Today, we will:

- Do an example problem – lateral hood design for removing vapors
- Discuss **Push-Pull** systems and do an example problem
- Briefly discuss **Design Plates** [Section 6.3] and the **ACGIH Ventilation Manual**
- Briefly discuss **Bulk Materials Handling** [Section 6.4]
- Do **Candy Questions for Candy Friday**

**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:**

**Step 1** – Use Table 6.2 to get the hazard potential (letter). This is letter B.

**Step 2** – Use Table 6.2 to get the hazard rate (number). This is number 2.

So… **the class is B2**.

**Step 3** – Use Table 6.3 to get the control velocity. The **control velocity is 100 FPM**.

**Step 4** – Use Table 6.4 to get \( \frac{Q}{A} \) in units of \( \text{ft}^3/(\text{min} \cdot \text{ft}^2) \):

- Case A has aspect ratio = \( \frac{W}{L} = \frac{3.0 \text{ ft}}{10.0 \text{ ft}} = 0.30 \)
- Case B has aspect ratio = \( \frac{(W/2)}{L} = \frac{1.5 \text{ ft}}{10.0 \text{ ft}} = 0.15 \) (see footnote 1)

(see tables on next pages)
Case A: lateral hood on one side, tank up against a wall.

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

<table>
<thead>
<tr>
<th>hazard potential</th>
<th>health standard for gas or vapor (PPM)</th>
<th>health standard for mist (mg/m³)</th>
<th>flash point (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 to 10</td>
<td>0 to 0.1</td>
<td>-</td>
</tr>
<tr>
<td>(B)</td>
<td>11 to 100</td>
<td>0.11 to 1.0</td>
<td>under 100</td>
</tr>
<tr>
<td>C</td>
<td>101 to 500</td>
<td>1.1 to 10</td>
<td>100 to 200</td>
</tr>
<tr>
<td>D</td>
<td>over 500</td>
<td>over 10</td>
<td>over 200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>rate</th>
<th>liquid temperature (°F)</th>
<th>degrees below boiling (°F)</th>
<th>evaporation time¹ (hr)</th>
<th>gassing²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>over 200</td>
<td>0 to 20</td>
<td>0 to 3 (fast)</td>
<td>high</td>
</tr>
<tr>
<td>2</td>
<td>(150 to 200)</td>
<td>21 to 50</td>
<td>3 to 12 (medium)</td>
<td>medium</td>
</tr>
<tr>
<td>3</td>
<td>94 to 149</td>
<td>51 to 100</td>
<td>12 to 50 (slow)</td>
<td>low</td>
</tr>
<tr>
<td>4</td>
<td>under 94</td>
<td>over 100</td>
<td>over 50 (nil)</td>
<td>nil</td>
</tr>
</tbody>
</table>

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

\[ T = 175^\circ F \]
\[ T_{boil} = 225^\circ F \]
\[ \Delta T = 50^\circ F \]
\[ H_k = B_2 \]

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

<table>
<thead>
<tr>
<th>class</th>
<th>enclosing hood</th>
<th>lateral hood¹</th>
<th>canopy hood⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 side open</td>
<td>2 sides open</td>
<td>3 sides open</td>
</tr>
<tr>
<td>A¹, A²</td>
<td>100</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>open</td>
<td>open</td>
<td>open</td>
</tr>
<tr>
<td>A³, A¹ (B², C¹)</td>
<td>75</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>B³, C², D¹³</td>
<td>65</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>A⁴, C³, D²³</td>
<td>50</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>B⁴, C⁴, D³³, D⁴</td>
<td>adequate general room ventilation required</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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)
Table 6.4  Minimum volumetric flow rates per unit surface area (CFM/ft²) for lateral exhaust systems (abstracted from ACGIH, 2001).

<table>
<thead>
<tr>
<th>control velocity (FPM)</th>
<th>aspect ratio = tank width/tank length (W/L)</th>
<th>tank against wall or baffled²</th>
<th>free-standing tank¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 0.09</td>
<td>0.1 - 0.24</td>
<td>0.25 - 0.49</td>
</tr>
<tr>
<td>tank against wall or baffled²</td>
<td>Q/A = 150 CFM/ft²</td>
<td>Q/A = 175 CFM/ft²</td>
<td>Q/A = 250 CFM/ft²</td>
</tr>
<tr>
<td></td>
<td>0.1 - 0.24</td>
<td>0.25 - 0.49</td>
<td>0.5 - 0.99</td>
</tr>
<tr>
<td></td>
<td>0.25 - 0.49</td>
<td>0.5 - 0.99</td>
<td>1.0 - 2.0</td>
</tr>
<tr>
<td></td>
<td>0.5 - 0.99</td>
<td>1.0 - 2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 - 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td>90</td>
<td>110</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>150</td>
<td>150</td>
<td>190</td>
<td>225</td>
</tr>
<tr>
<td>free-standing tank¹</td>
<td>50</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>110</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>150</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>225</td>
<td>250²</td>
</tr>
</tbody>
</table>

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/ft² is considered adequate for control

$$Q = \frac{Q/A}{A}$$

**Step 5**

Case A, Q = 150 ft³/min (10 ft)(3 ft) = 4500 CFM

Case B, Q = (175 ft³/min) = 5300 CFM

[Case A is “better”]
Example – Displacement ventilation

Given: A sensor is located in the middle of a room of volume $V$. The ventilation system is an **ideal displacement ventilation system** that supplies volume flow rate $Q$ of fresh air into the room. At $t = 0$, the air in the room is clean (no measurable contaminants). At $t = 0$, a tracer gas is injected into the room’s supply ducts, and continues to be injected for all $t > 0$.

- $V = 40 \text{ m}^3$
- $Q = 10 \text{ m}^3/\text{hr}$
- $c_{\text{in}} = 1.0 \text{ mg/m}^3$

To do: Calculate how long (in hours) it takes for the sensor to detect a concentration of the tracer gas greater than 0.632 mg/m$^3$.

Solution:

\[
N = \frac{Q}{V} = \frac{1}{4} \text{ hr}
\]

Take 4 hr to displace all air

\(2\text{ hr} \text{ to get halfway up}\)

Push-pull system

- Evaporating liquid
- Entralled air
- $Q_b$
- Blowing

Control box

Exhaust

Sensor

Supply: $Q$, $c_{\text{in}}$
Push-pull system:

- **blowing jet area** ($A_B$, ft$^2$)
- **blowing plenum cross sectional area** > 3$A_B$
- **blowing slot width** ($S_B$, in): $1/8" \leq S_B \leq 1/4"$ or, $1/4"$ diameter holes, spaced holes 3/4" to 2" apart
- **blowing volumetric flow rate**:
  $$\frac{Q_B}{L} = \frac{243(A_B/L)^{0.5}}{\text{ACFM/ft}}$$
  where $A_B/L$ is in units of (ft$^2$/ft)

**suction opening**: $A_S = L S_S$ ft$^2$

**suction slot width**: $S_S = 0.14W$

**suction volumetric flow rate**: depends on liquid temperature, i.e.
  - $T \leq 150^\circ F$, $Q_S/LW = 75$ ACFM/ft$^2$
  - $T > 150^\circ F$, $Q_S/LW = [0.40T(°F) + 15.]$ 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).

**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**: Same as previous example, but different chemical value.

---

$$Q_B$$

$W$

Liquid bath

$T = 150^\circ F$

$Q_S$

$W$

Liquid bath

$T = 50^\circ F$
CASE A

control vol. = 100 FPM

Table 6.4 - \( Q/A = 200 \text{ CFM/Ft}^2 \) \( \rightarrow Q = 7500 \text{ CFM} \)

CASE B

Push-pull system

Use Fig. 6.13

* Pick \( S_B = \text{slot height} = \frac{1}{4}'' \)

\[
\frac{Q_B}{L} = 243 \left( \frac{A_B}{L} \right)^{0.5} \left[ \frac{\text{CFM}}{\text{Ft}^2} \right]
\]

\[
Q_B = 2876 > 290 \text{ CFM} = Q_B \quad \text{(Blowing)}
\]

Fig. 6.13 - \( S_f = \text{ suction slot width } = 0.14 \text{ W} \)

\[ S_f = 0.64 \text{ ft} = 8'' \]

\[
\frac{Q_f}{LW} = 75 \quad \rightarrow Q_f = 75 \text{ LW}
\]

\[
\frac{\text{CFM}}{\text{Ft}^2} = 75 \frac{\text{Ft}^3}{\text{Ft} \cdot \text{min}} \cdot \left( 8.2 \text{ Ft} \right) \left( 4.85 \text{ Ft} \right)
\]

\[
= 2800 \text{ CFM} = Q_f
\]

Push pull is "better" - but more complex, expensive
Sample Design Plate (this one is for a welding hood)

![Diagram of a welding hood with design specifications]

**Figure 6.14** Sample design plate: lateral exhauster for a welding bench. From American Conference of Governmental Industrial Hygienists (ACGIH®), *Industrial Ventilation: A Manual of Recommended Practice*; copyright 2001; reprinted with permission.
Other example

Filling a tank with powder or granular material, e.g., "Quickcrete," grains

Fugitive emission (dust)

To control flow

Q

Displacement effect, just like filling liquid tanks

Q suction
How to control fugitive emissions?

Close-up

Water spray

WATER
e.g., Hoppers designed to reduce fugitive emissions – from DSH Systems LTD: