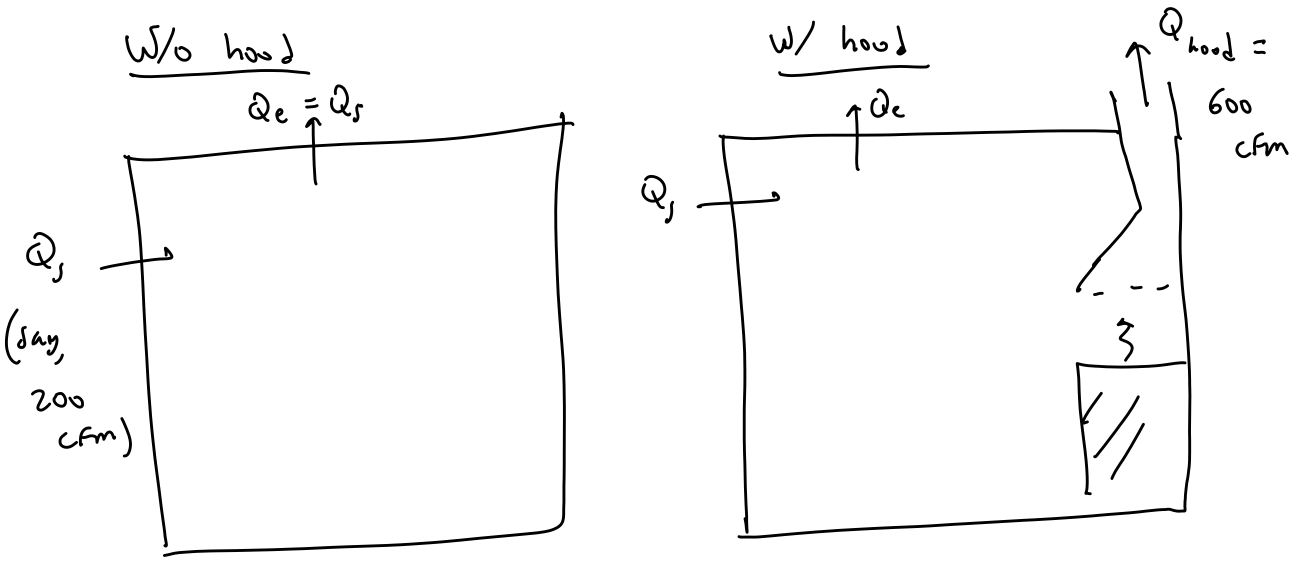
ME 405 Fall 2006 Professor John M. Cimbala Lecture 26 11/06/2006

Today, we will:

- Discuss the influence of local ventilation on general ventilation
- Discuss **Control of Vapors from Open Surface Vessels** in **Section 6.2**
- Do some example problems – capture of vapors
- Discuss **Design Plates** and the **ACGIH Ventilation Manual** in **Section 6.3**
- If time, discuss **Bulk Materials Handling** in **Section 6.4**

Influence of local ventilation (hood) on general ventilation (overall room)



What happens? – either Q_s must increase significantly

[Q_s = 600 cfm if $Q_e = 0$]

– or Q_e can become ⊖ve

[draw in exhaust air from other rooms]

– or lots of infiltration (under doors, etc.)

[room will be at a negative pressure]

SEC 6.2 Control of vapors

Design of hoods for vapors is different than design of hoods for particles

Control of particles → use capture velocity V_c

→ match V_c to the local U required

→ Generate required Q using isopleths

Control of vapors → use control velocity = a design parameter

[no symbol for control velocity]

Control Velocity → a concept introduced by ACGIH

used for design of hoods

→ match control velocity of the process to the control velocity of the hood ☆

4 Steps:

- Step 1 - Determine the hazard potential

— A letter A, B, C, D based on the hazard of the chemical.

☆ THE LOWER THE LETTER, THE MORE HAZARDOUS

☆ Choose the worst case   See Table 6.2 (top)

- Step 2 - Determine the rate of contaminant evolution

— A number from 1–4 based on the temperature & boiling point of the liquid

☆ Choose the worst case

☆ The lower the number, the higher the risk   See Table 6.2 (bottom)

Table 6.2 Hazard potential and rate of contaminant evolution (abstracted from ACGIH, 2001).

hazard potential	health standard for gas or vapor (PPM)	health standard for mist (mg/m^3)	flash point (°F)
A	0 to 10	0 to 0.1	-
B	11 to 100	0.11 to 1.0	under 100
C	101 to 500	1.1 to 10	100 to 200
D	over 500	over 10	over 200

rate	liquid temperature (°F)	degrees below boiling (°F)	evaporation time[1] (hr)	gassing[2]
1	over 200	0 to 20	0 to 3 (fast)	high
2	150 to 200	21 to 50	3 to 12 (medium)	medium
3	94 to 149	51 to 100	12 to 50 (slow)	low
4	under 94	over 100	over 50 (nil)	nil

[1] time for 100% evaporation
[2] extent to which gas or vapor are generated: rate depends on the physical process and the solution concentration and temperature

Define the class as the combination of the two. eg. class A2, C1, D3, etc.

Step 3: Determine the control velocity in FPM (ft/min)

See Table 6.3

Table 6.3 Minimum control velocities (FPM) for undisturbed locations (abstracted from ACGIH, 2001).

class	enclosing hood: 1 side open	enclosing hood: 2 sides open	lateral hood[1]	canopy hood[4]: 3 sides open	canopy hood[4]: 4 sides open
A1[2], A2[2]	100	150	150	do not use	do not use
A3[2], B1, B2, C1	75	100	100	125	175
B3[3], C2[3], D1[3]	65	90	75	100	150
A4[2], C3[3], D2[3]	50	75	50	75	125
B4, C4, D3[3], D4	adequate general room ventilation required				

[1] use Table 6.4 to compute the volumetric flow rate
[2] do not use a canopy hood for hazard potential A processes
[3] where complete control of hot water is desired, design as next highest class
[4] use Q = 1.4(PD) control velocity, where P is hood perimeter and D is distance between vessel and hood face (27)

Step 4: Determine minimum recommended Q, the volume flow rate Based on control velocity

See Table 6.4

Table 6.4 Minimum volumetric flow rates per unit surface area (CFM/ft^2) for lateral exhaust systems (abstracted from ACGIH, 2001).

control velocity (FPM)	**[2]aspect ratio = tank width/tank length (W/L)**				
	0 - 0.09	**0.1 - 0.24**	**0.25 - 0.49**	**0.5 - 0.99**	**1.0 - 2.0**
			tank against wall or baffled[1]		
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	250[3]	250[3]
			free-standing tank[1]		
50	75	90	100	110	125
75	110	130	150	170	190
100	150	175	200	225	250
150	225	250[3]	250[3]	250[3]	250[3]

[1] use half width to compute W/L for inlet along tank centerline or two parallel sides of tank

[2] inlet slot along the long side (L); if 6 < L <10 ft, multiple takeoffs are desirable; if L > 10 ft, multiple takeoffs in plenum are necessary if:

- W = 20 inches: slot on one side is suitable
- 20 <W <36 inches: slots on both sides are desirable
- 36 <W <48 inches: slots on both sides are necessary unless all other conditions are optimum
- W > 48 inches: lateral exhausts are not usually practical, use push-pull or enclosures
- it is undesirable to use lateral exhaust when W/L > 1 and not practical when W/L > 2

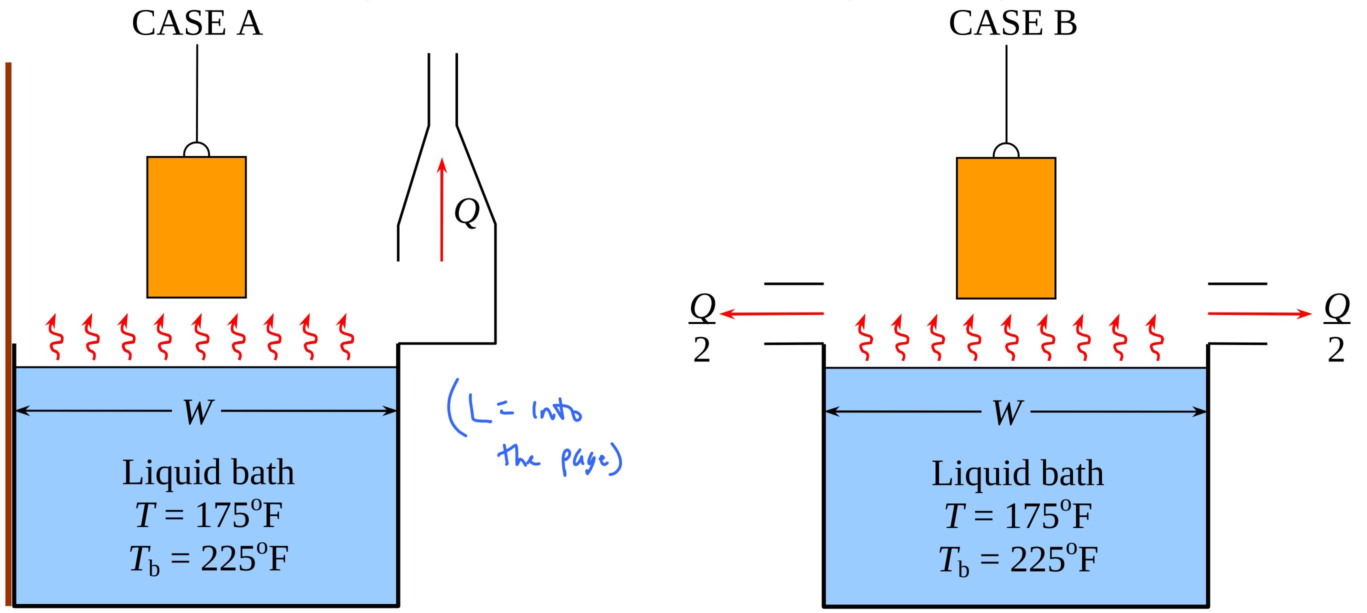
[3] while control velocities of 150 FPM may not be achieved, 250 CFM/ft^2 is considered adequate for control

Example (Example 6.3 in text – Pickling Copper in Sulfuric Acid)

Given: Copper plates are dipped from above into a tank of water and sulfuric acid. The tank is 10.0 ft long and 3.0 ft wide. The bath temperature is 175°F, and generates acid mist fumes. The liquid mixture boils at 225°F.

To do: Compare the required volume flow rate for:

- Case A: tank against a room wall, with a lateral exhaust on one side
- Case B: free-standing tank with lateral exhausts along both long sides of the tank



Solution:

Note: Difficult to capture acid mist in either case due to the candle effect

Step 1: Look up PEL → sulfuric acid mist → PEL = 1 mg/m³

Table 6.2 → B

Step 2: Table 6.2 (lower) — $T = 175°F$, $T_{boil} = 225°F$ } $\Delta T = 50°F$

[E.g. Suppose $T = 170°F$ → $\Delta T = 225 - 170 = 55°F$

ΔT → rate 3
T → rate 2 } would pick the lower one = 2]

Step 3 → Table 6.3 → @ B2 ; lateral hood → capture velocity = 100 FPM

Step 4: Table 6.4

CASE A — tank against a wall, suction one side only

@ control vel of 100 FPM

$$\text{Aspect ratio} = \frac{W}{L} = \frac{3\text{ ft}}{10\text{ ft}} = 0.30 \rightarrow \text{get } Q/A = 150\ \text{cfm}/\text{ft}^2$$

$$Q = (Q/A)A = \left(150\ \frac{\text{ft}^3}{\text{min ft}^2}\right)(10\text{ ft})(3\text{ ft}) = \boxed{4500\text{ cfm}}$$

CASE B Free standing tank, lateral hood on both sides

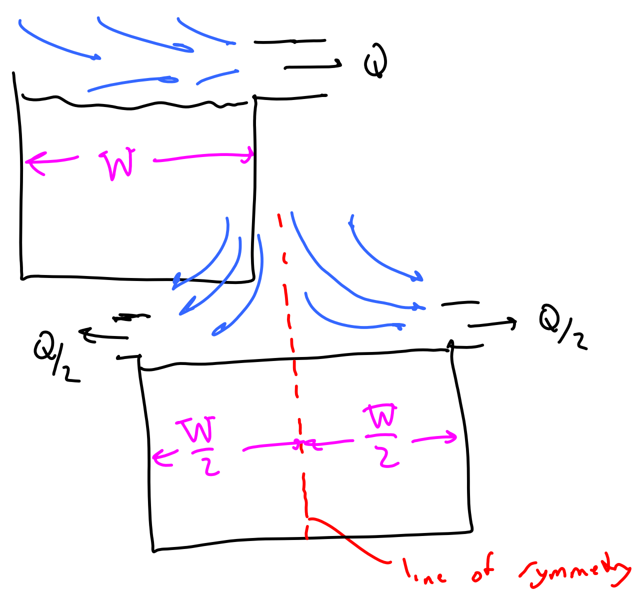
Step 3 – Table 6.3 → control velocity = 100 fpm as previously

Step 4 – Table 6.4 → see footnote 1

Use ½ of W/L for the aspect ratio

one side

two sides:



Use the real A, not half of A here

THIS IS THE TOTAL Q, NOT JUST ONE SIDE

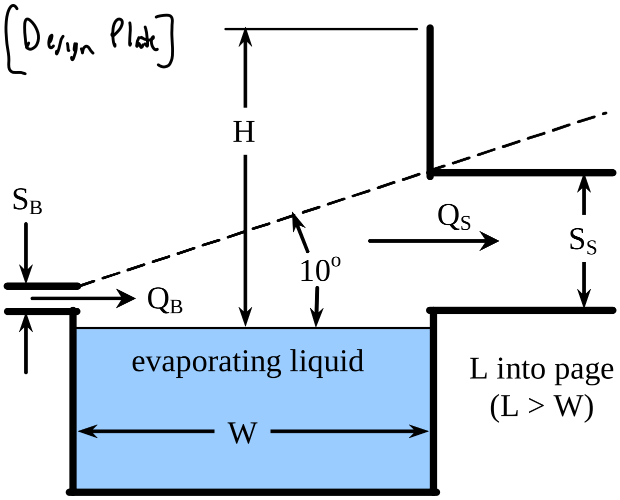
$$\text{Aspect ratio} = \frac{W/2}{L} = 0.15$$

Table 6.4, free standing @ aspect ratio of 0.15 & control vel. of 100 FPM } $Q/A = 175\ \frac{\text{cfm}}{\text{ft}^2}$

$$Q = (Q/A)A = \left(175\ \text{cfm}/\text{ft}^2\right)(3 \times 10\text{ ft}^2) = \boxed{5300\text{ cfm}}$$

Push-pull system:

[Design Plate]



blowing jet area (A_B, ft^2)
blowing plenum cross sectional area > $3A_B$
blowing slot width (S_B, in): $1/8" \le S_B \le 1/4"$ or, 1/4" diameter holes, spaced holes 3/4" to 2" apart
blowing volumetric flow rate: $Q_B/L = 243(A_B/L)^{0.5}$ ACFM/ft, where A_B/L is in units of (ft^2/ft)
suction opening: $A_S = LS_S$ ft^2
suction slot width: $S_S = 0.14W$
suction volumetric flow rate: depends on liquid temperature, i.e.
$T \le 150$ °F, $Q_S/LW = 75.$ ACFM/ft^2
$T > 150$ °F, $Q_S/LW = [0.40T(°F) + 15.]$ ACFM/ft^2

Figure 6.13 Push pull ventilation system for an open surface vessel for widths up to 10 ft (abstracted from ACGIH, 1988 and 1998).

Some disadvantages:
- Extra wind causes increase in evaporation rate!
- more equip (blower + suction device)
- could blow up into air if not working properly
- More limited access

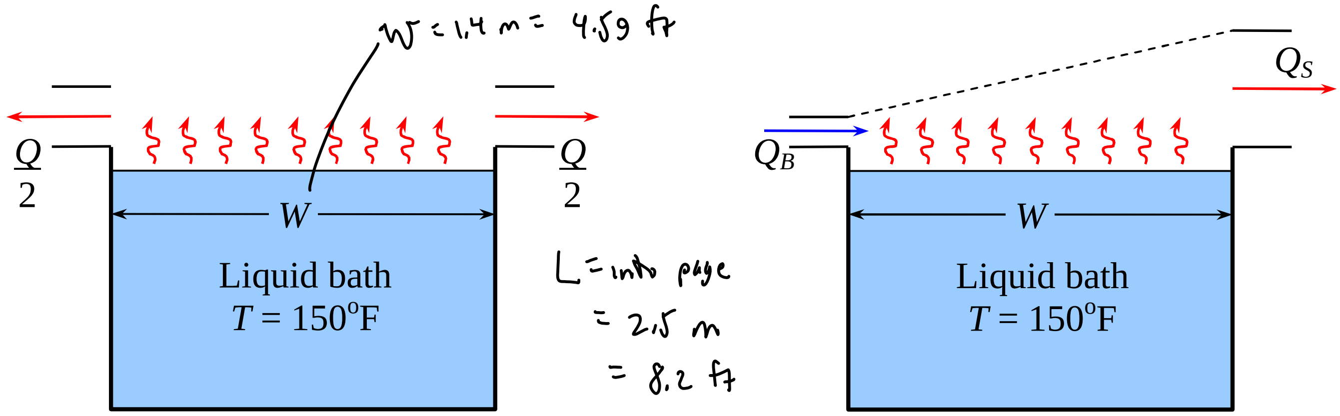
advantages. — can provide for less required suction Q_s

Example (Example 6.4 in text – Control of Vapor from an Open Vessel)

Given: A free-standing tank containing liquid trichloroethylene (TCE) at 150°F is used for degreasing operations. The tank is 1.4 m wide and 2.5 m long.

To do: Compare the required volume flow rate for:

- Case A: free-standing tank with lateral exhausts along both long sides of the tank
- Case B: push-pull system, as in Fig. 6.13



Solution:

MSDS → PEL = 100 ppm

Boiling temp $T_{boil} = 87°C = 189°F$

$\therefore \Delta T = 189 - 150 = 39°F$ below boiling

Table 6.2 → class **B2**

Table 6.3 → control velocity for a lateral hood = 100 fpm

Table 6.4 → Use Aspect ratio $= \frac{W/2}{L} = 0.28$

$Q/A = 200 \text{ cfm/ft}^2$

$Q = (Q/A)(A) = 7528 \text{ cfm} \approx$ **7500 cfm**

$A = (4.59 \text{ ft})(8.2 \text{ ft})$

CASE B: Push-Pull System

Choose $\frac{1}{4}'' = S_B$

$Q_B/L = 243\left(\frac{A_B}{L}\right)^{0.5}$ in units of cfm/ft

A_B = area of blowing jet $= \delta_B \cdot L$

$Q_B = 287.6$ cfm or $\boxed{Q_B = 290 \text{ cfm}}$ Blowing

δ_s = suction slot width $= 0.14\, W = \approx \underline{\underline{8''}}$

$\underline{Q_s = 75\, LW}$ since $T \leq 150°F$

$= 75\,(8.2 \text{ ft})(4.59 \text{ ft}) \rightarrow \boxed{Q_s = 2800 \text{ cfm}}$

Q_s Less than half of Q for lateral suction

Bottom line → Q_s (suction vol. flow rate) is significantly less the push-pull system, but there are disadvantages, as discussed above.

→ So, there is always a trade-off !