Class 8

- Examples of multiple unit systems
- Procedure for solving multi-unit problems
- Mixers and splitters are units - require material balances
- Degree of Freedom analysis on multi-unit processes (non-reacting)
- Solution Strategy
- What if the strategy doesn’t work?

Perform the DOF Analysis for This System

Step 1
Take a deep breath!

Step 2: Draw boxes around places where balances can be made (to do balances)

(These “dashed” boxes will be called subunits)
Step 3. DOF analysis on each subunit

<table>
<thead>
<tr>
<th>Subunit</th>
<th>Unknowns</th>
<th># unknowns</th>
<th># balance eqns.</th>
<th># other relations</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splitter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Step 4
Start finding desired unknown variables using boxes with 0 DOF

Note on Splitters

• Only one independent material balance can be written for a splitter because the compositions of the split streams are the same!

• Please remember this!

Splitter Example

\[ m_1 \quad x_{A,1}, x_{B,1} \]
\[ m_2 \quad x_{A,2}, x_{B,2} \]
\[ m_3 \quad x_{A,3}, x_{B,3} \]

Balances:
\[ m_1 = m_2 + m_3 \]
\[ x_{A,1}m_1 = x_{A,2}m_2 + x_{A,3}m_3 \]
\[ x_{B,1}m_1 = x_{B,2}m_2 + x_{B,3}m_3 \]

But... \[ x_{A,1} = x_{A,2} = x_{A,3} \]
\[ x_{B,1} = x_{B,2} = x_{B,3} \]

Not independent!!!!!!

Practice: Define the subunits for the process below, and label unknowns for Streams 1, 2, and 3.

50 kg A/hr 50 kg B/hr
36 kg A/hr 4 kg B/hr
18 kg A/hr 12 kg B/hr
50 kg A/hr 9 kg A/hr 21 kg B/hr

Note on Splitters

• Only one independent material balance can be written for a splitter because the compositions of the split streams are the same!

• Please remember this!

• Also, the split is hardly ever 50:50
One way to do this:

I chose to use mA1, mB1, etc....

Now Do the DOF Analysis

<table>
<thead>
<tr>
<th>Subunit</th>
<th>Unknowns</th>
<th># unknowns</th>
<th># balance eqns.</th>
<th># other relations</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>mA1.mB1</td>
<td>2</td>
<td>2</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Mixer</td>
<td>mA2.mB2</td>
<td>4</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Unit 2</td>
<td>mA3.mB3</td>
<td>4</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Overall</td>
<td>mA3.mB3</td>
<td>2</td>
<td>2</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Solution Strategy

• Start with units that have DOF = 0
• Cross out unknowns on table as they are solved for
• Systematically work through all units
• You should never need to solve more than a couple of simultaneous equations at a time

Deviser a solution strategy using the DOF table from the previous slide.

Try this one!

1. Identify subunits
2. Label unknowns
3. DOF Analysis
4. Outline strategy
5. Work problem

Try this one!

1. Identify subunits
2. Label unknowns
3. DOF Analysis
4. Outline strategy
5. Work problem
Work on Board in Class

Look at Upcoming Homework

4.28 and 4.29

What if no unit has DOF = 0?

- Write down equations—sometimes you can solve for a portion of the unknowns even if you can’t solve for all of them for a given unit
- Check your other relations—sometimes a relationship associated with one unit can be used to permit the solution of another unit
- Consider grouping units. For example, two units connected by a stream of unknown composition can sometimes be grouped together to permit solution

Problem 4.28

- Only need to do DOF
  - NO CALCULATIONS!!!
- 3 subunits plus the overall system

Problem 4.29

- 2 distillation columns in series
- Part (a)
  - Make diagram
  - DOF
  - Outline solution procedure (no calculations)
- Part (b)
  - Calculate only 2 variables (not all variables!!!)
    - % of feed benzene that makes it to overhead from 2nd column
    - % of feed toluene that makes it to bottoms of 2nd column
      (answer to this part is on the homework hints page)

Extra Practice

(Do DOF, Start Problem)