General and Dilution Ventilation

General Ventilation - Purpose

- General ventilation
  - Provide heating or cooling
  - Provide make-up air
  - Provide dilution and reduction of contaminants such as CO_2 and body odor
- Dilution ventilation
  - Provide dilution of contaminants to safe levels (<TLV or LEL)
  - Constrained by comfort and other factors
  - Usually initial cost: DV cost << LEV cost
  - Usually for operation: DV cost >> LEV cost

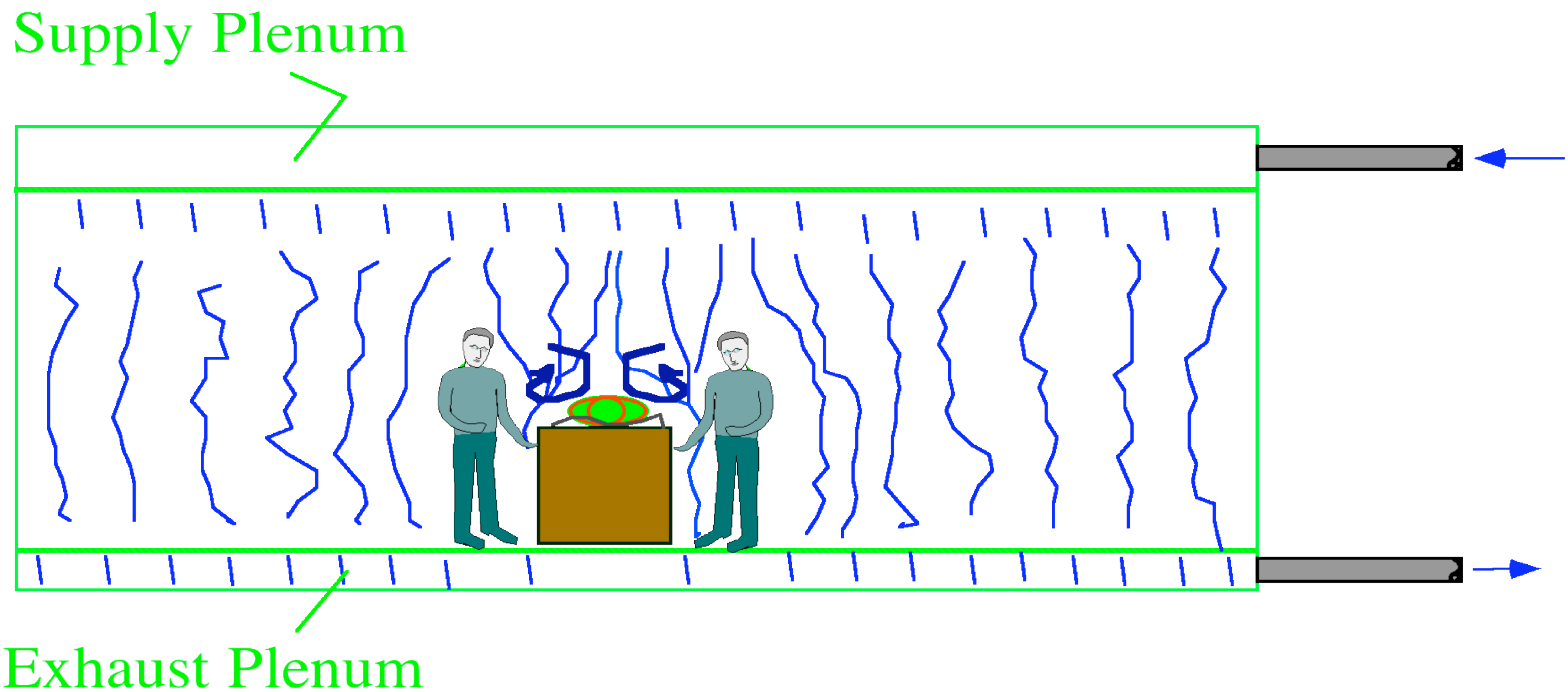
Dilution Ventilation - applications

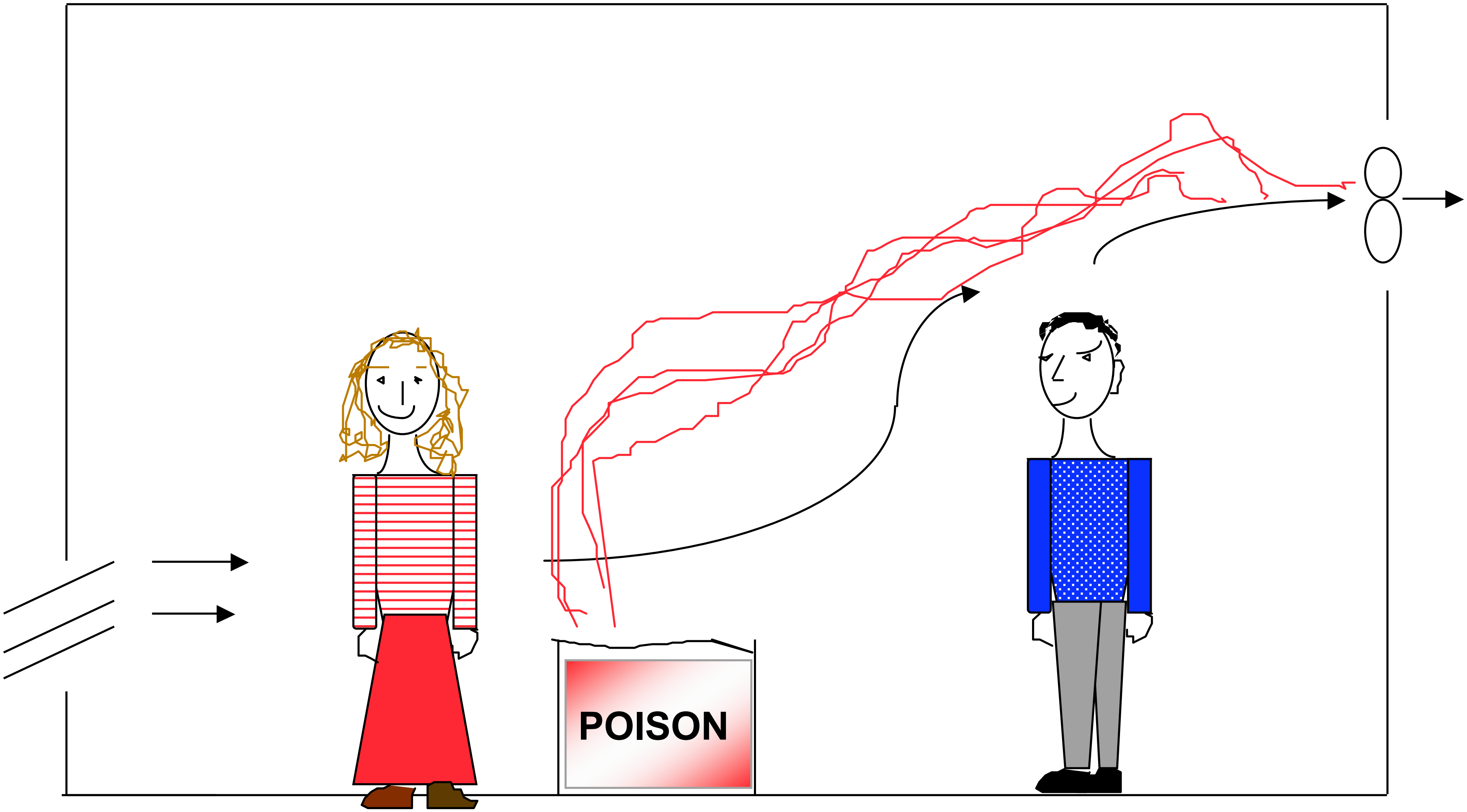
- Toxicity of contaminant is low to moderate (High TLV)
- Velocity and generation rate of contaminant low to moderate – must consider periodic generation too
- Sources are not well localized or identifiable
- Mobile sources or variable work process
- Energy costs are not a significant concern

Dilution Ventilation

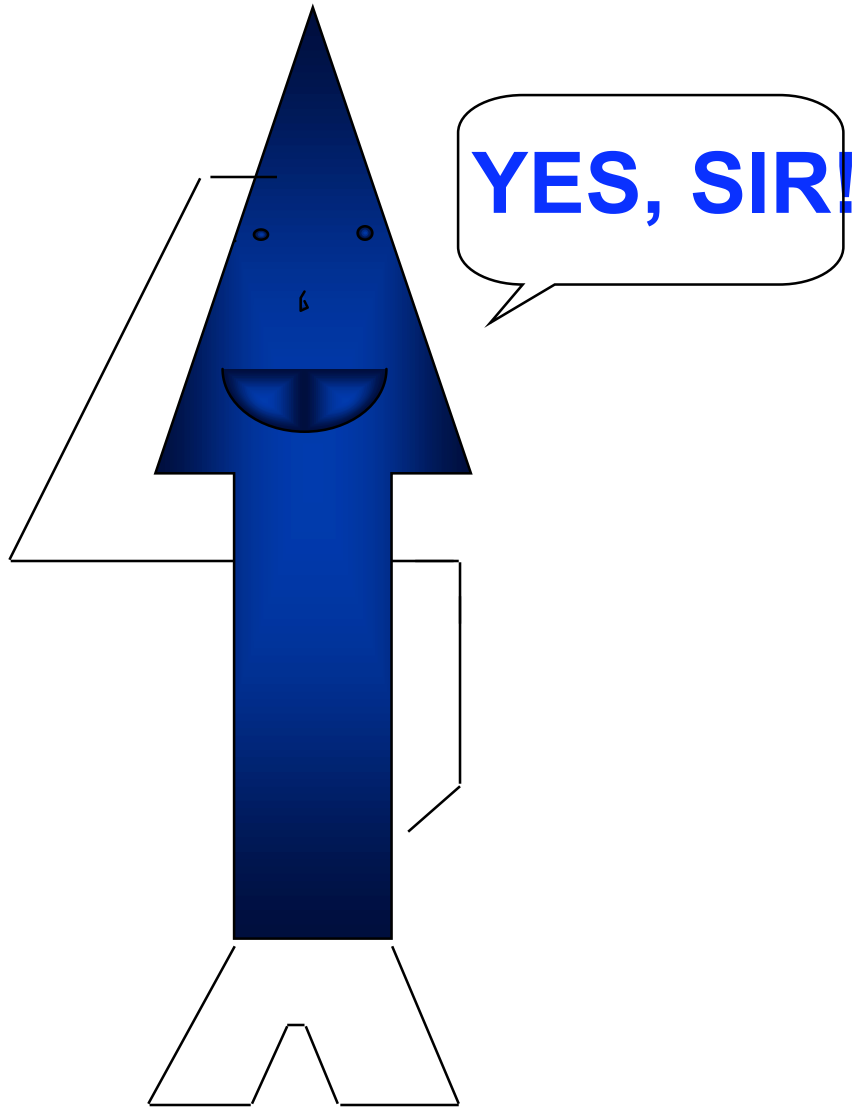
- The solution to pollution is dilution?
- Do you want to move a lot of air?
- What happens in the winter?
- How do you get a sweeping effect?
- Why bother with local exhaust if there are too many sources to vent them all?
- To have effective DV we need to:
  - Mix contaminated air with large volume of fresh air
  - Have sufficient air changes/hour to prevent build-up
  - Create air movement and mixing at all required locations

“Laminar” Flow Dilution System

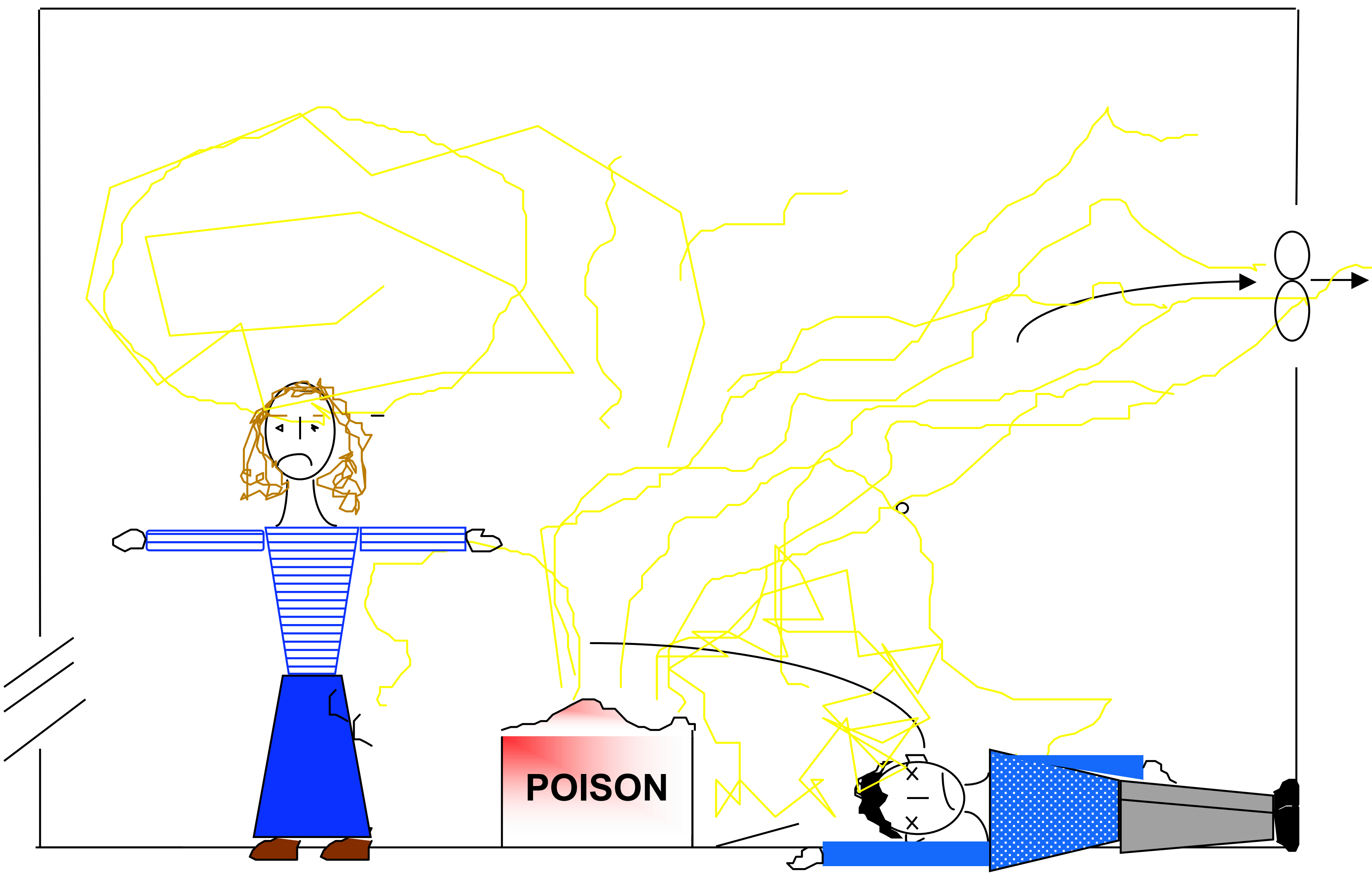




WITH ARROWS

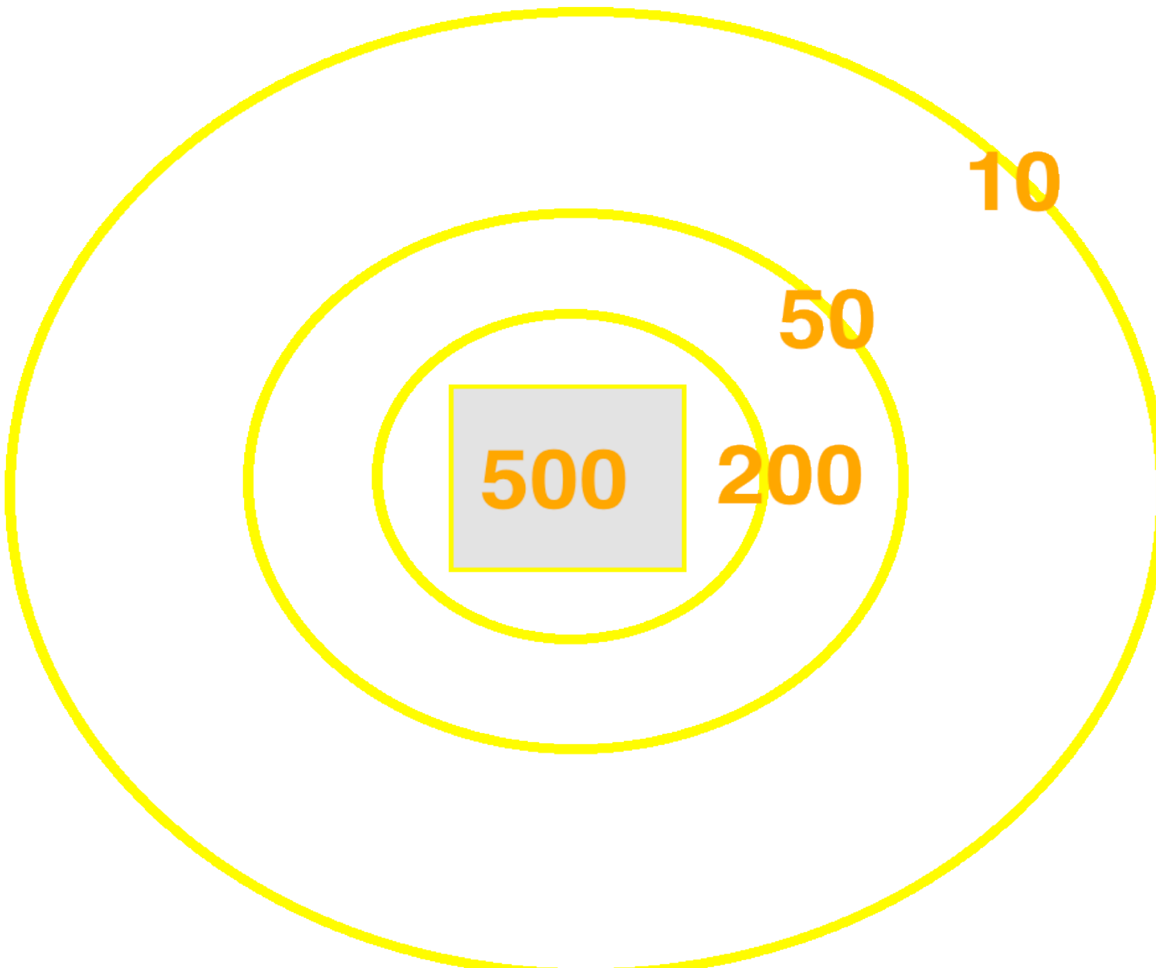


THE IMPORTANCE OF ARROWS



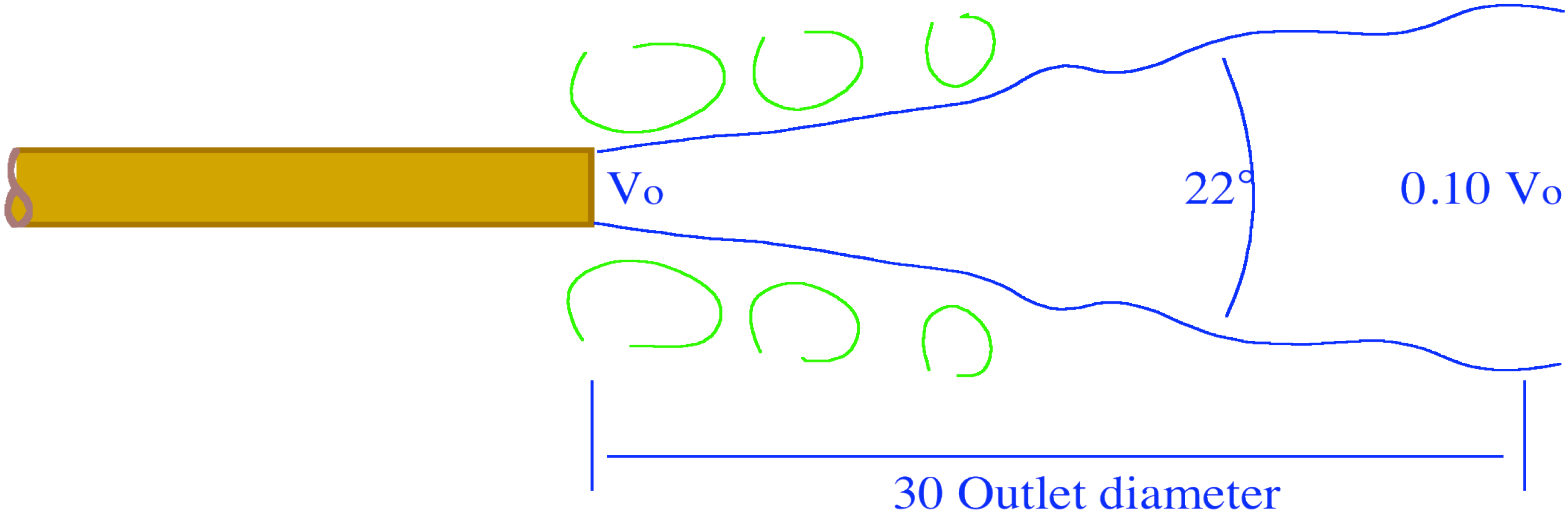
WITHOUT ARROWS

Distance from the source and concentration gradients When No Cross-Drafts Exists



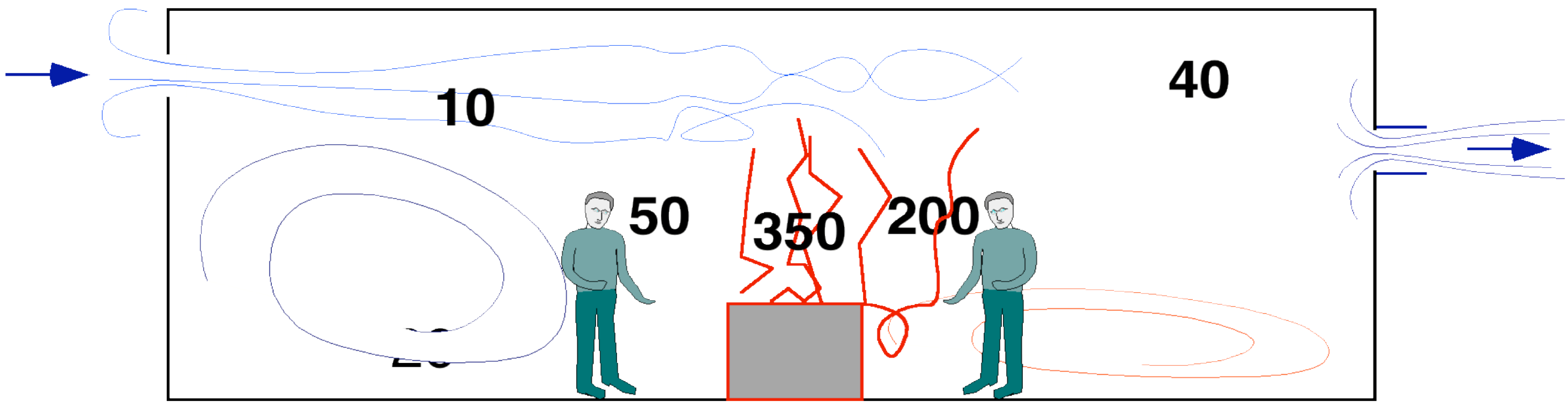
See Nicas: Am Ind Hyg Assoc J. 1996 Jun;57(6):542-50

Mixing by entrainment

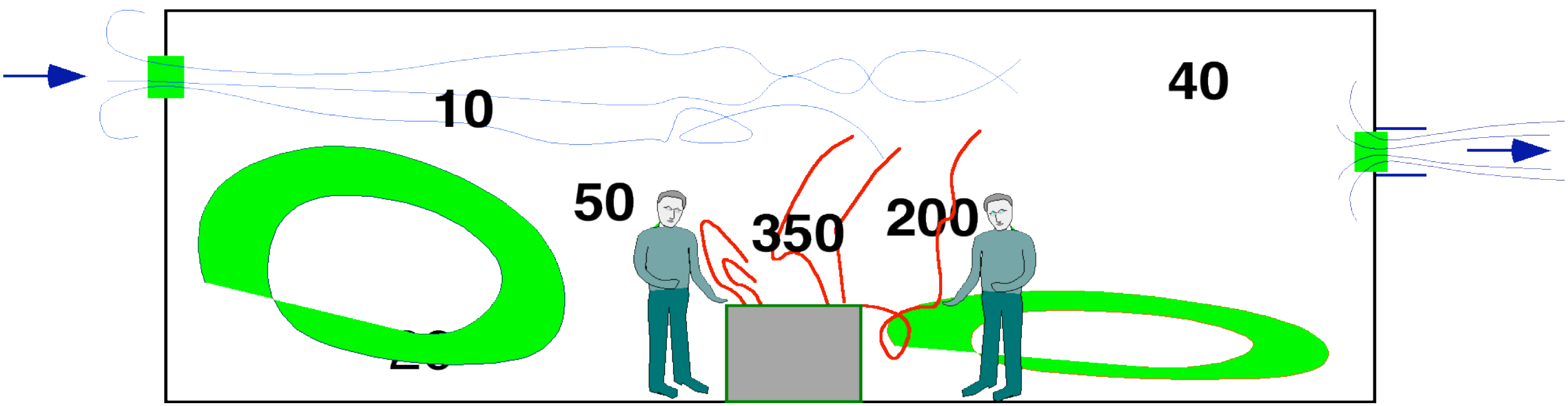


High velocity air entrains as much as 20 times its original volume.
Velocity falls to 10% at 30 diameters.

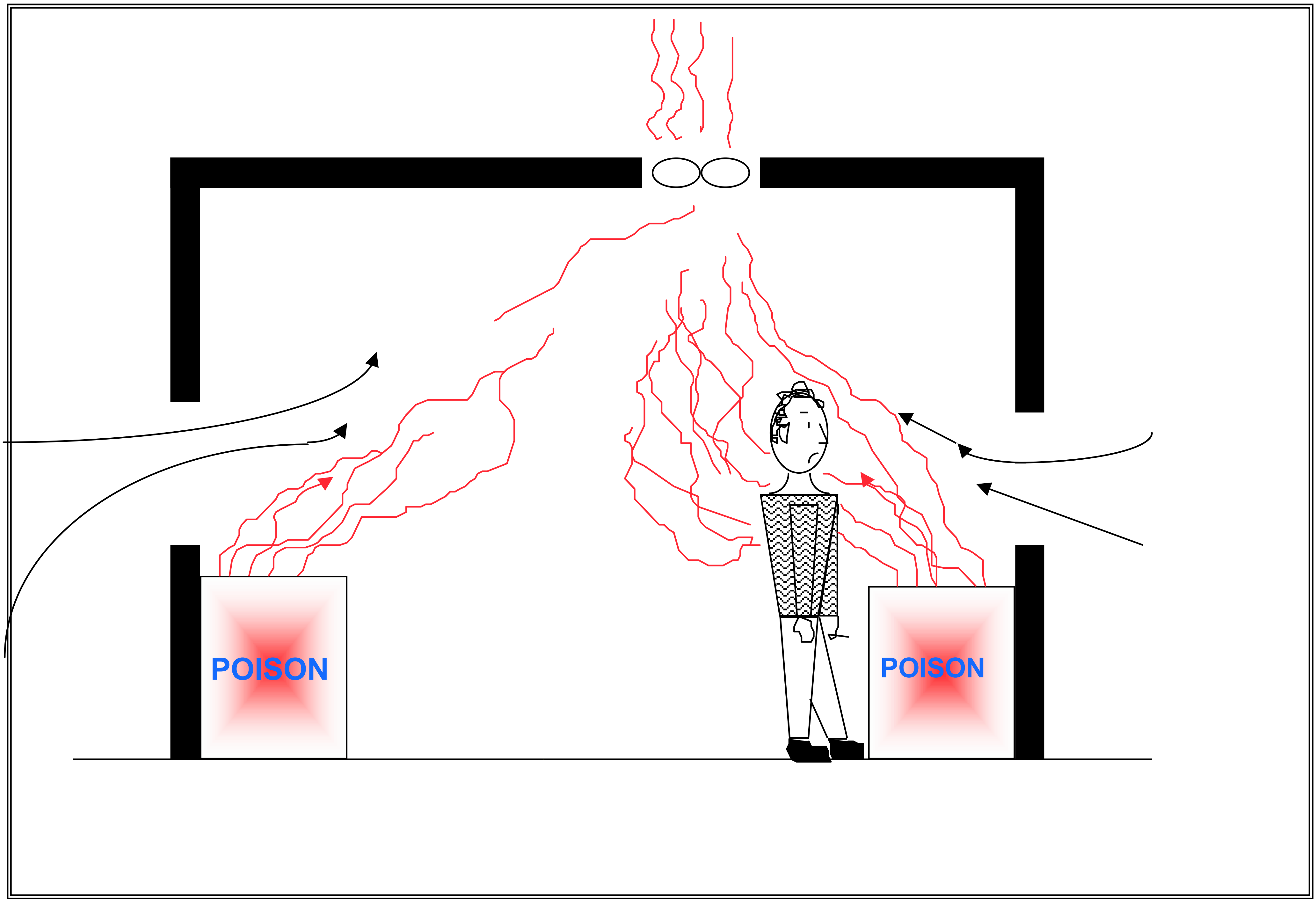
Interactive Effects of Cross-Drafts and Proximity to Exposure



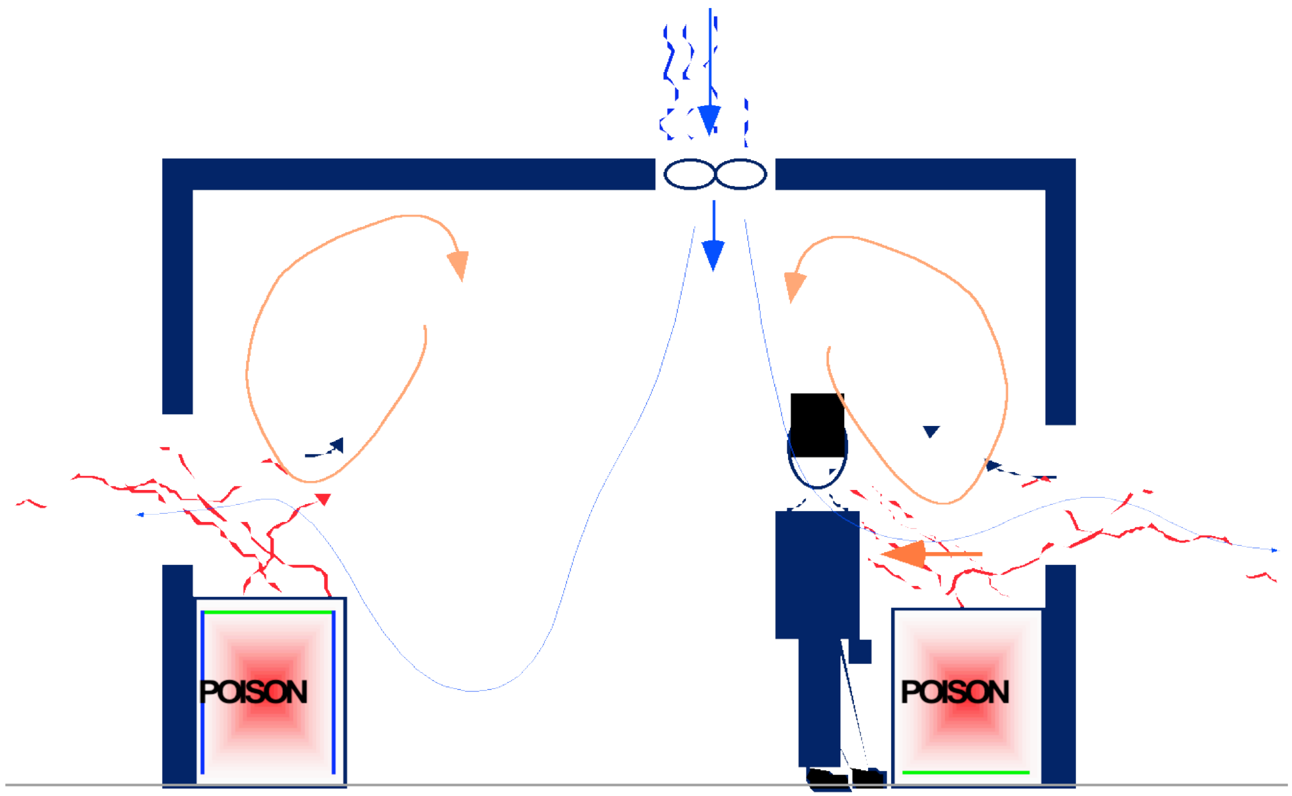
Effects of Cross-Drafts and Worker's Proximity to the Source



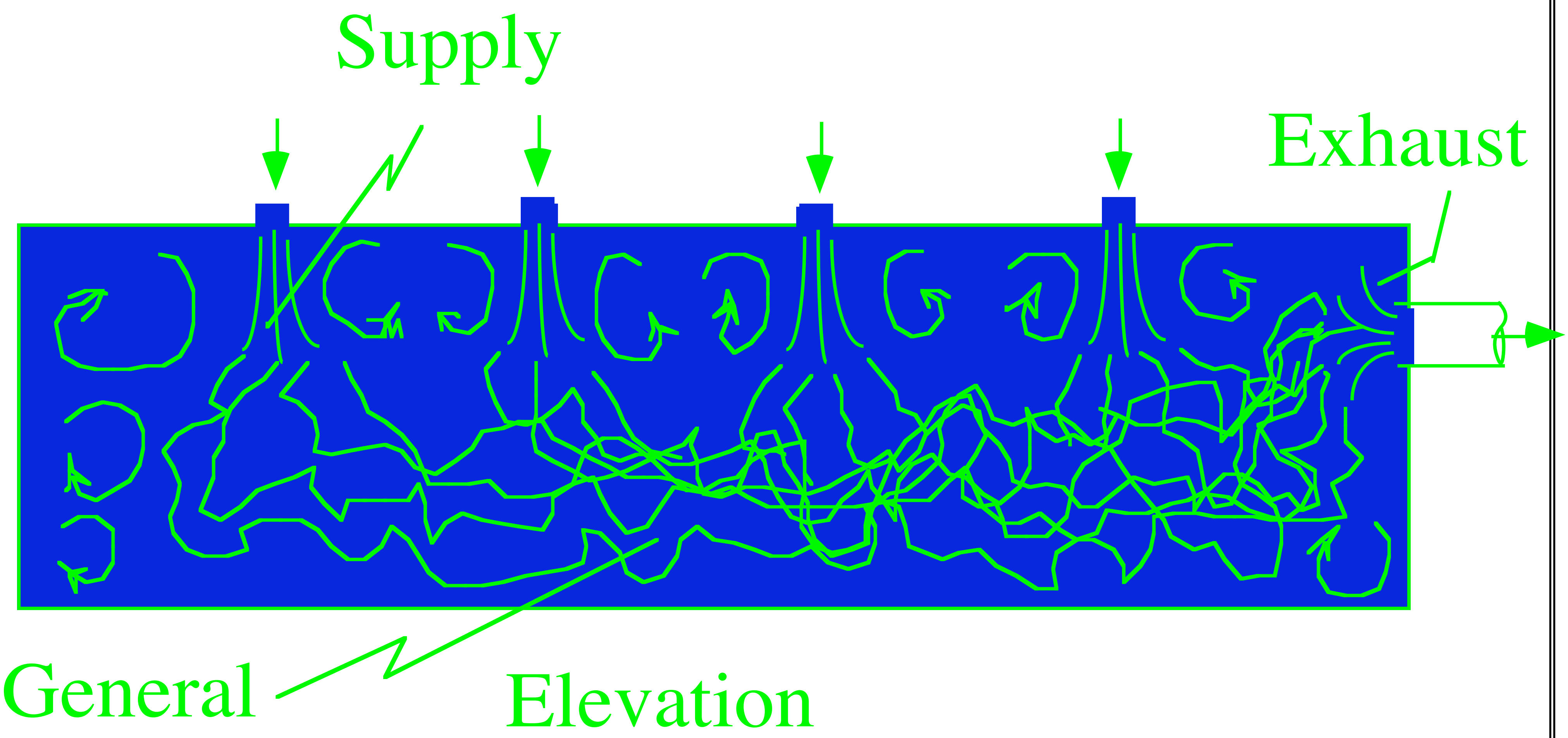
Wake zone downstream of body draws contaminant from source within hand's reach ("campfire" phenomenon)


POISON
POISON

Reverse the flow?



Zones of Ventilation



Blowing with entrainment produces large scale eddies & mixing

Computing Generation Rate

- We are concerned about dynamic conditions
- Assume constant generation rate

$$G = \frac{d\left(Vol_{vapor}\right)}{dt}$$

$$G = \frac{Amount\ \ Evaporated}{t_2 - t_1}$$

Calculating dilution volumes

$$VolumeCont = \frac{MassOfTheLiquid}{MassForOneMole} * VolumeForOneMole$$

$$VaporVol = \frac{MassOfTheLiquid}{MW} * 24.04\,L * \left(\frac{273.15C + T}{293.15}\right)\left(\frac{760_{mmHgO}}{P_{atm}}\right)$$

$$VaporVol = \frac{\left(sp.grav. * \rho_{H2O} * Vol_{liquid}\right)}{MW} * 24.04\,L * \left(\frac{273.15C + T}{293.15}\right)\left(\frac{760_{mmHgO}}{P_{atm}}\right)$$

Target Concentration

Toxicity	TLV ppm	C_t as a % TLV
highly toxic, radioactive or carcinogenic	< 20	local exhaust only
moderately toxic	20–100	25
somewhat toxic	100-200	50
slightly toxic	> 200	75

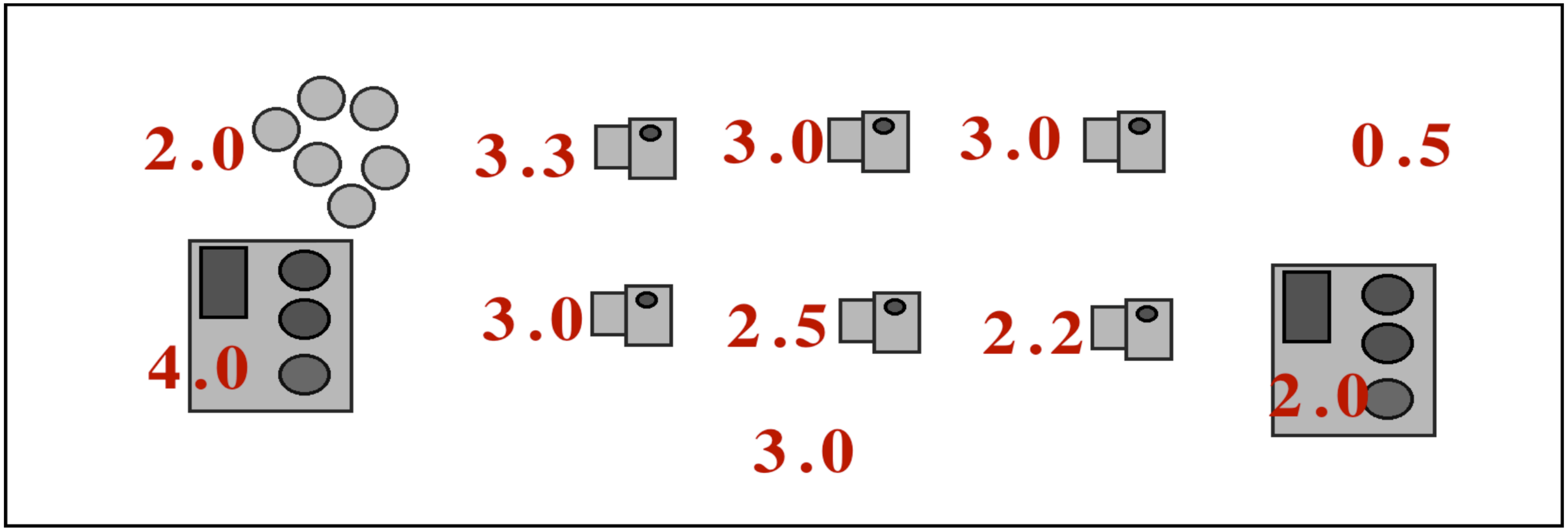
Concentration if perfect mixing

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

Concentration if not perfect mixing

$$C = \frac{G}{Q / m}$$

Values of m_i for each work station



Plan View

$$m_i = \frac{C_i}{C_{exhaust}}$$

m due to non-uniformity

- Supply air mixing
- Contaminant release
- Distance from worker

Mixing factors

$$m_i = \frac{C_i}{C_{exhaust}}$$

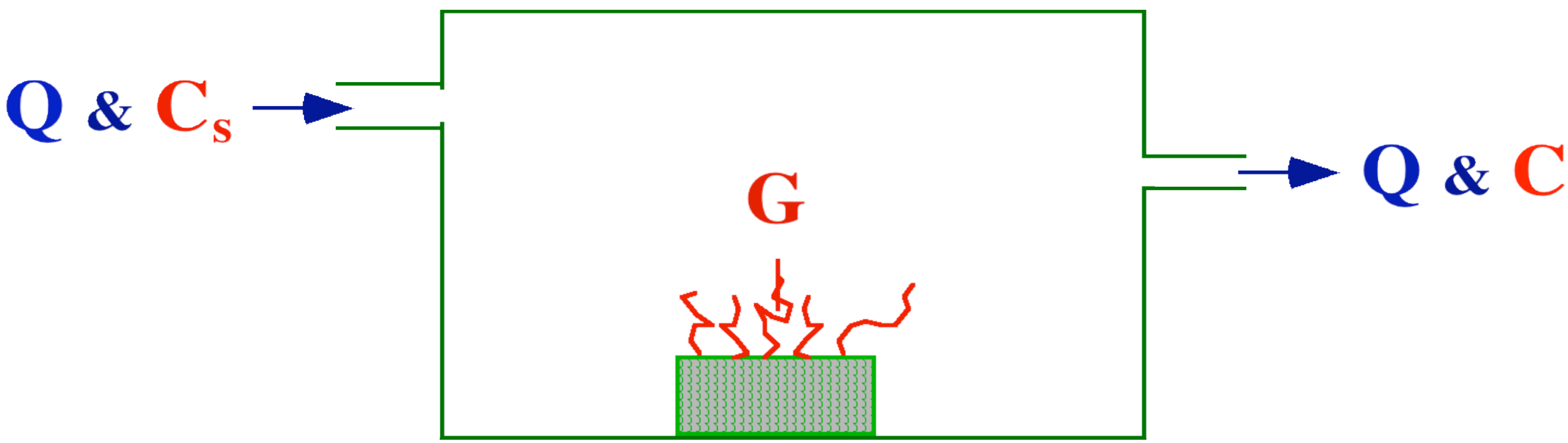
$$C_{avg} = \frac{1}{8\,hours} \sum_i^n C_i t_i$$

$$C_{avg} = \frac{C_{exhaust}}{8\,hours} \sum_i^n m_i t_i$$

$$M_{avg} = \frac{1}{8\,hrs} \sum_i^n m_i t_i$$

$$M_{peak} = \frac{\overline{C}_{15\,\mathrm{min}}}{C_{exhaust}}$$

Accumulation = Generation – Removal



$$V\frac{dC}{dt} = \left(G + \frac{Q}{m}C_s - \frac{Q}{m}C_t\right)$$

$$C_2 = C_1 e^{-Qt/mV} + \left(\frac{mG}{Q} + C_s\right)\left(1 - e^{-Qt/mV}\right)$$

ROOM VOLUME

$$C_2 = C_1 e^{-Qt/mV} + \left(\frac{mG}{Q} + C_s \right) \left(1 - e^{-Qt/mV} \right)$$

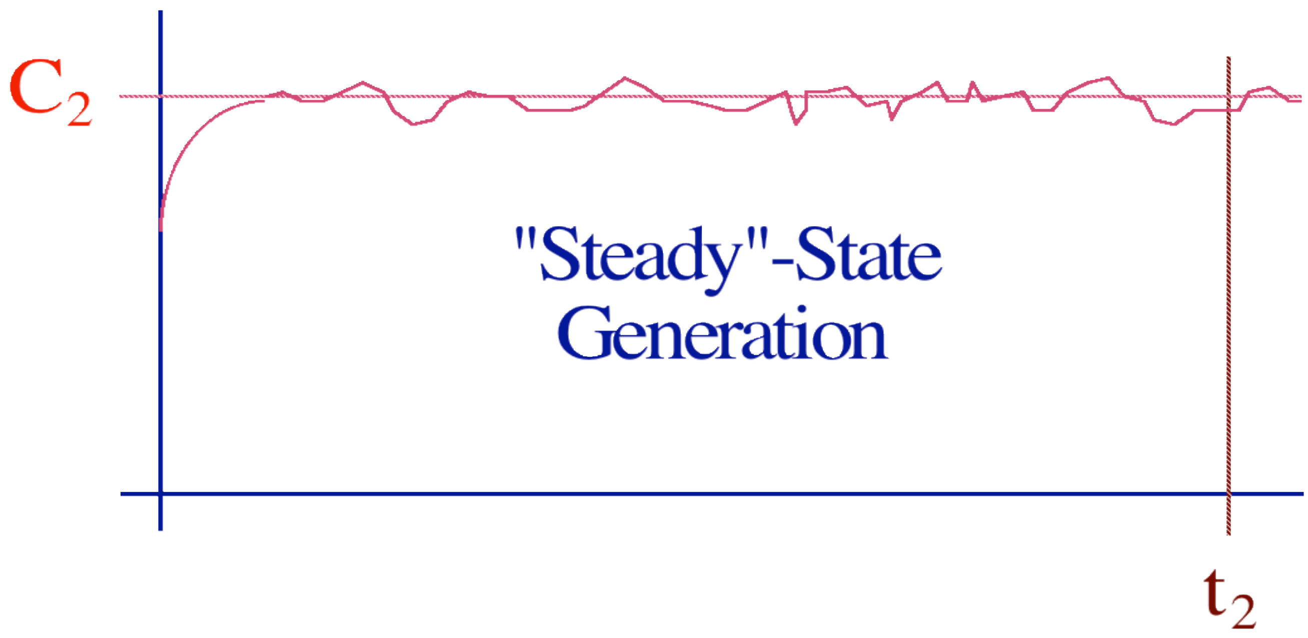
Important for transient conditions
Irrelevant for steady state

$$C_t = \frac{mG}{Q}$$

Application of Equations

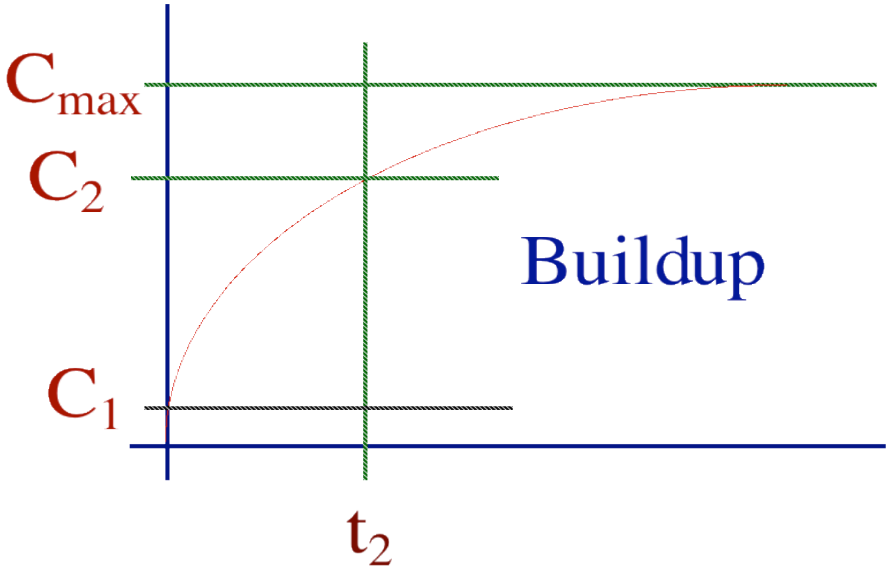
$$C_2 = C_1 e^{-Qt/mV} + \left(\frac{mG}{Q} + C_s \right)\left(1 - e^{-Qt/mV}\right)$$

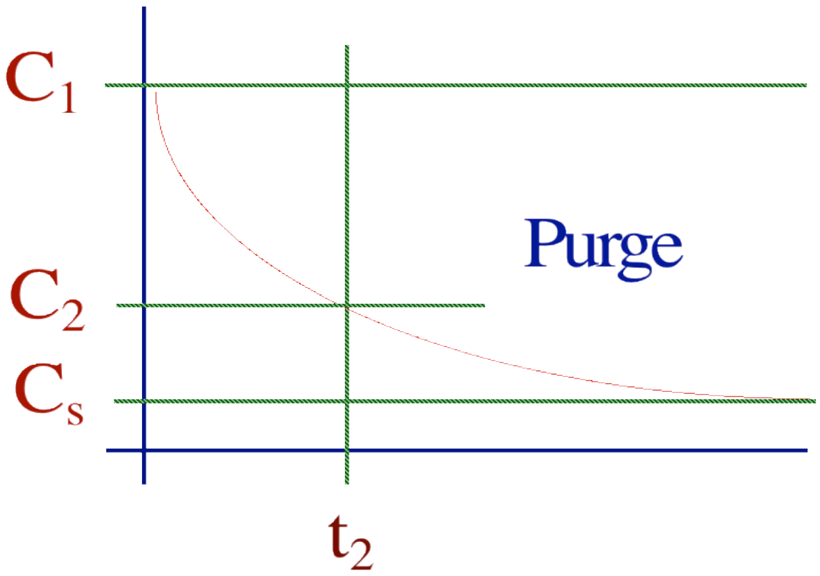
$$C_t = \frac{mG}{Q}$$



Application of Equations

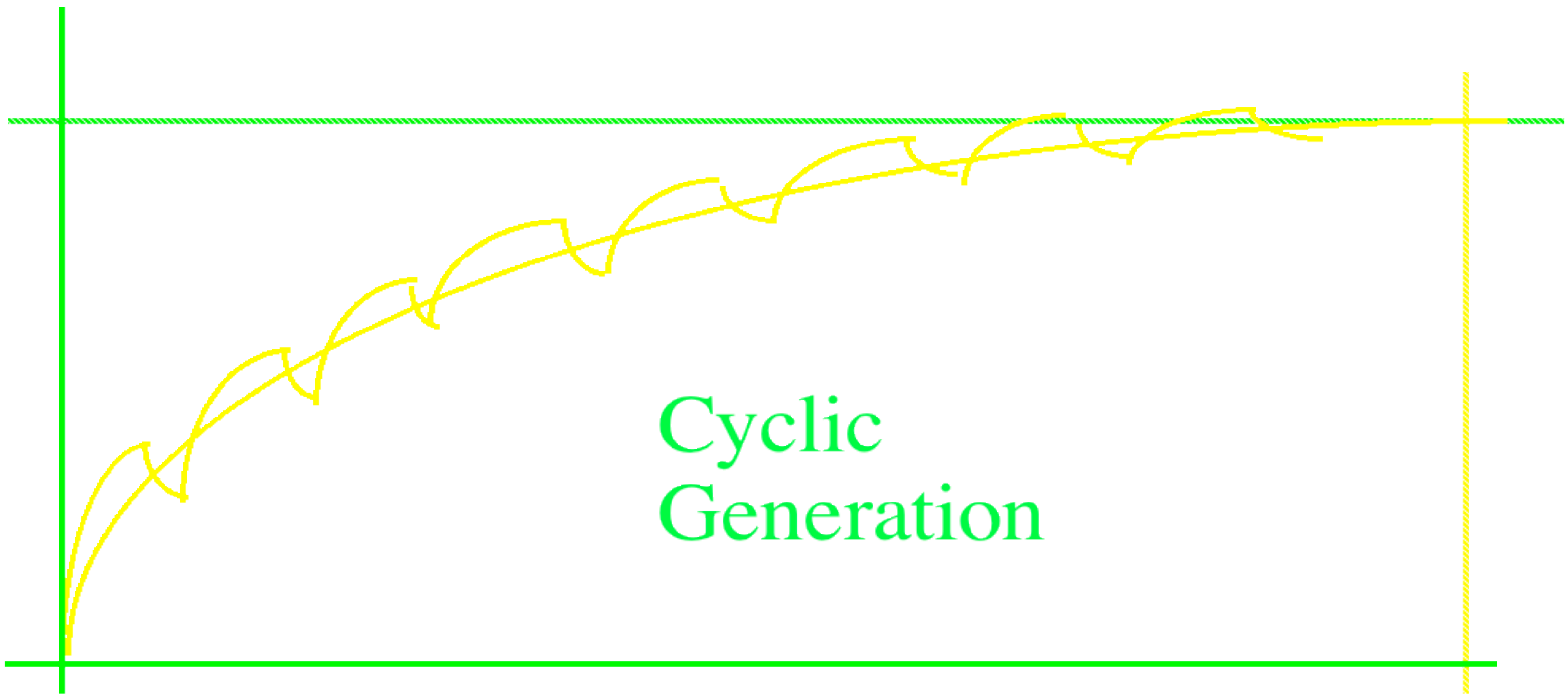
$$C_2 = C_1 e^{-Qt/mV} + \left(\frac{mG}{Q} + C_s \right) \left(1 - e^{-Qt/mV} \right)$$





Cyclic operations

- If short cycles, effects "average out"



When conditions change with time

- Solve for time interval during which all conditions are constant
- If conditions change continuously, make interval one minute
- Use result as initial conditions for next interval

$$C_2 = C_1 e^{-Qt/mV} + \left(\frac{mG}{Q} + C_s \right)\left(1 - e^{-Qt/mV}\right)$$

DESIGNING NEW SYSTEM

Locate sources near exhaust fans

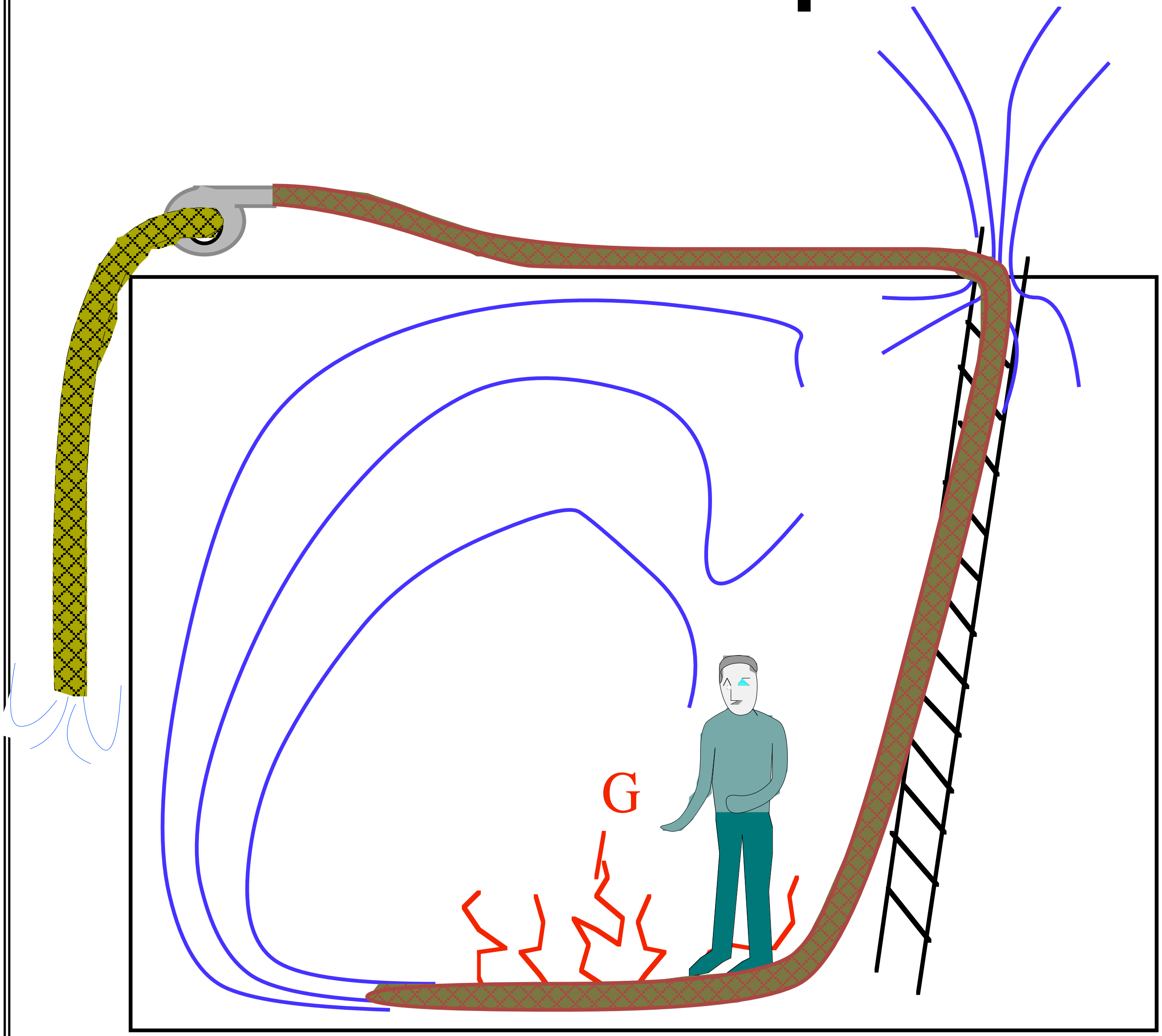
- ❑Locate supply air outlets to direct air away from face and towards exhaust fans
- ❑Separate sources from traffic using barriers
- ❑Block undesirable cross drafts and competing sources of motion using barriers.

EXISTING SYSTEM IMPROVEMENTS

- ❑Substitute less volatile or toxic chemicals
- ❑Install or improve local exhaust hoods
- ❑Reduce incidence of spills and leaks
- ❑Relocate supply and exhaust points
- ❑Relocate workers or the sources — or both
- ❑Increase airflow

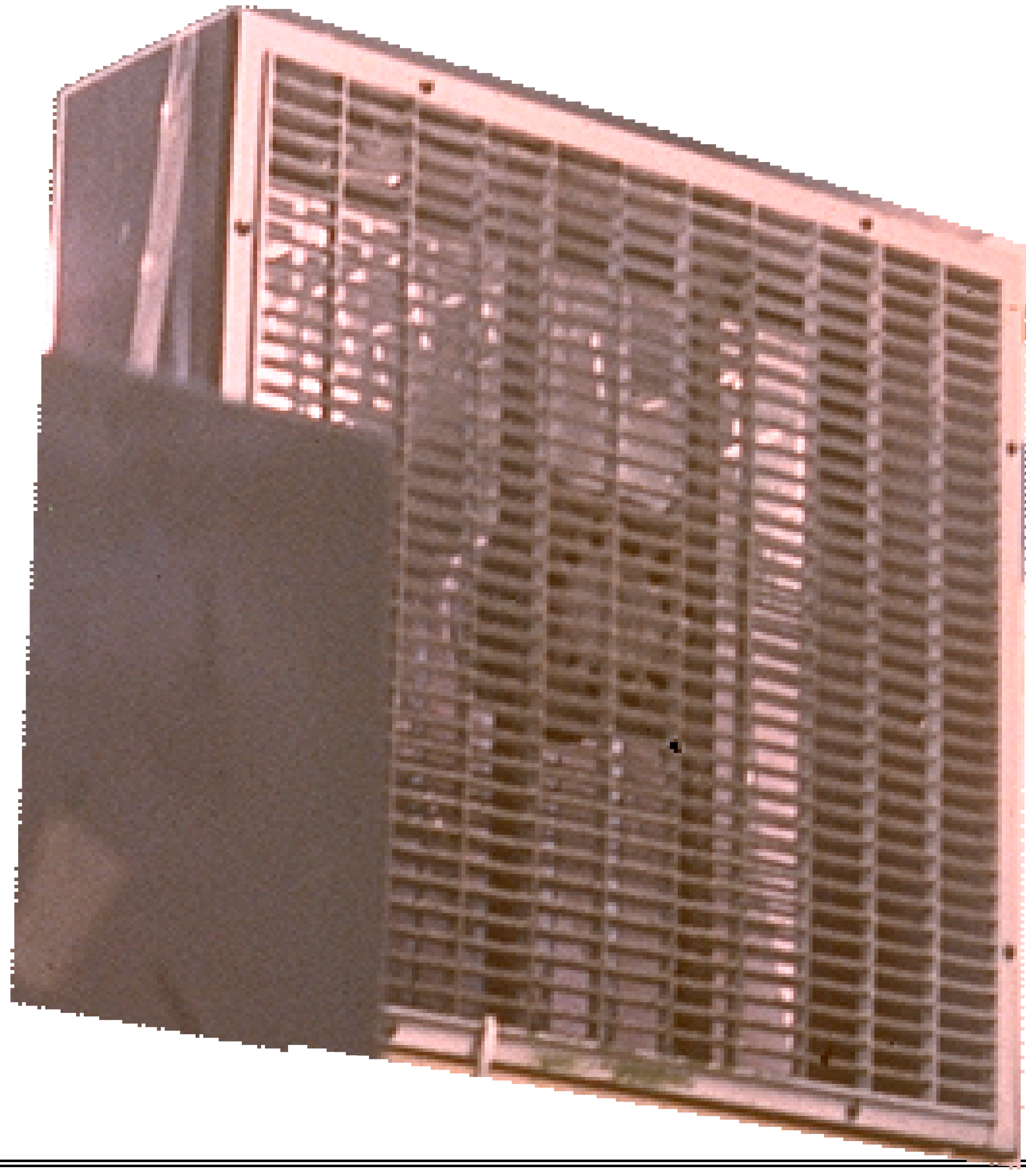
Confined Space Ventilation

Confined Space Ventilation



- Drain before purging
- Lock out
- Purge before entering
- Blow air in; don't suck it out
- Move nozzle around
- Measure before entering
- Purge during work

Purging fans

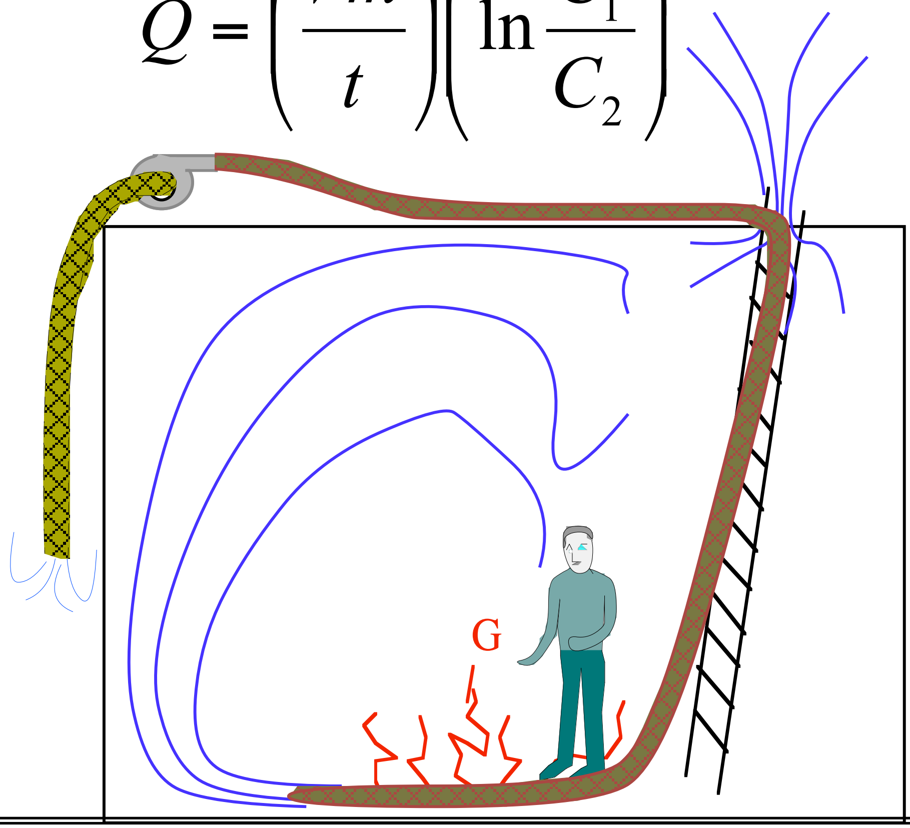


Confined Space Ventilation-Purge Time

If supply air clean, then:

$$t = \left(\frac{Vm}{Q}\right)\left(\ln\frac{C_1}{C_2}\right)$$

$$Q = \left(\frac{Vm}{t}\right)\left(\ln\frac{C_1}{C_2}\right)$$



- Should be computed
- Then test against measurements
- Wait minimum time even if measurement says okay
- Time less with bigger blower
- Bigger blower more costly, harder to manuever

Example Problem

Initial measurements indicate 10,000 ppm of xylene in a confined space. Assuming that Ct = 0.25 * TLV, how much should Q be to allow entry in 30 minutes if:

a. $R=1000\ ft^3$, M=3, $C_s = 0$

$$Q = \left(\frac{Rm}{\Delta t}\right) \ln\left[\frac{G + QC_s/m - Q\,C_o/m}{G + Q\,C_s/m - Q\,C_2/m}\right] = \left(\frac{1000\,ft^3 * 3}{30\,\text{min}}\right) \ln\left[\frac{010^{-2}}{025 * 10^{-6}}\right] = 599\ \text{ft3/min}$$

b. $R=2000\ ft^3$, M=3, $C_s = 0$: Solution: Q = 1198 ft3/min

c. $R=1000\ ft^3$, M=6, $C_s = 0$: Solution: Q = 1198 ft3/min

d. $R=1000\ ft^3$, M=6, $C_s = 15$ ppm: Solution: Q = 1381 ft3/min

Summary

- Estimating G and m is difficult
- Reduce G as much as possible
- Reduce greatest contributors to exposure and perceived exposure first
- Use sweeping, but be realistic about it
- Complement local exhaust systems
- Provide winter and summer
- Purge before and during confined space entry