Emission and Exposure Control-Related Ventilation Regulations, Standards and Guidelines in the United States of America

D. Jeff Burton, PE, CIH (VS)

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(email: jeff@eburton.com
web: www.eburton.com)

1.0 Regulations and Codes

OSHA is the primary federal agency that produces ventilation-related regulations. (A "regulation" implies the necessity by law of complying with its provisions.) Its coverage is nationwide.

Generally, OSHA ventilation regulations are outdated and difficult to update and therefore are considered secondary to consensus standards. (See Paragraph 3.) Compliance with the following federal OSHA regulations is generally assumed if the actual exposure to employees is within federal Permissible Exposure Limits (PEL). However if an employee exposure exceeds the PEL, the employer may be cited for not meeting ventilation standard requirements.

OSHA has promulgated a number of regulations and codes under its authority which refer to "engineering controls." In regulations found in the 29CFR1910.1000 series (chemical exposure to employees), for example, there are over 80 references to "engineering controls." Two of the most important OSHA ventilation-related control regulations are described here. Others may be accessed using the OSHA CD-ROM Index of OSHA Regulations, or contact OSHA, 200 Constitution Ave, NW., Washington, DC 20210.

1.1 OSHA — 29 CFR 1910.94; Ventilation.

This regulation describes four standards adopted from ANSI Z9 standards (circa 1969) on ventilation of open surface tanks, spray finishing operations, abrasive blasting, and grinding, buffing, and polishing.

Since 1969, the ANSI Z9 standards have been revised. Which should you use—the older but "mandatory" OSHA compliance codes or the more current "voluntary" consensus standards? OSHA policy, cost-effectiveness, and liability-avoidance concerns all suggest that adherence with the upgraded versions of the standards is appropriate. (See Paragraph 2.0 for the more-recent ANSI/AIHA Z9 standards.)

1.2 OSHA. 29 CFR 1910.1450; Occupational Exposures to Hazardous Chemicals in Laboratories, May 1, 1990.

This rule covers most labs that use hazardous chemicals. Employers are obligated to maintain lab employee exposures to below the OSHA PEL through the formulation and implementation of a Chemical Hygiene Plan (CHP) which includes engineering controls. Important provisions related to engineering controls include: (numbers in parenthesis refer to standard paragraph numbers)

- (e.3.iii) Requirements to incorporate measures to assure the proper use and functioning of fume hoods. The regulation does not specify ventilation rates or face velocities.
- (e.3.iii) Measures that must be taken to ensure adequate performance of ventilation equipment.
- (e.3.viii.B) Containment devices (such as glove box hoods) that must be used with certain carcinogenic materials.

The regulation provides (in an Appendix) NRC recommendations concerning engineering control practices in laboratories. Although not mandatory, these provisions are viewed as important by those reading or enforcing the standard. Requirements related to engineering controls are noted below:

- (A.3) Provision for adequate ventilation.
- (C.1) Requirements for (a) an appropriate general ventilation system with air intakes and exhausts located so as to avoid intake of contaminated air, (b) well-ventilated stockroom and storerooms, and (c) lab hoods.
- (C.2) Hoods and other control devices testing and maintenance provisions.
- (C.3.) The work conducted should be compatible with the quality of ventilation control provided.
- (C.4.a) General ventilation requirements related to: breathing air, replacement air, buildup of concentrations of hazardous airborne chemicals, and flow of air from non-lab spaces to labs.
- (C.4.b) Lab hoods and continuous monitoring devices to allow convenient confirmation of hood performance.
- (C.4.c) Other exhaust ventilation systems.
- (C.4.d) Exhaust air from glove boxes and isolation rooms and scrubbers or filters before release into regular exhaust duct systems.
- (C.4.e) Modifications to ventilation systems after testing has confirmed the continued protection of workers.
- (C.4.g) Air turbulence in the lab and within hoods.
- (C.4.h) Ventilation system evaluations.

2.0 Local Building and Fire Codes

Building and fire codes vary from location to location and may include differing rules for control ventilation. Such codes have generally been adopted from consensus standards. (See Paragraph 3.)

2.1 Types. Building and fire codes are normally adopted at the local level (city, county, state) and are enforced by building inspectors. Model building codes are written and developed by several organizations:

-- the Basic Building Code (BBC) of the Building Officials and Code Administrators (BOCA),
-- the Uniform Building Codes (UBC, UMC) of the International Conference of Building Officials (ICBO), and
-- the Southern Building Code (SBC) by the Southern Building Code Congress International.

2.2 Applications. Building and fire codes are applied at the time a building is built and are not generally retroactive to older buildings unless remodeling is performed which requires a building permit. However, economic forces often influence building owners to bring existing facilities up to current codes and standards of good engineering practice. See the next paragraph.

3.0 Consensus Standards

America is known as a free but litigious society, unburdened by numerous mandatory government codes and regulations. Instead, "voluntary" standards of good practice are often generated using a consensus process. Compliance with such standards is determined through the civil judicial process (as opposed to a government inspector who inspects and determines compliance with mandatory rules and regulations). As such, the role of consensus-developed "standards of practice" is very important in American society.

Every building owner and employer is open to accusations of "negligence" (and subsequent negative financial and legal outcomes) if current ventilation "standards of practice" are not known and followed. Currently, good standards of practice are the most important factor in the design and operation of modern control ventilation systems in the USA.

The strengths of this consensus standards approach are: (1) standard requirements are determined on a consensus basis with all stakeholders involved, (2) standards are maintained up-to-date and represent the state of the art, (3) stake holders are willing to comply voluntarily, (4) the process is cost-effective, (5) standards tend to be performance oriented (as opposed to specification oriented) and flexible, (6) such standards tend to be user-friendly, and (7) they usually include "how-to-comply" teaching tools.

Major current control ventilation "standards of practice" are consensus standards developed through ANSI, AIHA, ASHRAE, and other standards-setting organizations. (See Paragraph 6 for a list.) The following paragraphs present the most important standards.

3.1 ANSI/AIHA Z9. Health and Safety Standards for Exhaust Systems Series. (See Paragraph 6 for addresses for standard-setting organizations.)

These standards describe good practices in the design, operation, and maintenance of ventilation (e.g., LEV) equipment to provide a safe atmosphere in industrial, manufacturing, or construction operations by removing harmful substances by either local exhaust or general ventilation and safely disposing of such substances, and such supplementary standards on personal protection as may be necessary to prescribe methods for the protection of workers. Use latest versions!

3.1.1 ANSI/AIHA Z9.1. Open Surfaced Tanks - Ventilation and Operation

This standard describes general and specific requirements for the building, operation, and maintenance of ventilation systems used to control emissions from open surfaced tanks (e.g., in plating and metal cleaning operations). Sections include coverage of the following topics: standard scope and purpose, references and other standards, terms and definitions, locations and applications, design and construction of spray booths and rooms, ventilation requirements, velocity and airflow requirements, makeup air requirements, pollution control, use of fixed and portable ovens in spray areas, personal protective devices, and good work practices.

3.1.2 ANSI/AIHA Z9.2. Fundamentals Governing the Design and Operation of Local Exhaust Systems

The most important industrial ventilation standard in the USA, this outstanding standard describes general requirements for the building, operation, and maintenance of local exhaust ventilation systems used to control emissions and employee exposures. Sections include coverage of the following topics: standard scope and purpose, references and other standards, terms and definitions, locations and applications, design and construction of spray booths and rooms, ventilation requirements, velocity and airflow requirements, makeup air requirements, pollution control, use of fixed and portable ovens in spray areas, personal protective devices, and good work practices.

3.1.3 ANSI/AIHA Z9.3. Spray Finishing Operations - Safety Code for Design, Construction and Ventilation

This standard describes general and specific requirements for the building, operation, and maintenance of ventilation systems used to control emissions from spray finishing operations (e.g., paint spraying of materials). Sections include coverage of the following topics: standard scope and purpose, references and other standards, terms and definitions, hazards from spray finishing, enclosures, exhaust ventilation systems, paint booths, personal protective devices, and good work practices.

Revisions/additions being contemplated include: protection of persons outside spray booths and maintenance personnel, open floor spray operations, and harmonization with NFPA 33.

3.1.4 ANSI/AIHA Z9.4. Abrasive Blasting Operations - Ventilation and Safe Practices for Fixed Location Enclosures

This standard describes general and specific requirements for the building, operation, and maintenance of ventilation systems used to control emissions from abrasive blasting operations (e.g., using crystalline silica blasting to clean metal surfaces). Sections include coverage of the following topics: standard scope and purpose, references and other standards, terms and definitions, dust hazards from abrasive blasting enclosures, exhaust ventilation systems, personal protective devices, air supply and air compressors for breathing air, and good work practices.

3.1.5 ANSI/AIHA Z9.5. Laboratory Ventilation

This standard describes general and specific requirements for the building, operation, and maintenance of laboratory ventilation systems. Sections include coverage of the following topics: standard scope, references, terms and definitions, general requirements, lab fume hoods, ductwork, fans, storage facilities, catastrophe potentials, noise control, and good work practices.

It was being revised in 1999; the new version was published in 2000.

3.1.6 ANSI/AIHA Z9.6. Exhaust Systems for Grinding, Buffing, and Polishing

This standard describes general and specific requirements for the building, operation, and maintenance of ventilation systems used to control emissions from grinding, polishing, and buffing operations (e.g., grinding or polishing metal surfaces using grinding or polishing wheels). Sections include coverage of the following topics: standard scope and application, references and other standards, terms and definitions, hazards from materials created during grinding, polishing, and buffing, ventilation system design and operation, testing of exhaust ventilation systems, personal protective equipment, hood and enclosure design and operation, and work practices.

3.1.7 ANSI/AIHA Z9.7. Recirculation of Air from Industrial Process Exhaust Systems

This standard describes general and specific requirements for the building, operation, and maintenance of recirculating exhaust ventilation system. Sections include coverage of the following topics: standard scope and application, references and other standards, terms and definitions, exhaust system design including provisions for system configuration, hazard evaluation, special materials, and discharge, air cleaning equipment, monitoring devices, maintenance, record keeping, and signs.

3.2.1 ASHRAE/ANSI Standard 62.1— Ventilation for Acceptable Indoor Air Quality.

This is the premier engineering standard for maintaining adequate indoor air quality in commercial, institutional, and industrial buildings. The 2004 version is similar to versions with four important addenda: (Another dozen or so are in various stages of approval.)

a. References to tobacco smoking have been removed.
b. Compliance with the standard does not necessarily guarantee acceptable indoor air quality.
c. Carbon dioxide, when used as an indicator of outdoor air delivery, has been changed from a limit of "1000 ppm" to "background-plus-650 ppm."
d. References to thermal comfort have been removed (because it is covered in ASHRAE 55-1992).

The following topics are covered in the sections dealing with engineering control:

4.0 The Ventilation Rate Procedure and the Indoor Air Quality Procedure.
4.2 Ventilation supplied throughout the occupied zone.
5.4 Variable Air Volume Systems (VAV)
5.5 and 5.6 Growth and dissemination of microorganisms.
5.5 Inlets and outlets located to avoid contamination of the makeup air.
5.7 Exhaust systems remove contaminants at the source.
5.8 Adequate makeup air.
5.9 and 5.10 Particle filters and gas/vapor scrubbers.
5.11 Relative humidity.
5.12 AHU condensate pans designed for self drainage.

3.2.2 ASHRAE/ANSI Standard 110 — Method of Testing Performance of Laboratory Fume Hoods

This standard describes general and specific requirements for testing of laboratory fume hoods. Sections include coverage of the following topics: standard scope and purpose, references and bibliography, terms and definitions, instrumentation and equipment for testing, testing conditions, flow visualization and velocity determinations, tracer gas test procedures, and an appendix. The Foreword discusses good work practices and factors which could effect the performance of a lab fume hood (e.g., cross-drafts at the face of the hood.)

The standard describes three basic test approaches: flow visualization (e.g., using smoke), face velocity measurements (e.g., using a velometer), and a containment test (using a fixed emission rate of a tracer gas in the hood with measurement of tracer gas concentrations at the breathing zone of a manikin standing in front of the hood).

In the containment test, a tracer gas (e.g., SF_6) is released at a rate of 4 liter/minute inside the hood from a single dispersion nozzle. Three 5-minute samples of tracer gas are obtained in the breathing zone (BZ) of a manikin standing at three different positions in front of the hood. Results are reported as:

AM yy	AI yy	AU yy
SME-AM yy	SME-AI yy	SME-AU yy

"yy" refers to the BZ concentration, typically 0.01 ppm to 0.1 ppm. AM, AI, and AU refer to: As

Manufactured, As Installed, and As Used—three separate tests in different conditions. SME—Sash Movement Effect—refers to a separate test conducted when the sash moves.

ASHRAE 110-1995 (in its non-required comments) suggests that a hood with a rating of AM 0.05 and AU0.1 may provide acceptable containment. However, the standard does not specify a minimum acceptable performance. ASHRAE's test is quite detailed with specific dimensions and procedures. The estimated time of testing: 2 hours per hood.

3.2.3 ASHRAE/ANSI Standard 55. Thermal Comfort.

This important engineering control standard suggests ranges of temperature and humidity to which 80-90% of occupants will find the environment thermally acceptable. Satisfaction with air temperature, humidity, and movement is a complex subject. This standard attempts to predict what conditions of temperature, humidity, activity, clothing, air movement, and radiant heat sources which will satisfy 80-90% of the regular occupants. In its simplest form, the Standard suggests that in winter, for people typically clothed, temperatures should range from 68-74.5°F. For summer, the temperature should be 73-79°F. These temperatures take into account some allowance for energy conservation (e.g., cooler in winter, warmer in summer.) Relative humidities should be maintained within the range 30-60%.

3.2.3 ASHRAE/ANSI Standard 52.1 and 52.2: Filter Testing.

These standards describe methods for testing air filters. The older standard (ASHRAE 52.1) tests on the basis of "weight retained in the filter." The newer standard (ASHRAE 52.2) provides results in terms of particle diameter and is a more rigorous measure of the performance of filters. Both standards will coincide for a few years after which ASHRAE 52.1 will be discontinued.

ASHRAE 52.1-1992, Method of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter, the older standard, provides information on air filter testing. In this standard, the three performance characteristics of most importance are:

- A filter's efficiency in removing particles from the air stream.
- The resistance to air flow through the filter.
- The time interval between cleaning or replacement.

ASHRAE 52.1 describes two testing or rating procedures:

- The "ASHRAE Dust Spot Efficiency" test, sometimes referred to as the "52 Atmospheric" test.
- The "ASHRAE Arrestance" test, sometimes referred to as the "Weight Arrestance" test.

ASHRAE 52.1 defines testing equipment for carrying out the tests. It is intended for filters with air flow capacities over Q = 500 cfm and filter efficiencies at or less than 98%. (HEPA filters are tested under different standards, e.g., ASTM.) Some application are shown below.

3.3 ASTM D5116-90: Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Materials from Indoor Materials/Products; **D3960:** Standard Practice for Determining VOC content of Paint and Related Coatings; **E1330-90:** Test method for Formaldehyde Levels form Pressed Wood; see Annual Book of Standards, Vol 11.03.

These standards provide useful information for those wishing to determine emission factors for various materials. Useful in determining (and controlling) emissions from building materials to protect air quality, these standards will see increased importance in coming years as building materials and furnishings are specified by emission rates.

3.4 NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.

This important standard applies to most lab operations and contains requirements for lab experiments and for handling and storage of chemicals in the lab.The standard also includes provisions for hoods using perchloric acid. Although devoted primarily to fire protection, it contains many provisions which impact engineering controls used for emission and exposure protection. Major topics of Section 6 "Laboratory Ventilating Systems and Hood Requirements" are summarized below:

6.2 Lab hoods not be relied upon to provide explosion protection.
6.4 Location of outdoor air intakes.
6.4 Negative air pressure relative to corridors or adjacent non-lab areas.
6.4 Air supply diffusers.
6.5 Air recirculated.
6.5 Air exhausted from lab work passing unducted through other areas.
6.5 Lab hood face velocities.
6.6 Ducts materials.
6.6 Controls and dampers.
6.9 Hood baffles.
6.9 Air flow indicators.
6.10 Lab hoods in areas of minimum air turbulence.
6.11 Automatic fire dampers.
6.13 Lab hoods labeled.
6.13 Signage.
6.14 Inspections.
A-6.5 Ductless hoods.
A-6.8 Exhaust stacks.

4.0 Guidelines/Criteria Documents/Position Statements

Guidelines are often considered "standards of practice" when government regulations and consensus standards are not available. The following paragraphs present some of the most widely used.

4.1 ASHRAE Guideline. "Guideline for the Commissioning of HVAC Systems," 1989; Guideline 4-1993, "Preparation of O&M Documentation for Building Systems."

These guidelines provide information on commissioning, operation and maintenance of engineered systems for the control of the environment.

Commissioning is a process in which a new engineering control system's performance is identified, verified, and documented to assure proper operation and compliance with codes, standards, and design intentions. Commissioning often requires tests and demonstrations to verify that the system operates properly. Troubleshooting and maintenance activities also require system testing.

Most of the activities of commissioning are the same as O&M practices, e.g., one must be able to access the equipment to measure temperatures, read gages, and see the equipment during operation. Designing for "commissioning" achieves the same needs as designing for easy testing, troubleshooting, and servicing.

4.2 NSF, National Sanitation Foundation Standard No. 49 for Class II Biohazard Cabinetry (Laminar Flow), 2002.

Since 1976 the National Sanitation Foundation has issued standards for Class II biosafety or biohazard ventilated cabinets. Most recently revised in 1992, NSF Standard No. 49 describes appropriate materials of construction, design, placement, testing, and performance requirements. NSF No. 49 also requires three biological challenge tests be passed to obtain NSF certification (called "listing.") The NSF mark appears on all Class II cabinets listed by the Foundation.

4.3 USEPA and **NIOSH**, Building Air Quality -- A Guide for Building Owners and Facility Managers, EPA/400/1-91/033, 227 pages, December 1991. Call 202-260-2080 to order.

This 215-page text covers the following engineering control topics related to air quality: factors effecting air quality, managing buildings for good IAQ, diagnosing IAQ problems related to engineered systems, mitigating problems, controlling water, moisture, mold, radon, and air contaminants.

5.0 Reference Texts

Some association-developed and privately written reference texts have achieved the status of "standards of practice" when government regulations, consensus standards and guidelines are not available. The following paragraphs describe some of the most important references.

5.1 Industrial Ventilation Manual, ACGIH, 28th Edition; ISBN 1-882417-42-9;; about 700 pages. (See Paragraph 6 for addresses.)

Considered the "bible" of industrial ventilation in the USA, this important resource covers the following topics: general principles of airflow, dilution ventilation, local exhaust ventilation, air cleaning equipment, fans, replacement and recirculation systems, an overview of IAQ, testing of ventilation systems, and detailed descriptions of about 200 specific operations.

5.2 Heating and Cooling for Man in Industry, AIHA; ISBN: NA. ©200x; 140 pages.

Recently revised, the book contains much useful information covering: planning, control of radiant heat, ventilation for temperature control, adding and removing heat from a space, moisture control, heat conservation and recovery, air distribution, air filters, testing, instrumentation, and more.

5.3 Air Pollution Engineering Manual, AWMA; ISBN 0-442-00843-0; Van Nostrand Reinhold, NY, NY; 920 pages; 1992.

This classic text, updated in 1992, presents numerous approaches to the control of emissions from industrial processes. Chapter topics include general control of gaseous pollutants, particulates, fugitive emissions, odors, combustion sources, waste incineration sources, evaporative loss sources, surface coatings, and control of emissions from numerous industrial processes (e.g., chemical, food, metals, mineral products, pharmaceuticals, petroleum).

5.4 Hemeons Plant and Process Ventilation, edited by D. Jeff Burton; ISBN 1-56670-347-6; 3rd Edition;1999, 470 pages; CRC Press Inc, NY, NY 10016.

Known around the world as the "classic industrial ventilation text," and previously published in 1963, this extremely useful book has been updated and republished by CRC Press. Book covers dynamic properties of airborne contaminants, the principles of dispersion mechanisms, local exhaust ventilation, dilution, control of hot processes, push-pull hoods, troubleshooting techniques, materials handling ventilation, testing, and air cleaning.

5.5 Industrial Hygiene Engineering, edited by John T. Talty; ISBN 0-81551-17-52; 2nd Edition, 1988, Noyes Data Corp., Park Ridge, NJ; 825 pages.

Book covers all facets of engineering control (e.g., substitution, process control, ventilation, isolation, source modification) in sixty-one chapters. Major section topics include general approaches to engineering control, industrial ventilation, thermal stress, sound and noise, industrial illumination, radiation, ergonomics, hazardous materials handling, waste disposal, and costs.

6.0 Organizations Setting Standards of Practice

The following organizations are involved in the preparation of various types of "standards of practice" for the USA. All address are USA.

AIHA (AIH Journal, Engineering Committee, former ANSI Z9 Secretariat, training courses)
2700 Prosperity Ave, Suite 250, Fairfax, VA 22031
[www.aiha.org]

ACGIH (Engineering control publications; IV Manual, AOEH Journal)
1330 Kemper Meadow Drive, Cincinnati, Ohio 45240 [www.acgih.org]

AMCA (Fans and dampers; numerous publications)
30 W. University Drive Arlington Heights, Ill 60004
[www.amca.org]

ASHRAE (Numerous books, articles, standards; journal)
1791 Tullie Circle, NE, Atlanta, GA 30329
[www.ashrae.org]

ASSE (Secretariat for ANSI A9)
520 N. Northwest Hwy
Park Ridge, IL USA 60668

ASTM (Standards and guidelines; Subcommittee D22.05, testing for IAQ)
1916 Race Street, Philadelphia, PA 19103 [tel USA 610-832-9500] [www.astm.org]

NFPA (Standards, publications)
1 Batterymarch Park, Quincy, Mass 02269
[www.nfpa.org]

NIOSH (lists of publications, studies of laboratory health and safety, standards)
4646 Columbia Parkway, Cincinnati, Ohio 45226

NSF (Information on biosafety hoods) Box 1468, Ann Arbor, MI 48105

SMACNA (Publications, sheet metal, ductwork)
4201 Lafayette Center Drive, Chantilly, VA 22021
[www.smacna.org]

SEMI International (Standards for the semiconductor industry, e.g., S2, S6)
805 E. Middlefield Road, Mountain View, CA 94043
[tel USA 415-762-5587]

Use latest versions of all standards and guidelines.