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)

\[
\begin{align*}
\text{W/o hood:} & \quad Q_e = Q_f \\
\text{W/ hood:} & \quad Q_e = 600 \text{ cfm if } Q_f = 0
\end{align*}
\]

What happens:
- either \( Q_f \) must exceed significantly
  \[
  Q_f = 600 \text{ cfm if } Q_e = 0
  \]
- or \( Q_e \) can become \( Q_f \)
  \[
  \text{due in exhaust air from other rooms}
  \]
- or lots of infiltration (under doors, etc.)
  \[
  \text{room will be at a negative pressure}
  \]
SEC 6.2 | Control of vapors

Design of hood for vapors is different than design of hood for particulate.

Control of particulate
- Use capture velocity \( V_c \)
- Match \( V_c \) to the local \( U \) required
- Gravitational removal \( Q \) may be feasible

Control of vapor
- Use control velocity = a design parameter

[No symbol for control velocity]

Control Velocity = a concept introduced by ACGIH

Well for design of hood
- 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 (typ)

- **Step 2** - Determine the rate of contaminant evolution
  - A number from 1-4 based on the temperature and 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).

<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 (PEL)</td>
<td>0 to 0.1 (PEL)</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

Define the class as the combination of the two, e.g. class A₂ C₁, B₃ D₁

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).

<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>do not use</td>
</tr>
<tr>
<td>A₃, B₁ (B₂) C₁</td>
<td>75</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>B₃, C₂, D₁</td>
<td>65</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>A₄, C₃, D₂</td>
<td>50</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>B₄, C₄, D₃, D₄</td>
<td>adequate</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)

Step 4: Determine $Q$, the volume flow rate, based on control velocity

Minimum recommended

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).

<table>
<thead>
<tr>
<th>control velocity (FPM)</th>
<th>aspect ratio = tank width/tank length (W/L)</th>
<th>0 - 0.09</th>
<th>0.1 - 0.24</th>
<th>0.25 - 0.49</th>
<th>0.5 - 0.99</th>
<th>1.0 - 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>tank against wall or baffled(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td>90</td>
<td>110</td>
<td>130</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>125</td>
<td>150</td>
<td>175</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>150</td>
<td>190</td>
<td>225</td>
<td>250(^3)</td>
<td>250(^3)</td>
<td></td>
</tr>
<tr>
<td>free-standing tank(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>110</td>
<td>130</td>
<td>150</td>
<td>170</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>150</td>
<td>175</td>
<td>200</td>
<td>225</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>225</td>
<td>250(^3)</td>
<td>250(^3)</td>
<td>250(^3)</td>
<td>250(^3)</td>
<td></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/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.

\[ \text{Step 1: } \text{Look up PEL - sulfuric acid mist } \rightarrow \text{PEL} = 1 \text{ m/s}^2 \]

\[ \begin{align*}
\text{Step 2: } & \quad \text{Table 6.2 (low)} \quad - \quad T = 175°F \quad \text{AT} = 50°F \\
\text{Suppose } & \quad T = 170°F \quad \text{AT} = 225 - 170 = 55°F \\
\text{AT} & \quad \text{rate 2} \quad \text{would pick the lower one } = 2 \\
\text{rate 1} & \quad \text{rate 2} \\
\text{Step 3: Table 6.3 } & \quad \text{E (B2) i.e., lateral hood } \rightarrow \text{capture velocity } = 100 \text{ Fpm} \end{align*} \]
**Step 4:**

**CASE A**  - tank against a wall, suction on one side only

@ control vol of 100 FPM

Aspect ratio \( = \frac{W}{L} = \frac{2 \text{ ft}}{10 \text{ ft}} = 0.20 \) \( \rightarrow \) get \( \frac{Q}{A} = 150 \text{ cfm/ft}^2 \)

\[
Q = \left( \frac{Q}{A} \right) A = (150 \text{ ft}^3/\text{min ft}^2)(10 \text{ ft})(1 \text{ ft}) = 4500 \text{ CFM}
\]

**CASE B**  - Free standing tank, lateral flow on both sides

Sky 3  - Table 6.2 \( \rightarrow \) control velocity = 100 FPM as previously

Sky 4  - Table 6.4 \( \rightarrow \) see footnote 1

Use \( \frac{1}{2} \) of \( W/L \) for the aspect ratio

\[
\text{one side}
\]

\[
\text{two sides:}
\]

\[
A_{\text{aspect ratio}} = \frac{W/2}{L} = 0.15
\]

Table 6.4, free standing \( \frac{Q}{A} \) aspect ratio of 0.15

@ control vol of 100 FPM

\[
Q = \left( \frac{Q}{A} \right) A = (175 \text{ cfm/ft}^2)(3 \times 10 \text{ ft}^2) = 5300 \text{ CFM}
\]

**Note:** use the real \( A \), not half of \( A \) here.
Push-pull system:

- **blowing jet area** ($A_B$, ft²)
- **blowing plenum cross sectional area** > $3A_B$
- **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**: $Q_B/L = 243(A_B/L)^{0.5}$ ACFM/ft, where $A_B/L$ is in units of (ft²/ft)
- **suction opening**: $A_S = L S_S$ ft²
- **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/ft²
  - $T > 150 \, ^\circ F$, $Q_S/LW = [0.40T(\, ^\circ F) + 15]$. ACFM/ft²

**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 limits useful

Advantages:
- Can provide for less required within $Q_S$
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:**

\[
\text{MSEL} \rightarrow \text{PEL} = 100 \text{ ppm}
\]

\[
\text{Boiling temp. } T_{\text{boil}} = 87^\circ C = 189^\circ F
\]

\[\Delta T = 189 - 150 = 39^\circ F \text{ below boiling}\]

Table 6.3 – Control velocity for a lateral hood

\[= 100 \text{ FPM}\]

Table 6.4 – Use Aspect ratio: \(\frac{W}{L} = 0.28\)

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

\[Q = (\frac{Q}{A})A = 7528 \text{ cfm} \approx 7500 \text{ cfm}\]

(1.89 ft) (8.2 ft)

**Case B:** Push-Pull System

\[\frac{1}{4}'' = S_B\]

\[Q_0/L = 243(A_B)^{0.5} \text{ in units of cfm/ft}\]
\[ A_b = \text{area of blowing jet} = S_b \cdot L \]

\[ Q_b = 287.6 \text{ cfm} \quad \text{or} \quad Q_b = 290 \text{ cfm} \quad \text{Blowing} \]

\[ S_f = \text{suction slot width} = 0.14 \text{ W} = \approx 8'' \]

\[ Q_j = 75 \text{ cfm} \quad \text{since} \ T \leq 150^\circ F \]

\[ = 75 \cdot (8.2 \text{ ft})(4.59 \text{ ft}) = Q_j = 2800 \text{ cfm} \]

\[ Q_f \text{ Less than half of } Q \text{ for lateral suction} \]

**Bottom line** → \( Q_j \) (suction vol. flow rate) is significantly less than the push–pull system, but there are disadvantages, as discussed above.

→ So, there is always a trade-off!