Ventilation Systems
SAFETY AND HEALTH APPLICATIONS
Ventilation System Roles and Responsibilities

Safety and Health Professionals / Industrial Hygienists
Operations Managers and Supervisors
Ventilation Engineers / Industrial Hygienists.
Roles and Responsibilities

Safety and Health Professionals / Industrial Hygienists

- Ensure proper flow rates and velocities for given contaminants in design phase
- Ensure appropriate capture device (hood) for the work to be performed
- Cost benefit analysis between ventilation and other control options
- Audit the systems to ensure management of the system is working and identify gaps
- Exposure monitoring to determine effectiveness and protection
- Ensure compatibility of the system with the required work to be done (ergonomics)
Roles and Responsibilities

Operations Managers/Supervisors
- Understand how the system should be operating
- Ensure day to day correct operation
- Ensure correct use by employees
- Ensure proper maintenance (cleanout hatches closed, system re-assembled, etc.)
- Resources to deal with breakdowns or issues
- Check parameters to detect potential or actual problems
- Preventative maintenance
- Cost and resources to run the system
Roles and Responsibilities

Ventilation Engineers / Industrial Hygienists
- Verify all pressure losses are accurate
- Verify a balanced system (using blast gates, or a balanced design)
- Ensure proper air mover (fan) for required flow rate and pressure losses
- Appropriate air cleaner for regulations and health/safety
- Stack height and placement
- Make up air
- Air conditioning and heating
- Special considerations (bleed in air, branches, contractions, expansions, etc.)
Ventilation Information Source


American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240
Duly incorporated by reference. Legally binding upon all citizens and residents. Criminal penalties may apply for noncompliance.

ACGIH: Industrial Ventilation Manual
CFR Section(s): 40 CFR 63.2984(e)
Standards Body: American Conference of Governmental Industrial Hygienists

What other contributions has ACGIH made to legislation in recent decades?
1968 ACGIH recommendations (TLV’s)
Aerosol: An assemblage of small particles, solid or liquid, suspended in air. Diameter may vary from 100 microns to 0.01 micron or less (dust, fog, smoke).

Capture Velocity: The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air current and to capture the contaminated air at that point by causing it to flow into the hood.

Entry Loss: Loss in pressure caused by air flowing into a duct or hood (inches of water).

Hood: A shaped inlet designed to capture contaminated air and conduct it into the exhaust dust system.
Definition

**Minimum Design Duct Velocity (transport velocity):** Minimum air velocity required to move the particles in the air stream, fpm.

**Replacement Air:** A ventilation term used to indicate the volume of controlled outdoor air supplied to a building to replace air being exhausted.
Pressure Definitions

Static Pressure: The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of water gauge when dealing with air. (Tendency to either burst or collapse the pipe.)

Velocity Pressure: The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of water gauge.

Total Pressure: The algebraic sum of the velocity pressure and the static pressure.
Types of Contaminants

**Dust:** Small solid particles created by the breaking up of larger particles by process of crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.

**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.

**Mist:** Small droplets of materials that are ordinarily liquid at normal temperature and pressure.

**Smoke:** An air suspension (aerosol) of particles, usually but not necessarily solid, often originating in a solid nucleus, formed from combustion or sublimation.
General Principles of Ventilation
Introduction

The importance of clean uncontaminated air in industrial work environment is well known.

Reasons:

- Chemical compound used in industrial processes may be highly toxic which can exceed safe levels.
- Heat stress resulting in unsafe or uncomfortable work environments.
- Control odor, moisture, and other undesirable conditions.
Limits for Safe Working Environments

PEL – Permissible Exposure Limits (OSHA, MSHA)

TLV – Threshold Limit Values (ACGIH)

BEI – Biological Exposure Indices (ACGIH)

TWA – Time Weighted Average

\[ TWA = \frac{C_1 t_1 + C_2 t_2 + \ldots + C_n t_n}{(t_1 + t_2 + \ldots + t_n)} \]
Supply and Exhaust

Ventilation systems are of two generic types, SUPPLY and EXHAUST.

Supply: To supply clean and controlled air (usually) to a work space. Examples?

Exhaust: Remove contaminants generated by an operation to maintain a safe working environment.

Complete ventilations systems usually consider both supply and exhaust.

- What can happen when supply and exhaust systems are not considered together?
  - Temperature not optimal, exhaust system performance issues, higher energy and running costs.
Supply

Supply systems are typically used for two purposes in general ventilation

1) To create a comfortable environment (HVAC)
2) To replace air exhausted from the plant.

A system will have an air inlet system consisting of filters, heating and cooling equipment, fan, duct and register/grilles for distributing air within the workspace. (Air house consists off filters, heating and cooling equipment, and fan.)

If part of the air supplied in recirculated, a return system is sued to bring air back to air house.
Exhaust

Classified in two general groups.

1) General exhaust systems
2) Local exhaust systems

General Exhaust (Dilution Ventilation)

◦ Used for temperature control and removal of contaminants
◦ Dilute contaminant to safe levels when local exhaust is not feasible
Exhaust

Local Exhaust
- Captures a contaminant at or near its source
- Preferred method of control
- Lower cost of energy, air cleaning devices
- More efficient temperature control

What are the basic parts of a local exhaust ventilation system?
Local exhaust ventilation system made up of five basic parts
- The hood(s) = Capture
- The duct system (including exhaust stack and/or recirculation duct) = Transport
- Air cleaning device = Contaminant removal
- Fan = Overcome all pressure losses due to friction, hood entry, fittings, and produce needed flow rate.
- Stack
Volumetric Flow Rate

\[ Q = VA \]

- **Q** – Volumetric flow rate (cfm)
- **V** – Velocity (fpm)
- **A** – Area (sq. ft.)

\[ \text{ft}^3/\text{min.} = (\text{ft.}/\text{min.}) \times (\text{ft.}^2) \]

The contaminant determines which \( Q \) is required for protection

\( Q \) is fundamental in nearly all aspects of ventilation
Losses and Flow Rate

Flow rate of the system needs to be understood
- This can depend on the hood(s), contaminant, ducting, etc.

System pressure losses need to be understood

The fan must supply the correct amount of flow rate, and overcome the pressure losses at the same time

Pinching a garden hose
- Flow rate remains the same
- Area goes down
- $Q = VA$ What happens to the pressure?

Blowing through a straw
- PVC pipe vs coffee straw
Ventilation System Losses

Hood entry losses
- Expressed as either a loss coefficient (multiplied by duct velocity pressure), or hood entry coefficient
- Compound hood or simple hood

Duct losses
- Friction losses are due to friction in ducts related to duct velocity, diameter of the ducts, air density, air viscosity, and duct surface roughness
- Fitting losses are due to elbows, entries, contractions, expansions, air accelerations

Air cleaner losses
Characteristics of Exhausting Air

- LEV should not be used when process cannot be used in immediate vicinity of hood.
- Enclosing hoods should be used when possible.
- Supply air interference with LEV hood capture.
General Industrial Ventilation
Introduction

Refers to the supply and exhaust of air with respect to an area, room, or building.

- Dilution Ventilation = Dilution of contaminated air, with uncontaminated air for the purposes of controlling hazards, fire and explosions, odors, or nuisance-type contaminants.
  - Typically only used in situations where the contaminant in question is a relatively low hazard
- Heat Control Ventilation = Control of indoor atmospheric conditions associated with hot industrial environments.
General Dilution Basic Principals

1. Determine amount of air required for satisfactory dilution of a contaminant.

2. Locate exhaust opening near the sources of contamination, if possible, in order to obtain the benefit of “spot ventilation”.

3. Locate the air supply and exhaust outlets in a way which encourages air to pass through the zone of contamination. Employees should remain between the air supply and the source of the contamination.

4. Replace the exhausted air through the use of a replacement air system. This air should be heated during cold weather.

5. Avoid re-entry of contaminated air by placing the discharge point well clear of any opening or entry points (such as high above a roof).
Determine Amount of Air

Remember that the system is designed and contaminant is controlled, in part by \( Q \) (flow rate)

We need to determine which \( Q \) we need.

Air changes per hour is a metric generally is not used for control of contaminants through dilution.

How might we determine how much flow rate is needed?
1910.252(C)(2) – Ventilation for general welding and cutting.
  ◦ Mechanical ventilation required for welding when in space of less than 10,000 cubic feet per welder.
  ◦ Room with ceiling less than 16 feet.
  ◦ Ventilation at minimum rate of 2,000 cubic feet per minute per welder (unless LEV).

1910.252(C)(5) – Fluorine compounds
1910.252(C)(6) – Zinc
1910.252(C)(7) – Lead
1910.252(C)(8) – Beryllium
1910.252(C)(9) – Cadmium
OSHA and Ventilation

1910.252(C)(10) – Mercury
1910.252(C)(11) – Cleaning compounds
1910.252(C)(12) – Cutting of stainless steel
1910.94 – Open surface tanks, spray finish, grinding, polishing/buffing, abrasive blasting
1910 sub Z - PEL
TABLE 2-1. Dilution Air Volumes for Vapors

The following values are tabulated using the TLV values shown in parentheses, parts per million. TLV values are subject to revision if further research or experience indicates the need. If the TLV value has changed, the dilution air requirements must be recalculated. The values on the table must be multiplied by the evaporation rate (pts/min) to yield the effective ventilation rate (Q') (see Equation 2.5).

<table>
<thead>
<tr>
<th>Liquid (TLV in ppm)**</th>
<th>Ft³ of Air (STP) Required for Dilution to TLV*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone (500)</td>
<td>11,025</td>
</tr>
<tr>
<td>n-Amyl acetate (100)</td>
<td>27,200</td>
</tr>
<tr>
<td>Benzene (0.5)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>n-Butanol (butyl alcohol) (50)</td>
<td>88,000</td>
</tr>
<tr>
<td>n-Butyl acetate (150)</td>
<td>20,400</td>
</tr>
<tr>
<td>Butyl Cellosolve (2-butoxyethanol) (25)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Carbon disulfide (10)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Carbon tetrachloride (5)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Cellosolve (2-ethoxyethanol) (5)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Cellosolve acetal (2-ethoxyethyl acetate) (5)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Chloroform (10)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>1-2 Dichloroethane (ethylene dichloride) (10)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>1-2 Dichloroethylene (200)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Dioxane (25)</td>
<td>NOT RECOMMENDED</td>
</tr>
<tr>
<td>Ethyl acetate (400)</td>
<td>NOT RECOMMENDED</td>
</tr>
</tbody>
</table>

\[
(\text{ft}^3/\text{pint}) \times (\text{pints/min}) = \text{ft}^3/\text{min} = Q = \text{Volumetric flow rate}
\]
K Factors

Factor applied to a space which is ventilated.

Ventilated air generally doesn’t mix perfectly within a space. K allows us to adjust the flow rate and determine effective flow rate due to the fact that imperfect mixing is occurring.

Flow rate is the calculated flow rate. Effective flow rate is the actual flow rate accounting for incomplete mixing of the air.

Flow rate vs effective flow rate ($Q$ vs $Q'$)

$Q' = \frac{Q}{K}$
K factors = 1.0 – 5.0

Q' = Q/K
Basic Example

Room is 18,000 ft$^3$
Two welders operating.

1) Determine required $Q$

With ventilation system designed, don’t forget $Q'$ and adjust as needed to achieve your minimum $Q$.

$$Q' = \frac{Q}{K}$$

$Q = 2,000$ cfm per welder

$Q' \times K = Q$

$4,000 \text{ cfm} \times 2.5 = 10,000 \text{ cfm}$
Local Exhaust Ventilation
Basic Components of LEV

Hoods – Captures contaminant from a point source.
Ducting – Carries or transports the contaminant.
Air cleaner – Cleans the air of contamination.
Fan – Moves the air (providing differential pressure).
Exhaust – Expels the air.
Hoods

Hoods chosen are based on contaminant and work accommodation limitations.

Two main types of hoods:

1) Enclosing hoods – Completely or partially enclose the process or contaminant generation point.
2) Exterior hoods – Hoods located adjacent to an emissions source without enclosing it.
Enclosing Hoods
Exterior Hoods
Hood Nomenclature LEV

Capture Velocity
- Air velocity at any point in front of the hood, or at the hood opening necessary to overcome the opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.

Face Velocity
- Air velocity at the hood opening.

Can capture velocity and face velocity be the same?
Hood Nomenclature LEV

Slot Velocity
- Air velocity through the opening in a slot-type hood. It is used primarily as a means of obtaining uniform air distribution across the face of the hood.
- Often 2,000 fpm

Plenum Velocity
- Air velocity in the plenum. For good air distribution with slot-type of hoods, the maximum plenum velocity should be ½ of the slot velocity or less.
- Often 1,000 fpm
Hood Nomenclature LEV

Duct Velocity (transport velocity)
- Air velocity through the duct cross section. When solid material is present in the air stream, the duct velocity must be equal to or greater than the minimum air velocity required to move the particles in the air stream. If not, settling can occur.
- Transport velocity.
Capture Velocity

Enclosed hood = Capture velocity is the face velocity

External hood = Capture velocity and face velocity will normally be different.

Considerations
- What capture velocity is appropriate?
- How far in front of the hood is the contaminant?

Velocity decreases inversely with the square of the distance from the hood
External Hood Capture Velocity

\[ Q = V(10X^2 + A) \]

\( Q \) = Air flow, cfm
\( V \) = Centerline velocity at X distance
\( X \) = Distance outward along axis in ft.. (note, equation not appropriate for distances greater than 1.5 \( D \))
\( A \) = Area of hood opening, ft\(^2\)
External Hood Capture Velocity

Flange can increase velocity by about 25%

Rule of thumb = One duct diameter away is approximately 10% of face velocity
Determine Capture Velocity

<table>
<thead>
<tr>
<th>Condition of Dispersion of Contamination</th>
<th>Example</th>
<th>Capture Velocity, fpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Released with practically no velocity into quiet air.</td>
<td>Evaporation from tanks; degreasing, etc.</td>
<td>50–100</td>
</tr>
<tr>
<td>Released at low velocity into moderately still air.</td>
<td>Spray booths; intermittent container filling; low speed conveyor transfers; welding; plating; pickling</td>
<td>100–200</td>
</tr>
<tr>
<td>Active generation into zone of rapid air motion.</td>
<td>Spray painting in shallow booths; barrel filling; conveyor loading; crushers</td>
<td>200–500</td>
</tr>
<tr>
<td>Released at high initial velocity into zone at very rapid air motion.</td>
<td>Grinding; abrasive blasting; tumbling</td>
<td>500–2000</td>
</tr>
</tbody>
</table>

In each category above, a range of capture velocity is shown. The proper choice of values depends on several factors:

**Lower End of Range**

1. Room air currents minimal or favorable to capture.
2. Contaminants of low toxicity or of nuisance value only.
3. Intermittent, low production.
4. Large hood-large air mass in motion.

**Upper End of Range**

1. Disturbing room air currents.
2. Contaminants of high toxicity.
3. High production, heavy use.
4. Small hood-local control only.
Flow Rate Q

\[ Q = VA \]

After face velocity is determined, and hood area is known, a determination of required Q to protect an employee can be made.

Law of conservation of mass is the reason Q will not change from this point on assuming no air leaking in, branches, bleed in’s, etc.

Q will be important in selecting an appropriate fan.
Enclosed Hood Example

- Source = Welding chromium (moderately still air)
- Hood size = 3 X 4 ft..
- Q=VA

- What capture velocity do I need?
- What face velocity do I need?
- What Q is needed in the system to protect the employee?

- Capture velocity is 200 fpm (high side from hexavalent chromium exposure).
- Q is 2,400 cfm
  - Area = 12 ft$^2$
  - Velocity = 200 fpm
  - $Q = 200 \text{ fpm} \times 12 \text{ ft}^2$
- Face velocity is 200 fpm because the source is enclosed.
External Hood Example

- Source = Welding chromium (moderately still air)
- Hood size = 3 X 4 ft.
- Source = 2 ft. in front of hood

- What capture velocity do I need?
- What face velocity do I need?
- What Q is needed in the system to protect the employee?

- Capture velocity is 200 fpm (high side from hexavalent chromium exposure).
- Q is 10,400 cfm
  - $Q = V(10X^2 + A)$
- Face velocity is 867 fpm
  - $Q = VA \ (V = Q/A)$
# Hood Comparison

<table>
<thead>
<tr>
<th>ENCLOSED</th>
<th>EXTERNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face Velocity = 200 fpm</td>
<td>Face Velocity = 867 fpm</td>
</tr>
<tr>
<td>Q = 2,400 cfm</td>
<td>Q = 10,400 cfm</td>
</tr>
</tbody>
</table>

Potentially large cost difference.
- Fan
- Energy cost
- Wear and tear (particles)
Slots

Hoods with slots are called compound hoods
- Compound by way of pressure losses
- Slot entry loss
- Hood entry loss

Primary purpose is for uniform distribution of air flow across the face
- Path of least resistance air flow

Baffles essentially do the same thing, and are designed basically the same way.

Special considerations for slot velocity and plenum velocity
Ducting
Transport Velocity

For systems handling particulate a minimum transport velocity must be achieved to avoid settling and plugging of ducts. Excessively high transport velocities waste energy, and can cause excessive wear and abrasions of the system.
### Transport Velocities

**TABLE 3-2. Range of Minimum Duct Design Velocities**

<table>
<thead>
<tr>
<th>Nature of Contaminant</th>
<th>Examples</th>
<th>Design Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapors, gases, smoke</td>
<td>All vapors, gases, and smoke</td>
<td>Any desired velocity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(economic optimum velocity usually 1000–2000 fpm)</td>
</tr>
<tr>
<td>Fumes</td>
<td>Welding</td>
<td>2000–2500</td>
</tr>
<tr>
<td>Very fine light dust</td>
<td>Cotton lint, wood flour, litho powder</td>
<td>2500–3000</td>
</tr>
<tr>
<td>Dry dusts &amp; powders</td>
<td>Fine rubber dust, Bakelite molding powder dust, jute lint, cotton dust,</td>
<td>3000–4000</td>
</tr>
<tr>
<td></td>
<td>shavings (light), soap dust, leather shavings</td>
<td></td>
</tr>
<tr>
<td>Average industrial dust</td>
<td>Grinding dust, buffing lint (dry), wool jute dust (shaker waste), coffee</td>
<td>3500–4000</td>
</tr>
<tr>
<td></td>
<td>beans, shoe dust, granite dust, silica flour, general material handling,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>brick cutting, clay dust, foundry (general), limestone dust, packaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and weighing asbestos dust in textile industries</td>
<td></td>
</tr>
<tr>
<td>Heavy dusts</td>
<td>Sawdust (heavy and wet), metal turnings, foundry tumbling barrels and</td>
<td>4000–4500</td>
</tr>
<tr>
<td></td>
<td>shake-out, sand blast dust, wood blocks, hog waste, brass turnings, cast</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iron boring dust, lead dust</td>
<td></td>
</tr>
<tr>
<td>Heavy or moist</td>
<td>Lead dusts with small chips, moist cement dust, asbestos chunks from</td>
<td>4500 and up</td>
</tr>
<tr>
<td></td>
<td>transite pipe cutting machines, buffing lint (sticky), quick-lime dust</td>
<td></td>
</tr>
</tbody>
</table>
Example

Continuing on with the enclosed hood hexavalent chromium example.

- Transport velocity?
- Duct size?

Q = VA

Remember Q from the hood was 2,400 cfm.

Transport Velocity = 2250 fpm

Duct size = Under 1.2 ft.. Will need to choose a commercially available size.

- \( Q = VA \quad A = 1.1 \text{ ft}^2 \)
- \( A = \pi r^2 \quad r = 0.6 \text{ ft.} \)
Importance of Correct Duct Velocity
Air Cleaners
Introduction

Air cleaning devices remove contaminants from the air or gas stream

Particulate collectors divided into two groups

- Air filters
- Dust collectors
Selection of Dust Collector

Contaminant Characteristics
- Concentration
- Particle size

Efficiency Required
- Check efficiency claims by assessing actual mass emission rates (mg/m³)

Air generally discharged outdoors or recirculated
- Degree of contaminant collection can be determined by law, plant location, nature of contaminant, etc.
Dust Collector Types

Electrostatic precipitators
- Ionizes gas
- Charging particles
- Transporting particles to collection surface
- Neutralizing charge from particle surface
- Removing dust from collection surface
Electrostatic Precipitator
Dust Collector Types

Fabric Collectors
- Remove particles by: straining, impingement, interception, diffusion, electrostatic charge
- As dust cakes fabric, efficiency increases but flow rate decreases
- Reconditioning must occur before the flow rate drops below critical level (shaker, pulse-jet, reverse-air)
Fabric Collectors

**Tube Type**
- Motor driven vibrator
- Clean air outlet
- Dusty air inlet

**Envelope Type**
- Motor driven vibrator
- Clean air outlet
- Dusty air inlet
- Dust outlet

Diagram showing the components of fabric collectors including reverse air jet nozzles, fiber envelope, rotary valve, dust outlet, collection cell, clean air outlet, reverse jet piping, solenoid valves & controls, fabric element, and dust hopper.
Baghouse
Centrifugal Collectors

Separate particles from airstream by centrifugal, inertial, and gravitational force

Collection efficiency influenced by
- Particles size, weight, shape
- Collector size and design
- Velocity through cyclone
- Dust concentration
Cyclones

LOW PRESSURE CYCLONE

HIGH EFFICIENCY CENTRIFUGALS
Cyclones
Fans
Types of Fans

- **Propeller** – move air against low static pressures and used commonly for general ventilation
- **Tubeaxial** – duct fans, move air against moderate pressures (under 2” wg)
- **Vaneaxial** – can be used against higher pressures (up to 8” wg)
Types of Fans

Centrifugal Fans

- Forward Curved – Quiet operation, low to moderate static pressures, heating and air conditioning, not recommended for dust
- Radial Impellers - Resist material buildup, good for particulates, clean or dirty air
- Backward inclined – higher efficiency, prone to material buildup
Fan Pressures

Exhaust system calculations are based on static pressure.

Fan rating tables are typically based on Fan Static Pressure or Fan Total Pressures.

- \[ \text{FTP} = (\text{SP}_{\text{outlet}} + \text{VP}_{\text{outlet}}) - (\text{SP}_{\text{inlet}} + \text{VP}_{\text{inlet}}) \]

- \[ \text{FSP} = \text{FTP} - \text{VP}_{\text{inlet}} \]

Or

- \[ \text{FSP} = \text{SP}_{\text{outlet}} - \text{SP}_{\text{inlet}} - \text{VP}_{\text{inlet}} \]
Performance Curves

Pressure (P) and power (PWR) requirements plotted against flow rate (Q)
Performance Curves

Material handling applications in industrial plants.

Low pressure exhaust: kitchen, warehouse, general factory
Fans

The fan is chosen based on the system designed
- Total pressure losses and flow rate determine the correct fan
- Fan supports the hood(s), not the other way around.

Manufacturers can help you determine the best fan for the application.
Preliminary Steps

Layout of the operation
- Air cleaning device location
- System exhaust points

Sketch the ducting system
- Plan and elevation dimensions
- Fan location
- Air cleaning device location

Design or sketch the desired hood
- VS Diagrams in Ventilation Manual
Preliminary Steps

Operational Details
- Toxicity
- Ergonomics
- Physical and chemical characteristics
- Required flow rates
- Dust velocity (energy to overcome, inertia)
- Entry losses
- Capture velocities
Preliminary Steps

Replacement or makeup air
  ◦ Location
  ◦ Effect on the hoods operation
  ◦ Turbulence
Design Procedures

Select/design the hood
- Flow rate $Q$
- Capture and face velocity
- Duct velocity
- Entry loss(s)

Design duct segments
- Determine required duct area
- Transport velocity
- Material
- Elbows, expansions, contractions, branches, entries

Pressure losses for the duct segments
Design Procedures

Deal with branches by balancing
- Balance by design
- Balance by blast gates

Select air cleaning device

Select fan
- Final system flow rate $Q$
- Overall system resistance (pressure)
- Temperature
- Moisture
- Contaminant loading
Design Procedures

Check design against available space and deal with interferences
Maximum plenum velocity
1/2 slot velocity

\[ Q = 350 \text{ cfm/ft of hood length} \]

Hood length = required working space

\[ W = 24 \text{ maximum, if } W/24 \text{ see chapter 3} \]

Minimum duct velocity = 2000 fpm

\[ h_e = 1.74 \frac{W}{V_2} + 0.25 \frac{W}{V_6} \]

General ventilation, where local exhaust cannot be used:

A. For open areas where welding fume can rise away from the breathing zone:

flow required = \( 800 \times \text{lb/hour} \times \text{hours used} \)

B. For enclosed areas or positions where fume does not readily escape breathing zone:

flow required = \( 1600 \times \text{lb/hour} \times \text{hours used} \)

For toxic materials higher airflows are necessary and operator may require respiratory protection equipment.

Other types of hoods:

Local exhaust: See VS-90-02

Roof: For design see VS-90-30

\[ Q = 100 \text{ cfm/ft}^2 \text{ of face opening} \]

MIG welding may require precise air flow control.
**FLEXIBLE EXHAUST CONNECTIONS**

**RATE OF EXHAUST**

<table>
<thead>
<tr>
<th>X, inches</th>
<th>Plain duct, cfm</th>
<th>Flange or cone, cfm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 6</td>
<td>535</td>
<td>290</td>
</tr>
<tr>
<td>6-9</td>
<td>755</td>
<td>560</td>
</tr>
<tr>
<td>9-12</td>
<td>1335</td>
<td>1000</td>
</tr>
</tbody>
</table>

Face velocity = 1500 fpm

Minimum duct velocity = 3000 fpm

Plain duct entry loss = 0.93 VRE

Flange or cone entry loss = 0.25 VRE

Notes:
1. Location of hood is important.
2. Hoods perform best when located to the side of the work.
3. Ventilation rates may be inadequate for toxic materials.
4. Velocities above 100-200 fpm may disturb shield gas.

**GENERAL VENTILATION**, where local exhaust cannot be used:

<table>
<thead>
<tr>
<th>Rod, diam., in</th>
<th>cfm/welder</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/32</td>
<td>1000</td>
</tr>
<tr>
<td>5/16</td>
<td>1500</td>
</tr>
<tr>
<td>3/8</td>
<td>3000</td>
</tr>
<tr>
<td>1/4</td>
<td>5000</td>
</tr>
<tr>
<td>5/32</td>
<td>4500</td>
</tr>
</tbody>
</table>

For open areas, where welding fumes can rise away from the breathing zone:

Cfm required = 600 x lb/hour rod used

For enclosed areas or positions where fume does not readily escape breathing zone:

Cfm required = 1600 x lb/hour rod used

For toxic materials, higher airflows are necessary and operator should use respiratory protection equipment.

Other types of hoods:

- Bench, see VS-90-01
- Booth, for design see VS-90-30

Sign: 100 cfm/ft² of face opening

**DATE**: 1-91

**FIGURE**: VS-90-02
Test Equipment
Testing Ventilation Systems

Initial test
- Pitot tube and anemometer (velocicalc or similar)
- Review systems specifications (Capture velocity, face velocity, transport velocity, Q)
- Inspect the system for damage or abnormalities
  - Dents in duct, dirty slots on hoods, open bleed ins, leaks, etc.
- Select and identify test locations
- Measure Q, fan static pressure, motor amps, air temperature
- Record the data
- Compare data with design specifications
Periodic Tests

- Find test locations
- Inspect the system for physical damage
- Measure flow rate in the same locations as initial tests
- Measure static pressures in the same locations as the initial test
- Compare static pressures with initial test static pressures
Common Problems

Ducting plugging – Insufficient transport velocity
Hood not capturing – Insufficient capture or face velocity
Slots filling with debris – Lack of routine maintenance and inspection
Damaged ducting – Hit with equipment or tools
Fan or fan motor wearing out – Periodic maintenance and inspection of the system
Air leaking in – Poor duct connections
Open clean-outs, or maintenance panels
Blast Gates – Misadjusted
Additions to the system – What would happen if you introduced more Q?
Common Problems

System design Q and fan SP are key indicators (flow rate and pressure losses)
Questions?