Shell and Tube Heat Exchanger

October 7, 20XX
Cycle 2

Group 1X
Me
You
Her
Him

Use subtle, pleasing background. This one is a bit too ominous – like the Hand of God is about to reach out and touch us.
Outline

- Objectives
- Background
- Experimental Strategy
- Results
- Error Analysis
- Conclusions
- Recommendations
- References

An outline slide is required.

Number your slides – this is required and helps the audience during Q&A session.

Select a font size that is appropriate for the size of the room and size of the projection screen.
You only have 10 minutes. Create transitions but know that separate transition slides can waste time. Each slide has to be visible long enough for the audience to absorb the information.

Objectives and Background
Objectives

- Operate shell and tube heat exchanger varying steam flow
- Determine the outside overall heat transfer coefficient \( (U_o) \)
- Determine shellside heat transfer \( (Q_{SS}) \)
- Determine tubeside heat transfer \( (Q_{TS}) \)
Heat Exchanger Background

- Exchange heat between fluids
- Latent heat and sensible heat transfer
- Common to chemical process industry
- Types of heat exchangers
  - Air Cooled
  - Double Pipe
  - Spiral Plate and Tube
  - Shell and Tube
Heat Exchanger Background

Shell and Tube Heat Exchangers

- Account for 60% of heat exchangers in use today
- Can handle large flows, low temperatures and pressures, high temperatures and pressures
- Our shell and tube heat exchanger
  - Basco Type 500 U-tube Water Heater
  - 1 Shell Pass
  - 16 Tubes
Experimental Strategy
Figure 1. Unit Operations Lab: Shell and Tube Heat Exchanger (Group 1A)
Experimental Strategy

• 5 Runs Total
• Varied Steam Valve (TV-04) Position
  – 105% open
  – 75% open
  – 65% open
  – 60% open
  – 52% open
• Cooling water flow rate constant

These two experimental strategy slides say what was done, but not why this method was chosen.

"5 Runs" ??
One test at each of 5 conditions, or 5 replicates at each of these 5 test conditions?

What does 105% open mean to the audience?
Experimental Strategy

- Measured Variables
  - Condensate flow
  - Condensate temperature
  - Cooling water flow
  - Cooling water inlet temperature
  - Cooling water outlet temperature
Heat Exchanger Calculations

- Heat transfer rate
  - \( Q_{TS} = mC_p\Delta T \)
  - \( Q_{SS} = m\Delta H + mC_p\Delta T \)

- Overall heat transfer coefficient
  - \( U_o = \frac{Q_{SS}}{A_o \Delta T_{LM}} \)

- Log mean temperature
  - \( \Delta T_{LM} = \frac{((T_{hi} - T_{co}) - (T_{ho} - T_{ci}))}{\ln[(T_{hi} - T_{co}) - (T_{ho} - T_{ci})]} \)
Simplified Process Flow Diagram

This picture could have been used to show what/where measurements were taken.
Results
Experimental Results

Pay attention to **significant figures**!

<table>
<thead>
<tr>
<th>Steam Valve % Open</th>
<th>Heat Transfer Rate ($Q_{TS}$) (btu/ hr)</th>
<th>Heat Transfer Rate ($Q_{SS}$) (btu/ hr)</th>
<th>Overall Heat Transfer Coefficient ($U_o$) (btu/ lb* F* hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>105%</td>
<td>276489</td>
<td>275350</td>
<td>211</td>
</tr>
<tr>
<td>75%</td>
<td>250275</td>
<td>254588</td>
<td>201</td>
</tr>
<tr>
<td>65%</td>
<td>183357</td>
<td>181872</td>
<td>148</td>
</tr>
<tr>
<td>60%</td>
<td>134200</td>
<td>133777</td>
<td>112</td>
</tr>
<tr>
<td>52%</td>
<td>98289</td>
<td>93757</td>
<td>78</td>
</tr>
</tbody>
</table>

Compare these tabulated results to the graphs in the next slides. Which is easier for the audience to absorb?
Shellside vs. Tubeside Heat Transfer

Both values are equal. So, both axes should be scaled equally.

Heat Transfer Rate \( (Q) \)
Q-tubeside vs. Q-shellside

Both values are equal. So, both axes should be scaled equally.
Steam vs. Heat Transfer Rate \((Q_{TS}, Q_{SS})\)

Maybe after too many hours analyzing the data....
Steam vs. Overall Heat Transfer Coefficient

Heat Transfer Coefficient (btu/lb*F*hr)

Condensate Mass Out (lb/hr)

- U inside
- U outside
Error Analysis
Propagation of Error

- Determine the accuracy of measured variables
- Apply the propagation of error equation to each function

\[ \Delta y = \left[ \sum_{i=1}^{k} \left( \frac{\partial y}{\partial x_i} \Delta x_i \right)^2 \right]^{1/2} \]

The only thing important here is that RMS error propagation method was used.
Variable Measurement Accuracy

- Flow rate of the steam ± 5 lb/hr
- Flow rate of the cooling water ± 50 lb/hr
- Temperature readings ± 2 °F
- Largest sources of error
  - Mass flow rate of the steam
  - Mass flow rate of the cooling water

These values can be reported with the results. Either tabulate key results with uncertainty, or show graphically with error bars.
Calculated Error Values

- $\Delta Q_{TS} \approx +/- 1,000 \text{ btu/hr}$
- $\Delta Q_{SS} \approx +/- 50,000 \text{ btu/hr}$
- $\Delta U_0 \approx +/- 4 \text{ btu/lb °F hr}$
- $\Delta U_i \approx +/- 4 \text{ to } +/- 1.6 \text{ btu/lb °F hr}$

The problem with Error Analysis is that it is a lot of work, and you want everyone to know how hard you worked on it. Move all these slides (and any other supporting slides) after the Q&A slide at the end. If anyone has follow up questions on this, you can take them to the extra slides. This is an excellent technique that can really impress your audience.
This is just a repeat of an earlier slide with error bars included. Why put the audience through it twice?
Propagation of Error Heat Transfer Coefficient

Heat Transfer Coefficient (btu/lb*F*hr) vs. Condensate Mass Out (lb/hr)

- Blue diamonds: U inside
- Pink squares: U outside
Finally....

Conclusions and Recommendations
Conclusions

• $Q_{TS}$, $Q_{SS}$, $U_o$ all increase as the steam flow rate increases

• $Q_{TS}$, $Q_{SS}$, $U_o$ all have a linear relationship with the mass flow rate of the steam

• Heat transfer rate of the tube side is equal to the heat transfer rate of the shell side
Recommendations

- **Operation Recommendation**
  - Operate the shell and tube heat exchanger at approximately 75% for sufficient heat transfer and economic efficiency

- **Experiment Recommendations**
  - Monitor pressure gauge (PG-07) at low steam rates to prevent a vacuum
References

- API Heat Transfer. Shell and Tube Heat Exchanger Picture
  www.apiheattransfer.com/en/Products/HeatExchangers/ShellAndTube/
- Geankoplis, Christie J. *Transport Processes and Unit Operations*,
This presentation was 28 slides. That's enough for most 50 minute lectures! You only have 10.

Proofread.
Any spelin errors?
Appropriate grammar?
Format consistency?
Punctuation consistency?

Practice.
Use a stopwatch.
Don't rush it.
Work on voice rate, volume, clarity.
Avoid casual language!
Show confidence – you just ran the experiment and calculated the results – you are the resident expert on this project!