M505
Control of Hazardous Substances

Day 2

Today's Topics

- **Review of overnight questions**
- **Ventilation systems**
- **Group exercises**

Review of Overnight Questions

Questions?

Ventilation

Ventilation Systems

- **Ventilation in one of its forms has been employed to control emissions for centuries**
- **Ventilation can be an effective control measure**
- **For this to occur systems need to be well designed & maintained**
- **Unfortunately, poorly designed & maintained ventilation systems are common**

Types of Ventilation Systems

Two generic types:

- **Supply-used to supply clean air to a workplace**
- **Exhaust-used to remove hazardous substances generated in a process so as to ensure a healthy workplace**

Supply Systems

- **Two purposes:**
  - **to create a comfortable environment by the control of factors such as temperature and humidity**
  - **or to replace air exhausted from the workplace**

Exhaust Systems

Two general types:

- General Exhaust Systems – "dilution ventilation"
- Local Exhaust Systems – "local exhaust ventilation" (LEV)

Other Systems

- **Heating, Ventilation and Air-Conditioning (HVAC)**
  - **To mechanically provide fresh air for thermal comfort and health (known as general ventilation in some countries)**
- **Natural**
  - **To dilute contaminants in the air by using wind or temperature differences to induce airflow**

Definitions

Air Density :

$$\rho = \frac{\text{Mass}}{\text{volume}}$$

Units – kg m^{-3}

(Varies with temperature and pressure)

Standard Conditions

STP

1 atmosphere

- **101.325 kPa**
- **760 mm Hg**
- **1000 mB**
- **10^5 Pa**

0^0 C (273K)

NTP

1 atmosphere

20^0 C (293K)

In ventilation STP is normally taken as being 20^oC and 1 atmosphere

Air Density - Non Standard Conditions

$$\rho_0 = 1.2 \frac{b_0 T_s}{b_s T_0}$$

ρ_o = Air density at non standard conditions (kgm^{-3})
b_o = Barometric pressure at non standard conditions (Pa)
b_s = Barometric pressure at standard conditions (Pa)
T_o = Absolute temperature at non standard conditions (^oK)
T_s = Absolute temperature at standard conditions (293°K)

Pressure

- **For air to flow there must be a pressure difference and air will flow from the higher pressure to the lower pressure**

- **Pressure is considered to have two forms:**
  - **static pressure (P_s)**
  - **velocity pressure (P_v)**

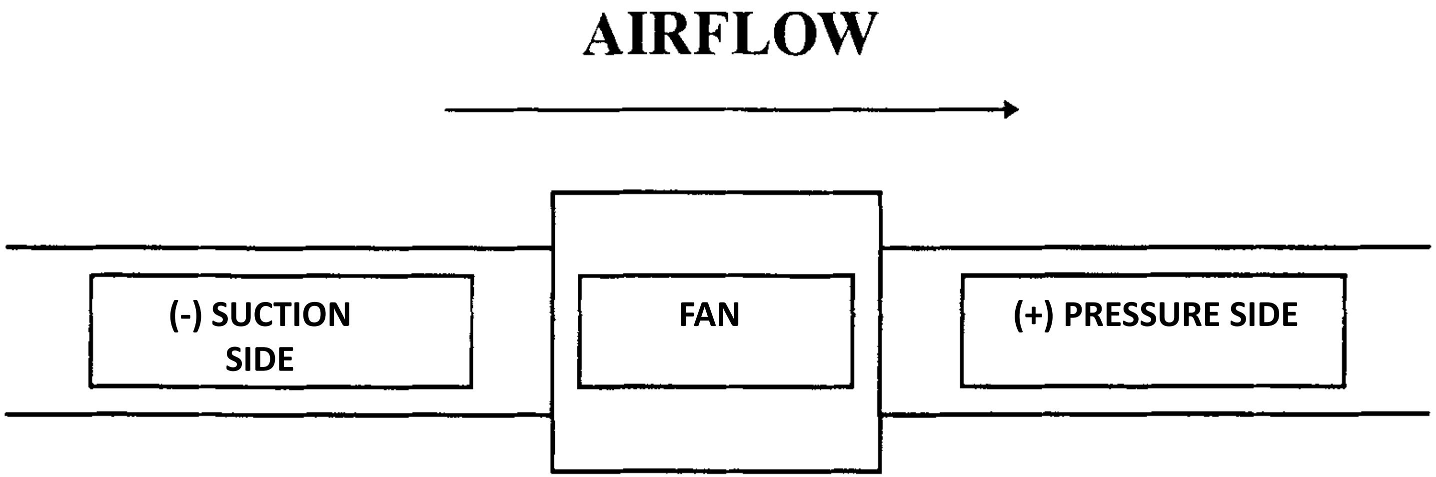
With the sum of these being total pressure (P_t).

Static Pressure

- Static pressure is defined as the pressure exerted in all directions by a fluid that is stationary

- If the fluid is in motion (as is the case in a ventilation system), static pressure is measured at 90° to the direction of the flow so as to eliminate the influence of movement (ie: velocity)

Static Pressure (Cont)



Can be both positive and negative depending if it is measured on the discharge or suction side of a fan

Velocity Pressure

- Defined as that pressure required to accelerate air from zero velocity to some velocity and is proportional to the kinetic energy of the air stream

- In simple terms, velocity pressure is the kinetic energy generated in a ventilation system as a result of air movement

Velocity Pressure (cont)

$$\mathbf{P_v = \rho \frac{v^2}{2}}$$

ρ = Density of air (kgm^{-3})

v = Air velocity ms^{-1}

P_v = Velocity pressure (Pa ie Nm^{-2})

Velocity Pressure (cont)

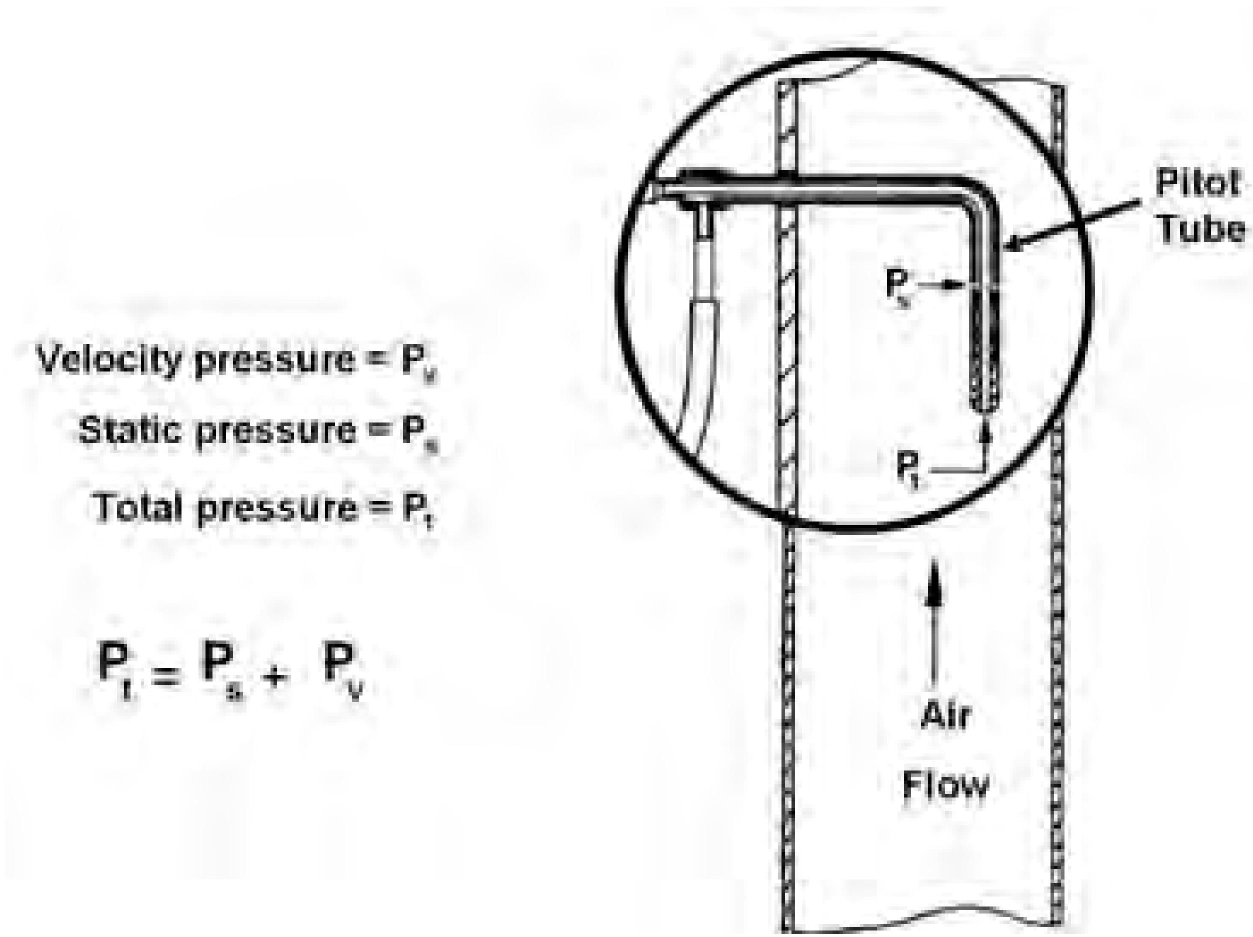
If standard temperature and pressure conditions are in existence, ie:

$$\rho \quad = \quad 1.2 \text{ kg m}^{-3}$$

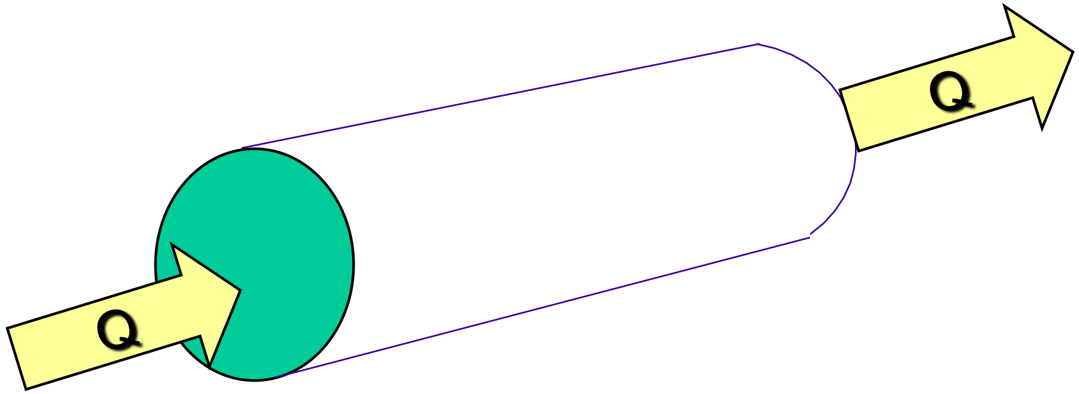
Then

$$P_v \quad = \quad 0.6\, v^2$$

Relationship is: $P_t = P_s + P_v$



Volume and Mass



$$Q = VA$$

Exercise 1

If the velocity inside a circular duct with a diameter of 0.5 metre is 9.1ms^{-1}, what is the volume flow?

Exercise 1- Answer

- **First, determine the area of the duct**

  $A = \pi r^2$ (r= radius of duct)

  $= 3.142 \times (0.25)^2$

  $= 0.2\ m^2$

- **Now Q = vA**

  So $Q = 9.1 \times 0.2$

  $= 1.82\ m^3s^{-1}$

Exercise 2

The face velocity at a booth (2 x 1.5 m) is 0.5 ms^{-1} and the duct from the booth is 0.4 m in diameter

- **What is the volume flow through the system?**
- **What is the velocity in the duct?**

Exercise 2 - Answer

What is the volume flow through the system?

$= 1.5\ m^3s^{-1}$

What is the velocity in the duct?

$Q = vA$

$1.5 = v \times 0.126$

$V = 1.5/0.126$

$V = 11.9\ ms^{-1}$

Exercise 3

The total pressure measured in a duct is -150 Pa

If the static pressure is -200 Pa, what is the velocity pressure?

Exercise 3 - Answer

$$P_t = P_s + P_v$$

$$P_v = P_t - P_s$$

$$= -150 - (-200)$$

$$= -150 + 200$$

$$= 50 \text{ Pa}$$

Exercise 4

Complete the following table

Ps	Pv	Pt
-289	173	
58		298
-260		-153
	124	166

Exercise 4 - Answers

Ps	Pv	Pt
-289	173	-116
58	240	298
-260	107	-153
42	124	166

Exercise 5

If the velocity pressure measured in a duct at room temperature is 50 Pa, what is the velocity of the airstream? (assume STP)

Exercise 5 - Answer

$P_v = 0.6\ v^2$ (at STP)

$50 = 0.6\ V^2$

$V = \sqrt{50/\ 0.6}$

$V = \sqrt{83.3}$

$V = 9.1\ ms^{-1}$

Exercise 6

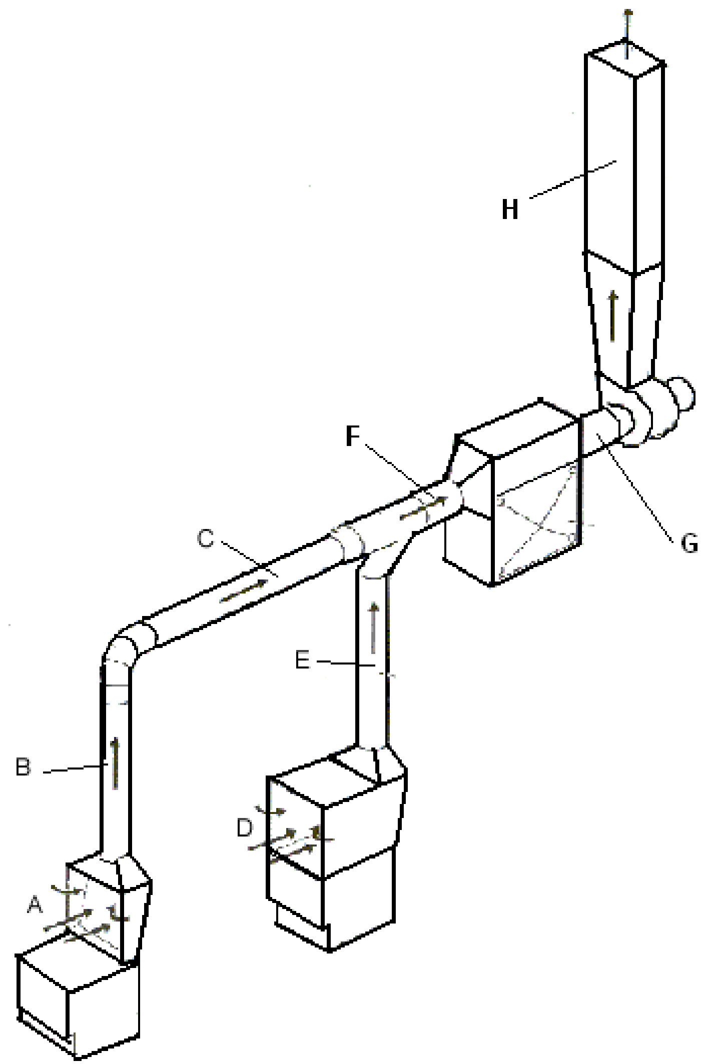
Complete the following table

Pv (Pa)	V (ms^{-1})
173	
240	
107	
124	

Exercise 6 - Answers

Pv (Pa)	V (ms^{-1})
173	17.0
240	20.0
107	13.3
124	14.4

Exercise 7



Exercise 7

Point	Dimensions	Pv (Pa)	V (m/s)	Q (m^3/s)
A	1 x 1 m	-	0.8	
B	0.3 m diam	75		
C	0.3 m diam	81		
D	1 x 1 m	-	1.0	
E	0.4 m diam	38		
H	0.8 x 0.4 m	19		

Exercise 7 - Answers

Point	Dimensions	Pv (Pa)	V (m/s)	Q (m^3/s)
A	1 x 1 m	-	0.8	**0.8**
B	0.3 m diam	75	**11.2**	**0.79**
C	0.3 m diam	81	**11.6**	**0.82**
D	1 x 1 m	-	1.0	**1.0**
E	0.4 m diam	38	**8.0**	**1.0**
H	0.8 x 0.4 m	19	**5.6**	**1.8**

Capture Velocity

Is the air velocity required at the source of emission so as to cause the contaminant to move towards the capture device and thus be removed

Capture Velocity (cont)

$$v = \frac{Q}{10X^2 + A}$$

Where v = air velocity at a distance X from the hood in ms^{-1}

Q = air flow rate in $m^3\ s^{-1}$

X = distance from hood in metres

A = cross-sectional area of hood in m^2

Typical Capture Velocities

Conditions of Dispersion of Contaminant	Examples	Capture Velocity (ms^{-1})
Released into still air with no velocity	Evaporation of solvents from degreasing tanks, paint dipping/drying, etc	0.3 – 0.5
Released at low velocity into moderately still air	Welding Soldering Liquid transfer	0.5 to 1.0
Released at moderate velocity into moving air	Crushing Spraying	1.0 to 2.5
Released at high velocity into very turbulent airstream	Cutting Abrasive blasting Grinding	2.5 to 10

Face Velocity

Is the air velocity at the opening of an enclosure or hood. Similarly, the slot velocity is the air velocity in slots

Transport Velocity

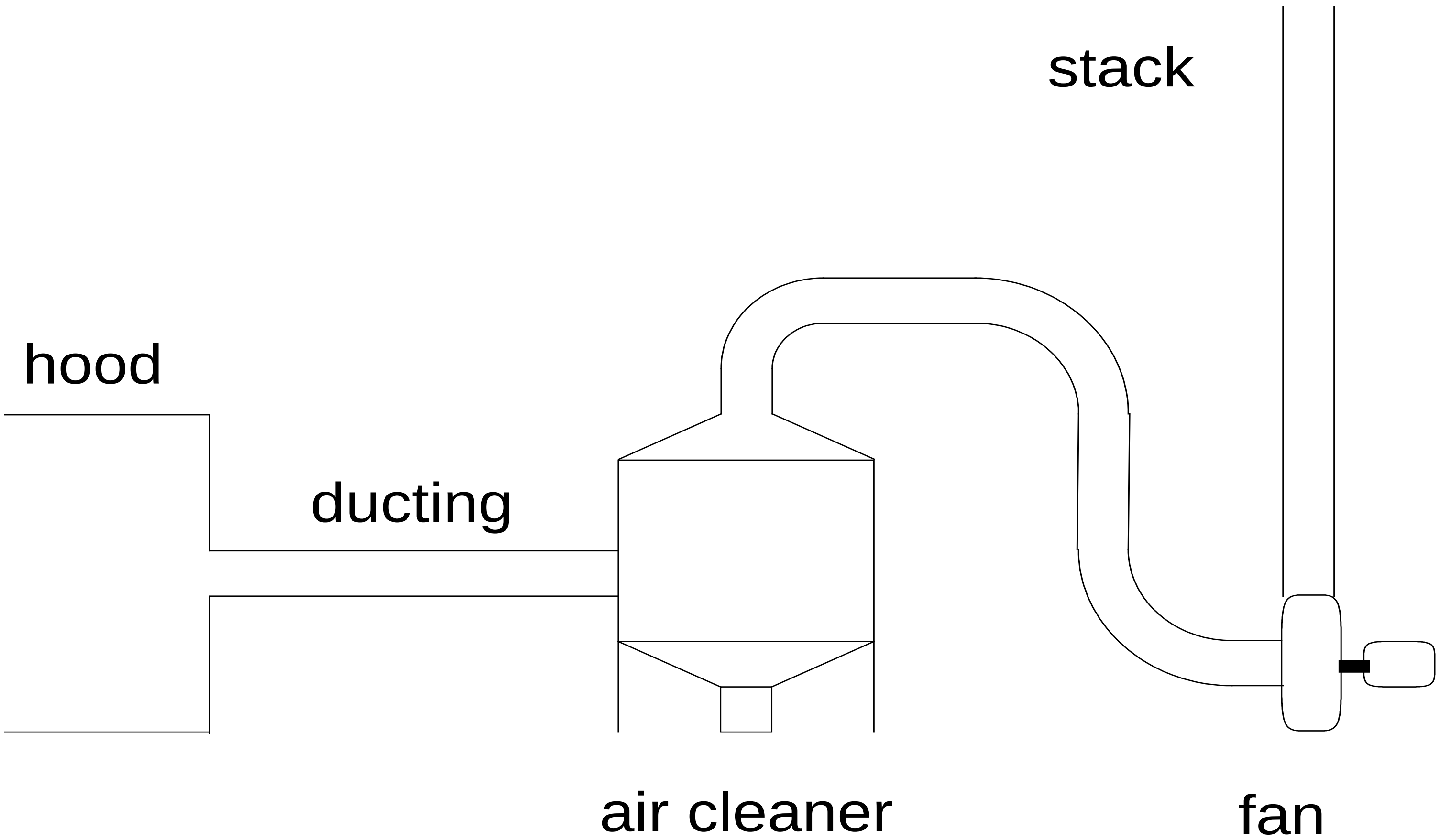
Is the minimum air velocity required at any point in the ventilation system to ensure that collected particles remain airborne and are thus not deposited within any part of the system except the collector

In simple terms, the lower the density and size of the particles the lower the transport velocity

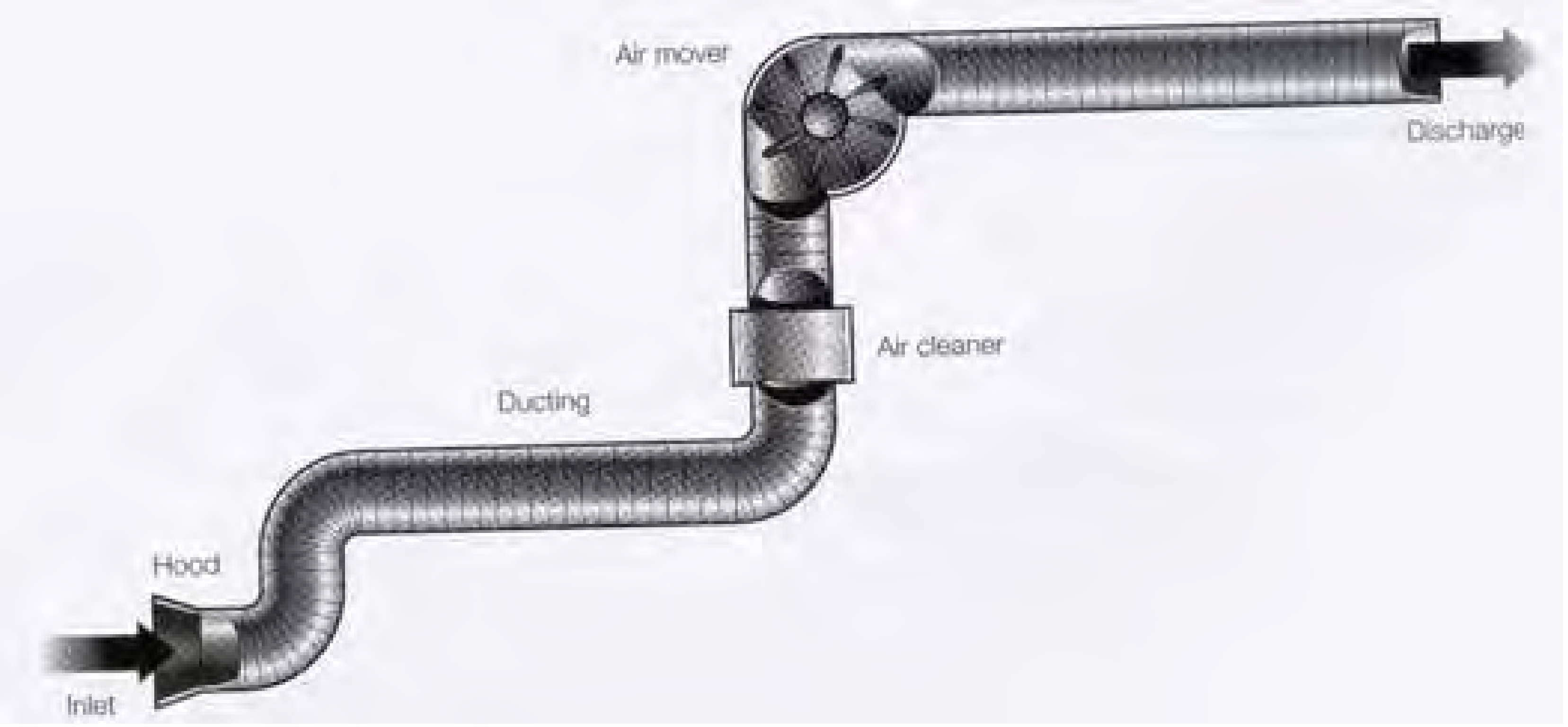
Recommended Transport Velocities

Type of Contaminant	Transport Velocity (ms^{-1})
Gases (non-condensing)	No minimum limit
Vapours, smoke and fumes	10
Light, medium density dusts and powders (eg: sawdust, plastic dusts)	15
Average industrial dusts (eg: grinding dust, silica, wood shavings)	20
Heavy dusts (eg: lead, metal turnings, dusts which are damp or tend to agglomerate)	25

A Typical LEV System



Basic Components of an LEV System



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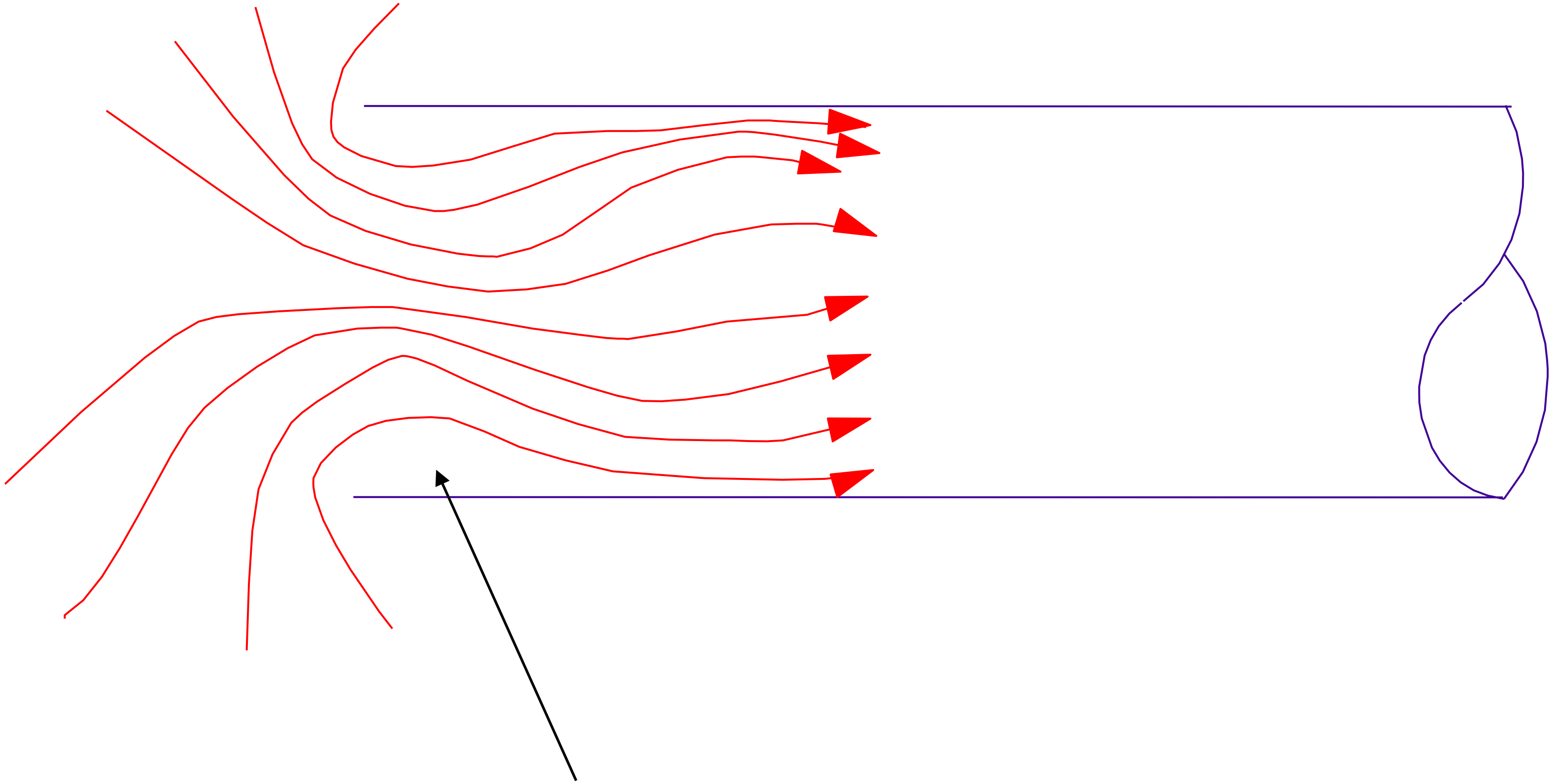
Hood Design

Captor Hood Characteristics

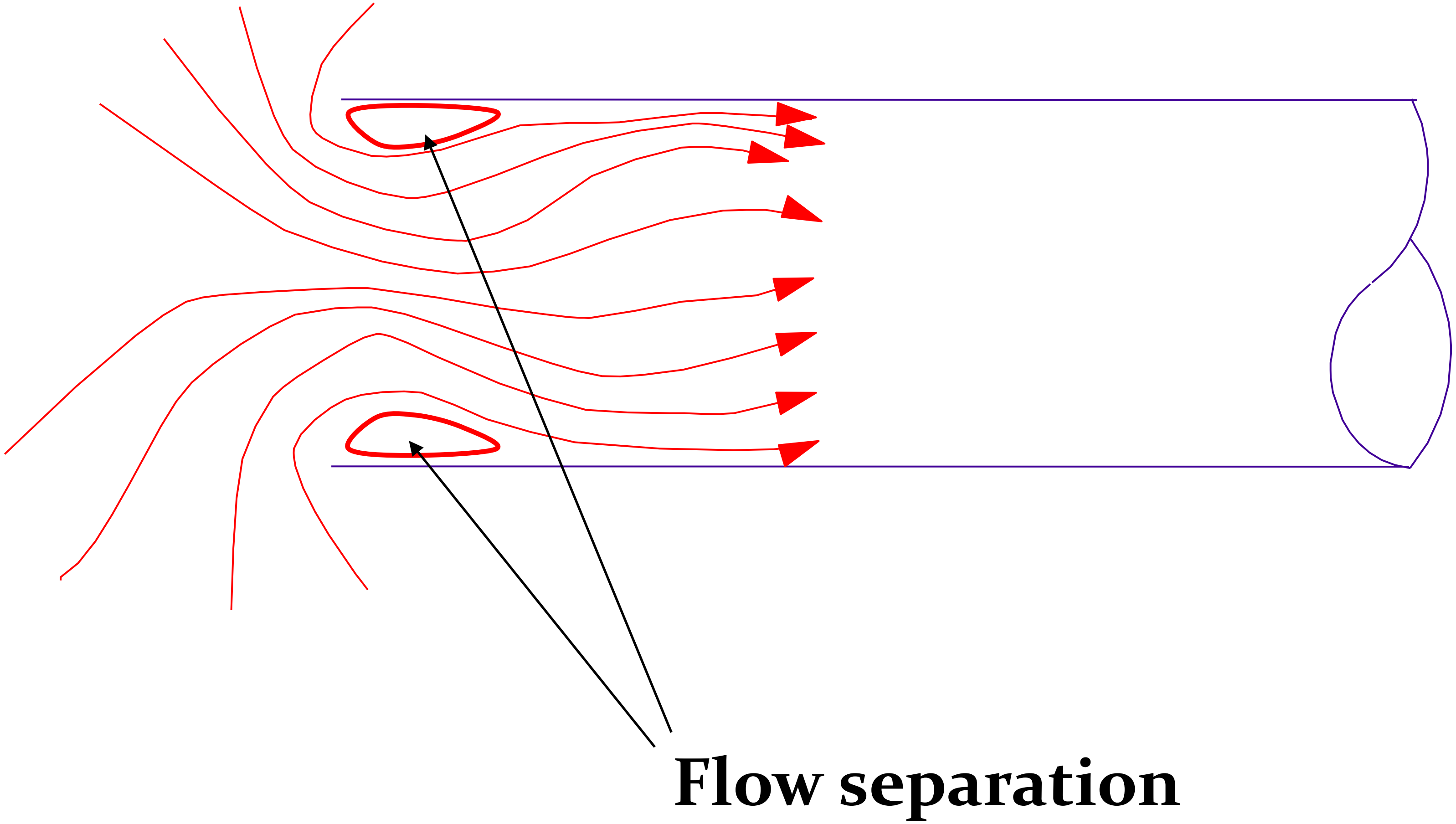
Show HSE Video Clip 3

Captor Hood Characteristics

Show HSE Video Clip 4



Vena contracta


Flow separation

Principles of Hood Design

- Enclose source as far as possible
- Capture close to source
- Pull contaminants away from workers
- Utilise momentum of contaminants
- Ensure adequate capture or face velocity
- Minimise eddies within hood

Types of Hood

- Total enclosures
- Partial enclosures
- Captor hoods
- Receptor hoods

Total Enclosures

- Advantages
  - Worker outside enclosure
  - Minimise air extracted
- Disadvantages
  - inhibit access
  - high exposure on entry

Abrasive Blasting Unit

(Source: Diamond Environmental Ltd – *reproduced with permission*)

Walk-in Booth

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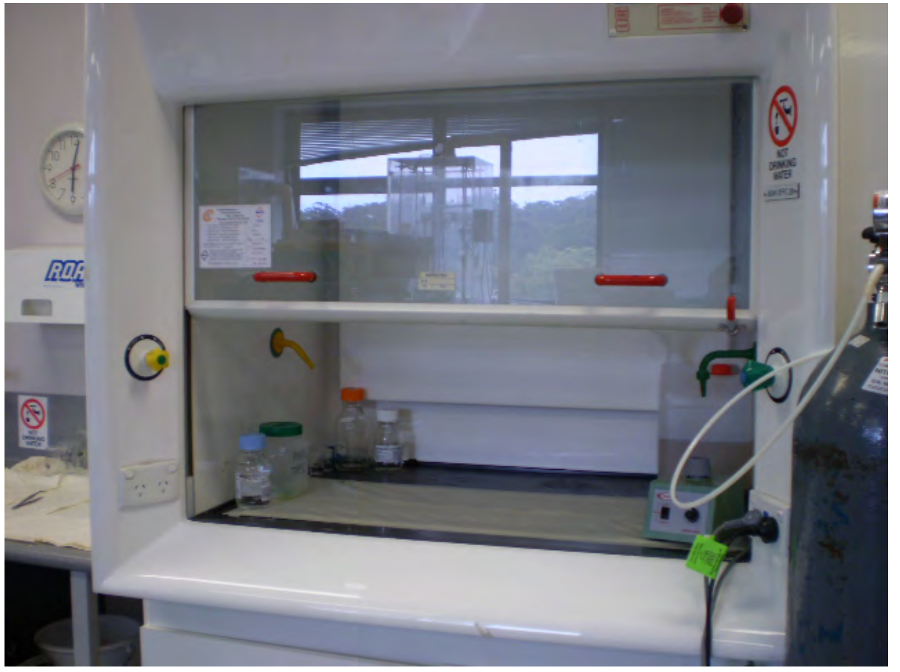
Partial Enclosures

- Source inside booth
- Minimise hood openings
- Adequate depth
- Face velocity 0.5 to 1.0 m/s
- Ensure even flow



Source: University of Wollongong

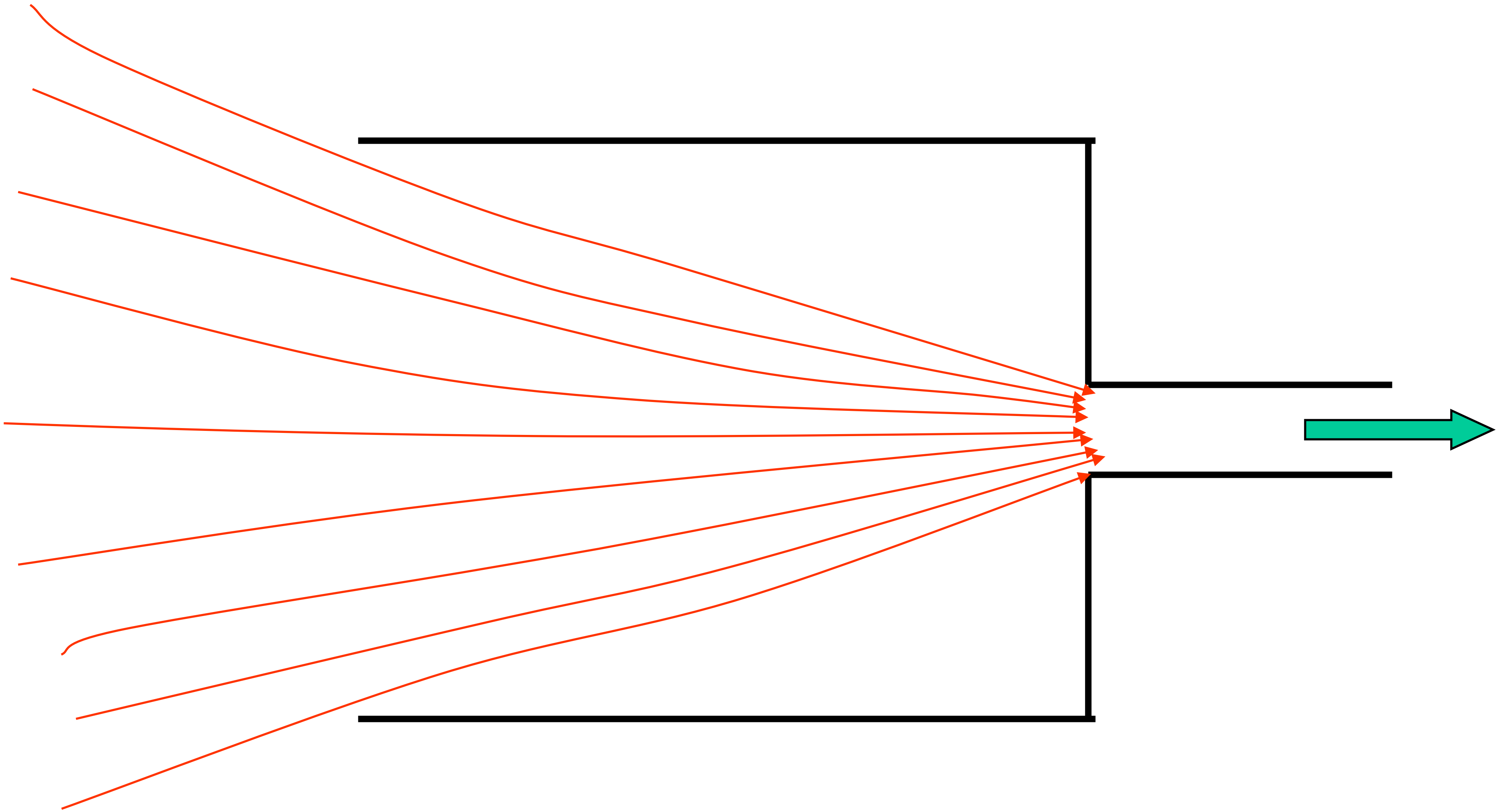
Captor Hood Characteristics

Show HSE Video Clip 5

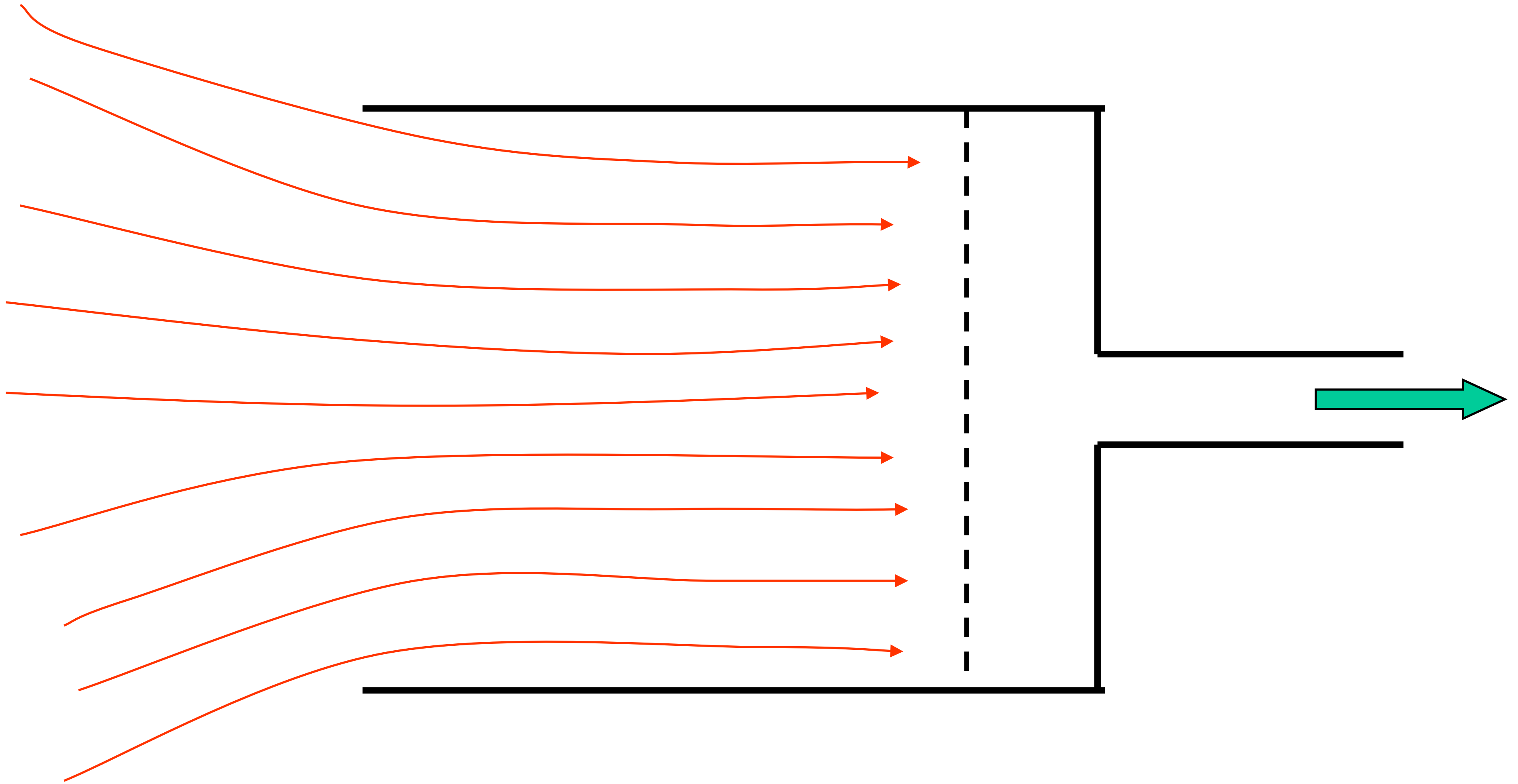
Captor Hood Characteristics

Show HSE Video Clip 6

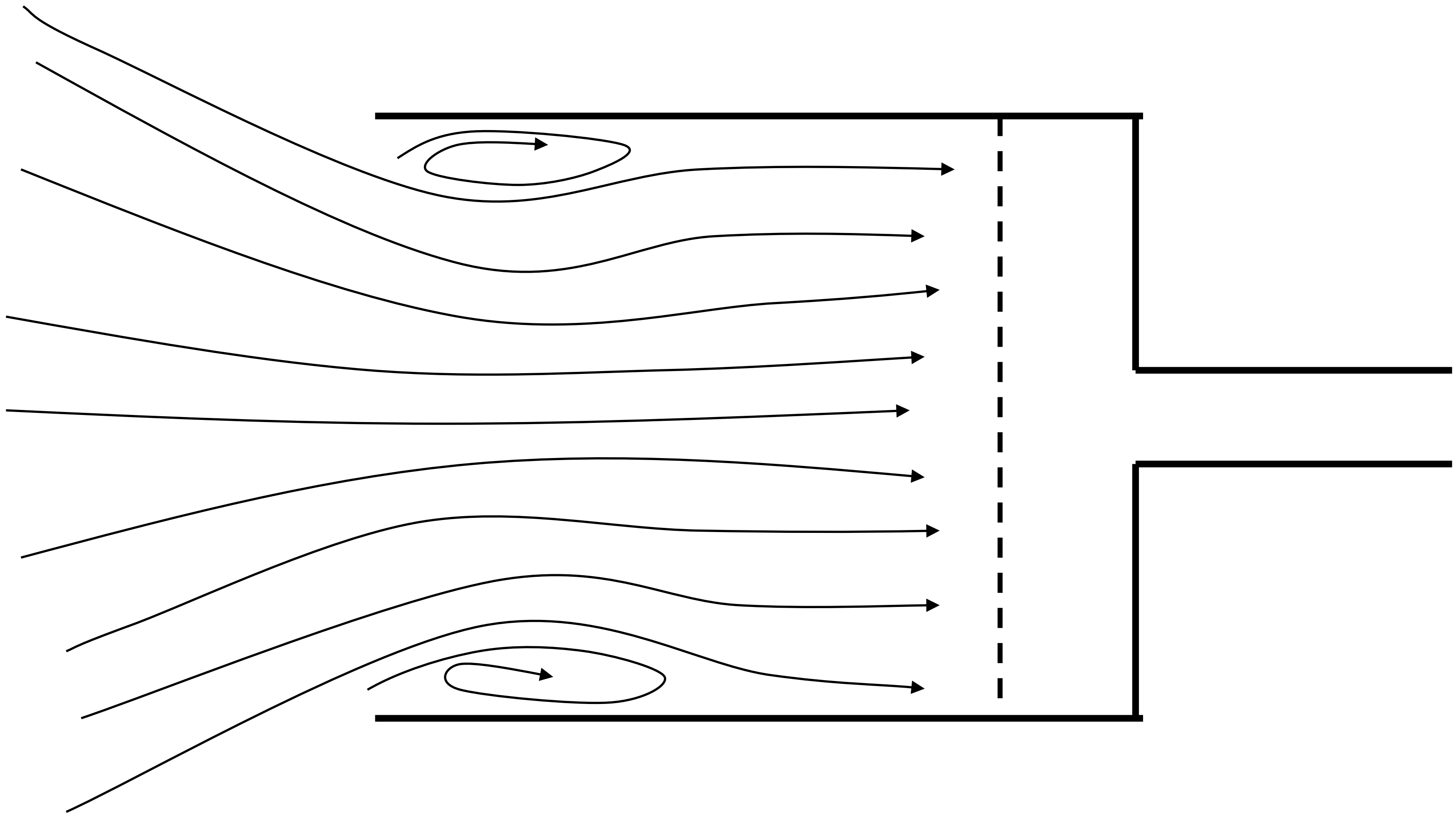
Uneven Air Flow



Evening Out the Flow Using a Plenum



Real Situation



Captor Hood Characteristics

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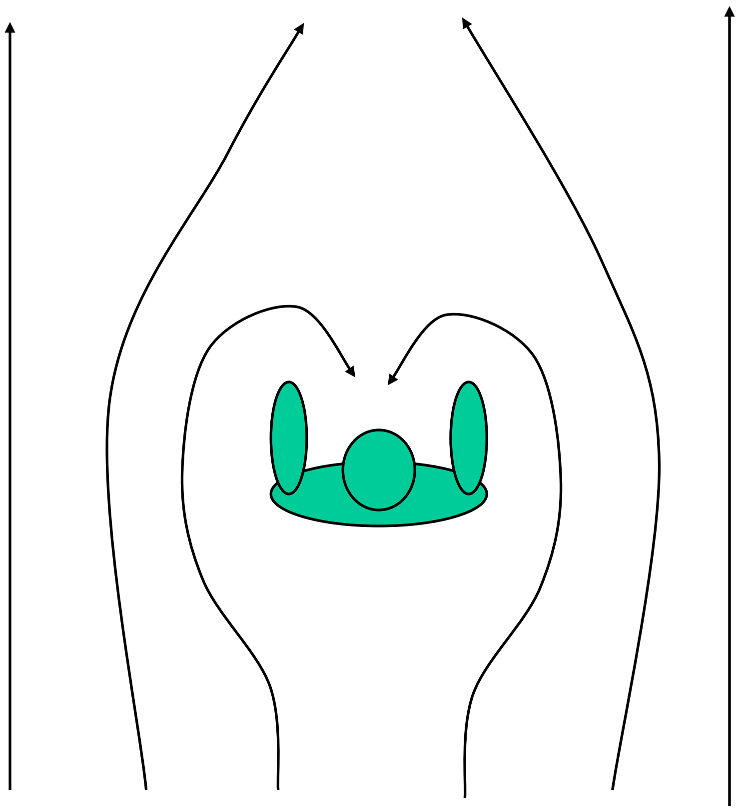
Air Flow Patterns



Captor Hood Characteristics

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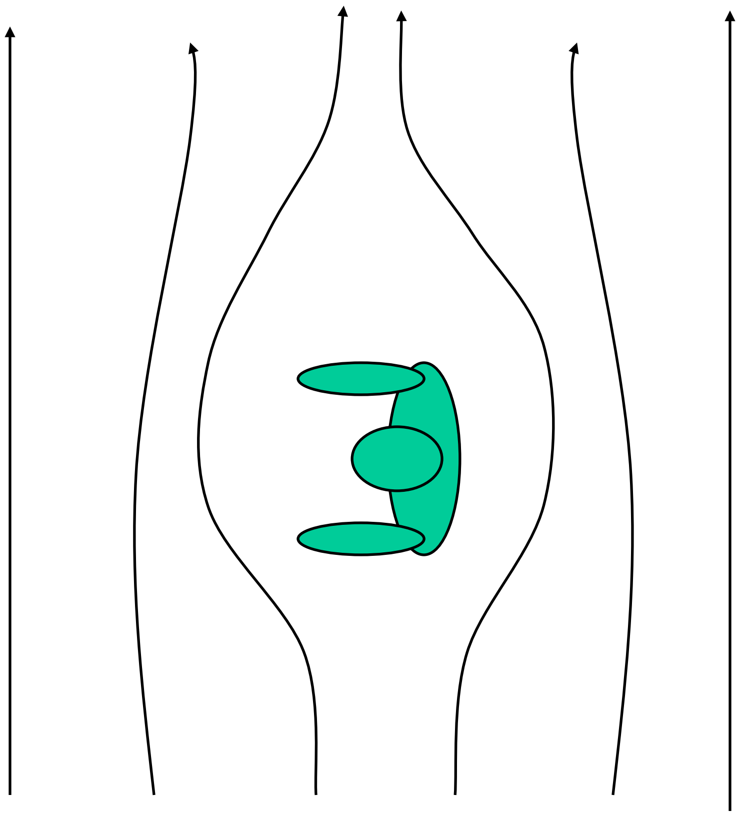
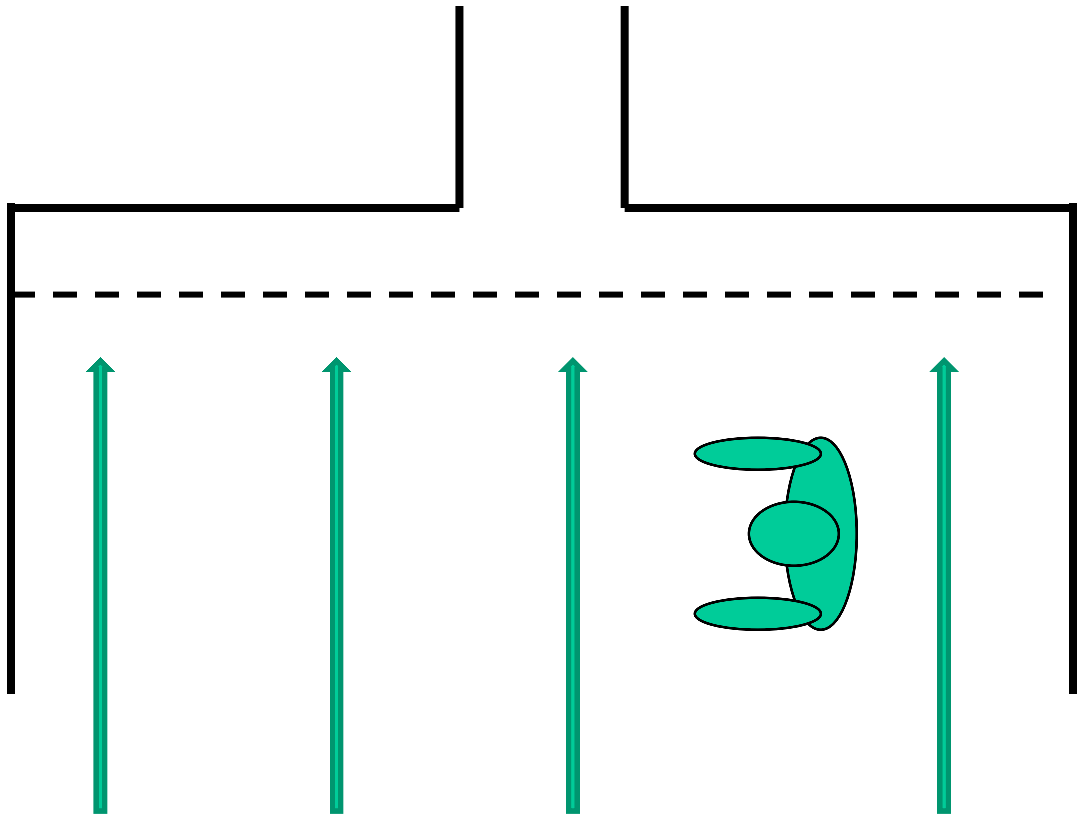
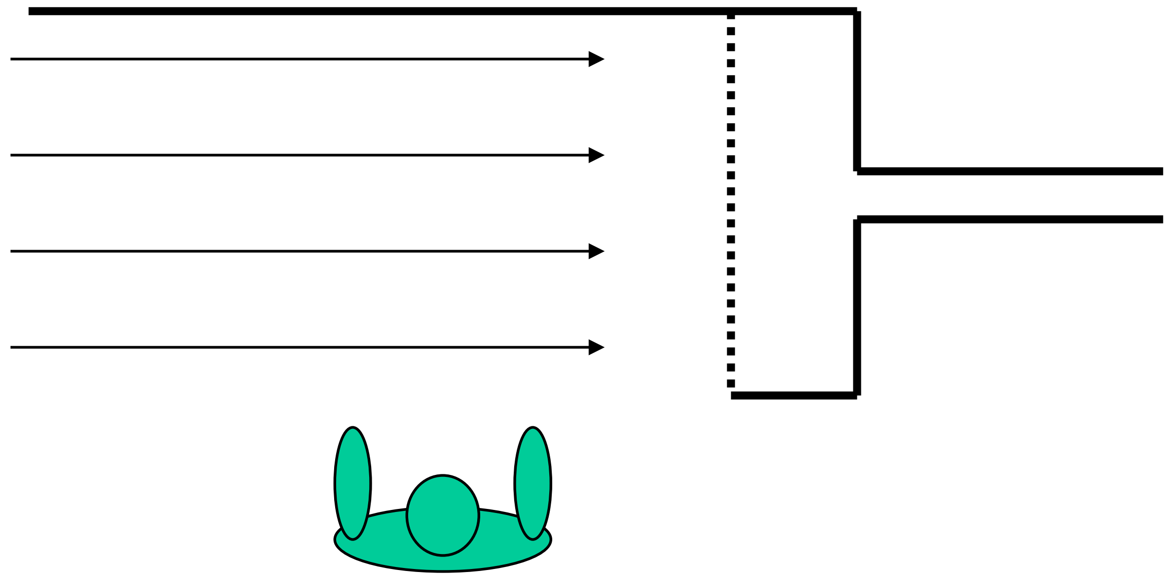
Worker Position



Positioning Worker at Right Angles to Flow



Side-flow Booth



Booth With Fixed Sash

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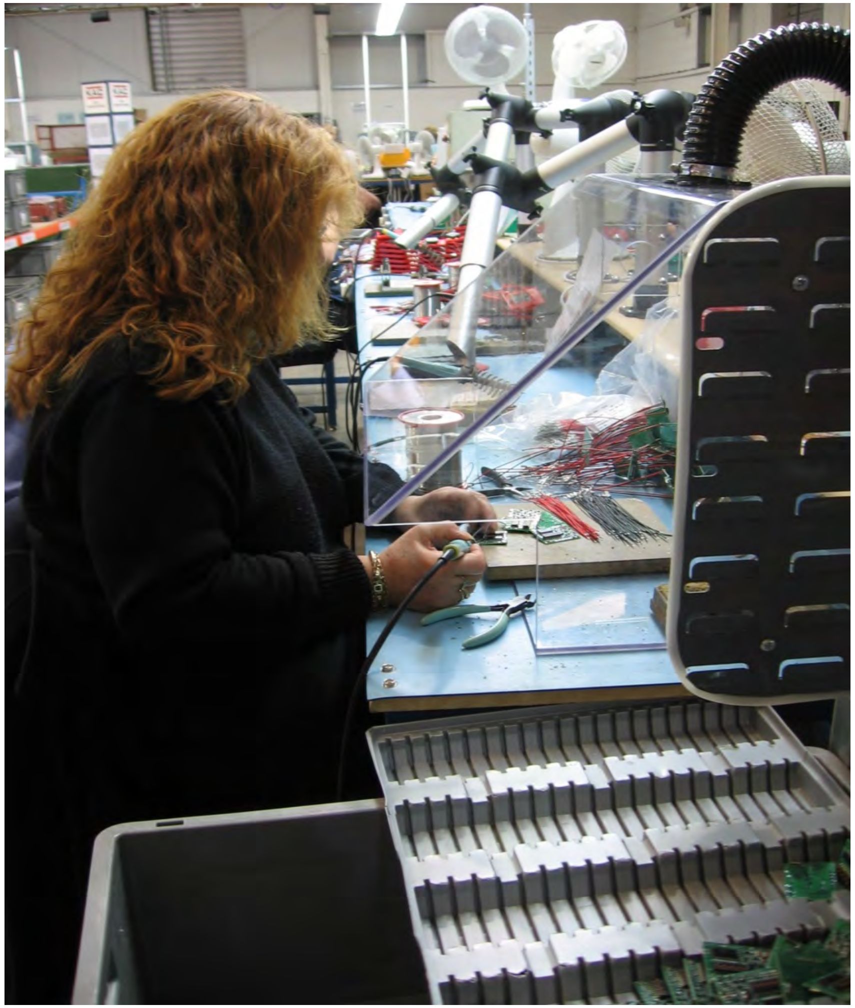
Transparent Booth for Soldering Operation



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What Improvements Could be Made Here?

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Recommended Face Velocities

Source conditions	Face velocity (m/s)
Gases and vapours	0.5 to 1.0
Dusts	1.0 to 2.5

Captor Hoods

- Source outside hood
- Ensure adequate capture velocity
- Velocity falls rapidly with distance
- Effectiveness improved by flanging

Typical Captor Hood

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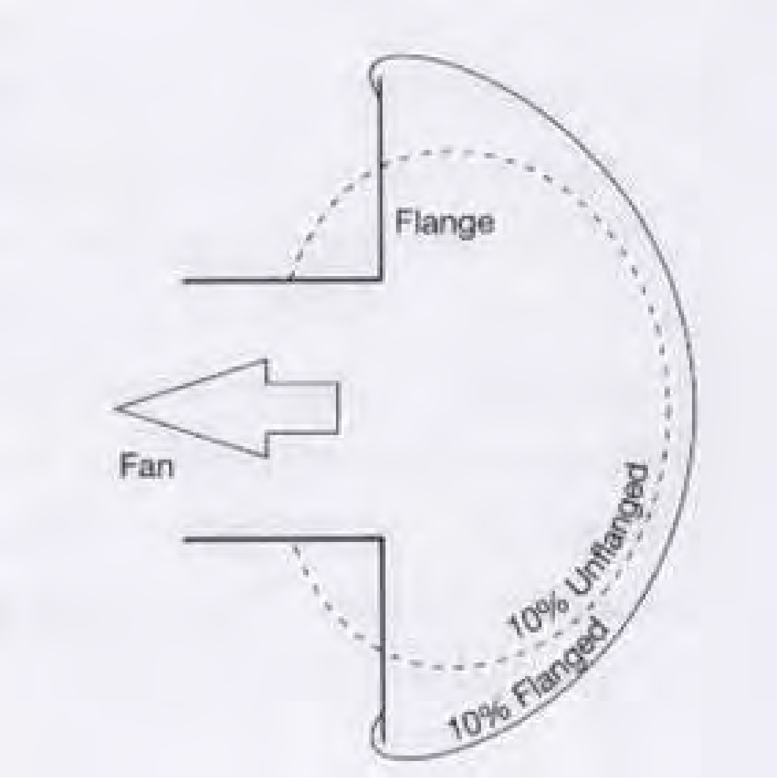
Effectiveness of a Flanged Hood



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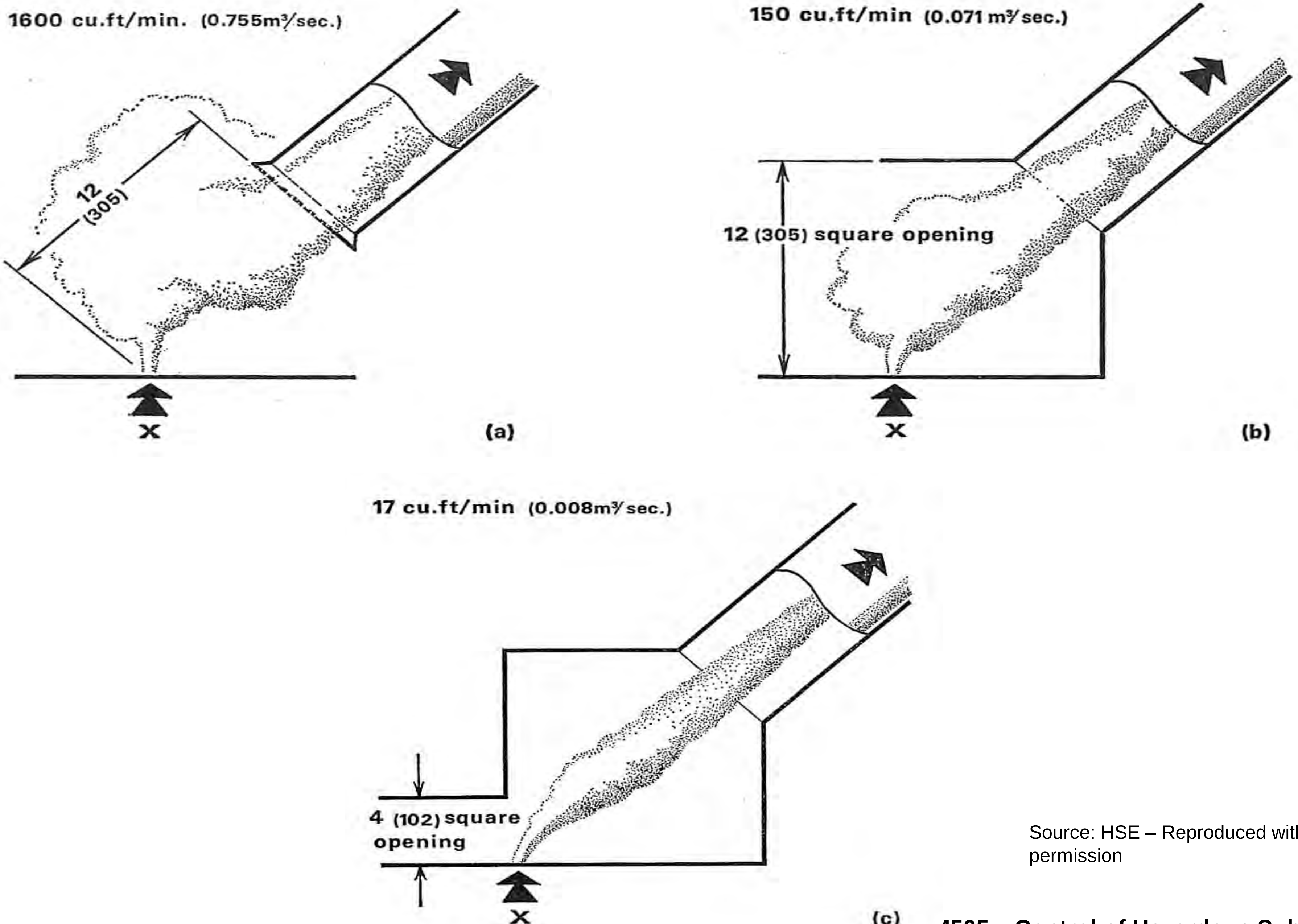

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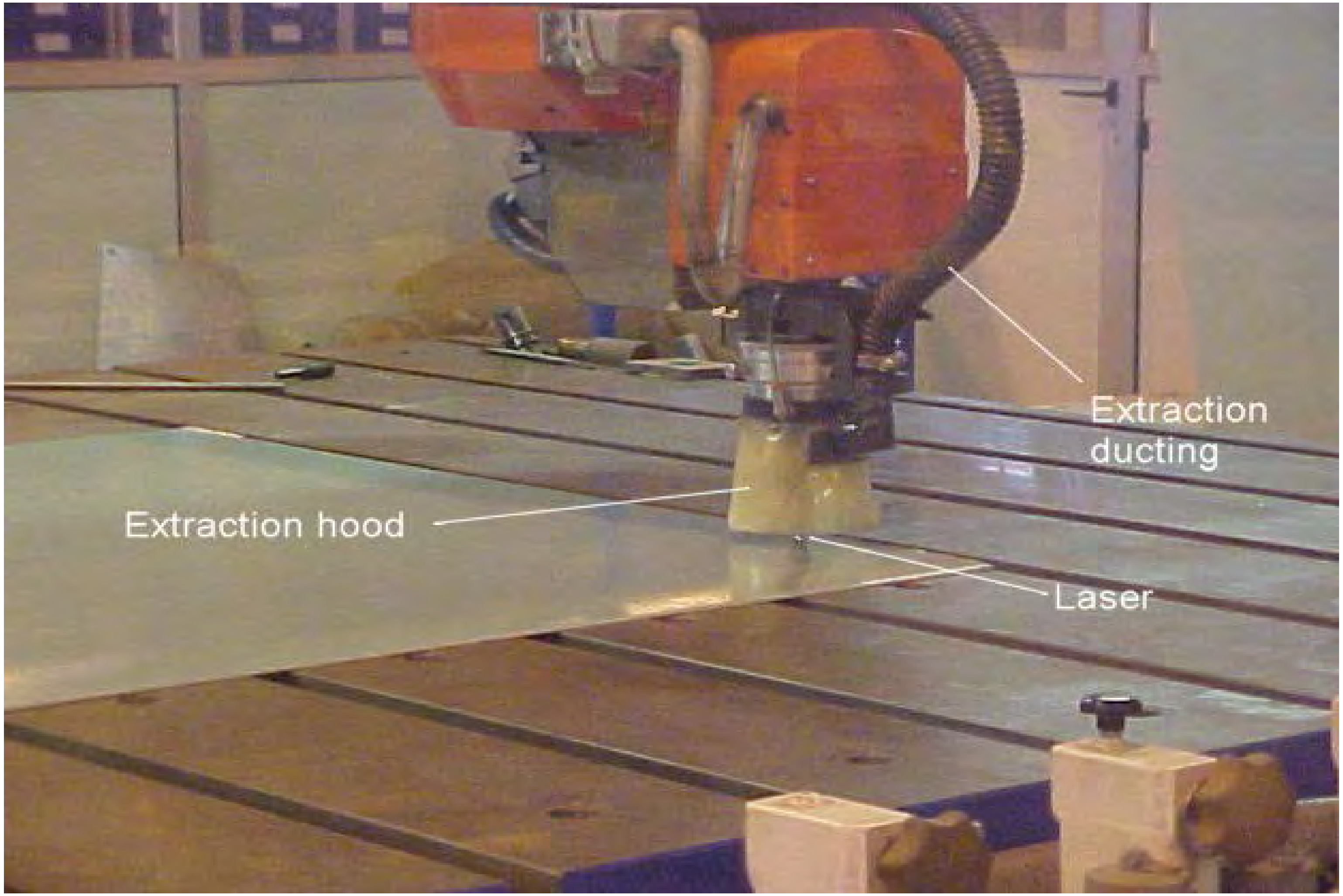
Captor Hood on Laser Cutting Titanium Plate



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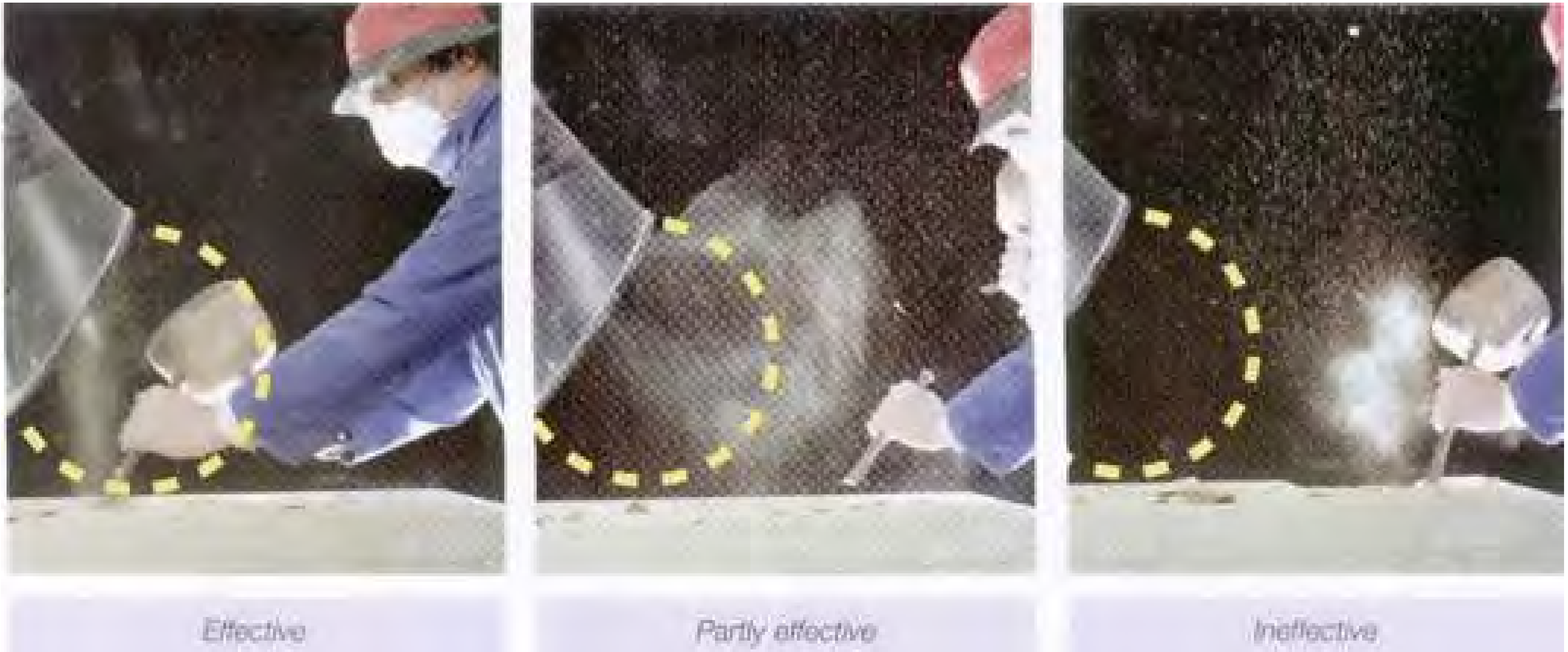
Relationship Between Capture , Working & Breathing Zones



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Low Volume High Velocity (LVHV) Systems

- **Low Volume High Velocity**
- **Portable tools**
- **Welding**
- **Soldering**

LVHV on a Soldering Iron

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Typical Capture Velocities

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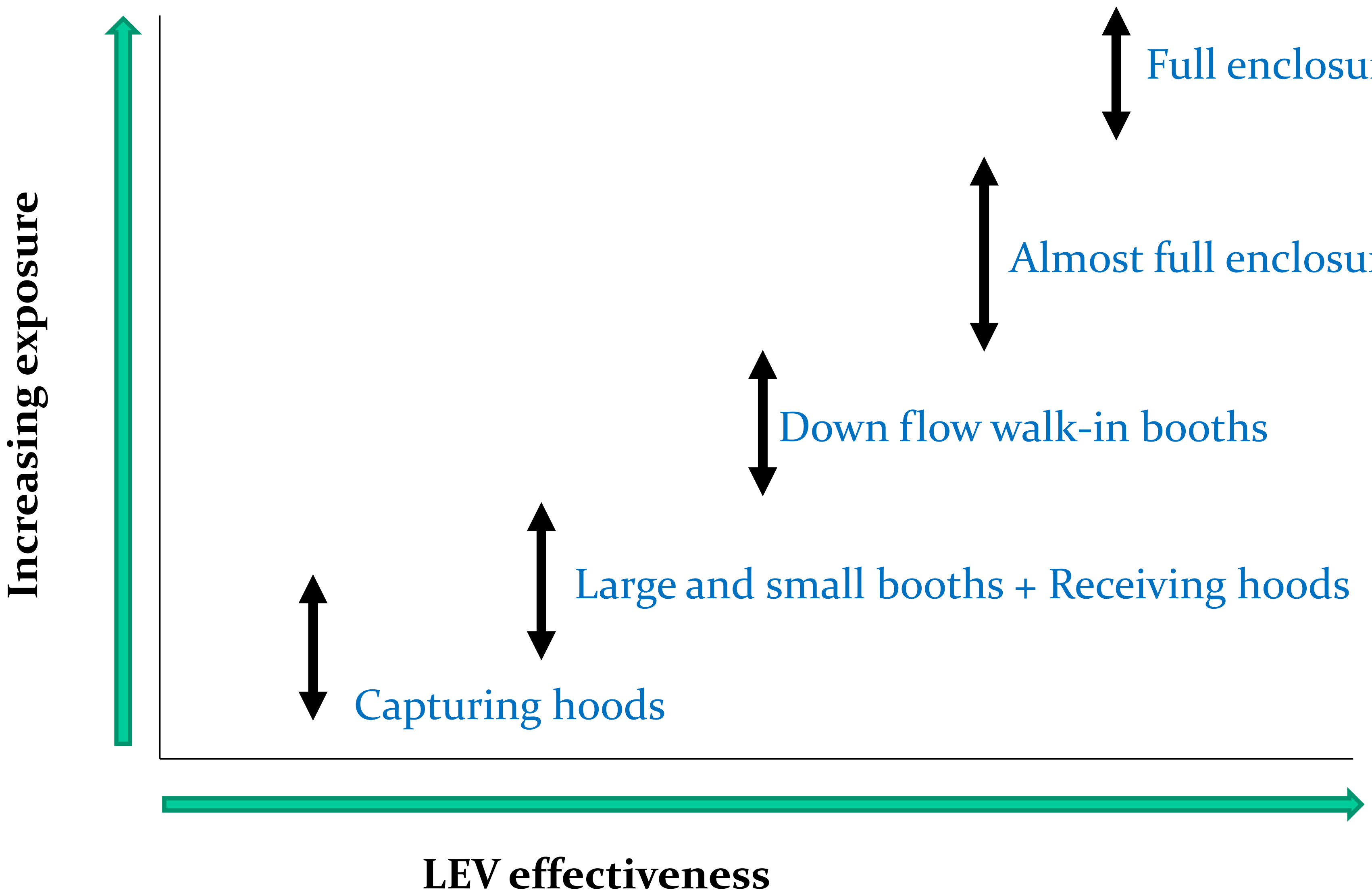
LEV Control Effectiveness



What About this Situation?

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A Better Option

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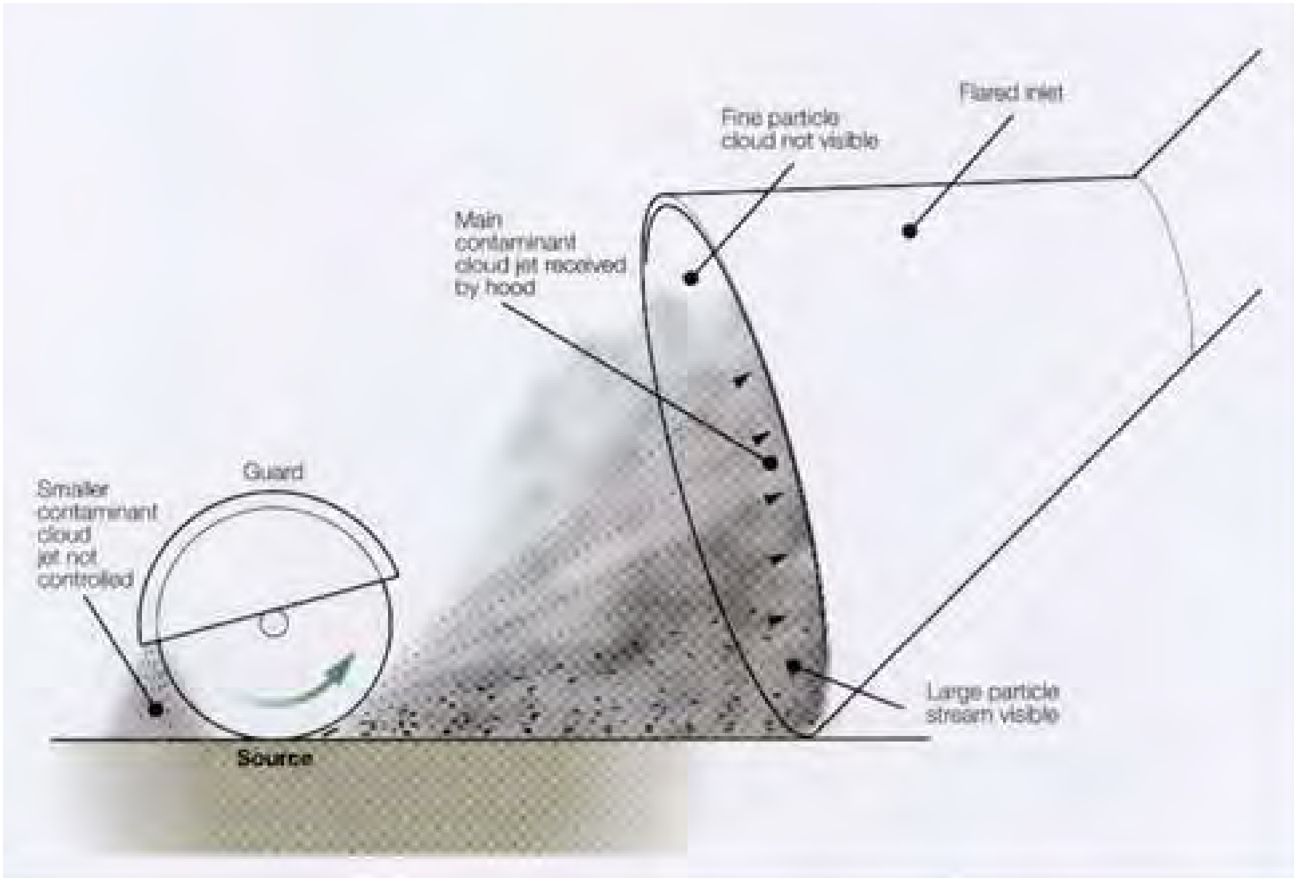
Receptor (Receiving) Hoods

- Receive contaminant
- Not active capture
- Adequate air flow to remove received contaminants

Receptor Hood



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What is the Problem with This Design?

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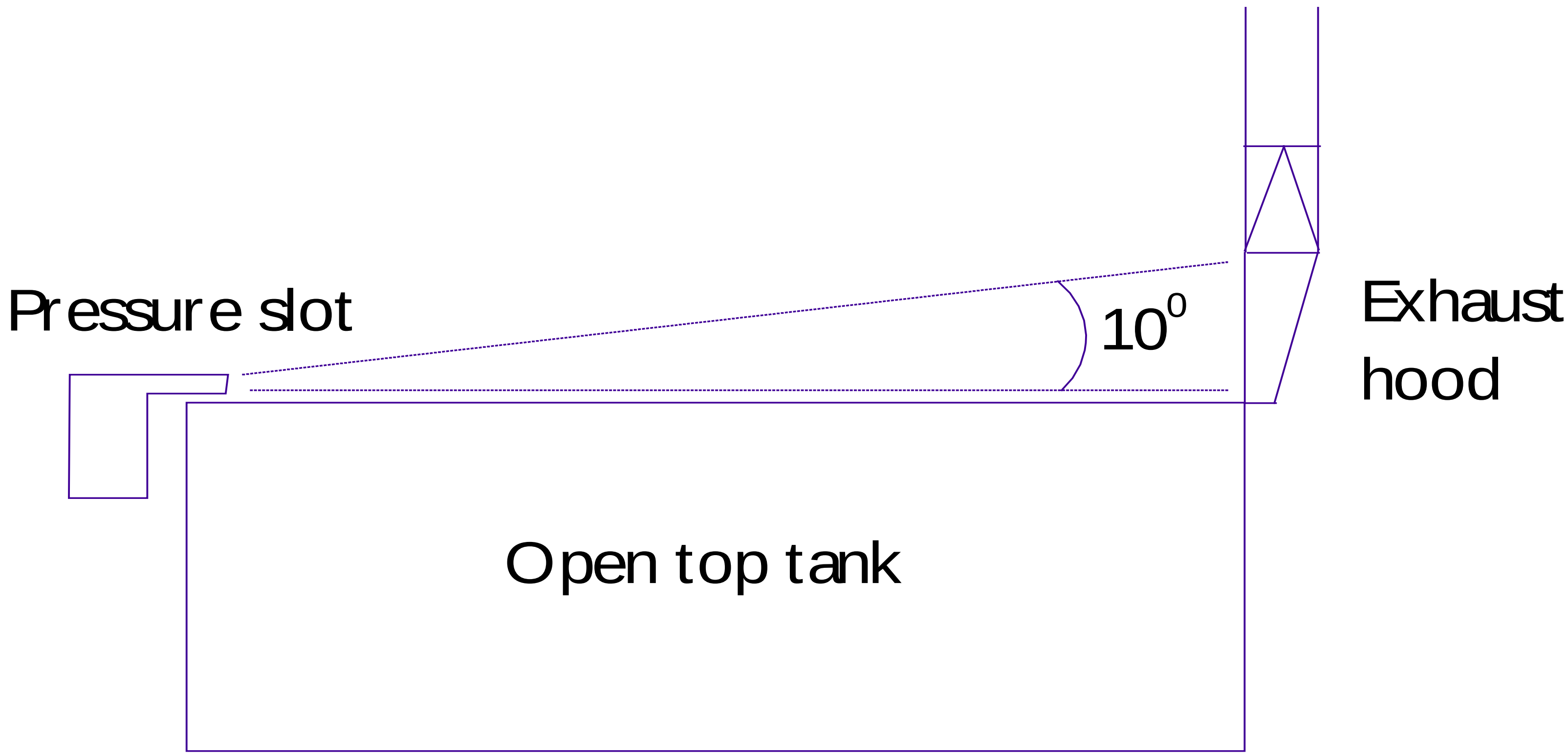
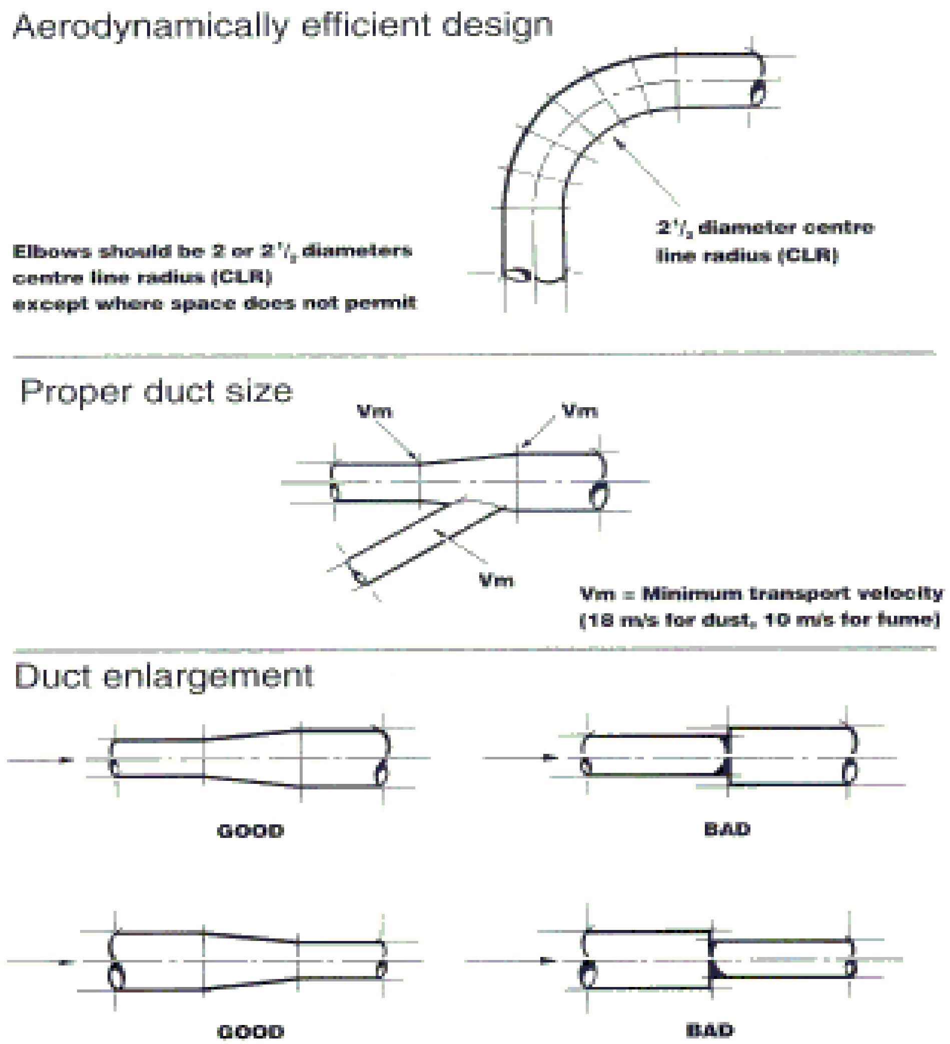
Push – Pull Systems



Duct Work

Design of Ductwork



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Recommended Transport Velocities

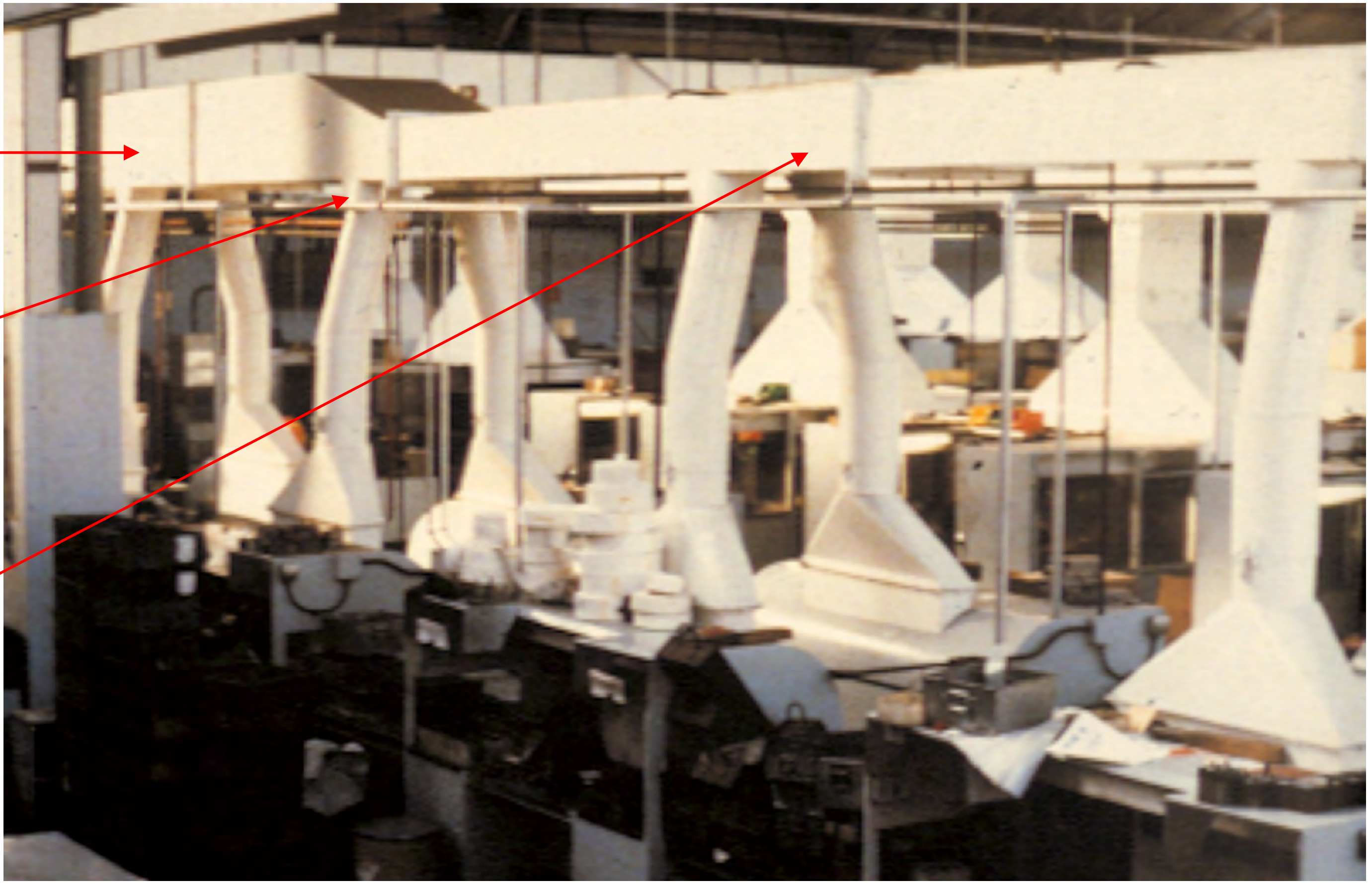
Type of Contaminant	Transport Velocity (ms^{-1})
Gases (non-condensing)	No minimum limit
Vapours, smoke and fumes	10
Light, medium density dusts and powders (eg: sawdust, plastic dusts)	15
Average industrial dusts (eg: grinding dust, silica, wood shavings)	20
Heavy dusts (eg: lead, metal turnings, dusts which are damp or tend to agglomerate)	25

Key Design Points

Rectangular not good for dust

T entry to main duct

Main duct does not taper to maintain velocity with join of side inlet



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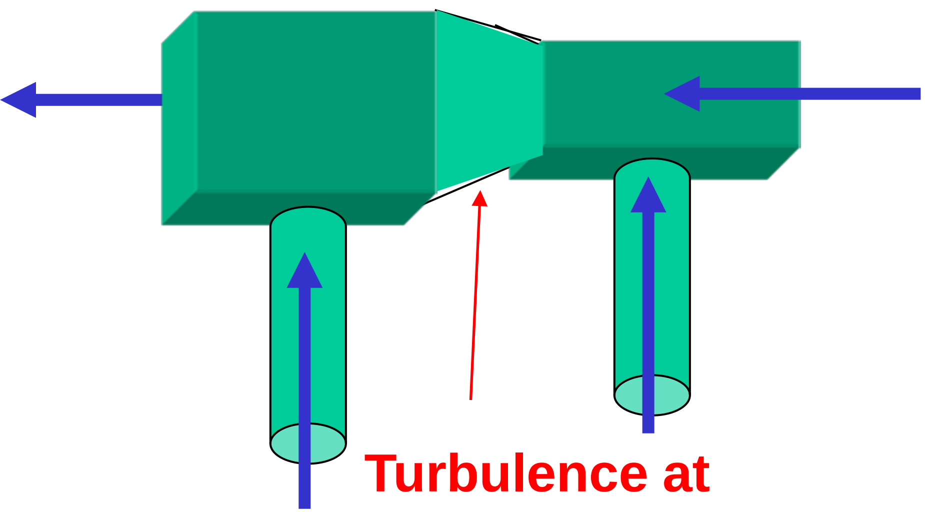
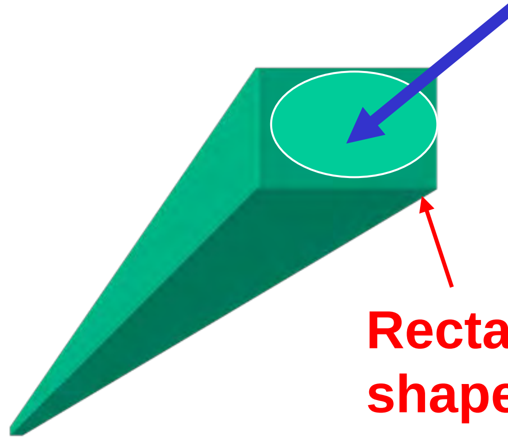
Key Design Points



Turbulence at junction will reduce velocity and cause dust to fall out of suspension

Cross section



Rectangular shape will leave areas with low velocity. Dust will fall out of suspension.

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What About this Situation?

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What About this Situation?

Source: University of Wollongong

Balancing a Dust System

- Balancing is to ensure that each branch of the system is operating at its maximum performance
- Balancing requires starting at each hood or branch and making adjustments while working towards the fan
- The correct balancing or rebalancing of a system is a highly skilled activity and should only be conducted by experienced persons

System Balancing

- Balance by design, or
- Use of blast gates

Inspection Openings

- In any duct system it is important to provide leak-proof inspection openings to allow for the inspection and cleaning of ducts
- It is also important to provide test points where at a minimum the static pressure can be measured
- These should be located after each hood or enclosure, at key points in the duct system and at certain components to measure pressure drops (ie: fans and filter)

Key Design Points

- Keep the design as simple as possible
- Keep the number of bends and junctions to a minimum so as to reduce flow resistance
- When changes in direction are necessary they should be made smoothly

Key Design Points (cont)

- ‘T’ junctions should never be used and tapered sections should be used when the duct cross section needs to change
- Avoid long lengths of flexible ducting, especially where high flow resistance is present
- Avoid ‘U’ bends as they act as traps for particles and can eventually block the duct

Fans

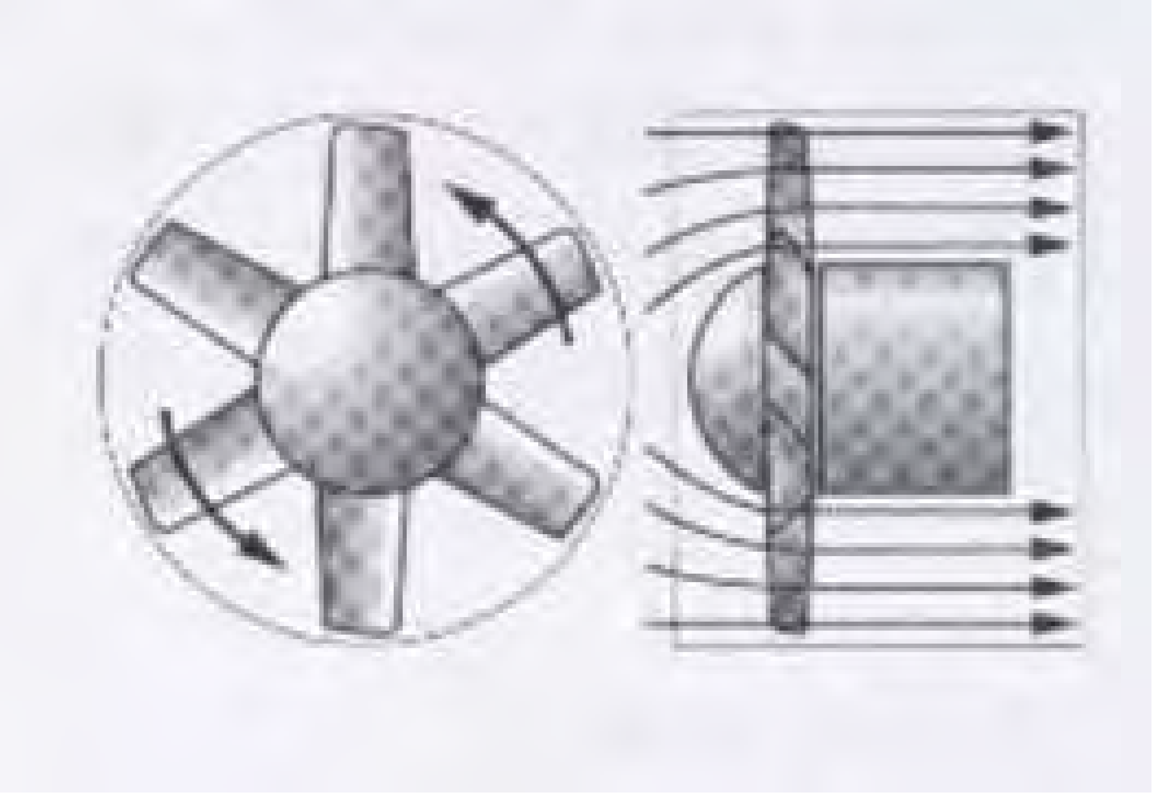
Fan Types

- Centrifugal
- Axial

Other Fan Types

- Propeller Fans
- Turbo exhausters or multistage centrifugal fans
- Compressed air driven air movers

Axial Fans



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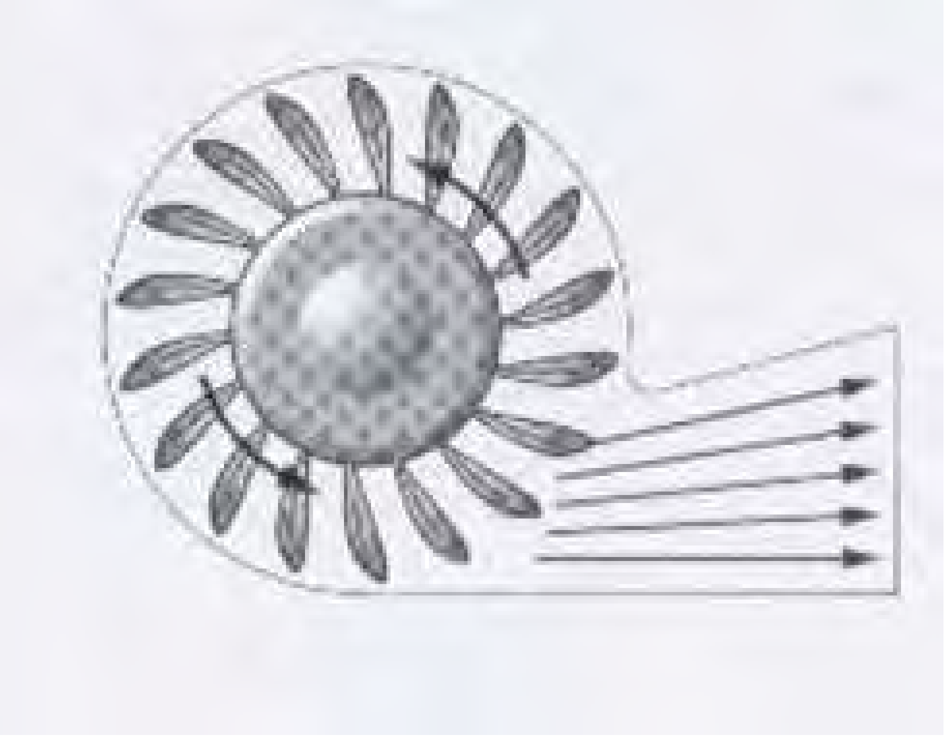
Centrifugal Fan



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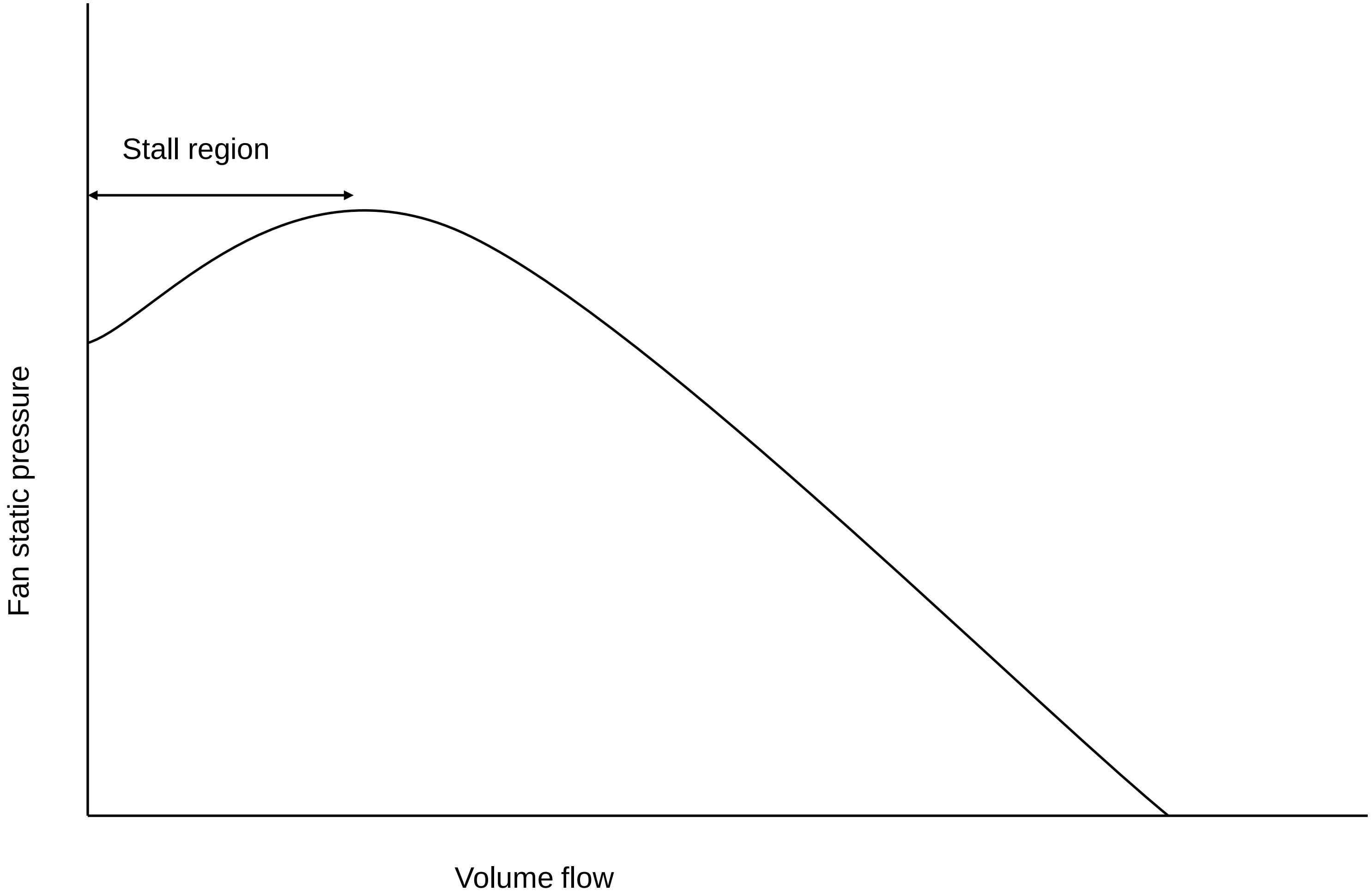
Centrifugal Fans

- Forward curved impellers
- Backward curved impellers
- Radial impellers

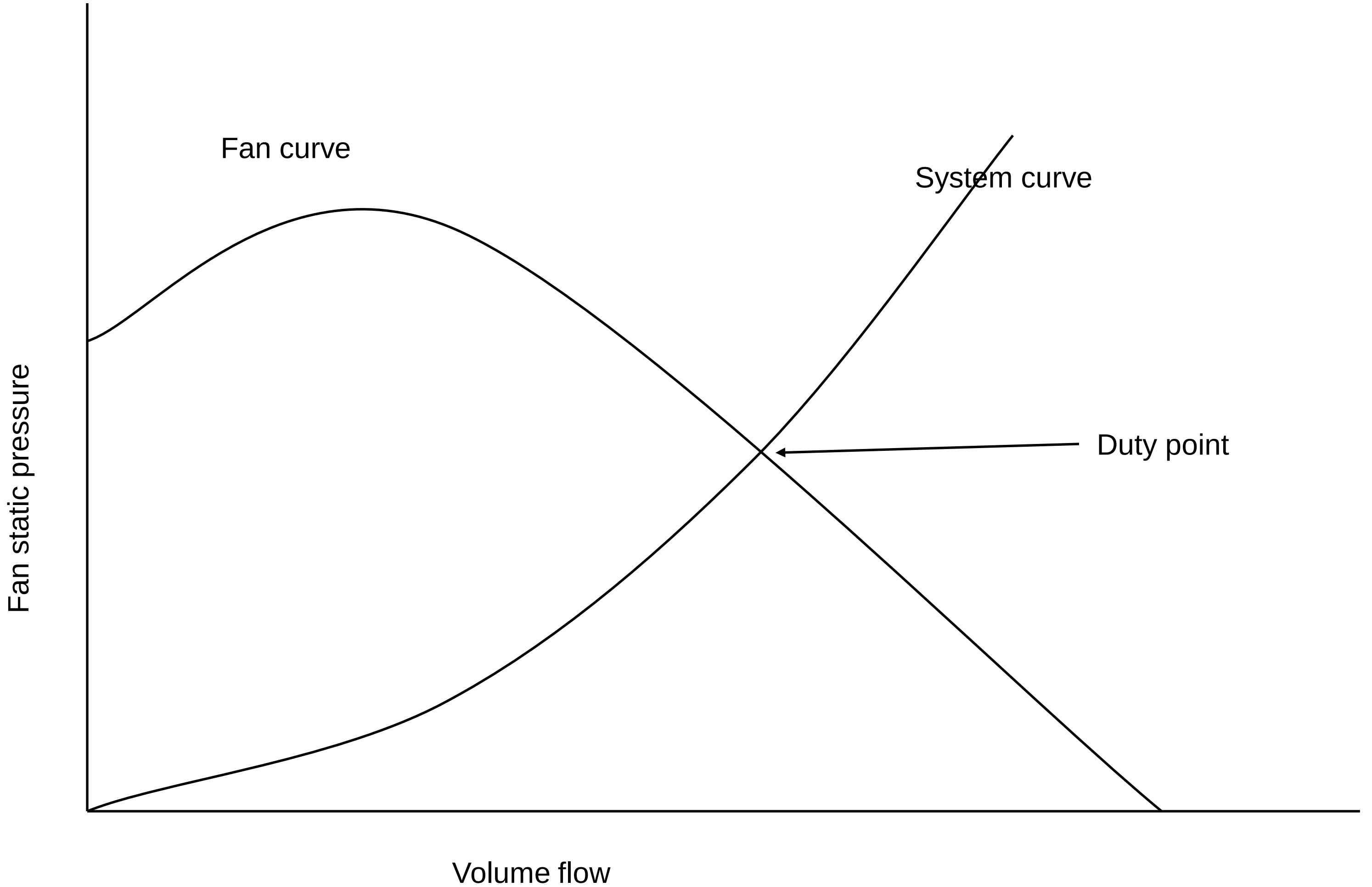
Air Movers

- Low operating efficiency
- Often used in flammable atmospheres
- Can be used with flammable, corrosive, sticky etc. contaminants

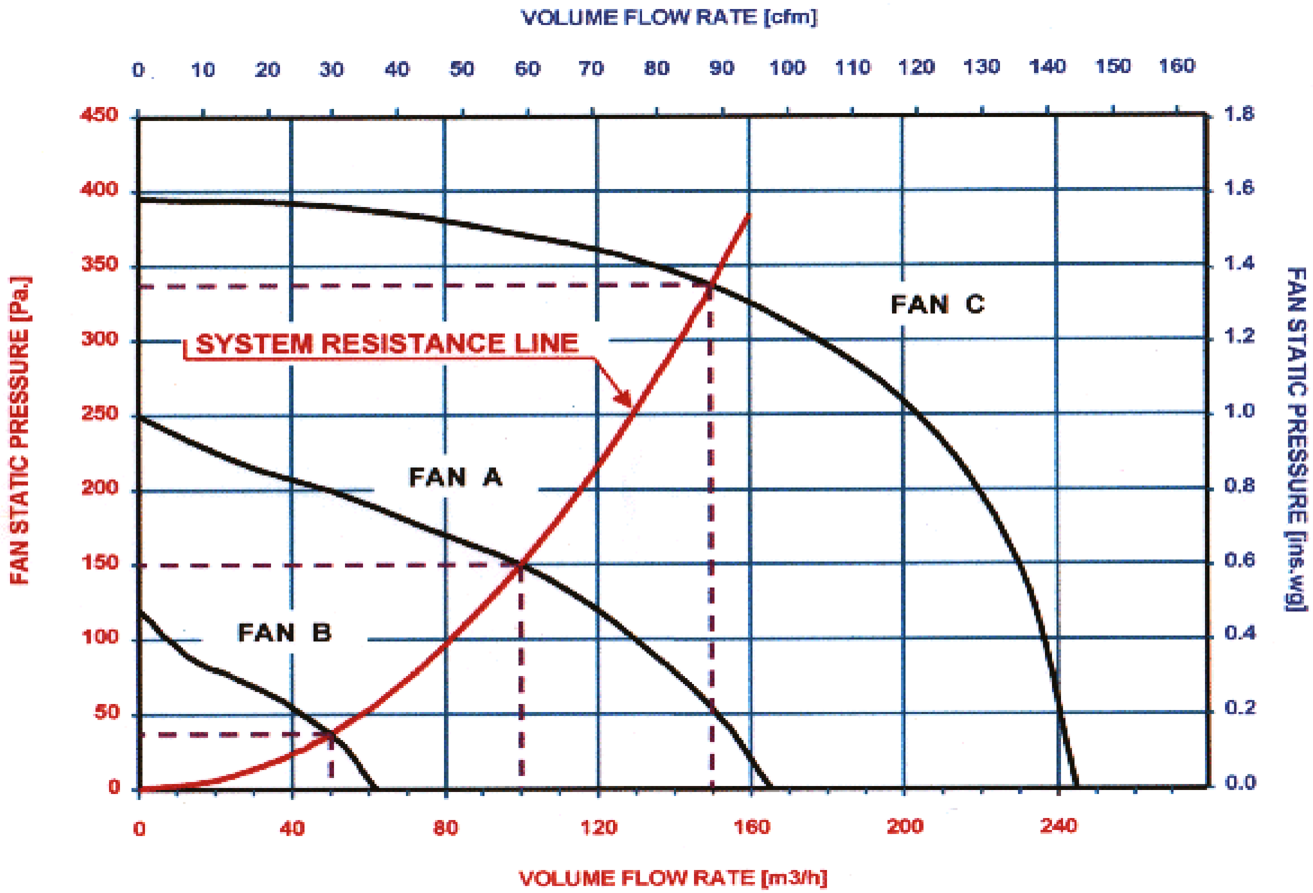
Fan Curves



Fan Curves


Fan curve
System curve
Duty point
Fan static pressure
Volume flow

Fan Curves


VOLUME FLOW RATE [cfm]
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
450 400 350 300 250 200 150 100 50 0
FAN STATIC PRESSURE [Pa.]
1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0.0
FAN STATIC PRESSURE [ins.wg]
FAN C
SYSTEM RESISTANCE LINE
FAN A
FAN B
0 40 80 120 160 200 240
VOLUME FLOW RATE [m3/h]

Air Cleaners

Types of Air Cleaners

Contaminant	Type of Air Cleaner	Performance & Comments
Particulates	Cyclone	Poor at low particle sizes (2 µm = 0%, 5 µm = 50%) but good at larger sizes (8 µm = 90%).
	Electrostatic Precipitator	<5 µm 80 - 99% 5 - 10 µm 99% Poor performance with particles that have a very low or high electrical conductivity.
	Fabric Filter	Very good for small particle sizes but flow resistance increases as dust builds up on filter.
	Wet Systems such as Venturi Scrubbers, Cyclones, etc	Lower performance (20 – 80%) with particles <5 µm but >95% with particles >5 µm. Produces a sludge which requires disposal.

Types of Air Cleaners (cont)

Gases & Vapours	Adsorption	Most common are activated carbon filters, however the filter can fail suddenly when saturated.
	Chemical Scrubbing	Suitable for specific contaminants.
	Thermal Destruction	Combustion may produce unwanted by-products.

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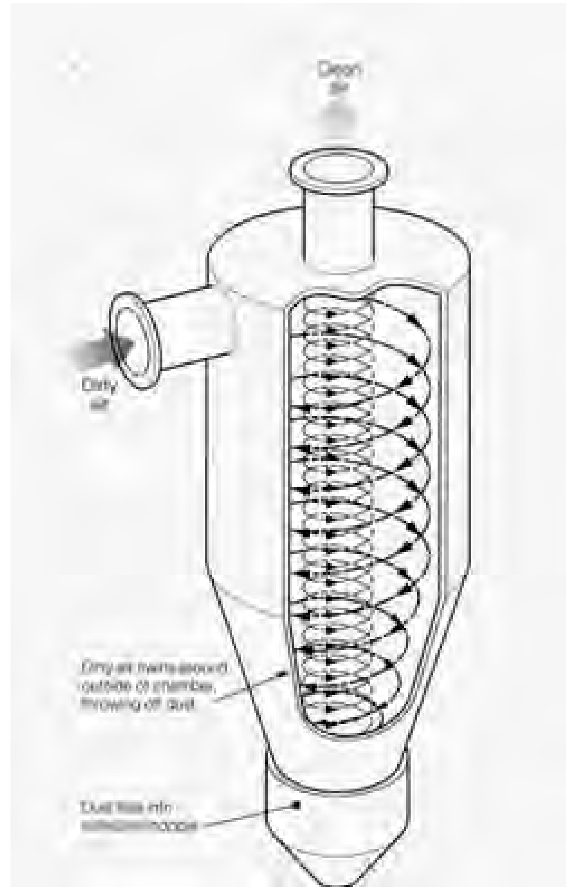
Cyclones

- **Good for**
  - **heavy dust loadings**
  - **dry and wet particles**
- **High efficiency for particle diameters > 10 um**



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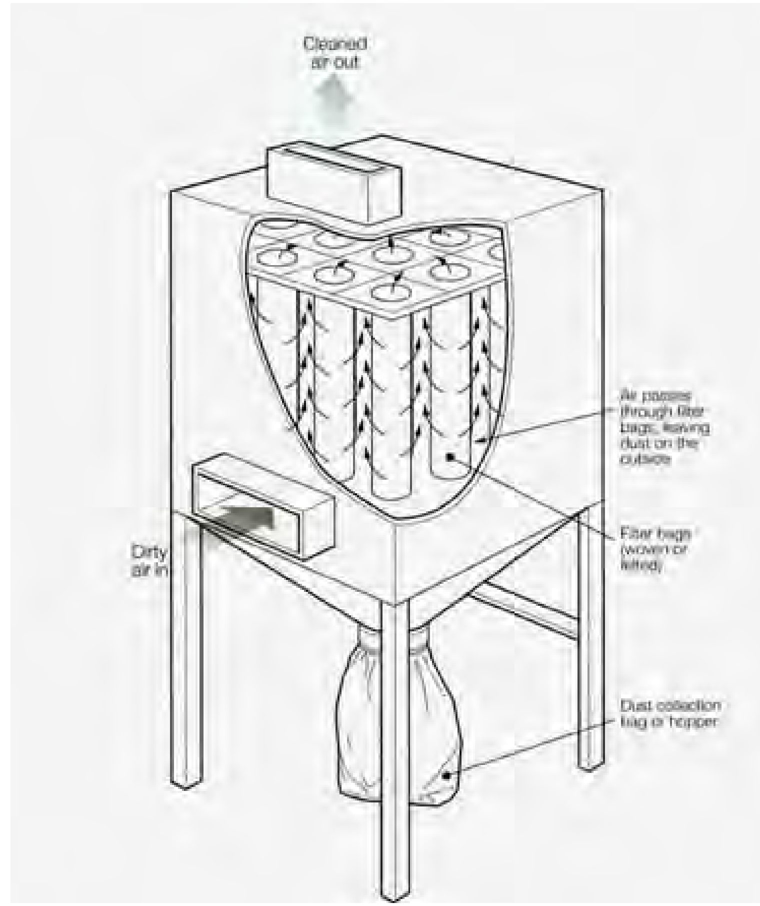
Filtration

- Location
- Replacement

Filtration

- **Good for moderate dust loadings**
- **High efficiency for all particle diameters**



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Filter Cleaning

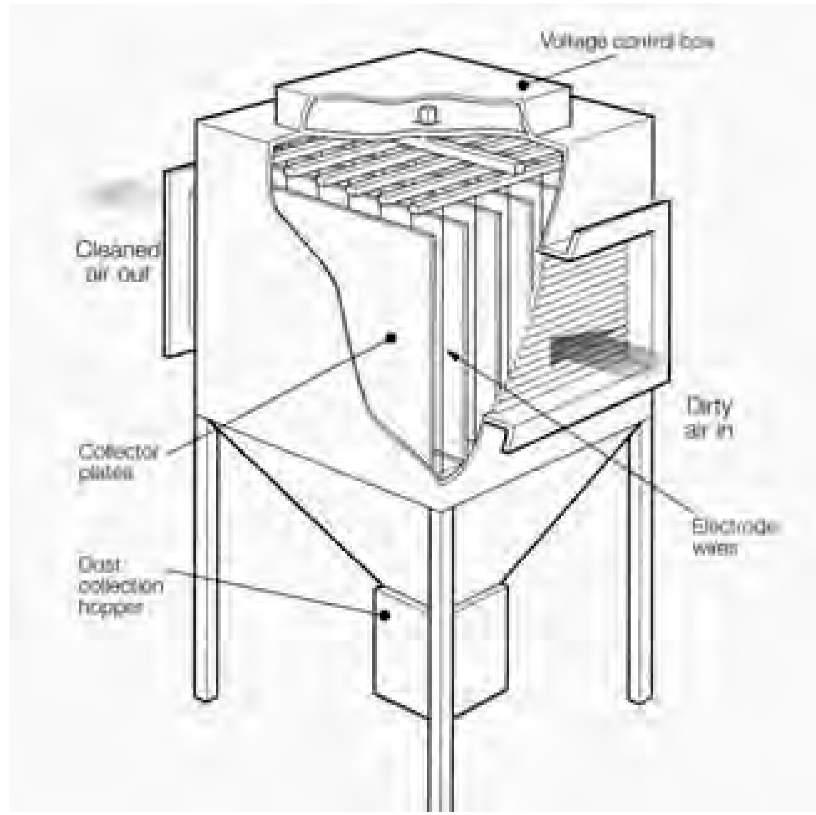
- Shaker motor
- Reverse flow
- Compressed air

HEPA Filters

- High Efficiency Particulate Arrestment
- Often used for
  - high toxicity dusts
  - radioactive dusts
  - micro-organisms

Electrostatic Precipitators

- **Good for moderate dust loadings**
- **High efficiency for particle diameters > 0.2u**



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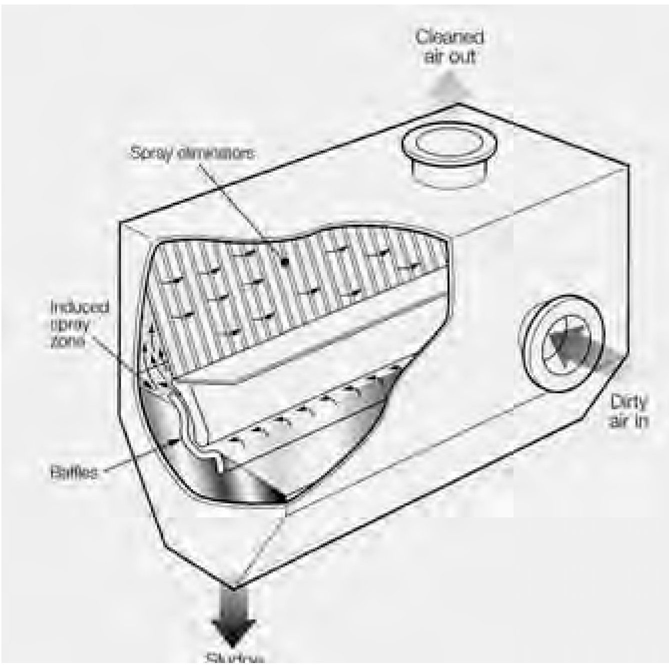
Spray Collectors



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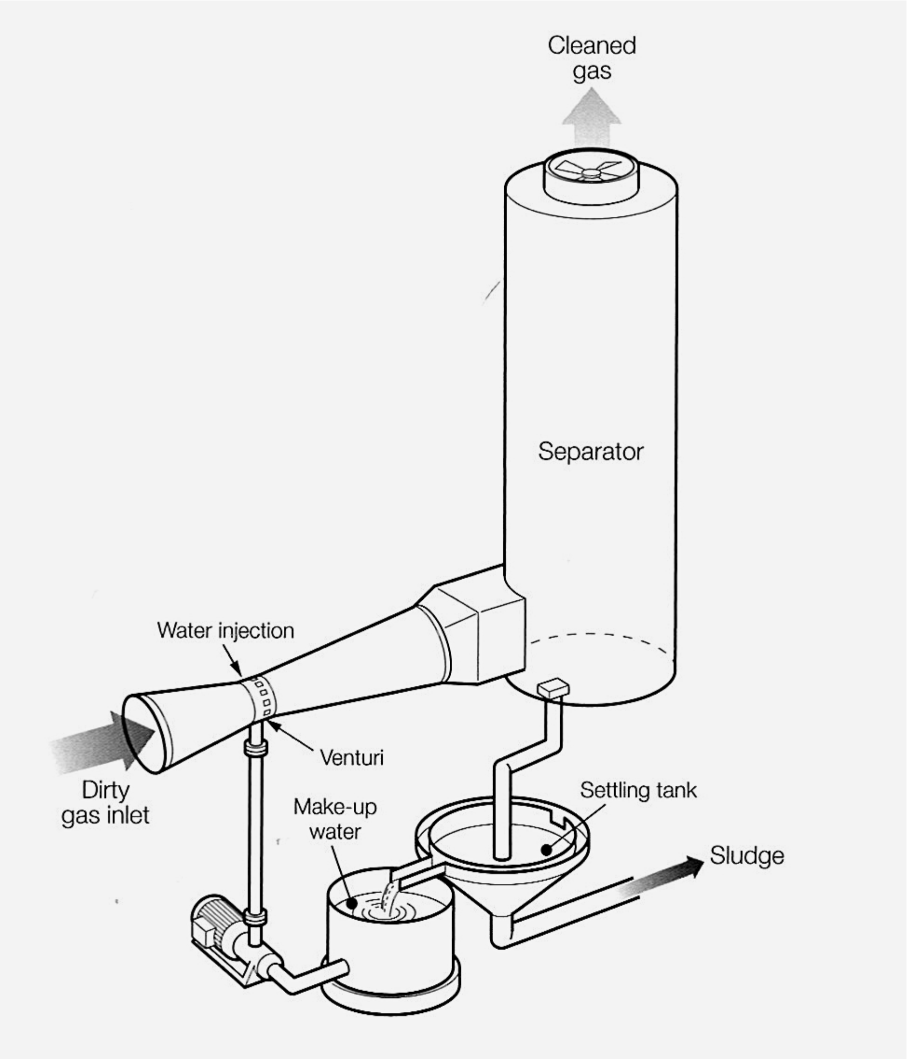
- **Good for**
  - **heavy dust loadings**
  - **dry and wet particles**
  - **hot gas streams**
- **Suitable for particle diameters > 10 u**

Venturi Scrubber



- **Good for**
  - **heavy dust loadings**
  - **dry and wet particles**
  - **hot gas streams**
- **High efficiency for particle diameters > 0.5 u**

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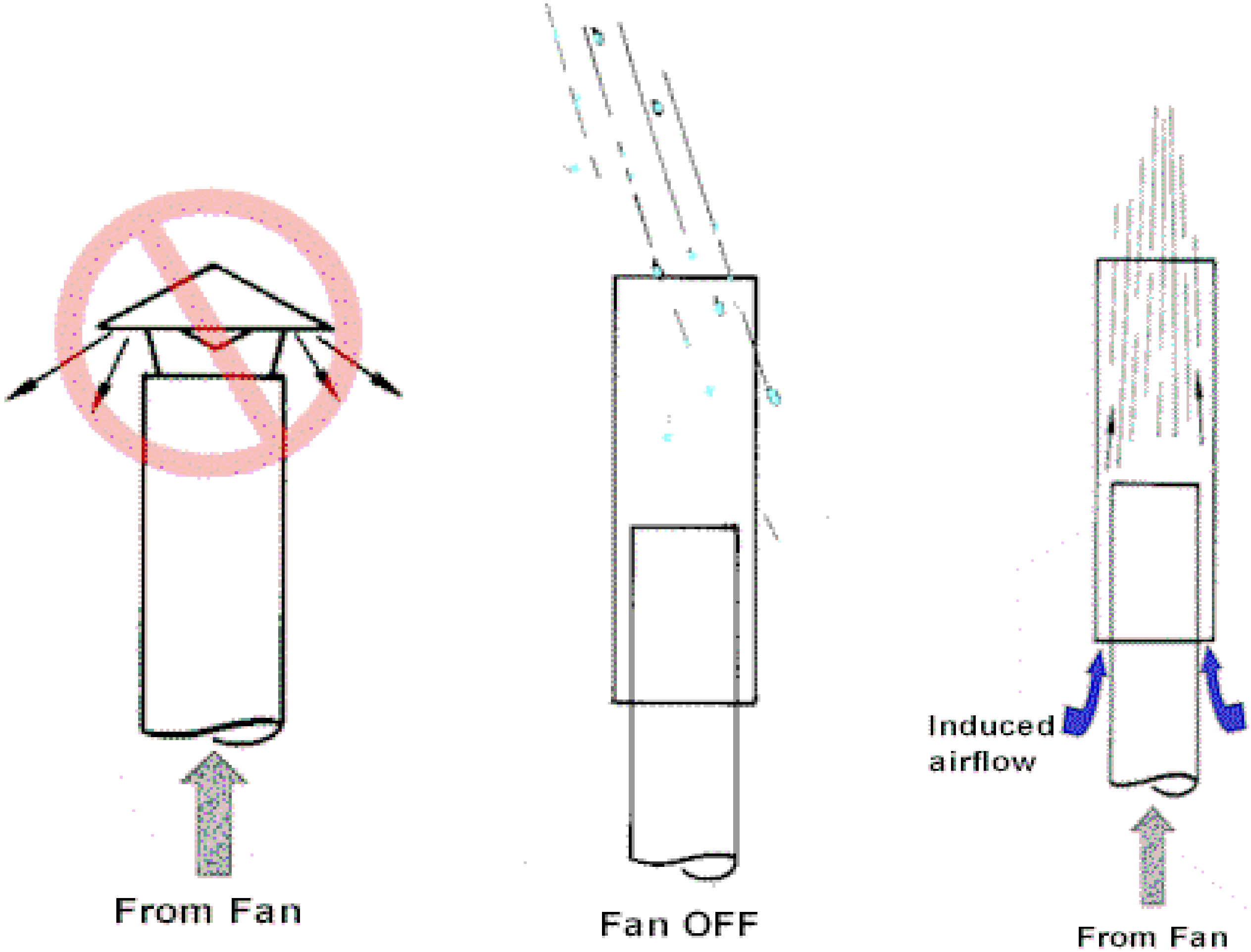
Gas and Vapour Removal

- Scrubbers
- Condensation
- Combustion
- Adsorption

Stack Design



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Stack Location and Height

When designing discharge systems there is a necessity to understand the airflow patterns around the location of the discharge so that the best possible location can be achieved

Poor Stack Exhaust Design

Source: University of Wollongong

Limitations of LEV Systems

- **Need to be purpose designed for a process, making process changes difficult if the same level of control is to be maintained**
- **High capital and operating cost. All LEV systems require energy for the fan, making operating costs an added expense**
- **High levels of noise are common with LEV system, resulting in them being turned off by operators in many cases**

Limitations of LEV Systems (cont)

- Many are of a fixed structure design making flexibility within the workplace difficult
- Many require the installation of an air supply system. Supplied air may need to be heated
- Not practical for large disperse contaminant clouds that have multiple sources
- Limited application for the control of moving sources

A Word of Caution

- The introduction of new or larger sources of chemicals or particulates may create hazards the previously satisfactory system cannot now handle
- A new process may include a substance whose airborne concentrations must be held to lower levels than those previously in use
- Any process change may effect worker exposures and needs careful evaluation

Testing Ventilation Systems

Testing Ventilation Systems

- **Initial evaluation**
- **Routine performance testing**

Initial Appraisal

- To ensure plant achieves specified performance
- To establish operating criteria

Routine Checks

- Carried out on a daily, weekly or monthly basis
- Inspect hoods, ductwork etc for damage
- Observe any evidence of failure or deterioration in control
- Read instruments fitted to system
- Undertake minor servicing

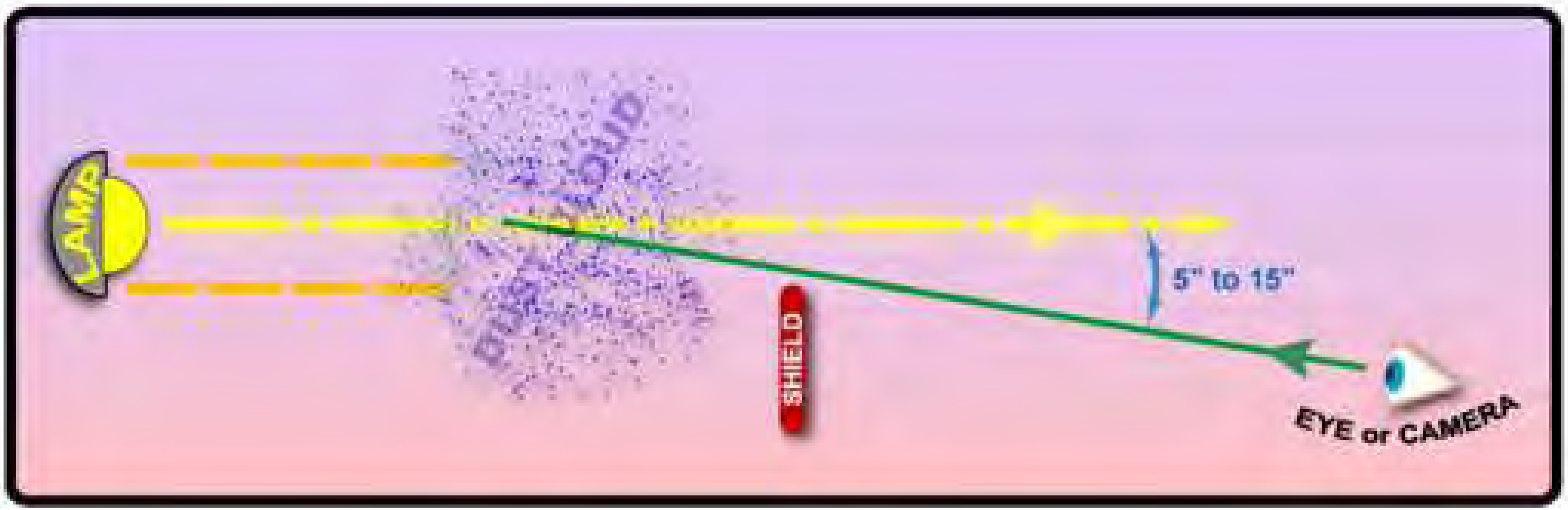
Thorough Examination and Test

- Visual checks
- Assessment of control
- Measurement of plant performance
- Assessment of air cleaner (where air recirculated)

Assessment of Control

- Dust lamp
- Dust monitors
- Smoke
- Air sampling

Principle of the Dust Lamp



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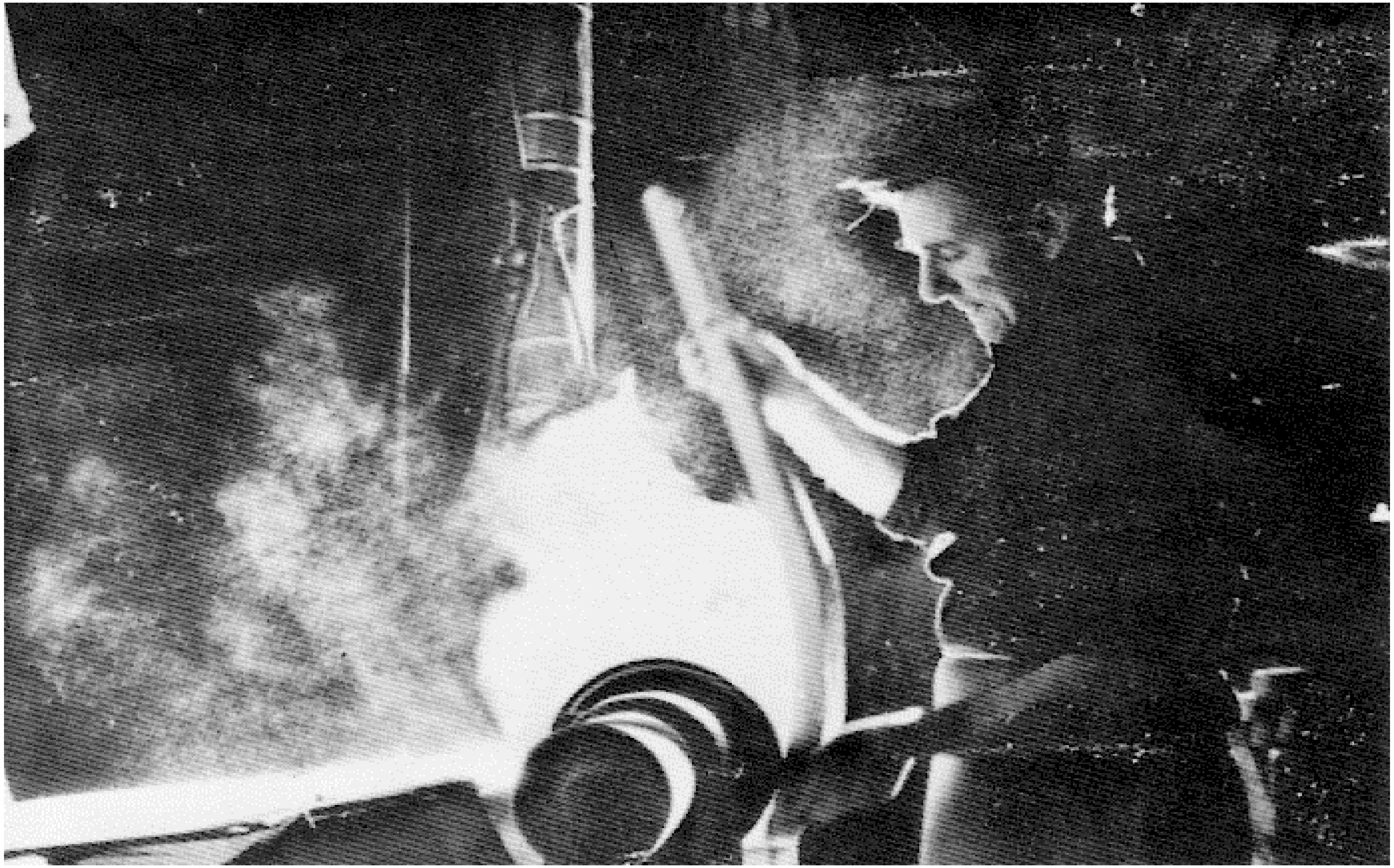
Visualisation of Dust Cloud



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Dust Lamp

Show HSE Video Clips 9 & 10

Smoke Tubes Indicating Air Movement

Source: R Alesbury-reproduced with permission

Smoke Tubes

Source: NOHS

Show HSE Video Clip 11

Measurement of Plant Performance

- Face velocities
- Capture velocities
- Duct velocity and volume flow rate
- Static pressure behind each hood or enclosure

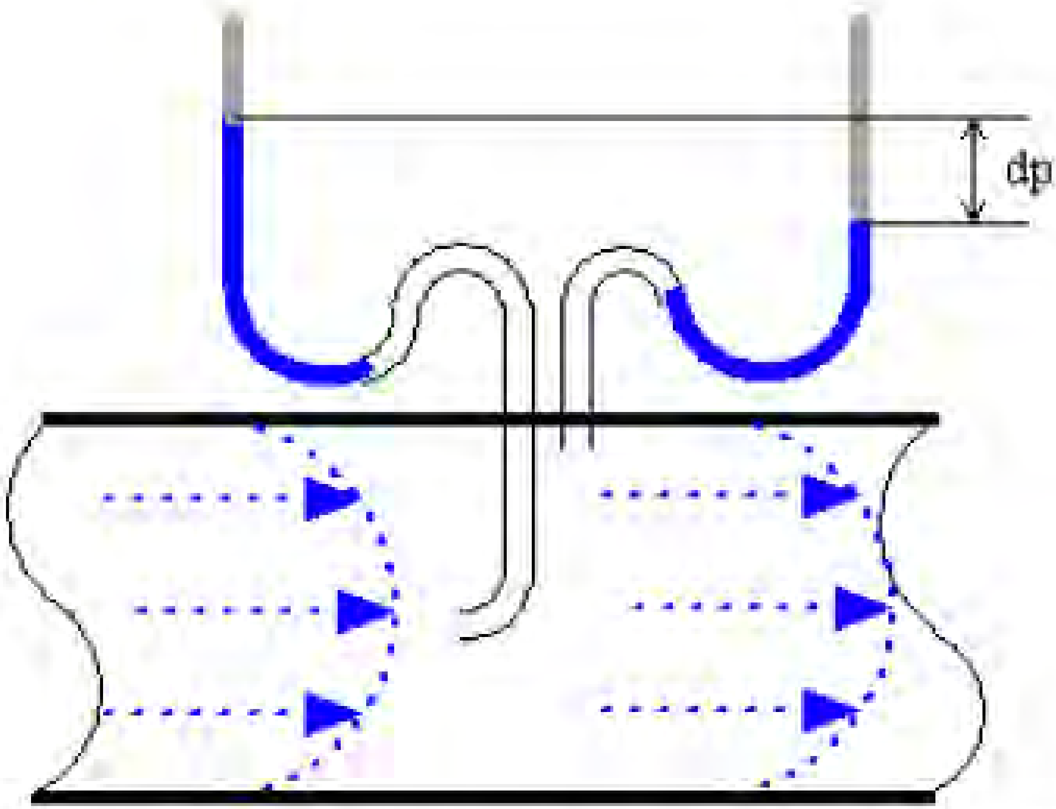
Vane Anemometer

Source: University of Wollongong

Hot-wire Anemometer

Source: University of Wollongong

Pitot Tubes



(Source: The Engineering Toolbox - *reproduced under conditions of copyright*)

Pitot Tube and Manometer with Digital Readout

Source: TSI Inc – *reproduced with permission*

Velocity and Velocity Pressure

$$P_v = \frac{\rho v^2}{2}$$

$$v = 1.29\sqrt{P_v} \qquad \text{(at room temperature)}$$

$$V = 1.291\sqrt{\frac{1013.25}{B} \times \frac{T}{293} \times \frac{100000}{100000 + P_s} \times P_v}$$

Pitot Tubes (cont)

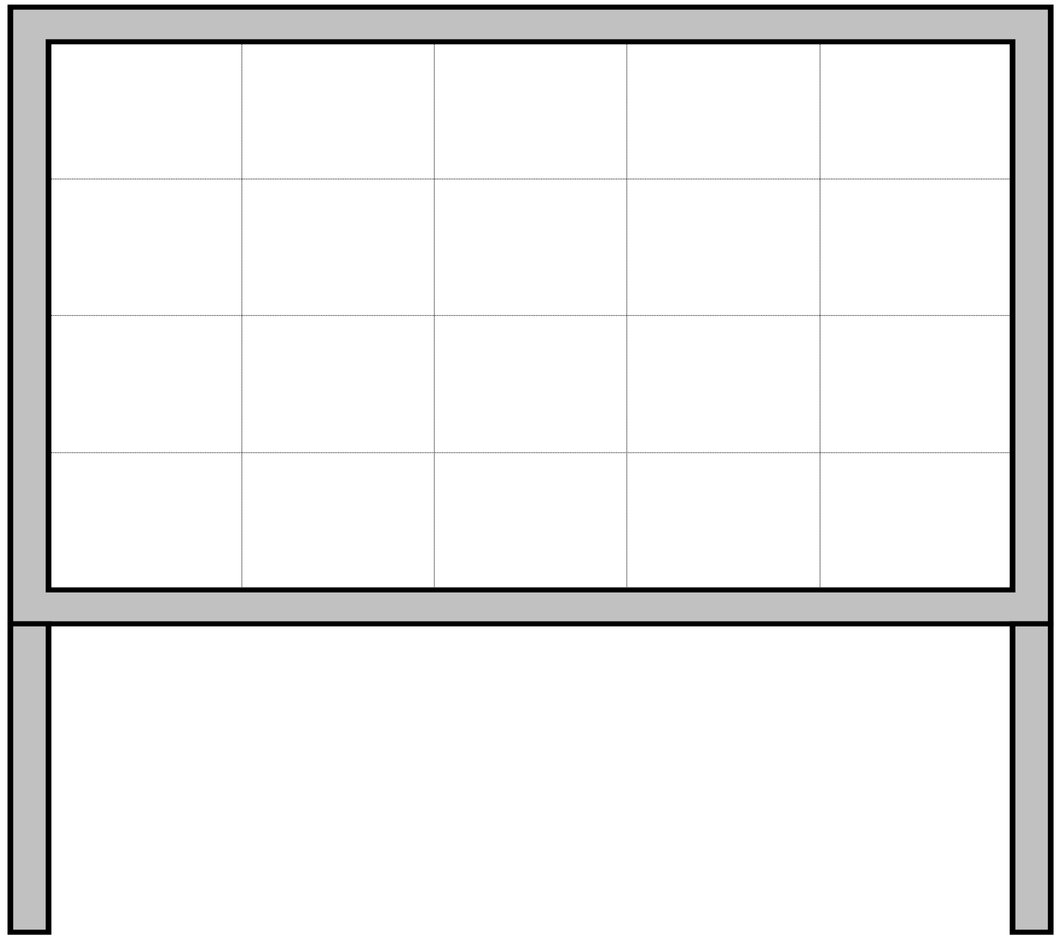
- **Need no calibration, however measurements must be made in an area of ductwork where there are no obstructions, bends or turbulence**

- **Pitot tubes are generally not considered reliable to measure airflows with velocities less than 3 ms^{-1}.**

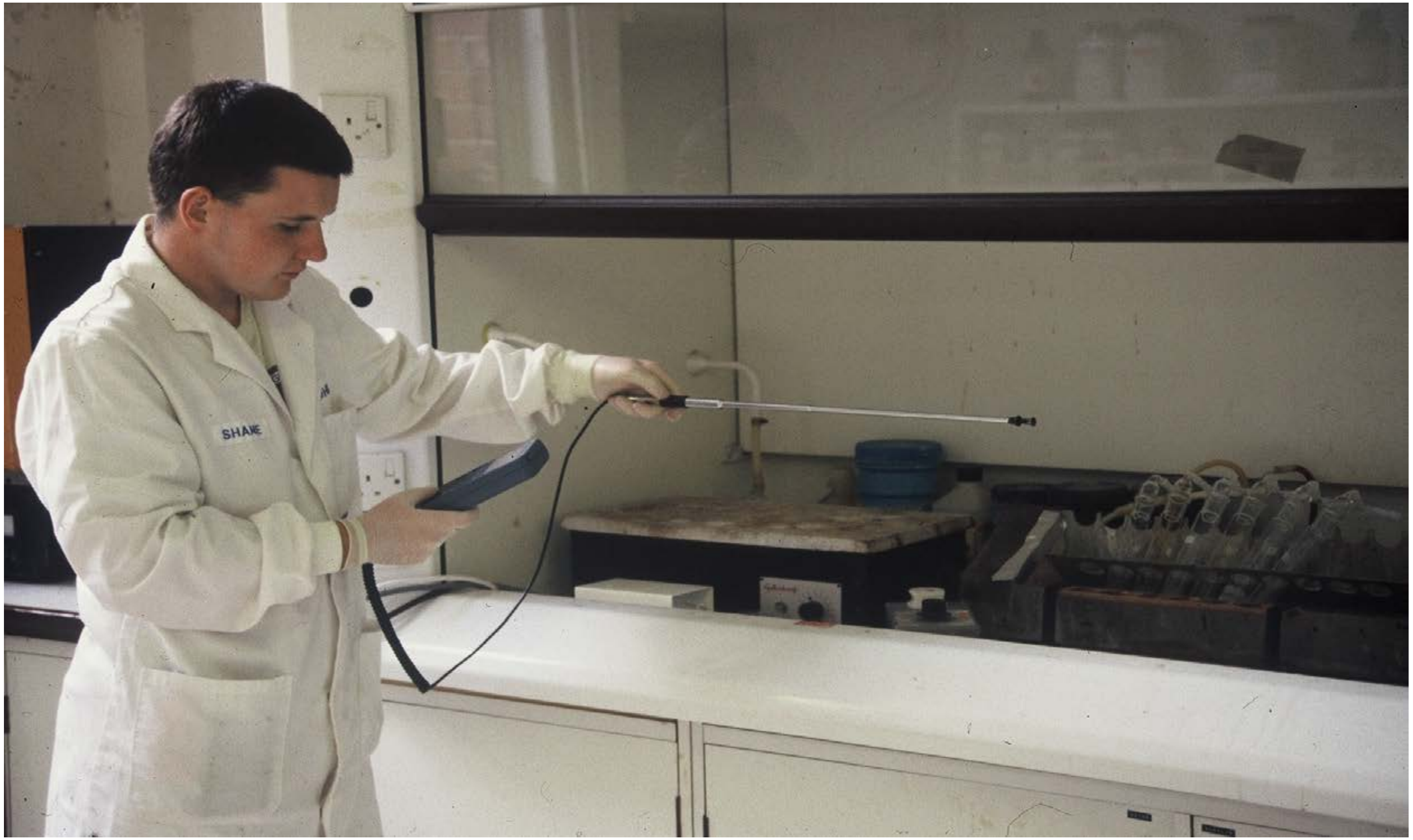
Partial Enclosures

- Hood face velocities
- Use anemometer

Air velocity measurements at the face of a booth - taken at the centre of each sector of the grid.



Measuring Face Velocity

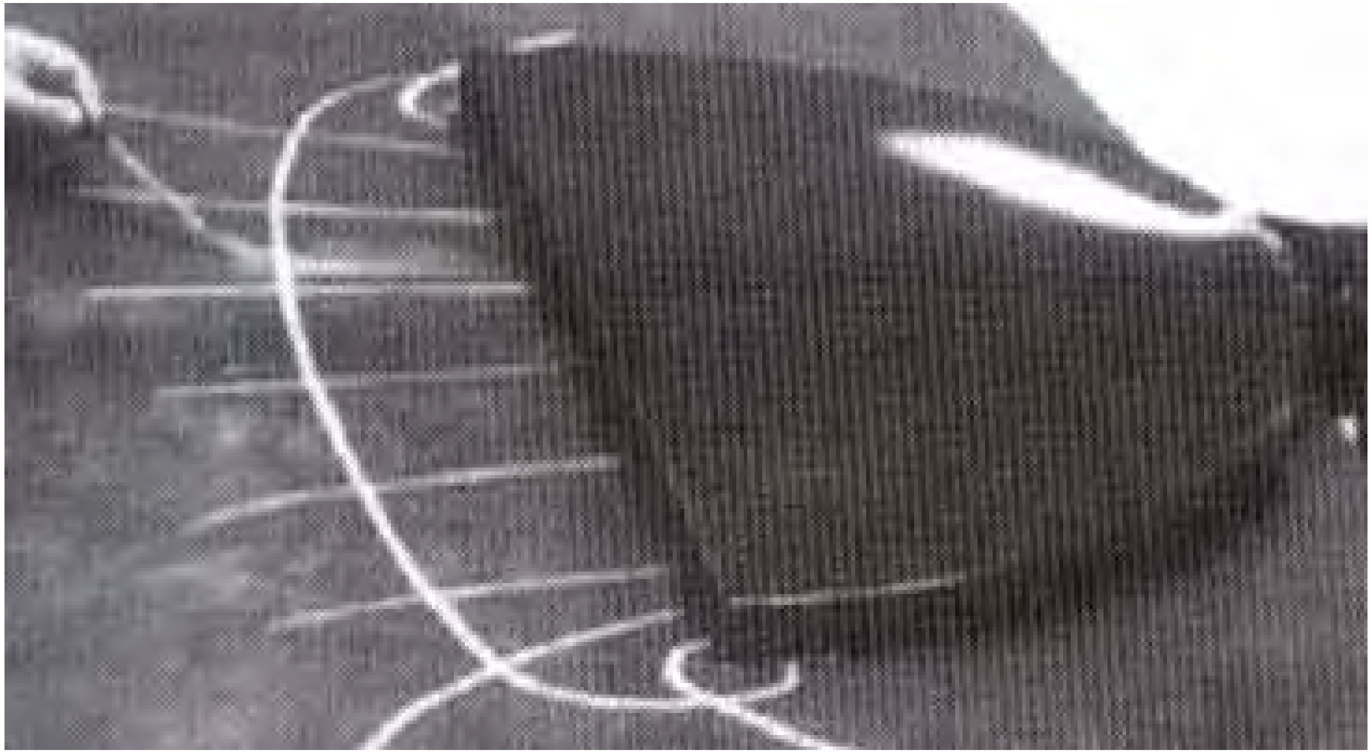


Source: NOHS

Captor Hoods

- Capture velocity
- Define capture zone
- Face velocity

Capture Zone of a Hood



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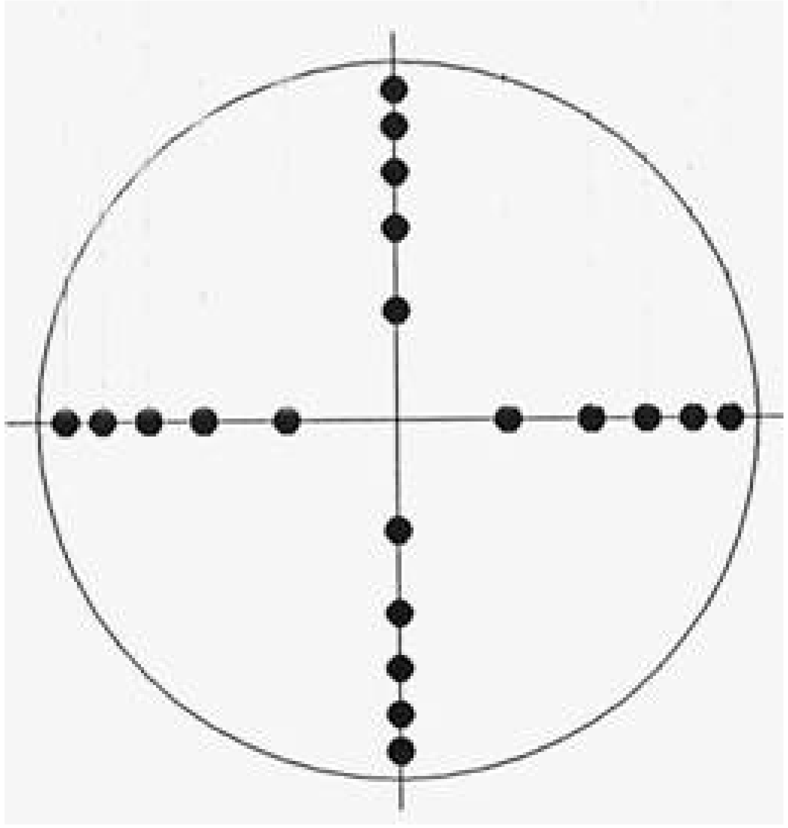
Measuring Duct Velocities

- Sampling position location
- Traverse across duct
  - in at least 2 sampling planes

Measuring Duct Velocities

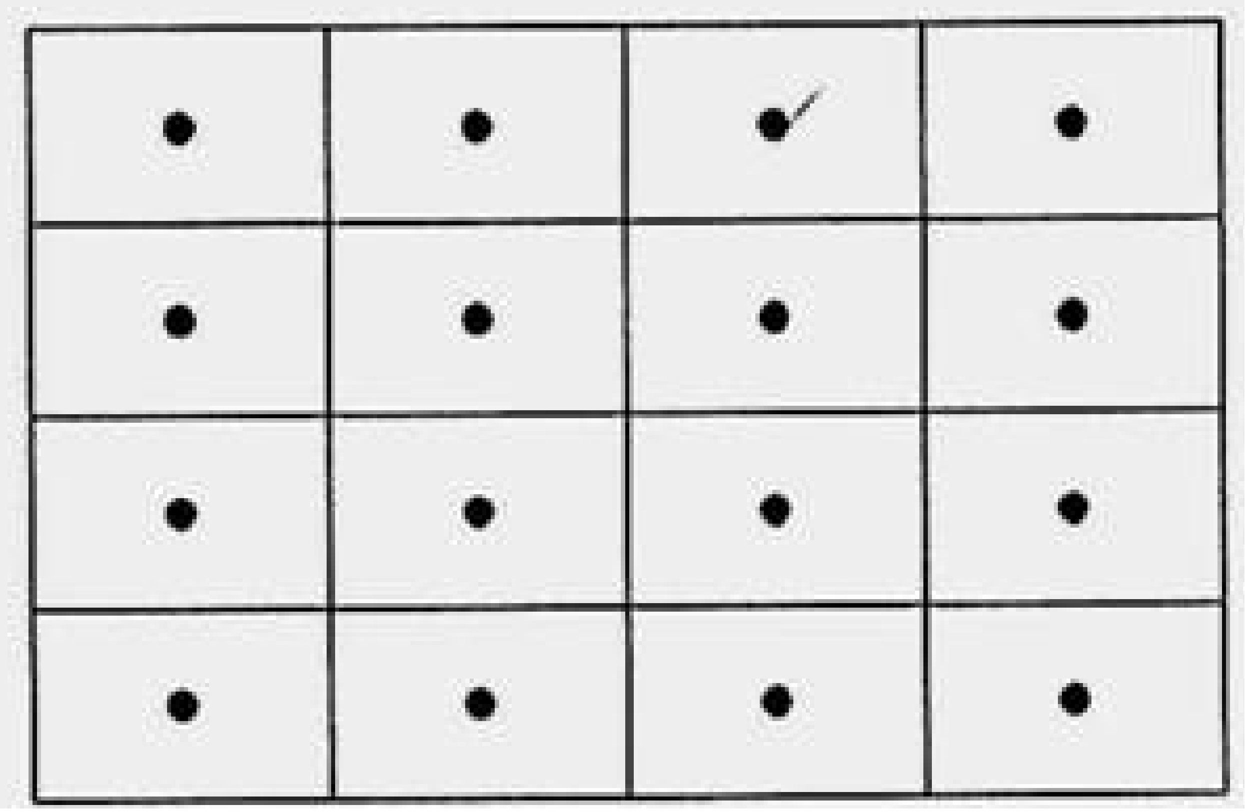
- Sampling position location
- From bends, fan, air cleaners etc
  - Minimum of 7.5 duct diameters downstream from any major flow disturbance

Typical 10 Point Traverse – Round Dust



Source: University of Wollongong

Duct Traverse - Square Duct

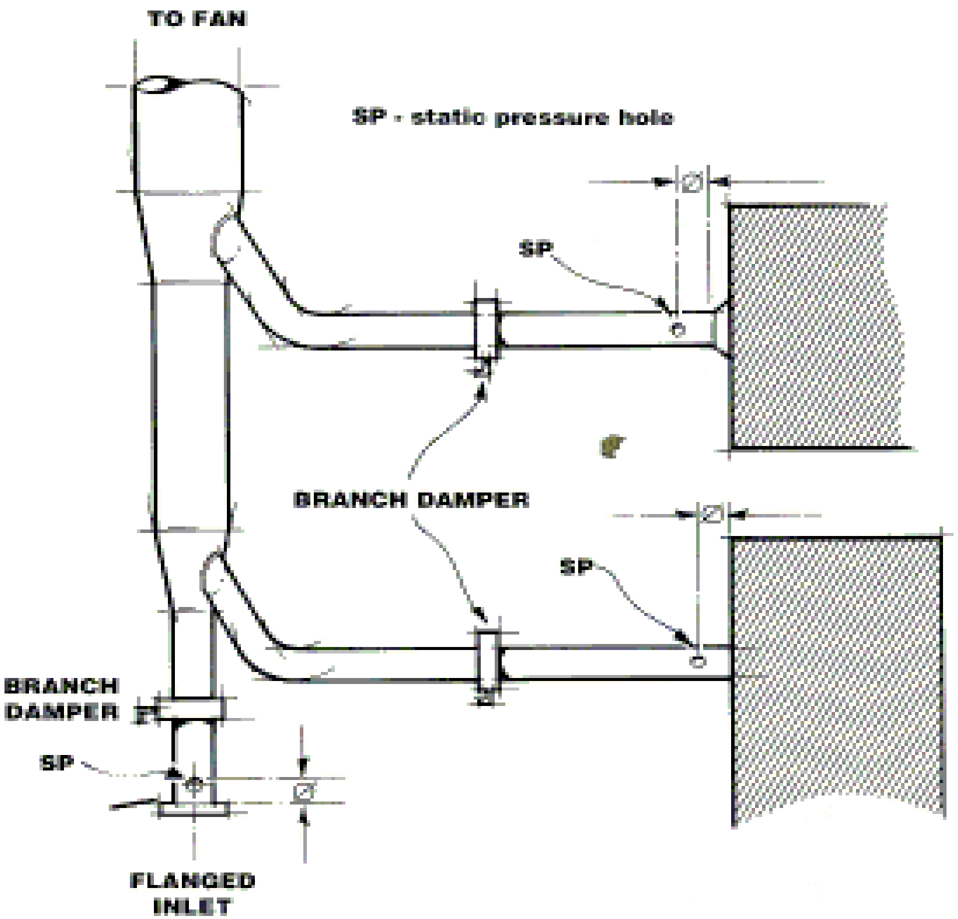


Source: University of Wollongong

Pressure Measurement

- Manometer
- Magnehelic gauge
- Velometer

Hood Static Pressure



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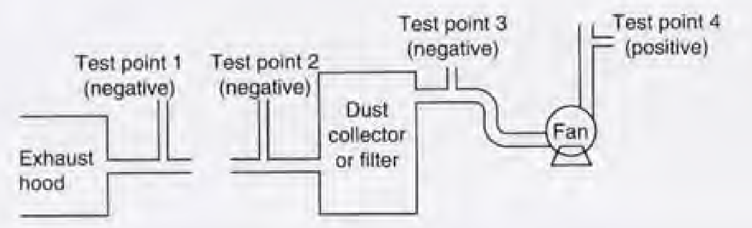
Use of Static Pressure for Fault-Finding in LEV Systems



Static pressure at test point compared with normal				Typical fault
1	2	3	4	
Normal	Normal	Normal	Normal	System operating normally
Low	High	High	Low	Blockage in duct or closed damper between points 1 and 2
Low	Low	High	Low	Blocked filter dust collector
High	High	Low	High	Missing or damaged filter Low water level in wet dust collector
Low	Low	Low	Low	Faulty fan; incorrect fan speed, slipping drive belts, deposits on or damaged blades, incorrect electrical wiring
High	High	High	Low	Build-up of dust and debris in, or blockage of, hood etc
Low	Low	Low	High	Blockage in exhaust stack

Source: HSE – *Reproduced with permission*

Safety Aspects

- Undertake risk assessment
- Coordinate with site management
- If it isn't safe don't do it !

General Ventilation Systems

Reasons for Use :

- Odours, tobacco smoke, perspiration etc.
- Low concentrations of contaminants
- Flammable gases
- Humidity
- Thermal environment

May be Appropriate When (AIOH)

- The air contaminant has low toxicity
- There are multiple sources
- The emission is continuous
- The concentrations are close to or lower than the occupational exposure limit

May be Appropriate When (cont)

- The volume of air needed is manageable
- The contaminants can be sufficiently diluted before inhalation
- Comfort or odour is an issue
- A spill has occurred and extended airing of the workplace is needed

Equilibrium Concentration

$$Q = \frac{r}{C}$$

Where

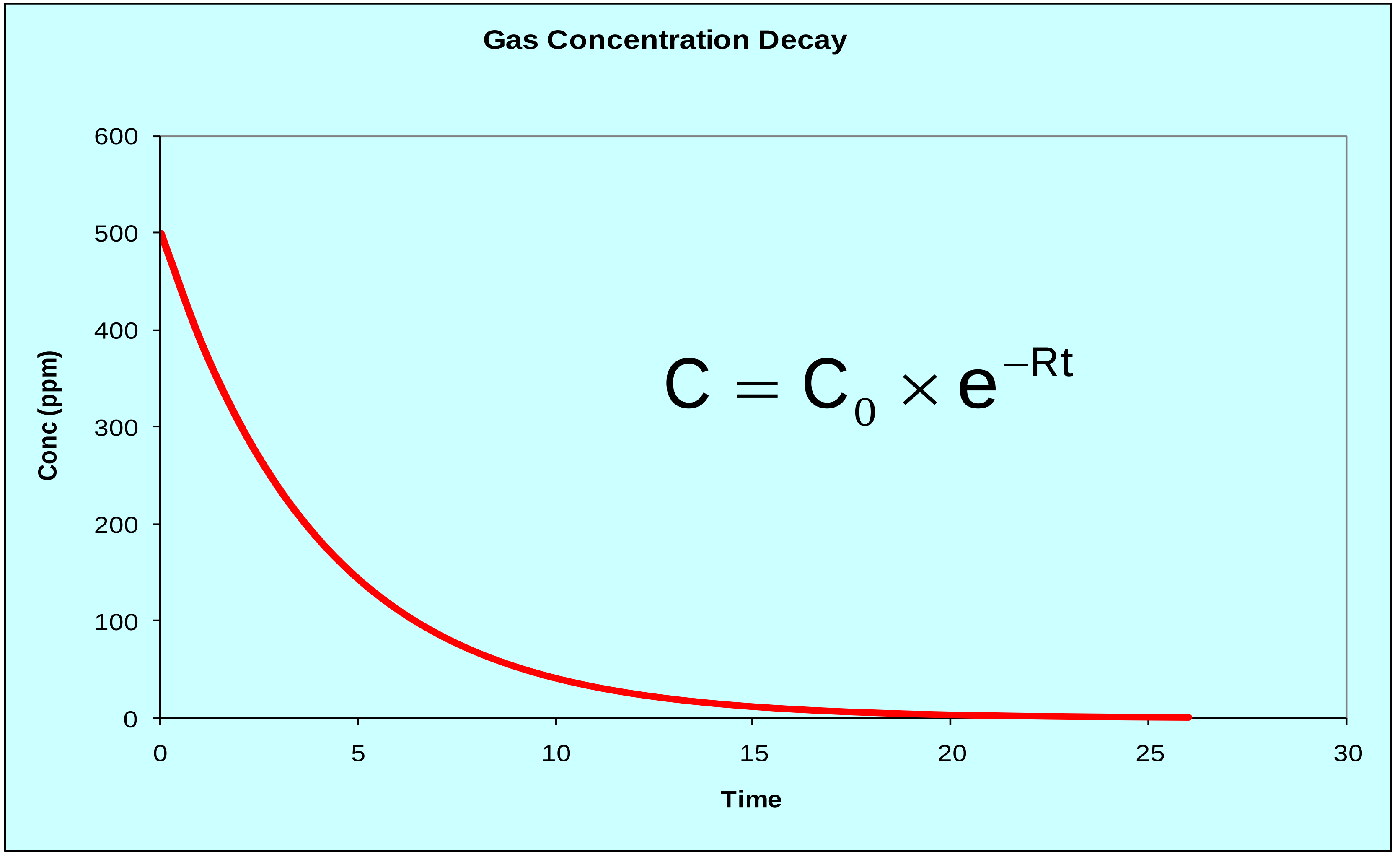
Q	=	Airflow rate in $m^{-3}s$
r	=	Emission rate in mgs^{-1}
C	=	Equilibrium concentration in mgm^{-3}

Decay in Contaminant Concentration with Time

$$C = C_o\ e^{-Rt}$$

Where

C_o	=	Initial contamination concentration (ppm)
Q	=	Airflow ($m^3\ s^{-1}$)
V	=	Volume of ventilated space (m^3)
t	=	Time (s)
R	=	Ventilation rate (Q/v)



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Example

Consider a room of 10 m^3 with an initial contaminant concentration of 1,000 ppm and a diluting airflow of 0.1 $m^3\ s^{-1}$

What would the concentration be after 10 minutes?

Example - Solution

$$C = 1000e^{-0.01x600}$$

$$= 2.5 \text{ ppm}$$

So, the concentration in the room after 10 minutes would be 2.5 ppm (complete mixing)

Incomplete Mixing

- **Example refers to perfect mixing**

- **Incomplete mixing would probably result in an underestimate of concentration**

Incomplete Mixing

- To over come this issue it is common to apply a “K” factor
- K factors range from 1.0 to 0.1

For a Particular Substance

$$Q = \frac{\text{Rate of Evaporation}}{\text{Density x ES}}$$

Q = amount of air to reduce vapour concentration to exposure standard (ES)

Need to apply a suitable K factor

General Ventilation

- **Infiltration (natural ventilation)**
- **Mechanical ventilation**

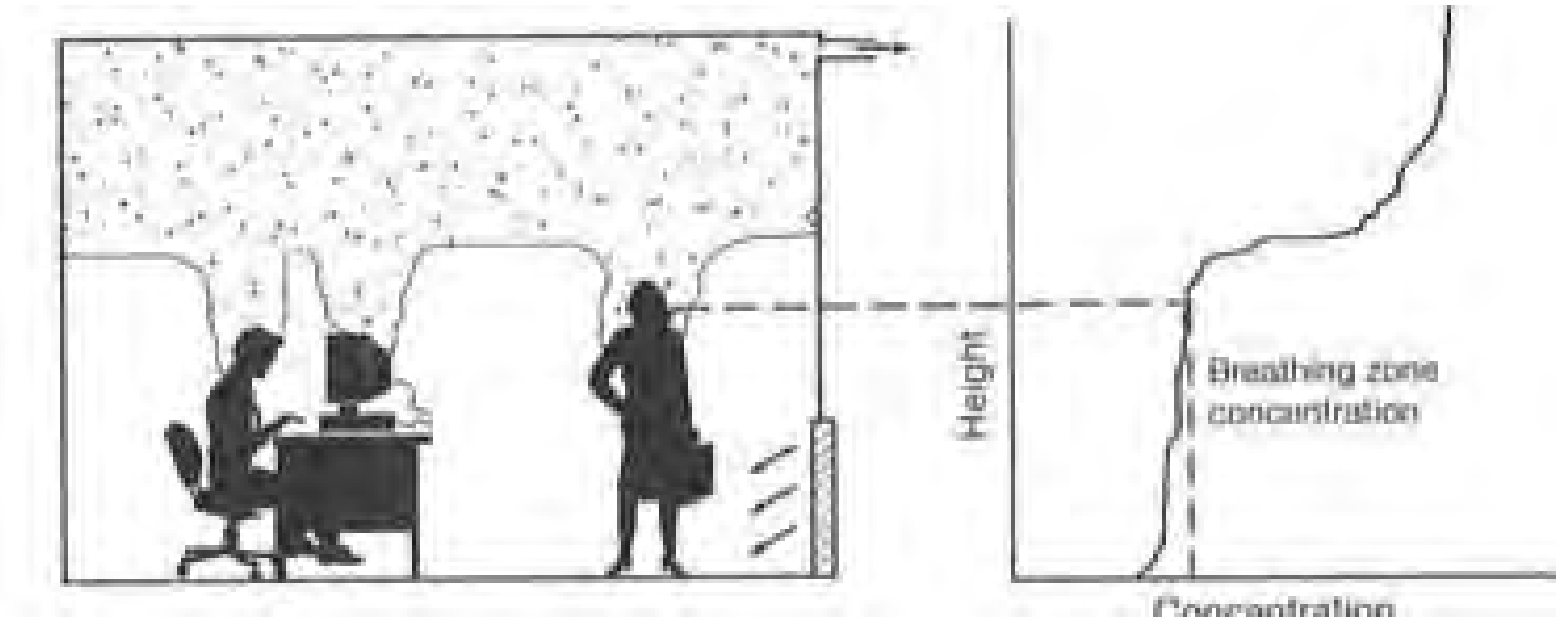
Displacement Ventilation

- **Thermal displacement ventilation**
- **Not used in many countries for the control of hazardous substances**

Displacement Ventilation (cont)

- New slightly cooler air is introduced to the workplace near floor level
- Contaminant-laden air (which is slightly warmer) rises and exits from the workplace near the roof

Thermal Displacement Ventilation



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Application of Thermal Displacement

Source: Photograph copyright of Colt International Licensing Limited

Works Best When:

The contaminants are warmer than the surrounding air

The supply air is slightly cooler than the surrounding air

The room is relatively tall (>3 m)

There is limited movement in the room.

Limitations of General Ventilation Systems

- No guarantee that all air has been changed at least once
- Hazardous substances may be moved towards the worker
- Process that have short high level releases require large amounts of air

Limitations of General Ventilation Systems (cont)

- Seasonal reductions in ventilation rate may result in unacceptable conditions
- Loss of efficiency may occur as system ages
- Entering air (supply) is assumed to be clean which is often not the case

Review of Today's Topics

- Review of overnight questions
- Ventilation systems
- Group exercises