Introduction to
Fume Hoods
Laminar Flow Cabinets
Biological Safety Cabinets

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Section 1
Clean Air

Clean Air

Def: Number of solid & liquid particles are controlled

ISO classification number (*N*)	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)					
	0,1 µm	0,2 µm	0,3 µm	0,5 µm	1 µm	5 µm
ISO Class 1	10	2				
ISO Class 2	100	24	10	4		
ISO Class 3	1 000	237	102	35	8	
ISO Class 4	10 000	2 370	1 020	352	83	
ISO Class 5	100 000	23 700	10 200	3 520	832	29
ISO Class 6	1 000 000	237 000	102 000	35 200	8 320	293
ISO Class 7				352 000	83 200	2 930
ISO Class 8				3 520 000	832 000	29 300
ISO Class 9				35 200 000	8 320 000	293 000

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

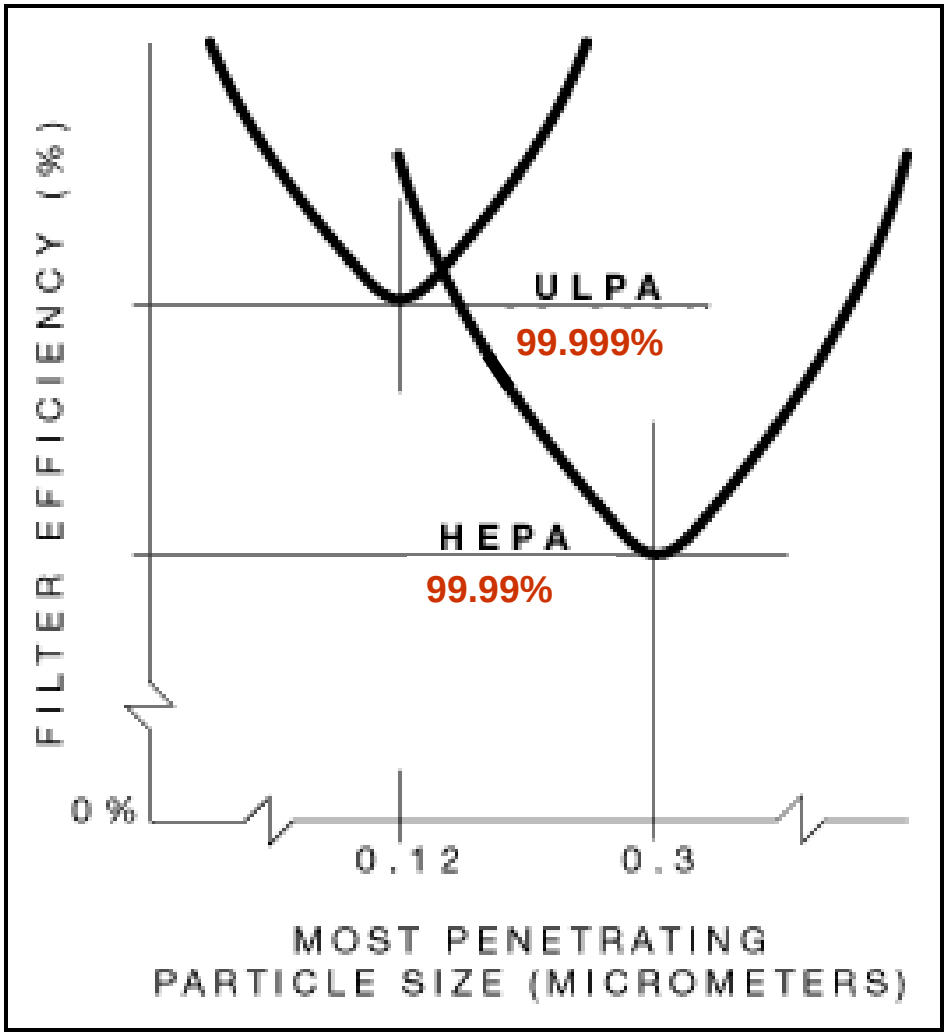
HEPA & ULPA Filter

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

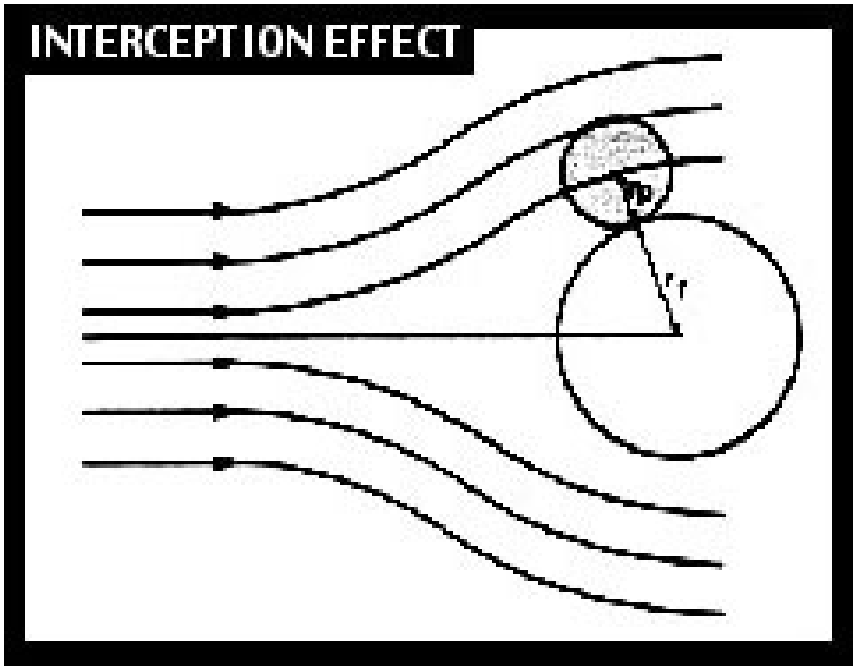
Per IEST-RP-CC001.3 (USA) :

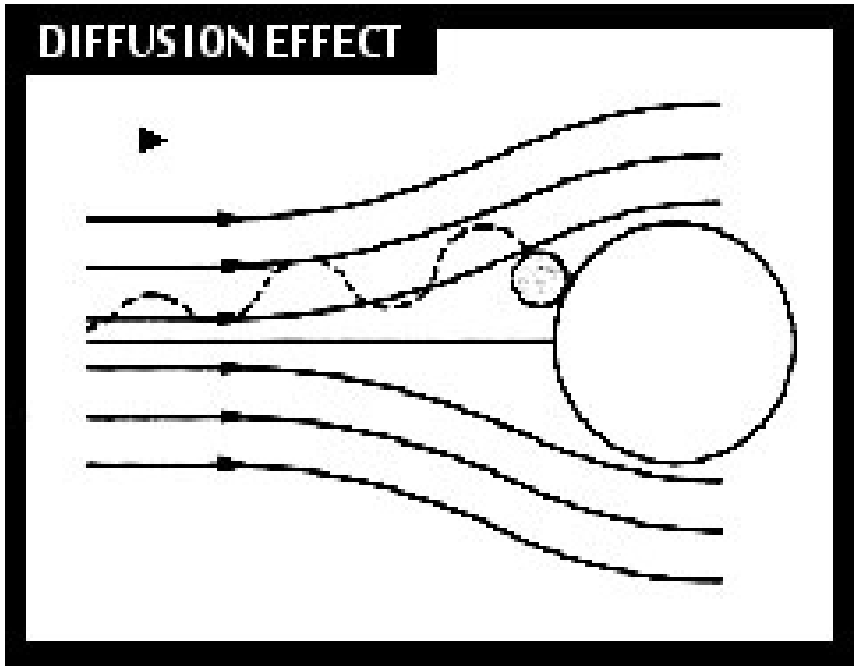
HEPA: 99.99% at 0.3 microns

ULPA: 99.999% at between 0.1 to 0.2 microns



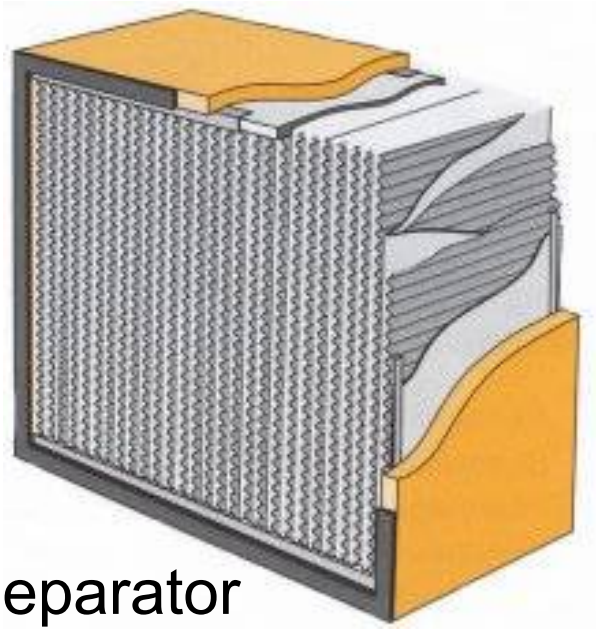
Most Penetrating Particle Size





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)

Separator vs. Separatorless Filter



Separator

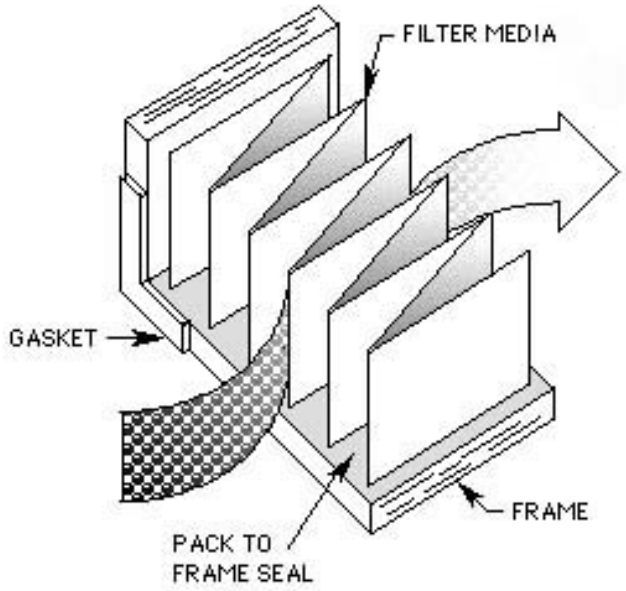
Separatorless

Aspect	Separator	Separatorless
Shared area with separator	Yes	No
Media area, capacity, life	Less	More
Media damage from separator	Likely	No
Frame exposed to moisture	Swelling	Resistant

Filter Construction

HEPA / ULPA filter construction:
Media pack of pleated borosilicate glass fibers

- Pack is glued into a frame
- Frame is gasketed to form final assembly



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Color Convention

For Cabinet Airflow Pattern

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Color Convention


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

Laminar Flow Cabinet

Principle of laminar flow cabinet:

Sterilize air though filter and blow it across work surface as a particle-free laminar air stream

Typical laminar air flow velocity:

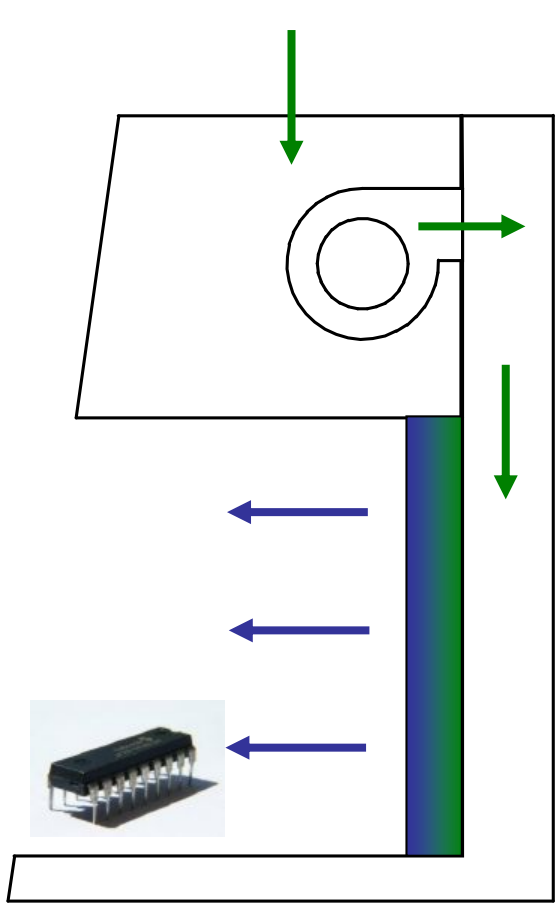
0.3 - 0.5m/s

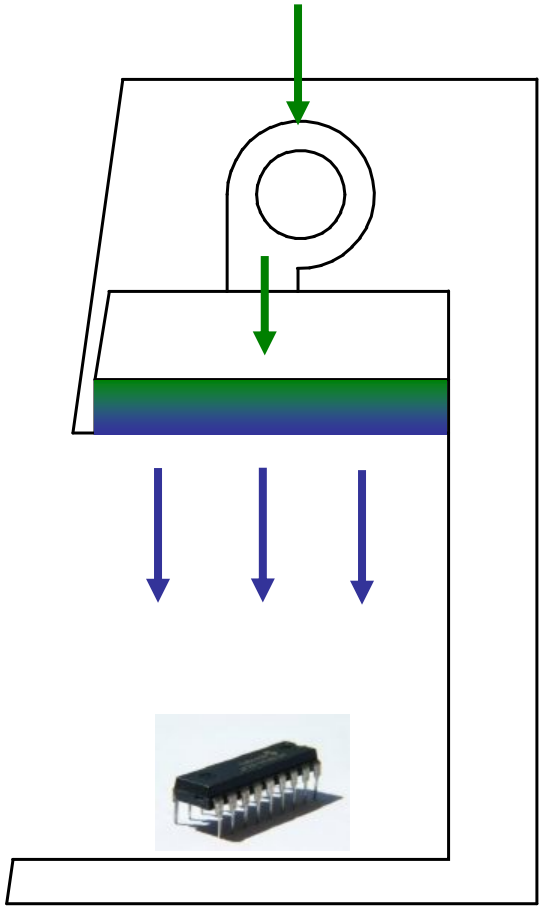
Purpose of a laminar flow cabinet:

Product protection from room contaminants (does not protect operator)

Laminar Flow Cabinet

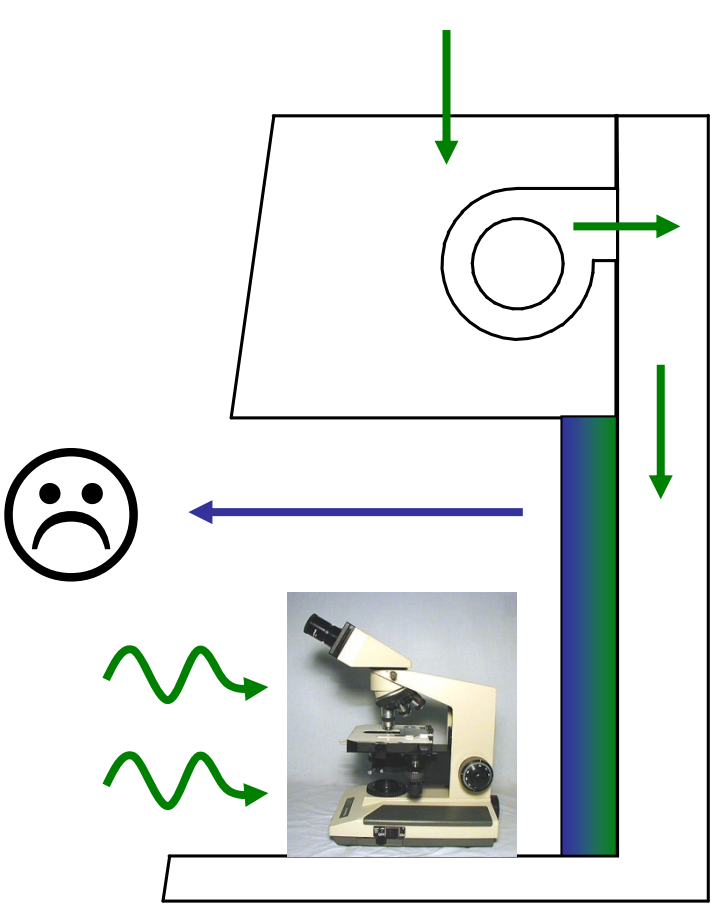
- Laminar Flow Cabinet (Clean Bench):
  - Product protection (no personnel protection)
  - Not for biohazard agents or chemical fumes

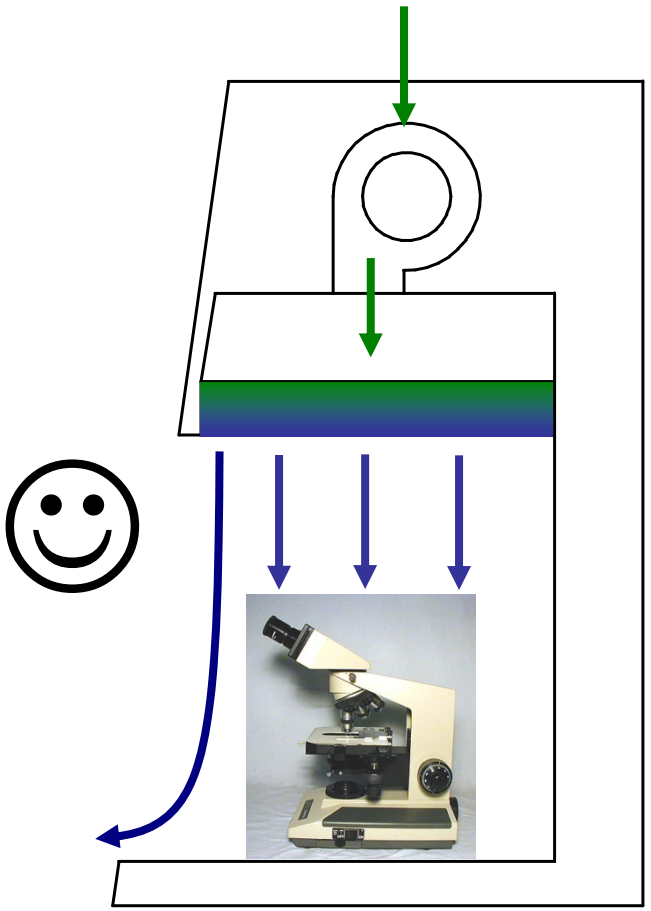




Horizontal vs. Vertical

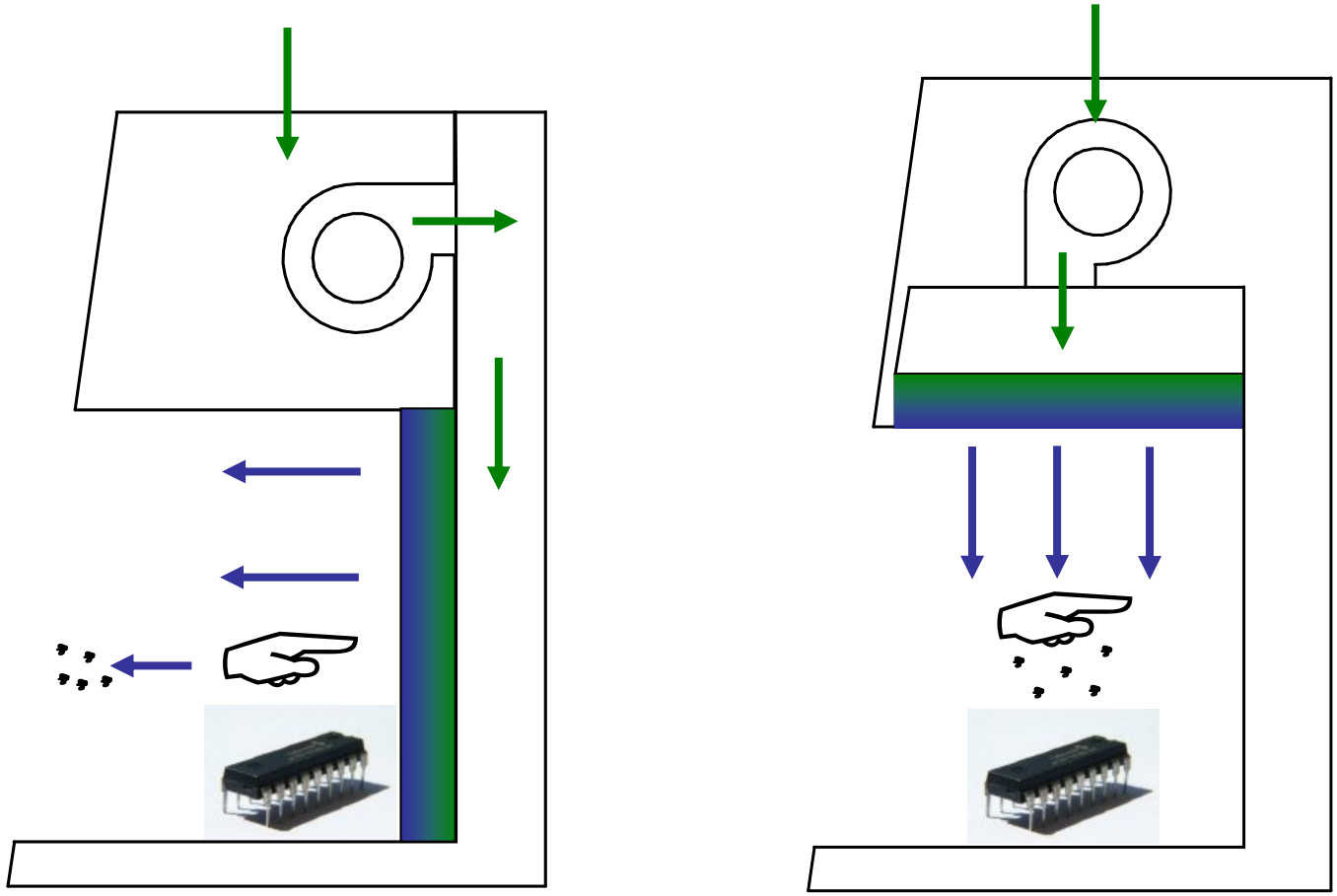
- Advantage of Vertical Laminar Flow Cabinet:
  - No blocking caused by large object
  - Not blowing air straight to operator's face 8hrs/day





Horizontal vs. Vertical

- 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

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Fume Hood

Principle of fume hood:

Discharge chemical vapor outside the building or absorb it with carbon filter

Typical inflow face velocity (per ASHRAE-110):

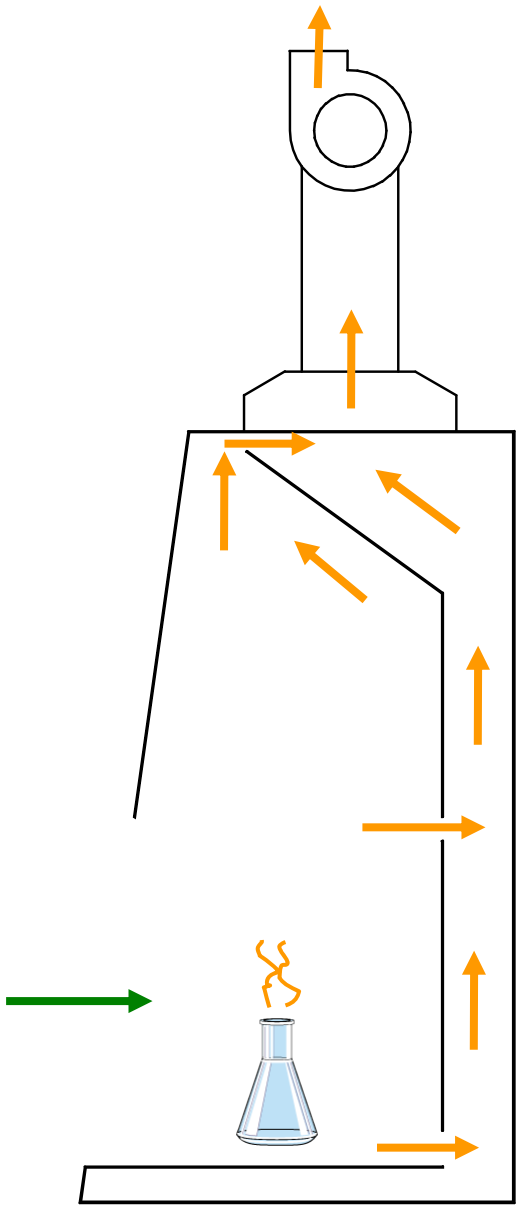
0.40 - 0.60 m/s

Purpose of a laminar flow cabinet:

Handle chemical vapor, including strong acid & base

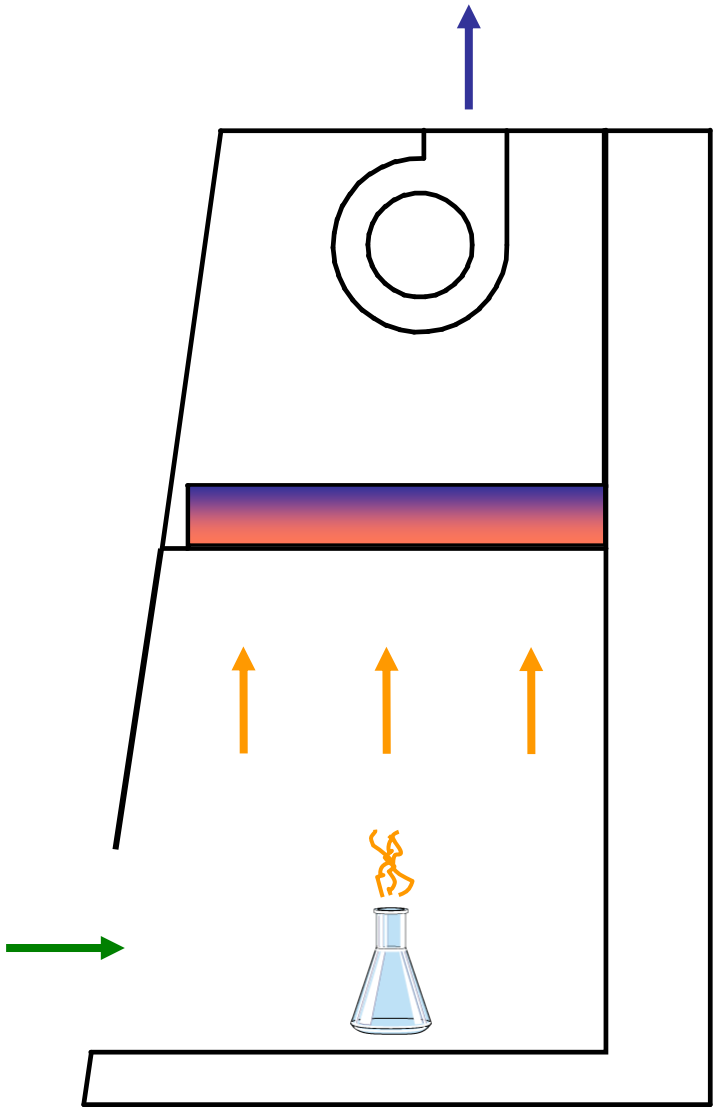
Fume Hood (Ducted)

- Ducted Fume Hood:
  - Removes toxic chemical (with ducting)
  - Has no HEPA filter
    - ➪ not suitable for biohazard



Fume Hood (Ductless)

- Ductless Fume Hood:
  - Removes toxic chemical (with charcoal / carbon filter)
  - Has no HEPA filter
    ➪ not suitable for biohazard



Section 4
Biological Safety Cabinets

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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

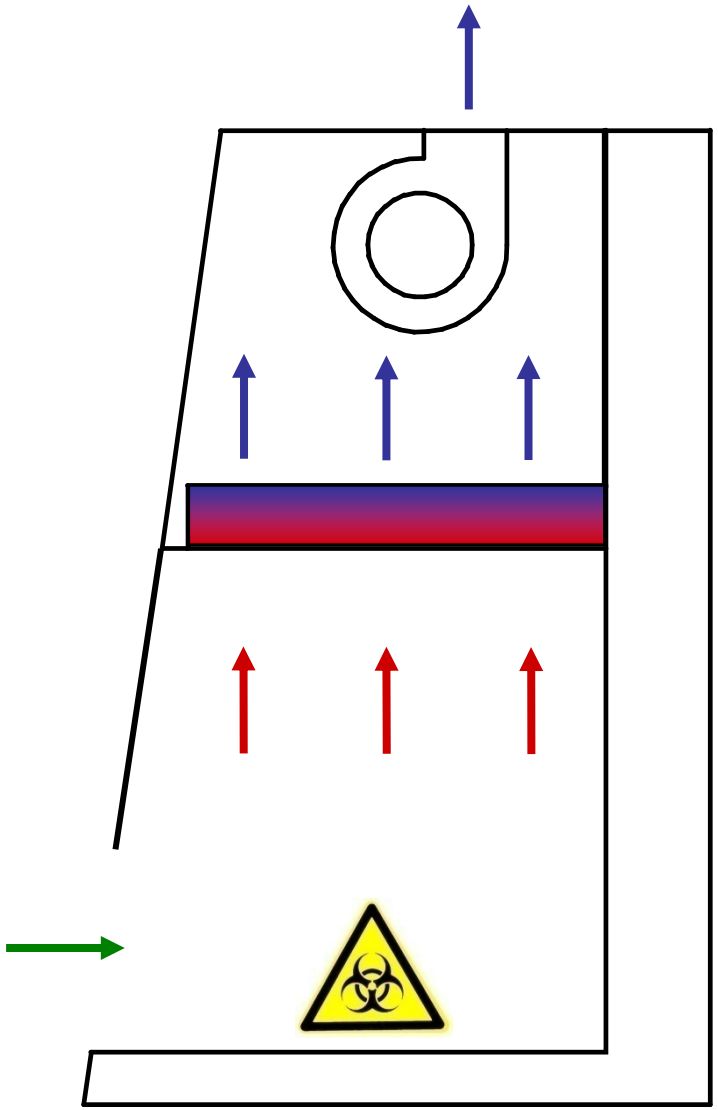
Class	Min Inflow Velocity (fpm)	Recirc. Air	Exhaust Air	Contaminated Plenum Surrounded by	Exhaust Alternatives	Biosafety Level
I	75	0%	100%	Outside air (Lab room)	Inside room / Hard Duct	1,2,3
II A1	75	70%	30%	Outside air (Lab room)	Inside room / Thimble Duct	1,2,3
II A2	100	70%	30%	Negative pressure	Inside room / Thimble Duct	1,2,3
II B1	100	30%	70%	Negative pressure	Hard duct only	1,2,3
II B2	100	0%	100%	Negative pressure	Hard duct only	1,2,3
III	Closed P>0.5"WG	0%	100%	Negative pressure	Inside room / Hard Duct	1,2,3,4

Bio Safety Level (BSL)

	Lethality	Medium	Cure	Example
1	Safe	Liquid	Yes	B.Subtilis
2	Some	Liquid	Some	HIV
3	Serious	Airborne	Some	TBC
4	Extreme	Airborne	None	Ebola

Class I BSC

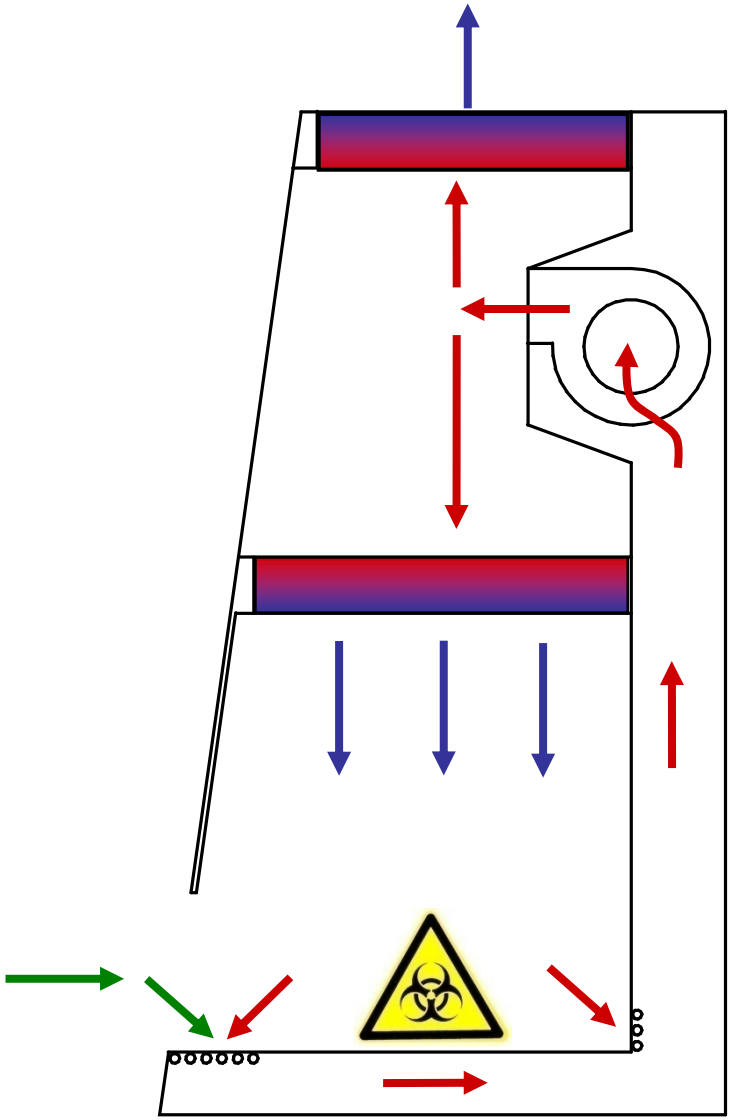
- Only operator protection (no product protection).
- Biosafety level 1,2,3
- Inflow away from operator.
- HEPA filtered exhaust to environment.
- Current trend: Switch to Class II



Class II BSC: Basics

- 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 A1 BSC: Airflow



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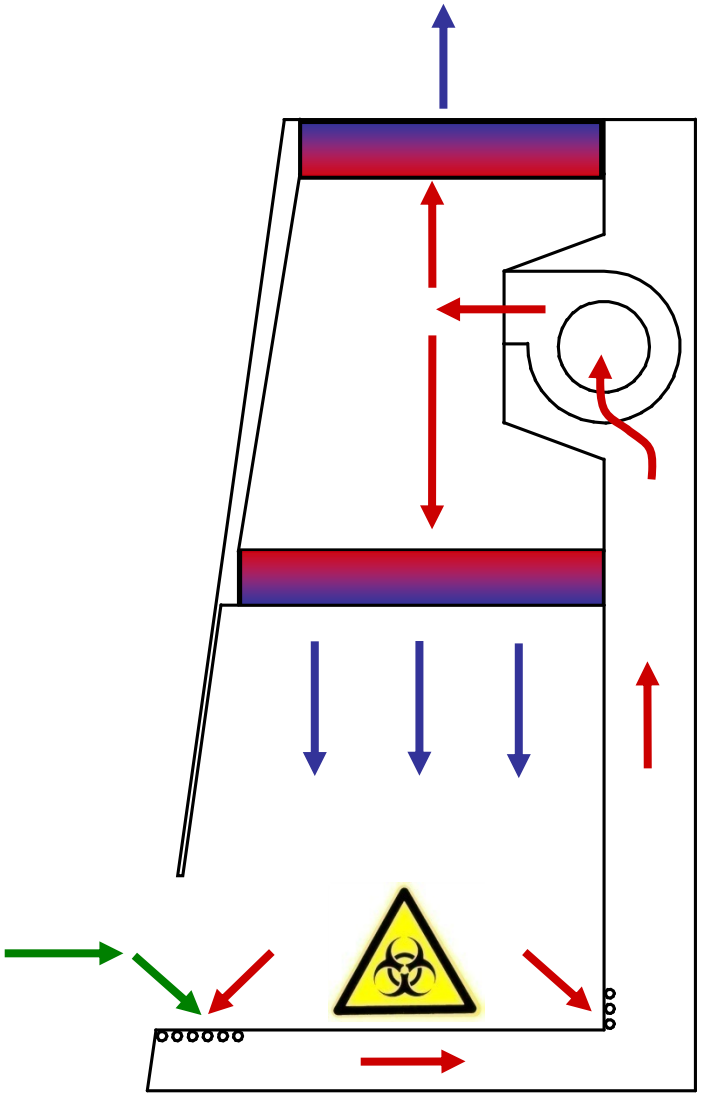
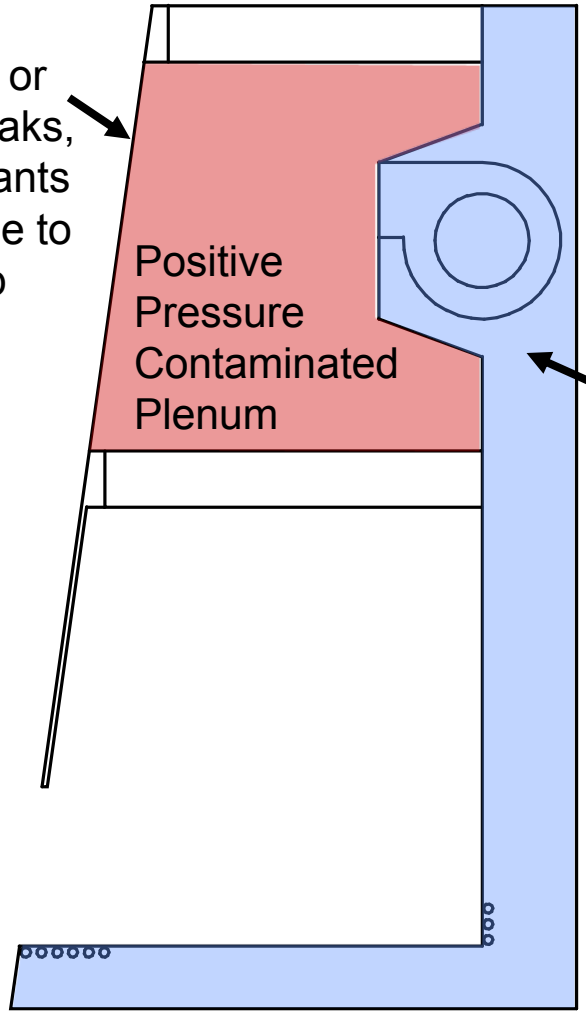
Class II Type A2 BSC Airflow

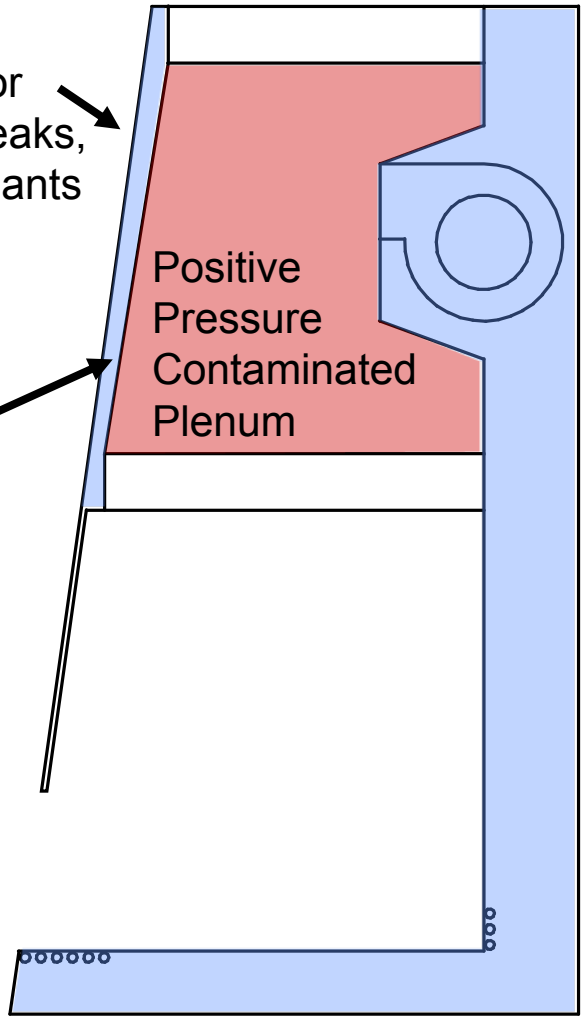


Class II Type A1 vs A2: Negative Pressure Isolated Plenum

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



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



Negative Pressure Space from Blower Suction

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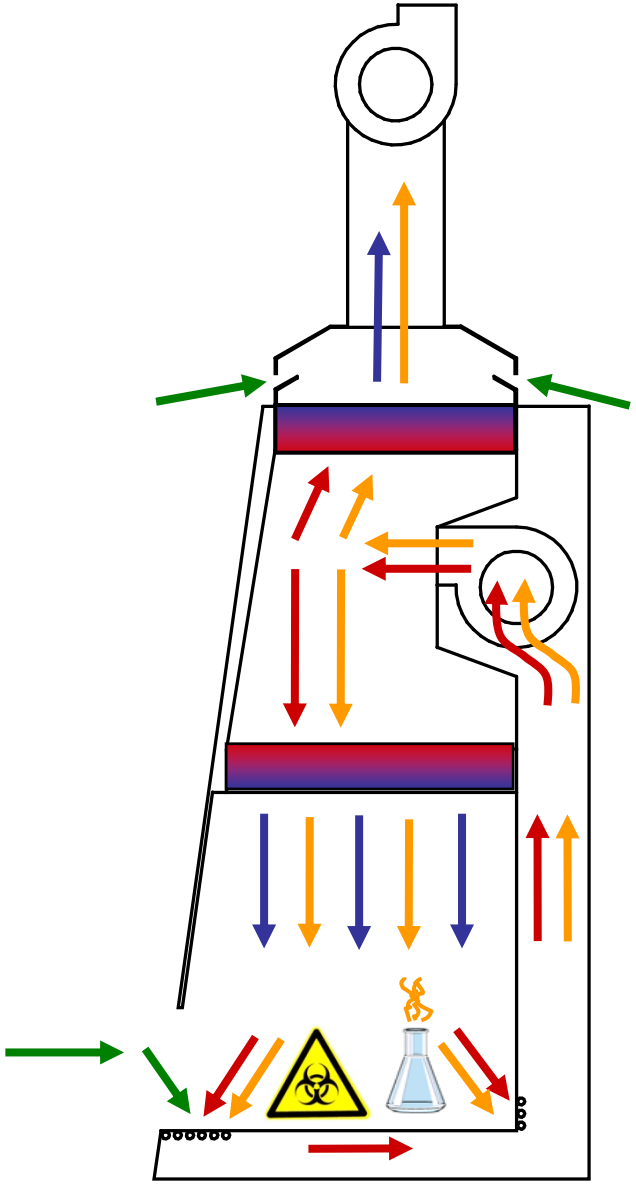
Class II Type A2 with Thimble Ducting



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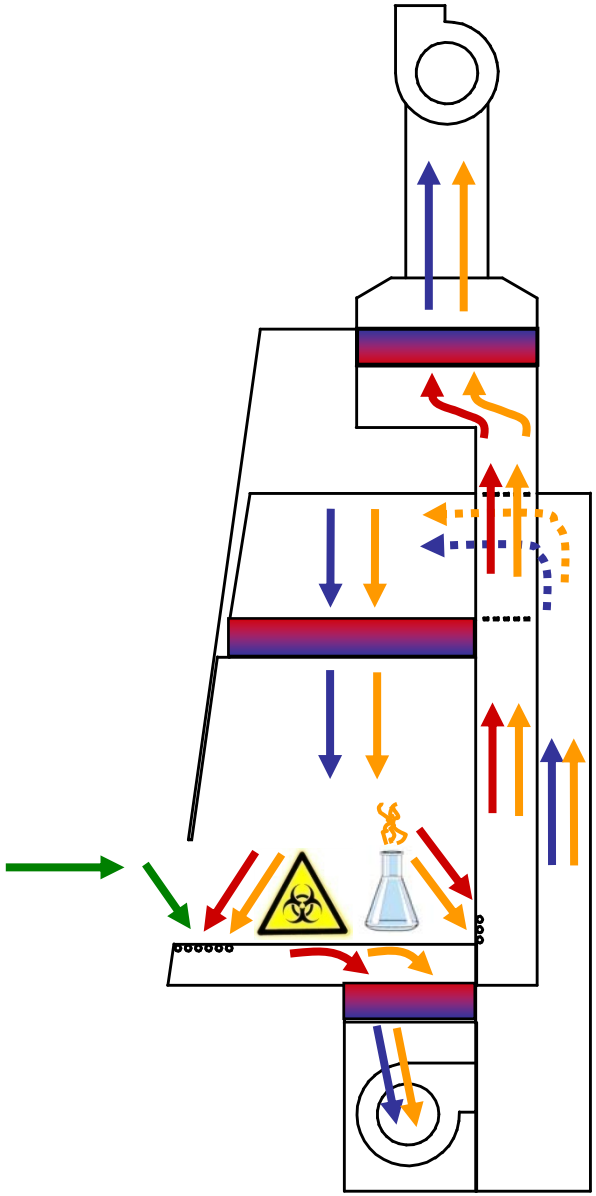
Class II B1 BSC: Airflow



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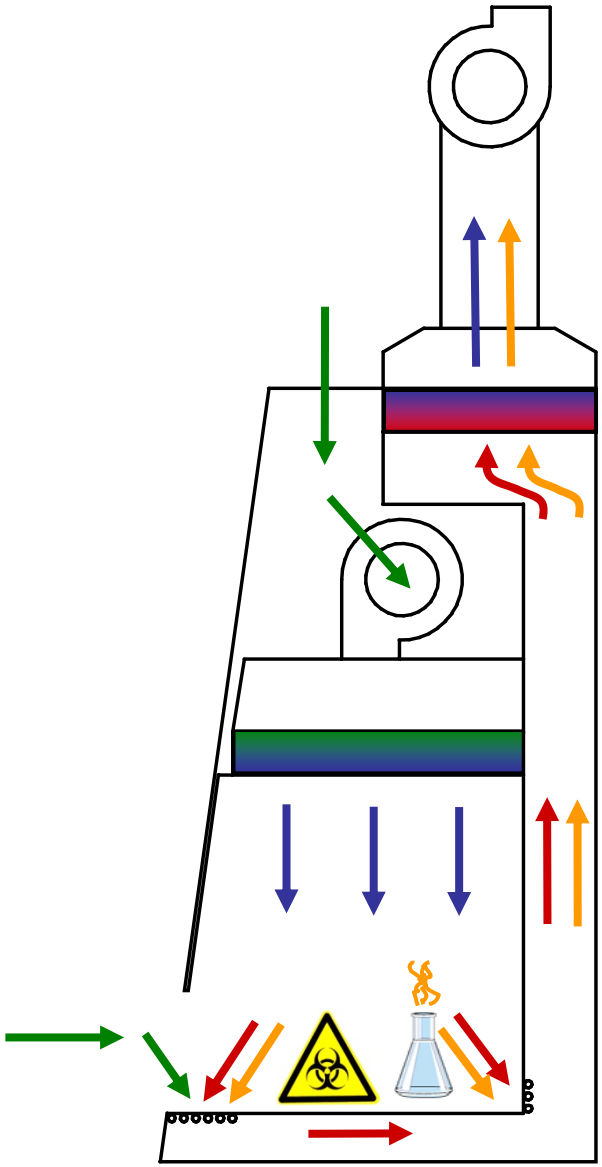
Class II B2 BSC Airflow



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NIOSH Alert on Chemical Vapor Ducting

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

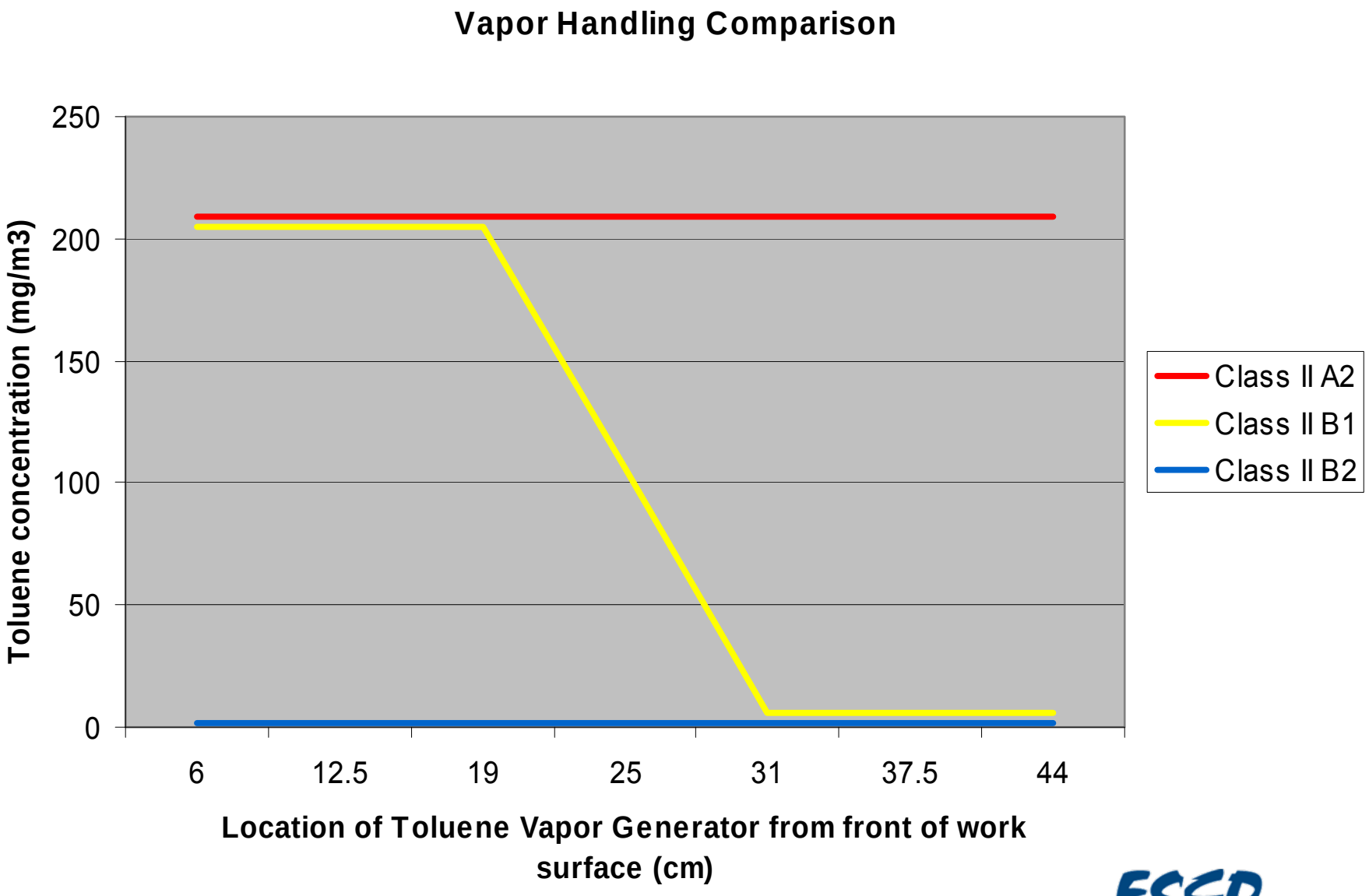
- Ensure that the chemicals used will not damage HEPA / ULPA filters
- Exhausting 1420 cmh (830 cfm) for 4ft unit: expensive to operate
- Need interlock system: if building exhaust fails, cabinet internal blower must be turned off
- Exhaust fan must be able the cabinet:
  - airflow volume
  - static 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



Risk Assessment

We must do risk assessment first before jumping down and choosing a cabinet

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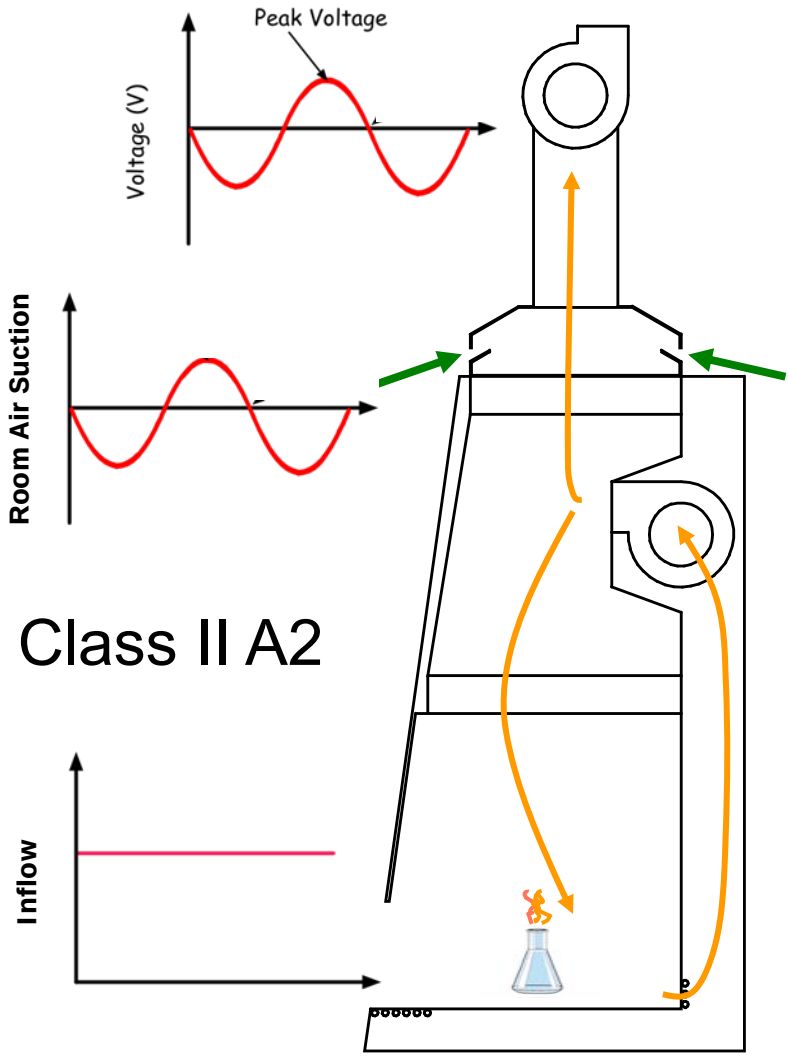
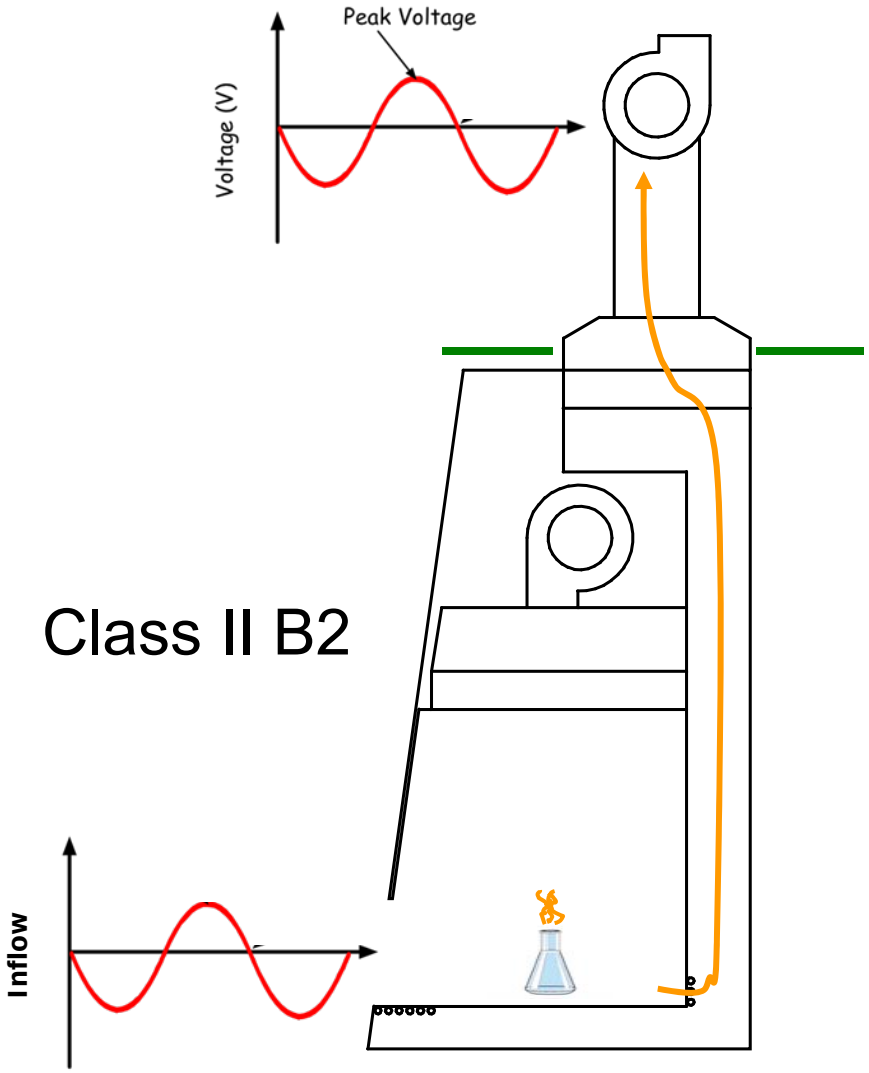
Class II A2 vs B2: Pro and Con



Class II A2

Pro: Easy to install & operate

Con: Recirculation of chemical vapor



Class II B2

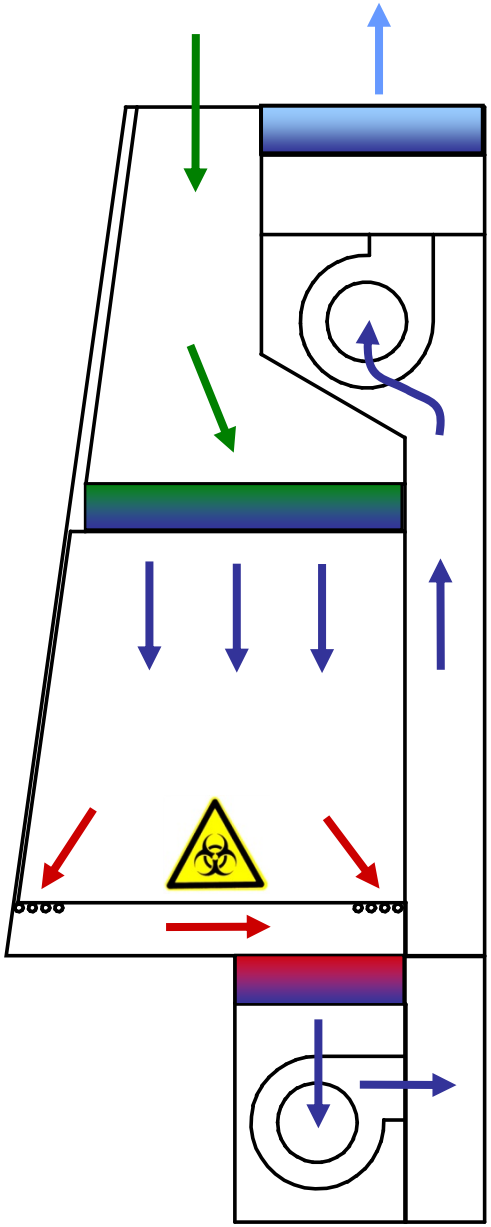
Con: Hard to install & operate

Pro: No recirculation of chem. vapor

Class III BSC

- Biosafety level 1, 2, 3, 4
- Product and operator protection
- Gas leak tight $1x10^{-5}$ cc/sec leak rate
- Internal operations with attached glove
- Material transfer: through 2 doors pass box
- Negative air pressure > 0.5 “WG
- Supply is HEPA filtered
- Double exhaust HEPA filter in series or:
  Single exhaust HEPA and an incinerator

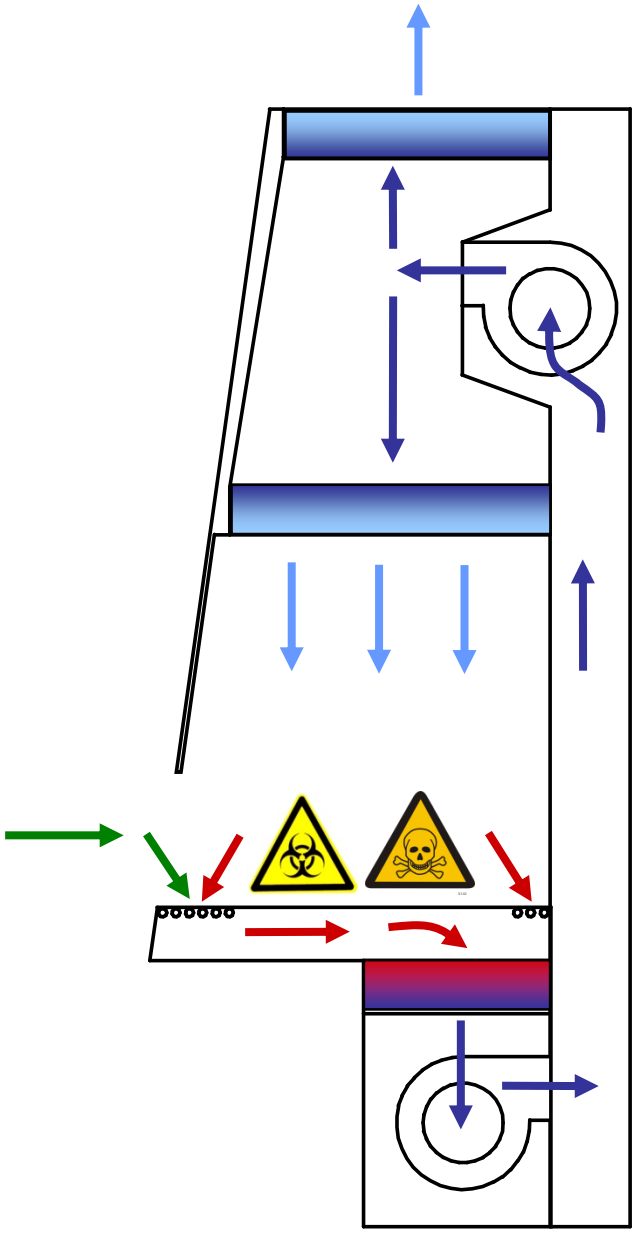
Class III BSC



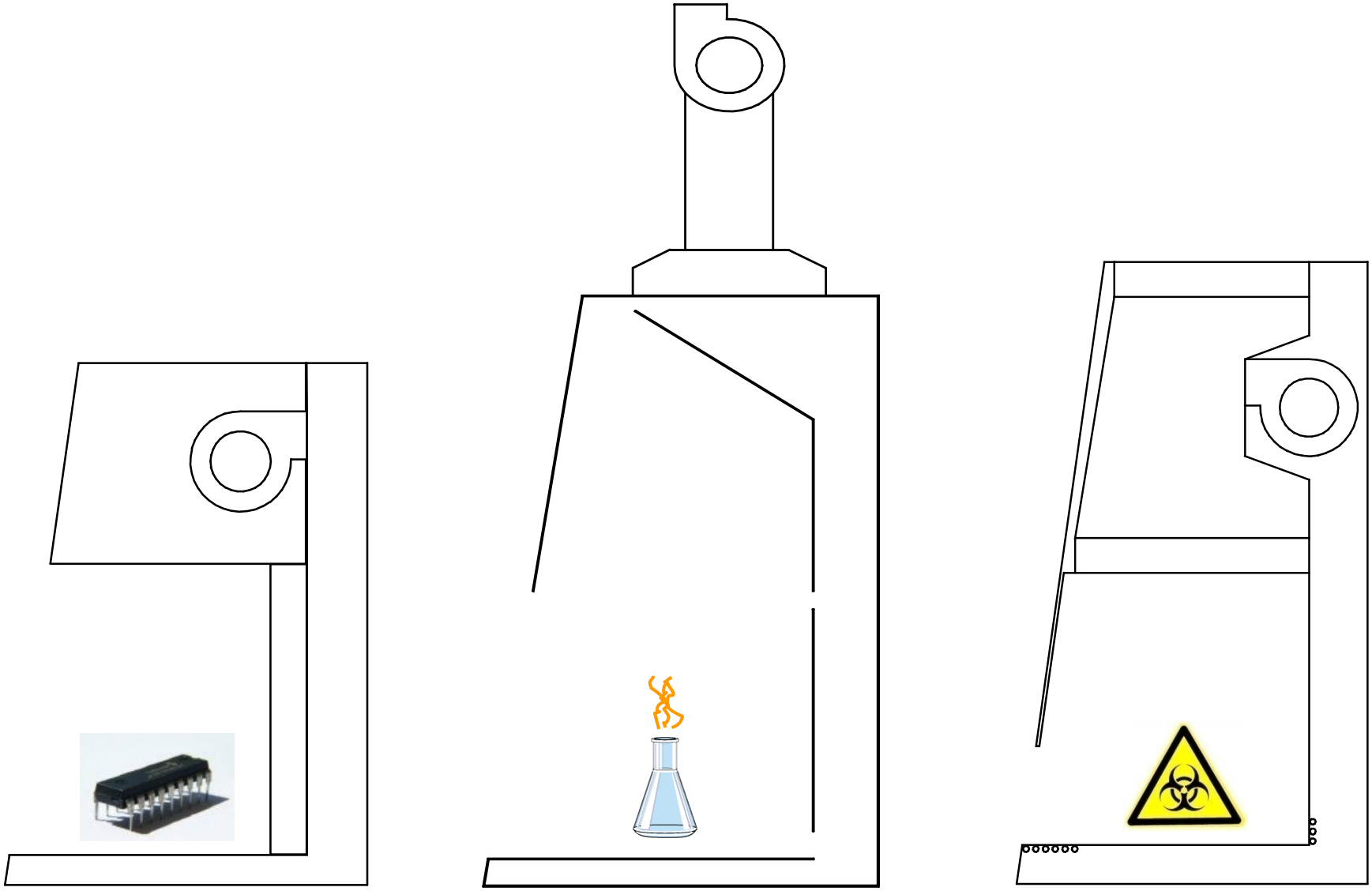
Cytotoxic Safety Cabinet

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



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Section 5
Cabinet Installation and Field Testing

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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*

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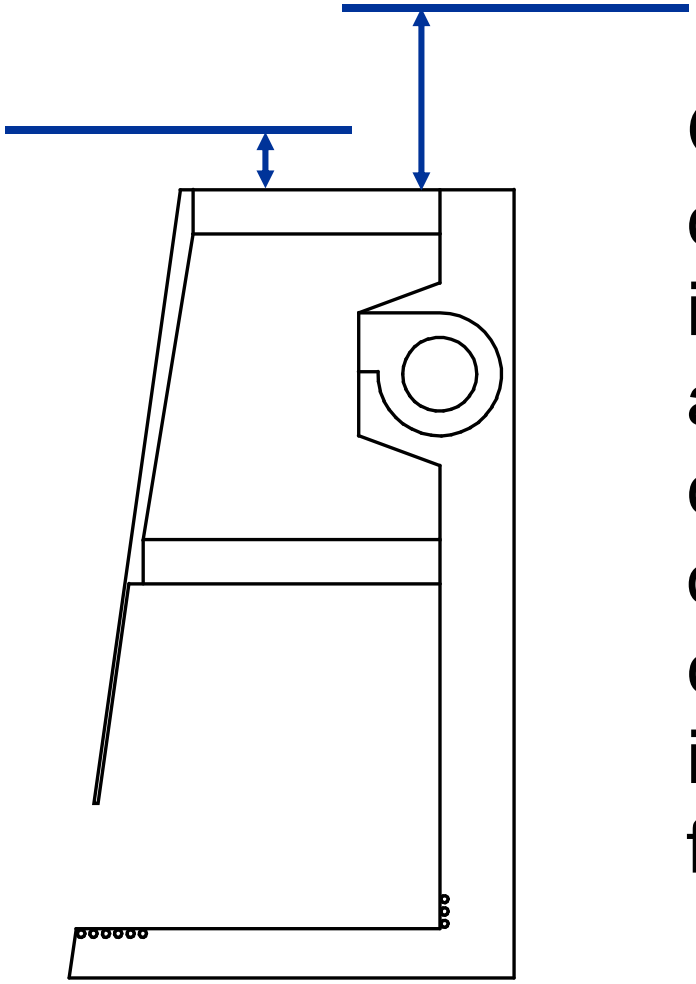
Adequate Height Clearance

Check the manufacturer's requirement for minimum height clearance to prevent backpressure on exhaust filter or exhaust flow sensor discrepancy



Other considerations includes adequate clearance for on-site certification i.e. exhaust filter testing

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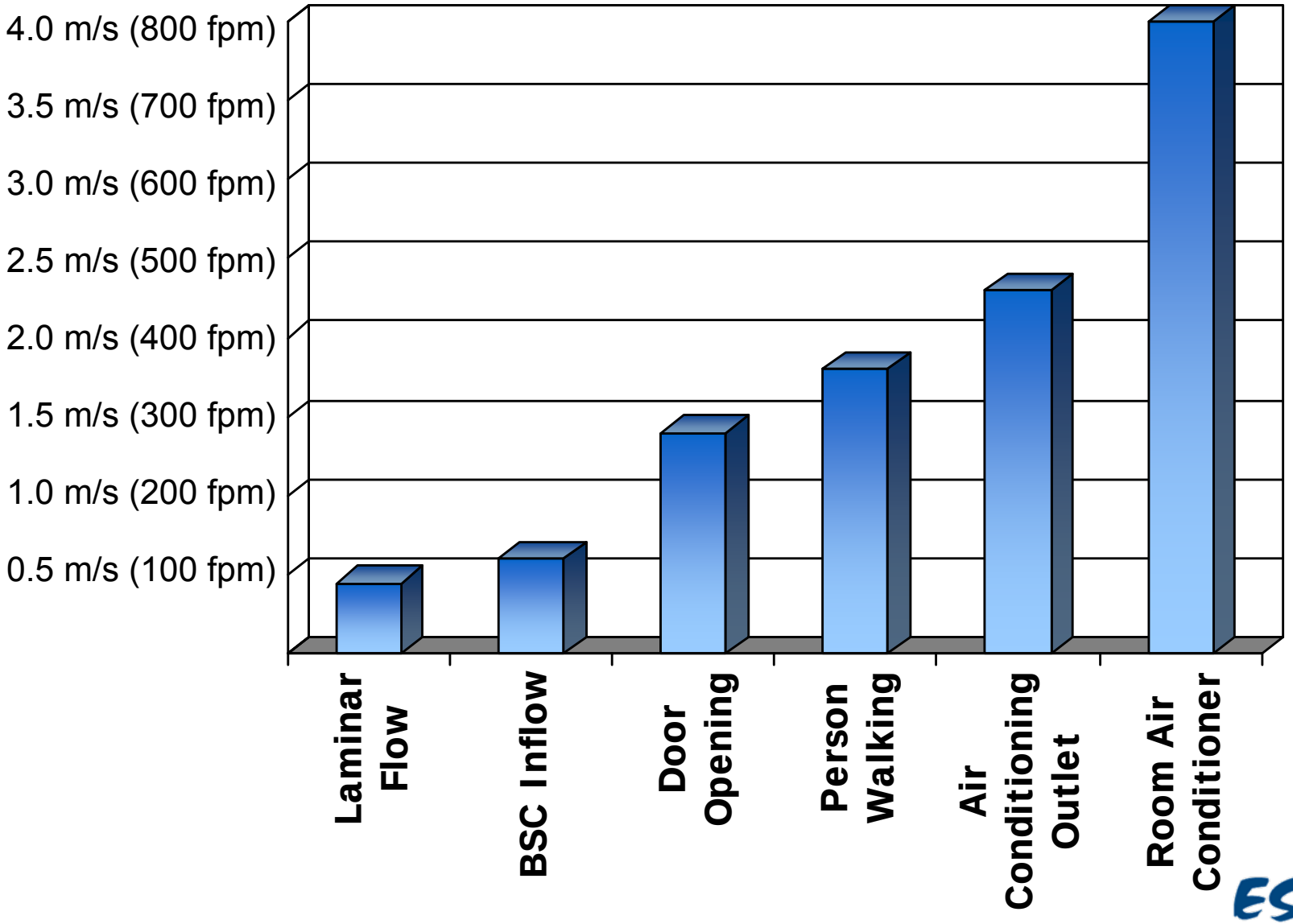
Installation Precaution

- 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

Relative Air Velocities



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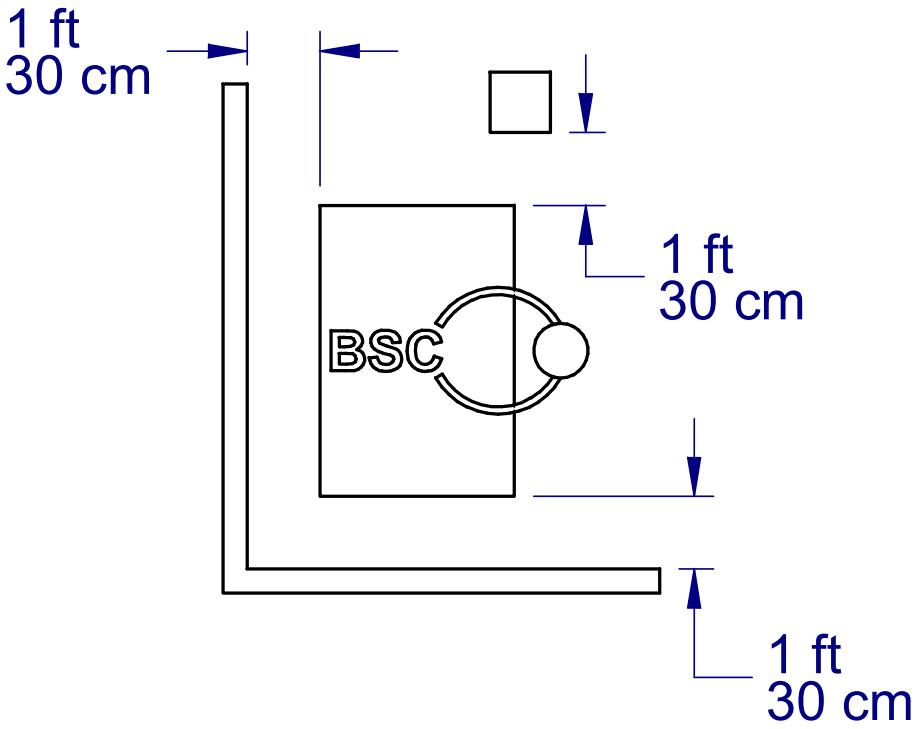
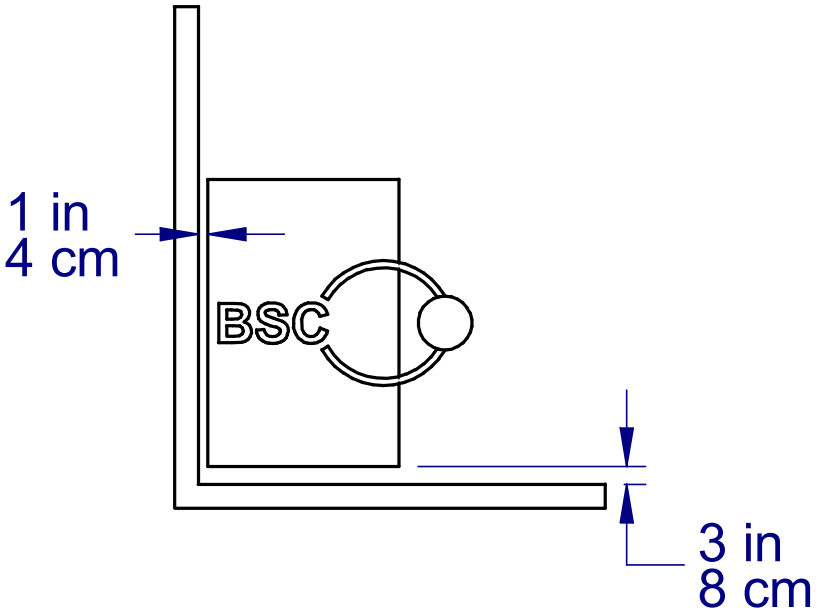
BS 5726: Distance to Wall



Ideal



Min recommended
by NSF/ANSI 49

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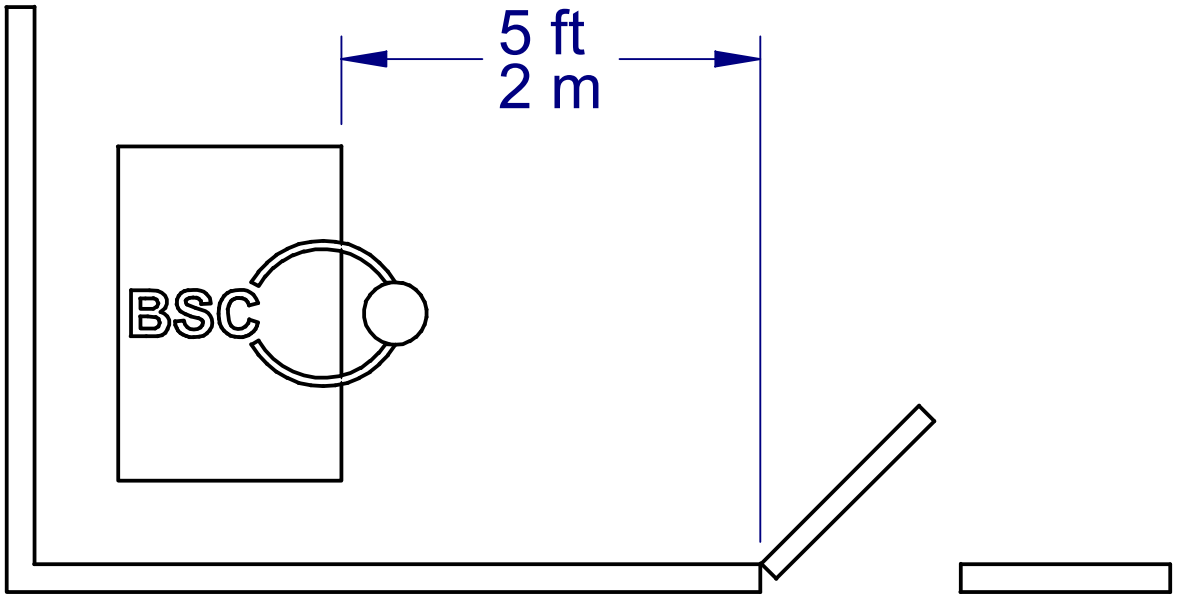
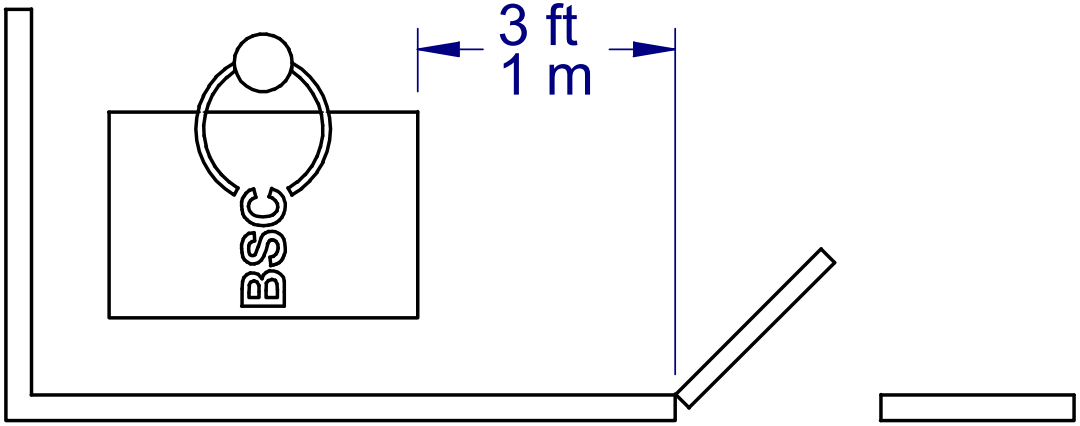
BS 5726: Distance to Door





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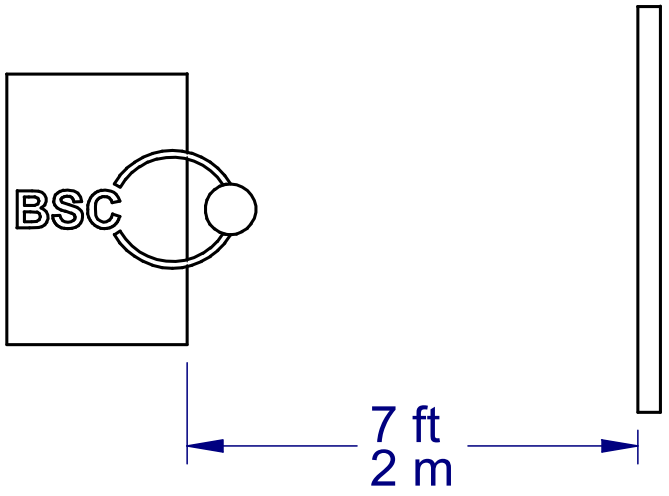
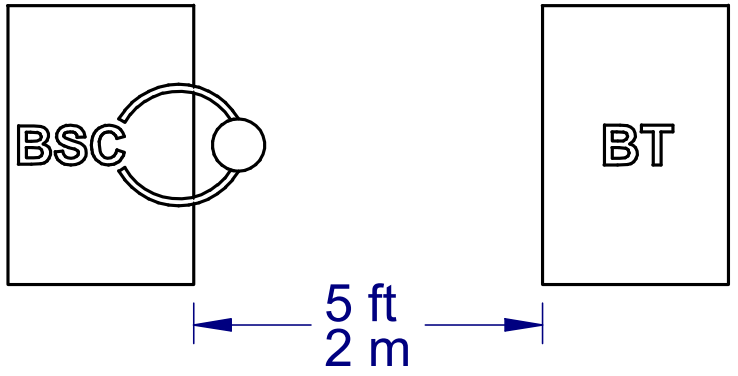
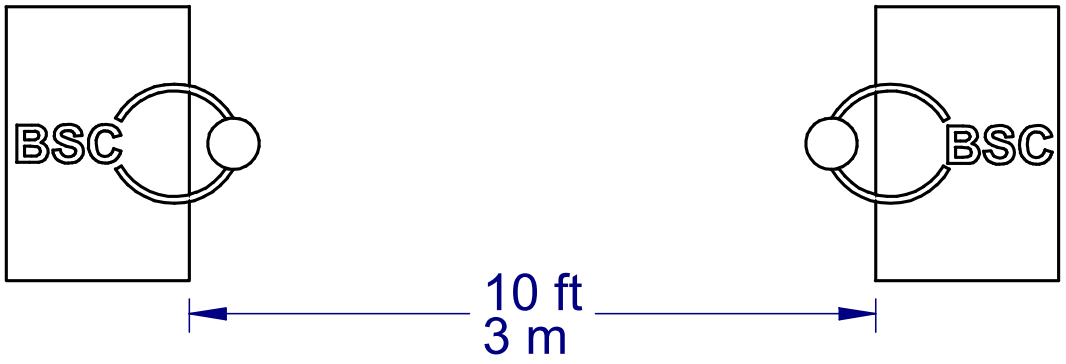
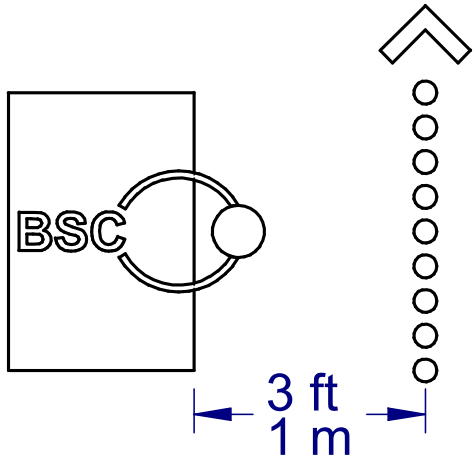
BS 5726: Front Clearance

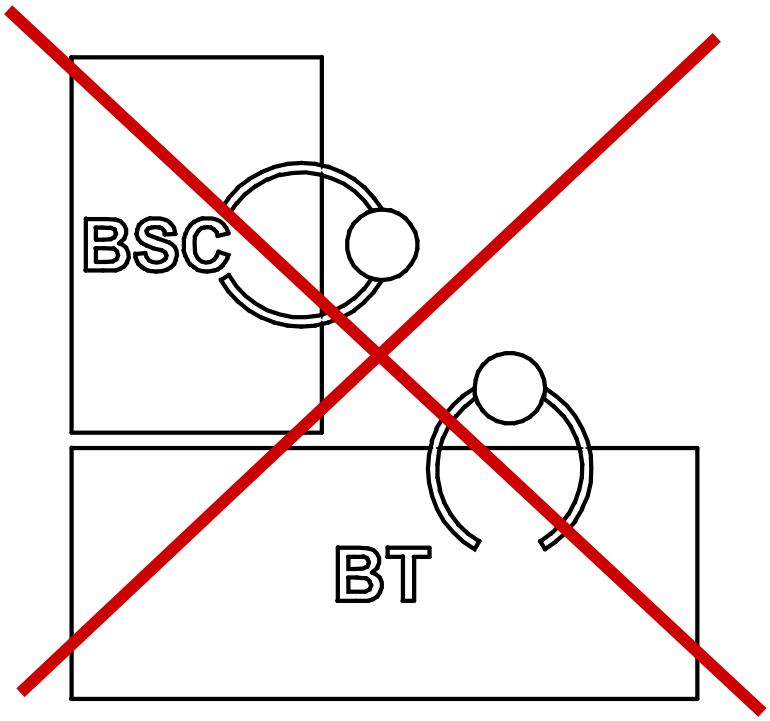


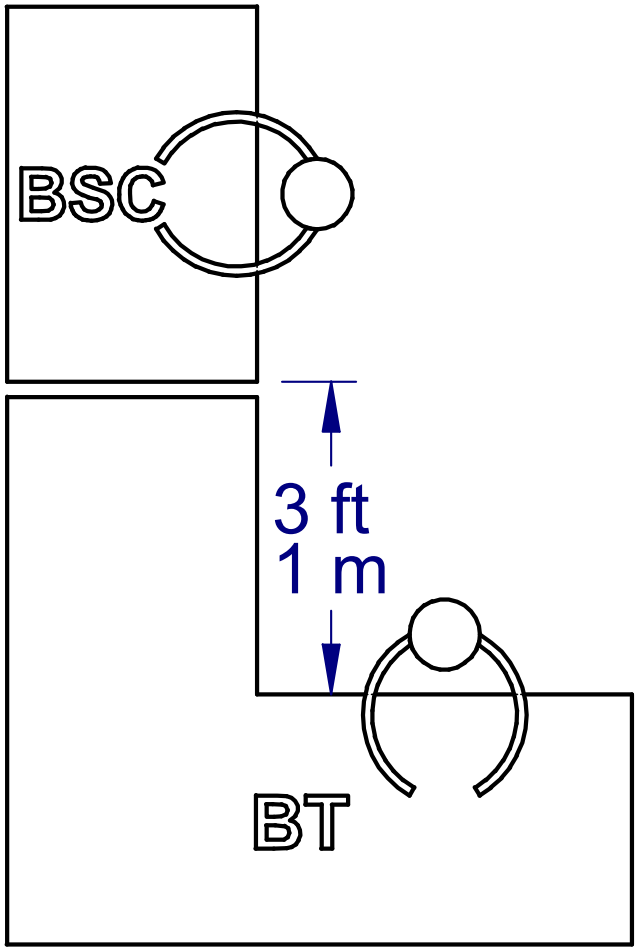






BS 5726: Side Table Top





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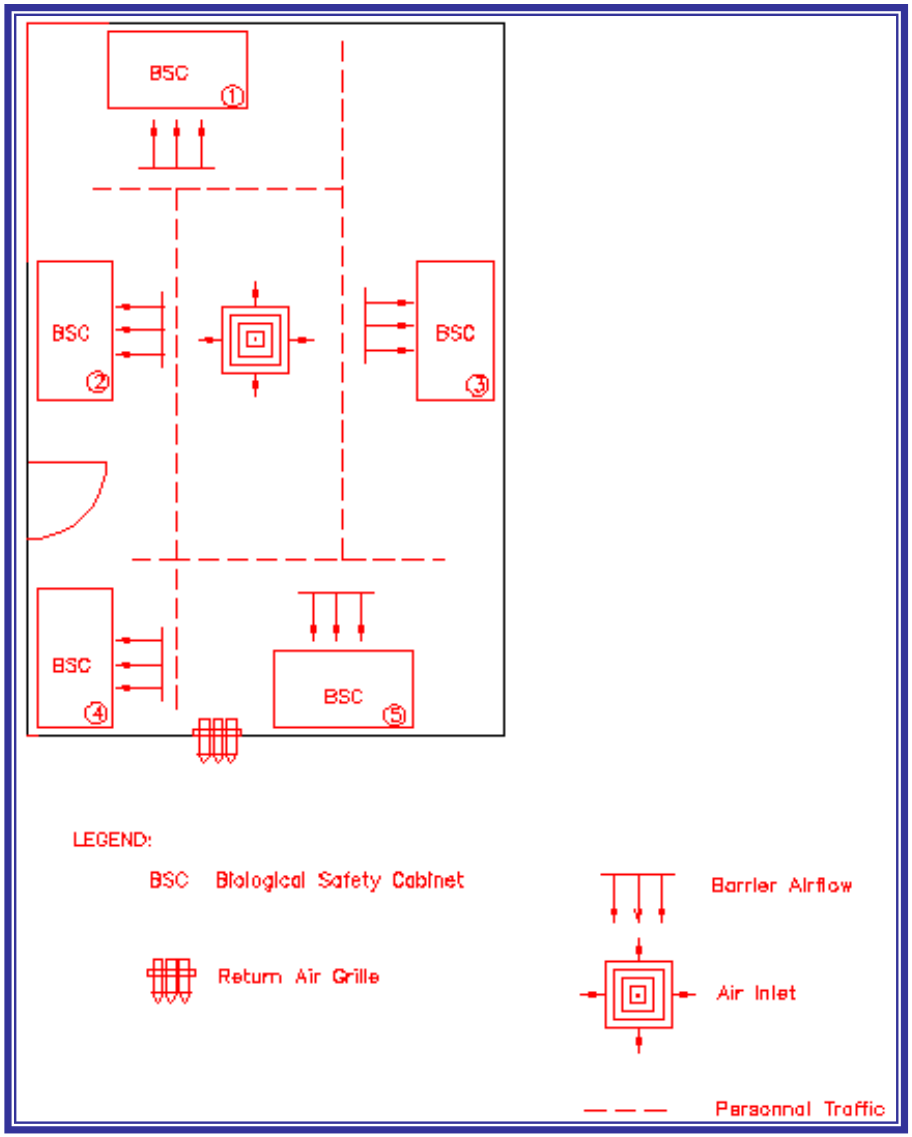
Best Installation Location



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.

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Standards and Testing

The most widely used standards in the world for Biological Safety Cabinet:

- American Standard ANSI/NSF 49
- European Standard EN 12469

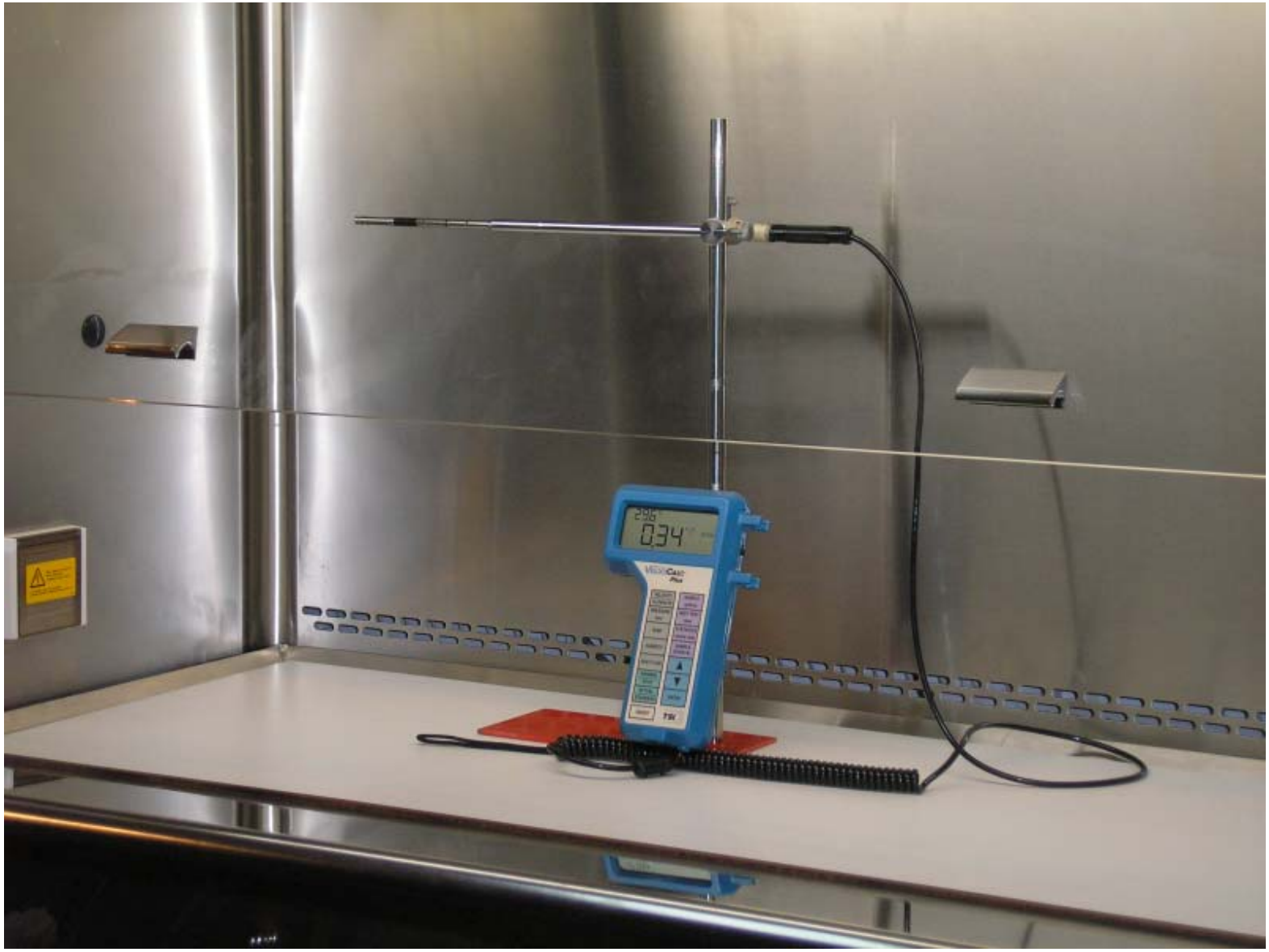
On-Site Field Tests Required by NSF/ANSI 49

- Downflow velocity
- Inflow velocity
- Airflow smoke patterns
- HEPA/ULPA filter leak
- Site installation assessment tests
- Cabinet leak test (only for A1 cabinets)

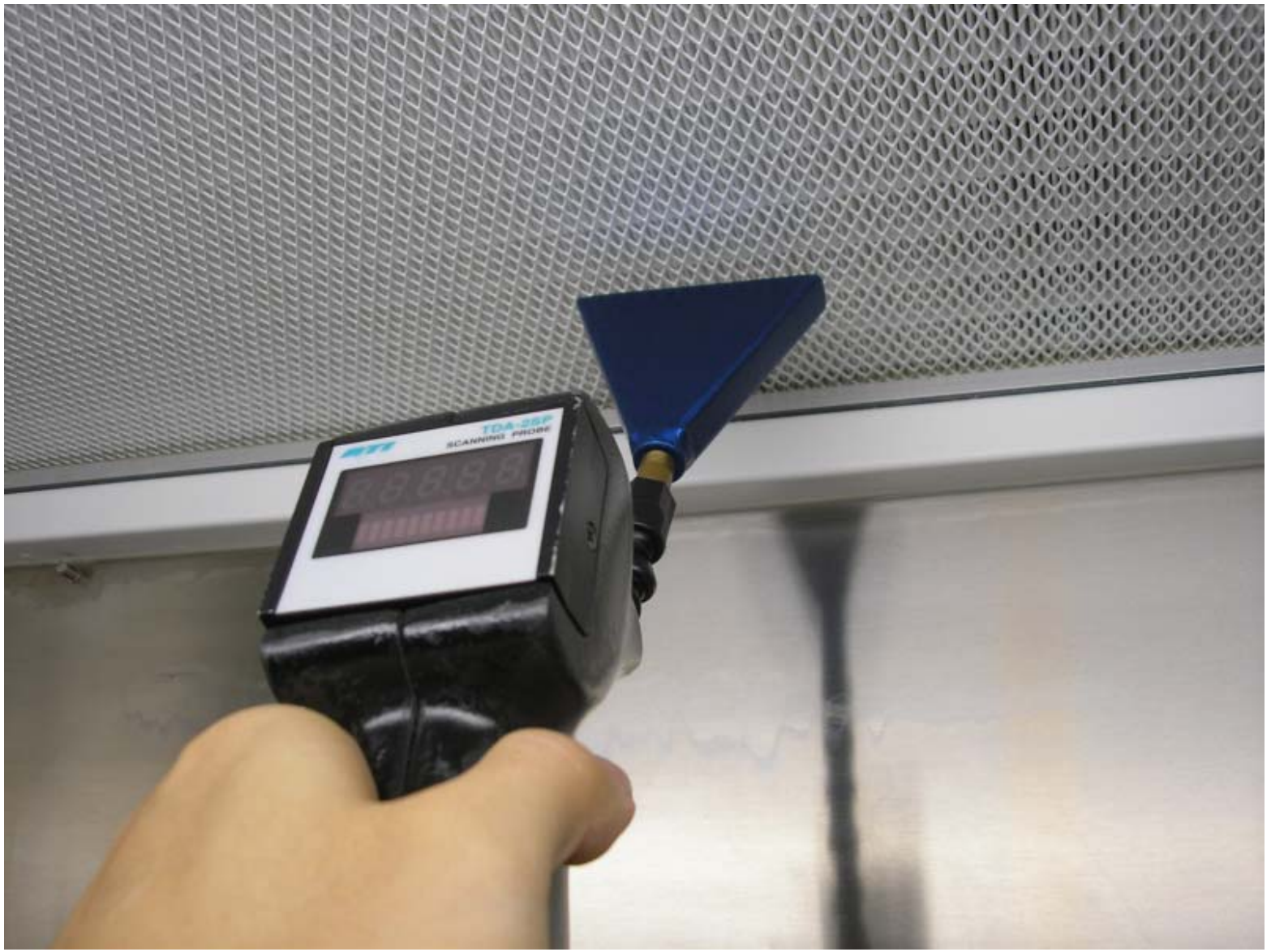
Consideration in installing the cabinet must be taken so these tests can be performed

Inflow Velocity Testing

Downflow Velocity Testing



Filter Integrity Testing



Smoke Pattern Testing

Site Installation Assessment Testing

- Airflow Alarm
- Sash alarm
- Blower interlock (B2 only)
- Airflow smoke pattern on exhaust duct connection

Section 6
Class II Type B2 Installation

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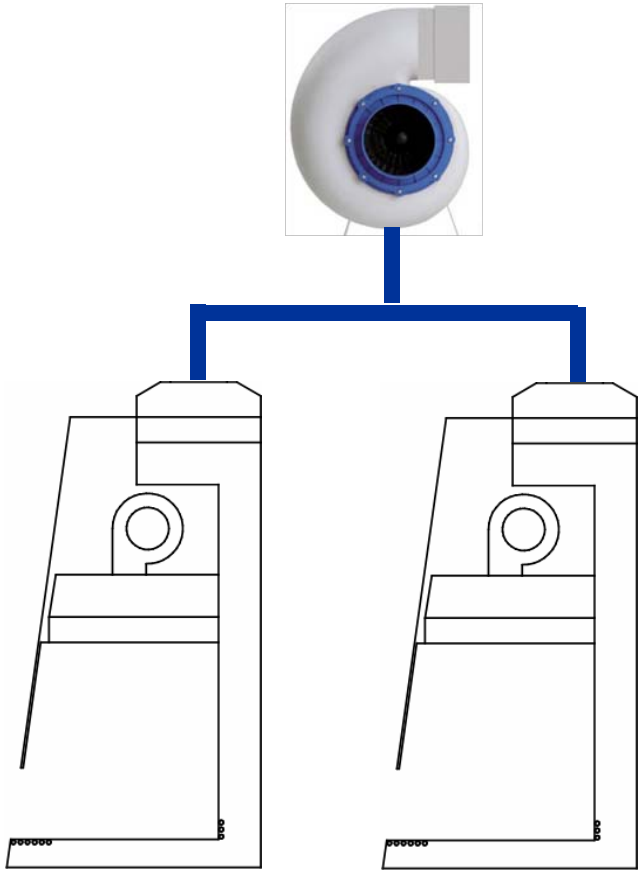
Connecting Multiple Cabinets to Exhaust Fan



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

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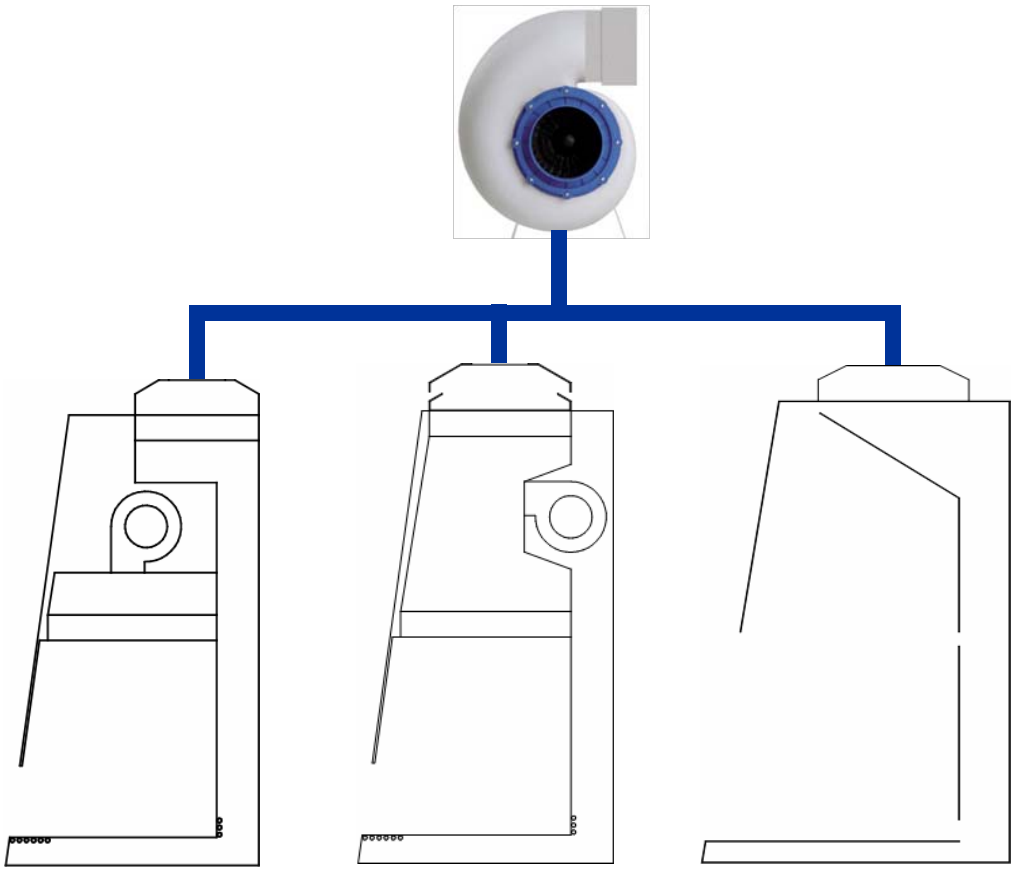

Class II B2 BSC
V=1510cmh(888cfm)
P=590Pa(2.4“WG)

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

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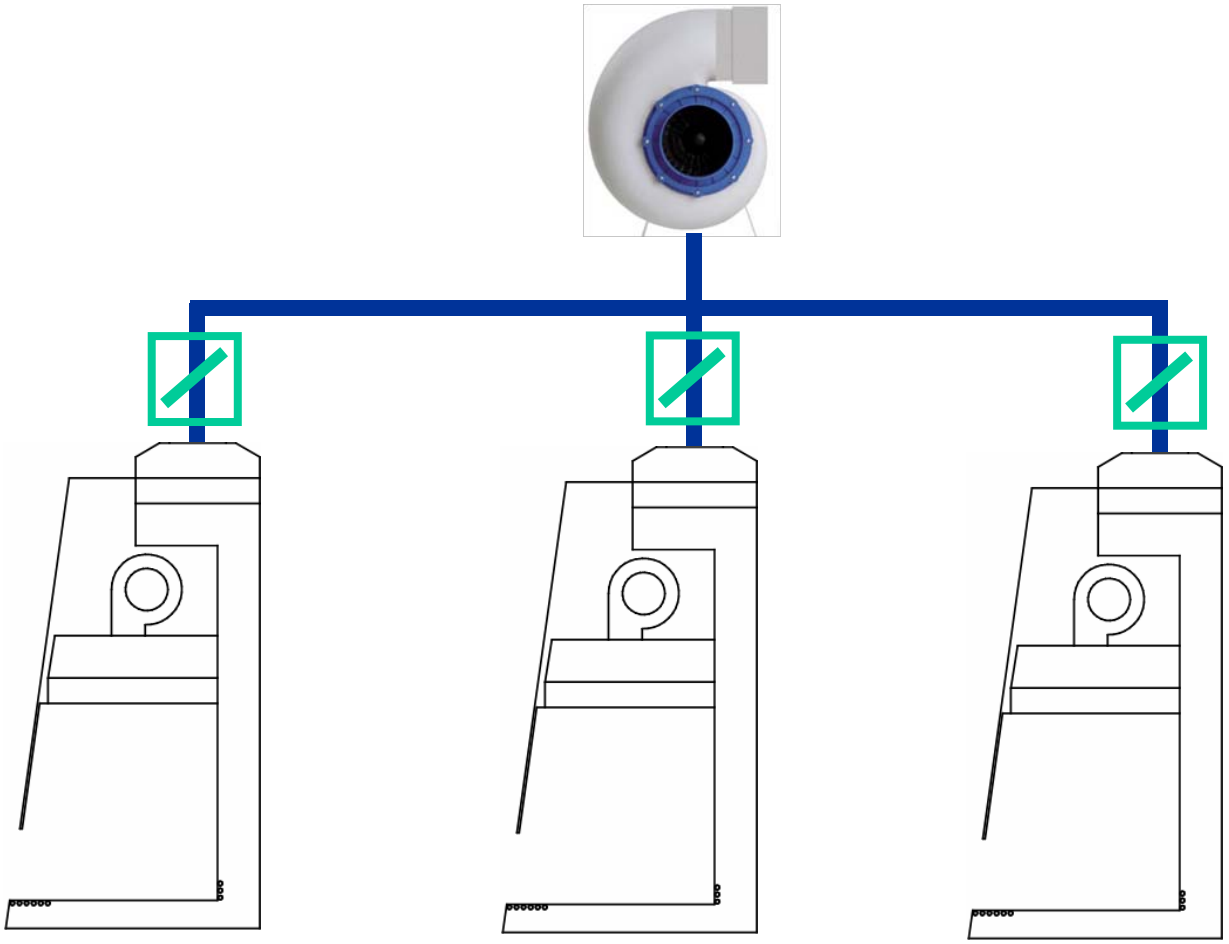
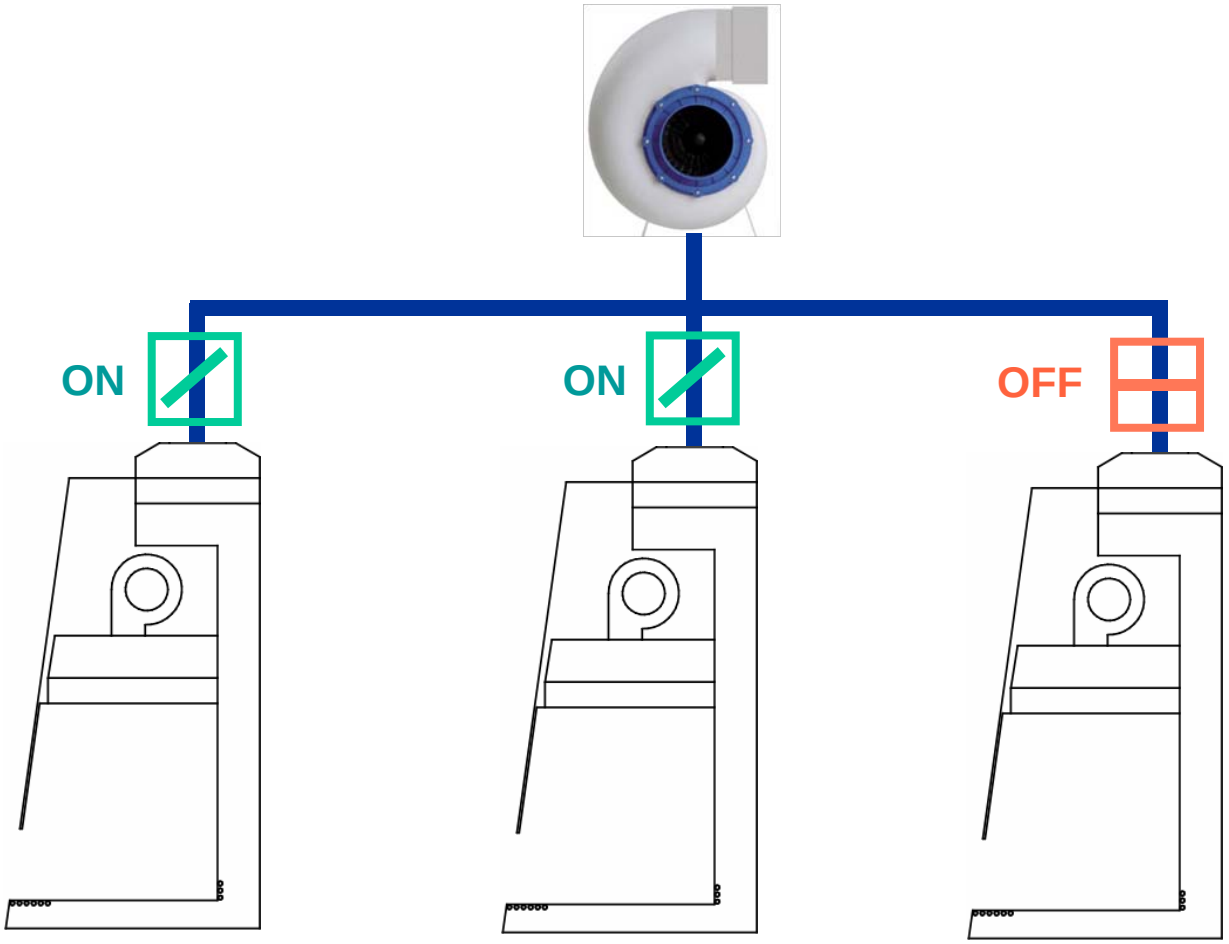
Difficulty in Balancing Exhaust for Multi Cabinets



-Need to do iteration to balance the airflow

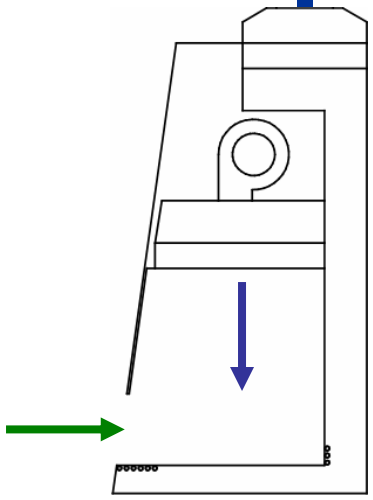
-Trouble when exhaust filter get loaded at different rate

Disrupted Airflow Balance if 1 Cabinet is OFF



Exhaust	Cabinet #1	Cabinet #2	Cabinet #3
All ON	1510cmh (888cfm)	1510cmh (888cfm)	1510cmh (888cfm)
2 x ON	2265cmh (1332cfm)	2265cmh (1332cfm)	0

Must “Super-Size” the External Fan

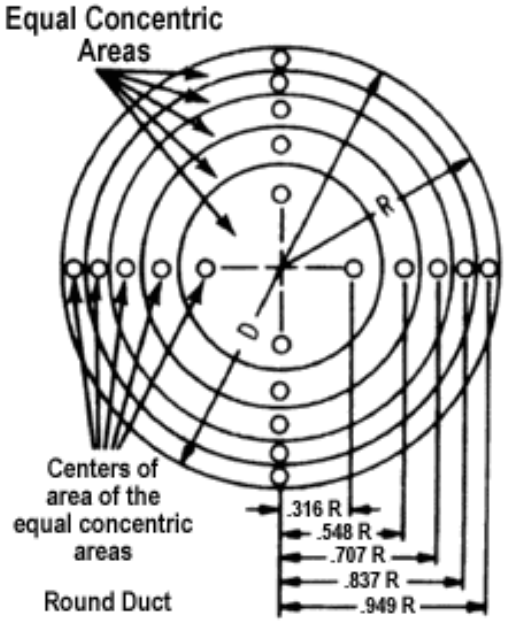


10 x d

Pitot tube

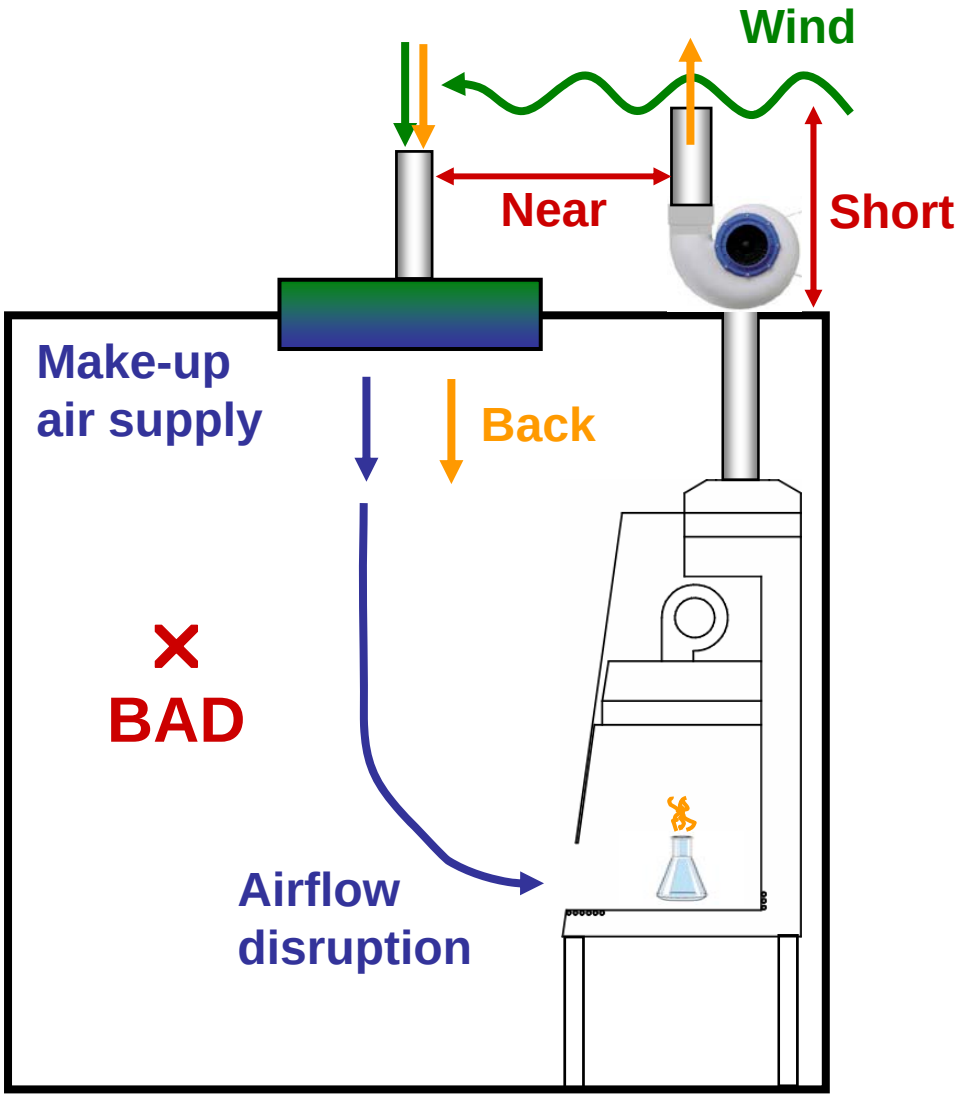
Must “super-size” the external fan:

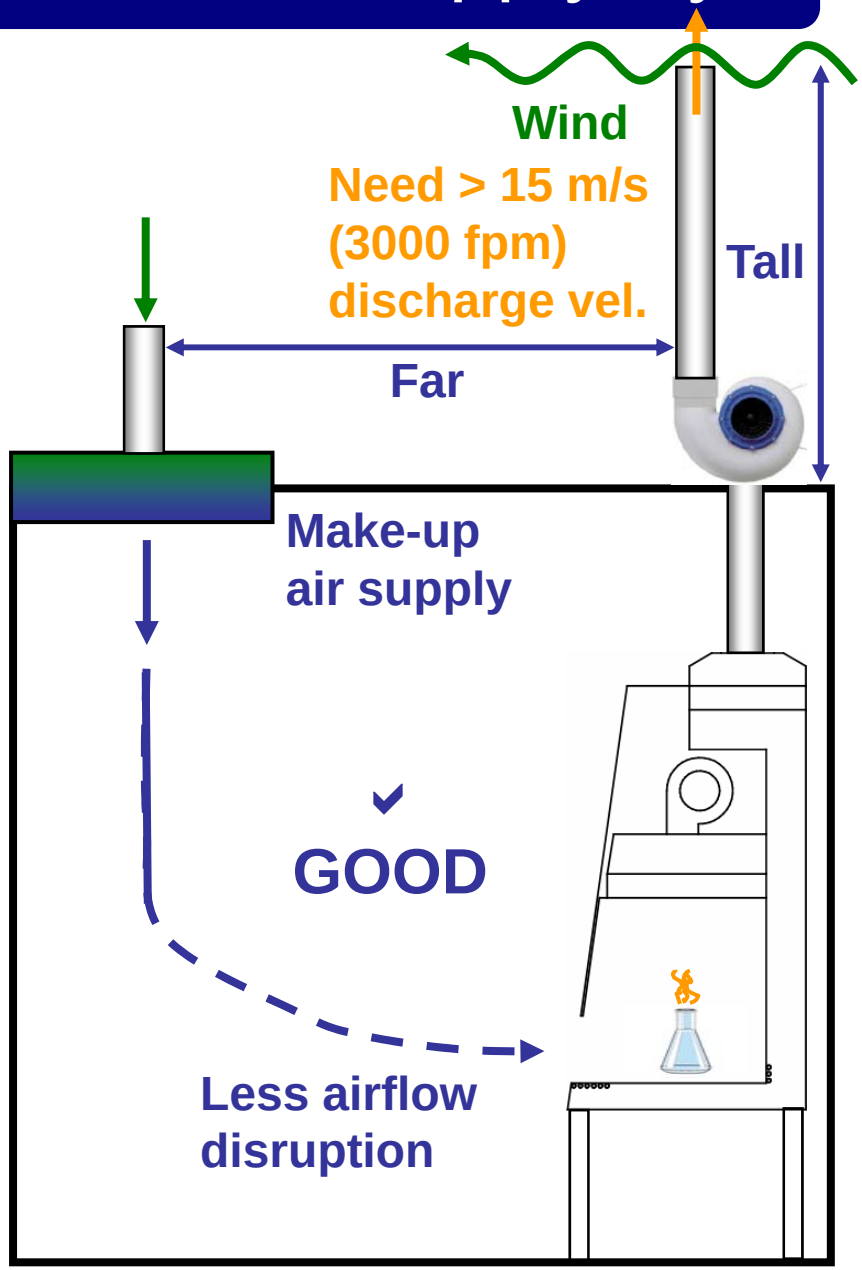
1. Volume: Pitot tube reading is 4-12% higher than Inflow + Downflow
2. Pressure: depends on duct length, diameter, bends/valve/etc, must add 15-50% extra pressure capacity



ft	Inflow + Downflow	Pitot Traverse (cmh)	Pitot Traverse (cfm)
4	1420 cmh | 840 cfm	1480 – 1600 cmh	870 – 940 cfm
6	2100 cmh | 1200 cfm	2200 – 2350 cmh	1280 – 1380 cfm

Bad and Good Building Exhaust & Supply Sys.





Volumetric Flow and Exhaust Requirement

Cabinet model	Volumetric airflow (Supply + DIM Inflow)		Volumetric airflow (Pitot Duct Traverse). Range depends on accuracy and measurement condition in doing duct traverse						Pressure with clean exhaust filter		Required Concurrent Balance Value for Pressure per NSF 49:2008	
	cmh	cfm	cmh	to	cmh	cfm	to	cfm	Pa	"WG	Pa	"WG
LB2-3BX	1081	636	1124	to	1210	662	to	712	450	1.8	624	2.5
LB2-4BX	1420	836	1477	to	1590	869	to	936	416	1.7	590	2.4
LB2-5BX	1755	1033	1826	to	1966	1075	to	1157	421	1.7	595	2.4
LB2-6BX	2093	1232	2177	to	2344	1281	to	1380	482	1.9	656	2.6
AB2-3BX	885	521	920	to	991	542	to	583	436	1.7	610	2.4
AB2-4BX	1166	686	1213	to	1306	714	to	769	371	1.5	545	2.2
AB2-5BX	1447	852	1505	to	1621	886	to	954	370	1.5	544	2.2
AB2-6BX	1728	1017	1797	to	1936	1058	to	1139	374	1.5	548	2.2

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

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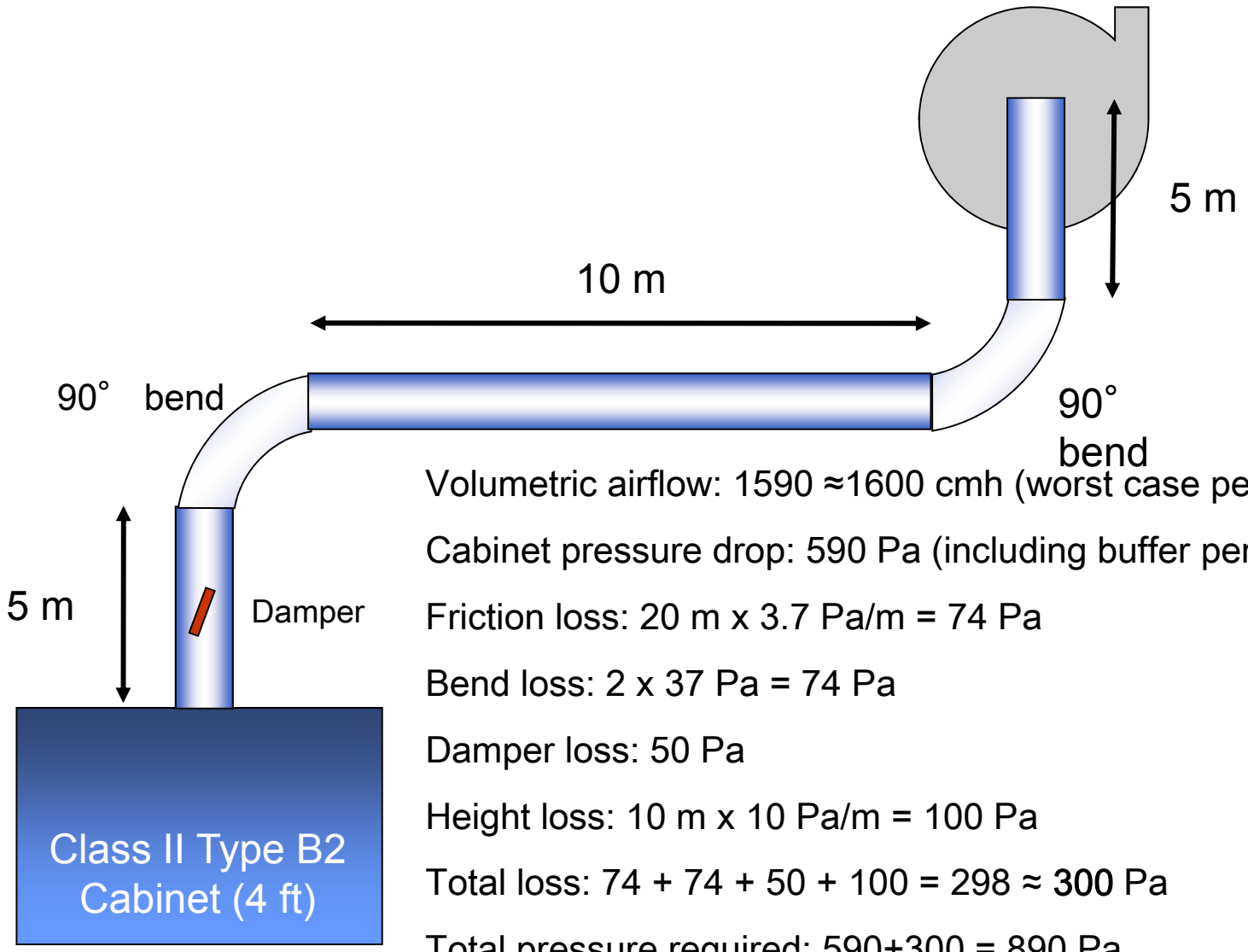
Class II Type B2 Installation

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 ≈1600 cmh (worst case per pitot duct)

Cabinet pressure drop: 590 Pa (including buffer per NSF CBV)

Friction loss: 20 m x 3.7 Pa/m = 74 Pa

Bend loss: 2 x 37 Pa = 74 Pa

Damper loss: 50 Pa

Height loss: 10 m x 10 Pa/m = 100 Pa

Total loss: 74 + 74 + 50 + 100 = 298 ≈ **300** Pa

Total pressure required: 590+300 = 890 Pa

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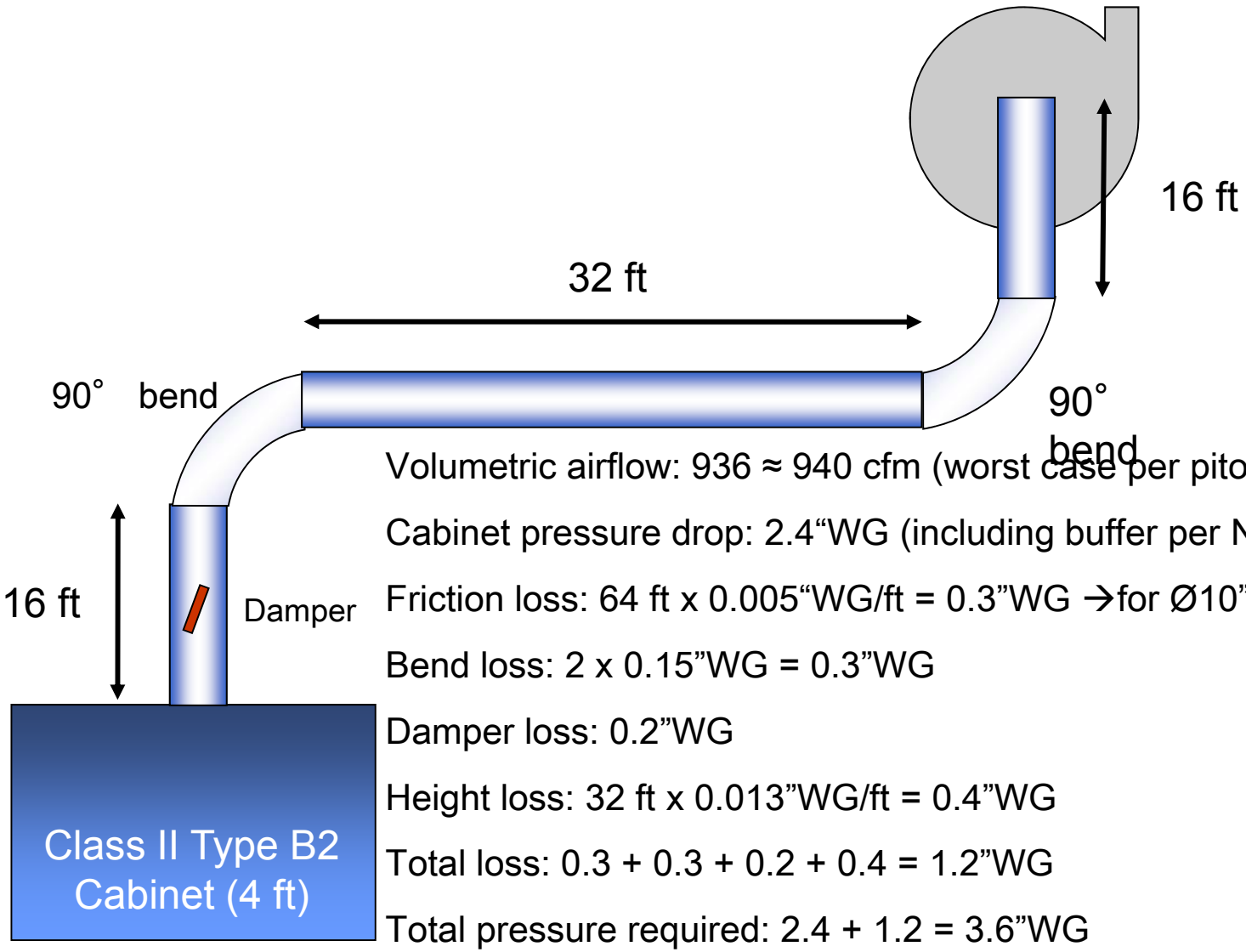
Case Study: Ducting System (Imperial)



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

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

Friction loss: 64 ft x 0.005“WG/ft = 0.3”WG →for Ø10” round duct

Bend loss: 2 x 0.15”WG = 0.3”WG

Damper loss: 0.2”WG

Height loss: 32 ft x 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 ?