

# 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.

page 91

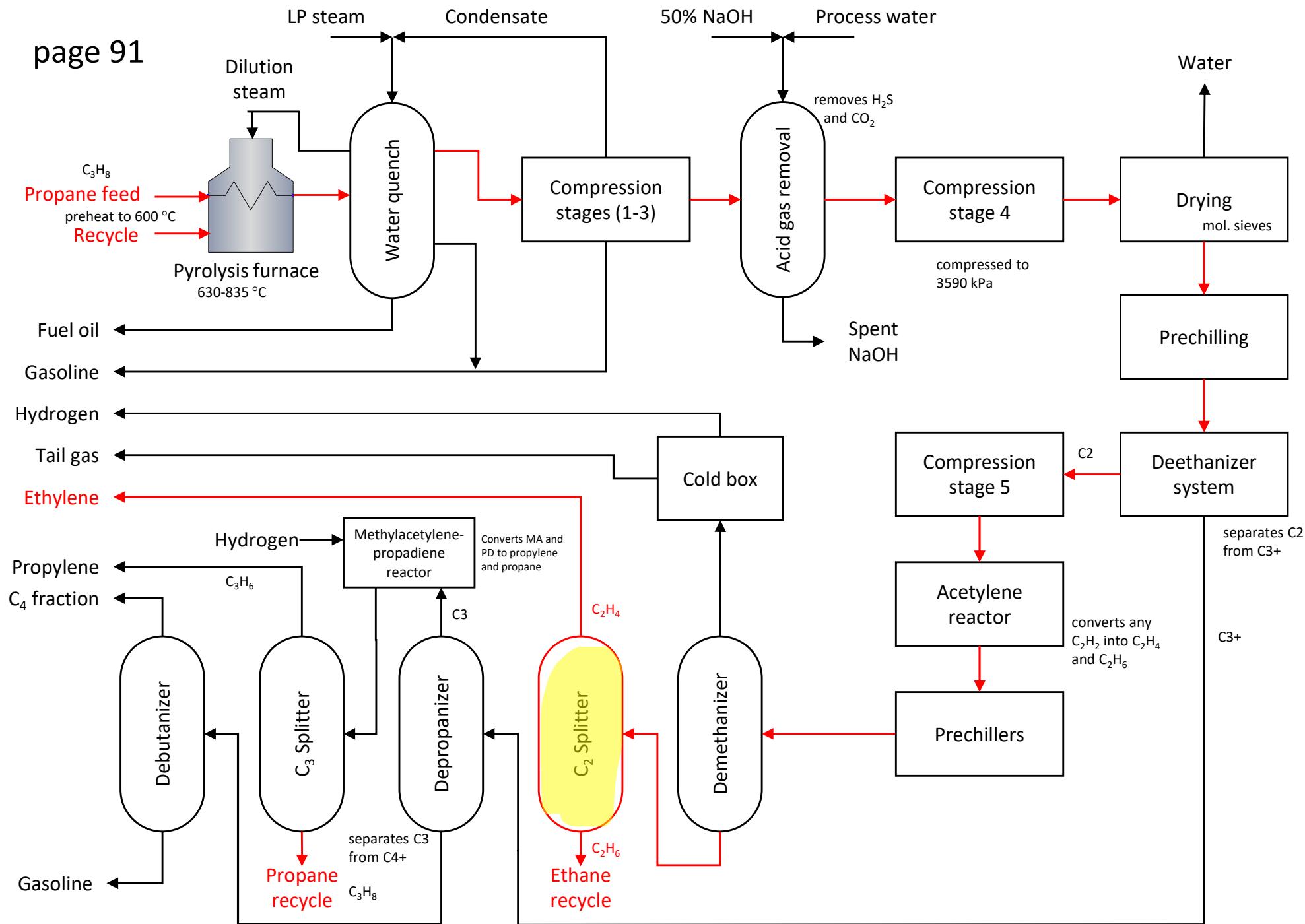


Figure 3-13. Product Separation Section

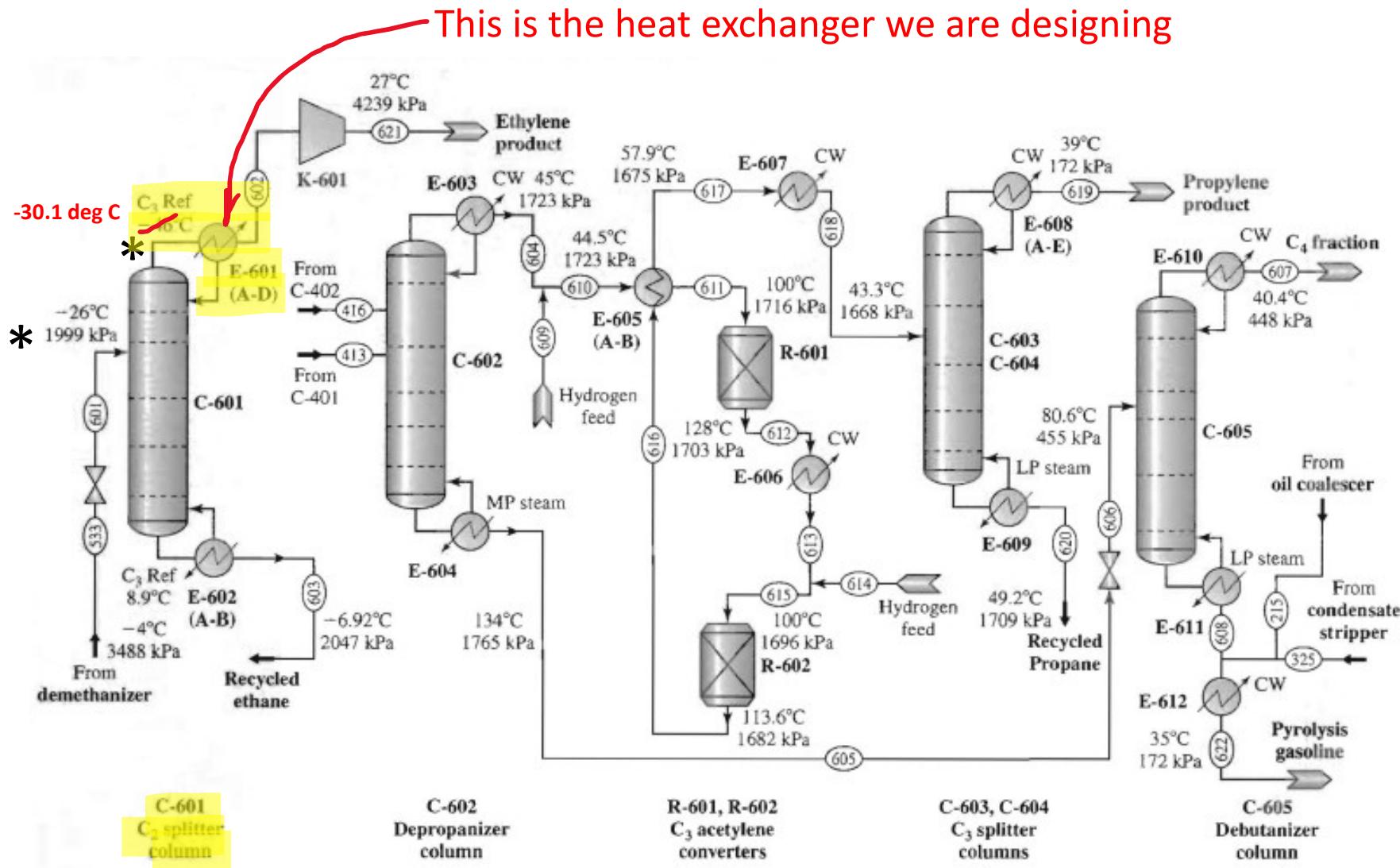


Figure 3-13. Product separation section.

Change CEPCL to Feb 2026 for PS5

Change engineering units

File Home Drawing View Thermodynamic Component C Specification Analysis Sizing Tools CC-THERM

Select Components Thermodynamic Settings Edit Streams UnitOps Edit Edit Stream Property Reports

Steady State Dynamic Run All Run from Initial State Charts Reports

Edit Setup Specification Run Results

Engineering Units

System Profiles

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

User Profiles

- ALT SI
- Research

Current Flowsheet Settings: Custom Save As

Fundamental

Time	sec
Mole/Mass	kg
Temperature	C
Pressure	kPa
Enthalpy	J
Work	kJ

Fluid Flow

Liquid Volume Rate	m <sup>3</sup> /h
Vapor Volume Rate	m <sup>3</sup> /h
Vapor Density	kg/m <sup>3</sup>
Liquid Density/Conc...	kg/m <sup>3</sup>
Crude Flow Rate	m <sup>3</sup> /h
Velocity	m/sec

Fluid Properties

Heat Capacity	kJ/kg-K
Specific Heat	kJ/kg
Heat Transfer Coef...	W/m <sup>2</sup> -K
Thermal Conductivity	W/m-K
Viscosity	N-s/m <sup>2</sup>
Surface Tension	N/m

Dimensions

Length	m
Thickness	m
Diameter	m
Area	m <sup>2</sup>
Liquid Volume	m <sup>3</sup>
Vapor Volume	m <sup>3</sup>

Misc

Solubility Parameter	(J/m <sup>3</sup> ) <sup>0.5</sup>
Dipole Moment	C.m
Cake Resistance	m/kg
Packing dP	mm-water/m
Currency	\$
Currency Factor	1.000000

Stream Flow Units

Total Flow	Default mole/r
Component Flow	Default mole/r
Stream Edit	Automatic con

VBA Flow Units

Flow unit option for some VBA functions.

Mole

Pipe Table Selection

Default pipe table for Pipe, Orifice, and line sizing tool.

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

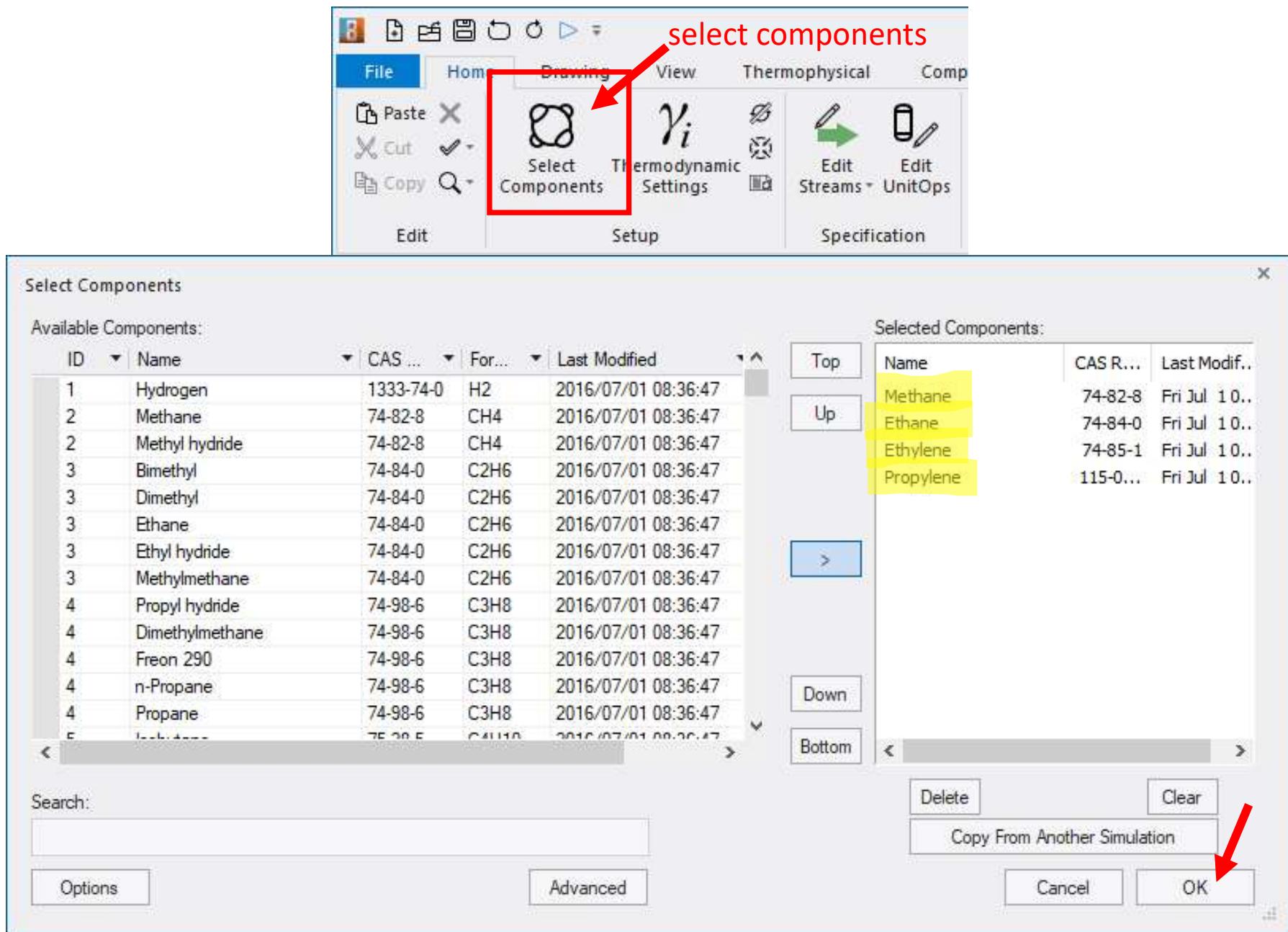
Palette

- 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

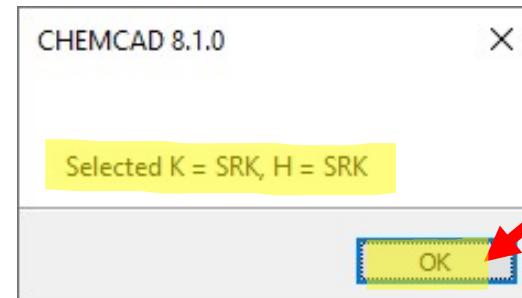
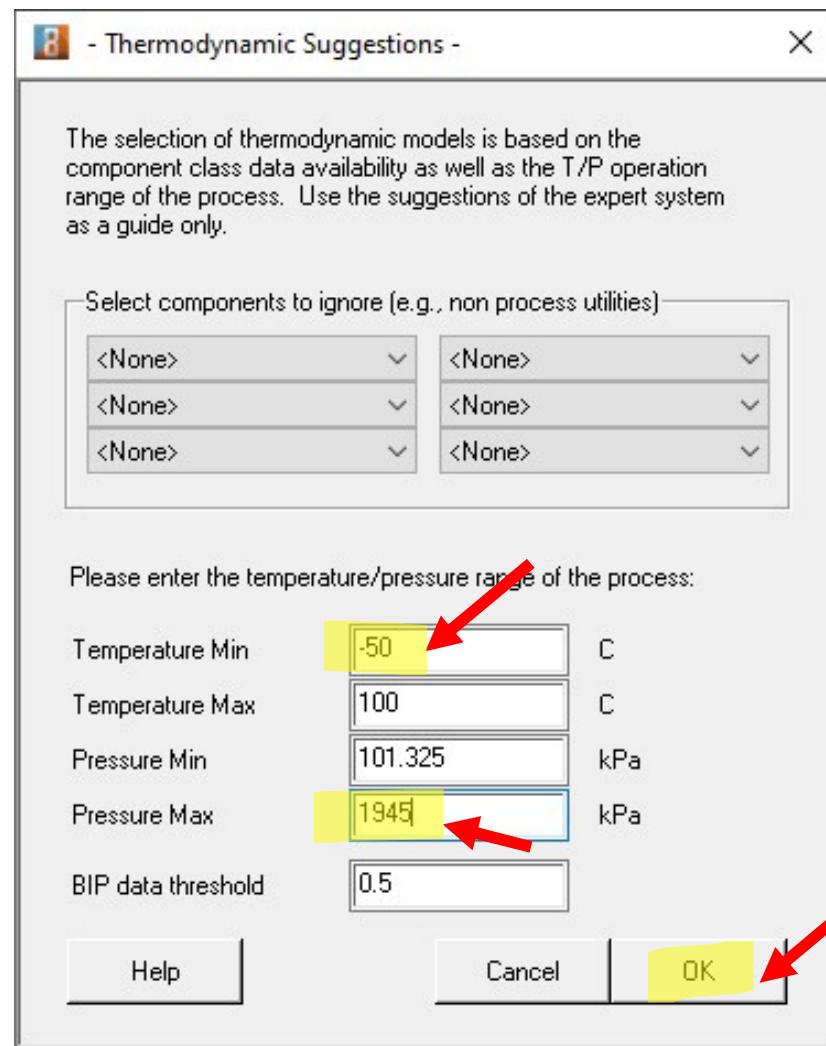
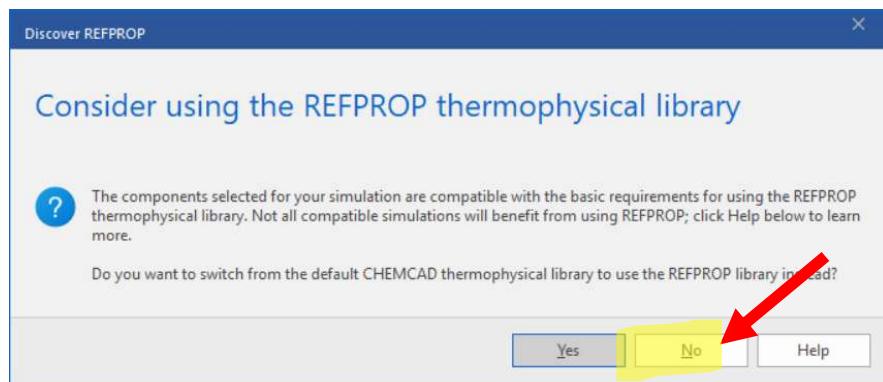
Steady State

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

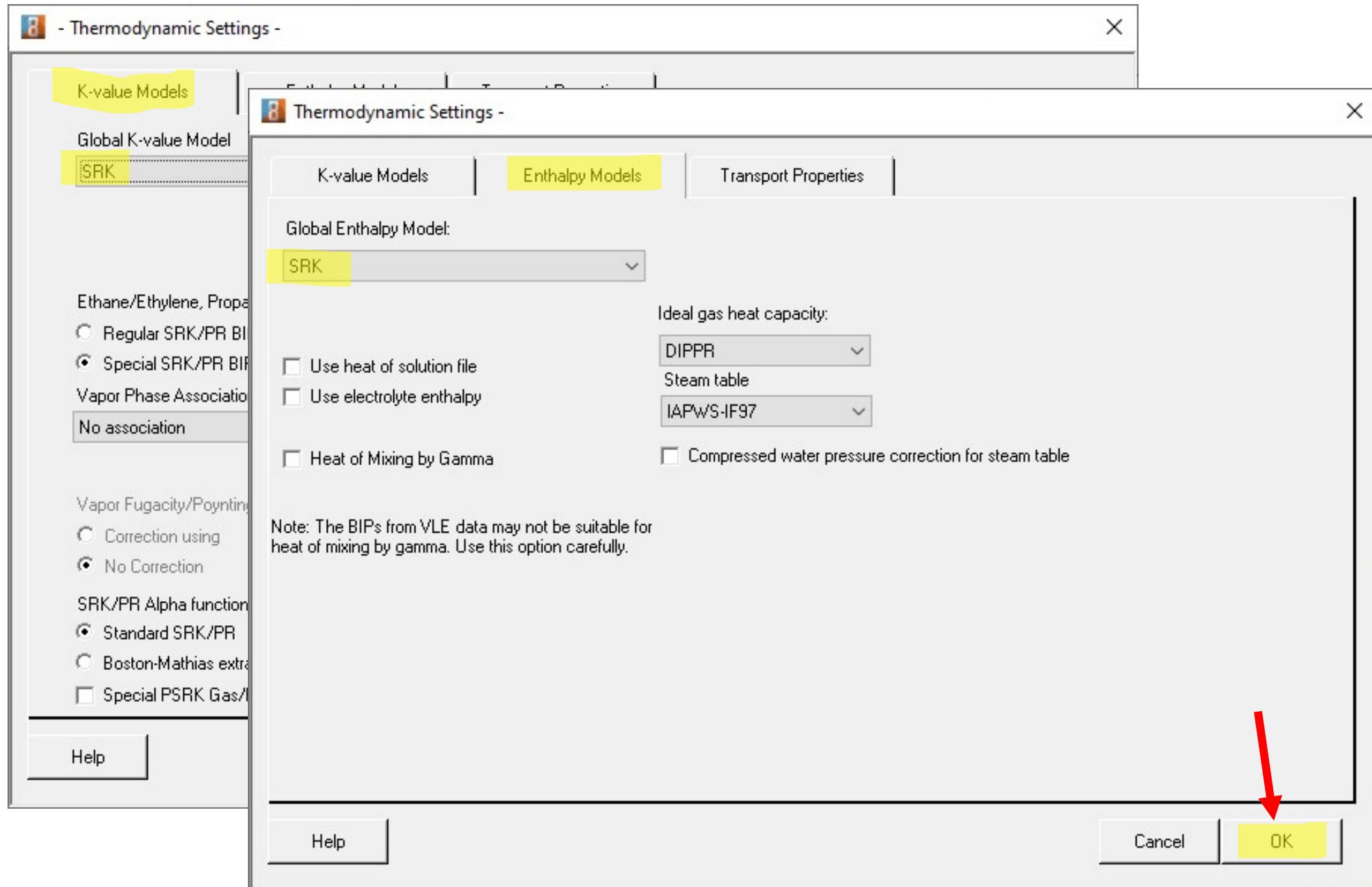


"Thermodynamic Suggestions" window launches automatically when you click OK.

# Thermodynamic Suggestions



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



CHEMCAD 8.1.0 - [Untitled\*]

File Home Drawing View Thermophys Component Specification Analysis Sizing Tools CC-THERM

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

Draw flowchart and solve m/e balances.

Step 1 – Lesson 8, slide 3.

Overhead vapor → 3

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

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.

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

# 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.

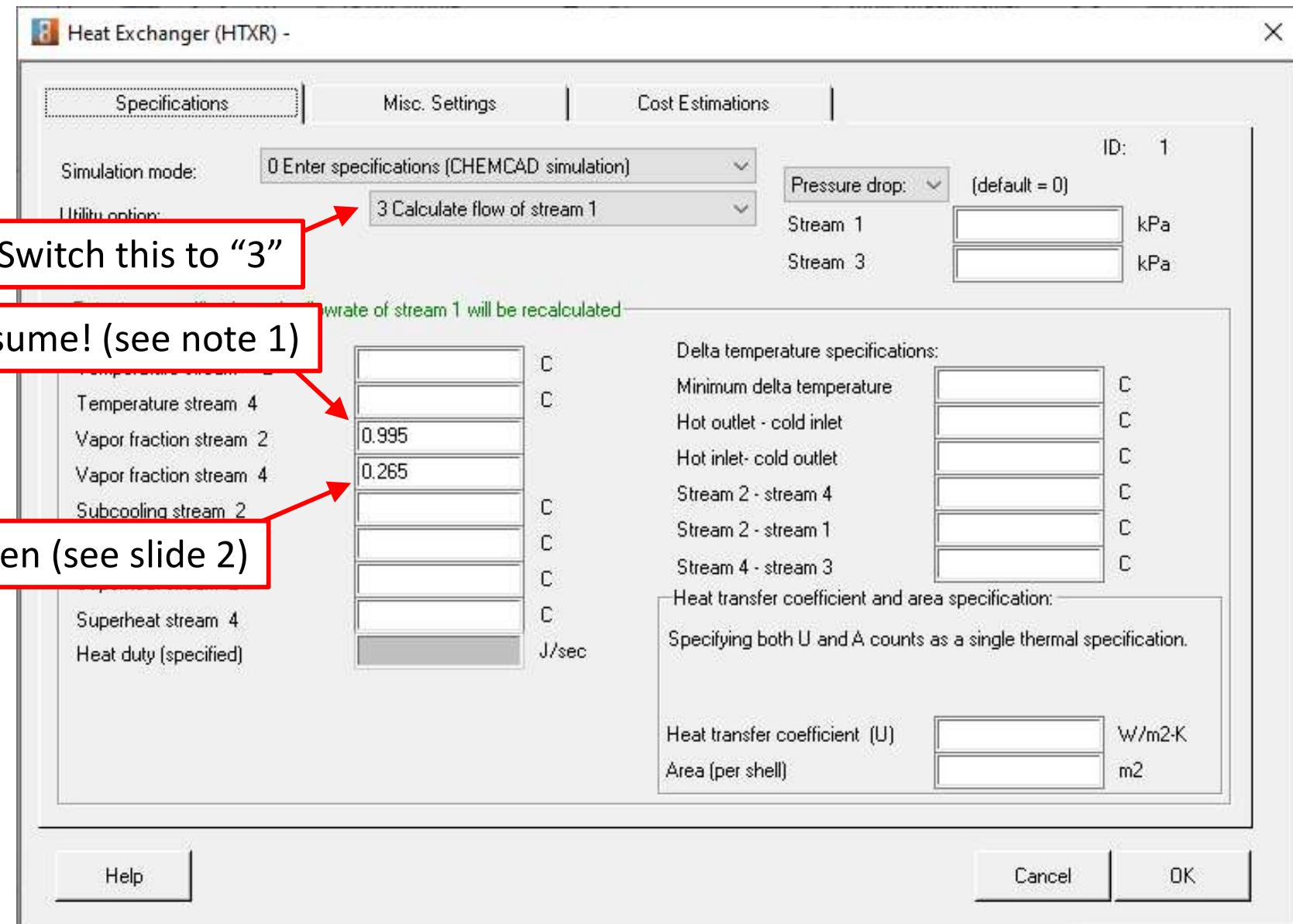
Edit Streams		
	Flash	X
Stream No.	1	3
Stream Name		
Temp C	-46	-30.1
Pres kPa	125	1945.806
Vapor Fraction	0	1
Enthalpy J/sec	-77463.29	1.114613e+08
Total flow	1	64.5956
Total flow unit	kg/sec	kg/sec
Comp unit	kg/sec	kg/sec
Methane	0	0.003
Ethane	0	0.0626
Ethylene	0	64.53
Propylene	1	0

Two specs needed:  
Set temperature and  
vapor fraction.

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

CHEMCAD will solve for the  
actual flow rate later.

# 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 toolbar on the left contains icons for Select Components, Thermodynamic Settings, Edit Streams, Edit UnitOps, Steady State (which is highlighted in blue), and Run All. 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 arrow points to the 'Steady State' button in the toolbar.

**Edit Streams**

Flash

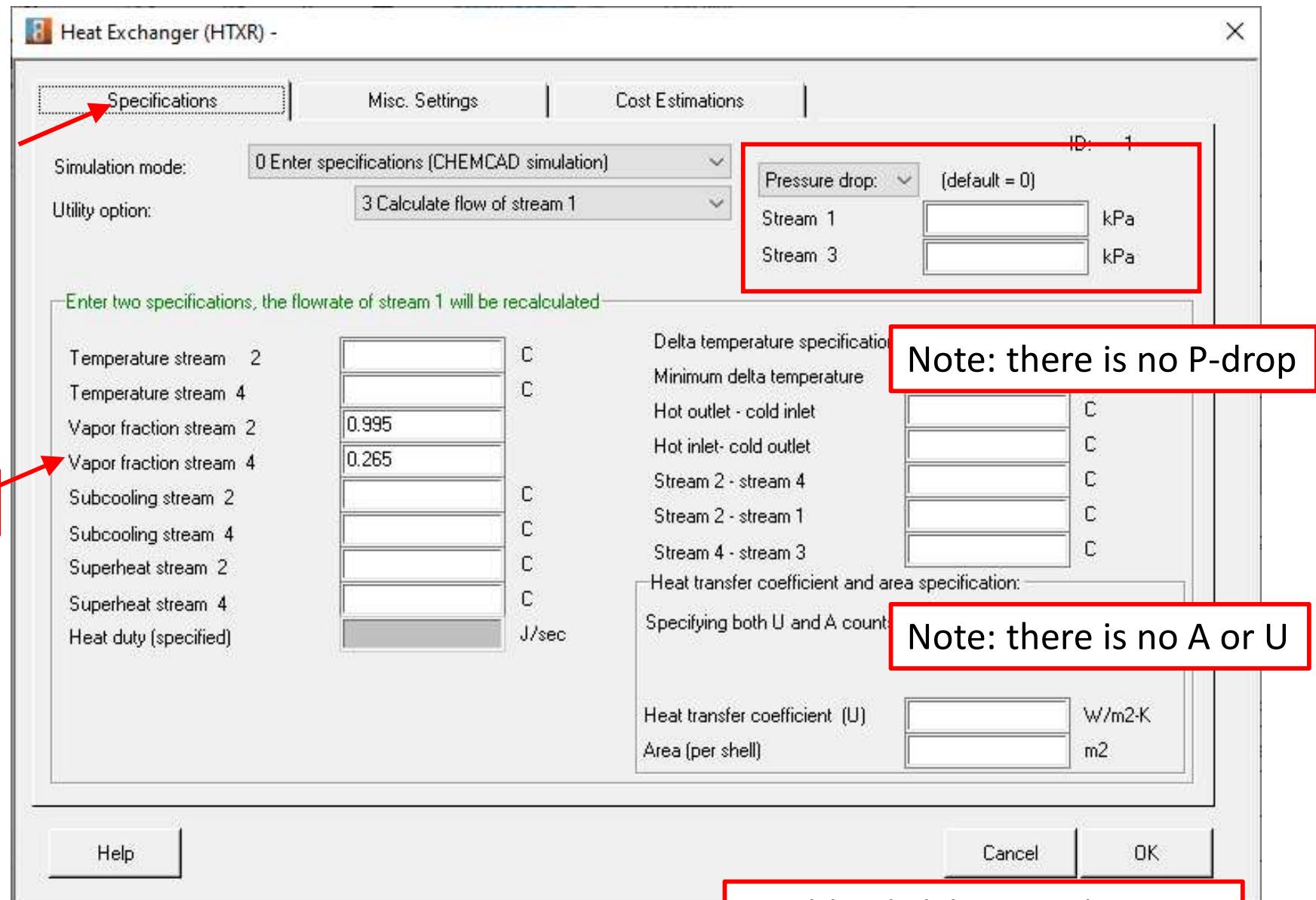
Stream No.	1
Stream Name	
Temp C	-46
Pres kPa	125
Vapor Fraction	0
Enthalpy J/sec	-2733769
Total flow	35.29116
Total flow unit	kg/sec
Comp unit	kg/sec
Methane	0
Ethane	0
Ethylene	0
Propylene	35.29116

Double-click stream 1 to check results

Stream 1 properties:

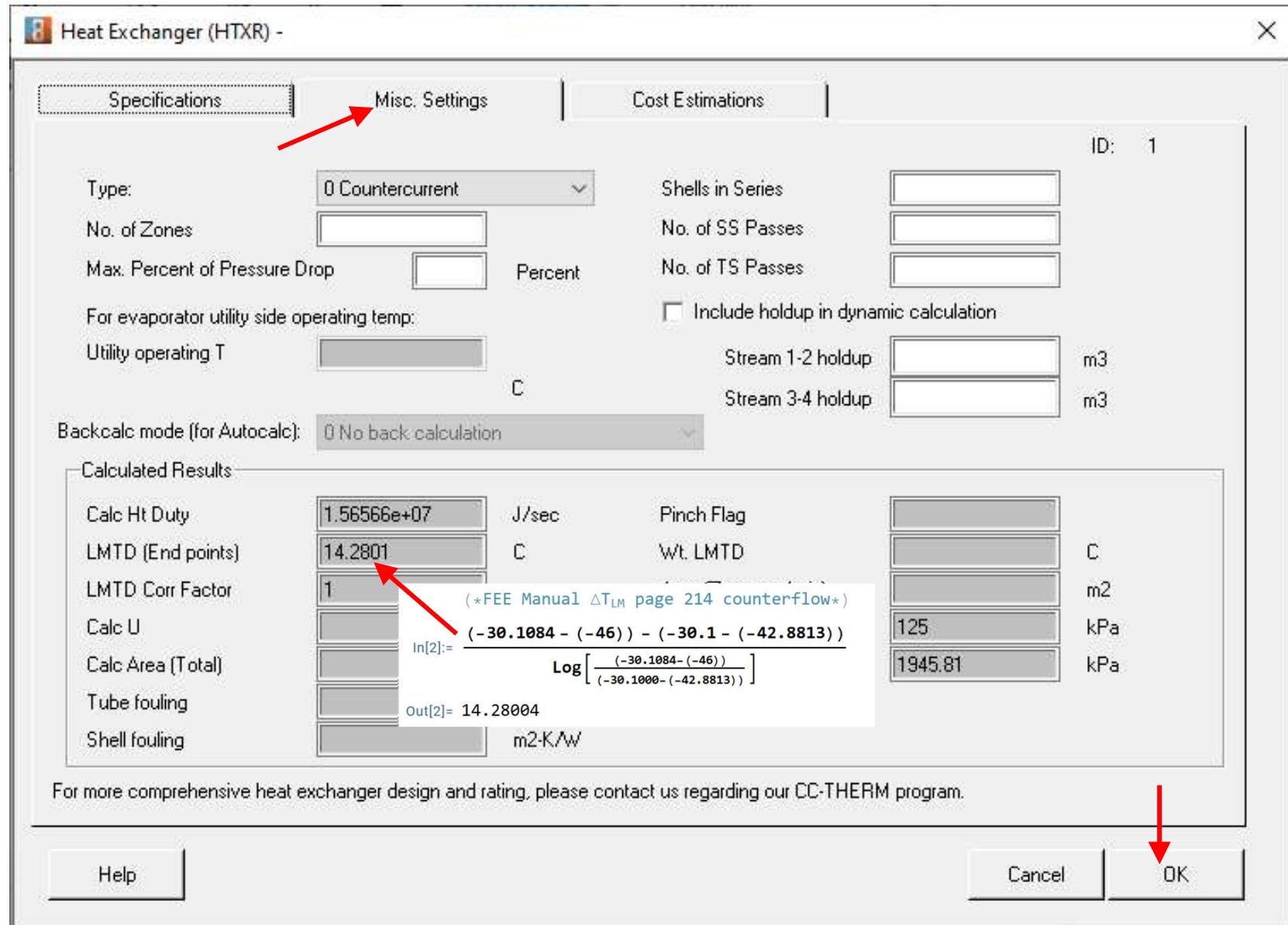
- Stream Name: (empty)
- Temp C: -46
- Pres kPa: 125
- Vapor Fraction: 0
- Enthalpy J/sec: -2733769
- Total flow: 35.29116
- Total flow unit: kg/sec
- Comp unit: kg/sec
- Methane: 0
- Ethane: 0
- Ethylene: 0
- Propylene: 35.29116

# Confirm Results (2/3)



Double-click heat exchanger  
to confirm results

# Confirm Results (3/3)



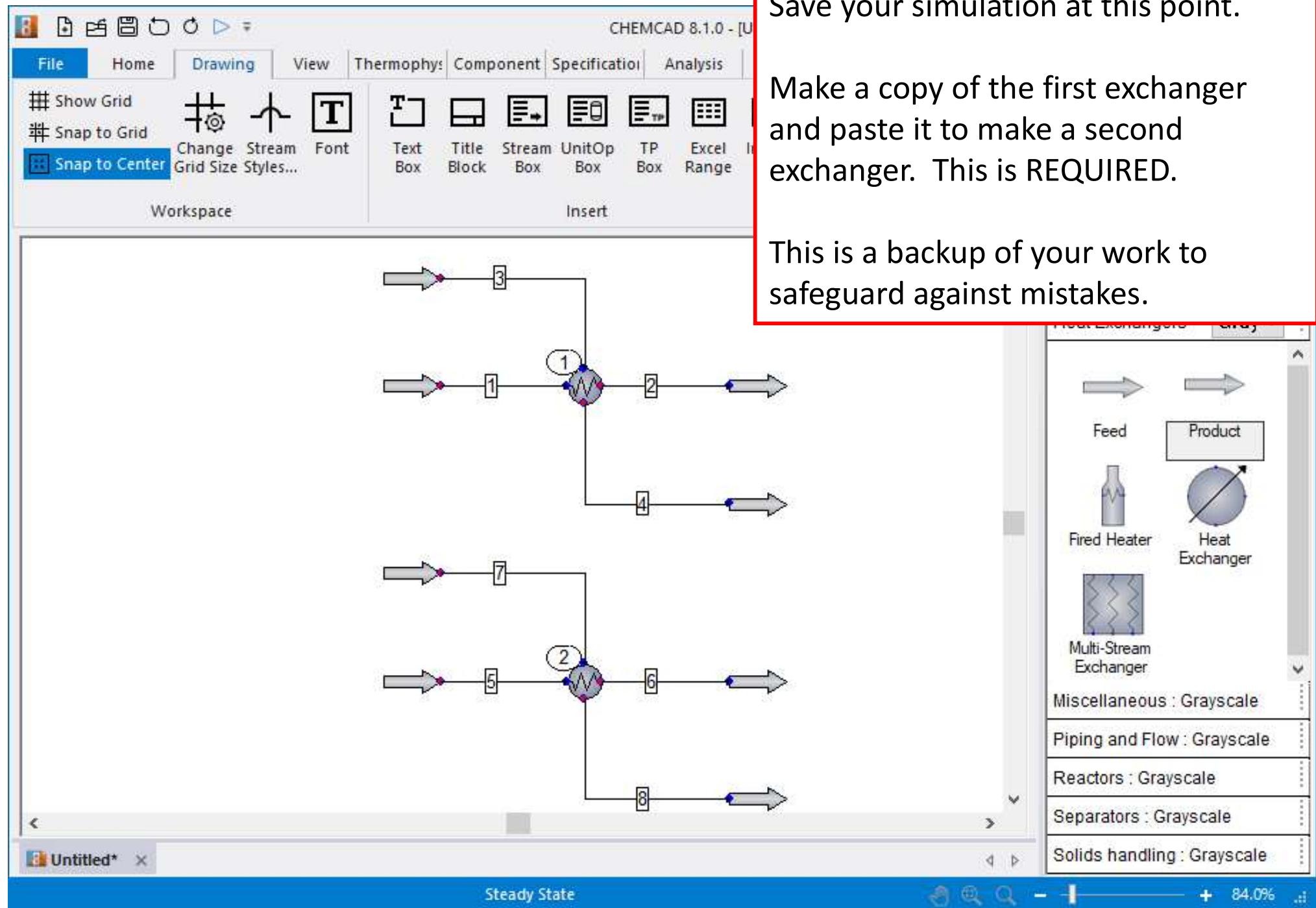
Numbers in gray fields were calculated by CHEMCAD

# 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.

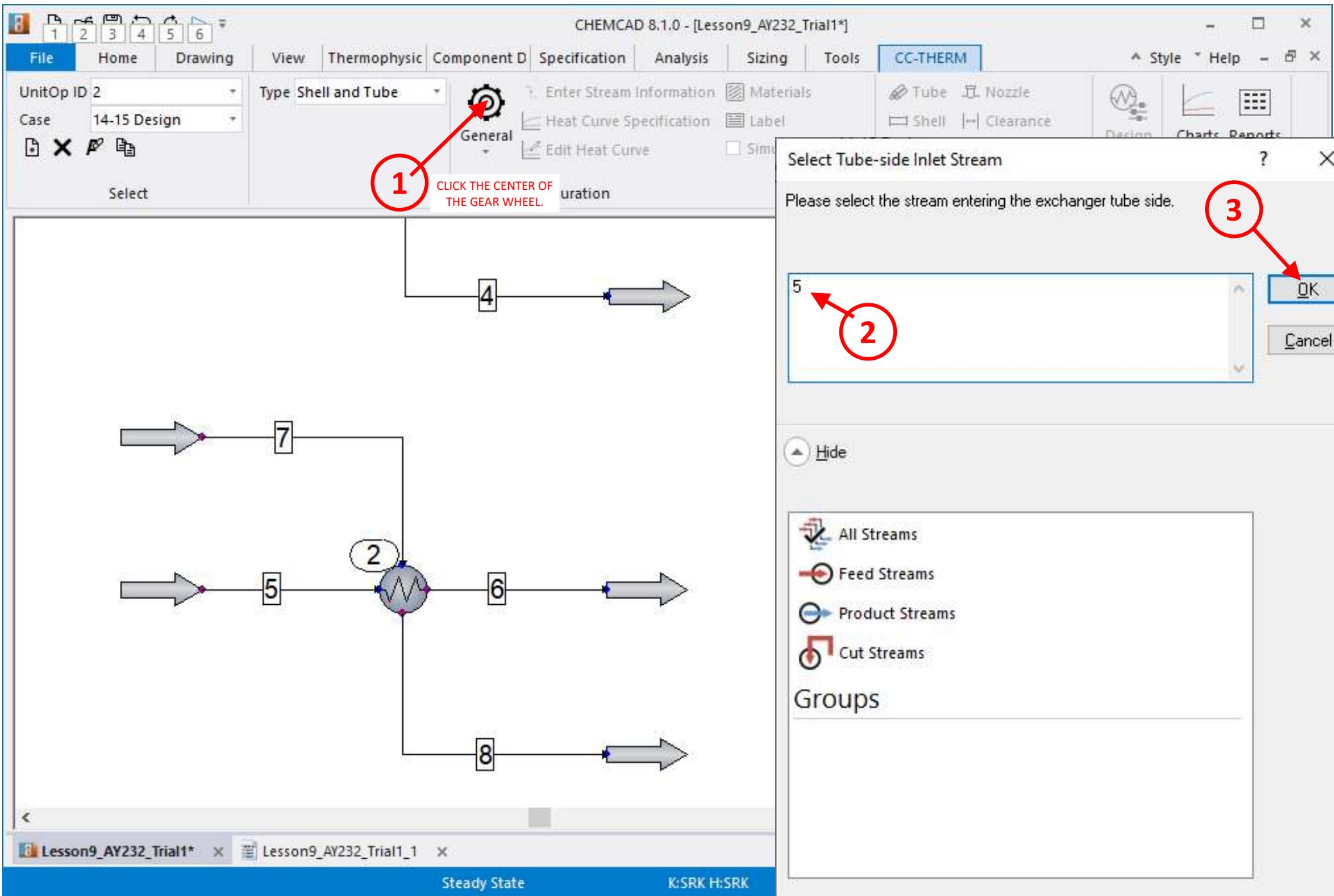


Click "Sizing," then "Shell-and-tube."

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

The screenshot shows the CHEMCAD 8.1.0 software interface with the following elements:

- Toolbar:** File, Home, Drawing, View, Thermophys, Component, Specification, Analysis, Sizing (highlighted), Tools.
- Tool Buttons:** Tray, Packing (circled with red arrow 2), Shell and Tube (highlighted), Plate, Double Pipe, LV Vessel, LLV Vessel, Pipe, Orifice, Control Valve, Relief Device, Safe.
- Flowsheet:** A process flow diagram with two heat exchangers. The top heat exchanger has ports labeled 1, 2, 3, and 4. The bottom heat exchanger has ports labeled 5, 6, 7, and 8. Arrows indicate the flow direction through each unit.
- Select UnitOps Dialog:** A modal dialog titled "Select UnitOps" with the following content:
  - Type a UnitOp ID or select UnitOps with the left mouse button.
  - To select all UnitOps, click flowsheet and then press [CTRL-A].A list box contains the numbers 2 and 3, with red circle 3 pointing to it. The dialog includes OK and Cancel buttons.
- New CC-THERM Case Dialog:** A modal dialog titled "New CC-THERM Case" with the following content:
  - Enter the name of the new CC-THERM case: "14-15 Design" (highlighted with red circle 5).
  - Cancel and OK buttons.
- Status Bar:** Untitled\*, Steady State.



## TEMA Type AEL Exchanger. Take all defaults.

General Specifications

General Information Modeling Methods

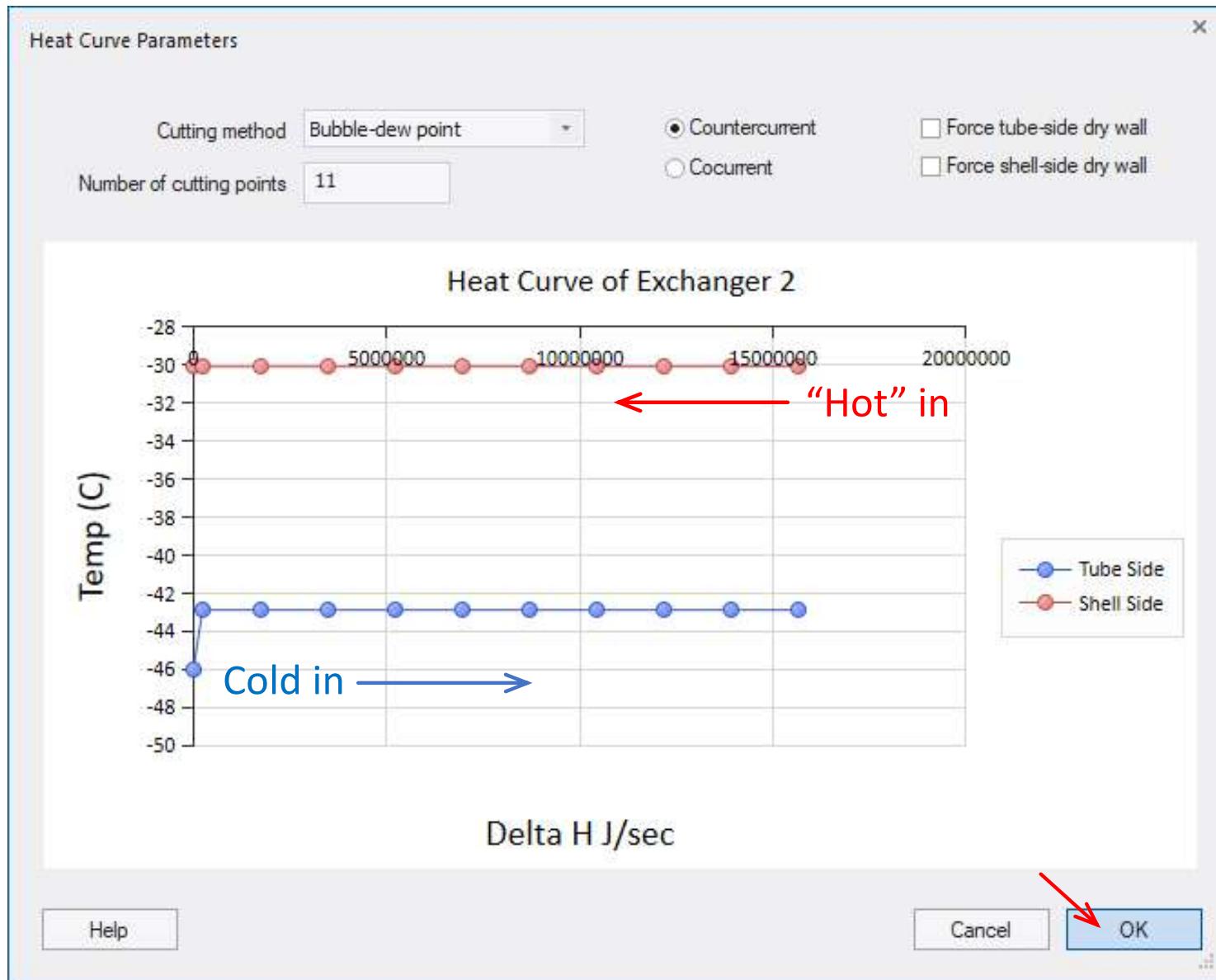
TEMA class/ standard	TEMA R
Orientation	Horizontal
TEMA front end head	A - Channel Removable Cover
TEMA shell type	E - One Pass
TEMA rear end head type	L - Fixed Tubesheet (A head)
Stream name	Tube Side
Process type	Forced Evaporation
Fouling factor	0.00017610948 m <sup>2</sup> -K/W
Optional h Coeff.	W/m <sup>2</sup> -K
Shell Side	Horiz Condensation
	0.00017610948 m <sup>2</sup> -K/W
	W/m <sup>2</sup> -K

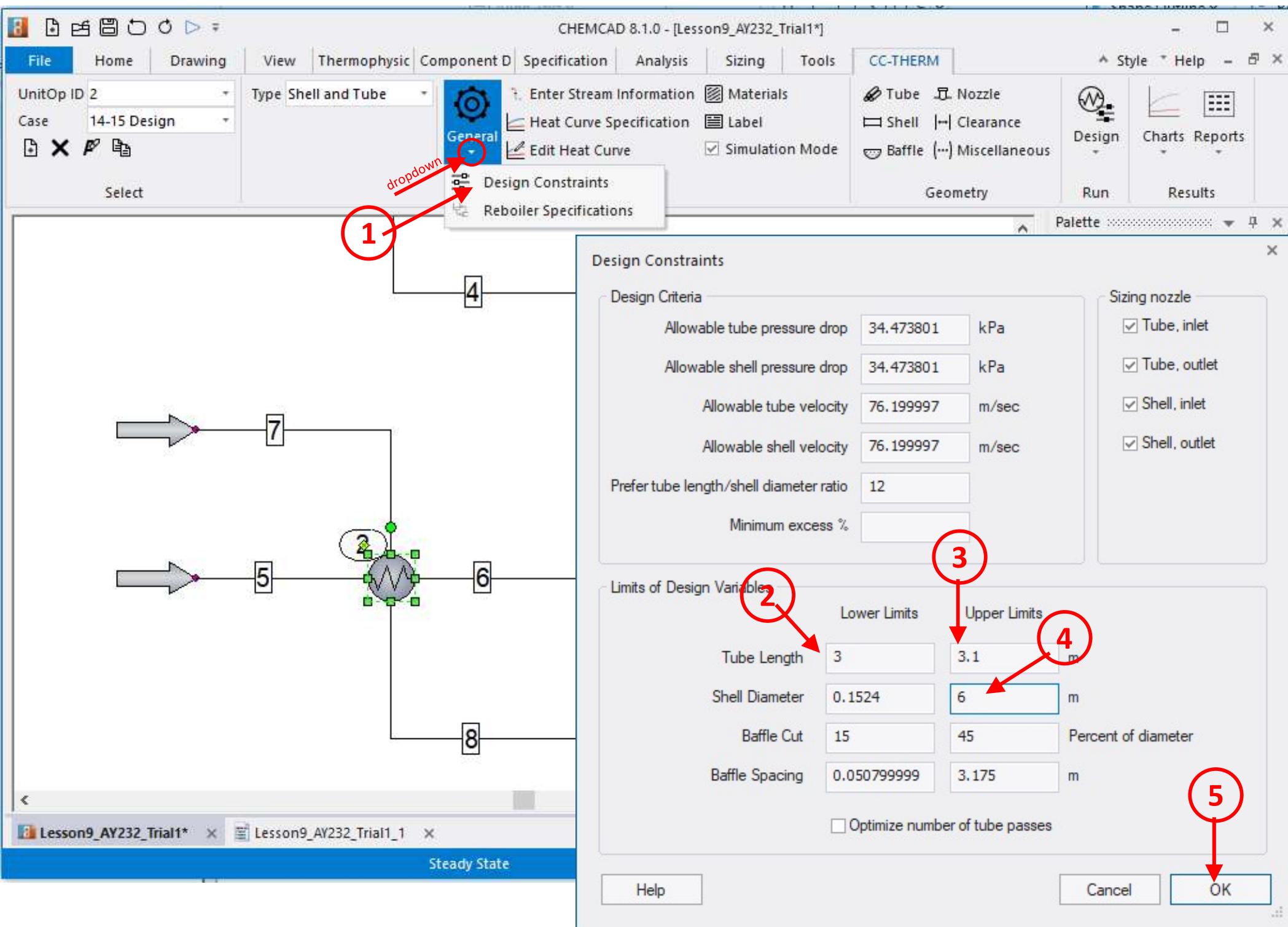
For fouling rating calculations: Calculate tube-side fouling only

Help Cancel OK

3

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





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

Case 14-15 Design

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) ← 4

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

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

Steady State K:SRK H:SRK

128.0%

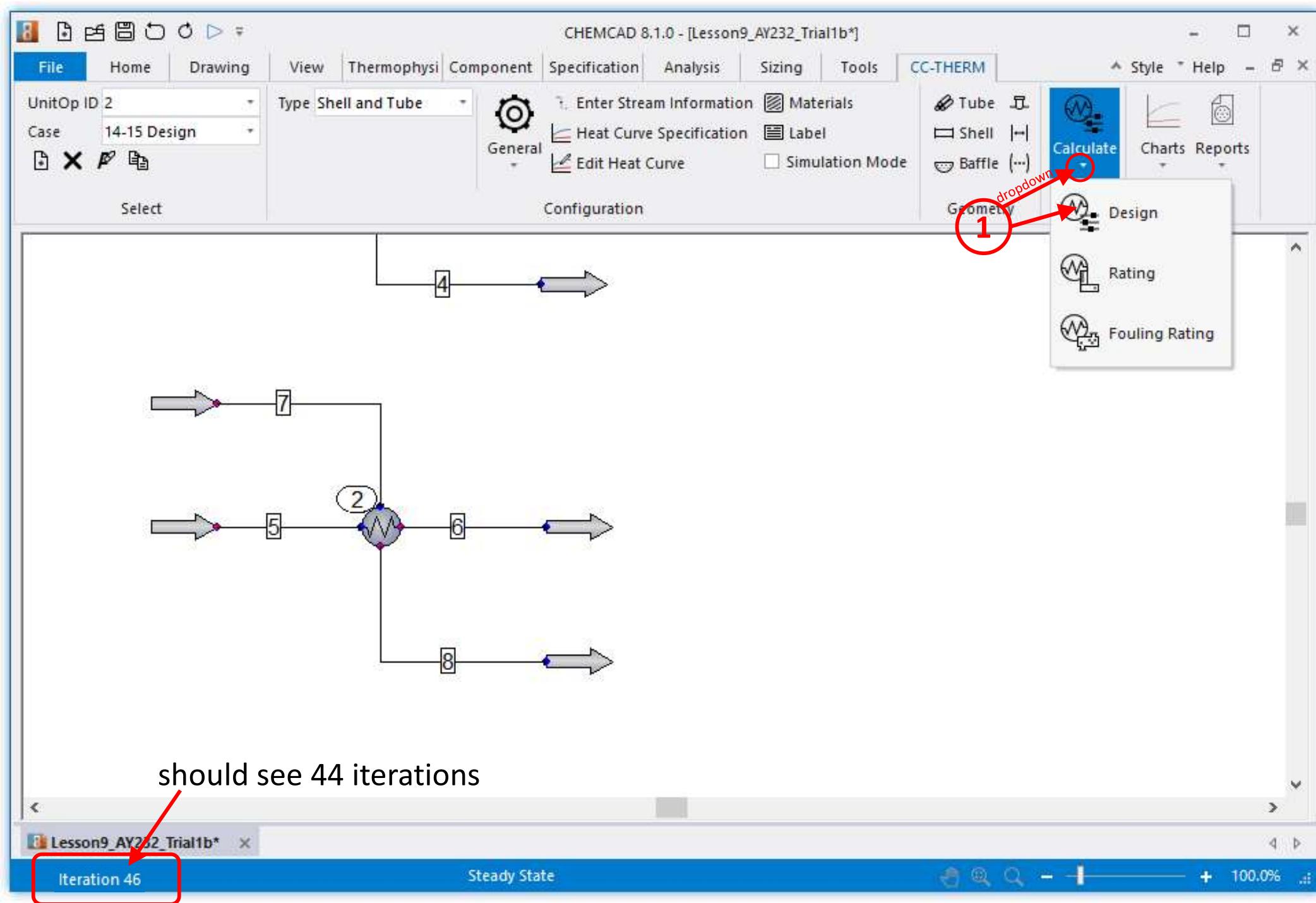
1

2

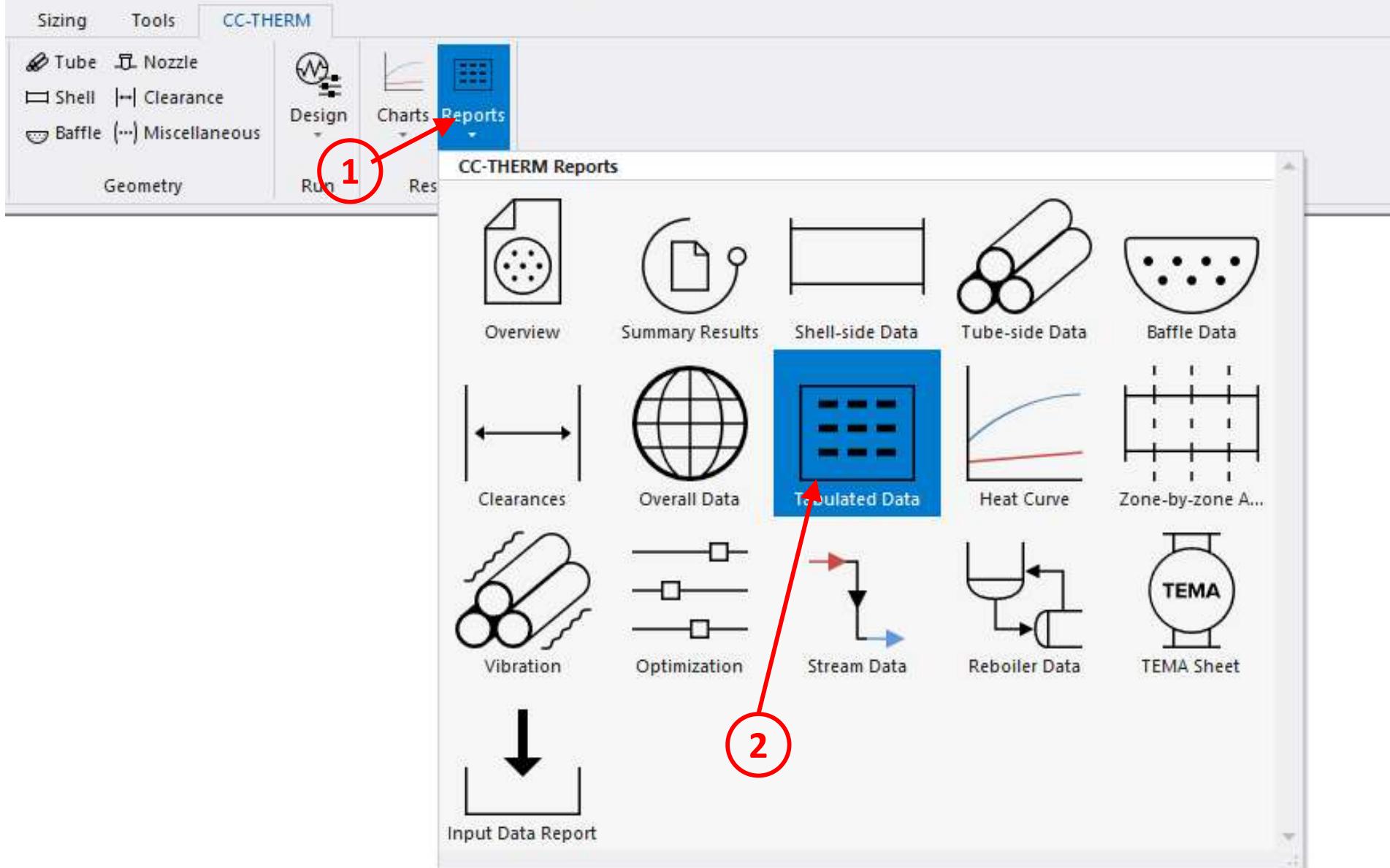
3

4

5



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



# Design Results – CHEMCAD NXT 1.2.0

## TABULATED ANALYSIS

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### Overall Data:

Area Total	m <sup>2</sup>	2348.77	% Excess	5.97	
Area Required	m <sup>2</sup>	2161.02	U Calc. W/m <sup>2</sup> -K	566.06	
Area Effective	m <sup>2</sup>	2290.05	U Service W/m <sup>2</sup> -K	534.16	
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	0.00069
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

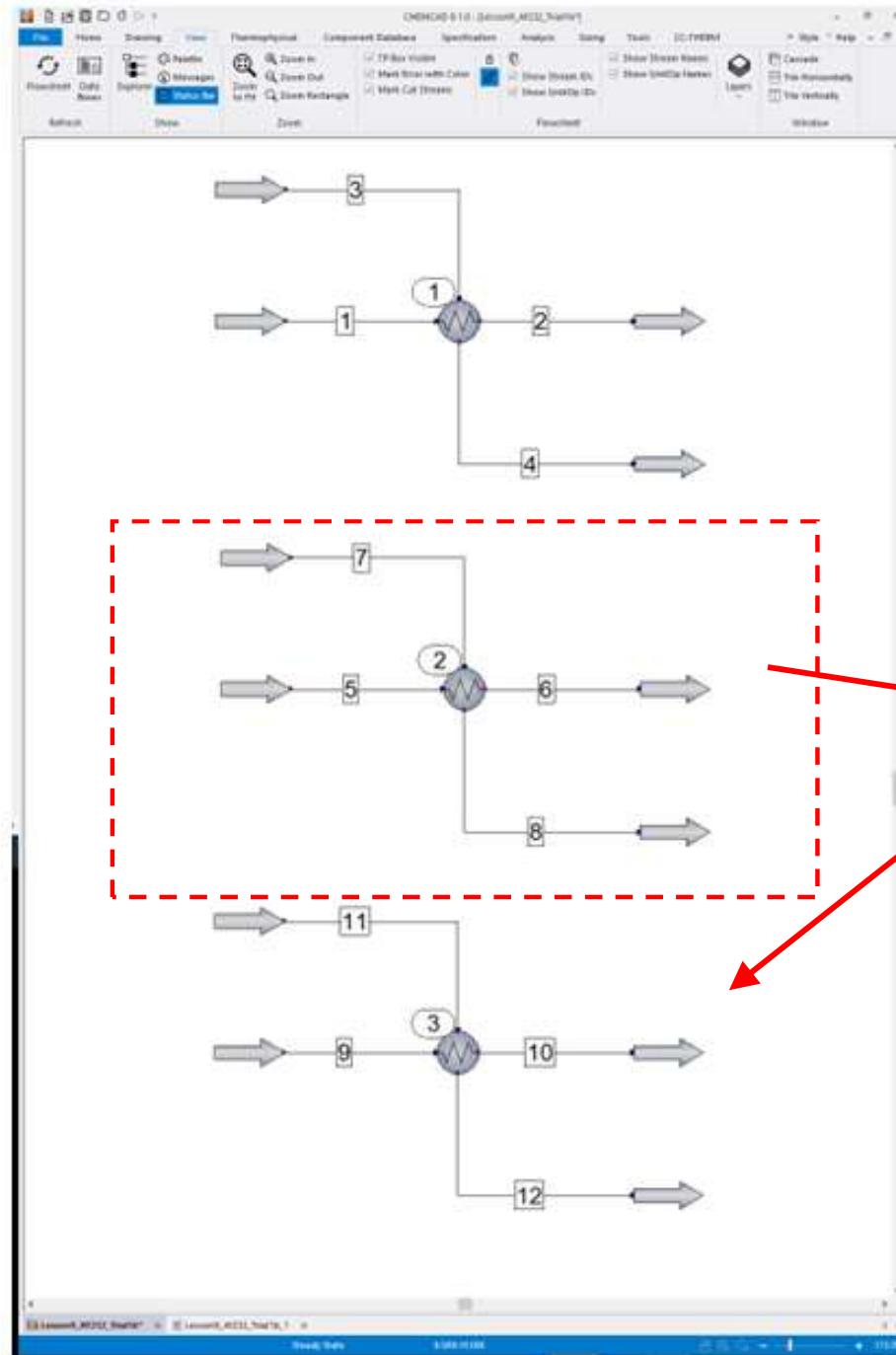
Answers to first three questions are found here. How many tubes? Shell diameter? Largest resistance?

# 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 Status Bar

Refresh Show Zoom Flowsheet Window

CHEMCAD 8.1.0 - [Lesson9\_AY232\_Trial3\*]

Palettes Messages Zoom to Fit

TP Box Visible Mark Error with Color Mark Cut Streams

Show Stream IDs Show UnitOp IDs

- 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 and

Heat transfer coefficient (U)

Area (per shell)

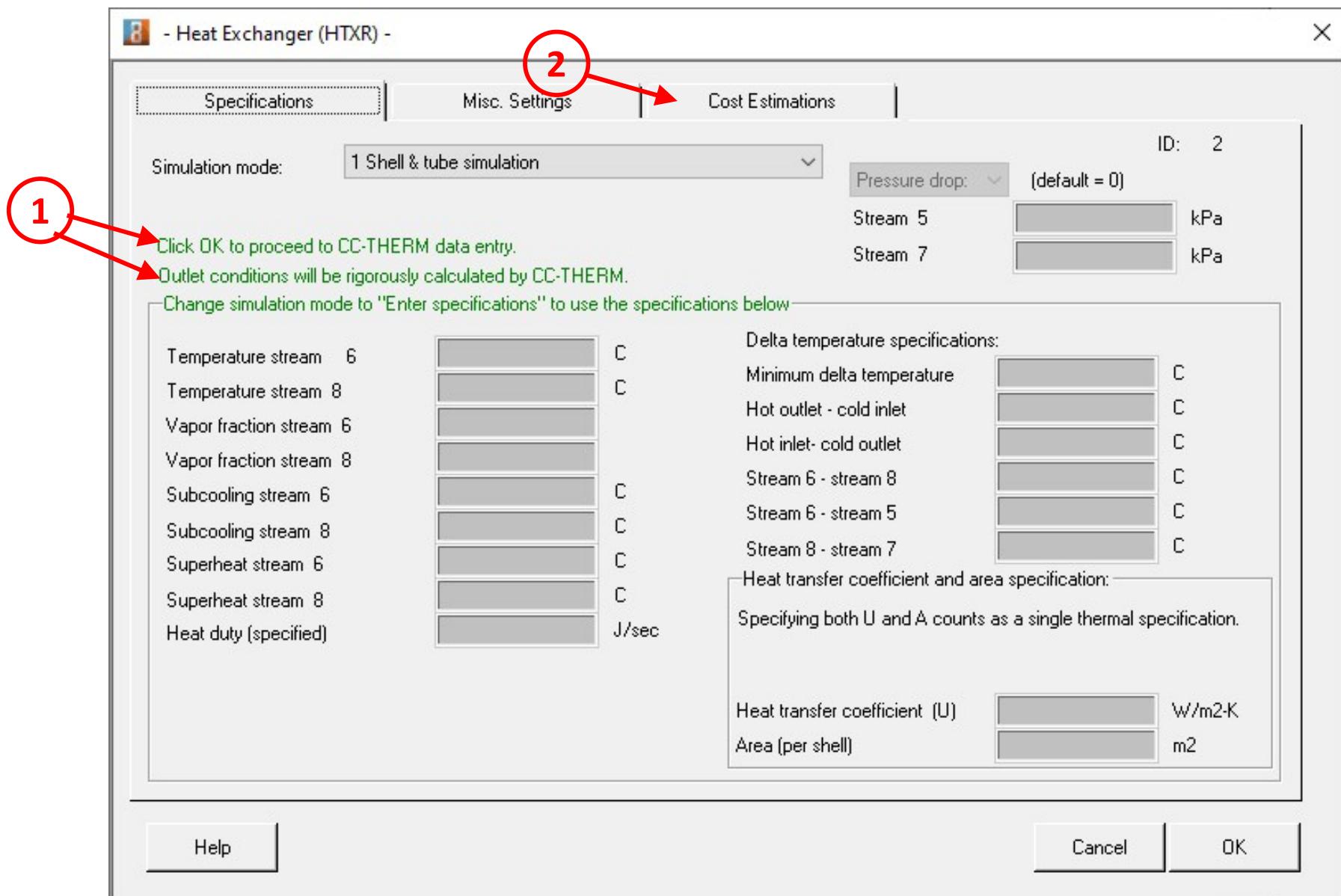
Help Cancel OK

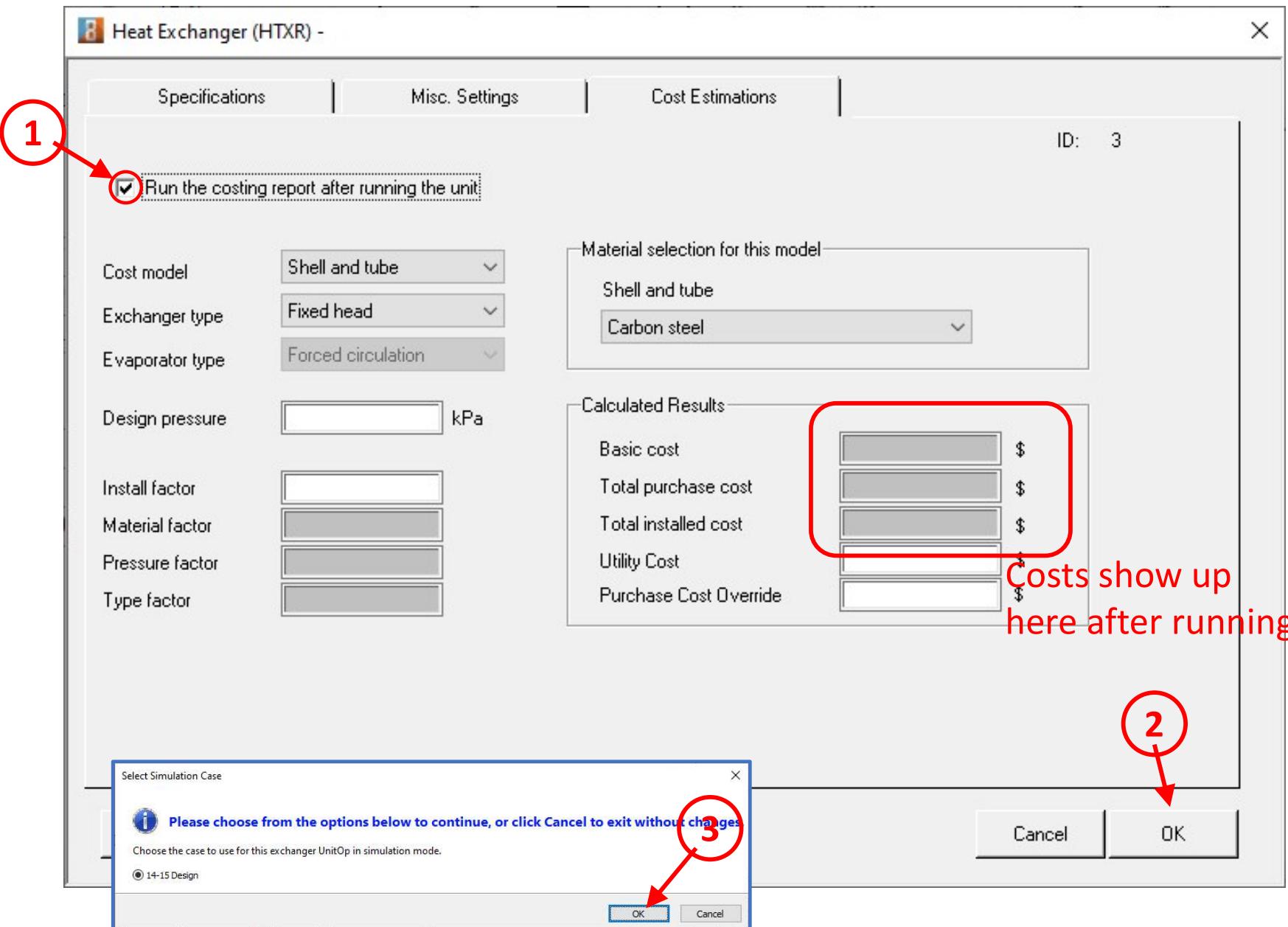
Steady State

double-click 1 2

The image shows the CHEMCAD 8.1.0 software interface. On the left, a flowsheet diagram of a heat exchanger is displayed. Stream 9 enters from the bottom left, passes through a valve (labeled 3), and then enters the heat exchanger (represented by a wavy pipe). Stream 11 enters from the top left and passes through the heat exchanger before exiting as stream 10. Stream 10 then passes through a valve (labeled 2) and exits as stream 12. A red circle labeled '1' points to the valve on stream 10, with the text 'double-click' above it. A red circle labeled '2' points to the dropdown menu in the 'Simulation mode:' field of the dialog box. The dialog box title is '- Heat Exchanger (HTXR) -'. It has tabs for 'Specifications', 'Misc. Settings', and 'Cost Estimations'. The 'Specifications' tab is active. The 'Simulation mode:' dropdown is set to '1 Shell & tube simulation'. Below it, instructions say 'Click OK to proceed to CC-THERM data entry.' and 'Outlet conditions will be rigorously calculated by CC-THERM.' A note says 'Change simulation mode to "Enter specifications" to use the specifications below'. A table lists various specification fields: Temperature stream 10, Temperature stream 12, Vapor fraction stream 10, Vapor fraction stream 12, Subcooling stream 10, Subcooling stream 12, Superheat stream 10, Superheat stream 12, and Heat duty (specified). The right side of the dialog box contains descriptions for these specifications. At the bottom are 'Help', 'Cancel', and 'OK' buttons. The status bar at the bottom of the screen shows 'Steady State'.

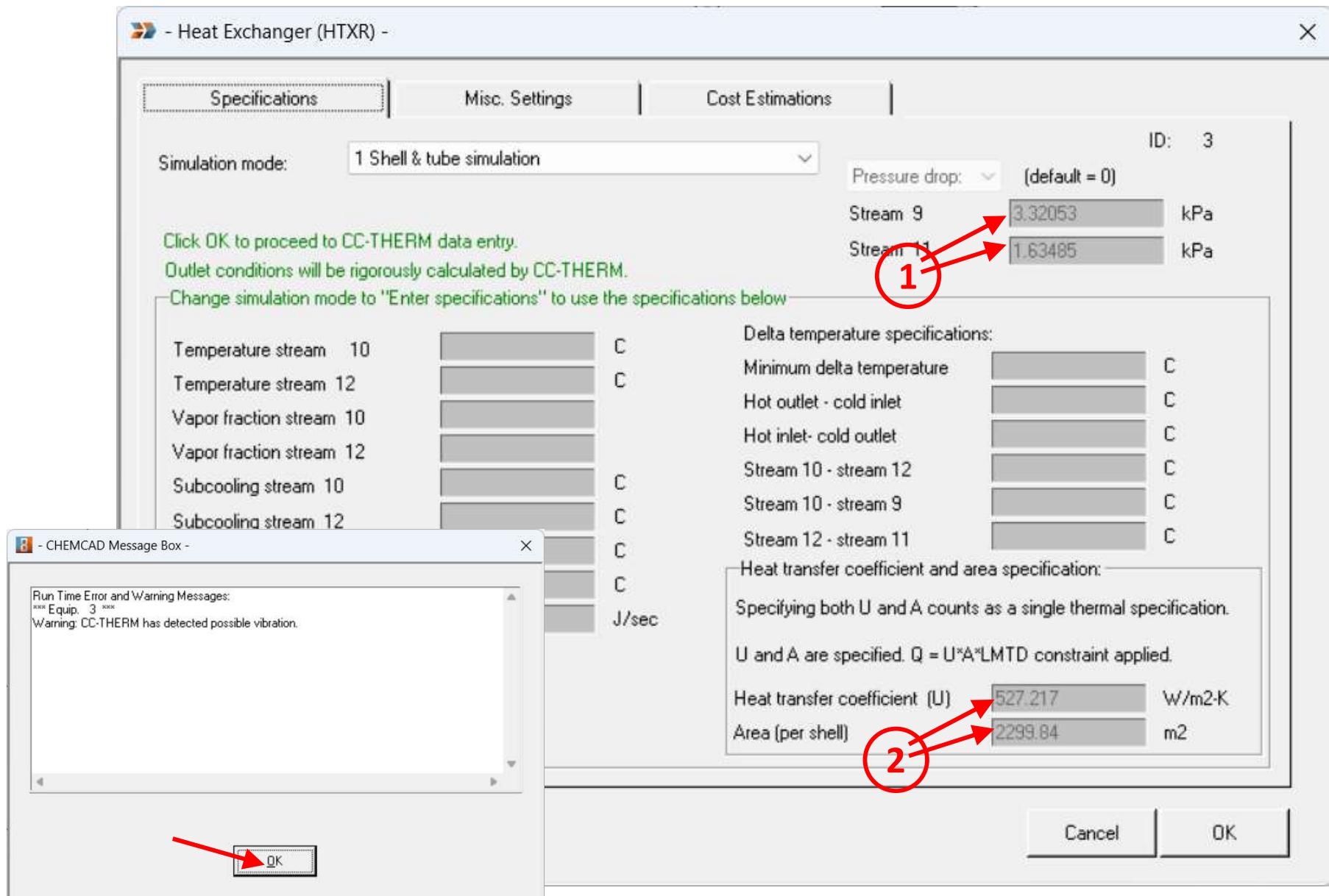
# Heat Exchanger Before Running





Click OK then run the simulation.

# Heat Exchanger After Running



Click “Run All” in the Home tab



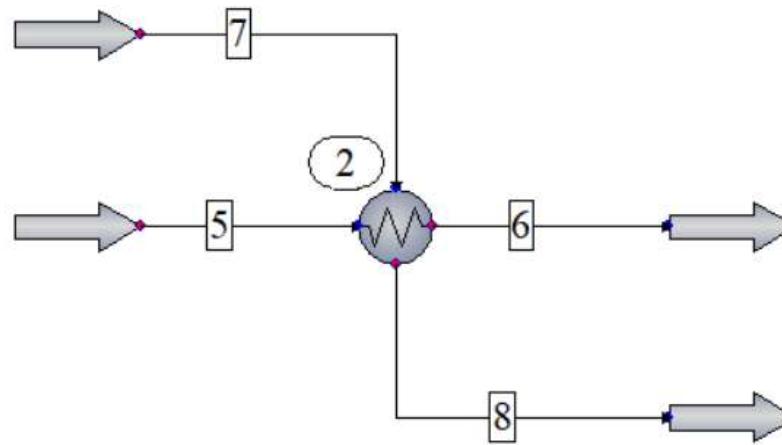
File Home Drawing View Thermophysical Component Database Specification Analysis Sizing Economics Tools CC-THERM ^ Style Help

Show Grid Snap to Grid Change Stream Font

Snap to Center Grid Size Styles...

Workspace Insert Objects

ID	7
T	-30.10 C
P	1945.81 kPa

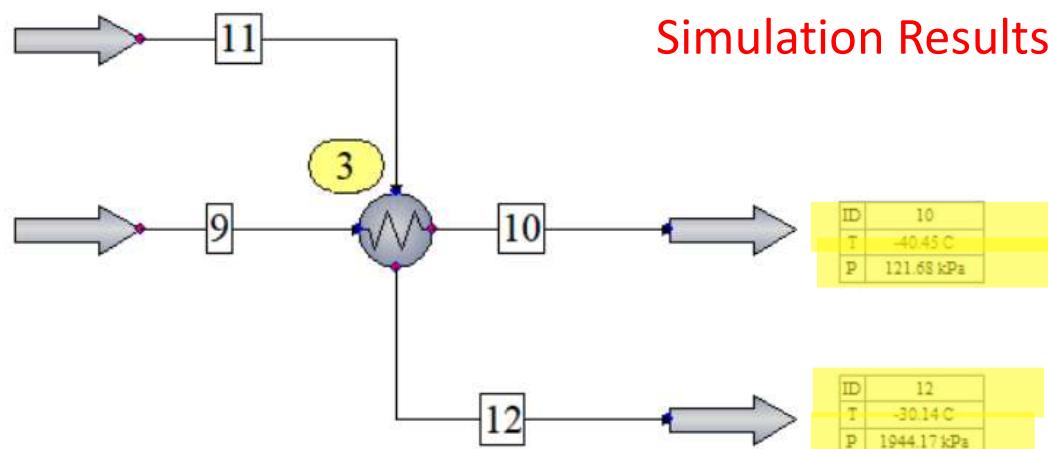


ID	6
T	-42.88 C
P	125.00 kPa

ID	8
T	-30.11 C
P	1945.81 kPa

ID	11
T	-30.10 C
P	1945.81 kPa

ID	9
T	-45.00 C
P	125.00 kPa



## Simulation Results

ID	10
T	-40.45 C
P	121.53 kPa

ID	12
T	-30.14 C
P	1944.17 kPa

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...

Data Map Chemical Engineering Plant Cost Index Environmental Flowsheet

Chemical Engineering Plant Cost Index

Year/Month Selection for the Cost Index

Year: 2026      Month: February      Source: Database

make sure to set this to February 2026

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

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

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

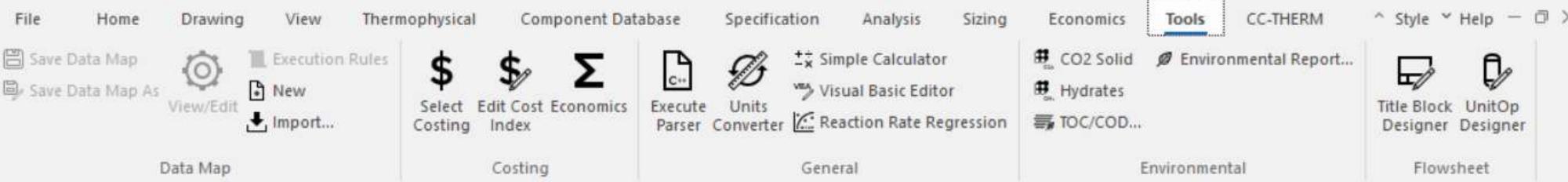
ID: 10 T: -40.45 C P: 121.68 kPa

ID: 12 T: -30.14 C P: 1944.17 kPa

Help Cancel OK

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

Steady State K:SRK H:SRK 196.0%



ID	11
T	-30.10 C
P	1945.81 kPa

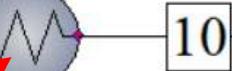


ID	9
T	-46.00 C
P	125.00 kPa



3

double-click



10

ID	10
T	-40.45 C
P	121.68 kPa

12

ID	12
T	-30.14 C
P	1944.17 kPa



ID	8
T	-30.11 C
P	1945.81 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