CHAPTER 8

BATTERY MAINTENANCE FACILITIES

8-1 **FUNCTION.** Battery maintenance facilities contain space and equipment for receiving, cleaning, testing, charging, and issuing batteries. Sizes range from a small booth to a room with storage area. In these facilities, batteries are not in operation while being charged. Two types of electrochemical battery in general use are lead-acid and nickel-cadmium (NICAD). This chapter does not address battery-post repair operation. Design of facilities for installation of battery banks, such as UPS, will be covered in a different UFC.

8-2 **OPERATONAL CONSIDERATIONS.** Batteries generate a small amount of hydrogen and other gases while they are being charged or discharged. Hydrogen build-up could lead to an explosion. Provide ventilation to keep the hydrogen concentration below 25 percent of the LEL (LEL = 4 percent) to prevent an accumulation of an explosive mixture.

8-3 **DESIGN CRITERIA.** Design the facilities using NAVFAC DM-28.4, *General Maintenance Facilities*. Design the ventilation system using general technical requirements in chapter 4 of this UFC and the specific requirements in this Chapter.

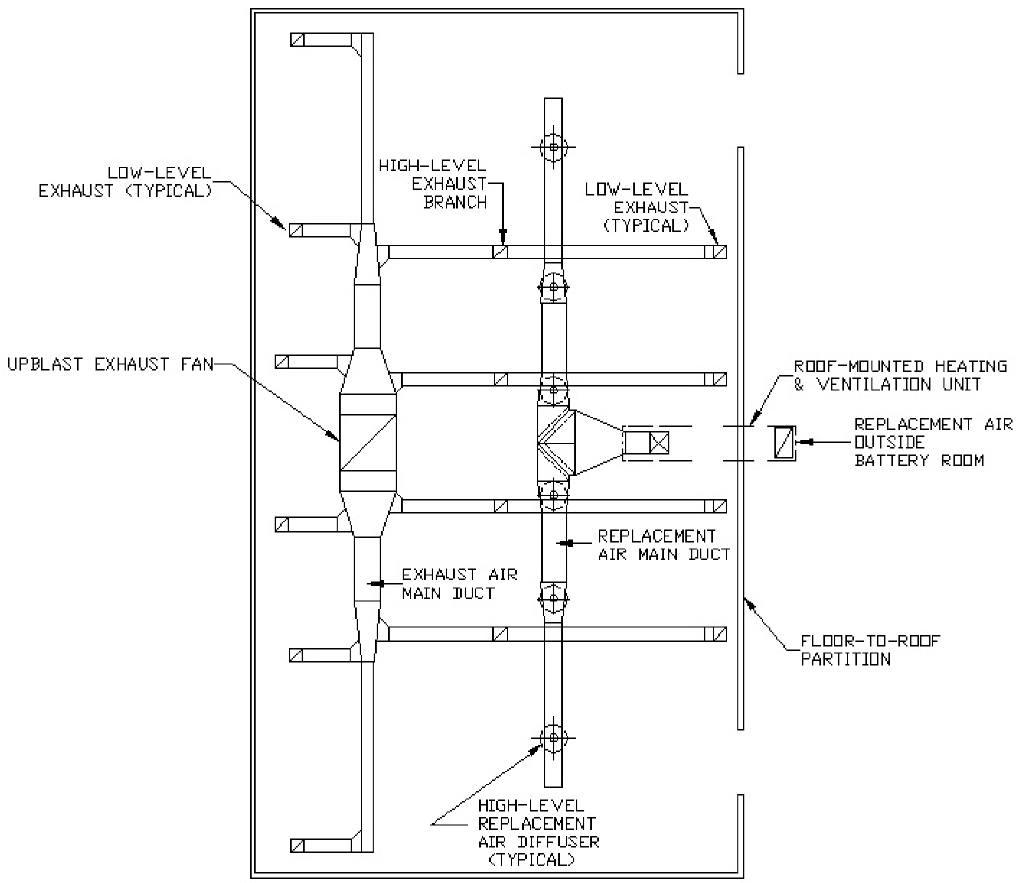
8-3.1 **Exhaust System**. Design exhaust ventilation to have both high-level exhaust for hydrogen and low-level exhaust for electrolyte spills (acid fumes and odors). Distribute one-third of the total exhaust flow rate to the high-level exhaust to ventilate all roof pockets. Locate low-level exhaust at a maximum of 304.8-mm (1-ft) above the floor. See Figure 8-1 for a floor plan of a battery maintenance room.

8-3.1.1 **Minimum Flow Rate Calculation.** To determine the amount of required volumetric airflow rate, the amount of hydrogen produced must be calculated for the total number of battery cells in the room. The volume of hydrogen generated is governed by the amount of charging current (ampere) supplied to the fully charged battery by the charger. Significant amounts of hydrogen are evolved only as the battery approaches full charge. To determine a minimum required volumetric airflow rate, use the following formulas:

$$C = (FC/100) \times AH \times K \times N \quad (1)$$

$$Q = (C/60)/ PC \quad (2)$$

Figure 8-1. Ventilation system for battery maintenance facilities.



Where:

C = Hydrogen generated, in cubic feet per hour (cfh).

FC = Float current per 100 ampere-hour. FC varies with battery types, battery condition, and electrolyte temperature. It will double/halve for each 15 degrees F (8 degrees C) rise/fall in electrolyte temperature.

AH = Ampere hour.

K = A constant of 0.016 cubic feet of hydrogen per 1 ampere-hour per cell (at sea level and 77 degrees F ambient temperature).

N = Number of battery cells.

Q = Minimum required ventilation airflow rate, in cubic feet per minute (cfm).

PC = Percent concentration of hydrogen allowed in room (PC = 0.01 to keep the hydrogen concentration at 1 percent).

Formula (2) assumes complete mixing of the air inside the battery maintenance facility. In most cases, use a safety factor k to determine the actual ventilation rate. See Figure 2.1 of the ACGIH IV Manual to select a "k" value.

Q_A = Q x k (3)

Q_A = The actual volumetric ventilation rate, in cubic feet per minute (cfm), which can be expressed in air change per hour (ACH) using the following formula:

ACH = Q_A x 60 /Room Volume (4)

<u>Example</u>. Per manufacturer specification, one fully charged lead calcium cell, at 77 degrees F (25 degrees C), will pass 0.24 amperes of charging current for every 100 ampere-hour cell capacity, measured at the 8-hour rate, when subject to an equalizing potential of 2.33 volts. Calculate the required rate of ventilation for a battery bank consisting of 182 cells. Each cell has a nominal 1,360-amphere hours capacity at the 8-hour rate and being equalized at an electrolyte temperature of 92 degrees F (30 degrees C).

At 92 degrees F (30 degrees C), FC is doubled

FC = 0.24 amp x 2 = 0.48 amp

AH = 1360 amp hr

K = 0.016 ft^3/amp hr cell

$$C = \frac{0.48 \text{ amp}}{100 \text{ amp hr}} \times 1360 \text{ amp hr} \times 0.016 \frac{ft^3}{\text{amp hr cell}} \times 182 \text{ cell} = 19 \frac{ft^3}{hr}$$

$$Q = \frac{19 \frac{ft^3}{hr} \times \frac{1 \text{ hr}}{60 \text{ min}}}{0.01} = 32 \frac{ft^3}{min} \qquad (5)$$

Assume a room size of 8,000 cubic feet (226.5 cubic meters) with a safety factor of k = 2, charging 3 banks of battery.

$$Q_A = 32\frac{ft^3}{min} \text{ x } 3 \text{ x } 2 = 192 \frac{ft^3}{min}$$

$$ACH = 192 \frac{ft^3}{min} x \frac{60 \text{ min}}{hr} x \frac{1AC}{8000 \text{ ft}^3} = 1.44 \frac{AC}{hr} \qquad (6)$$

8-3.2 **Ductwork**. Design ductwork in accordance with paragraph 2-4.1. Use FRP or PVC ductwork.

8-3.3 **Fans and Motors**. Select fans in accordance with paragraph 2-4.2. Use AMCA 201, Type B spark resistant construction and explosion proof motors. Fans must have non-sparking wheel. Locate the motor outside of the air stream.

8-3.4 **Weather Stack Design and Location**. Avoid re-entry of exhaust air by discharging the exhaust high above the roof line or by assuring that no window, outdoor intakes, or other such openings are located near the exhaust discharge. See paragraph 2-4.3 for additional considerations.

8-3.5 **Air Cleaning Device**. Due to the quantities and types of contaminants generated by this process, there is no requirement for air pollution control equipment.

8-3.6 **Replacement Air**. Design a replacement air system in accordance with paragraph 2-4.5. Design the replacement air volumetric flow rate for approximately 95 percent of the exhaust airflow rate to provide a negative pressure inside the maintenance facility. Use 100 percent outside air. Do not re-circulate exhaust air back to the maintenance facility.

8-3.7 **System Controls**. Design system control in accordance with paragraph 2-5 and the following criteria:

a. Interlock the charging circuit and the exhaust fan in the shop to ensure chargers will not operate without ventilation.

b. Provide indicator light showing that the exhaust system is functioning properly.

8-4 **SAFETY AND HEALTH CONSIDERATIONS.** In accordance with 29 CFR 1926.403, *Battery Rooms and Battery Charging*, provide the following.

a. Face shields, aprons, and rubber gloves for workmen handling acids or batteries.

b. Facilities for quick drenching of the eyes and body, within 7.6 m (25 ft) of the work area for emergency use. See UFC 3-420-01 for eyewash station requirements.

c. Facilities for flushing and neutralizing spilled electrolyte, and for fire protection.

d. Non-slip rubber insulating matting in front of all charging benches to protect personnel from electric shock and slipping hazards

e. Warning signs, such as: "Hydrogen, Flammable Gas, No Smoking, No Open Flames."

CHAPTER 9

PAINT SPRAY BOOTHS

9-1 **FUNCTION.** Paint spray booths provide surface finishing capabilities for a wide range of parts, equipment, and vehicles. Paint spray booth sizes range from bench type units for painting small parts, to large walk-in booths or rooms for painting vehicles, tractors or large equipment. Design aircraft maintenance hangars in accordance with Chapter 10 of this UFC.

9-2 **OPERATIONAL CONSIDERATIONS.** During paint spray operations, paint is atomized by a spray gun and then deposited on the object being painted. Depending on the application equipment and spray method used, transfer efficiencies vary greatly. Transfer efficiency is the amount of paint solids deposited on a surface divided by the total amount of paint sprayed, expressed as a percentage.

a. Use equipment with a high transfer efficiency, such as electrostatic or high volume low pressure (HVLP) spray guns, to reduce overspray. Overspray is the paint that is sprayed but not deposited on the surface being painted. This equipment not only saves in paint cost, but also reduces volatile organic compound (VOC) emissions and maintenance requirements.

b. Warm the paint before applying, whenever possible. This lowers the paint viscosity enabling spray painting at a lower pressure, thereby minimizing the amount of overspray generated. The lower viscosity also decreases the quantity of solvent used to thin the paint prior to spraying. This results in reduced solvent consumption and VOC emissions.

9-2.1 **Painting Equipment Types.** Spray-painting equipment must conform to national, state, and local emission control requirements. One of these requirements is transfer efficiency. Five primary types of paint spraying equipment and their typical transfer efficiencies include:

1. Conventional air spray (25 percent transfer efficiency).
2. Airless spray (35 percent transfer efficiency).
3. Air-assisted airless spray (45 percent transfer efficiency).
4. Electrostatic spray (65 percent transfer efficiency).
5. High volume/low pressure (HVLP) spray (up to 75 percent transfer efficiency).

9-3 **DESIGN CRITERIA.** Design or procure paint spray booths in accordance with the general technical requirements in Chapter 2 of this UFC and the specific requirements in this Chapter.

9-3.1 **Walk-in Spray Paint Booths**. The ventilation system for a walk-in booth is mainly to prevent fire and explosion. A well-designed ventilation system will also reduce paint overspray, help control workers' exposure, and protect the paint finish. Workers must use appropriate respiratory protection irrespective of the airflow rate. On 9 February 2000, OSHA issued an interpretation of 29 CFR 1910.94 and 1910.107, *Spray Finishing Using Flammable and Combustible Materials* for determining the airflow rate required for a walk-in paint booth. In accordance with OSHA's interpretation letter, following NFPA 33 will provide protection from fire and explosion. The guidance listed in Subpart Z of 29 CFR 1910.94 provides protection for workers. See Appendix B for OSHA's interpretation.

a. Use the Painting Operations section in the ACGIH IV manual to determine the design volumetric airflow rate. Ensure that this design volumetric airflow rate will keep the concentration of vapors and mists in the exhaust stream of the ventilation system below the 25 percent of the LEL. See 1910.94(c)(6)(ii) for an example of airflow rate requirement calculations.

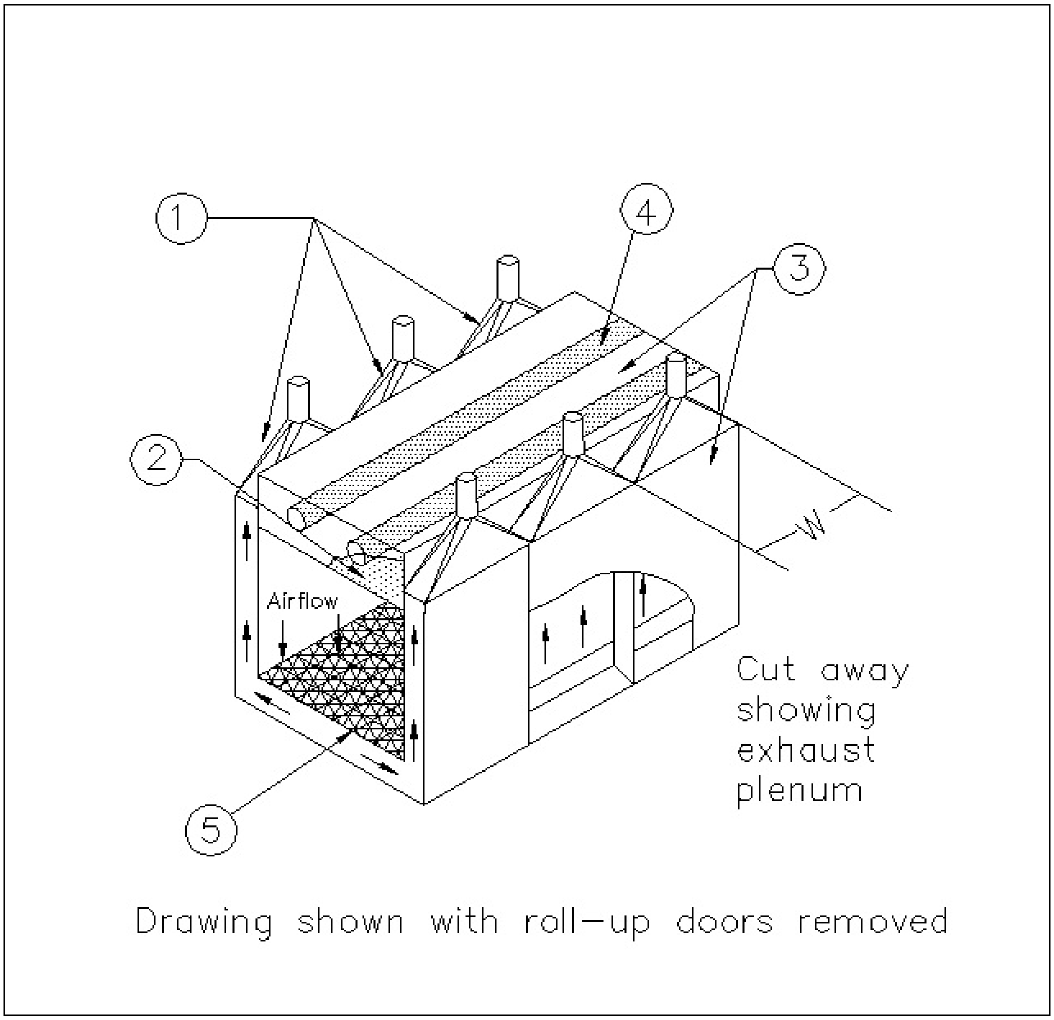
b. Do not re-circulate exhaust air while painting.

9-3.1.1 **Exhaust Configurations**. The two main ventilation system configurations are downdraft and crossdraft. In a downdraft booth, air enters through filters in the ceiling of the booth and leaves through filters that cover trenches under a metal grate floor. In a crossdraft booth, air enters through filters in the front of the booth and leaves through filters in the back of the booth. Both configurations are commercially available.

9-3.1.1.1 **Downdraft Paint Spray Booths**. Downdraft booth configuration provides a cleaner paint job than the crossdraft booth configuration and controls exposures to workers better than crossdraft booth configuration. The downdraft configuration should be the primary choice in designing or selecting of paint spray booths. Figure 9-1 is an example of a downdraft configuration.

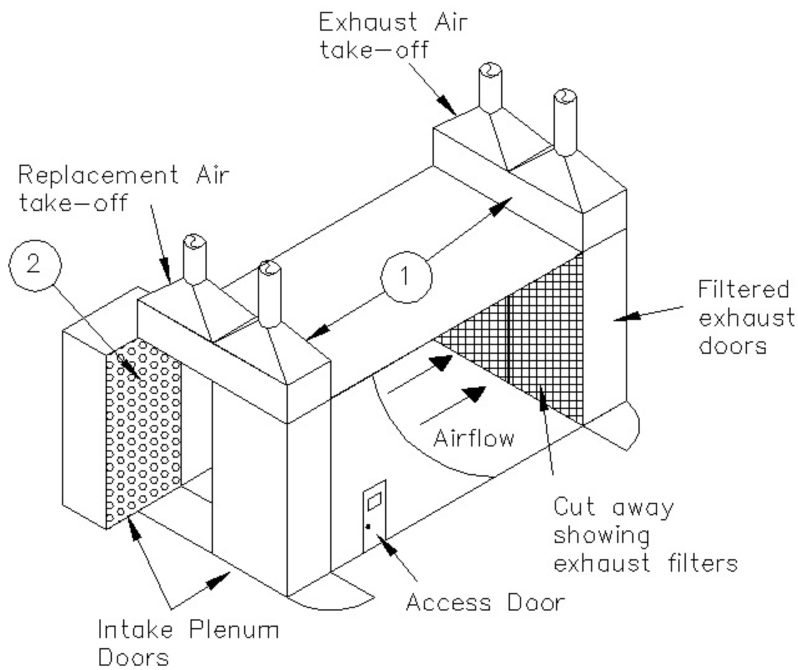
9-3.1.1.2 **Crossdraft Paint Spray Booths**. The crossdraft paint spray booth usually requires less total volumetric airflow rate than the downdraft spray paint booth because the vertical cross-sectional area of the booth is often smaller than the booth footprint area. Figures 9-2 and 9-3 are examples of drive-through crossdraft paint spray booth configurations.

Figure 9-1. Walk-in downdraft paint booth.



NOTES:
1. Size each plenum take-off for no more than 2.44 m (8 ft) of plenum width (W).
2. Perforated plate with 9.53-mm (3/8-in) holes. Size open area for an airflow velocity of 5.08 m/s (1,000 fpm) through holes.
3. Size exhaust plenum for a maximum plenum velocity of 5.08 m/s (1,000 fpm). Size replacement air plenum for a maximum plenum velocity of 2.54 m/s (500 fpm).
4. Use manufacturer's recommendations for sizing perforated ductwork.
5. Removable filters and floor grating.

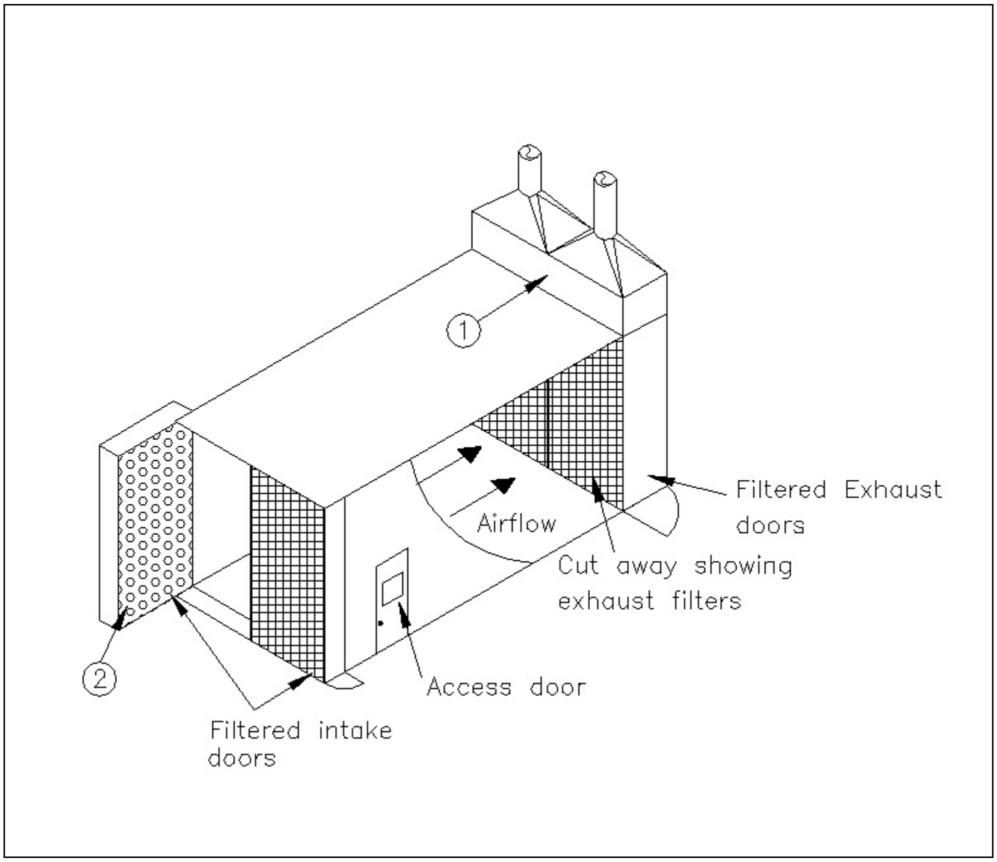
Figure 9-2. Drive-through cross draft paint booth with mechanical replacement air.



NOTES:

1. Size each plenum take-off for no more than 2.44 m (8 ft) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 5.08 m/s (1,000 fpm). Size replacement air plenum for a maximum plenum velocity of 2.54 m/s (500 fpm).
2. Perforated plate with 9.53-mm (3/8-in) holes. Size open area for an airflow velocity of 10.16 m/s (2,000 fpm) through holes.

Figure 9-3 Drive-through crossdraft paint booth with no Mechanical replacement air



NOTES:
1. Size each plenum take-off for no more than 2.44 m (8 ft) of plenum width. Size the exhaust plenum for a maximum plenum velocity of 5.08 m/s (1,000 fpm). Size replacement air plenum for a maximum plenum velocity of 2.54 m/s (500 fpm).
2. Perforated plate with9.53-mm (3/8-in) holes. Size open area for an airflow velocity of 10.16 m/s (2,000 fpm) through holes.

9-3.1.2 **Paint Spray Booth Exhaust Filtration System**. There are two types of exhaust air filtration systems. The first type is a water wash system. A water curtain is created at the exhaust plenum by a pump providing continuous circulation of water. The second type is a dry filter system, where the exhaust air passes through filter media. Consider the following.

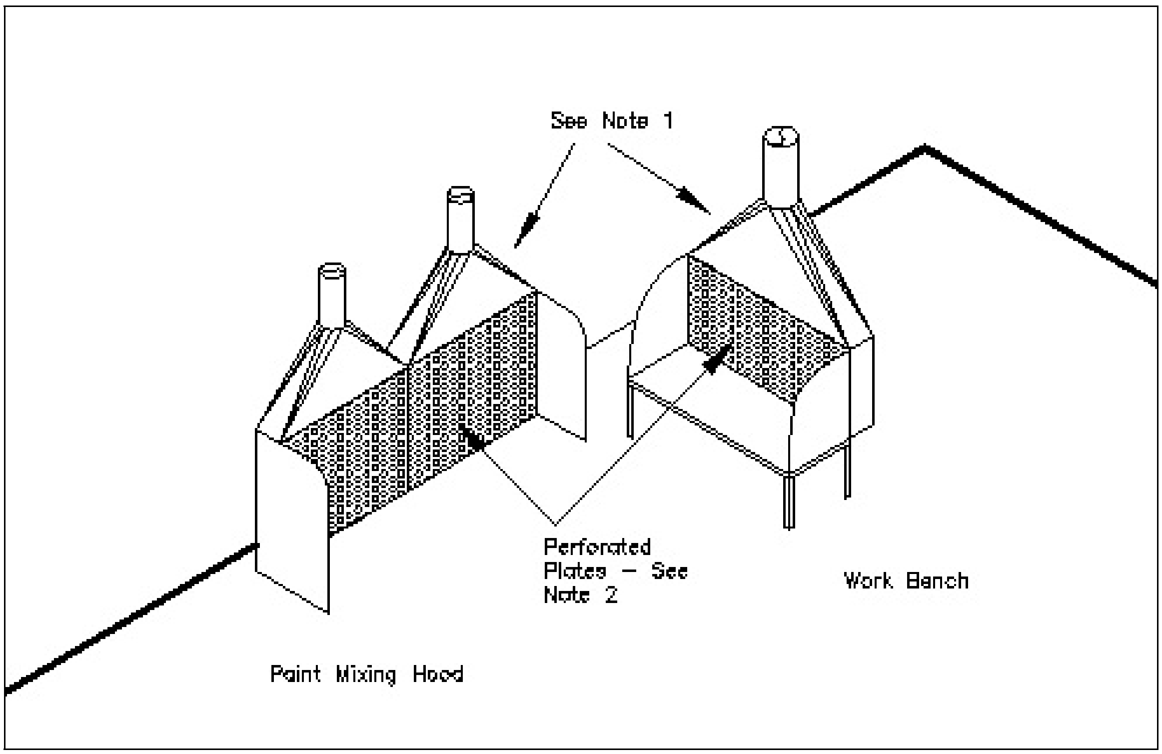
a. Do not design or purchase the water wash paint spray booths. The water wash system requires more energy to operate than the dry filter system. The wastewater must be treated and the hazardous constituents removed (often at great cost to the generating facility) before it may be discharged to a municipal treatment plant.

b. Neither water wash nor dry filter filtration systems can reduce the concentration of volatile organic compounds in the exhaust air stream. Consult the environmental department for controlling volatile organic compounds.

9-3.2 **Storage and Mixing Room**. Refer to the ACGIH IV Manual, Paint Mix Storage Room, VS-75-30 for the design of ventilation system.

9-3.3 **Paint Mix Hoods**. Figure 9-4 is an example of a workbench and a floor hood designed for paint mixing. Provide 0.5 m^3/s per m^2 (100 cfm per square foot) of hood face.

Figure 9-4 Paint mixing hood and work bench



NOTES:

1. Size each plenum take-off for no more than 2.44 m (8 ft) of plenum width. Size each plenum for a maximum plenum velocity of 5.08 m/s (1,000 fpm).
2. Perforated plate with 9.53 mm (3/8-in) holes. Size open area for an airflow velocity of 10.16 m/s (2,000 fpm) through holes.

9-4 **FANS AND MOTORS.** Use explosion proof motor and electrical fixtures for exhaust fan. Do not place electric motors, which drive exhaust fans, inside booths or ducts. See 4-4.2 for more detailed information about fan selection.

9-5 **REPLACEMENT AIR.** There is no control over the room temperature or room static pressure for non-mechanical replacement air systems. Dust from outside often enters the paint spray booths through cracks and damages the paint finish. Therefore, provide a mechanical replacement air system to maintain a neutral air pressure inside the booth. This will prevent dust from entering the paint spray area. The neutral air pressure will also prevent paint overspray and vapors from escaping the booth and migrating into adjacent work areas. For paint mixing room replacement air, refer to the ACGIH IV Manual, Paint Mix Storage Room, VS-75-30.

9-5.1 **Air Distribution**. Distribution of replacement air within the spray booth is as significant as the average air velocity through the booth. Distribute the replacement air evenly over the entire cross section of the booth to prevent turbulence or undesirable air circulation. The preferred means of distributing the replacement air is through perforated plate as shown in Figures 9-1, 9-2, and 9-3. See paragraph 2-4.5 for additional replacement air design criteria.

9-5.2 **Heating and Air Conditioning**. See paragraph 2-4.5. Most new paint spray booth ventilation systems have a painting mode and a curing mode. Do not re-circulate air during the painting mode. About 10 percent of the booth airflow is from outside the booth and 90 percent of the exhaust air is recycled during curing. Review the paint drying requirements before specifying temperature and humidity ranges. Refer to ANSI Z9.7 for exhaust air re-circulation requirements.

9-6 **SYSTEM CONTROLS**. Design system controls in accordance with paragraph 2-5.

9-7 **RESPIRATORY PROTECTION.** See paragraph 2-7.3.

CHAPTER 10

AIRCRAFT CORROSION CONTROL HANGARS

10-1 **FUNCTION.** Aircraft corrosion control hangars provide space and equipment for the corrosion control processing of aircraft. Processes include: deicing, limited detergent washing and rinsing, paint stripping, corrosion removal, protective coating application and painting, and finish curing and drying.

10-2 **OPERATIONAL CONSIDERATIONS**. See paragraph 9-2 for spray paint operation considerations.

10-3 **DESIGN CRITERIA.** Design hangars in accordance with MIL-HDBK-1028/1, *Aircraft Maintenance Facilities* and the specific ventilation system design requirements in this Chapter.

10-3.1 **Exhaust Air System**. The ventilation system for an aircraft corrosion control hangar is mainly to prevent fire and explosion. A well-designed ventilation system will also reduce paint overspray, help control workers' contaminant exposure, and protect the paint finish. Workers must use appropriate respiratory protection irrespective of the airflow rate. On 8 April 1997 and 1 July 1999, OSHA issued interpretations of 29 CFR 1910.94 and 1910.107 for determining the airflow rate required for an aircraft corrosion control hangars. In accordance with OSHA's interpretation letters, see Appendix D, an aircraft corrosion control hangar must minimally comply with the requirements of NFPA 33 and with Subpart Z of 29 CFR 1910 for hazardous substances.

NOTE U. S. Army: Army facilities will be designed to the requirements of 29 CFR 1910.94 and 1910.106 as well as NFPA33 and Subpart Z of 29 CFR 1910.

10-3.1.1 **Painting Mode**. Design the volumetric airflow rate to keep the concentration of vapors and mists in the exhaust stream of the ventilation system below the 25 percent of the LEL. See 29CFR1910.94(c)(6)(ii) for an example of airflow rate requirement calculations. However, this calculated airflow rate often is too low to capture the paint overspray. Do not re-circulate exhaust air while painting.

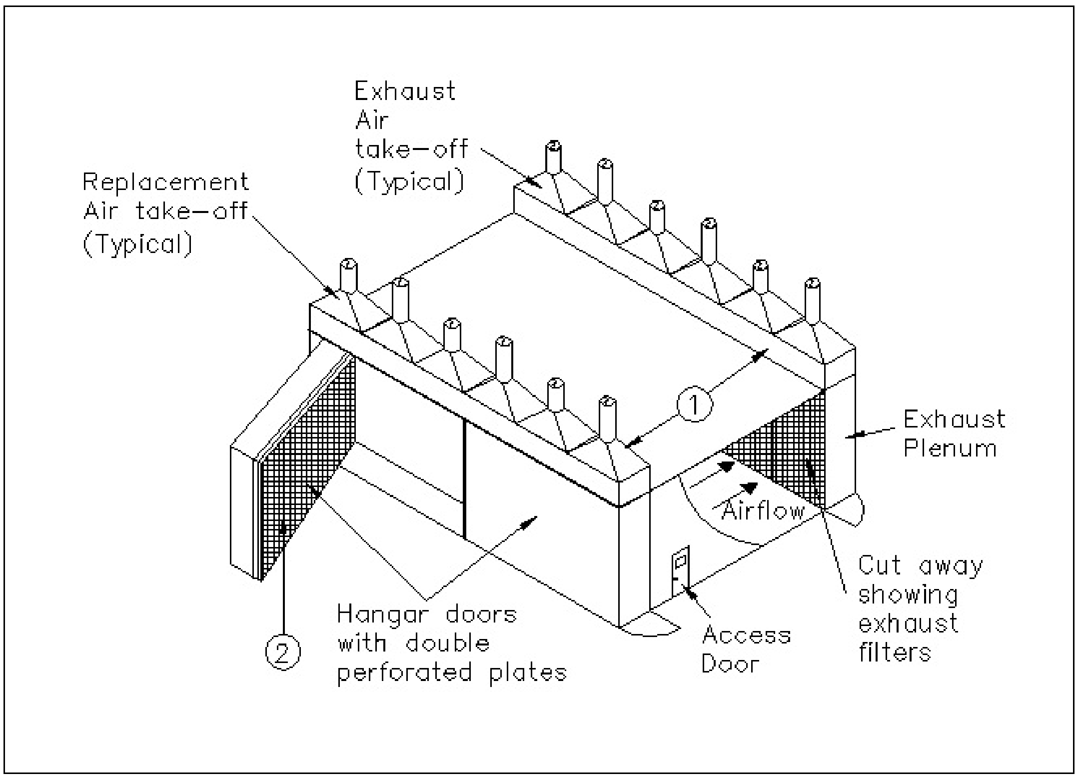
NOTE U. S. Army and U.S Air Force: Recirculation of exhaust air may be considered provided requirements of ANSI Z9.7, NFPA 33, ASHRAE, and OSHA are met.

10-3.1.2 **Drying Mode**. Review the paint drying requirements before specifying temperature and humidity ranges. Consider maintaining the airflow rate at the same level as in the painting mode for the simplicity of the system. However, a lower ventilation airflow rate can be used for the drying mode to conserve energy. Recirculation of exhaust air can be used if sufficient outside air is provided to keep the concentration of vapors and mists in the exhaust stream of the ventilation system below the 25 percent of the LEL. Note that the quantity of off gassed vapors is higher early in the drying process, tapering off at the end of the drying cycle. Refer to ANSI Z9.7 for exhaust air re-circulation requirement.

10-3.1.3 **Grinding Mode**. Provide vacuum exhaust grinding tools to remove dust during operations. The grinding process should be controlled separately from the painting and drying processes. When feasible, grinding should be performed in a separate grinding booth.

10-3.2 **Ventilation System Configurations**. Design or specify the entire exhaust air system using criteria for a crossdraft hangar configuration. Figure 10-1 is one method of designing hangar airflow distribution. When considering alternatives to the perforated supply plenum doors, the designs should introduce the make up air in a laminar manner and minimize the creation of dead air pockets. This will help to capture the paint overspray and reduce the possible build up of contaminants.

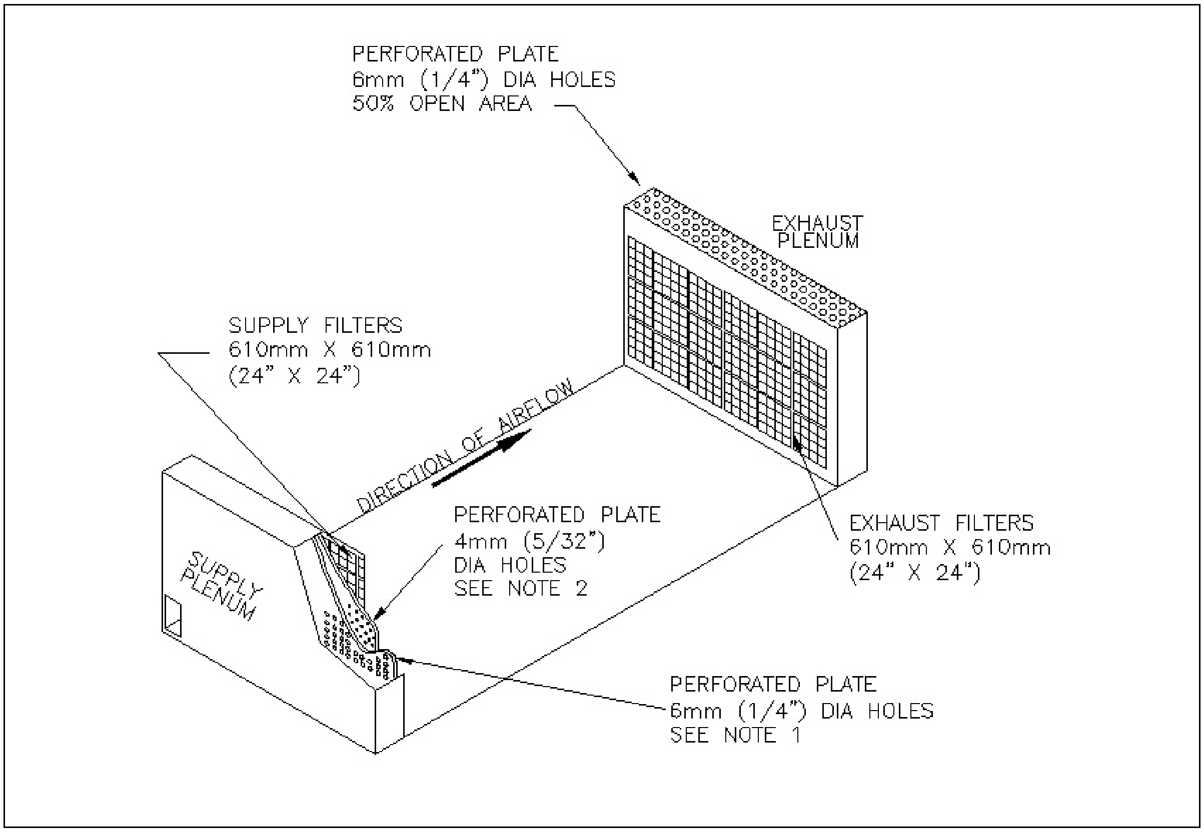
Figure 10-1. Crossdraft corrosion control hangar.



NOTES:

1. Size each plenum take-off for no more than 2.44 m (8 ft) of plenum width (W). Size the exhaust plenum for a maximum plenum velocity of 5.08 m/s (1,000 fpm). Size the replacement air plenum for a maximum plenum velocity of 2.54 m/s (500 fpm).
2. See Figure 10-2 for hangar doors and exhaust plenum details.

Figure 10-2. Hangar door and exhaust plenum details.



NOTES:
1. Size open area for an airflow velocity of 10.16 m/s (2,000 fpm) through holes.
2. Size open area for an airflow velocity of between 3 to 3.5 m/s (600 to 700 fpm) through holes.

10-3.3 **Exhaust Filtration System**. See paragraph 9-3.1.2

10-3.4 **Auxiliary Walk-in Paint Spray Room**. See Chapter 9 for a paint spray room design.

10-3.5 **Storage and Mixing Room**. Refer to the ACGIH IV Manual, Paint Mix Storage Room, VS-75-30 for ventilation system design.

10-3.6 **Paint Mixing Hood**. See paragraph 9-3.3.

10-4 **FANS AND MOTORS.** Use explosion proof motor and electrical fixtures for exhaust fan. Do not place electric motors, which drive exhaust fans, inside hangars or ducts. See paragraph 2-4.2 for more detailed information about selecting a fan.

10-5 **REPLACEMENT AIR**. Design the replacement air system to maintain a neutral air pressure inside the hangar. This will prevent dust from entering the paint spray area or paint overspray and vapors from escaping and migrating into adjacent work areas. See paragraph 2-4.5 for detailed design criteria.

NOTE U. S. Army and U.S. Air Force: Design the replacement air system at Army facilities to maintain a slightly negative air pressure inside the hangar.

10-5.1 **Heating and Air Conditioning**. See paragraph 2-4.5.

10-6 **SYSTEMS CONTROLS**. Design system controls in accordance with paragraph 2-5.

10-7 **RESPIRATORY PROTECTION**. See paragraph 2-7.3.

GLOSSARY

Air cleaner	A device designed for the purpose of removing atmospheric airborne impurities such as dusts, gases, vapors, fumes, and smoke. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters.)
Air filter	An air cleaning device to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: loadings up to 0.0069 g/m^3 (3 grains per thousand ft^3). Note: Atmospheric air in heavy industrial areas and in-plant air in many collectors are then indicated for proper air cleaning.
Air, standard	Dry air at 70 degrees F, 21.11 degrees C, and 29.92 in. Hg barometer. This is substantially equivalent to 0.075 pounds per cubic feet (lb/ft^3). Specific heat of dry air = 0.24 Btu/lb-F (1.004 kJ/(kg.K).
Aspect ratio (AR)	Ratio of the width to the length; AR = W/L.
Blast gate	Sliding damper.
Capture velocity	Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.
Dust	Small solid particles created by the breaking up of larger particles by processes crushing, grinding, frilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, and sweeping.
Dust collector	Air cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: loadings 0.003 grains per cubic foot and higher.
Fan class	This term applies to the fan's performance abilities. The required fan class is determined according to the operating point of the ventilation system. AMCA 99-2408 provides a set of five minimum performance limit standards (Class I through V) which manufactures use to apply the correct class to their fans.

FRP	Fiberglass reinforced plastic used in construction of such items as boats and airplanes. It is also used for ductwork in corrosive environments.
Fumes	Small, solid particles formed by the condensation of vapors of solid materials.
Gases	Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.
Gravity, specific	Ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2 degrees F is the standard substance usually referred to for gases, dry air, at the same temperature and pressure as the gas is often taken as the standard substance.
Hood	A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.
Humidity, relative	Ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.
Lower explosive limit (LEL)	Lower limit of flammability or explosiveness of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 degrees F. Above these temperatures, it should be decreased by a factor of 0.7 since explosiveness increases with higher temperatures.
Manometer	An instrument for measuring pressure; essentially a U-tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted in the instrument.
Micron	A unit of length; the thousandth part of 1 millimeter or the millionth of a meter (approximately 1/25,000 of an inch).
Mists	Small droplets of materials that are ordinarily liquid at normal temperature and pressure.
Plenum	A pressure equalizing chamber.

Pressure, static	Potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse the pipe.)
Pressure, total	The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).
Replacement air	Ventilation term used to indicate the volume of controlled outdoor air supplied to a building to replace air being exhausted.
Slot velocity	Linear flow rate of contaminated air through a slot. Usually measured in meters per second (m/s) [feet per minute (fpm)].
Smoke	An air suspension (aerosol) of particles, usually not solid, often originating in a solid nucleus, formed from combustion or sublimation.
Threshold limit values (TLV)	Values, established by ACGIH, for airborne toxic materials are used as guides in the control of health hazards and represent time-weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects.
Transport (conveying))	Minimum air velocity required to move the particulates in the air stream, measured in m/s (fpm).
Vapor	The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature.
Work piece	Equipment or machinery that, while operating, generates a fume, gas, vapor, or particulate hazardous to the health of the operator. Parts washers, wood saws, and degrease units are work pieces.

ABBREVIATIONS AND ACRONYMS

A

ACGIH	American Conference Of Governmental Industrial Hygienists, Inc.
ACH	air changes per hour
AMCA	Air Movement and Control Association, Inc.
ANSI	American National Standards Institute, Inc.
AR	Aspect ratio
ASHRAE	American Society of Heating, Refrigeration And Air Conditioning Engineers, Inc.

C

C	Degrees Celsius
cfh	cubic feet per hour
cfm	cubic feet per minute
cfm/ft2	cubic feet per minute per square foot
CFR	Code of Federal Regulations
cm	centimeter
cms	cubic meters per second

D

D	depth
dbA	decibels on the A-weighted scale
dM	Design Manual

F

F	Degrees Fahrenheit
fpm	feet per minute
FRP	fiberglass reinforced plastic

G

GSSDC	Guide for steel stack design and construction

H

H	Height
HEPA	high efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
HVLP	High volume, low pressure

I

IMC	International Mechanical Code
IV	Industrial ventilation

L

LEL	Lower Explosive Limit
LVHV	low volume, high velocity

M

m	meter
MEC	minimum explosive concentration
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
mm	millimeter
m/s	meter per second
MSDS	Material Safety Data Sheet

N

NAVAIR	Naval Air System Command
NAVFAC	Naval Facilities Engineering Command
NFPA	National Fire Protection Association
NICAD	nickel-cadmium
NIOSH	National Institute of Occupational Safety and Health

O

O/I	organization and intermediate
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Safety and Health Administration

P

Pa	Pascal
PEL	permissible exposure limit
PPE	personal protective equipment
PVC	polyvinyl chloride

R

REO	Regional Engineering Office
RIDCS	Round industrial duct construction standard

S

SCBA	self-contained breathing apparatus
SMACNA	Sheet Metal And Air Conditioning Contractors National Association

T

TLV	Threshold Limit Value
TM	Technical Manual
TWA	time-weighted average

V

VFD	variable frequency drive
VOC	Volatile Organic Compound

W

W	width
wg	water gage

APPENDIX A

REFERENCES

GOVERNMENT PUBLICATIONS:

1. DEPARTMENT OF DEFENSE http://dod.wbdg.org/	UFC 3-420-01, Design: Plumbing Systems UFC 3-450-01, Design: Noise and Vibration Control UFC 3-600-01, Design: Fire Protection Engineering For Facilities UFC 4-216-02N, Design: Maintenance Facilities for Ammunition, Explosives, and Toxins
2. Department of the Navy http://neds.nebt.daps.mil.usndirs.htm	OPNAVINST 5100.23, Navy Occupational Safety and Health Program Manual
3. Naval Sea Systems Command www.navsea.navy.mil	NAVSEA OP5, Volume 1, Ammunition and Explosives Ashore Safety Regulations for Handling, Storing, Production, Renovation, and Shipping NAVSEA S6340-AA-MMA-010, Otto Fuel II Safety, Storage, and Handling Instructions
4. Naval Facilities Engineering Command Engineering Innovation and Criteria Office 6506 Hampton Blvd, Norfolk, VA 23508 http://dod.wbdg.org/	DM 28.4, General Maintenance Facilities MIL-HDBK-1003/3, Heating, Ventilating, Air Conditioning, and Humidifying Systems MIL-HDBK-1004/6, Lightning (and Cathodic) Protection MIL-HDBK-1028/1A, Aircraft Maintenance Facilities P-970, Protection Planning in the Noise Environment
5. U.S. Department of Labor Occupational Safety and Health Administration www.osha.gov	DHEW 79-117, NIOSH Industrial Noise Control Manual 29 CFR 1919.94(a), Abrasive Blasting

29 CFR 1910.94(c), Spray Finishing Operation

29 CFR 1910.107, Spray Finishing Using Flammable and Combustible Materials

29 CFR 1910.134, Respiratory Protection

29 CFR 1910.1000, Air Contaminants

29 CFR 1910.1001, Asbestos, General Industry

29 CFR 1915.1001, Asbestos, Shipyards

29 CFR 1926.403, Battery Rooms and Battery Charging

OSHA Pub 3048, Noise Control, A Guide for Workers and Employees

6. U.S. Environmental Protection Agency
www.epa.gov

EPA-560-OPTS-86-001, A Guide to Respiratory Protection for the Asbestos Abatement Industry

NON-GOVERNMENT PUBLICATIONS

1. Air Movement and Control Association, Inc.

30 West University Drive
Arlington Heights, IL 60004-1893

www.amca.org

AMCA 201, Fans and Systems

AMCA 99-2408, Operating Limits for Centrifugal Fans (Performance Classes)

2. American Conference of Governmental Industrial Hygienists, Inc

1330 Kemper Meadow Dr., Ste 600
Cincinnati, OH 45240

www.acgih.org

ACGIH IV Manual, Industrial Ventilation; A Manual of Recommended Practice

3. American National Standards Institute, Inc

ANSI O1.1, Woodworking Machinery, Safety Requirements

11 West 42nd Street,
New York, NY 10036

www.ansi.org

4. American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc

1791 Tullie Circle, N.E.
Atlanta, GA 30329

www.ashrae.org

5. National Fire Protection Association

1 Batterymarch Park
Quincy, MA 02269-9101

ANSI Z9.4, Abrasive-Blasting – Ventilation & Safe Practices for Fixed Location Enclosures

ANSI Z9.7, Recirculation of Air from Industrial Process Exhaust Systems

ASHRAE Handbook, Fundamentals

ASHRAE Handbook, HVAC Systems and Equipment

ASHRAE Standard 52.2, Method of Testing General Ventilation air Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE Guideline 1, The HVAC Commissioning Process

NFPA 33, Standard Spray Application Using Flammable and Combustible Materials

NFPA 34, Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids

NFPA 65, Standard for the Processing and Finishing of Aluminum

NFPA 68, Guide for Venting Deflagrations

NFPA 69, Standard on Explosion Prevention

NFPA 70, National Electrical Code

NFPA 91, Standard for Exhaust Systems for Air Conveying of Materials

NFPA 480, Storage, Handling, and Processing of Magnesium

NFPA 481, Storage, Handling, and Processing of Titanium

NFPA 482, Storage, Handling, and Processing Zinc

NFPA 485, Storage, Handling and Processing Lithium

NFPA 650, Pneumatic Conveying Systems for Handling Combustible Particulate Solids

NFPA 654, Standard for the Prevention of Fire and Dust Explosions form the Manufacturing, Processing, and Handling of Combustible Particulate Solids

NFPA 664, Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

6. Sheet Metal and Air Conditioning Contractors National Association

SMACNA
4201 Lafayette Center Dr.
Chantilly, VA 20151-1209

SMACNA GSSDC, Guide for Steel Stack Design and Construction

SMACNA RIDCS, Round Industrial Duct Construction Standards

SMACNA RTIDCS, Rectangular Duct Construction Standards

7. Compressed Gas Association

4221 Walney Road, 5th Floor
Chantilly, VA 20151-2923
703-788-2700 (fax) 703-961-1831
cga@cgane.com
www.cganet.com

G-7.1, Commodity Specification for Air

APPENDIX B

LETTERS RELATED TO AIRFLOW REQUIREMENTS FOR WALK-IN SPRAY PAINT BOOTHS

B-1 **SCOPE**. This Appendix contains NFESC's letter requesting OSHA interpret ventilation rates for walk-in spray paint booths. See Figure B-1. This Appendix also contains OSHA's response to NFESC's request. See Figure B-2.

Figure B-1. NFESC's letter to OSHA.

DEPARTMENT OF THE NAVY

NAVAL FACILITIES ENGINEERING SERVICE CENTER
1100 23RD AVE
PORT HUENEME CA 93043-4370

5090 IN REPLY REFER TO:
ESC425
6 Jan 1999

From: Commanding Officer, Naval Facilities Engineering Service Center, Port Hueneme
To: Office of Federal Agency Programs, 200 Constitution Avenue N.W., Room N3112, Washington DC 20210 (Director/Mr. John E. Plummer)

Subj: VENTILATION RATE FOR FULLY ENCLOSED WALK-IN PAINT BOOTH/ROOM

1. The Naval Facilities Engineering Service Center and other Navy engineering organizations are currently evaluating designs for several walk-in spray paint booths/rooms. Typical Navy walk-in spray booth/rooms are used for maintaining paint finishes on such items as: vehicles, small boats, antenna towers, aircraft carrier anchor chains, and other small parts from ships and aircraft.

2. These booth/rooms are fully enclosed and the worker stands inside. Industrial ventilation for these systems can be defined as dilution ventilation, since the painter works within the contaminated area and is not isolated from the contaminated air stream. When Navy employees use the walk-in spray paint booth/rooms, they are fully trained in the hazards to which they are exposed, escape routes, fire protection plans, health requirements and the use of personnel protective equipment (PPE).

3. Airflow requirements for Navy designs of walk-in spray paint booth/rooms are currently determined using 29 CFR 1910.94(c) and 29 CFR 1910.107. However, the listed airflow rates in Table G10 and 29 CFR 1910.107(b)(5)(i) will not ensure that worker exposure remains below the Permissible Exposure Limit/Level. Workers must use appropriate respiratory protection irrespective of the airflow rate.

4. The primary purposes of ventilation in these walk-in spray paint booth/rooms are for fire protection and to provide a quality paint finish. Therefore, the requirements in NFPA 33, Flammable and Combustible Material apply.

5. We request your concurrence with our interpretation that:
   1) The minimum ventilation rates in 1910.94(c)(6)(i) (Table G-10) and 1910.107(b)(5)(i) are not applicable to the walk-in paint booth/rooms.
   2) A walk-in spray paint booth need only comply with the requirements of NFPA 33 and with subpart Z of 29 CFR 1910 for hazardous substances.

6. We appreciate your prompt attention.

DAVID M. CHAVEZ
NAVOSH Engineering Branch
Naval Facilities Engineering Service Center

Figure B-2. OSHA's interpretation.

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

FEB 9 2000

Reply to the Attention of: DCP/OFAP/RC

Commanding Officer
Naval Facilities Engineering Service Center
Naval Occupational Safety and Health - Air (ESC 425)
1100 23rd Avenue
Port Hueneme, CA 93043-4370

Dear Mr. Chavez:

Thank you for your faxed letter of January 6, 2000 to the Office of Federal Agency Programs. You have requested our concurrence with your interpretation of the applicability of OSHA standards to the ventilation rate for a fully enclosed walk-in paint booth/room.

Specifically, you would like OSHA's concurrence that:

1) The minimum ventilation rates in 1910.94(c)(6)(i) (Table G-10) and 1910.107(b)(5)(i) are not applicable to the walk-in paint booth/rooms.

2) A walk-in spray paint booth need only comply with the requirements of NFPA 33 and with Subpart Z of 29 CFR 1910 for hazardous substances.

OSHA does not concur with these statements. Both 29 CFR 1910.94(c)(6(i) (Table G-10) and 1910.107(b)(5)(i) are applicable to walk-in paint booths/rooms. However, if the Navy follows NFPA 33-1995 and 29 CFR Subpart Z, OSHA would consider the lack of compliance with 29 CFR 1910.94(c)(6(i) (Table G-10) and 1910.107(b)(5)(i) as *de minimis* violations (a technical violation that is not cited). Following NFPA 33-1995 will provide protection from fire and explosion and the guidance listed in Subpart Z of 29 CFR 1910 will provide protection for your employees.

Thank you for your interest in occupational safety and health. We hope that you find this information helpful. Please be aware that OSHA's enforcement guidance is subject to periodic review and clarification, amplification, or correction. Such guidance could also be affected by subsequent rulemaking. In the future, should you wish to verify that the guidance provided herein remains current, you may consult OSHA's website at http://www.osha.gov. Should you have further questions, please feel free to contact Mr. John E. Plummer or Mr. Ron Cain of my staff at 202-693-2122.

Sincerely,

Richard E. Fairfax

Richard E. Fairfax, Director
Directorate of Compliance Programs

APPENDIX C

LETTERS RELATED TO AIRFLOW REQUIREMENTS FOR CORROSION CONTROL HANGARS

C-1 **SCOPE**. This Appendix contains the NFESC Memorandum (less enclosures 1,2,3 and 4) requesting OSHA interpret the ventilation rates for aircraft corrosion control hangars. See Figure C-1. This Appendix also contains OSHA's response to NFESC's request. See Figure C-2.

Figure C-1. NFESC Memorandum to OSHA

DATE: May 13, 1999

MEMORANDUM

To: Ron Cain, Office of Federal Agency Programs, Occupational Safety and Health Administration, Washington, DC 20210

Via: John Plummer, Director, Office of Federal Agency Programs, Occupational Safety and Health Administration, Washington, DC 20210

From: Kathleen M. Paulson, P.E.
Naval Facilities Engineering Service Center
Naval Occupational Safety and Health - Air (ESC 425),
1100 23rd Avenue
Port Hueneme, CA 93043-4370
Commercial:(805) 982-4984, DSN: 551-4984, FAX:(805) 982-1409
Internet: paulsonkm@nfesc.navy.mil
Web Page: http://www.nfesc.navy.mil/enviro/esc425/NoshArBr.htm

SUBJ: INDUSTRIAL VENTILATION FLOW RATES IN AIRCRAFT HANGARS

We appreciate your offer to revisit the OSHA standard interpretation you provided to the Department of the Navy, Office if the Assistant Secretary, (Installations and Environment) regarding spray painting in aircraft hangars. See Enclosures (1) and (2). When we tried to apply the interpretation that you provided to us dated April 8, 1997, we discovered discrepancies in our characterization of the processes performed in Navy Final Finish and Corrosion Control Hangars. Enclosure (3) defines the operations performed in each of the various level hangars.

Our questions are:

1. What is your definition of a production spray finishing operation?
2. How do you characterize the five operational levels of hangars discussed in Enclosure 3?
3. What airflow rate criteria is required for each of the five levels?
4. If 100 cubic feet per minute per square foot of cross-sectional area is required for any of the five operational levels, please define the term cross-sectional area. Is it:

    a) Area of the exhaust filter bank?
    b) Area of the exhaust filter bank?

c) Air envelope around the plane, which excludes the "empty" area where there will be no aircraft parts?
d) Full opening of the hangar, for instance the approximate side of the hangar door opening plus about 5 feet on the top and sides of the hangar reserved for maneuverability?
e) Full opening of the hangar including open space for roof trusses?

Naval Facilities Engineering Command (NAVFAC) assigned the NAVOSH Air Branch of NFESC to revise Military Handbook 1003/17, Industrial Ventilation Systems. The handbook defines engineering design criteria for use by all components of the Department of Defense. We are adding a new chapter to the MIL-HDBK discussing the criteria for spray painting in aircraft hangars. We are having difficulties applying the interpretation to our criteria. To add to the urgency, NAVFAC is also in the process of designing several new aircraft hangars. Reducing the flow rate from 100 cubic feet per minute per square foot of cross-sectional area will provide a significant reduction in equipment first costs and annual operating costs.

Our position is - Aircraft hangars should not be designed for 100 cubic feet per minute per square foot of cross-sectional area due to the size of the space and the dilution effect. Regardless of the flow rate, not all the paint overspray will reach the filters and we acknowledge some will drop to the floor. This is particularly true for the portion of the aircraft farthest from the exhaust filter bank. Paint spray criteria in the ACGIH Industrial Ventilation Manual permits airflow in large spaces as low as 50 cubic feet per minute per square foot of cross-sectional area. Both the NFPA 33 and the ANSI Z9.3 consensus standards require a sufficient ventilation rate to prevent vapor build-up by requiring airflow to keep the vapor less than 25% of the LEL. Airflow calculations based on LEL are typically 10-25% of the rates required for health protection. Enclosure (4) reiterates our understanding of the pertinent regulations.

Our experience shows that even in spray painting operations using flow rates of 100 cubic feet per minute per square foot of cross-sectional area, some employee's occupational exposure exceeds the PEL for certain paints and paint components. Therefore, our employees use respiratory protection when painting in hangars.

Thank you for continuing to consider our concern. Based on our phone conversation today, I understand that you are also working on this issue with the US Air Force. Could you direct us to their point of contact? Our contacts are Kappy Paulson and Trinh Do (805) 982-4984.

Figure C-2. OSHA interpretation.

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

Reply to the Attention of:

JUL 1 1999

MEMORANDUM FOR: KATHLEEN M. PAULSON, P.E.
NAVOSH Air Branch
Naval Facilities Engineering Service Center

FROM: RICHARD FAIRFAX, Director
Directorate of Compliance Programs

SUBJECT: NFESC e-mail dated May 13, 1999

This memorandum is in response to your email of May 13, 1999 and confirms subsequent e-mail correspondence between you and Ron Cain of my staff.

OSHA considers the Department of Defense corrosion control hangars described in the NFESC memo dated May 13, 1999 as "spray areas." As such, the spray areas must comply with the requirements of NFPA 33, 1995 edition for "Spray Application Using Flammable or Combustible Materials," and with subpart Z of 29 CFR 1910 for hazardous substances. Non-compliance with table G-10 in 29 CFR 1910.94 will be considered *de minimis* by OSHA as long as the above requirements are met.

Should you require further assistance in this or any other matter, feel free to contact John Plummer or Ron Cain of my staff at 202-693-2122.

NOTE: De Minimis Violations. De minimis violations are violations of standards that have no direct or immediate relationship to safety or health. Whenever de minimis conditions are found during an inspection, they must be documented in the same way as any other violation but would not be included on the citation.