Today, we will:

- Continue our discussion about **hood suction velocities** and **isopleths**
- Do an example problem – capture velocity
- Discuss **reach** and the influence of local ventilation on general ventilation
- Discuss **Control of Vapors from Open Surface Vessels** [Section 6.2]
- Discuss the difference between **capture velocity** and **control velocity**

**Example: Capture velocity and hood design**

**Given:** A flanged round inlet is used as a hood to capture overspray particles from spray painting. The hood inlet (face) diameter is 0.50 m. The spray paint region of concern extends to $x = 0.50$ m (axially) and $r = 0.25$ m (radially) as sketched.

**To do:** Calculate the range of required volume flow rate through the hood.

**Solution:**

*Table 6.1 - get $V_c$ (capture velocity)

$$V_c = \frac{Q}{0.5D}$$

where $Q$ is the volume flow rate, $D$ is the face (hood) diameter, and $V_c$ is the capture velocity.

**Table 6.1 Capture velocities (abstracted from ACGIH, 2001).**

<table>
<thead>
<tr>
<th>characteristics of contaminant emission</th>
<th>examples</th>
<th>capture velocity (FPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. contaminant enters quiescent air with negligible velocity</td>
<td>degreasing tank, evaporation</td>
<td>50-100</td>
</tr>
<tr>
<td>2. contaminant enters slightly moving air with a low velocity</td>
<td>welding, vessel filling</td>
<td>100-200</td>
</tr>
<tr>
<td>3. contaminant actively generated and enters rapidly moving air</td>
<td>spray painting, stone crushers</td>
<td>200-500</td>
</tr>
<tr>
<td>4. contaminant air enters rapidly at high velocity</td>
<td>grinding, abrasive blasting</td>
<td>500-2000</td>
</tr>
</tbody>
</table>

**Lower values of capture velocity:**
- room air movement minimal or conducive to capture
- contaminants of low toxicity
- intermittent use or low production rates
- large hood and large mass of air moved

**Upper values of capture velocity:**
- adverse room air movement
- contaminants of high toxicity
- heavy use and high production rates
- small hood and small mass of air moved

**Range of $V_c = 200$ to $500$ fpm.**
Figure 6.10 Velocity isopleths (curves of constant $U/U_{face}$, %) for a flanged circular opening (adapted from ASHRAE HVAC Applications Handbook, 1995).

\[
\frac{U}{U_{\text{face}}} = 0.075
\]

Set \( U = V_c \)

\[
Q_{\text{reqd}} = U \times A_{\text{face}}
\]

\[
\frac{U}{U_{\text{face}}} = \frac{V_c}{0.075} = \frac{\pi D^2}{4} = \frac{\pi D}{0.075}
\]

Range

\[
Q = \frac{200 \text{ ft}^3/\text{min}}{0.075} \pi (0.5 \text{ m})^2 = \frac{1}{(0.3048 \text{ m})}^2 = 5636 \text{ ft}^3/\text{min}
\]
Low end of range = 5600 CFM

Similarly, high end of range = 14000 CFM

Comment: avg = 10000 CFM

Typ kitchen hood = 5800 CFM

Here need 20x more than kitchen hood.

Fundamental problem with capture velocity:

\( V_c \) is actually a speed, not a velocity.

Noting in \( V_c \) about direction of particle.

\( V_p = \text{particle speed} \)

Worst case scenario is when \( V_p \) is in opposite direction of air flow.

The \( V_c \) values are ultra conservative based on worst-case scenario.
Terminology: \( \text{Reach} \) = the volume of air in front of the hood capable of capturing the particulate.

- Flanged

- Unflanged

- Smaller reach for some conditions

How to increase reach:

- Move closer to source
- Add a flange — helps a little
- Make face of hood larger — typ funnel

Problem: limited visual access
Influence of local ventilation on general ventilation

Room designed w/o a hood, choose $Q_s$ for HVAC purpose

$Q_e = Q_d$

$q_{typ.} = 200 \text{ cfm}$

Later:

$Q_e \uparrow$

Low $P$ in room

Infiltration under doors, etc.

$Q_{hood} \geq 600 \text{ cfm}$

Worst case - "exhaust" can go backwards. $Q_e$ can be $\Theta$

Best to design hoods at same time as design HVAC system.

But often hoods added at a later time.

$\text{CAPTURE OF VAPORS (90\%)}$ [typ. from evaporation]

Hood design is very different from hood design for particulate capture.
- Control of particles → Use \( V_c = \text{capture velocity} \) (a physical speed)
  - Match \( V_c \) to local \( V \) of the hood

- Control of vapor → Use \( \text{control velocity} \)
  - Not a physical speed — it is simply a design parameter
  - Match control velocity of the process to that of the hood

Control velocity — we give no symbol for it in our book
- Design parameter introduced by ACGIH

A PROCEDURE for hood design for vapor capture

• Step 1 — Determine the hazard potential — a letter

Table 6.2
Letter A–D

Always choose the most conservative hazard potential

E.g., B is more conservative (higher hazard) than C
Step 2: Determine the rate of contaminant evolution

Combine steps 1 & 2 into a letter & number → B2

CHOOSE THE LOWER # TO BE CONSERVATIVE

E.g., 2 is more conservative (higher value) than 1

Step 3: Determine the control velocity

In units of FPM

Based on the class & type of hood

See Table 6.3

Step 4: Determine volume flow rate per unit area (evaporation from tanks)

\[
\frac{Q}{A} \quad [\text{CFM} / \text{ft}^2]
\]

Based on control velocity & tank aspect ratio

See Table 6.4
Tables for Hood Design using Control Velocity

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 (Higher)</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 time (hr)</th>
<th>gassing</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

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>A1², A2²</td>
<td>100</td>
<td>150</td>
<td>do not use</td>
</tr>
<tr>
<td>A3², B1, B2, C1</td>
<td>75</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>B3³, C2³, D1³</td>
<td>65</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>A4², C3³, D2³</td>
<td>50</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>(\frac{W}{L}) aspect ratio = tank width/tank length</th>
<th>(0.0 - 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 baffled¹</td>
<td></td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75</td>
<td>75</td>
<td>90</td>
<td>110</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>100</td>
<td>125</td>
<td>150</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>150</td>
<td>190</td>
<td>225</td>
<td>250³</td>
</tr>
<tr>
<td>free-standing tank¹</td>
<td></td>
<td>50</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75</td>
<td>110</td>
<td>130</td>
<td>150</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>150</td>
<td>175</td>
<td>200</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>225</td>
<td>250³</td>
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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

**Example → we have a tank against the wall with an aspect ratio of 0.3**

\[ Q/A = 150 \text{ CFM/ft}^2 \]

**Steps → calculate**

\[ Q = \frac{Q}{A} \cdot A \]

Where \(A = \) surface area of evaporating liquid
Example – Hazard potential

**Given:** Vapors of a certain chemical are evaporating from a large tank in which the liquid temperature is 140°F. The PEL of the chemical is 600 PPM, its flash point is 110°F, and its boiling temperature is 170°F. Evaporation time is about 40 hours, and gassing is low.

**To do:** What hazard potential class (letter and number, e.g., A4, B2, C1…) would you assign as per Table 6.2?

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

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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

\[170°F - 140°F = 30°F\] below boil,