Introduction to
Fume Hoods
Laminar Flow Cabinets
Biological Safety Cabinets
Section 1
Clean Air
**Clean Air**

Def: Number of solid & liquid particles are controlled

<table>
<thead>
<tr>
<th>ISO classification number (N)</th>
<th>Maximum concentration limits (particles/m³ of air) for particles equal to and larger than the considered sizes shown below (concentration limits are calculated in accordance with equation (1) in 3.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0,1 µm</td>
</tr>
<tr>
<td>ISO Class 1</td>
<td>10</td>
</tr>
<tr>
<td>ISO Class 2</td>
<td>100</td>
</tr>
<tr>
<td>ISO Class 3</td>
<td>1 000</td>
</tr>
<tr>
<td>ISO Class 4</td>
<td>10 000</td>
</tr>
<tr>
<td>ISO Class 5</td>
<td>100 000</td>
</tr>
<tr>
<td>ISO Class 6</td>
<td>1 000 000</td>
</tr>
<tr>
<td>ISO Class 7</td>
<td></td>
</tr>
<tr>
<td>ISO Class 8</td>
<td></td>
</tr>
<tr>
<td>ISO Class 9</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE** Uncertainties related to the measurement process require that concentration data with no more than three significant figures be used in determining the classification level
HEPA & ULPA Filter

HEPA: High Efficiency Particulate Air
ULPA: Ultra Low Penetration Air

Per IEST-RP-CC001.3 (USA):

HEPA: 99.99%
at 0.3 microns

ULPA: 99.999%
at between 0.1 to 0.2 microns
Most Penetrating Particle Size

MPPS: particle small enough to follow air stream around the fibres and avoid side interception, but not too small so the Brownian movement have minimal effect (avoid diffusion)
<table>
<thead>
<tr>
<th>Aspect</th>
<th>Separator</th>
<th>Separatorless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared area with separator</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Media area, capacity, life</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Media damage from separator</td>
<td>Likely</td>
<td>No</td>
</tr>
<tr>
<td>Frame exposed to moisture</td>
<td>Swelling</td>
<td>Resistant</td>
</tr>
</tbody>
</table>
HEPA / ULPA filter construction:
Media pack of pleated borosilicate glass fibers

- Pack is glued into a frame
- Frame is gasketed to form final assembly
Color Convention
For Cabinet Airflow Pattern
Room Air
Biohazard – Contaminated Air
Chemically – Contaminated Air
HEPA – Filtered Clean Air
Double HEPA – Filtered Clean Air
HEPA Filter: From Room to Clean Air
HEPA Filter: From Biohazard to Clean Air
HEPA Filter: From 1st HEPA to 2nd HEPA
Carbon Filter: From Chem. Vapor to Clean Air
Section 2
Laminar Flow Cabinets
Principle of laminar flow cabinet:
Sterilize air through filter and blow it across work surface as a particle-free laminar air stream

Typical laminar air flow velocity:
0.3 - 0.5m/s

Purpose of a laminar flow cabinet:
Product protection from room contaminants (does not protect operator)
Laminar Flow Cabinet

- Product protection (no personnel protection)
- Not for biohazard agents or chemical fumes
• Advantage of Vertical Laminar Flow Cabinet:
  - No blocking caused by large object
  - Not blowing air straight to operator’s face 8hrs/day
• Advantage of Horizontal Laminar Flow Cabinet:
  - Easier to put sensitive object near HEPA filter
  - Not blowing dust on straight to sensitive object
Section 3
Fume Hoods
Principle of fume hood:
Discharge chemical vapor outside the building or absorb it with carbon filter

Typical inflow face velocity (per ASHRAE-110):
0.40 - 0.60 m/s

Purpose of a laminar flow cabinet:
Handle chemical vapor, including strong acid & base
• Ducted Fume Hood:
  - Removes toxic chemical (with ducting)
  - Has no HEPA filter
    ➔ not suitable for biohazard
• **Ductless Fume Hood:**
  - Removes toxic chemical (with charcoal / carbon filter)
  - Has no HEPA filter
  ➥ not suitable for biohazard
Section 4
Biological Safety Cabinets
Biological Safety Cabinets

Principle of BSC:
Create inflow to protect the operator by exhausting air from cabinet through HEPA filter

Typical inflow velocity for most BSC:
Based on EN12469 (EU): > 0.40 m/s
Based on NSF/ANSI 49 (USA): > 0.50 m/s

Purpose of BSC:
Operator protection from microorganisms. Most BSC also offer product protection from room contaminants
# Types of BSC

<table>
<thead>
<tr>
<th>Class</th>
<th>Min Inflow Velocity (fpm)</th>
<th>Recirc. Air</th>
<th>Exhaust Air</th>
<th>Contaminated Plenum Surrounded by</th>
<th>Exhaust Alternatives</th>
<th>Biosafety Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>75</td>
<td>0%</td>
<td>100%</td>
<td>Outside air (Lab room)</td>
<td>Inside room / Hard Duct</td>
<td>1,2,3</td>
</tr>
<tr>
<td>II A1</td>
<td>75</td>
<td>70%</td>
<td>30%</td>
<td>Outside air (Lab room)</td>
<td>Inside room / Thimble Duct</td>
<td>1,2,3</td>
</tr>
<tr>
<td>II A2</td>
<td>100</td>
<td>70%</td>
<td>30%</td>
<td>Negative pressure</td>
<td>Inside room / Thimble Duct</td>
<td>1,2,3</td>
</tr>
<tr>
<td>II B1</td>
<td>100</td>
<td>30%</td>
<td>70%</td>
<td>Negative pressure</td>
<td>Hard duct only</td>
<td>1,2,3</td>
</tr>
<tr>
<td>II B2</td>
<td>100</td>
<td>0%</td>
<td>100%</td>
<td>Negative pressure</td>
<td>Hard duct only</td>
<td>1,2,3</td>
</tr>
<tr>
<td>III</td>
<td>Closed P&gt;0.5”WG</td>
<td>0%</td>
<td>100%</td>
<td>Negative pressure</td>
<td>Inside room / Hard Duct</td>
<td>1,2,3,4</td>
</tr>
<tr>
<td>Lethality</td>
<td>Medium</td>
<td>Cure</td>
<td>Example</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>-------</td>
<td>-------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe</td>
<td>Liquid</td>
<td>Yes</td>
<td>B. Subtilis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some</td>
<td>Liquid</td>
<td>Some</td>
<td>HIV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serious</td>
<td>Airborne</td>
<td>Some</td>
<td>TBC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme</td>
<td>Airborne</td>
<td>None</td>
<td>Ebola</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Class I BSC

- Only operator protection (no product protection).
- Biosafety level 1, 2, 3
- Inflow away from operator.
- HEPA filtered exhaust to environment.
- Current trend: Switch to Class II
• Both operator and product protection
• Biosafety level 1, 2, 3
• Inflow away from operator
• HEPA filtered exhaust to environment
• HEPA filtered laminar downflow
• If you use Volatile (Vaporizing) Toxic Chemical in cell culture ➩ you need ducting
Class II Type A1 vs A2: Negative Pressure Isolated Plenum

**Danger:**
If Plenum or Gasket leaks, contaminants will escape to room / lab

**Safe:**
If Plenum or Gasket leaks, contaminants pulled by blower

Danger: If Plenum or Gasket leaks, contaminants will escape to room / lab

Safe: If Plenum or Gasket leaks, contaminants pulled by blower

Positive Pressure Contaminated Plenum

Positive Pressure Contaminated Plenum

Negative Pressure Space from Blower Suction
Class II Type A2 with Thimble Ducting
Class II B1 BSC: Airflow
Class II B2 BSC Airflow
If the hazardous chemicals in use will volatilize (vaporize) while:
- Being handled
- After they are captured by HEPA filter

Do not use a ventilated cabinet that re-circulates air:
- Inside the cabinet
- Exhaust air back to the room / lab

Therefore for vaporizing chemical:
- Use Class II B2
- Don’t use Class II A2 even with thimble ducting
Class II Type B2 Precautions

- Ensure that the chemicals used will not damage HEPA / ULPA filters
- Exhausting 1420 cmh (830 cfm) for 4ft unit: expensive to operate
- Need interlock system: if building exhaust fails, cabinet internal blower must be turned off
- Exhaust fan must be able the cabinet:
  - airflow volume
  - static pressure
  - plus extra pressure drop from ducting system
- Fluctuations in building exhaust cfm can be ±10%
Ducting Exhaust Fluctuations

- Thimble duct on A2: have holes for room air
  ➥ Building exhaust fluctuations will not affect cabinet airflow

- Hard ducting on B2: no holes for room air
difficulty from exhaust fan fluctuations
  ➥ Building exhaust must precisely match the cabinet airflow requirements
Vapor Handling Comparison

Vapor Handling Comparison

Toluene concentration (mg/m³) vs. Location of Toluene Vapor Generator from front of work surface (cm)

- Class II A2
- Class II B1
- Class II B2
We must do risk assessment first before jumping down and choosing a cabinet.
Class II A2 vs B2: Pro and Con

**Class II A2**
- **Pro:** Easy to install & operate
- **Con:** Recirculation of chemical vapor

**Class II B2**
- **Con:** Hard to install & operate
- **Pro:** No recirculation of chemical vapor
Class III BSC

- Biosafety level 1, 2, 3, 4
- Product and operator protection
- Gas leak tight $1 \times 10^{-5}$ cc/sec leak rate
- Internal operations with attached glove
- Material transfer: through 2 doors pass box
- Negative air pressure $> 0.5 \text{ "WG}$
- Supply is HEPA filtered
- Double exhaust HEPA filter in series or: Single exhaust HEPA and an incinerator
Class III BSC
Cytotoxic drug (ex: cancer drug) is very hazardous for the technician who change the filter, and it can not be neutralized by formalin or hydrogen peroxide.

The first exhaust filter, located under the work tray, can be sealed and removed when the cabinet is still running, so the negative pressure protects the technician. This filter prevents particle spread inside cabinet, unlike if Class II type B2 is used.
Clean Bench, Fume Hood & BSC
Section 5
Cabinet Installation and Field Testing
Cabinet Delivery – Common Problems

• Will it fit?
  – Hallways & door
  – Elevators
  – Room to turn the unit

• Do you have or need
  – Loading docks
  – Inside delivery
  – Lift mechanism

• Utility connections
  – Gas, vacuum
  – Exhaust ducting
Check the manufacturer’s requirement for minimum height clearance to prevent backpressure on exhaust filter or exhaust flow sensor discrepancy. Other considerations include adequate clearance for on-site certification i.e. exhaust filter testing.
To prevent airflow disturbance, install the cabinet away from:
- room air conditioning diffusers
- supply / make up air outlet
- room exhaust grille
- areas of high human traffic

Be aware of multiple cabinets positioning
BS 5726: Distance to Wall

Ideal

Min recommended by NSF/ANSI 49
BS 5726: Distance to Door

- 5 ft (2 m)
- 3 ft (1 m)
BS 5726: Side Table Top

Left: BSC and BT are not allowed together.

Right: BSC and BT are allowed with a 3 ft and 1 m distance.
No.1 The location of cabinet 1 is appropriate with respect to the avoidance of excessive air movements from the surrounding.

No.2 Cabinet 2 is too close to the doorway and could be influenced by the air inlet.

No.3 The airflow of cabinet 3 could be influenced by the air inlet.

No.4 Cabinet 4 is too close to the doorway.

No.5 Cabinet 5 is well-sited providing that the adjacent return air grille does not influence cabinet airflow.
The most widely used standards in the world for Biological Safety Cabinet:

- American Standard ANSI/NSF 49
- European Standard EN 12469
- Downflow velocity
- Inflow velocity
- Airflow smoke patterns
- HEPA/ULPA filter leak
- Site installation assessment tests
- Cabinet leak test (only for A1 cabinets)

Consideration in installing the cabinet must be taken so these tests can be performed
Inflow Velocity Testing
Downflow Velocity Testing
Filter Integrity Testing
- Airflow Alarm
- Sash alarm
- Blower interlock (B2 only)
- Airflow smoke pattern on exhaust duct connection
Section 6
Class II Type B2 Installation
Connecting Multiple Cabinets to Exhaust Fan

Class II B2 BSC
V=1510cmh (888cfm)
P=590Pa (2.4"WG)

Class II B2 BSC
V=1510cmh (888cfm)
P=590Pa (2.4"WG)

Class II B2 BSC
V=1510cmh (888cfm)
P=590Pa (2.4"WG)

Class II A2 BSC
V=715cmh (420cfm)
P=25Pa (0.1"WG)

Fume Hood
V=970cmh (570cfm)
P=50Pa (0.2"WG)

All are Class II B2 BSC: Possible to Balance, but requires some iteration

Impossible to Balance, due to big difference on pressure & airflow
Difficulty in Balancing Exhaust for Multi Cabinets

- Need to do iteration to balance the airflow
- Trouble when exhaust filter get loaded at different rate
Disrupted Airflow Balance if 1 Cabinet is OFF

<table>
<thead>
<tr>
<th>Exhaust</th>
<th>Cabinet #1</th>
<th>Cabinet #2</th>
<th>Cabinet #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ON</td>
<td>1510cmh (888cfm)</td>
<td>1510cmh (888cfm)</td>
<td>1510cmh (888cfm)</td>
</tr>
<tr>
<td>2 x ON</td>
<td>2265cmh (1332cfm)</td>
<td>2265cmh (1332cfm)</td>
<td>0</td>
</tr>
</tbody>
</table>
Must “Super-Size” the External Fan:

1. Volume: Pitot tube reading is 4-12% higher than Inflow + Downflow

2. Pressure: depends on duct length, diameter, bends/valve/etc, must add 15-50% extra pressure capacity

<table>
<thead>
<tr>
<th>ft</th>
<th>Inflow + Downflow</th>
<th>Pitot Traverse (cmh)</th>
<th>Pitot Traverse (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1420 cmh</td>
<td>840 cfm</td>
<td>1480 – 1600 cmh</td>
</tr>
<tr>
<td>6</td>
<td>2100 cmh</td>
<td>1200 cfm</td>
<td>2200 – 2350 cmh</td>
</tr>
</tbody>
</table>
Bad and Good Building Exhaust & Supply Sys.

Wind

Need > 15 m/s (3000 fpm) discharge vel.

Tall

Airflow disruption

Make-up air supply

BAD

Back

Near

Short

Good

Less airflow disruption
## Volumetric Flow and Exhaust Requirement

<table>
<thead>
<tr>
<th>Cabinet model</th>
<th>Volumetric airflow (Supply + DIM Inflow)</th>
<th>Volumetric airflow (Pitot Duct Traverse). Range depends on accuracy and measurement condition in doing duct traverse</th>
<th>Pressure with clean exhaust filter</th>
<th>Required Concurrent Balance Value for Pressure per NSF 49:2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cmh</td>
<td>cfm</td>
<td>cmh</td>
<td>to</td>
</tr>
<tr>
<td>LB2-3BX</td>
<td>1081</td>
<td>636</td>
<td>1124</td>
<td>to</td>
</tr>
<tr>
<td>LB2-4BX</td>
<td>1420</td>
<td>836</td>
<td>1477</td>
<td>to</td>
</tr>
<tr>
<td>LB2-5BX</td>
<td>1755</td>
<td>1033</td>
<td>1826</td>
<td>to</td>
</tr>
<tr>
<td>LB2-6BX</td>
<td>2093</td>
<td>1232</td>
<td>2177</td>
<td>to</td>
</tr>
<tr>
<td>AB2-3BX</td>
<td>885</td>
<td>521</td>
<td>920</td>
<td>to</td>
</tr>
<tr>
<td>AB2-4BX</td>
<td>1166</td>
<td>686</td>
<td>1213</td>
<td>to</td>
</tr>
<tr>
<td>AB2-5BX</td>
<td>1447</td>
<td>852</td>
<td>1505</td>
<td>to</td>
</tr>
<tr>
<td>AB2-6BX</td>
<td>1728</td>
<td>1017</td>
<td>1797</td>
<td>to</td>
</tr>
</tbody>
</table>

Always use the values of:
1. Volumetric airflow from Pitot Duct Traverse (the center point is a reasonable estimate)
2. Pressure requirement from Concurrent Balance Value per NSF/ANSI 49:2008
1. Check manufacturer’s required pressure and exhaust flow
2. Need to throttle suction at connection with air-tight damper
3. Need air-tight damper for decontamination. When damper is closed, make up air need to be shut off, or room in +P
4. Cabinet draws air out. Need HVAC-processed make up air
5. If no make up air: avoid multiple cabinet in small room
6. External fan connected to emergency power
7. Suction capacity verified by HVAC engineer
8. Cabinet performance verified by certifier
9. Drill 2 holes, 90° apart at 10 d from bend for pitot duct traverse and PAO/DOP testing. Plug hole in normal use.
**Case Study: Ducting System (Metric)**

- **Volumetric airflow:** 1590 \(\approx\) 1600 cmh (worst case per pitot duct)
- **Cabinet pressure drop:** 590 Pa (including buffer per NSF CBV)
- **Friction loss:** 20 m \(\times\) 3.7 Pa/m = 74 Pa
- **Bend loss:** 2 \(\times\) 37 Pa = 74 Pa
- **Damper loss:** 50 Pa
- **Height loss:** 10 m \(\times\) 10 Pa/m = 100 Pa
- **Total loss:** 74 + 74 + 50 + 100 = 298 \(\approx\) 300 Pa
- **Total pressure required:** 590 + 300 = 890 Pa
Case Study: Ducting System (Imperial)

Volumetric airflow: \(936 \approx 940\) cfm (worst case per pitot duct)

Cabinet pressure drop: \(2.4''\)WG (including buffer per NSF CBV)

Friction loss: \(64\) ft \(\times 0.005''\)WG/ft = \(0.3''\)WG → for Ø10” round duct

Bend loss: \(2 \times 0.15''\)WG = \(0.3''\)WG

Damper loss: \(0.2''\)WG

Height loss: \(32\) ft \(\times 0.013''\)WG/ft = \(0.4''\)WG

Total loss: \(0.3 + 0.3 + 0.2 + 0.4 = 1.2''\)WG

Total pressure required: \(2.4 + 1.2 = 3.6''\)WG
Thank You for Your Time

Questions?