

Document Number: GLP-QS-1800.1.7

Revision: D

Effective Date: 3/22/2022

Expiration Date: 3/22/2027

Occupational Health Programs Manual – Chapter 7

Local Exhaust Ventilation

Approved by: QS/Chief, Safety and Health Division

Distribution: BMS Library

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Cleveland, OH 44135**

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Change Record

Revision	Effective Date	Expiration Date	GRC25, Change Request #	Description
B	4/17/2012	4/17/2017	272	Added contents to the appendix. Driving requirements here added to 6.1 responsibilities
Change 1	4/11/2014	4/17/2017	272	Administrative change to add front cover and change history log to comply with NPR 1400.1, and added "The GRC shall implement requirements of NPR1800.1C" in Section 4.0 Policy.
Change 2	11-6-14	4-17-2017	N/A	Administrative changes to update SHed organization references, location of ventilation share drive, and updated LEV tags (GRC760 forms).
Change 3	9/30/2015)	4/17/2017	N/A	Administrative change to remove hyperlinks.
C	5/18/2017	5/18/2022	17-012	Administrative changes to the standardized naming convention of verbal forms for describing requirements in Applicability Section 2.0 and Policy (Measurement and Verification) Section 4.0.
D	3/22/2022	3/22/2027	22-004	Administrative change to update references to the current edition in use, Clarify appendix C – Industrial Ventilation Manual attachments, and Reformatted Section Personnel Training and or Certification.

***Include all information for each revision. Do not remove old revision data. Add new rows to table when space runs out by pressing the tab key in the last row, far right column.*

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Chapter 7—Local Exhaust Ventilation (LEV)

***NOTE:** The current version of this chapter is maintained and approved by the Safety and Health Division (SHeD) The last revision date of this chapter was March 22, 2022. The current version is located on the Glenn Research Center (GRC) intranet within the BMS Library. Approved by the Chief of Safety and Health Division.*

1.0 PURPOSE

This chapter establishes minimum requirements for Local Exhaust Vent (LEV), an engineering system used for controlling occupational exposure to air contaminants at GRC.

2.0 APPLICABILITY

2.1 The provisions of this document are applicable to NASA Glenn Research Center personnel and contractors associated with the review of SHeD program chapters.

2.2 In this chapter, all mandatory actions (i.e., requirements) are denoted by statements containing the term “shall.” The terms “may” denotes a discretionary privilege or permission, “can” denotes statements of possibility or capability, “should” denotes a good practice and is recommended, but not required, “will” denotes expected outcome, and “are/is” denotes descriptive material.

3.0 BACKGROUND

3.1 The GRC personnel use a variety of materials, ranging from inert gases to highly toxic, carcinogenic materials. An LEV is a specific engineering control used to minimize worker exposure to airborne hazardous substances. An LEV system typically consists of at least a hood to capture or contain the contaminants, ducts to transport the air containing the contaminants, and a fan to power the system. Depending on the system and the level of contaminant generation, the LEV may be equipped with an air filtration unit, such as high-efficiency particulate air (HEPA) filters, scrubber, electrostatic precipitator, or other air pollution control device.

3.2 Examples of LEV at GRC include laboratory fume hoods, exhausted gas cabinets, snorkels (e.g., welding fume control), canopies, and spray-painting booths. The LEV for toxic materials may require an air pollution permit for operation. Please refer to the GRC Environmental Programs Manual (EPM), Chapter 4, “Air Pollution Control” for additional information.

4.0 POLICY

4.1 Construction, installation, inspection, and maintenance of all LEV systems shall comply with the Occupational Safety and Health Administration (OSHA) standards, as well as with national consensus standards, such as the American National Standards Institute (ANSI) and the American Conference of Governmental Industrial Hygienists (ACGIH). The GRC shall follow the requirements of NASA Procedural Requirement (NPR) 1800.1C.

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4.2 Compliance with the responsibilities and requirements of this chapter are measured and verified through the use of programmatic self-assessments, regulatory, and Agency audits and internal field inspections.

5.0 RESPONSIBILITIES

5.1 Occupational Health Branch (OHB) LEV Program Lead

- a. Give guidance on the requirements for conducting LEV system surveys.
- b. Provide guidance on the requirements of Federal, State, and local ventilation regulations, as well as on standard industry practice guidelines.
- c. Update the Industrial Hygiene Procedure: Testing LEV Systems manual (see APPENDIX C).
- d. Provide training on LEV systems.

5.2 OHB Technician/Specialist

- a. Maintain database for LEV systems.
- b. Follow the Industrial Hygiene Procedure: Testing LEV Systems manual (see APPENDIX C).

5.3 Safety Inspectors

Shall report any LEV system not in compliance to the operations team technician, program lead or industrial hygienist.

5.4 OHB Chief

Shall provide final approval of the Testing LEV Systems manual.

5.5 Waste Management

Shall ensure that potentially contaminated ventilation equipment is disposed of properly.

5.6 Area Safety Committee Industrial Hygiene Members shall:

- a. Review new or modified LEV installations and assist with the compliance of this program.
- b. Report any discrepancies to the LEV Program Lead.

5.7 Facilities Division (FD), Project Engineers shall:

- a. Obtain training either through college course work or continuing education in ventilation design for contaminant control as outlined in the Industrial Ventilation: A Manual of Recommended Practice, 27th edition, 2010 or later.
- b. Obtain support from the LEV Program Lead during the design phase of projects that may require local exhaust ventilation.
- c. Ensure that LEV design specifications comply with the requirements of this program and standards.
- d. Review and approve all new or modified LEV systems prior to purchase and installation.
- e. Inform the LEV Program Lead of all newly installed or modified LEV systems and request a

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ventilation survey before releasing the system for use.

5.8 Support Service Contractors, Operations, and Maintenance Personnel

Shall inform the LEV Program Lead of any modifications or repairs of LEV systems and request a ventilation survey before releasing the system for use.

5.9 LEV Operators/Users/Designees/Supervisors/Safety Permit Holders shall:

- a. Ensure that LEV is operated in accordance with the requirements of this program.
- b. Stop operations, tag the LEV “out of service,” and contact F-IXIT (3-4948) if a LEV system is suspected of being deficient or if a continuous-airflow monitoring device malfunctions.
- c. Contact FD and LEV Lead for design assistance and approvals prior to the preliminary stages of tasks involving the installation or modification of LEV systems (all LEV systems must be reviewed and approved by FD before they are installed).
- d. Inform LEV Lead of all newly installed LEV systems and all modifications or repairs of LEV systems and request a ventilation survey before releasing the system for use.

5.10 LEV Users/Designees shall:

- a. Operate LEV systems in accordance with this program.
- b. Report any LEV that does not appear to adequately control exposure to air contaminants.
- c. Respond to a laboratory hood that is alarming by immediately lowering the sash to a level at which the alarm ceases and resetting it (if the alarm continues, notify the LEV Lead and submit a work request to the Facility Division’s F-IXIT for repair).
- d. Enlist area safety committee members, in their review of new or modified LEV installations, to assist with the compliance of this program and to report any discrepancies to the LEV Lead.
- e. Require that employees who need to operate unfamiliar LEV systems request training for the appropriate use of the LEV system from their supervisor or from one of the OHB industrial hygienists.

6.0 REQUIREMENTS

All active LEV systems are inspected, velocity flow tested and have their monitor gauges checked at least annually by the LEV technician to comply with NPR 1800.1 and 29 Code of Federal Regulations (CFR) 1910.94. If the checks are not satisfactory, a work request (WR) must be initiated by the owner/operator of the LEV system. Each LEV system shall be tagged (green, yellow, or red) with an identification number, the date of the test (month/year), and the name and telephone number of the person conducting the inspection. APPENDIX C of this document sets forth the procedure in the appendixes of the Industrial Hygiene Procedure: Testing LEV Systems.

7.0 RECORDS

- a. Ventilation Surveys - The database for ventilation surveys shall be maintained by the LEV technician and shall be kept in-network location \\smad12\QSH\$.

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- b. Training Records.
- c. LEV training records shall be maintained in the System for Administration, Training, Education Resources for NASA (SATERN).
- d. LEV Supervisors/Safety Permit Holders are required to attend Laboratory and Local Exhaust Ventilation Function and Safety training (SATERN course number: GRC-4R1631).
- e. LEV Users/Designees shall receive training on the specific equipment from their supervisors, and the supervisors shall be responsible for maintaining the training record information.
- f. Hood Repair Records - Hood repair records shall be maintained in the FD current work order database system.
- g. Safety Inspections - Ventilation systems shall be added to the safety inspection forms by the building inspectors under the current inspection system.

8.0 REFERENCES

Document number	Document name
29 CFR 1910.94	Occupational Safety & Health Administration (OSHA), Ventilation in General Industry
ACGIH Industrial Ventilation	American Conference of Governmental Industrial Hygienists, Industrial Ventilation: A Manual of Recommended Practice for Operations and Maintenance 28 th edition 2010 and 30 th edition 2019
CDC 21-1112	Biosafety in Microbiological and Biomedical Laboratories (BMBL) 5 th Ed. HHS Publication No. (CDC) 21-1112, 2009.
NSF Int. Std. #49	National Science Foundation (NSF) American National Standards Institute (ANSI) International Standard Number 49, 2020.
Appendix C	NASA Glenn Research Center, Testing Local Exhaust Ventilation (LEV) Systems Guidance Manual, April 2012
NPR 1800.1	NASA Procedural Requirements, NASA Occupational Health Program Procedures
Z9.2	American National Standards Institute (ANSI), Fundamentals Governing the Design and Operation of Local Exhaust Systems, 2018
Z33.1	American National Standards Institute (ANSI), Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal or Conveying, 1961
Z9.5	American National Standards Institute (ANSI), American National Standard for Laboratory Ventilation, 2012

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APPENDIX A.—DEFINITIONS

Air cleaning device.—Device that separates contaminants from the airstream before discharge to the ambient air; filters, scrubbers, electrostatic precipitators, cyclones, dropout boxes, and afterburners.

Air filter.—Mechanical device that removes contaminants from the airstream.

Air velocity.—Rate of air motion in a given direction, measured as distance per unit time; meters per second (m/sec), feet per minute (ft/min or fpm), miles per hour (mph).

Anemometer.—A device for measuring air velocity and commonly used to take face velocity measurements.

Carcinogen.—Substance or agent capable of causing or producing cancer in mammals, including humans; a chemical is considered to be a carcinogen or potential carcinogen if it has been:

- Evaluated by the International Agency for Research on Cancer and found to be a carcinogen or potential carcinogen.
- Listed as a carcinogen or potential carcinogen in the annual report on carcinogens published by the National Toxicology Program.
- Regulated by OSHA as a carcinogen.

Capture velocity.—At any point in front of the hood, the velocity of air necessary to overcome opposing air currents and to capture the contaminated air by causing it to flow into the exhaust hood.

Duct.—Passageway made of sheet metal or other suitable material used for conveying air, gases, vapors, dust, mist, or fumes; usually exhausts contaminants from the hood outside the building

Entry loss.—Loss in pressure caused by airflow resistance in a duct or hood; usually measured in inches (in.) of water gauge.

Fan.—Local exhaust ventilation system component that provides the energy required by a specific design to move air through a system.

Flow monitor.—Device used on a lab fume hood to continually monitor the hood face velocity of the air entering the hood.

HEPA filter.—Filter that removes at least 99.97 percent of airborne particles 0.3 micrometer (μm) in diameter; composed of a mat of randomly arranged fiberglass fibers having diameters between 0.5 and 2.0 μm . Key factors affecting function are fiber diameter, filter thickness, and face velocity. The air space between HEPA filter fibers is much greater than 0.3 μm . Unlike

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membrane filters, where particles as wide as the largest opening or distance between fibers cannot pass in between them at all, HEPA filters are designed to target much smaller particles. Diffusion predominates below the 0.1- μm -diameter particle size. Impaction and interception predominate above 0.4 μm . In between, near 0.3 μm , diffusion and interception predominate.

Hood face velocity.—Air velocity measured at the hood face opening in fpm.

Inclined Manometer.—A device for measuring air pressure and routinely used in LEV systems to monitor for filter condition (service life indicator).

Inert gas.—Gas that does not react or undergo any change of state in a system or process.

Laboratory fume hood.—Device that encloses, captures, or receives emitted contaminants to effectively capture and control contaminants at the source with minimum airflow and power consumption; a shaped inlet designed to capture contaminated air and direct it into the exhaust duct system.

Local exhaust ventilation.—System that captures and removes emitted contaminants before they are released into the workplace environment; components are the hood, or air capture device, duct system, air cleaning device, fan, and exhaust stack.

Magnehelic gauge.—A device for measuring air pressure and routinely used in LEV systems to monitor for filter condition (service life indicator).

Plenum.—Chamber used in local exhaust ventilation systems to equalize pressure.

Pressure, static.—Potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, pressure is measured in a direction normal to the direction of flow and is usually expressed in inches water gauge when dealing with air. Static pressure is the tendency to either burst or collapse a duct.

Pressure, velocity.—Kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity that is usually measured in inches water gauge.

Stack.—Device used to discharge air away from a building.

Toxicity.—Relative property of a chemical agent that refers to the harmful effect it exerts on some biologic mechanism and the conditions under which the effect occurs.

Ventilation.—The process of supplying or removing air by natural or mechanical means to or from any space.

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APPENDIX B.—ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
EPM	Environmental Programs Manual
FD	Facilities Division
FPM	Feet per minute
HEPA	High-efficiency particulate air
IH	Industrial hygienist
in	Inches
LEV	Local exhaust ventilation
mph	Miles per hour
NPR	NASA Procedural Requirement
NSF	National Science Foundation
OH	Occupational health
OHB	Occupational Health Branch
OSHA	Occupational Safety & Health Administration
PPE	Personal protective equipment
SATERN	System for Administration, Training, Education Resources for NASA
WR	Work request
µm	Micrometer

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APPENDIX C.—INDUSTRIAL HYGIENE PROCEDURE: TESTING LOCAL EXHAUST VENTILATION (LEV) SYSTEMS

C.1 PURPOSE

This procedure will establish guidelines for evaluating the function of LEV systems, which are also known as process exhaust systems. The general steps in this process include determining what flow is needed to remove the contaminant of interest, deciding how best to measure this flow in a safe, efficient, and reproducible manner, documenting these flow requirements and flow measurements, and communicating relevant results to our customers.

C.2 REFERENCES

C.2.1 Applicable Documents

- a. ACGIH, INDUSTRIAL VENTILATION, A Manual for Recommended Practice for Design, 30th edition (2019)
- b. GRC OHPM, Chapter 7, Glenn Research Center, Occupational Health Programs Manual, Chapter 7, Local Exhaust Ventilation

C.2.2 Records and Forms

- a. GRC 760a, Local Exhaust Ventilation (LEV) Survey Tag—Green
- b. GRC 760b, Local Exhaust Ventilation (LEV) Warning Notice Tag—Yellow
- c. GRC 760c, Local Exhaust Ventilation (LEV) Out of Service Notice Tag—Red

NOTE: The forms listed above are located at the end of Appendix C in the Testing Local Exhaust Ventilation (LEV) Systems manual.

C.2.3 Definitions

Area (A).—Surface area of a hood opening or duct; measured as round duct $A = 3.14 \times (\text{radius})^2$ or $A = 0.79 \times (\text{diameter})^2$; typically measured as rectangular duct $A = (\text{length}) \times (\text{width})$ in square feet (ft²).

Duct.—Passageway made of sheet metal or other suitable material used for conveying air, gasses, vapors, particulates, mist, or fumes.

Local exhaust ventilation (LEV).—Industrial ventilation system that captures and removes emitted contaminants before they are released into the workplace environment.

Pitot tube probe.—Type of probe that simultaneously measures the static pressure and total pressure within a duct, thereby allowing the velocity pressure to be calculated.; velocity is proportional to the square root of the velocity pressure times 4004.4 for dry air at 70 degrees Fahrenheit and a barometric pressure of 29.92 inches of mercury.

Thermal anemometer probe.—Type of probe used to measure velocity and depends upon the known thermal capacitance of an airstream to cool the thermocouple (“hot wire”) once it has been heated.

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Velocity (V).—Time rate of movement of air in a given direction, typically measured as feet per minute (ft/min or fpm), meters per second (m/sec), or mph.

Velocity, face.—Air velocity measured at the face opening of a hood or duct.

Velocity, capture.—Velocity of the air induced by a hood to capture emitted contaminants external to the hood; acceptable capture velocity depends upon the mass of the contaminant being captured, the prevailing air currents nearby, thermal properties of the contaminant (e.g., hot fumes rise), and the velocity of the contaminant relative to hood flow (e.g., belt sander throwing dust into or away from its exhaust duct).

Volumetric flow rate (Q).—Volume or quantity of air that passes a given location per unit of time and that is related to the average velocity and cross-sectional area by $Q = VA$.

C.3 DISCUSSION

C.3.1 Local exhaust ventilation, or process exhaust, systems are used throughout industrial and laboratory environments to move airborne contaminants away from workers to minimize their exposures. These systems must be designed to not only handle the type and quantity of contaminant being generated but also to accommodate the employee and work activities associated with the task. LEV systems are composed of several components that include the hood, ducting, air mover, and possibly some type of contaminant removal mechanism. The design of such systems must also take into account the facility where the LEV will be located and the other ventilation systems therein. The design and layout of LEV systems is performed by Facilities Division engineering staff with input from a facility team IH.

C.3.2 Evaluating the performance and adequacy of process exhaust systems at the worker-LEV interface is performed by industrial hygiene staff. Many parameters must be considered when determining the flow velocity and rate necessary to adequately remove a contaminant from a work zone and successfully transport it through the ventilation system. Considerations include contaminant type (particle or gas), particle size (if not a gas), contaminant temperature, contaminant initial velocity (speed and direction), ambient air movement, hood type, hood location, and worker location. Periodic checks of the LEV system are used to compare system performance to the established flow parameters and also to determine if the system/equipment setup has changed, necessitating the establishment of new flow parameters.

C.4 SAFETY PRECAUTION

C.4.1 Testing of local exhaust ventilation systems can involve potential safety and health hazards that must be managed appropriately. When there are questions regarding the LEV system or equipment, IH personnel should contact the individual responsible for the LEV system, experimental rig, or facility/room as needed.

C.4.2 Safety considerations associated with surveying LEV systems include those related to working on step ladders or step stools to make flow measurements, entering areas with industrial safety hazards (foot, hand, eye, etc.), and any potential safety hazards presented by the experiment/equipment or materials being stored or used. Managing such hazards involves following prescribed precautions and wearing appropriate PPE.

C.4.3 Potential occupational health (OH) hazards associated with testing LEV systems will vary and depend upon the status of the contaminant-generating activity or material/chemical

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storage/use and the efficacy of the ventilation system. The surrounding work environment could also present OH concerns that should be considered (e.g., high noise, lasers) Again, these hazards can be managed by using appropriate PPE and by following any specifically prescribed safety precautions in addition to observing the general work practices associated with working in a research environment.

C.5 TOOLS, EQUIPMENT AND MATERIALS

C.5.1 Hot Wire Anemometer/Air Velocity Meter

This meter measures velocity and temperature, calculates flow rate, performs multivalued averaging, and determines minimum and maximum readings. Prior to use, this instrument shall have a current annual calibration sticker and appear to be functioning properly.

C.5.2 Hot Wire Anemometer Multi-Parameter Ventilation Meter

This meter simultaneously measures, and data logs several ventilation parameters using a single probe with multiple sensors. The ventilation meter measures temperature, humidity, and pressure. The meter also features automatic calculation of flow rate and automatic conversion between actual and standard velocity readings. Prior to use, this instrument shall have a current annual calibration sticker and appear to be functioning properly.

- a. Reserved for alternate venation meter.
- b. Smoke device that generates vapor/fume for visualizing flow of LEV systems.
- c. Vinyl tag holders and miscellaneous administrative supplies.
- d. Tape measure and miscellaneous tools (adjustable wrench, screwdriver).

C.5.3 Additional Equipment

- a. Smoke tube kit that generates vapor/fume for visualizing flow of LEV systems.
- b. Vinyl tag holders and miscellaneous administrative supplies.
- c. Tape measure and miscellaneous tools (adjustable wrench, screwdriver).

C.6 RESPONSIBILITIES [perhaps “Industrial Hygiene Personnel Responsibilities?”]

Personnel performing industrial hygiene functions within GRC’s SHED are responsible for being familiar with and implementing this work instruction.

C.7 PERSONNEL TRAINING AND/OR CERTIFICATION

Industrial hygiene personnel who perform local exhaust ventilation system surveys should:

- a. Have received the necessary training associated with entering most areas at the Center.
- b. Have a general understanding of ventilation systems and flow parameter calculations.
- c. Know how to operate survey equipment and be familiar with the equipment manuals.

C.8 INSTRUCTIONS

C.8.1 Administrative and Data Management Functions

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C.8.1.1 Database

A database is used to track local exhaust ventilation systems at GRC. Information in this database includes a unique identifying number for the LEV system, point of contact, type of system, operating parameters (i.e., flow specifications), face or capture velocity (or observed reading), distance from face, and comments. In addition, images are being added to the database to aid in identifying each system and where and how the flow measurements should be secured. Standard database functions are used to sort, query, and, otherwise, manage the LEV system information. It is important that IH personnel actively maintain this data resource to reflect changes in system information or the performance of periodic surveys.

The fields “operating parameter” and “comments” should be used to provide specific instruction on how and where the flow parameter should be measured, what the requirement is, and, if needed, a description of how this flow requirement was determined.

C.8.1.2 Naming Convention

The LEV systems are uniquely identified using the following convention: Building No. – Room/Cell No. – Hood No.

Examples: 302 – 219 – 5

005 – CW5 – 2

Hoods are numbered sequentially, with there being no significance or priority associated with the actual number. When a new LEV system is added to a room, it receives the next available unused number. Numbers for systems that have been removed from a room or cell are decommissioned with the system and are not reused.

C.8.2 Establishing Required Flow Parameters

C.8.2.1 General Discussion

C.8.2.1.2 Velocity and/or flow requirements for some LEV system types can come straight from OSHA regulations or directly out of industry guidelines, such as the ACGIH manual *Industrial Ventilation, A Manual of Recommended Practice for Design*, hereinafter identified as the “Ventilation Manual.” The manufacturer of the equipment being ventilated by the LEV system may also provide a specification for process exhaust performance. Establishing flow requirements for many other systems will depend upon assessing the LEV application along with its target activity using guidance provided in relevant ventilation references.

C.8.2.1.3 Although not an exhaustive list, the following guidance is intended to address most of the LEV system types found at GRC. Other LEV applications might require a bit of researching and the application of general principles to establish its flow requirements. In addition, changes to prescribed flow parameters might be allowable to address unusual LEV needs.

C.8.2.1.4 Once established, the flow requirements for an LEV system along with supporting information shall be recorded in the database operating parameter field and the comments field, respectively.

C.8.2.2 Laboratory Fume Hood

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C.8.2.2.1 The average face velocity of nine readings (3×3) taken over the laboratory hood opening should range between 80 and 120 fpm, with a target value of 100 fpm.

C.8.2.2.2 If the LEV system is a continuous-flow laboratory fume hood, the hood shall provide a face velocity of 100 ft/min (fpm) ±20 percent. If the LEV system is not a continuous-flow laboratory fume hood, then the sash shall be adjusted such that the hood provides a face velocity of 100 fpm ±20 percent. The sash height shall be marked on the survey tag or on the hood itself to clearly indicate the required sash height. Hoods that are equipped with airflow monitoring gauges must indicate the tested velocity flow within ±10 percent. If not, a WR must be submitted to address the discrepancy.

C.8.2.2.3 Newly purchased laboratory fume hoods shall include a continuous face velocity monitor for the purpose of measuring hood performance. Each monitor shall be calibrated annually.

C.8.2.2.4 Laboratory hoods should not be used for general chemical storage. Keep materials stored in hoods to a minimum and do not allow them to block vents or airflow.

C.8.2.2.5 Refer to the Ventilation Manual pages 6-3>17, 13>50>53 and figures VS-35-01>04 for further details on laboratory fume hood design (Appendix C).

NOTE: Laboratory fume hoods and paint spray booths are not created equal. A paint spray booth is a specifically designed enclosure for the control of paint vapors and particulate overspray, equipped with air filtration to contain emissions and protect against combustible paint film buildup in ductwork, and includes fire suppression. Often, laboratory fume hoods do not meet this criteria. Air flow recommendations for paint booths also vary. Refer to Ventilation Manual figures VS-75-01>02 for further details (Appendix C).

C.8.2.3 Biological Safety Cabinets

Biological safety cabinets require annual recertification according to National Science Foundation (NSF) American National Standards Institute (ANSI) International Standard Number 49 for downflow, inflow, flow pattern, and system leakage integrity. This procedure shall be accomplished by an NSF Accredited Class II Biosafety Cabinet Certifier. Please refer to the Industrial Ventilation Manual figures VS-35-10- and VS-35-11 for further details on cabinet design considerations (Appendix C) and for complete biosafety considerations in “Biosafety in Microbiological and Biomedical Laboratories (BMBL) 5th Edition, HHS Publication No. (CDC) 21-1112, 2021 6th edition.

C.8.2.4 Snorkel-Type Hood (Articulated Arm)

The flow requirement for this system will depend on the characteristics of the contaminant and the distance from the point of contaminant generation to the hood opening. Typically, the hood shall be as close to this point as possible without interfering with the work task or otherwise creating another safety hazard. The flow specification can be either a capture velocity at a specified distance from the hood to reflect the work scenario or a face velocity at the hood or duct to correspond to this needed capture velocity. Note that the face velocity required to achieve a specific capture velocity at some distance *X* increases very rapidly as the distance *X* gets larger. Please refer to Ventilation Manual pages 6-18>29, 13-104>106, and 13-167>170 and figures VS-65-01 and VS-90-02 for further details (Appendix C).

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Example Welding Operation

The LEV uses a 6-in.-diameter flexible duct, and the hood expands to a diameter of 12 inches. The welding operation is 9 in. from the face of the hood.

Assume a required capture velocity Q of 150 fpm for welding low-toxicity materials in moderately still air (Ventilation Manual, VS-90-2, 2010).

$Q = 150 C_f(10X^2 + A)$ (Ventilation Manual, VS-90-2, 2010), where $C_f = 0.75$ for tapered duct, X = distance from hood to capture point, A = cross-sectional area of hood opening $Q = 150 \text{ fpm} \times 0.75 \times [10 \times (9/12)^2 \text{ ft}^2 + 0.7854 \text{ ft}^2]$
 $= 721 \text{ ft}^3/\text{min}$ (cfm) Note that the area A of an 12" circle is 0.7854 square feet.

The corresponding hood face velocity $V = Q/A = (721 \text{ cfm})/(0.7854 \text{ ft}^2) = 918 \text{ fpm}$ The corresponding duct face velocity $V = (721 \text{ cfm})/(0.2 \text{ ft}^2) = 3605 \text{ fpm}$

This example shows three possible velocity measurements that could be made to check the performance of such an LEV system: capture velocity = 150 fpm (minimum), hood face velocity = 918 fpm, and duct face velocity = 3605 fpm. [only pertains to a specified capture velocity of 150 fpm and a hood location 9" from the point of fume generation, with a 12" hood and 6" duct opening]

C.8.2.5 Canopy Hood

Flow requirements depend not only on the characteristic of the contaminant generated and the distance to the hood but on the type of canopy hood (open sides = 4, 3, 2, or 1). Because of this openness, their size, and the distance to the target activity, canopy hoods are not very efficient means of contaminant removal. Consequently, significant flow may be necessary to properly remove the emission from the work environment. Canopy hoods shall provide a capture velocity based on source toxicity, distance from contaminant source, temperature of process and cross drafts. Refer to Ventilation Manual pages 6-18>31, 13-35>41, and 13-111>115, and figure VS-99-03 for further details (Appendix C).

Example Canopy Hood Operation

The canopy hood is above an oven where hot emissions are released in an environment of relatively still air. The oven has a footprint of 2 by 2 ft. The canopy profile is 3 by 3 ft; the hood is open on all four sides, and the bottom of the canopy is 1 ft above the top of the oven. The canopy hood is attached to 8-in.-diameter ductwork.

Assume a required capture velocity Q of 75 fpm for hot effluent into quiet air (Ventilation Manual, Table 6-2). $Q = 1.4 PHV$ (Ventilation Manual, VS-99-3), where P = emission source (oven) perimeter, H = distance from bottom of canopy to target zone

$$Q = 1.4 \times (8 \text{ ft}) \times (1 \text{ ft}) \times (75 \text{ ft}/\text{min}) = 840 \text{ cfm}$$

The corresponding **hood** face velocity $V = (840 \text{ cfm})/(9\text{ft}^2) = 93 \text{ fpm}$

The corresponding **duct** face velocity $V = (840 \text{ cfm})/(0.349) \text{ ft}^2) = 2406 \text{ fpm}$

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Three choices for velocity measurements can be made to check the performance of such an LEV system: capture velocity = 75 fpm (minimum), hood face velocity of 93 fpm, and duct face velocity = 2406 fpm.

C.8.2.6 Cabinet

The flow requirements for a cabinet-style LEV system are logically somewhat lower than an those for an open-type LEV hood because the target volume is enclosed on all sides. A capture velocity can be selected from Table 6-2 of the Ventilation Manual (See Appendix C) and the calculations made to determine the corresponding duct face velocity (cabinet outlet) or filter/slot panel velocity (cabinet inlet).

Example Cabinet Operation

A ventilated cabinet houses an activity involving a high-intensity ultraviolet xenon lamp; ozone (O₃) production is expected. The cabinet width and depth are both 2 ft. The cabinet has a 4-in.-diameter exhaust at the top on its back panel and a 6- by 12-in. filtered inlet near the bottom of the front panel.

Assume a required capture velocity of 25 fpm for the emission of a gas in a quiet, enclosed cabinet. $Q = VA$ $Q = (25 \text{ fpm}) \times (2 \text{ ft}) \times (2 \text{ ft}) = 100 \text{ cfm}$.

The corresponding duct face velocity $V = (100 \text{ cfm}) / (0.09 \text{ ft}^2) = 1150 \text{ ft/min}$.

The corresponding filter inlet face velocity, $V = (100 \text{ cfm}) / (0.5 \text{ ft}^2) = 200 \text{ ft/min}$.

Depending upon accessibility, there may be up to three choices for making a measurement to check the performance of this system; the least intrusive would be a measurement of the inlet filter face velocity, which has a minimum specification of 200 fpm.

C.8.2.7 Sander/Grinder

The particles generated in these mechanical abrasion operations are relatively large and require high capture and duct velocities to grab the contaminant and keep it suspended during transport. Table 6-2 of the ventilation manual specified a minimum capture velocity of 500 to 2000 fpm for contaminants released at a high initial velocity into a zone of very rapid air motion (e.g., grinding). Other flow requirements for a sanding/grinding operation are specified based upon the type of operation and the size of the abrading media. Typical operation types include wheel, belt, and disk with pertinent dimensions being wheel width, belt width, and disk diameter. These flow requirements are specified as minimum exhaust flow rates in cubic feet per minute. Assigning a flow requirement for a particular system will depend upon how best to make a relevant and meaningful measurement.

Table 6.2 Recommended Capture Velocities

Energy of dispersion	Example	Velocity, feet/minute
Little motion	<i>Evaporation from tanks: degreasing</i>	75-100
Average motion	<i>Intermittent container filling: low speed</i> <i>Conveyor transfer: welding: plating: pickling</i>	100-200
High motion	<i>Barrel filling: conveyor loading: crushers</i>	200-500

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Very High motion *Grinding: abrasive blasting: tumbling* 500-2000

C.8.2.8 Other

In general, establishing a capture velocity parameter for an LEV system based upon the operation being ventilated is the best approach for evaluating the effectiveness and performance of such a system. Ranges of capture velocities for many applications can be found in references such as the Ventilation Manual, but often a decision must be made to establish a flow requirement not covered by such a reference. In some cases, experience and professional judgment may be adequate to establish a minimum capture velocity. In other cases, personal exposure monitoring may be necessary to assess the adequacy of an LEV system.

Engineered Nanomaterials Ventilation Requirements for Engineered Nanomaterials are covered in Section 13.67 of the Industrial Ventilation manual (See Appendix C). Nanoparticles have unknown human health effects due to unique chemical and physical properties including particle size, shape, surface area, charge, chemical properties, solubility, oxidant generation potential, and degree of agglomeration.

Note: Section 13.67.2.1 Applicable Engineering Controls. If the potential hazard cannot be eliminated or substituted with a less hazardous substance, then engineering controls should be installed and tailored to the process. Engineering control techniques such as source enclosure and local exhaust ventilation systems should be effective for capturing airborne nanoparticles. However, the type of engineering control used should take into account information on the potential hazardous properties of the precursor materials and intermediates as well as those of the resulting nanomaterial. In light of current scientific knowledge about the generation, transport, and capture of aerosols, airborne exposure to nanomaterials can most likely be controlled using a variety of engineering control techniques similar to those used in reducing exposures to general aerosols. Current knowledge indicates that a well-designed HEPA filter should effectively remove nanomaterials.

C.8.3 Performing LEV System Surveys

C.8.3.1 General Discussion

Prior to performing LEV system assessments, the surveyor should ensure that the instrument is calibrated and appears to be functioning properly. The surveyor should also verify that the subject LEV system is operating and make note of any pertinent valve/damper positions and other conditions of the mechanical ventilation system. Inspect the exhaust system and its associated ductwork and mechanical components for any obvious signs of damage or other problems. (e.g., clogged ductwork or intake, breached ductwork, broken dampers, missing or damaged seals, unusually loud motor noises or oscillations). Do not test the LEV system if it is not operable or is of questionable integrity. Raise concerns about the system with the system point of contact and/or facility personnel.

The surveyor should record as much information about the testing scenario as is necessary to properly document the LEV system's compliance with performance specifications and to allow for reproducible measurements to be taken in the future. This information shall include distances from duct faces where capture velocity measurements were taken, damper positions (when applicable), the type of contaminant generated, pertinent dimensions of the

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system/layout, assumptions made that impacted testing, and so forth.

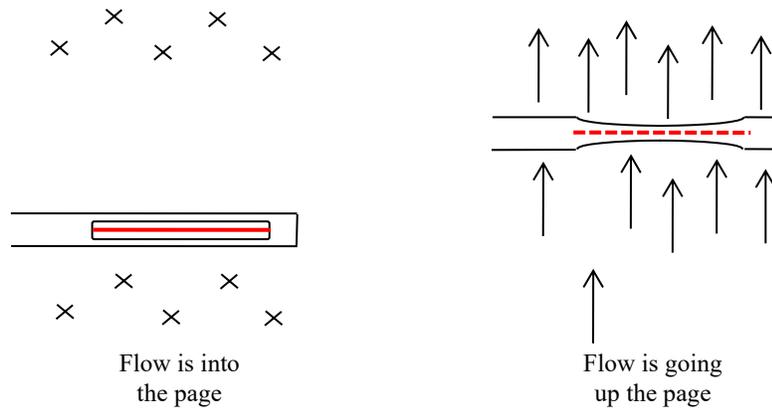
Although the purpose of the LEV surveys is to verify proper operation of the process exhaust system, the tools and methods being used can also be used to optimize systems or work scenarios that do not meet their flow specifications. Tracing smoke and measuring flow velocities can be used to identify the boundaries of an appropriate work zone for an LEV system or identify items that adversely impact the performance of such a system.

C.8.3.2 Use of Smoke Devices

The vapor and/or fume generated by a smoke device provides a convenient method for visualizing airflow. The value of this tool in assessing the performance of an LEV system is somewhat limited because of the subjective nature of the method and its result. Its use can be considered for a qualitative assessment of systems where flow adequacy is easily achieved and other flow parameters are difficult to measure. One example could be a toxic material storage cabinet whose exhaust is intended to remove contaminants resulting from a small leak. In this instance, the smoke can be used (1) near the door while slightly cracking the door open or (2) near an intake panel, if present. Another use would be an enclosed bead/sand blasting unit where the smoke could be used to check the integrity of enclosure seals or to determine if the exhaust system is adequately drawing or sucking on the box to keep this work volume negative in pressure relative to where the blaster operators are located.

C.8.3.3 Use of the Thermal Anemometer Probe [Do not use in explosive, flammable or combustible atmospheres]

The Anemometer survey instruments include a thermal anemometer probe as their primary means of flow velocity measurement. The probes include a telescoping, articulated rod that allows the user to make measurements at a distance and with the probe's hot wire at varying angles and orientations. The end of the probe should be placed in the two-dimensional plane of the opening being measured. In addition, the probe should be oriented to achieve the maximum flow of air over the hot wire (see figures below). The observed flow rate will decrease rapidly as the probe is rotated out of this maximum flow scenario. The probe has a direction of flow marking (a dot) on the tip that shall be oriented upstream. With exhaust systems, this means the dot will be visible to the operator when taking measurements.



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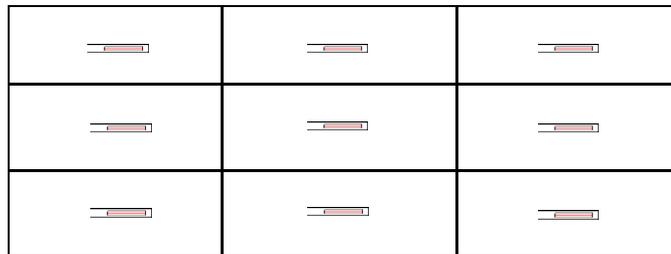
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In addition to facilitate making measurements out of one’s normal reach, the probe’s extendable, telescoping wand enables readings to be performed away from the instrument operator, thereby reducing the flow interference effects caused by the operator’s body.

C.8.3.4 Use of Pitot-Tube Probe—Reserved.

C.8.3.5 Laboratory Hood Surveys

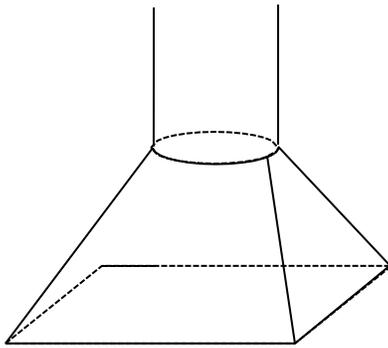
Nine velocity measurements, arranged in a three-by-three (3x3) grid over the hood face, should be taken when surveying a laboratory ventilation hood. Visualize the following when performing a laboratory hood survey and make velocity measurements at the center of each of the nine rectangles.



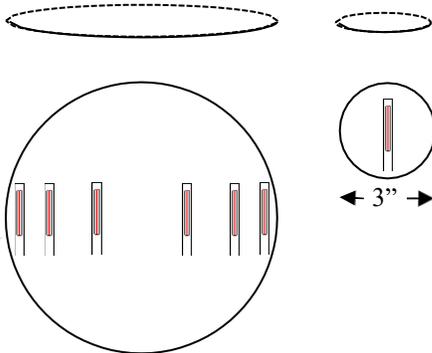
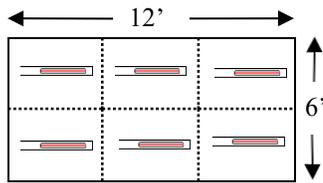
The VelociCalc® meters will average the results for the operator. Particular attention should be paid to keeping the probe hot-wire opening perpendicular to the airflow and using the telescoping feature of the wand to stay as far away from the measurement zone as possible. The height of the vertical sash should be adjusted to get the average flow velocity to be approximately 100 fpm. The acceptable range is 80 to 120 fpm.

C.8.3.6 Obtaining a Face Velocity Measurement for a Duct or Hood Opening

Opening size and shape, location, orientation, obstructions, and accessibility all have bearing on how one can assess the face velocity of the opening. Many times a single centerline flow velocity measurement is adequate (e.g., small round duct face) or is all that can be readily obtained. However, this centerline flow velocity will overestimate the actual duct velocity and should be multiplied by 0.9 to estimate the average flow velocity of the duct. Larger and more accessible hood faces allow for more measurements to be made and then averaged. More measurements typically yield more accurate results; however, the above-mentioned considerations as well as the safety of the surveyor should be taken into account. Below are two examples:



For a rectangular hood, imagine it is broken up into a grid (2x2, 3x2, 3x3, or whatever seems appropriate for the size and shape of the rectangle). Then average the readings taken in each of the grids to obtain the face velocity for that hood. The hood shown was broken down into a 3x2 grid.



For a round opening, single or multiple measurements can be taken. The larger duct example identifies six measurements being taken with positions comparable to those found in references for performing a 6-point traverse. Each pair of measurement locations (1,6; 2,5 and 3,4) represent measurements within three equal-area donut-shaped disks within the duct. The average of the six readings represents the average duct face velocity. The smaller round opening has dimensions approaching that of the hot-wire probe itself, making it difficult to take multiple measurements. So a single measurement is taken and corrected with the 0.9 multiplication factor.

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← 8" →

Again, particular attention should be paid to keeping the probe hot-wire opening perpendicular to the airflow and using the telescoping and feature of the wand to stay as far away from the measurement zone as possible.

C.8.3.7 Obtaining a Capture Velocity Measurement

When possible, a capture velocity reading is the best measure of the effectiveness of an LEV system because the surveyor is observing the flow effects experienced by the contaminant itself. Often, however, such measurements are difficult to make because of limited accessibility (enclosures, obstructions), requiring that some other surrogate measurement (e.g., duct face velocity) be made. When using the thermal anemometer to make these measurements, the probe's articulating and telescoping features should be utilized to keep the hot-wire opening (1) perpendicular to the airflow and (2) away from interference created by the surveyor.

C.8.4 LEV System Results: Tags and Documentation

C.8.4.1 General Discussion

The documentation of LEV survey results involves displaying results locally at the LEV system and recording the results in the LEV database. Both modes play an important role in ensuring the health of workers relying on such engineering controls. Local postings describe whether the system is functioning properly, if there are restrictions on its use (e.g., maximum sash height of a lab hood or maximum effective range of a snorkel hood), or if there are requirements to be met prior to using the system for worker protection.

C.8.4.2 Recording Results Locally at LEV system

A system of multicolor tags will be used to document survey results in the field. These tags will replace the fluorescent orange "Survey" tags and red "Do Not Use" postings being used as of May 2007. In most instances, the colored tags will fit into vinyl sleeves that will be placed (using Velcro® or other adhesion method) on the LEV system to allow conspicuous viewing of the colored tags. For LEV systems where this is not possible, a brass grommet is to be added to the vinyl sleeve that will then be hung at the LEV system, again in a location to allow conspicuous viewing of the tag. In addition, sash-height labels will be placed on the side of laboratory fume hoods to identify the required position at the bottom of the sliding vertical sash.

C.8.4.2.1 Green LEV Survey Tag

The green "LEV Survey Tag" shown in Attachment A is to be used when survey results satisfy the system flow requirements. Tags are filled in to identify the system, document the survey results, and list any restrictions associated with the LEV system use. An example of a use restriction would be specifying a maximum effective range of 8 in. for a flexible snorkel being used for welding activities.

C.8.4.2.2 Yellow LEV Warning Notice Tag

The yellow "LEV Warning Notice Tag" shown in Attachment B is to be used when there is inadequate information to verify the efficacy of the system. The hood ID and any other relevant

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comments are to be included on the tag. For example, a canopy hood or duct drop is positioned over an area that has no source of contaminant emission. Without knowing the emission characteristics and distances involved, it would not be possible to adequately assess the adequacy of such an LEV system.

C.8.4.2.3 Red LEV Out of Service Notice Tag

The red “LEV Out of Service Notice Tag” shown in Attachment C is to be used when survey results do not satisfy the system flow requirements. The hood ID and any other relevant comments are to be included on the tag. After placing a red out of service notice on a system, the surveyor shall contact the LEV system point of contact or local facility personnel to discuss the deficiency. When needed, an industrial hygienist shall be contacted to evaluate the LEV system with input from the user, facility, and maintenance personnel.

C.8.4.3 Updating Database

The LEV system database allows for storage of system information, testing requirements, and survey results. Typical database features such as sorting, querying, and report generating allow for convenient data manipulation and display. Following an LEV system survey, the fields within the unique record for that particular system are to be updated to reflect the survey results, date, surveyor, and if not already identified, the survey conditions and specific flow requirements and any relevant assumptions in establishing the criteria.

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**ATTACHMENT A.—GRC-760a LOCAL EXHAUST VENTILATION (LEV)
SURVEY TAG**

LEV I.D. _____

IN COMPLIANCE

100 fpm (average) face velocity for lab hood

_____ fpm minimum capture velocity

Airflow check is OK using smoke (tracer)

_____ fpm at _____ in. from fume hood/duct face

SHeD Surveyor: _____

Telephone: _____

Expires on: _____

Please contact Safety and Health Division if this Local Exhaust Ventilation (LEV) is taken out-of-service or relocated.

fpm = feet per minute GRC 760A 10/14 (1.0)

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**ATTACHMENT B.—GRC-760b LOCAL EXHAUST VENTILATION (LEV)
WARNING NOTICE TAG**

<p>LEV I.D. _____</p> <p align="center">CAUTION</p> <p align="center">Do not operate until contacting SHeD Surveyor regarding LEV usage or experimental setup.</p> <p>SHeD Surveyor: _____</p> <p>Telephone: _____</p> <p>Notice Date: _____</p> <p>Review date: _____</p> <p>Please contact Safety and Health Division if this Local Exhaust Ventilation (LEV) is taken out-of-service or relocated. SHeD = Safety and Health Division GRC 760B 10/14 (1.0)</p>
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**ATTACHMENT C.—GRC-760c LOCAL EXHAUST VENTILATION
(LEV) OUT OF SERVICE NOTICE TAG**

LEV I.D. _____

OUT OF SERVICE

Contact Fix-it 3-4948 for service

Improper flow _____

Missing or broken parts _____

Flow monitor repair/calibration _____

Other: _____

Once repaired or if relocated/excessed, please contact:

SHeD Surveyor: _____

Telephone: _____

Notice Date: _____

LEV = Local Exhaust Ventilation
SHeD = Safety and Health Division

GRC 760C 10/14 (1.0)

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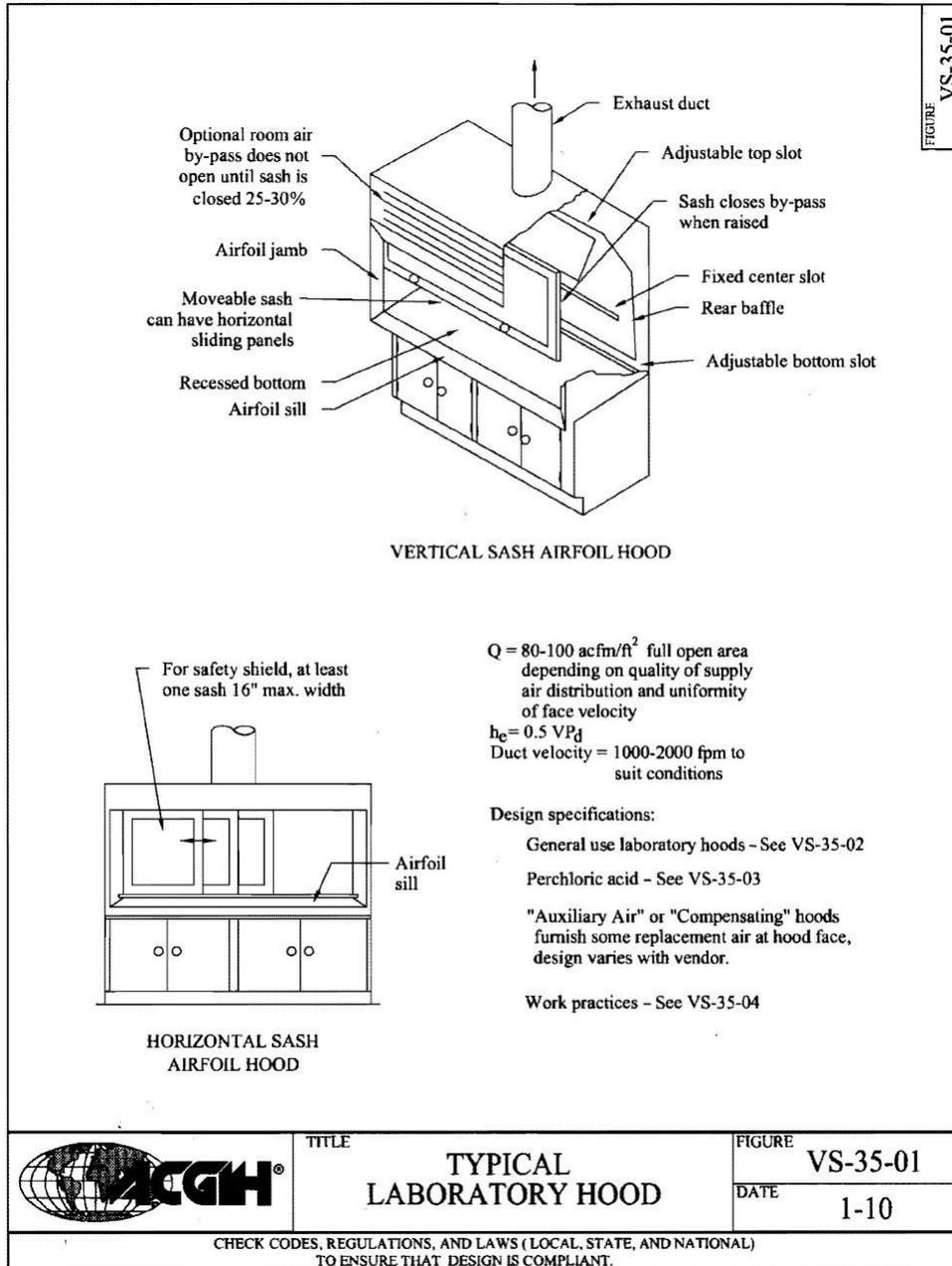
APPENDIX D—INDUSTRIAL VENTILATION: A MANUAL OF RECOMMENDED PRACTICE FOR DESIGN, 27th EDITION FIGURES:

TITLE	FIGURE/TABLE/SECTION
Laboratory Hood	VS-35-01
Biological Safety Cabinet, Type A	VS-35-10
Biological Safety Cabinet, Type B	VS-35-11
Movable Exhaust Hoods	VS-65-01
Large Paint Booth	VS-75-01
Small Paint Booth	VS-75-02
Capturing Hood for Low Toxicity Welding	VS-90-02
Canopy Hood	VS-99-03
Area and Circumferences of Circles	Table 5-8

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Laboratory Hood

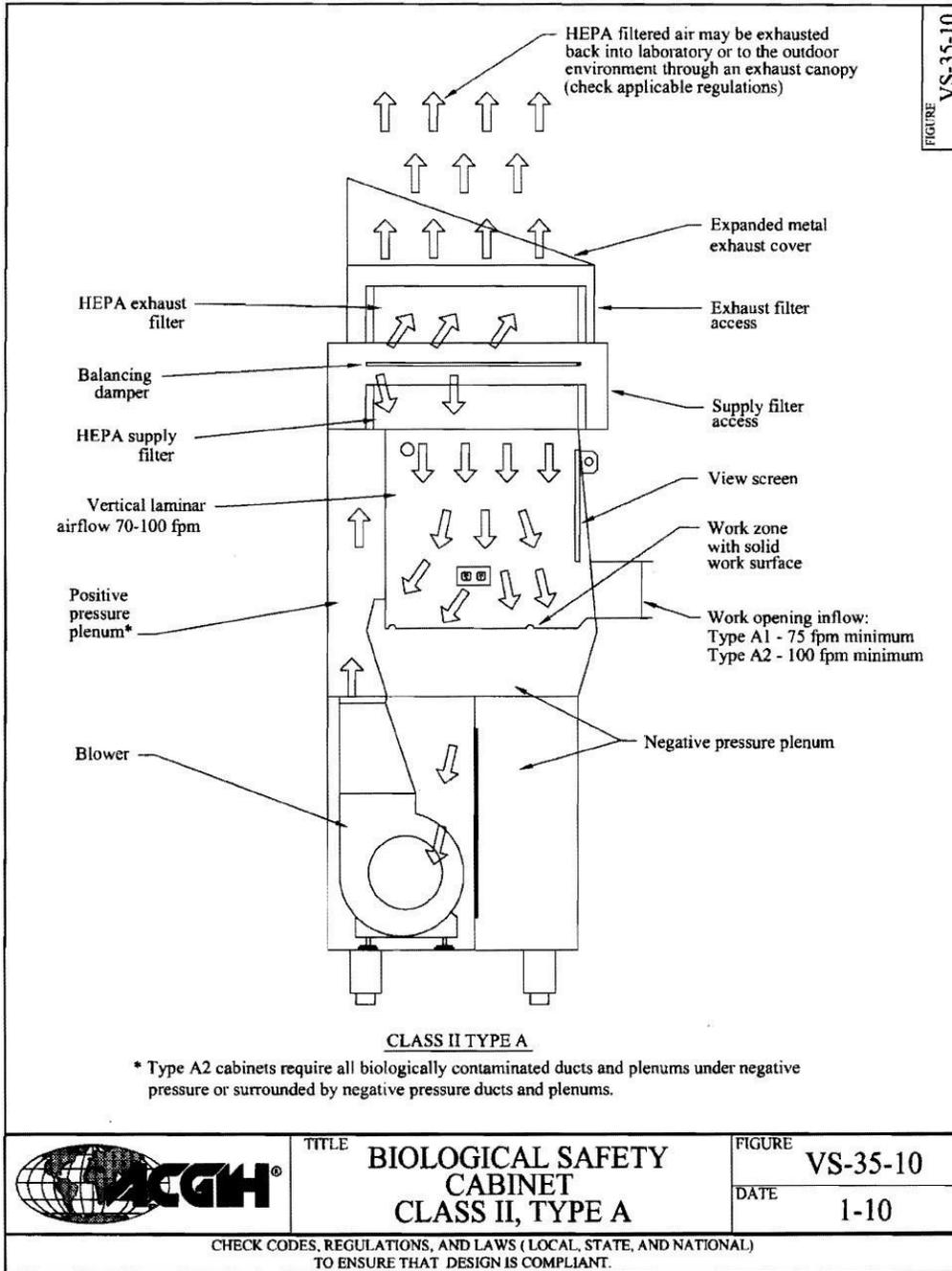
VS-35-01



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Biological Safety Cabinet, Type A

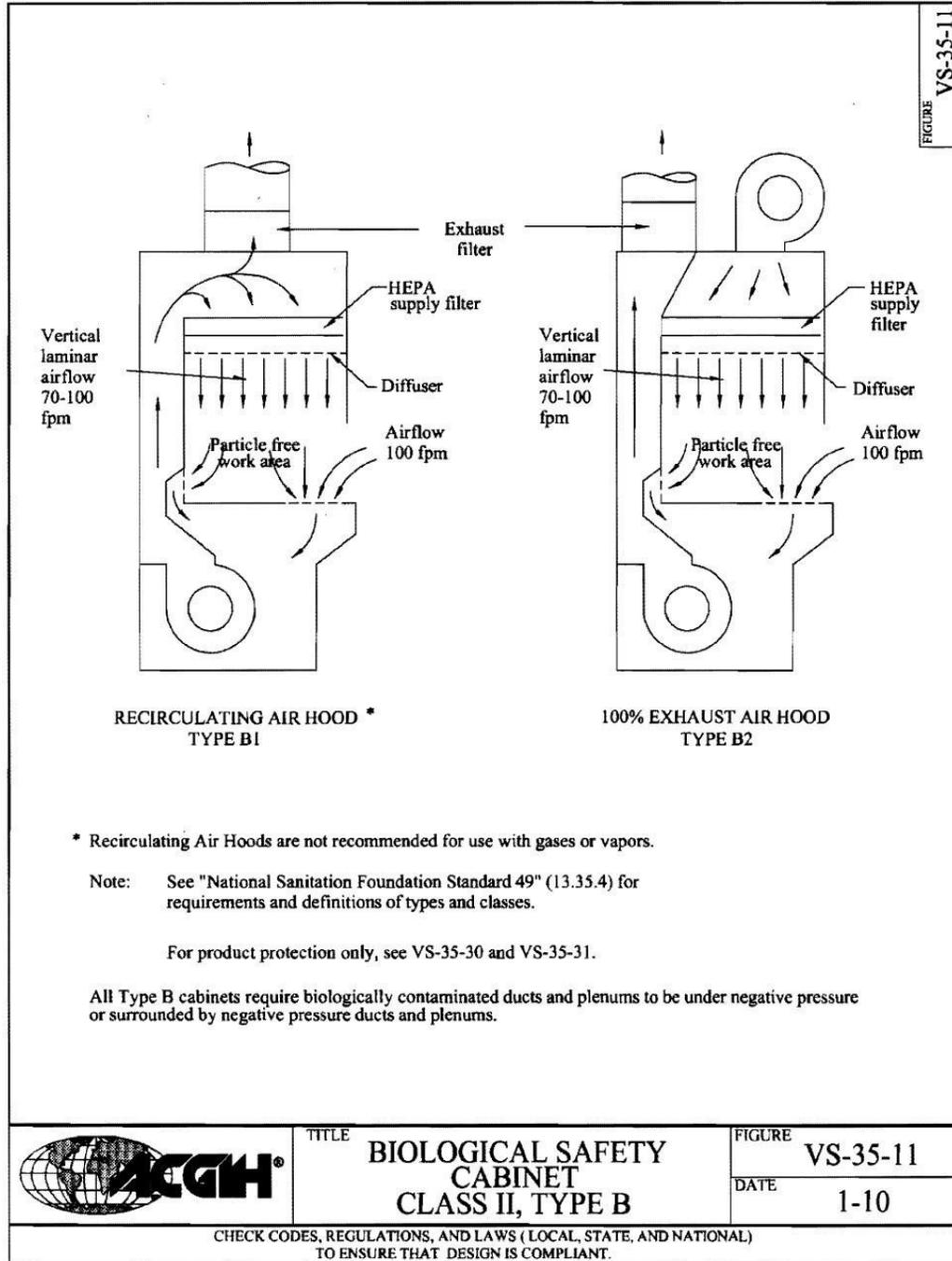
VS-35-10



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Biological Safety Cabinet, Type B

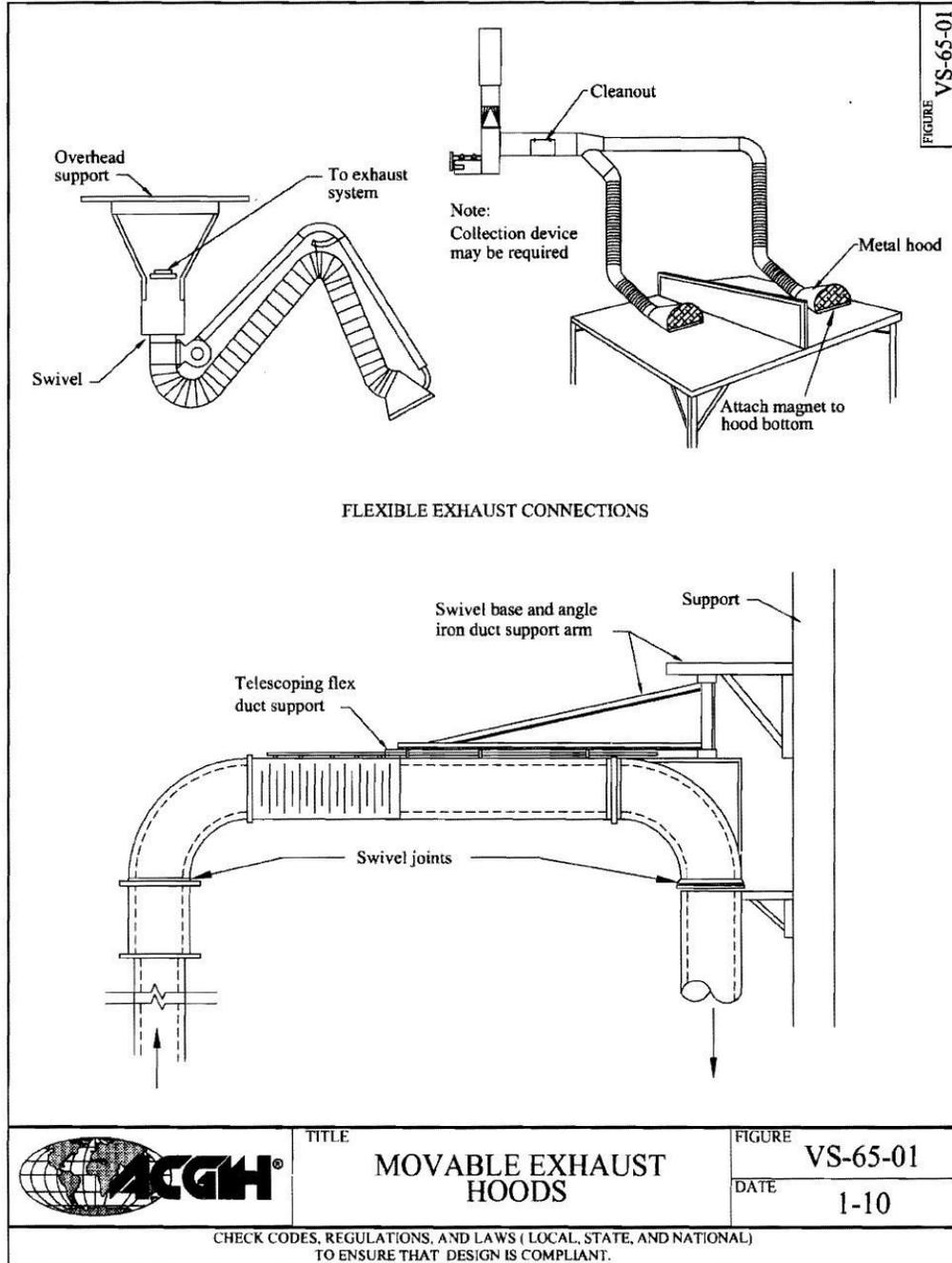
VS-35-11



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Movable Exhaust Hoods

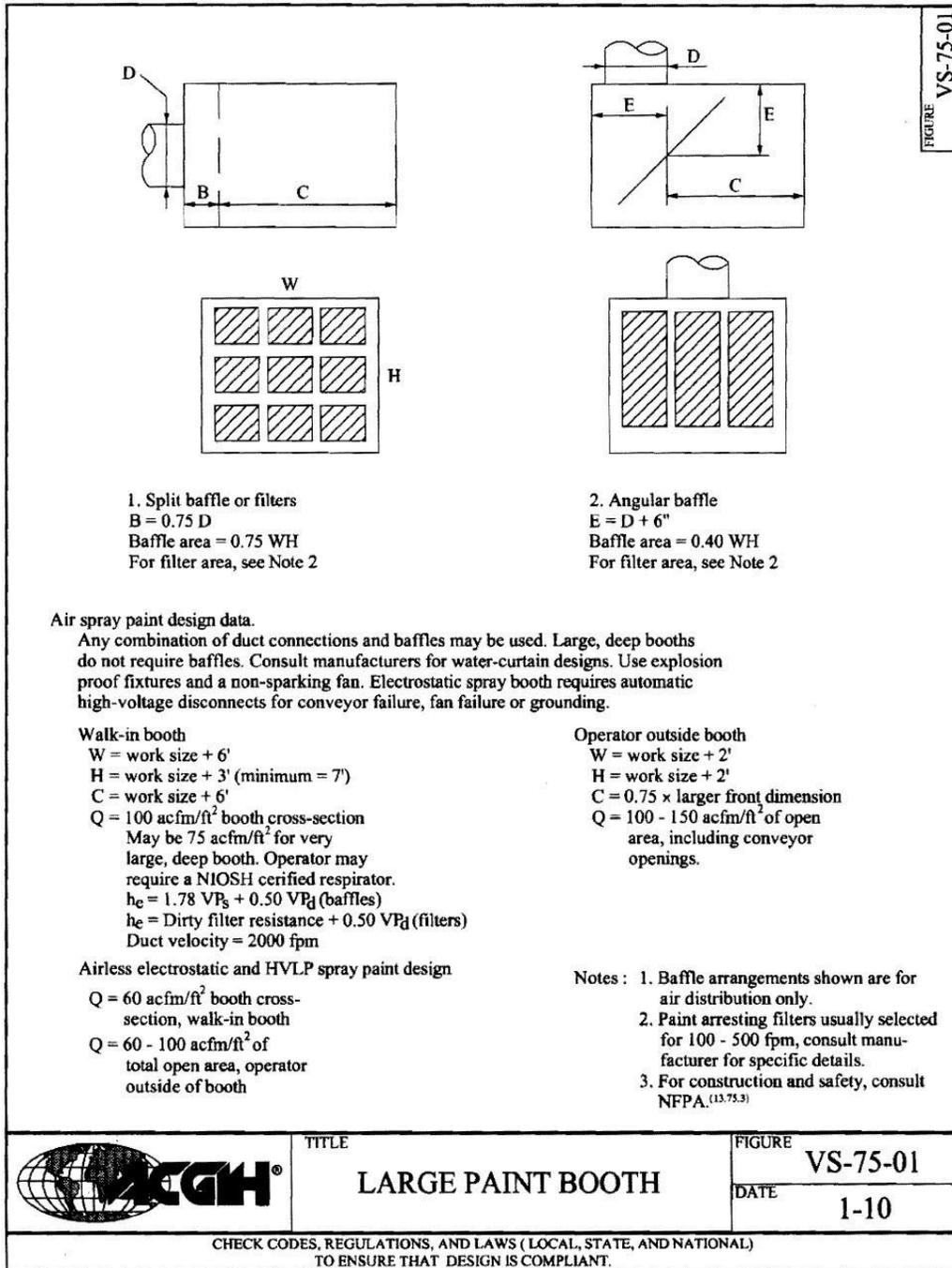
VS-65-01



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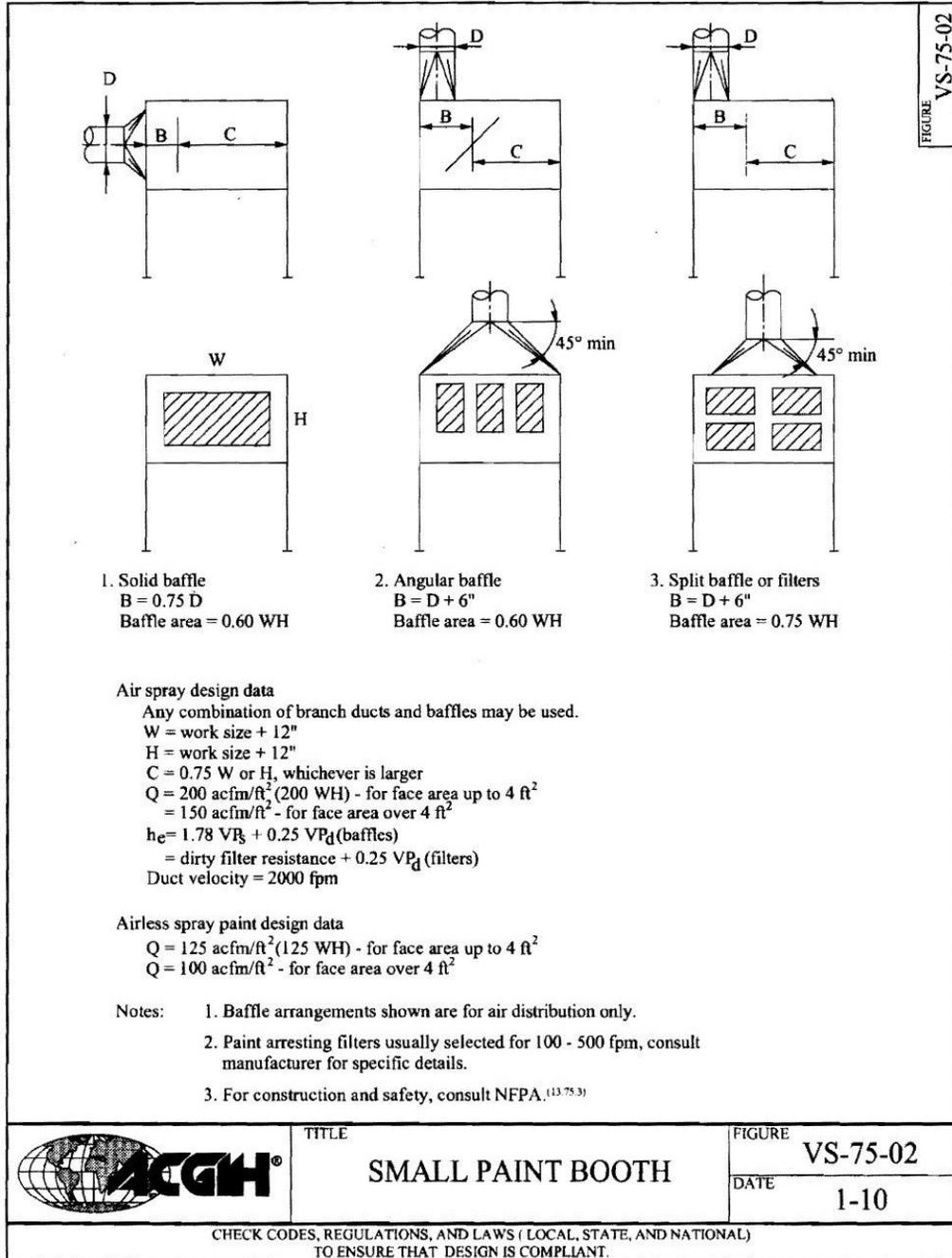
Large Paint Booth

VS-75-01



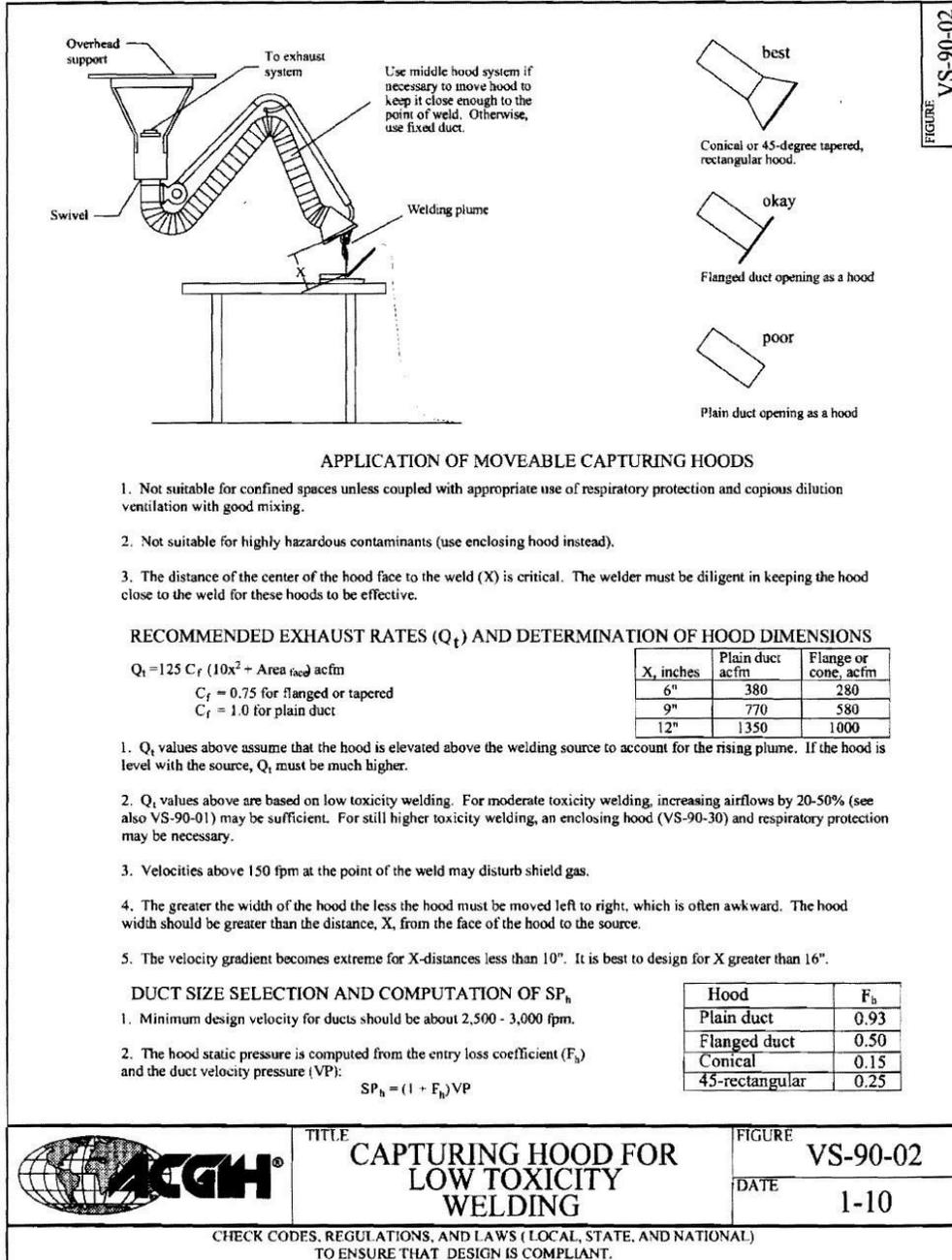
Small Paint Booth

VS-75-02



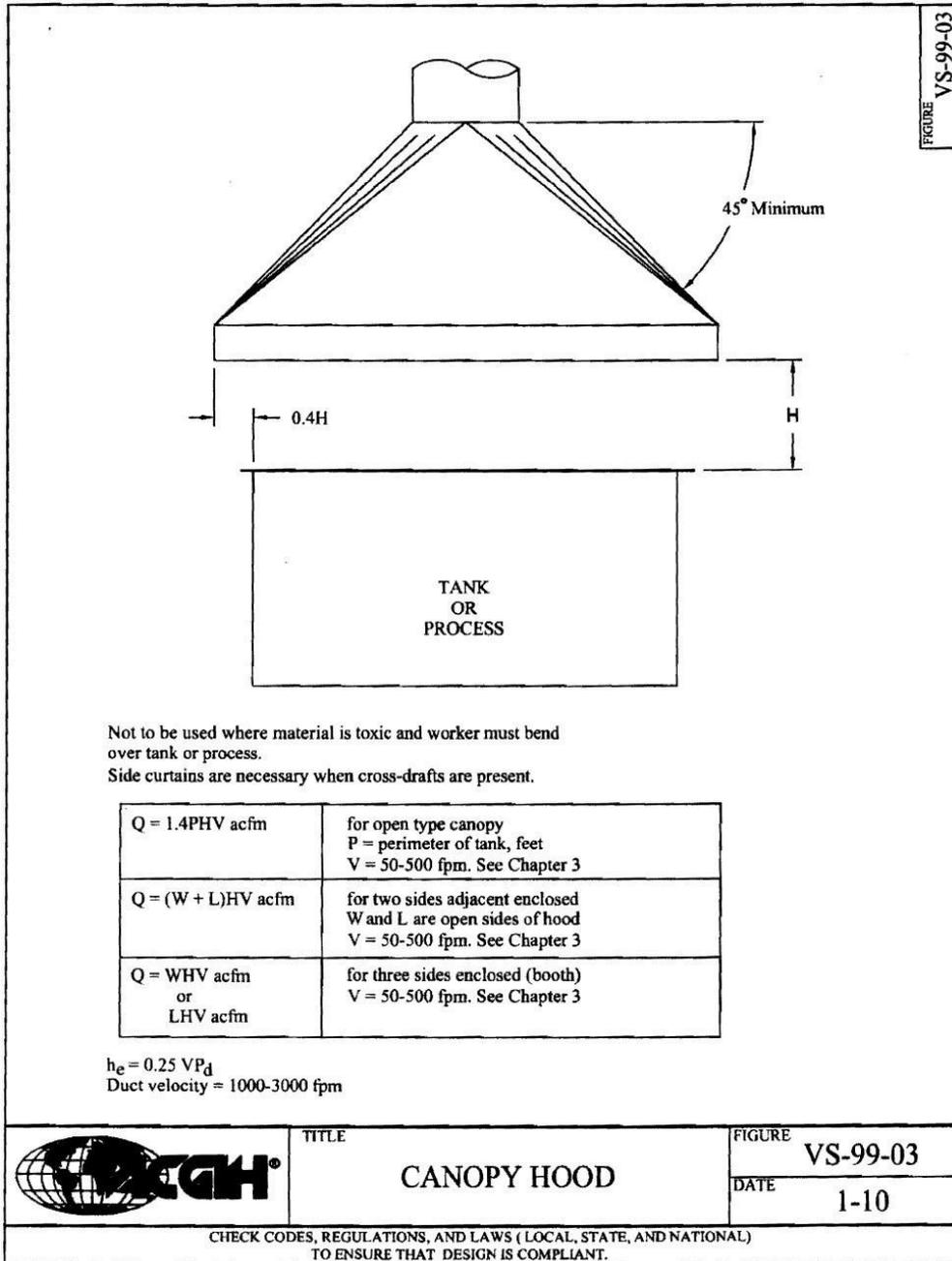
Capturing Hood for Low Toxicity Welding

VS-90-02



Canopy Hood

VS-99-03



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Area and Circumferences of Circles

Table 5-8

TABLE 5-8. Area and Circumference of Circles

Dia. In Inches	AREA		CIRCUMFERENCE		Dia. In Inches	AREA		CIRCUMFERENCE	
	Square Inches	Square Feet	Inches	Feet		Square Inches	Square Feet	Inches	Feet
1	0.79	0.0055	3.14	0.2618	30	706.9	4.909	94.2	7.854
1.5	1.77	0.0123	4.71	0.3927	31	754.8	5.241	97.4	8.116
2	3.14	0.0218	6.28	0.5236	32	804.2	5.585	100.5	8.378
2.5	4.91	0.0341	7.85	0.6545	33	855.3	5.940	103.7	8.639
3	7.07	0.0491	9.42	0.7854	34	907.9	6.305	106.8	8.901
3.5	9.62	0.0668	11.00	0.9163	35	962.1	6.681	110.0	9.163
4	12.57	0.0873	12.57	1.0472	36	1017.9	7.069	113.1	9.425
4.5	15.90	0.1104	14.14	1.1781	37	1075.2	7.467	116.2	9.687
5	19.63	0.1364	15.71	1.3090	38	1134.1	7.876	119.4	9.948
5.5	23.76	0.1650	17.28	1.4399	39	1194.6	8.296	122.5	10.210
6	28.27	0.1963	18.85	1.5708	40	1256.6	8.727	125.7	10.472
6.5	33.18	0.2304	20.42	1.7017	41	1320.3	9.168	128.8	10.734
7	38.48	0.2673	21.99	1.8326	42	1385.4	9.621	131.9	10.996
7.5	44.18	0.3068	23.56	1.9635	43	1452.2	10.085	135.1	11.257
8	50.27	0.3491	25.13	2.0944	44	1520.5	10.559	138.2	11.519
8.5	56.75	0.3941	26.70	2.2253	45	1590.4	11.045	141.4	11.781
9	63.62	0.4418	28.27	2.3562	46	1661.9	11.541	144.5	12.043
9.5	70.80	0.4922	29.85	2.4871	47	1734.9	12.048	147.7	12.305
10	78.54	0.5454	31.42	2.6180	48	1809.6	12.566	150.8	12.566
10.5	86.59	0.6013	32.99	2.7489	49	1885.7	13.095	153.9	12.828
11	95.03	0.6600	34.56	2.8798	50	1963.5	13.635	157.1	13.090
11.5	103.87	0.7213	36.13	3.0107	52	2123.7	14.748	163.4	13.614
12	113.10	0.7854	37.70	3.1416	54	2290.2	15.904	169.6	14.137
13	132.73	0.9218	40.84	3.4034	56	2463.0	17.104	175.9	14.661
14	153.94	1.0690	43.98	3.6652	58	2642.1	18.348	182.2	15.184
15	176.71	1.2272	47.12	3.9270	60	2827.4	19.635	188.5	15.708
16	201.06	1.3963	50.27	4.1888	62	3019.1	20.966	194.8	16.232
17	226.98	1.5763	53.41	4.4506	64	3217.0	22.340	201.1	16.755
18	254.47	1.7671	56.55	4.7124	66	3421.2	23.758	207.3	17.279
19	283.53	1.9689	59.69	4.9742	68	3631.7	25.220	213.6	17.802
20	314.16	2.1817	62.83	5.2360	70	3848.5	26.725	219.9	18.326
21	346.36	2.4053	65.97	5.4978	72	4071.5	28.274	226.2	18.850
22	380.13	2.6398	69.12	5.7596	74	4300.8	29.867	232.5	19.373
23	415.48	2.8852	72.26	6.0214	76	4536.5	31.503	238.8	19.897
24	452.39	3.1416	75.40	6.2832	78	4778.4	33.183	245.0	20.420
25	490.87	3.4088	78.54	6.5450	80	5026.5	34.907	251.3	20.944
26	530.93	3.6870	81.68	6.8068	82	5281.0	36.674	257.6	21.468
27	572.56	3.9761	84.82	7.0686	84	5541.8	38.485	263.9	21.991
28	615.75	4.2761	87.96	7.3304	86	5808.8	40.339	270.2	22.515
29	660.52	4.5869	91.11	7.5922	88	6082.1	42.237	276.5	23.038

The usual sheet metal fabricator will have patterns for ducts in 0.5-inch steps through 5.5-inch diameter; 1 inch steps 6 inches through 20 inches and 2-inch steps 22 inches and larger diameters.