

# CH402 Chemical Engineering Process Design

Class Notes L9

Heat Exchanger Design – You are expected to know this!

Problem 14-15 using CHEMCAD

“3-Step” Heat Exchanger Design Method

(use desktop computer unless laptops have updated price index)

# Problem Statement 14-15

The overhead vapor from the C2 splitter in Figure 3-13 is partially condensed in E-601. The process conditions for the vapor entering the condenser are

Temperature, °C	-30.1
Pressure, kPa	1945*

Species Flow rates, kg/s

CH <sub>4</sub>	0.003
C <sub>2</sub> H <sub>6</sub>	0.0626
C <sub>2</sub> H <sub>4</sub>	64.53

\* Value has been changed  
from the book value. The  
authors report 2944 kPa.

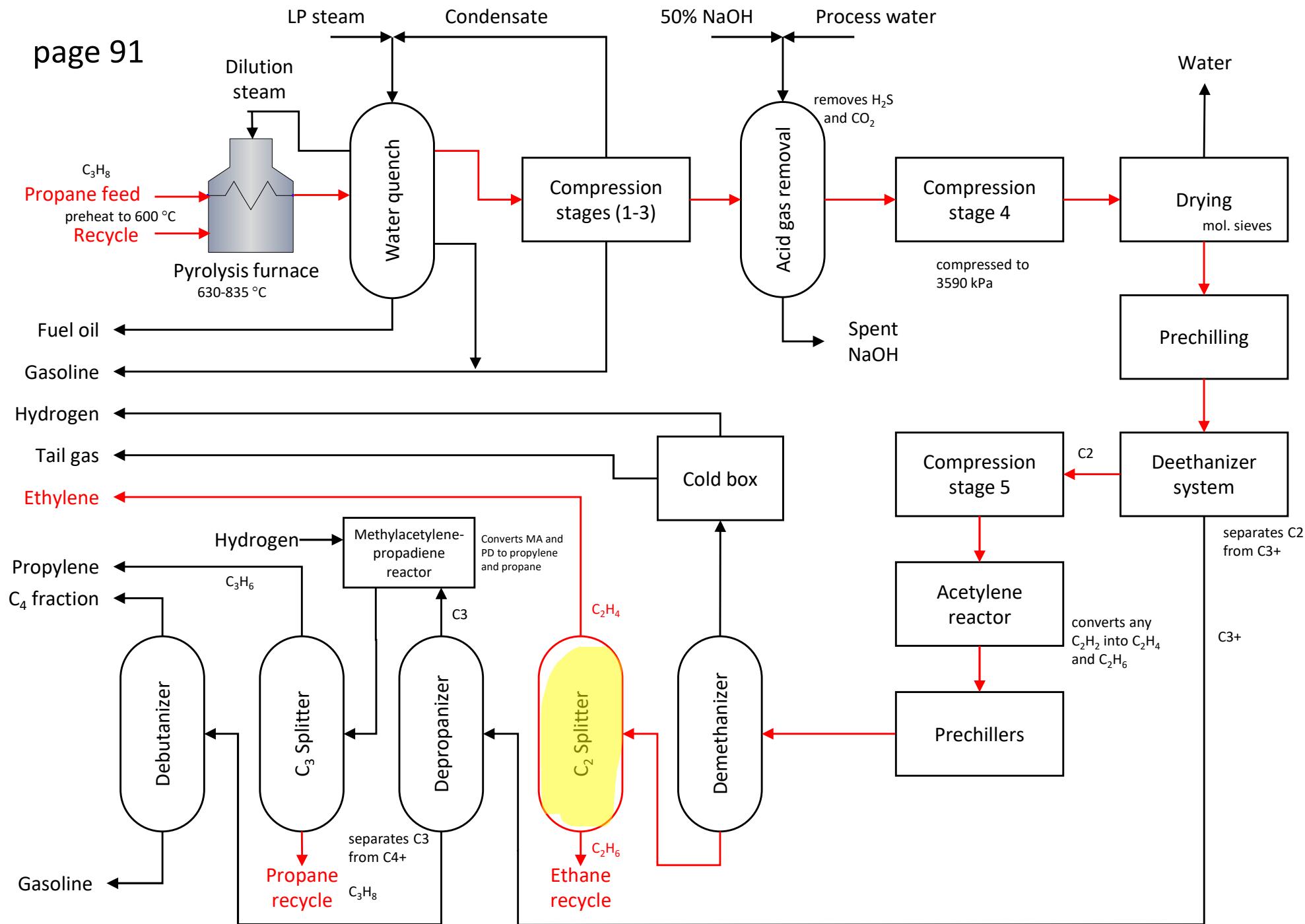
A shell-and-tube heat exchanger is to be used to condense 73.5 % of the overhead vapor. Use an appropriate software package (based on TEMA guidelines) to obtain the overall heat transfer coefficient and the area required for the condensation if the tubes have an outside diameter of 0.0127 m and an inside diameter of 0.0094 m. Assuming that the maximum length of the tubes is 3.05 m long, how many tubes will be required and what shell diameter is recommended? Propylene at -46 °C and 125 kPa serves as the coolant for the condensation process.

Additional Questions: (1) Identify the largest resistance to heat transfer in the exchanger and, (2) determine the total purchase cost of the exchanger in Feb. 2026.

# Process Background - Conventional Ethylene Process – Fig. 3-7.

3

page 91



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Figure 3-13. Product Separation Section

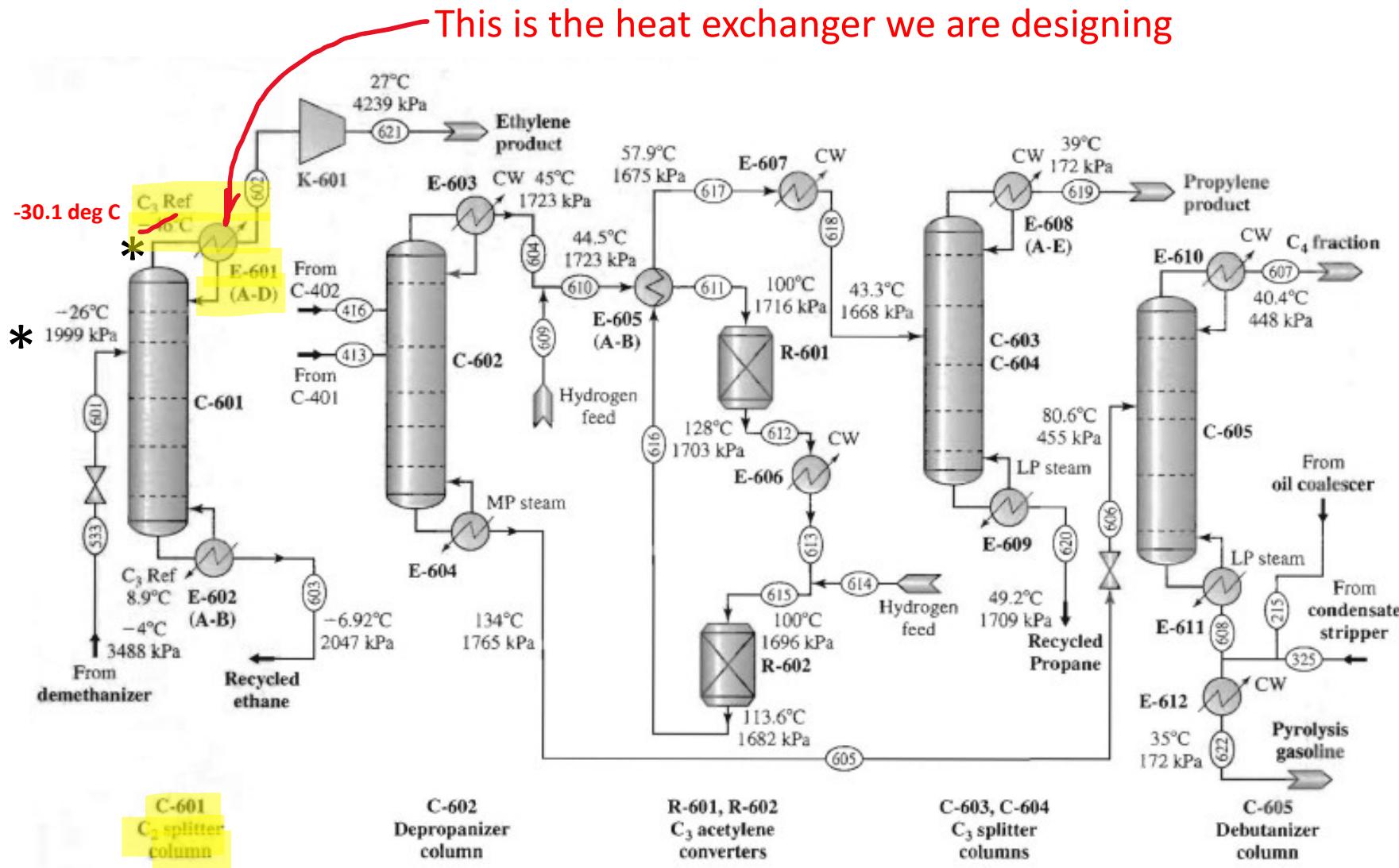


Figure 3-13. Product separation section.

Change CEPCI to  
Feb 2026 for PS5

**Change engineering units**

The screenshot shows the CHEMCAD 8.1.0 software interface with the 'Tools' tab selected. A red arrow points to the 'Tools' tab. Another red arrow points to the 'Engineering Units' dialog box, which is open in the foreground. Inside the dialog box, the 'Common SI' profile is selected in the 'System Profiles' list. Red arrows highlight the 'Time' unit (set to 'sec'), the 'Pressure' unit (set to 'kPa'), and the 'Enthalpy' unit (set to 'kJ'). The 'Apply' button at the bottom right of the dialog box is also highlighted with a red arrow. The background shows a process flow diagram with components like a Fired Heater and a Heat Exchanger.

Change CEPCI to Feb 2026 for PS5

Engineering Units

System Profiles

- English Default Profile
- Common SI**
- Formal SI
- Metric

User Profiles

- ALT SI
- Research

Current Flowsheet Settings: Custom Save As

Fundamental	Fluid Flow	Fluid Properties
Time	Liquid Volume Rate m <sup>3</sup> /h	Heat Capacity kJ/kg-K
Mole/Mass	Vapor Volume Rate m <sup>3</sup> /h	Specific Heat kJ/kg
Temperature	Vapor Density kg/m <sup>3</sup>	Heat Transfer Coef... W/m <sup>2</sup> -K
Pressure	Liquid Density/Con... kg/m <sup>3</sup>	Thermal Conductivity W/m-K
Enthalpy	Crude Flow Rate m <sup>3</sup> /h	Viscosity N-s/m <sup>2</sup>
Work	Velocity m/sec	Surface Tension N/m

Dimensions	Misc	Stream Flow Units
Length m	Solubility Parameter (J/m <sup>3</sup> ) <sup>0.5</sup>	Total Flow Default mole/r
Thickness m	Dipole Moment C.m	Component Flow Default mole/r
Diameter m	Cake Resistance m/kg	Stream Edit Automatic con
Area m <sup>2</sup>	Packing dP mm-water/m	VBA Flow Units Flow unit option for some VBA functions.
Liquid Volume m <sup>3</sup>	Currency \$	Mole
Vapor Volume m <sup>3</sup>	Currency Factor 1.000000	

Pipe Table Selection: ASME (B36.10M-2015, B36.19M-2004)

Atmospheric Pressure Reference: This is the reference for determining gauge pressure.

Default 101.3249817 kPa

Custom

Vapor Reference Temperature: This is the reference for determining standard vapor volume flow rate.

Default 0.00 C

Custom

Cancel Apply

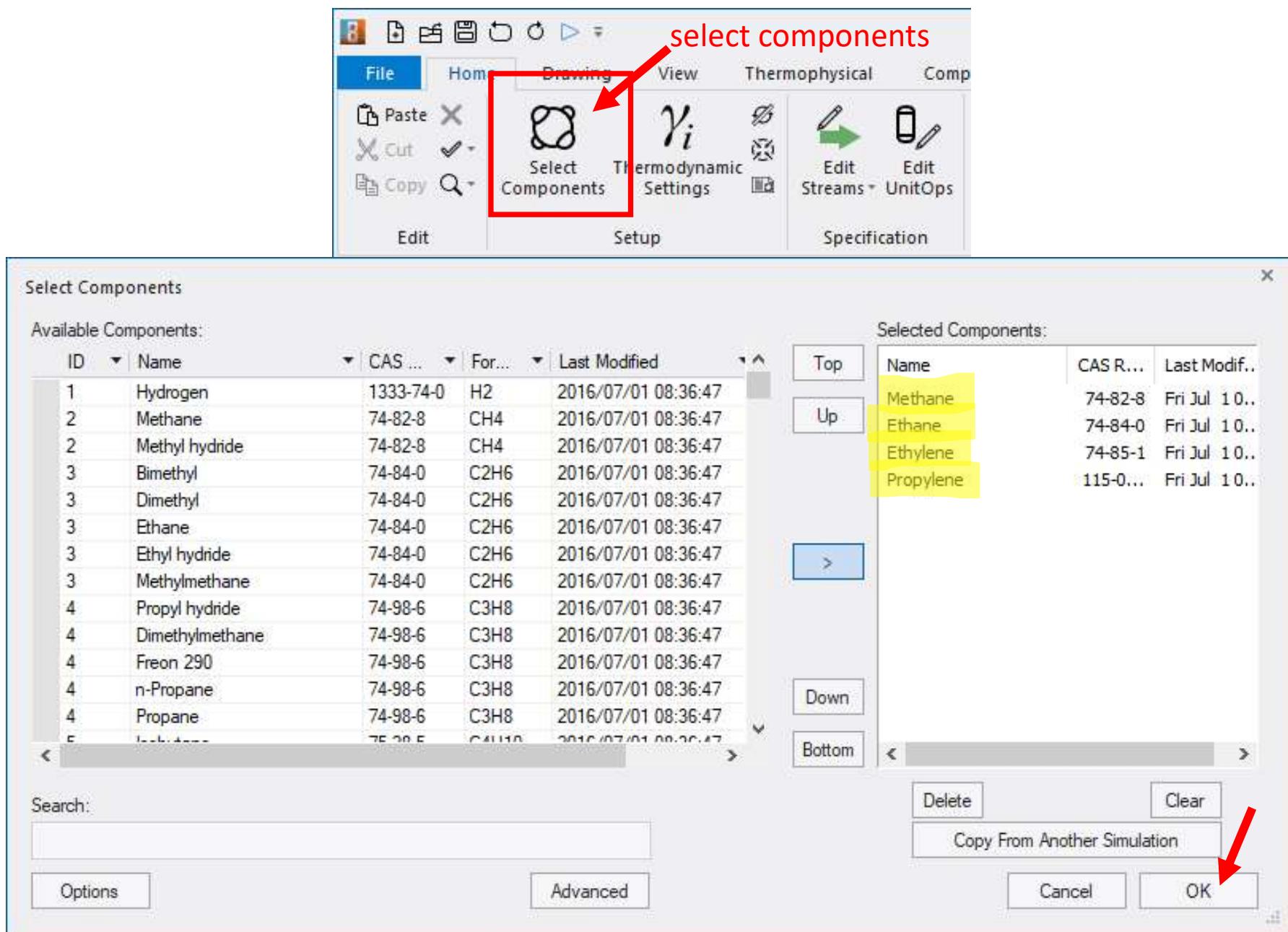
Palette

- All UnitOps : Grayscale
- Heat Exchangers Gray
- Feed Product
- Fired Heater Heat Exchanger
- Multi-Stream Exchanger
- Miscellaneous : Grayscale
- Piping and Flow : Grayscale
- Reactors : Grayscale
- Separators : Grayscale
- Solids handling : Grayscale

Untitled

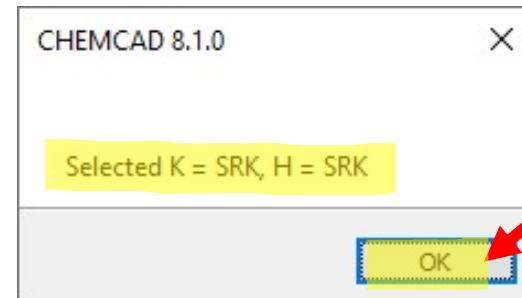
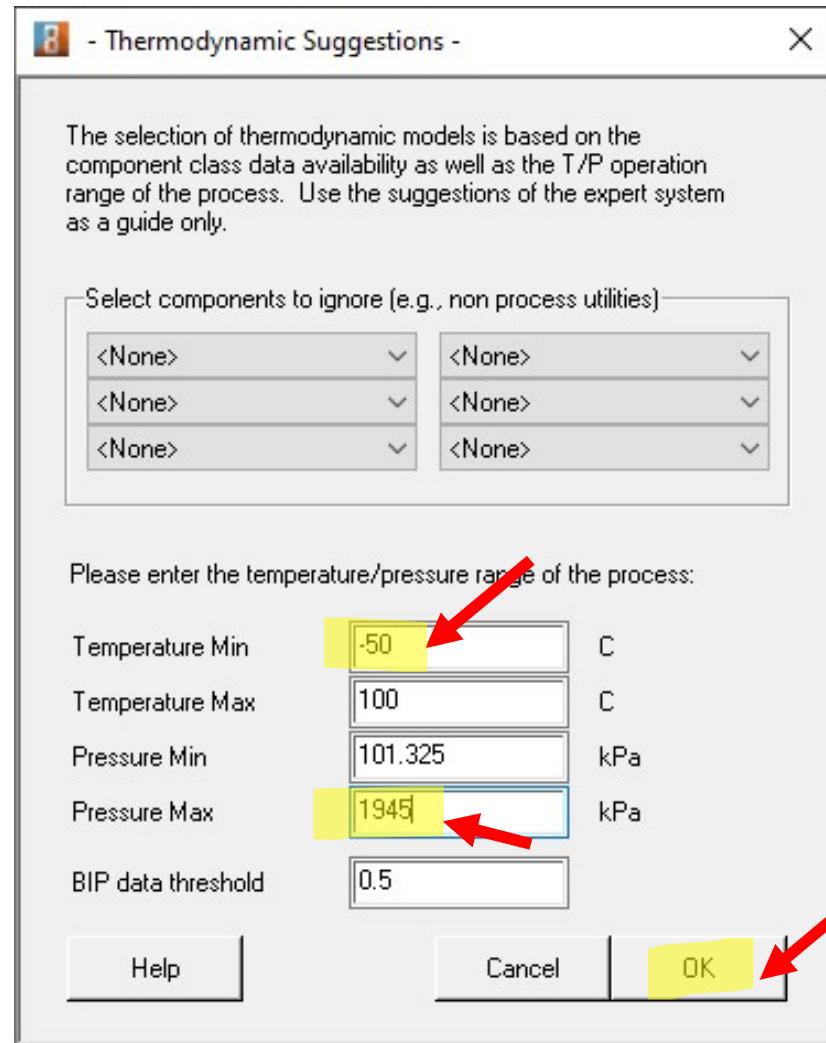
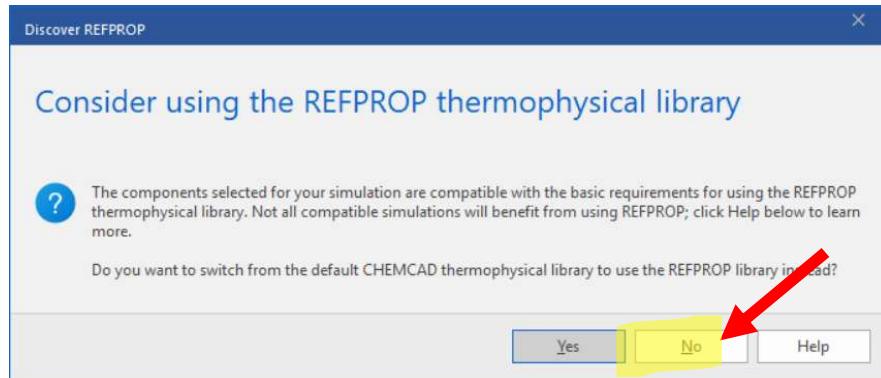
Steady State

On my computer, I have Common SI set as the default.



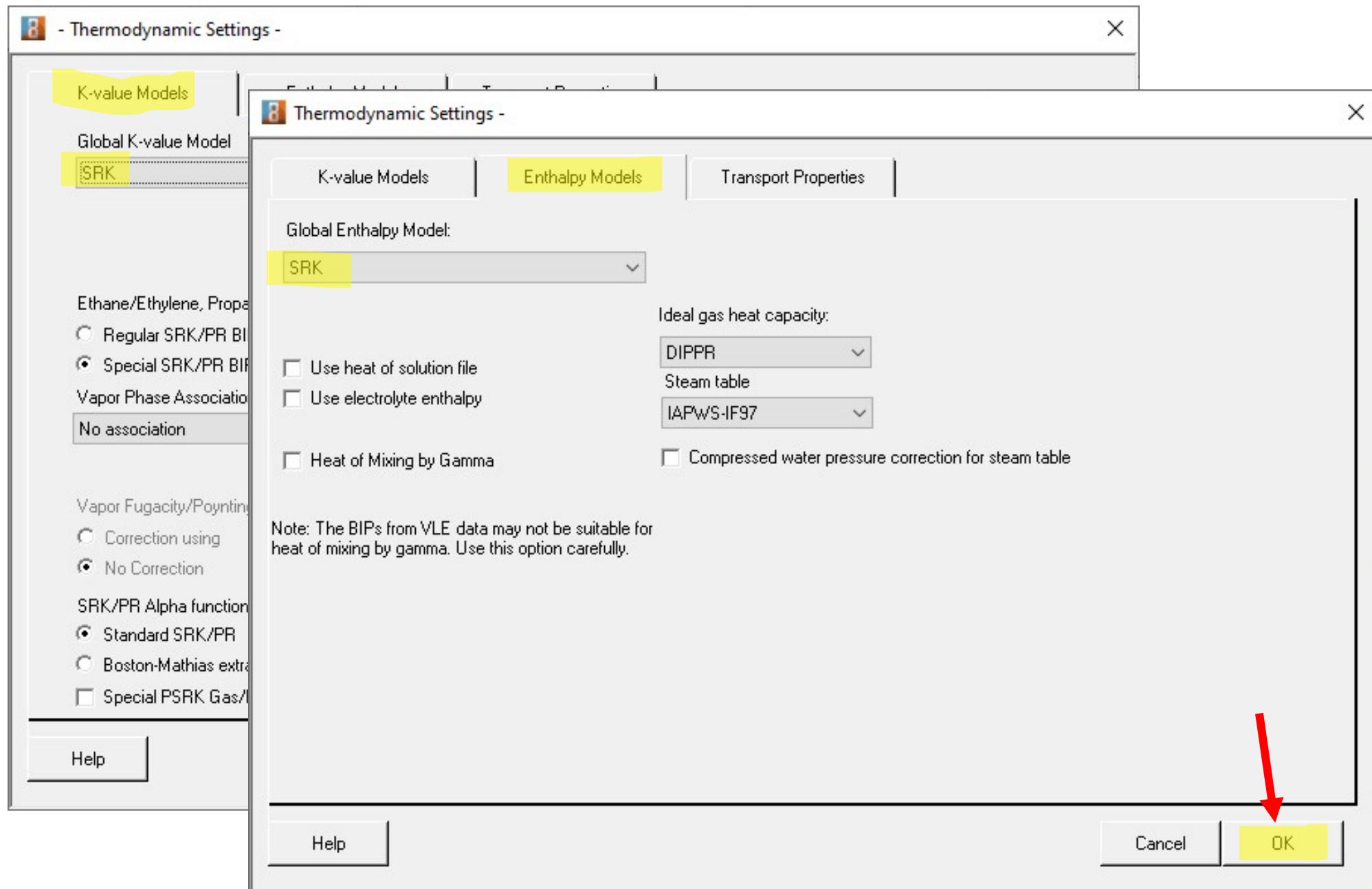
"Thermodynamic Suggestions" window launches automatically when you click OK.

# Thermodynamic Suggestions



SRK is good!

Thermodynamic suggestions: Check defaults in both tabs and click OK.



CHEMCAD 8.1.0 - [Untitled\*]

**Draw flowchart and solve m/e balances.**

**Step 1 – Lesson 8, slide 3.**

Overhead vapor → 3

Coolant – tube side → 1 → Heat Exchanger #4 → 2 → Product

4 → Overhead vapor

**Pro tip 1:** default fonts can be set in the “drawing” tab by clicking “font”

**Pro tip 2:** connect streams in the order shown here. Your streams should be numbered the same. This helps troubleshooting.

Steady State

Flowsheet Data Boxes Explorer Zoom to Fit Zoom

TP Box Visible  
Mark Error with Color  
Mark Cut Streams

Show Stream Names  
Show Stream IDs  
Show UnitOp Names  
Show UnitOp IDs

Layers

Cascade  
Tile Horizontally  
Tile Vertically

Window

Palette

- All UnitOps : Grayscale
- Heat Exchangers Gray
- Feed
- Product
- Fired Heater
- Heat Exchanger
- Multi-Stream Exchanger
- Miscellaneous : Grayscale
- Piping and Flow : Grayscale
- Reactors : Grayscale
- Separators : Grayscale
- Solids handling : Grayscale

Untitled\*

# Set Feed Stream 1: Propylene

(Propylene at -46 °C and 125 kPa is available as a coolant.)

Place propylene coolant tubeside (Stream 1)

Tube-side coolant in a condenser is a good idea.

Given: Propylene at -46 °C and 125 kPa serves as the coolant for the condensation process.

The pressure was not specified in the book. Engineers “fill in the blanks.”

This will be explained further in slides 11 and 20.

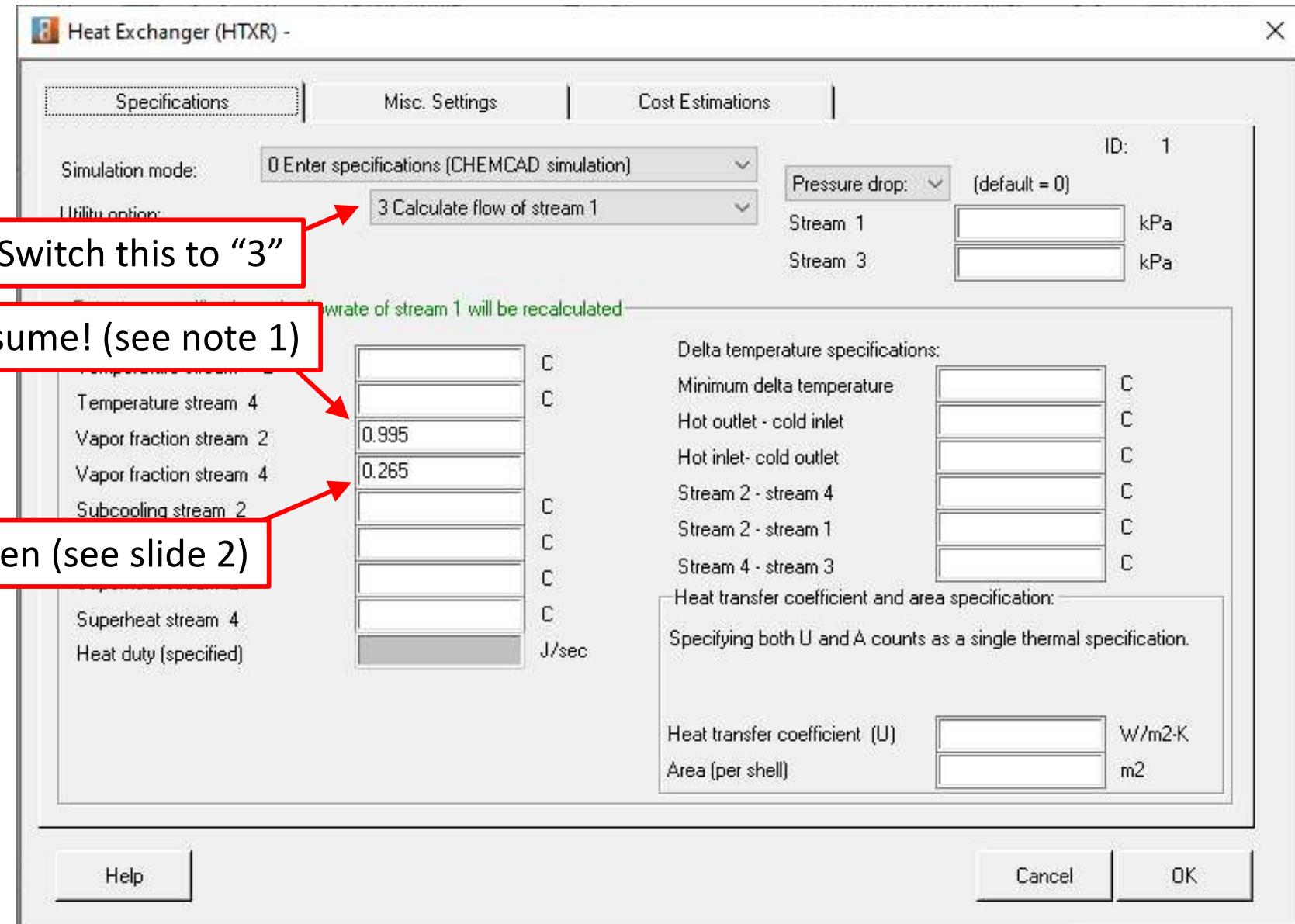
We don't know the propylene flow rate.  
Set it to 1 kg/s.

CHEMCAD will solve for the actual flow rate later.

Edit Streams		
	Flash	X
Stream No.	1	3
Stream Name		
Temp C	-46	-30.1
Pres kPa	125	1945.806
Vapor Fraction	0	1
Enthalpy J/sec	-77463.29	1.114613e+08
Total flow	1	64.5956
Total flow unit	kg/sec	kg/sec
Comp unit	kg/sec	kg/sec
Methane	0	0.003
Ethane	0	0.0626
Ethylene	0	64.53
Propylene	1	0

Two specs needed:  
Set temperature and vapor fraction.

# Complete Specs on Heat Exchanger and Coolant Flow Rate



**Note 1:** The largest “thermal reservoir” in the coolant is the latent heat of the phase transition. Any further warming of the coolant beyond the phase change will involve relatively small enthalpy changes.

Click OK, then Run

# Run the Simulation and Confirm Results (1/3)

The screenshot shows the CHEMCAD 8.1.0 software interface. The top menu bar includes File, Home, Drawing, View, Thermophys, Component, Specification, Analysis, Sizing, Tools, CC-THERM, Style, Help, and a zoom control. The Home tab is selected. The toolbar contains icons for Select Components, Thermodynamic Settings, Edit Streams, Edit UnitOps, Steady State (which is highlighted in blue), and Run All. A red arrow points to the Run All button.

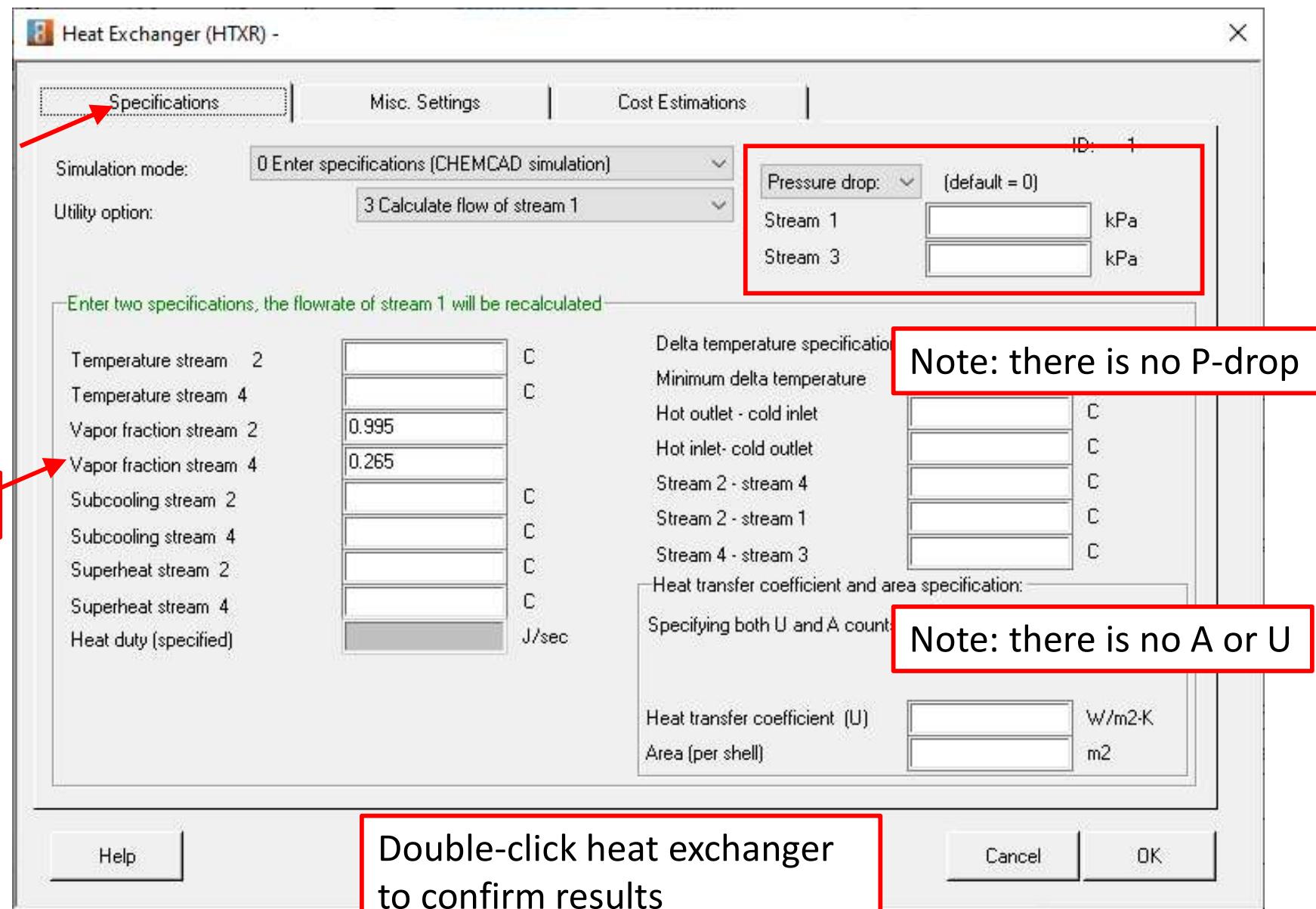
The main workspace displays a process flow diagram with four streams labeled 1 through 4. Stream 1 enters a vessel (represented by a grey circle with a wavy line) from the bottom left. Stream 2 exits the vessel to the right. Stream 3 enters the vessel from the top. Stream 4 exits the vessel from the bottom right. A red circle highlights stream 1.

A 'Edit Streams' dialog box is open, titled 'Flash'. It lists the properties for Stream No. 1:

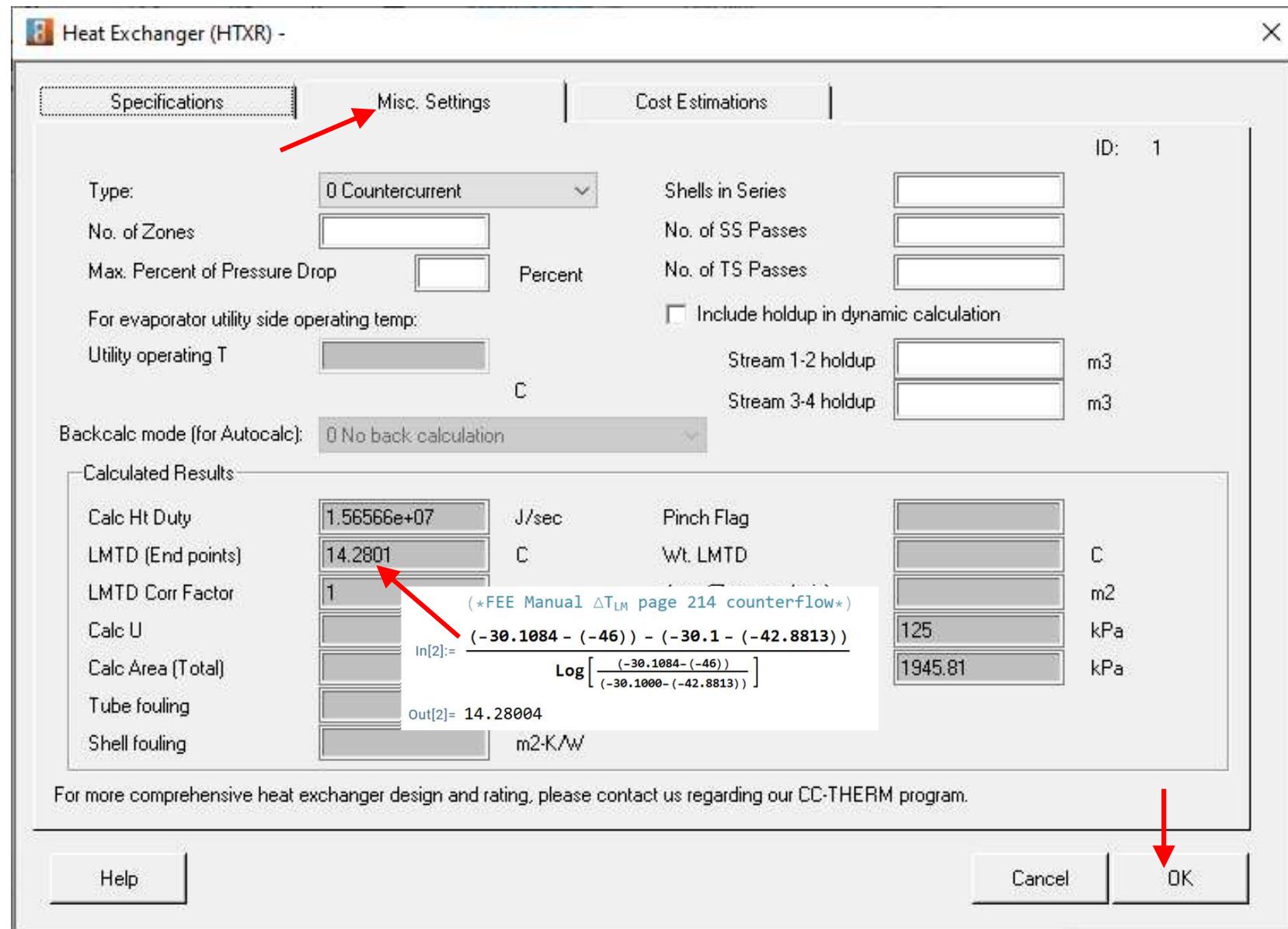
Stream No.	1
Stream Name	
Temp C	-46
Pres kPa	125
Vapor Fraction	0
Enthalpy J/sec	-2733769
Total flow	35.29116
Total flow unit	kg/sec
Comp unit	kg/sec
Methane	0
Ethane	0
Ethylene	0
Propylene	35.29116

A red arrow points to the value '35.29116' under the 'Propylene' row. A red box with the text 'Double-click stream 1 to check results' is overlaid on the bottom right of the dialog box.

# Confirm Results (2/3)



# Confirm Results (3/3)



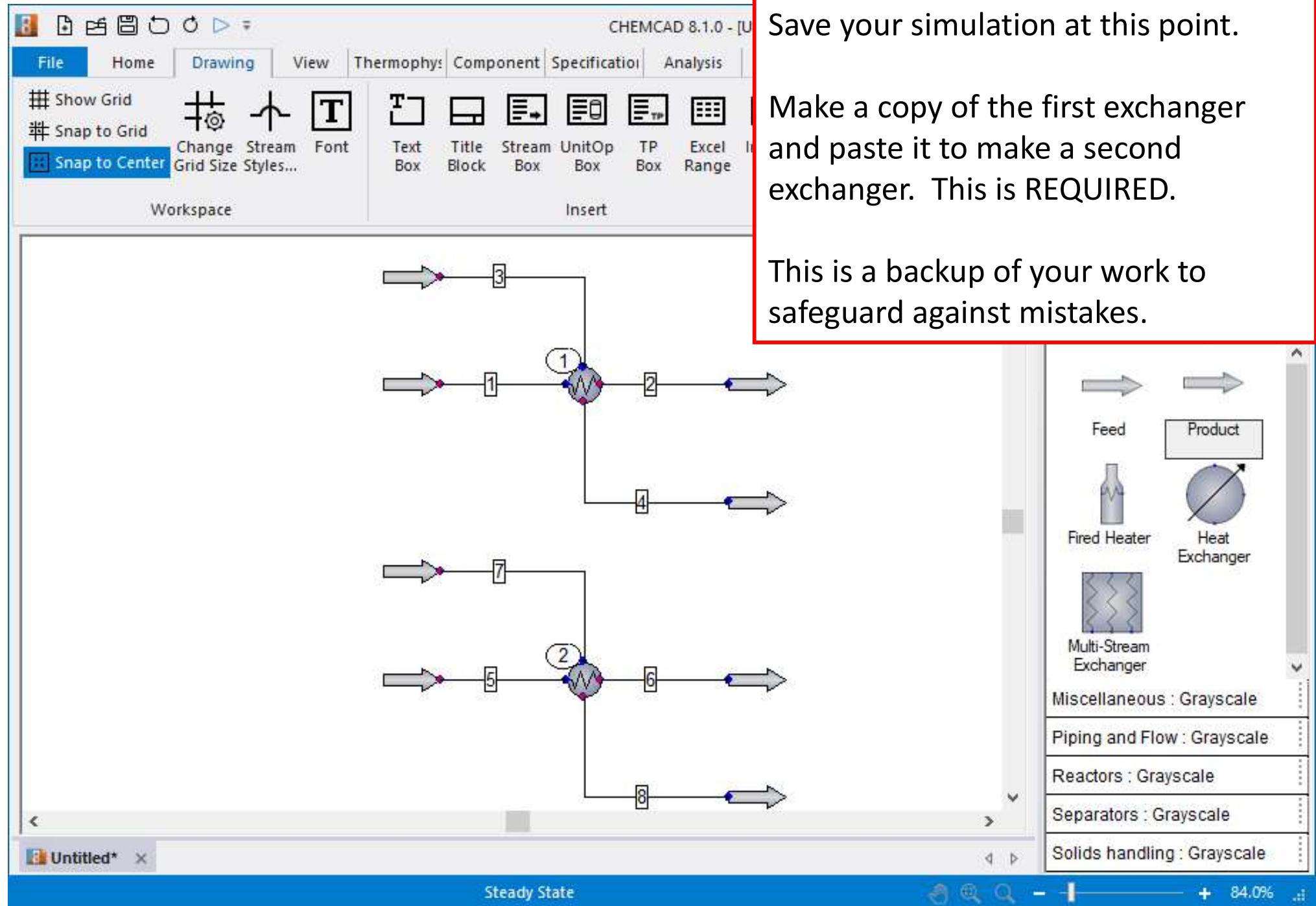
Numbers in gray fields were calculated by CHEMCAD

# STOP HERE

Confirm results in slides 12 to 14 before proceeding

Step 1 (L8 Slide 3) is complete:

Determined the flow rates and heat transfer rates  
necessary to meet the given conditions.



Click “Sizing,” then “Shell-and-tube.”

This initiates steps 2-5 of the design process (L8 slide 5).

File Home Drawing View Thermophys Component Specification Analysis Sizing Tools

Tray Packing Shell and Tube Plate Double Pipe LV Vessel LLV Vessel Pipe Orifice Control Valve Relief Device

Distillation Heat Exchanger Vessel Flow Safety

**Shell and Tube**  
Perform shell and tube heat exchanger sizing

1 2 3 4

2 3 4

1 2 3 4

5 6 7 8

Select UnitOps  
Type a UnitOp ID or select UnitOps with the left mouse button.  
To select all UnitOps, click flowsheet and then press [CTRL-A].

OK Cancel

All UnitOps

Groups

New CC-THERM Case  
Enter the name of the new CC-THERM case  
14-15 Design

Cancel OK

Untitled\* Steady State

CHEMCAD 8.1.0 - [Lesson9\_AY232\_Trial1\*]

File Home Drawing View Thermophysic Component D Specification Analysis Sizing Tools CC-THERM Style Help Charts Reports

UnitOp ID 2 Case 14-15 Design

Select

Type Shell and Tube General Enter Stream Information Materials Heat Curve Specification Label Edit Heat Curve Simulation

Tube Nozzle  
Shell Clearance

Design Charts Reports

1 2 3 4 5 6

1 CLICK THE CENTER OF THE GEAR WHEEL.

2

3

4

5

6

7

8

Select Tube-side Inlet Stream  
Please select the stream entering the exchanger tube side.

OK Cancel

All Streams  
Feed Streams  
Product Streams  
Cut Streams

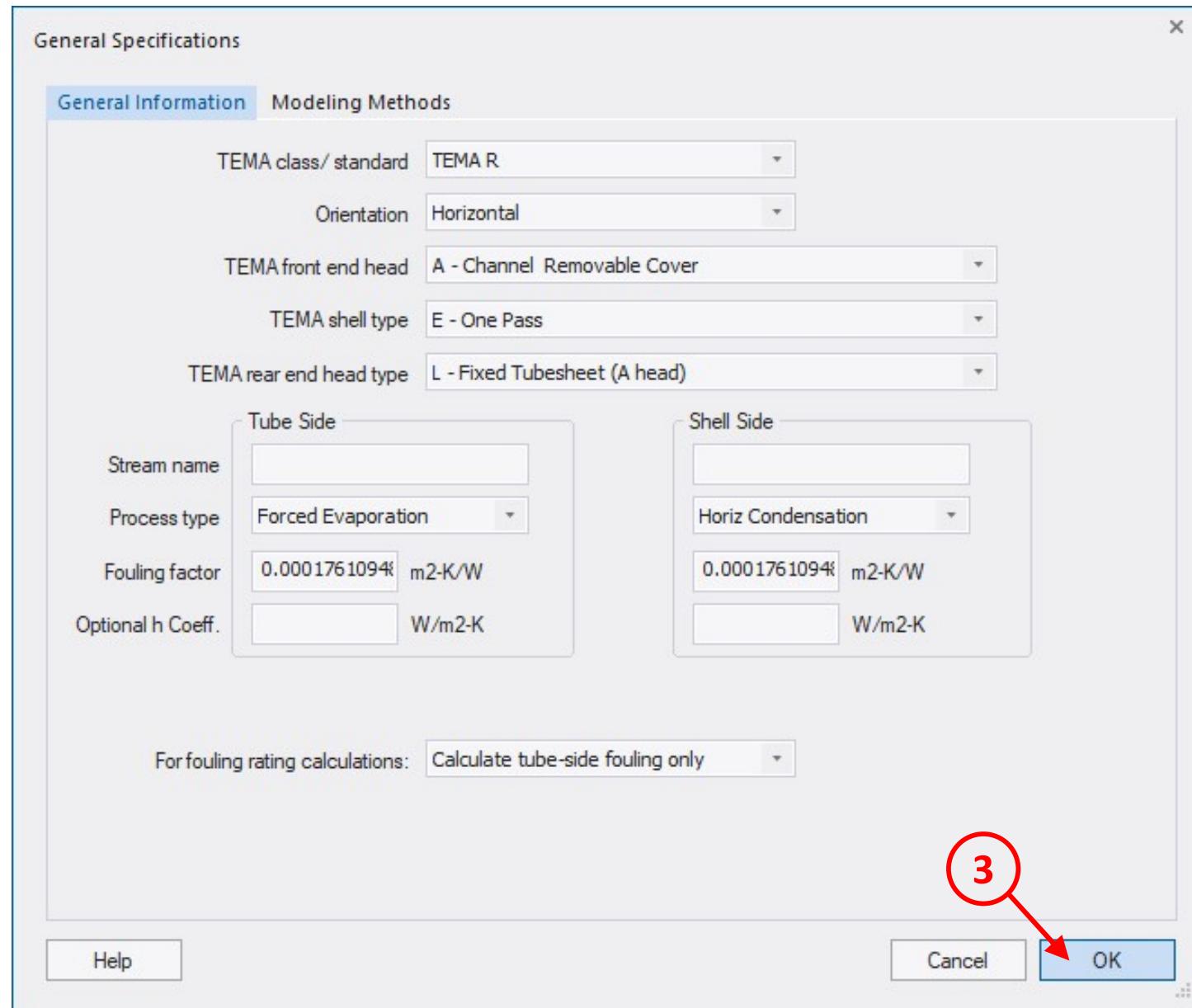
Groups

Lesson9\_AY232\_Trial1\* Lesson9\_AY232\_Trial1\_1

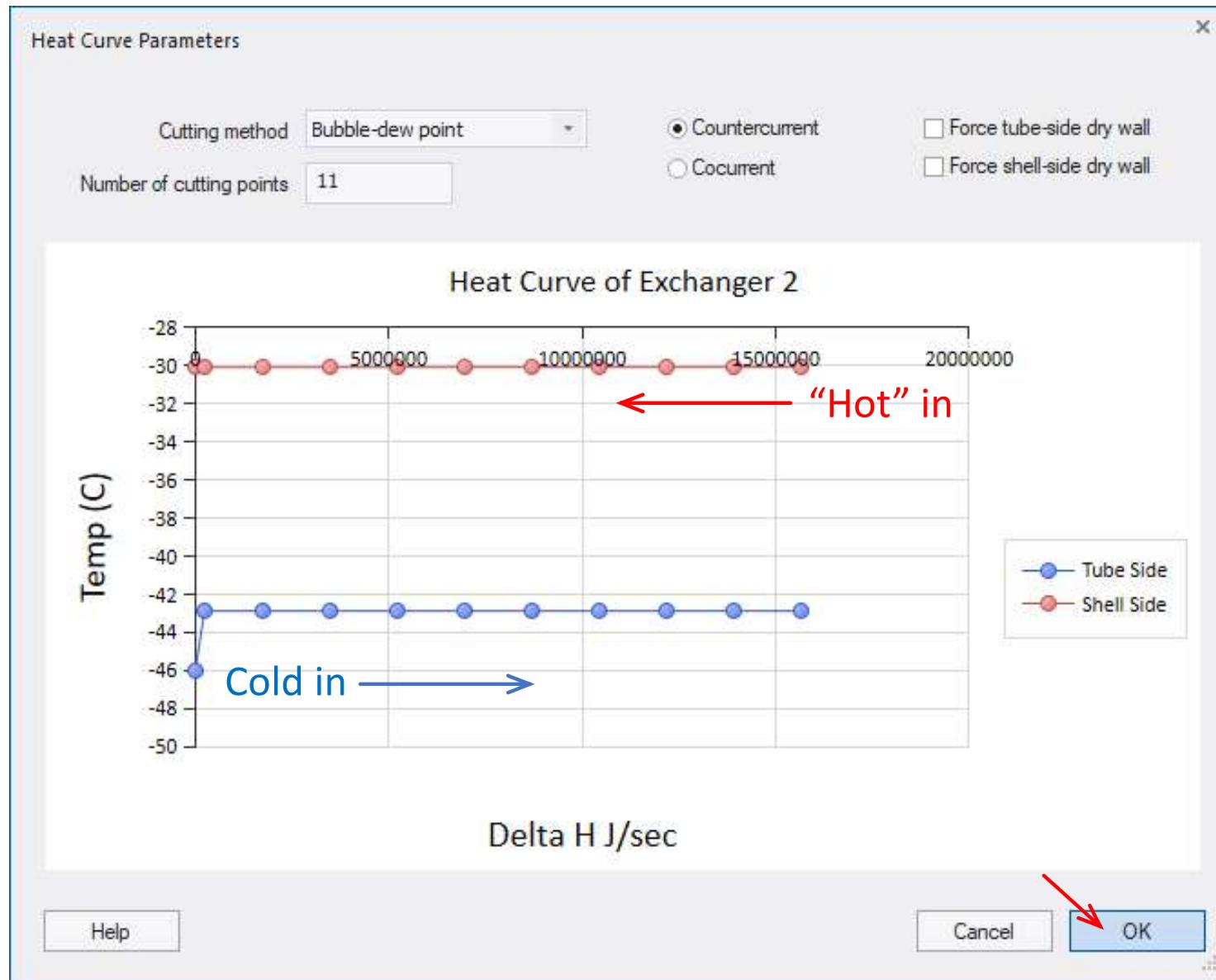
Steady State K:SRK H:SRK

The image shows the CHEMCAD 8.1.0 software interface. On the left, there is a process flow diagram with streams labeled 1 through 8. Stream 1 enters a gear wheel icon. Stream 2 enters a valve icon. Stream 3 exits the gear wheel. Stream 4 exits the valve. Stream 5 enters the valve. Stream 6 exits the valve. Stream 7 enters the gear wheel. Stream 8 exits the gear wheel. A red circle with the number 1 and the text 'CLICK THE CENTER OF THE GEAR WHEEL.' points to the center of the gear wheel icon. A red circle with the number 2 points to stream 2. A red circle with the number 3 points to the 'OK' button in a dialog box. The dialog box is titled 'Select Tube-side Inlet Stream' and contains the instruction 'Please select the stream entering the exchanger tube side.' It also includes a list of stream types: All Streams (checked), Feed Streams, Product Streams, and Cut Streams. At the bottom of the dialog box, there is a 'Hide' button and a 'Groups' section. The software's ribbon bar at the top includes tabs for File, Home, Drawing, View, Thermophysic, Component D, Specification, Analysis, Sizing, Tools, CC-THERM, Style, Help, Charts, and Reports. The 'CC-THERM' tab is currently selected. The status bar at the bottom shows 'Steady State' and 'K:SRK H:SRK'. The title bar indicates the file name is 'Lesson9\_AY232\_Trial1\*'.

## TEMA Type AEL Exchanger. Take all defaults.



Heating-cooling curve can be seen by clicking “Heat Curve Specification.”



Bumping up the cold feed pressure to 125 kPa drops the first data point so I can identify the cold inlet in the heating-cooling curve.

CHEMCAD 8.1.0 - [Lesson9\_AY232\_Trial1\*]

**General**

1. Enter Stream Information 2. Materials  
 Heat Curve Specification 3. Label  
 Edit Heat Curve 4. Simulation Mode

Tube Nozzle  
 Shell Clearance  
 Baffle Miscellaneous

Design Charts Reports

Geometry Run Results

1. Select

2. Design Constraints

3. Reboiler Specifications

4. General

5. Allowable tube pressure drop: 34.473801 kPa  
 6. Allowable shell pressure drop: 34.473801 kPa  
 7. Allowable tube velocity: 76.199997 m/sec  
 8. Allowable shell velocity: 76.199997 m/sec  
 9. Prefer tube length/shell diameter ratio: 12  
 10. Minimum excess %: (empty)

11. Sizing nozzle  
 12. Tube, inlet  
 13. Tube, outlet  
 14. Shell, inlet  
 15. Shell, outlet

16. Lower Limits  
 17. Upper Limits  
 18. Tube Length: 3 m to 3.1 m  
 19. Shell Diameter: 0.1524 m to 6 m  
 20. Baffle Cut: 15 to 45 Percent of diameter  
 21. Baffle Spacing: 0.050799999 m to 3.175 m

22. Optimize number of tube passes  
 23. OK

CHEMCAD 8.1.0 - [Lesson9\_AY232\_Trial1\*]

File Home Drawing View Thermophysic Component D Specification Analysis Sizing Tools CC-THERM Style Help

UnitOp ID 2 Case 14-15 Design

Type Shell and Tube General Enter Stream Information Materials Heat Curve Specification Label Edit Heat Curve Simulation Mode

Tube Nozzle Shell Clearance Baffle Miscellaneous

Design Charts Reports

Select Configuration

Tube Specifications

Number of tubes \* 1396  
Number of tube passes \* 1  
Tube outer diameter .0127 m  
Tube wall thickness 0.00165 m  
Tube length \*  
Roughness factor 1.5748e-06 m  
Tube pattern Rotated Triangular (60)  
Tube pitch 0.023812501 m  
Trufin tube code Plain tube  
Turbulator No Turbulator  
Tubesheet thickness 0.01905 m  
Number of tubesheets 2

\* Field may be recalculated when design calculation is run

Help Cancel OK

Tube Access tube specifications

Heat Exchangers Gray

Feed Product

Fired Heater Heat Exchanger

Multi-Stream Exchanger

Miscellaneous : Grayscale

Piping and Flow : Grayscale

Reactors : Grayscale

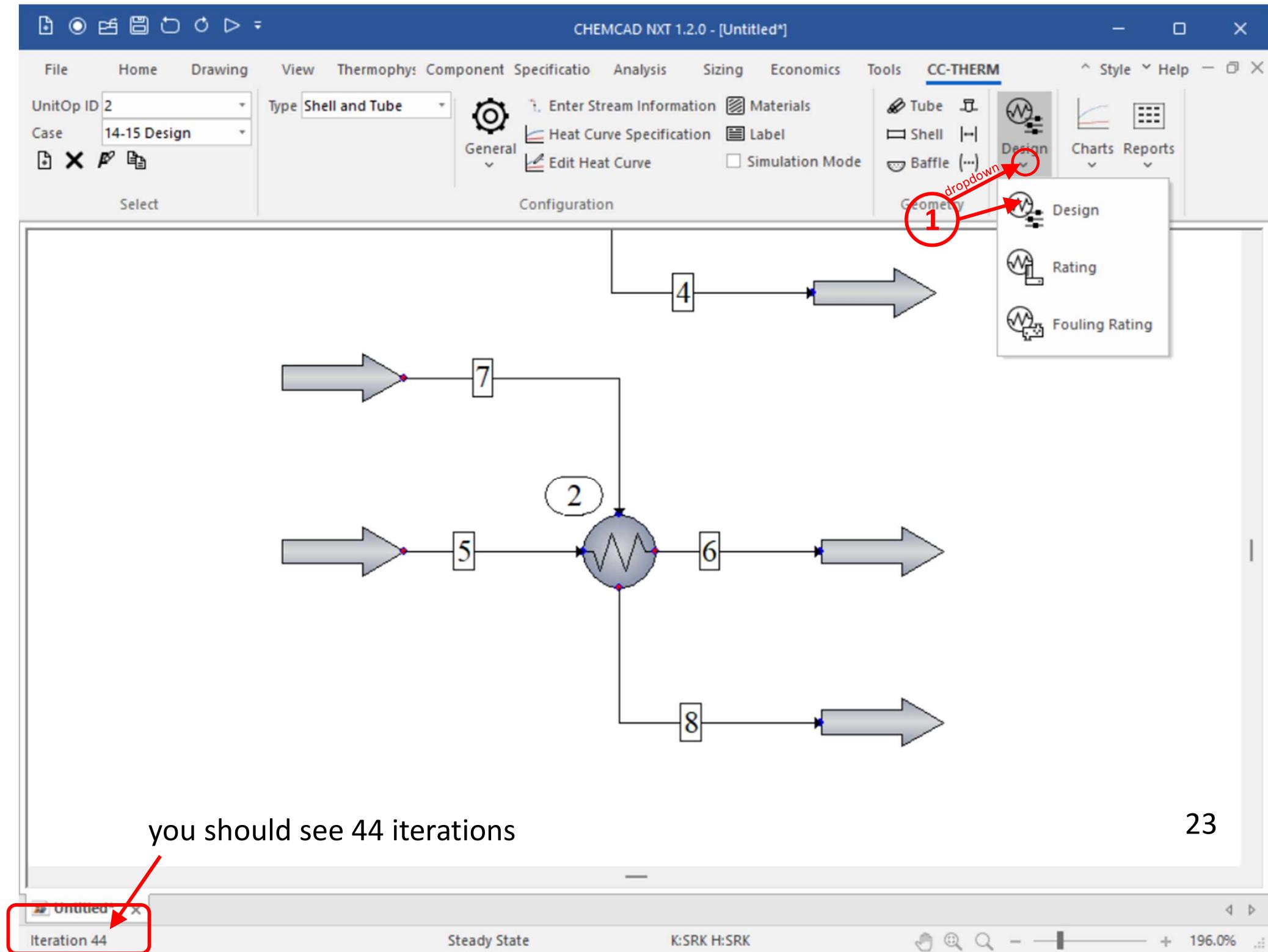
Separators : Grayscale

Solids handling : Grayscale

Steady State K:SRK H:SRK

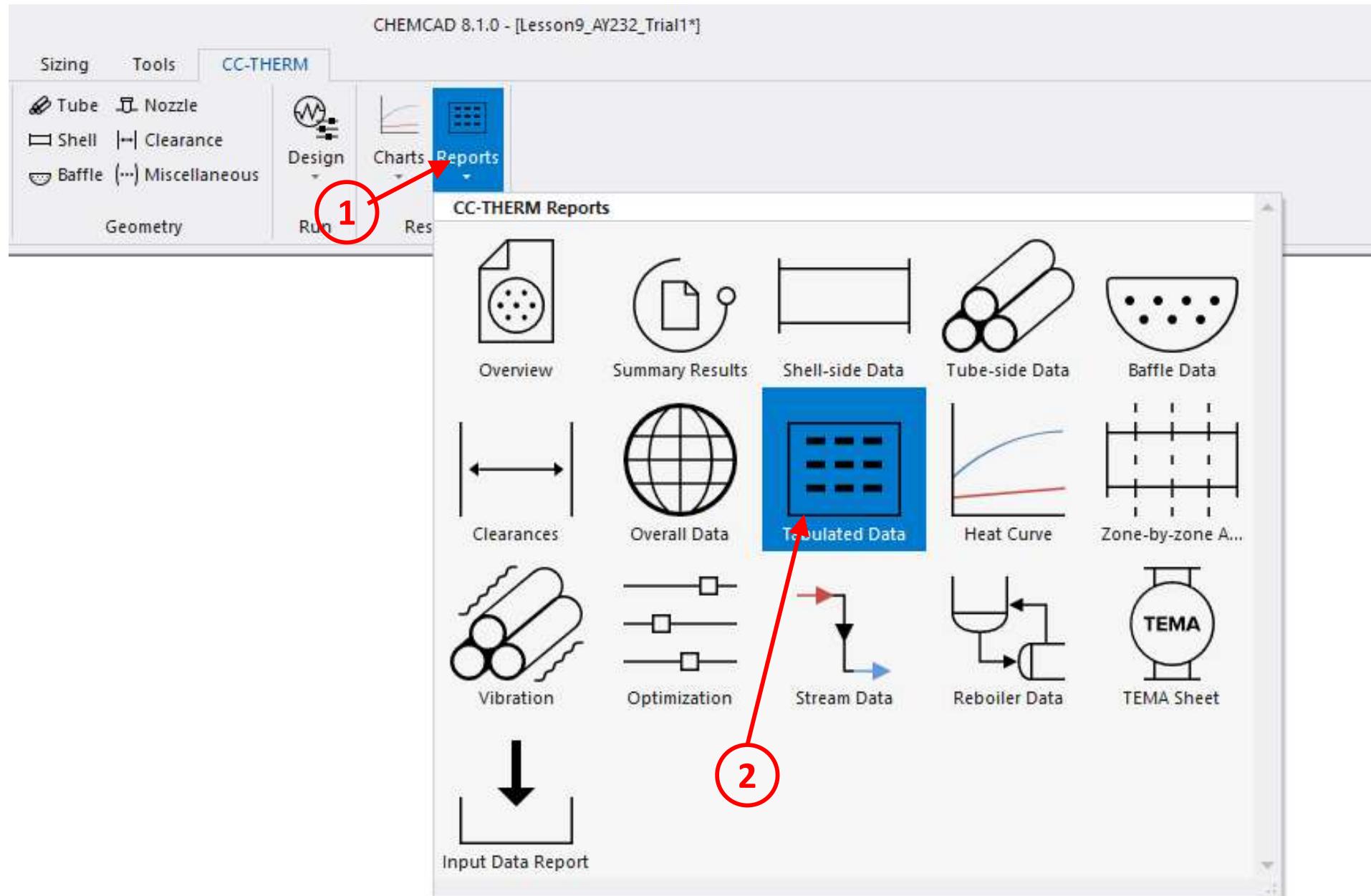
Lesson9\_AY232\_Trial1\* Lesson9\_AY232\_Trial1\_1

128.0%



you should see 44 iterations

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# Design Results – CHEMCAD NXT 1.2.0

## TABULATED ANALYSIS

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**Overall Data:**

Area Total	m <sup>2</sup>	2348.77	% Excess	6.13
Area Required	m <sup>2</sup>	2157.83	U Calc. W/m <sup>2</sup> -K	566.94
Area Effective	m <sup>2</sup>	2290.05	U Service W/m <sup>2</sup> -K	534.21
Area Per Shell	m <sup>2</sup>	2290.05	Heat Duty J/sec	1.57E+07
Weight LMTD C	12.80	LMTD CORR Factor	1.0000	CORR LMTD C 12.80

---

**Shell:**

Shell O.D.	m	3.68	Orientation	H
Shell I.D.	m	3.66	Shell in Series	1
Bonnet I.D.	m	3.66	Shell in Parallel	1
Type		AEL	Max. Heat Flux Btu/ft <sup>2</sup> -hr	0.00
Imping. Plate	Impingement Plate		Sealing Strip	5

---

**Tubes:**

Number		19314	Tube Type	Bar
Length	m	3.05	Free Int. Fl Area m <sup>2</sup>	0.00
Tube O.D.	m	0.013	Fin Efficiency	0.000
Tube I.D.	m	0.009	Tube Pattern	TRI60
Tube Wall Thk.	m	0.002	Tube Pitch m	0.024
No. Tube Pass		1		
Inner Roughness	m	0.0000016		
Number of tubesheets		2	Tubesheet thickness, m	0.019

---

**Resistances:**

Shell-side Film	m <sup>2</sup> -K/W	0.00068
Shell-side Fouling	m <sup>2</sup> -K/W	0.00018
Tube Wall	m <sup>2</sup> -K/W	0.00004
Tube-side Fouling	m <sup>2</sup> -K/W	0.00018
Tube-side Film	m <sup>2</sup> -K/W	0.00047
Reference Factor (Total outside area/inside area based on tube ID)		1.351

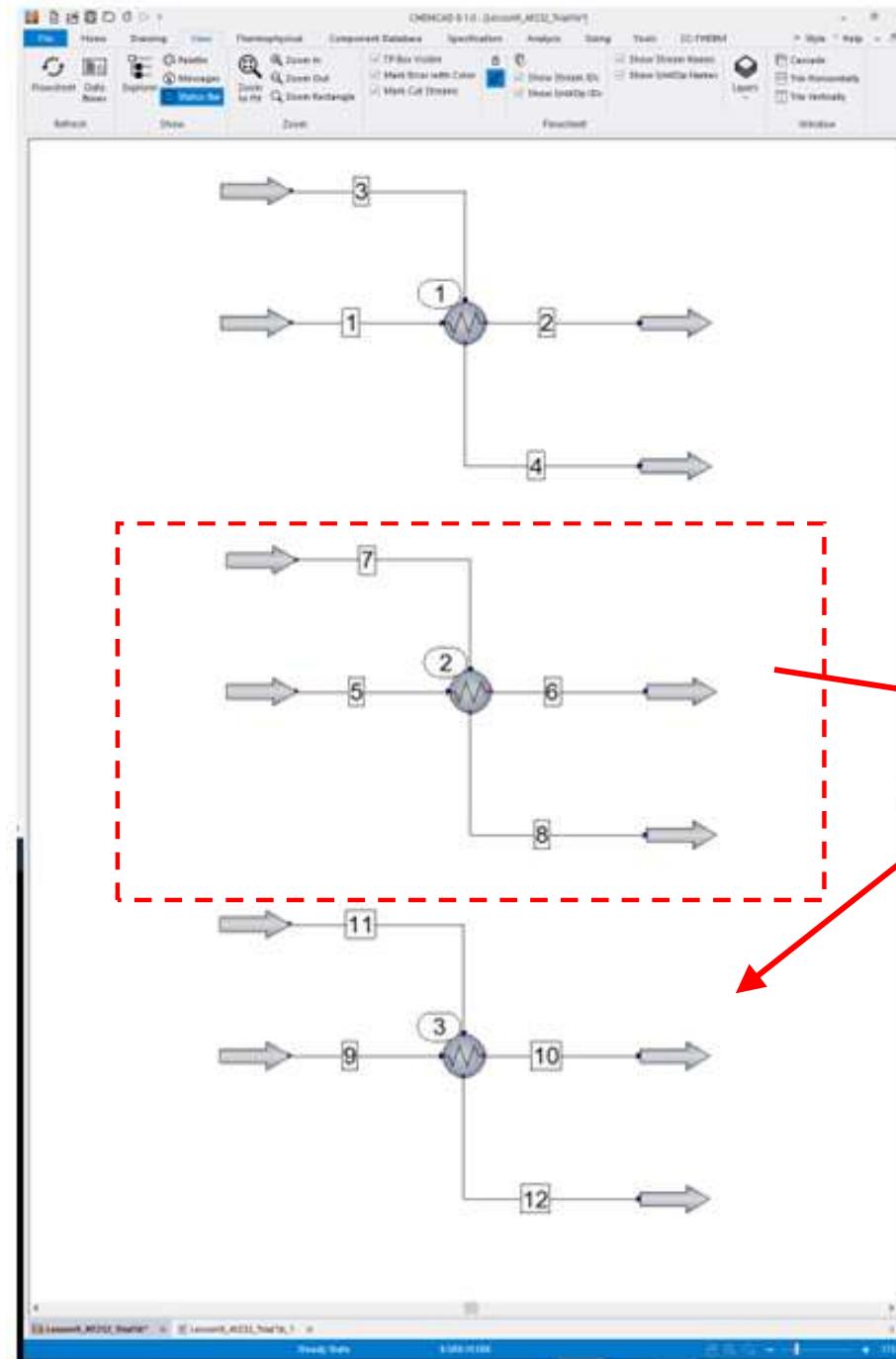
Answers to first three questions are found here. How many tubes? Shell diameter? Largest resistance?

# STOP HERE

Confirm results in slide 25 and save your simulation before proceeding

Steps 2-5 of L8 Slide 3 are now complete:  
Type of exchanger, geometric details, overall U,  
thermal driving force, area, and P-drops.

# Exchanger Simulation



Copying and pasting is an important step.

It preserves the design work down in exchanger 2 as a backup.

Setting the “Simulation Mode” to “1 Shell & tube simulation initiates step 6 of the design process (L8 slide 3).

File Home Drawing View Thermophys Component Specification Analysis Sizing To

Flowsheet Data Boxes Explorer Palette Messages Zoom to Fit Status Bar

Refresh Show Zoom Flowsheet Window

Flowsheet

- Heat Exchanger (HTXR) -

Specifications Misc. Settings Cost Estimations

Simulation mode: 1 Shell & tube simulation

Click OK to proceed to CC-THERM data entry.

Outlet conditions will be rigorously calculated by CC-THERM.

Change simulation mode to "Enter specifications" to use the specifications below

Temperature stream 10 C Delta temperature specification  
Temperature stream 12 C Minimum delta temperature  
Vapor fraction stream 10 C Hot outlet - cold inlet  
Vapor fraction stream 12 C Hot inlet- cold outlet  
Subcooling stream 10 C Stream 10 - stream 12  
Subcooling stream 12 C Stream 10 - stream 9  
Superheat stream 10 C Stream 12 - stream 11  
Superheat stream 12 C Heat transfer coefficient and a  
Heat duty (specified) J/sec Specifying both U and A count  
Heat transfer coefficient (U)  
Area (per shell)

Help Cancel OK

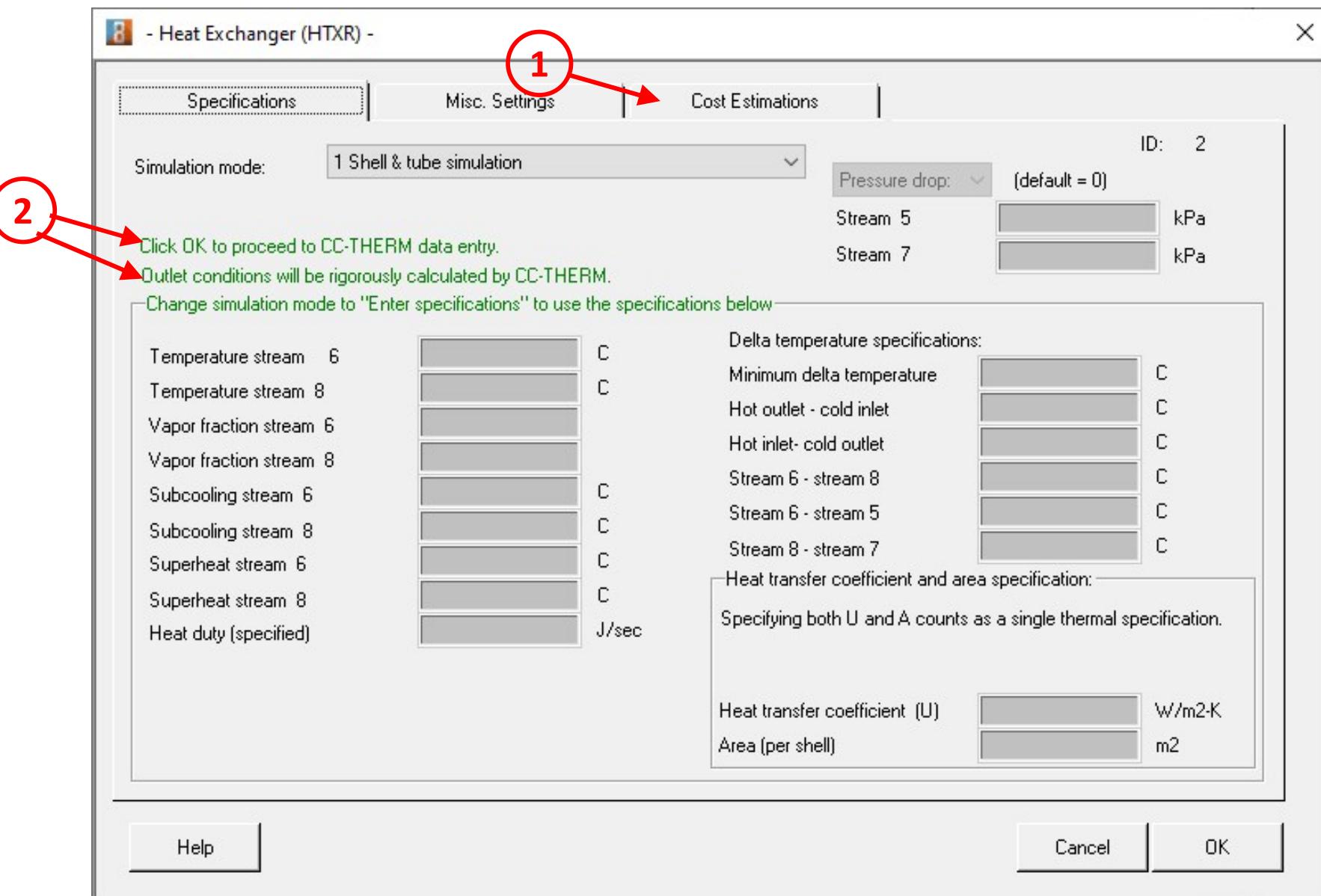
Steady State

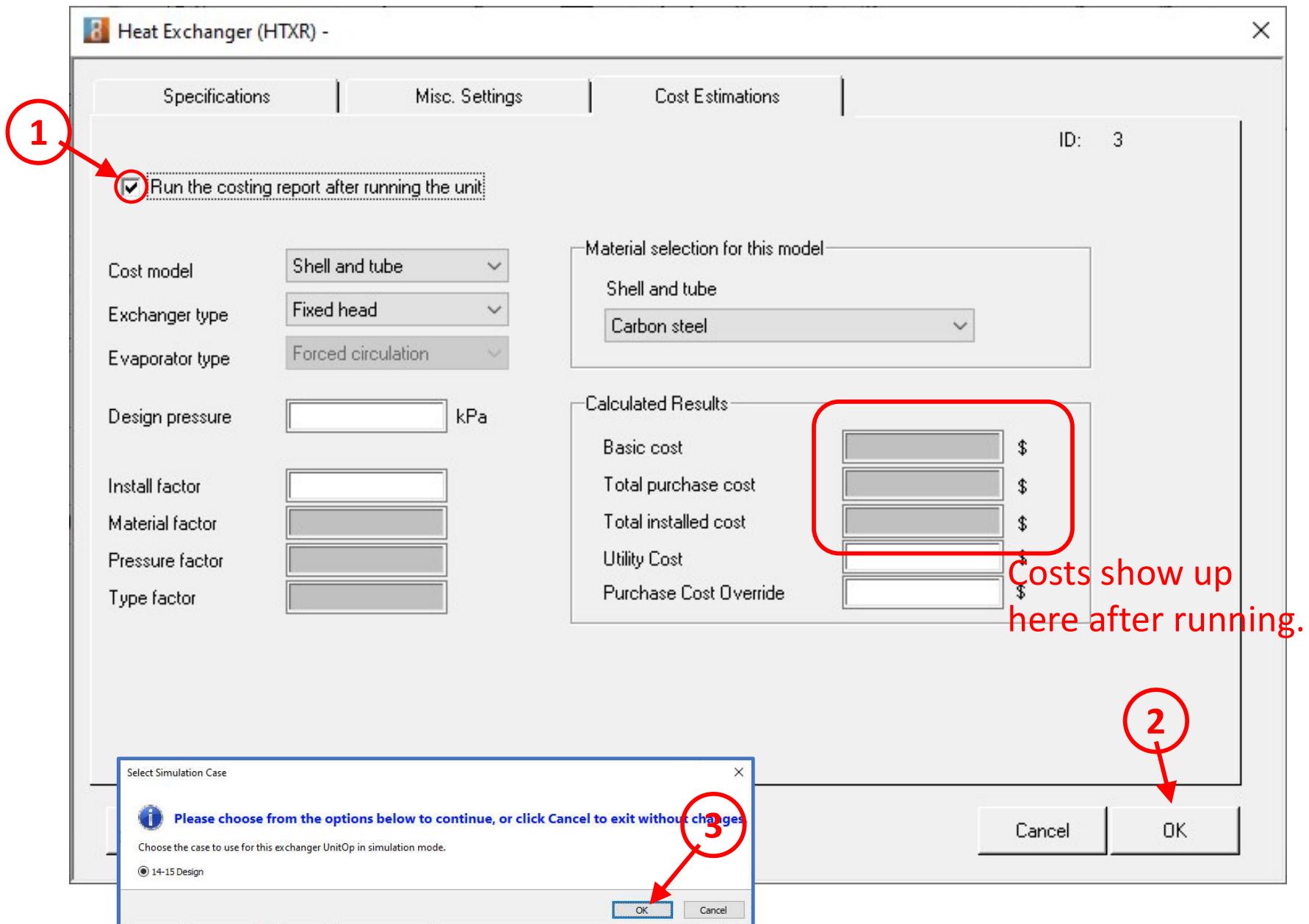
Lesson9\_AY232\_Trial3\* Lesson9\_AY232\_Trial1b\_1

double-click 1 2

The screenshot shows the CHEMCAD 8.1.0 software interface. At the top, there's a menu bar with File, Home, Drawing, View, Thermophys, Component, Specification, Analysis, Sizing, and To. Below the menu is a toolbar with icons for Flowsheet, Data Boxes, Explorer, Palette, Messages, Zoom to Fit, and Status Bar. The Status Bar is highlighted with a blue border. The main area shows a flow diagram of a heat exchanger with streams 9, 10, 11, and 12. Stream 9 enters from the left, passes through a valve (labeled 3), and then enters the heat exchanger. Stream 11 enters from the top and passes through the heat exchanger. Stream 10 exits the heat exchanger and passes through a valve (labeled 1) before exiting to the right. Stream 12 exits from the bottom of the heat exchanger. A red callout 'double-click' points to the valve on stream 10. A red circle labeled '1' points to the valve on stream 10. A red circle labeled '2' points to the '1 Shell & tube simulation' option in the 'Simulation mode:' dropdown of the 'Heat Exchanger (HTXR)' dialog box. The dialog box also contains instructions to click OK for CC-THERM data entry and a note about outlet conditions being rigorously calculated. It lists various specification fields for the heat exchanger, such as temperature streams, vapor fractions, subcooling, superheat, and heat duty. The bottom of the dialog box has Help, Cancel, and OK buttons. The status bar at the bottom of the screen shows 'Steady State'.

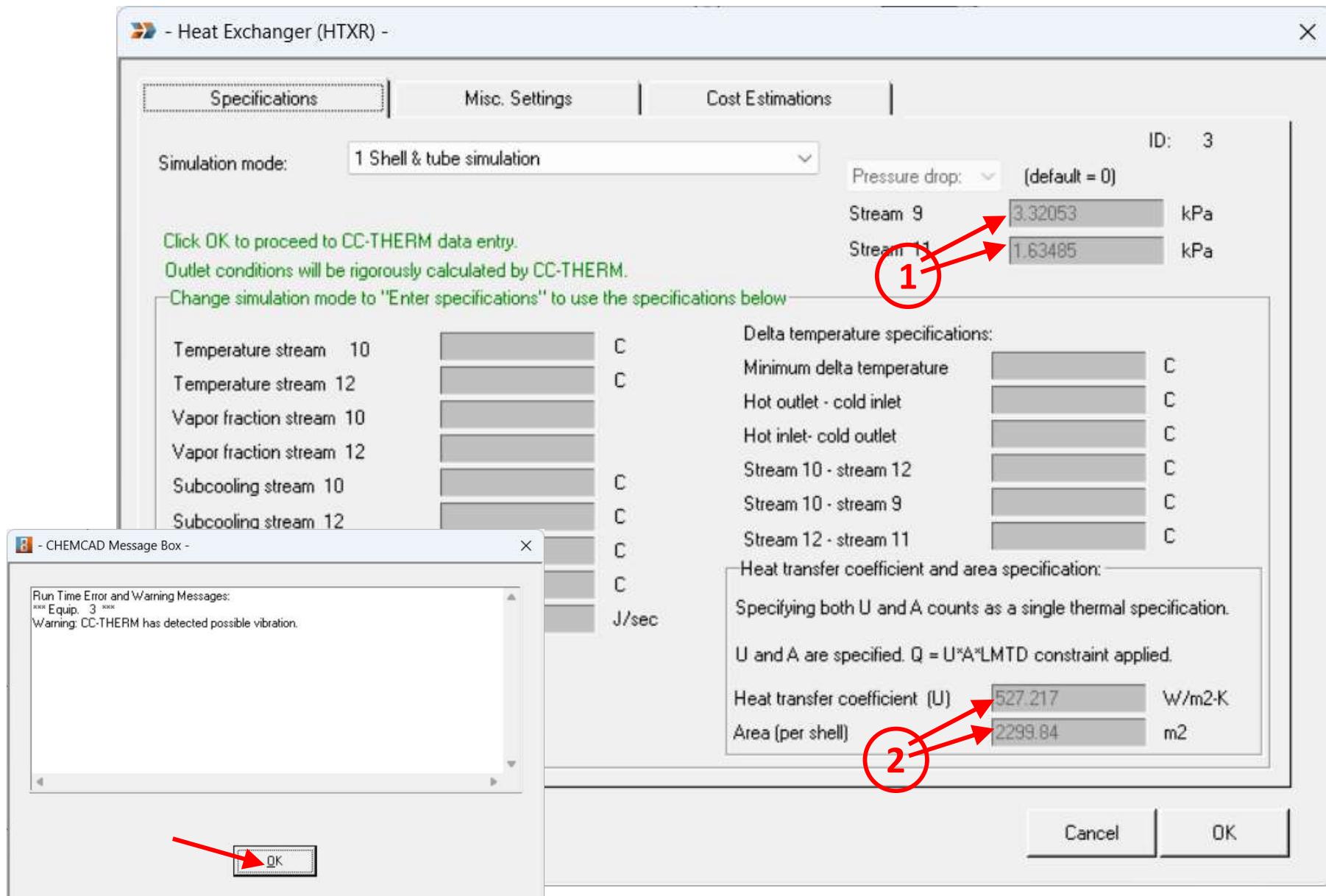
# Heat Exchanger Before Running



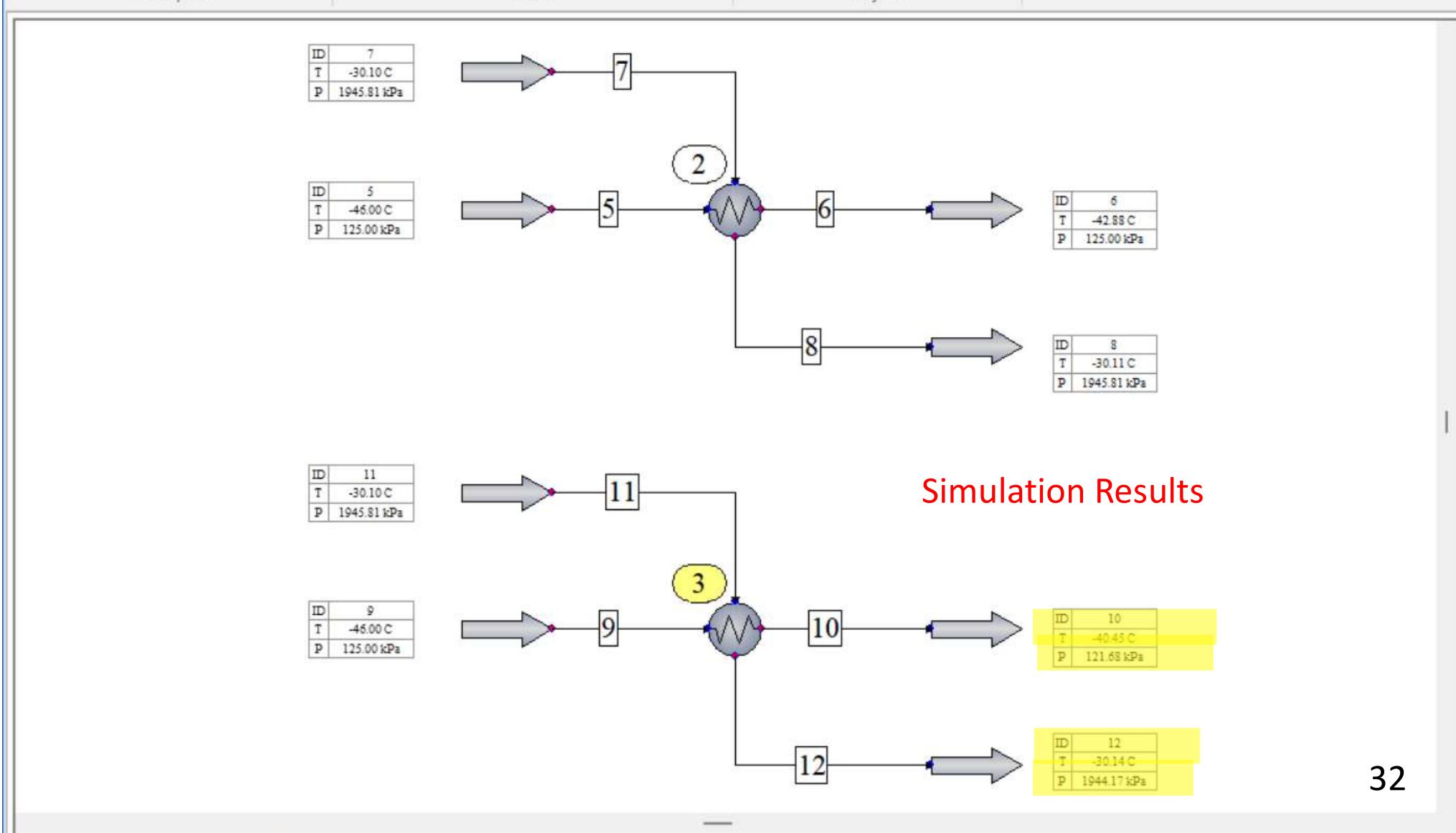
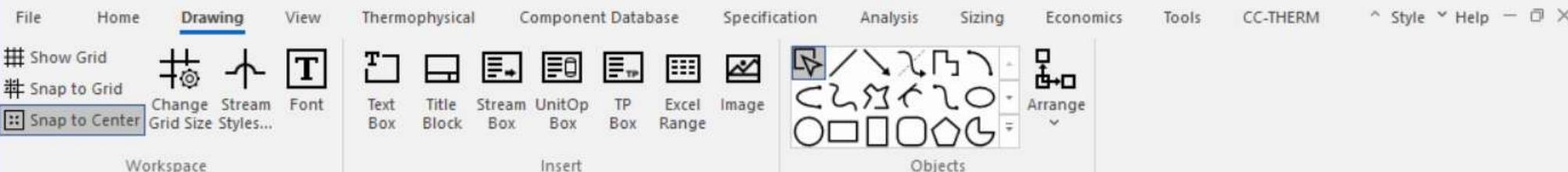


Click OK then run the simulation.

# Heat Exchanger After Running



Click “Run All” in the Home tab



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CHEMCAD NXT 1.2.0 - [14-15 Practice Trial4 - NXT\*]

File Home Drawing View Thermophysical Component Database Specification Analysis Sizing Economics Tools CC-THERM Style Help

Save Data Map Save Data Map As View/Edit New Import... Select Cost Index Edit Cost Economics Costing Index

Execution Rules Simple Calculator Visual Basic Editor Units Converter Reaction Rate Regression CO2 Solid Hydrates TOC/COD...

Title Block UnitOp Designer Designer

Data Map Chemical Engineering Plant Cost Index

Year/Month Selection for the Cost Index

Year: 2026      Month: February      Source: Database

ID: 11      T: -30.10 C      P: 1945.81 kPa

ID: 9      T: -46.00 C      P: 125.00 kPa

Chemical Engineering Plant Cost Index

Type	Cost Index
CE Index	830.50
Equipment	1045.80
Heat exchangers and tanks	815.70
Process machinery	1057.50
Pipes, valves, and fittings	1410.40
Process instruments	620.50
Pumps and compressors	1677.10
Electrical equipment	917.90
Structural supports and misc.	1142.00
Construction labor	390.30
Buildings	835.10
Engineering and supervision	313.20

make sure to set this to February 2026

1      2      3      4

OK

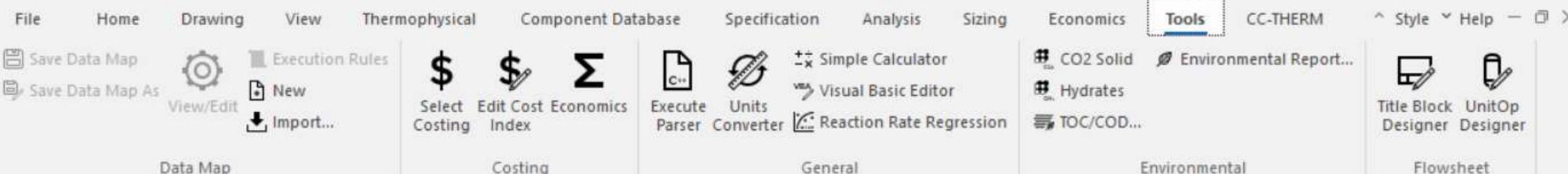
Cancel

Help

Steady State K:SRK H:SRK

14-15 Practice Trial4 - NXT\* 14-15 Practice Trial4 - NXT\_1

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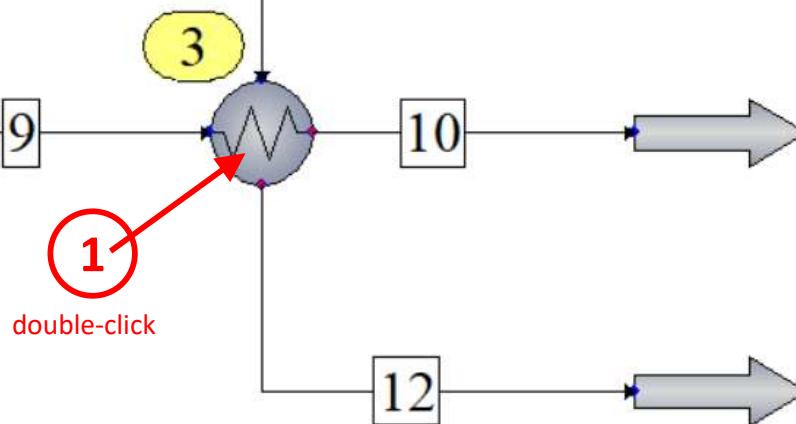
ID	11
T	-30.10 C
P	1945.81 kPa



ID	9
T	-46.00 C
P	125.00 kPa



ID	10
T	-40.45 C
P	121.68 kPa



ID	12
T	-30.14 C
P	1944.17 kPa

# Cost Results

Heat Exchanger (HTXR) - X

Run the costing report after running the unit

Cost model	Shell and tube	Material selection for this model
Exchanger type	Fixed head	Shell and tube
Evaporator type	Forced circulation	Carbon steel
Design pressure	_____ kPa	Calculated Results
Install factor	2	Basic cost <span style="background-color: #cccccc;">317634</span> \$
Material factor	1	Total purchase cost <span style="background-color: #ffff00;">810750</span> \$
Pressure factor	1.28102	Total installed cost <span style="background-color: #cccccc;">1.6215e+06</span> \$
Type factor	0.819535	Utility cost <span style="background-color: #cccccc;">0</span> \$/sec
		Purchase cost override <span style="background-color: #cccccc;">0</span> \$
		 <span style="background-color: #cccccc;">317634</span> \$ <span style="background-color: #cccccc;">767912</span> \$ <span style="background-color: #cccccc;">1.53582e+06</span> \$
		CC NXT 1.2.0

Help Cancel OK

Answer to last question is found here (total purchase cost in Feb 2026).

# STOP HERE

Finished.

Submit CHEMCAD file, tabulated results report,  
and answers to the four (4) questions