AIHA	Fundamentals Governing the Design and Operation of Local Exhaust Systems
ANSI Z9.1-1977	AIHA ASHRAE	Practices for Ventilation and Operation of Open-Surface Tanks
ANSI Z9.3-1964	ANSI	Safety Code for Design, Construction, and Ventilation of Spray Finishing Operations (reaffirmed 1971)
ANSI Z9.4-1979 ANSI Z9.4A-1981	ANSI	Ventilation and Safe Practices of Abrasives Blasting Operations
ANSI Z9.5-1992	AIHA	Laboratory Ventilation
Fans		
AMCA 99-83 ANSI/UL 507-1976	AMCA UL	Standards Handbook Electric Fans (1977)
ASHRAE 51-75 AMCA 210-74	ASHRAE	Laboratory Methods of Testing Fans for Rating
ANSI/ASHRAE 87.7-1983	ASHRAE	Methods of Testing Dynamic Characteristics of Propeller Fans--Aerodynamically Excited Fan Vibrations and Critical Speeds
AMCA 210-74	AMCA	Laboratory Methods of Testing Fans for Rating Purposes
AMCA 99-2404-78	AMCA	Drive Arrangement for Centrifugal Fans
AMCA 99-2406-83	AMCA	Designation for Rotation and Discharge of Centrifugal Fans
AMCA 99-2407-66	AMCA	Motor Positions for Belt or Chain Drive Centrifugal Fans
AMCA 99-2410-82	AMCA	Drive Arrangement for Tubular Centrifugal Fans

CONSENSUS STANDARDS (Continued)

Industrial duct

SMACNA	SMACNA	Round Industrial Duct Construction
SMACNA	SMACNA	Rectangular Industrial Duct Construction

Venting

NFPA 68	NFPA	Guide for Explosion Venting
NFPA 204M	NFPA	Guide for Smoke and Heat Venting
SMACNA	SMACNA	Guide for Steel Stack Design and Construction (1983)

Ventilation

NFPA 96	NFPA	Vapor Removal from Cooking Equipment (1984)
NFPA-88A, 88B	NFPA	Parking Structures (1979); Repair Garages (1979)
ASHRAE 62-1989	ASHARAE	Ventilation for Acceptable Indoor Air Quality
ACGIH	ACGIH	Industrial Ventilation

3. SOURCES OF CONSENSUS STANDARDS

Copies of the consensus standards are published and available directly from the organization issuing the standard. A minimal fee is often required.

Source	***Organization***
ACGIH	American Conference of Governmental Industrial Hygienists 6500 Glenway Ave., Bldg. D-5 Cincinnati, OH 45211
AIHA	American Industrial Hygiene Association 2700 Prosperity Ave., Suite 250 Fairfax, VA 22031-4319
AMCA	Air Movement and Control Association 30 W. University Dr. Arlington Heights, IL 60004
ANSI	American National Standards Institute 1430 Broadway New York, NY 10018

SOURCES OF CONSENSUS STANDARDS (continued)

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329
NFPA	National Fire Protection Association Batterymarch Park Quincy, MA 02269
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association 8224 Old Courthouse Rd. Vienna, VA 22180
UL	Underwriters Laboratories Inc. 333 Pfingsten Rd. Northbrook, IL 60062

APPENDIX III:3-4.
Troubleshooting an Exhaust System – Some Helpful Hints

Most of the following checks can be made by visual observation and do not require extensive measurements.

If air flow is low in hoods, check:

- Fan rotation (reversed polarity will cause fan to run backwards; a backward-running centrifugal fan delivers only 30-50% of rated flow);
- Fan RPM;
- Slipping belt;
- Clogged or corroded fan wheel and casing;
- Clogged ductwork (high hood static pressure and low air flow may indicate restricted ducts; open clean-out doors and inspect inside ducts);
- Closed dampers in ductwork;
- Clogged collector or air cleaning devices;
- Weather cap too close to discharge stack (a 3/4 duct- diameter gap should exist between cap and stack; weather caps are not recommended);
- Poorly designed ductwork (short radius elbows); (branch entries enter main duct at sharp angles); (duckwork diameter too small for the air-flow needed; and
- Lack of make-up air (high negative pressures affect propeller fan system output; lack of supplied make-up air causes high airflow velocities at doors and windows).

If air flow is satisfactory in a hood but contaminant control is poor, check:

- Crossdrafts (from process air movements); (worker-cooling fans and air-supply systems); (open doors and windows);
- Capture velocity (work operation too far from hood opening);
- Hood enclosure: (door, baffles, or sides may be open or removed); and
- Hood type: (canopy hoods are inappropriate for toxic materials).