

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 ₄	0.003
C ₂ H ₆	0.0626
C ₂ H ₄	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

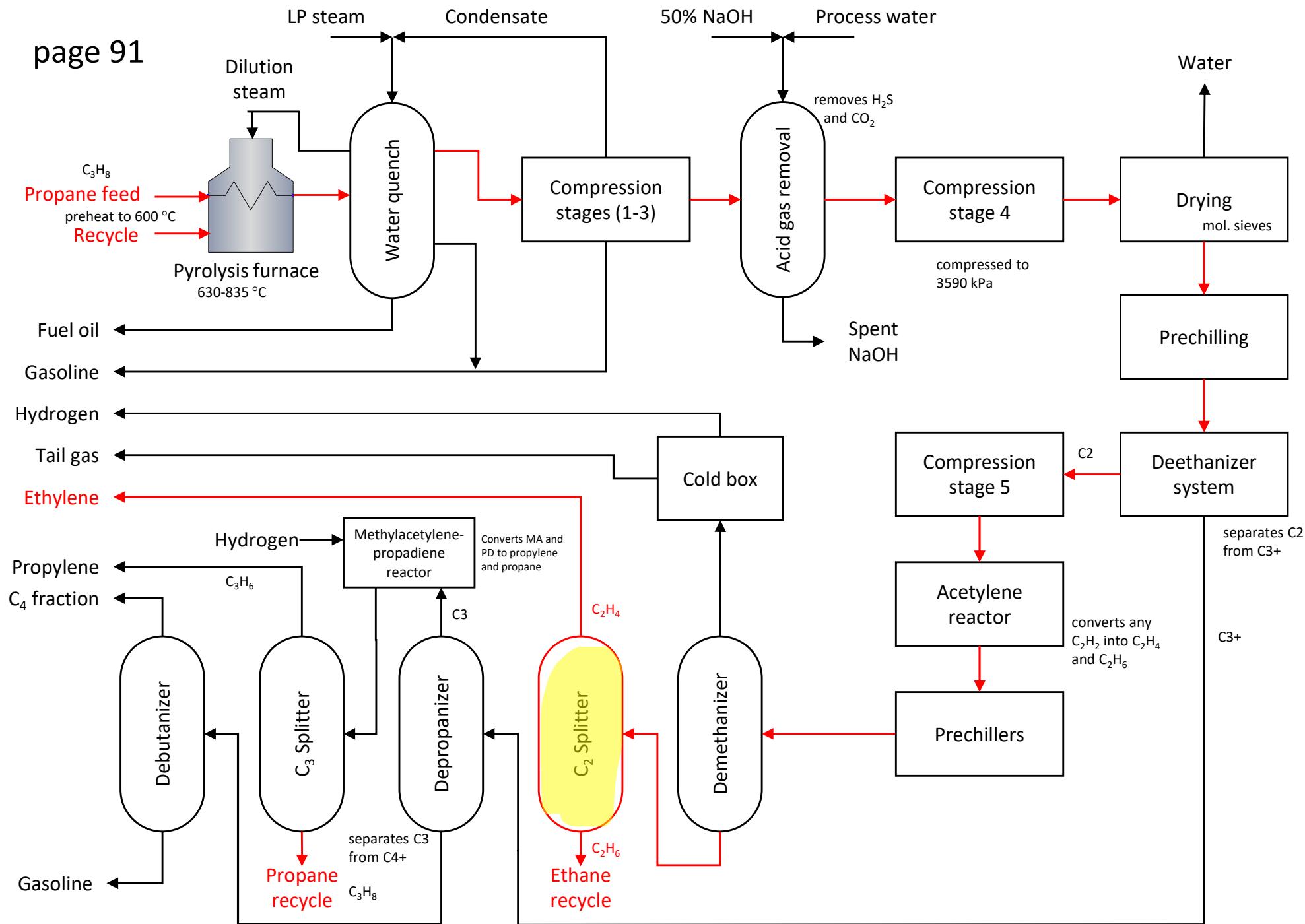


Figure 3-13. Product Separation Section

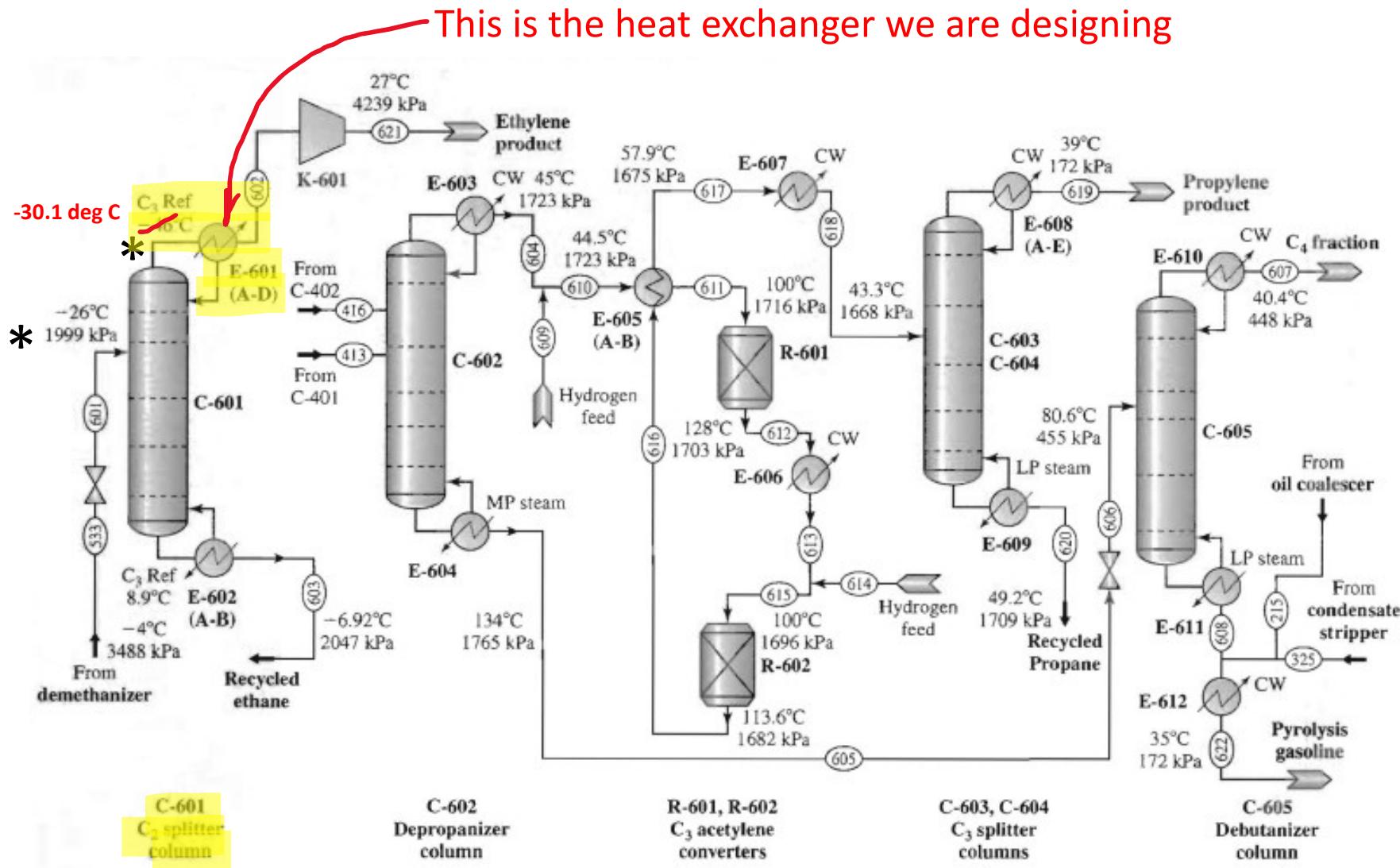


Figure 3-13. Product separation section.

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

Report Viewer MS Excel

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

Fluid Properties

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

Dimensions

Length	m
Thickness	m
Diameter	m
Area	m ²
Liquid Volume	m ³
Vapor Volume	m ³

Misc

Solubility Parameter	(J/m ³) ^{0.5}
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

Engineering Units

All UnitOps : Grayscale

Heat Exchangers Gray

Feed Product

Fired Heater Heat Exchanger

Multi-Stream Exchanger

Miscellaneous : Grayscale

Piping and Flow : Grayscale

Reactors : Grayscale

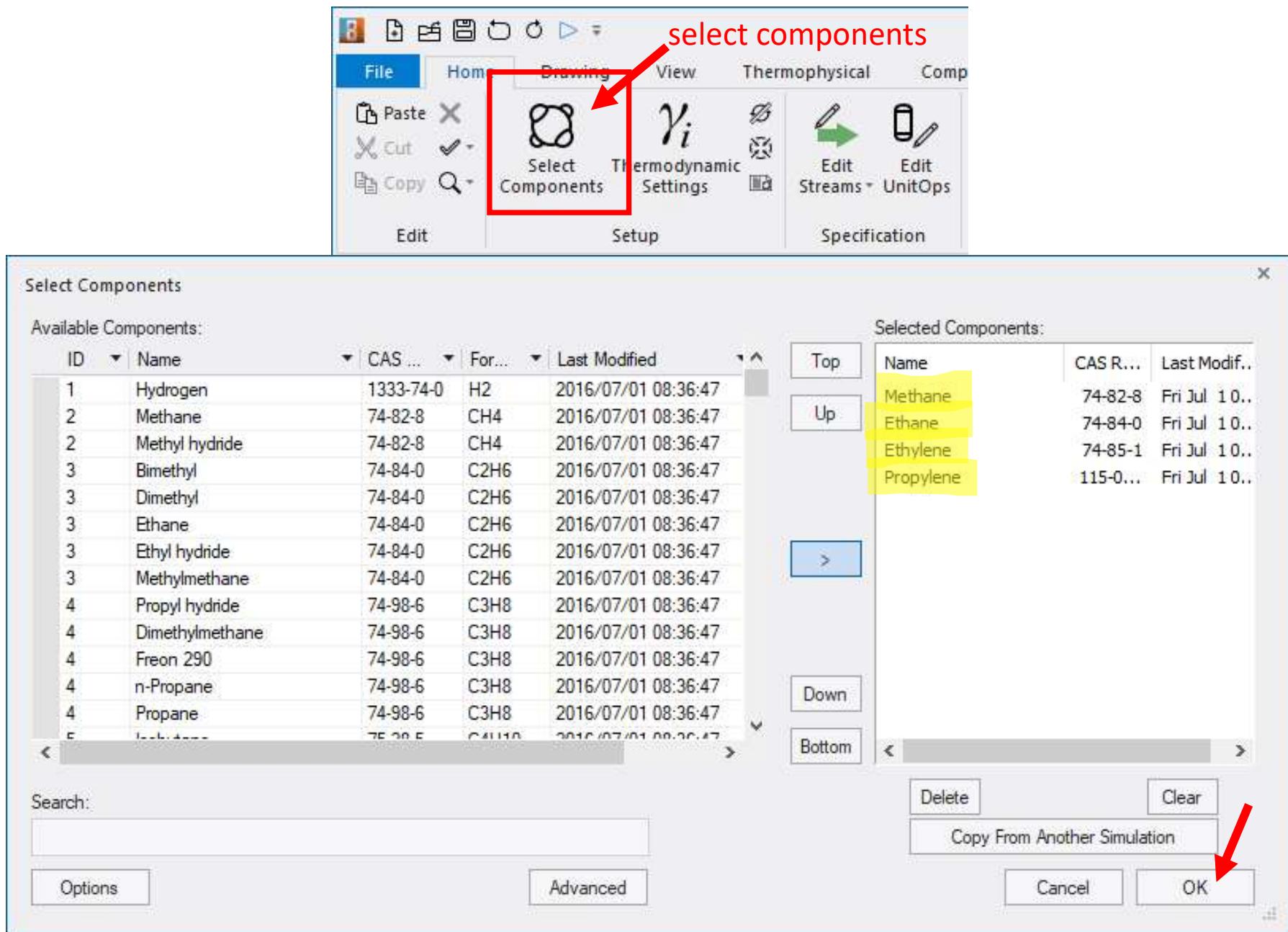
Separators : Grayscale

Solids handling : Grayscale

Untitled

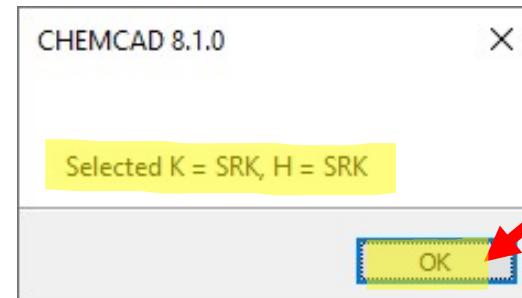
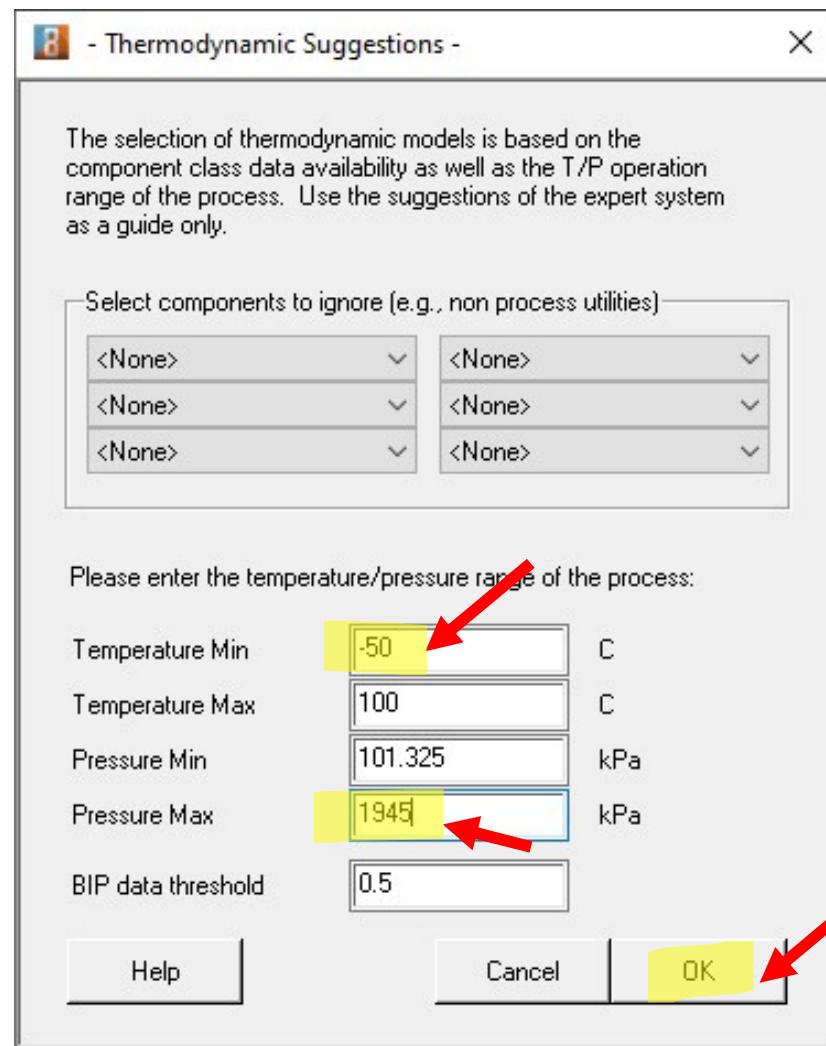
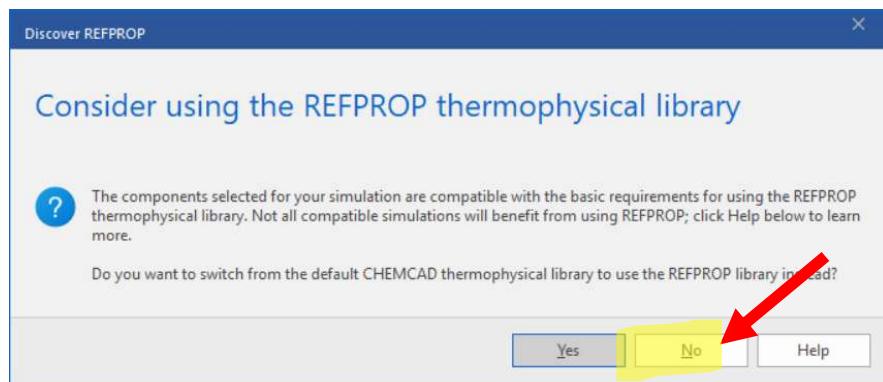
Steady State

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

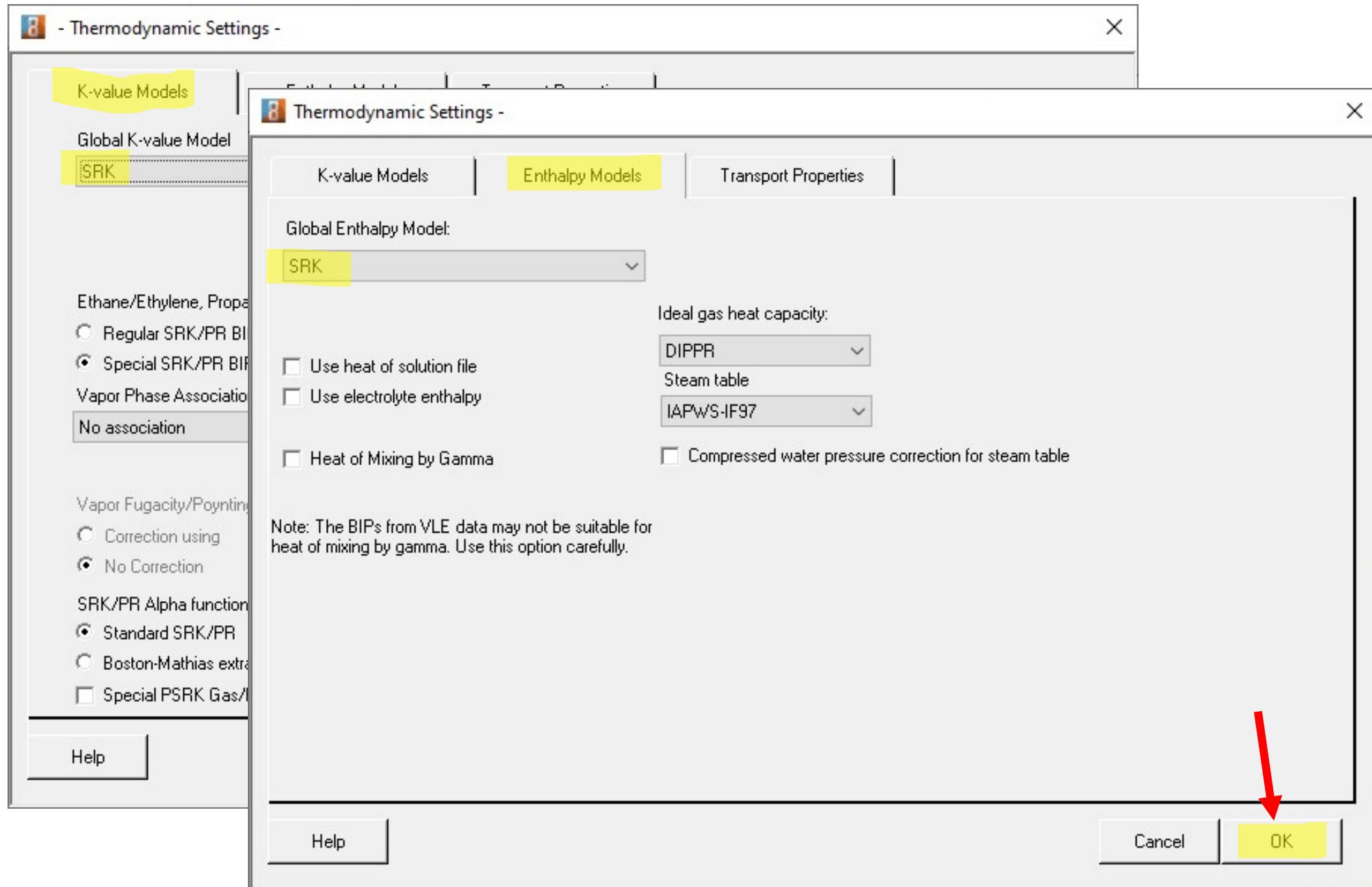


"Thermodynamic Suggestions" window launches automatically when you click OK.

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.

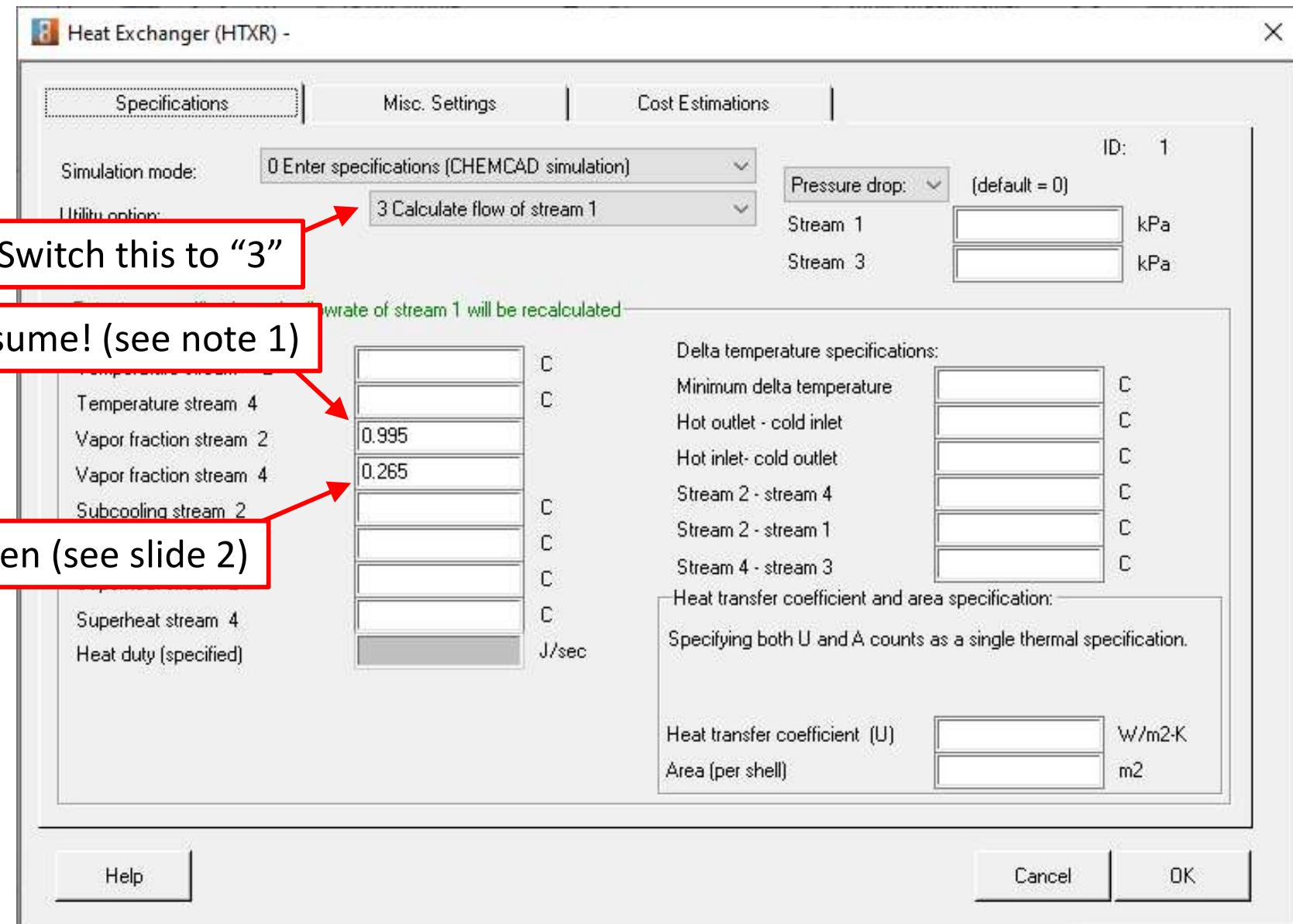
Edit Streams		
	Flash	X
Stream No.	1	3
Stream Name		
Temp C	-46	-30.1
Pres kPa	125	1945.806
Vapor Fraction	0	1
Enthalpy J/sec	-77463.29	1.114613e+08
Total flow	1	64.5956
Total flow unit	kg/sec	kg/sec
Comp unit	kg/sec	kg/sec
Methane	0	0.003
Ethane	0	0.0626
Ethylene	0	64.53
Propylene	1	0

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.

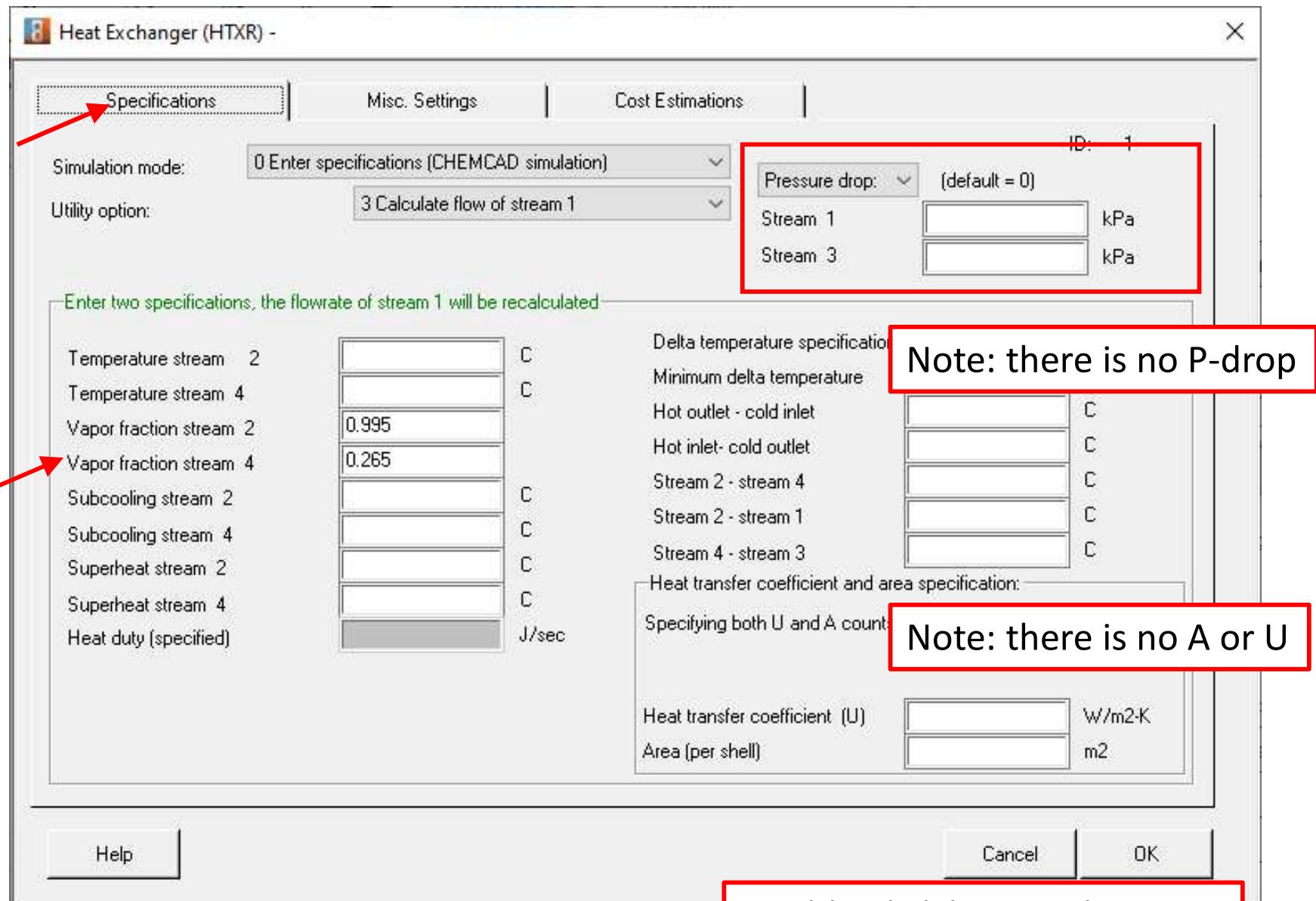
Edit Streams

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

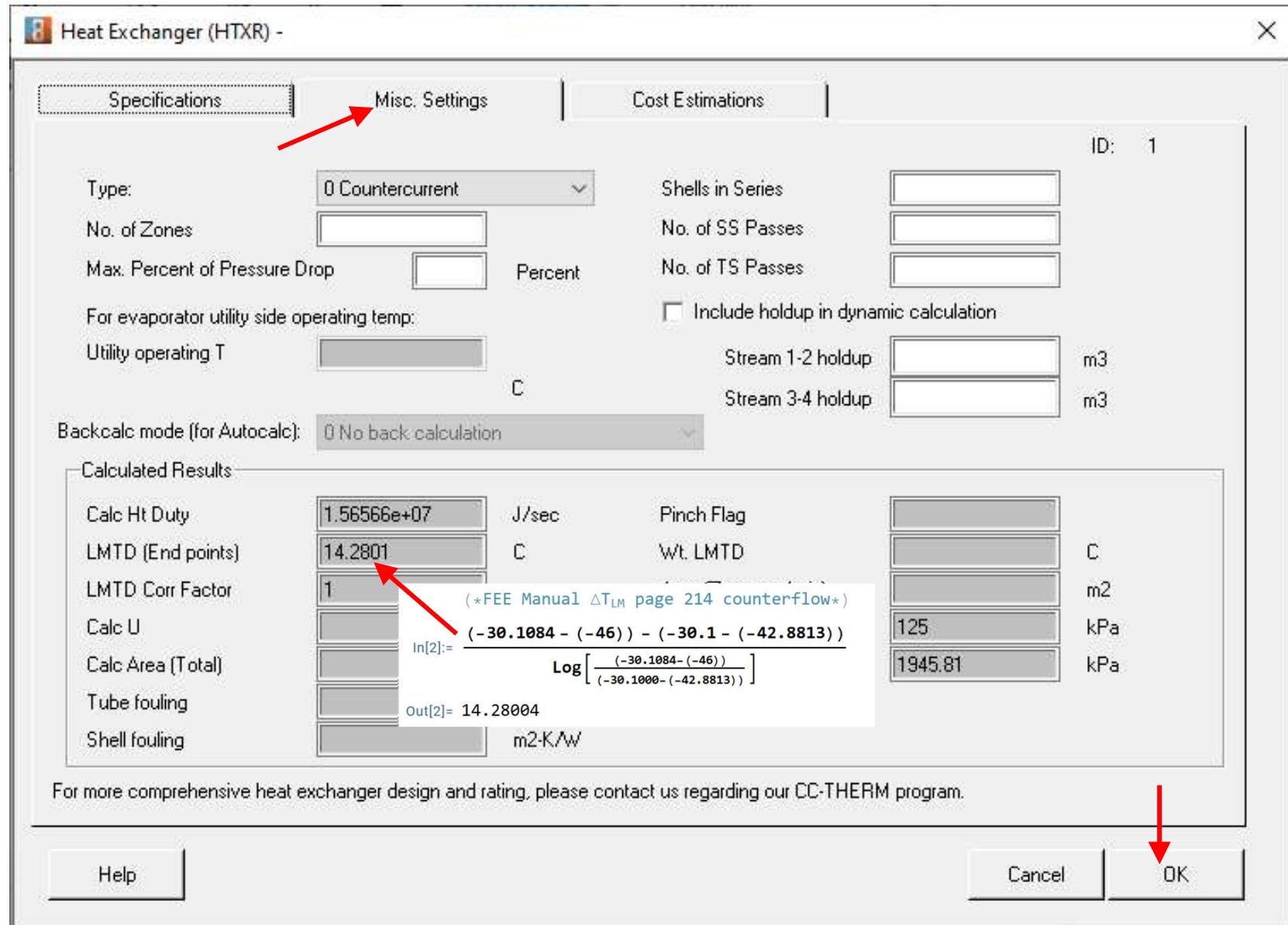
Double-click stream 1 to check results

Confirm Results (2/3)



Double-click heat exchanger
to confirm results

Confirm Results (3/3)



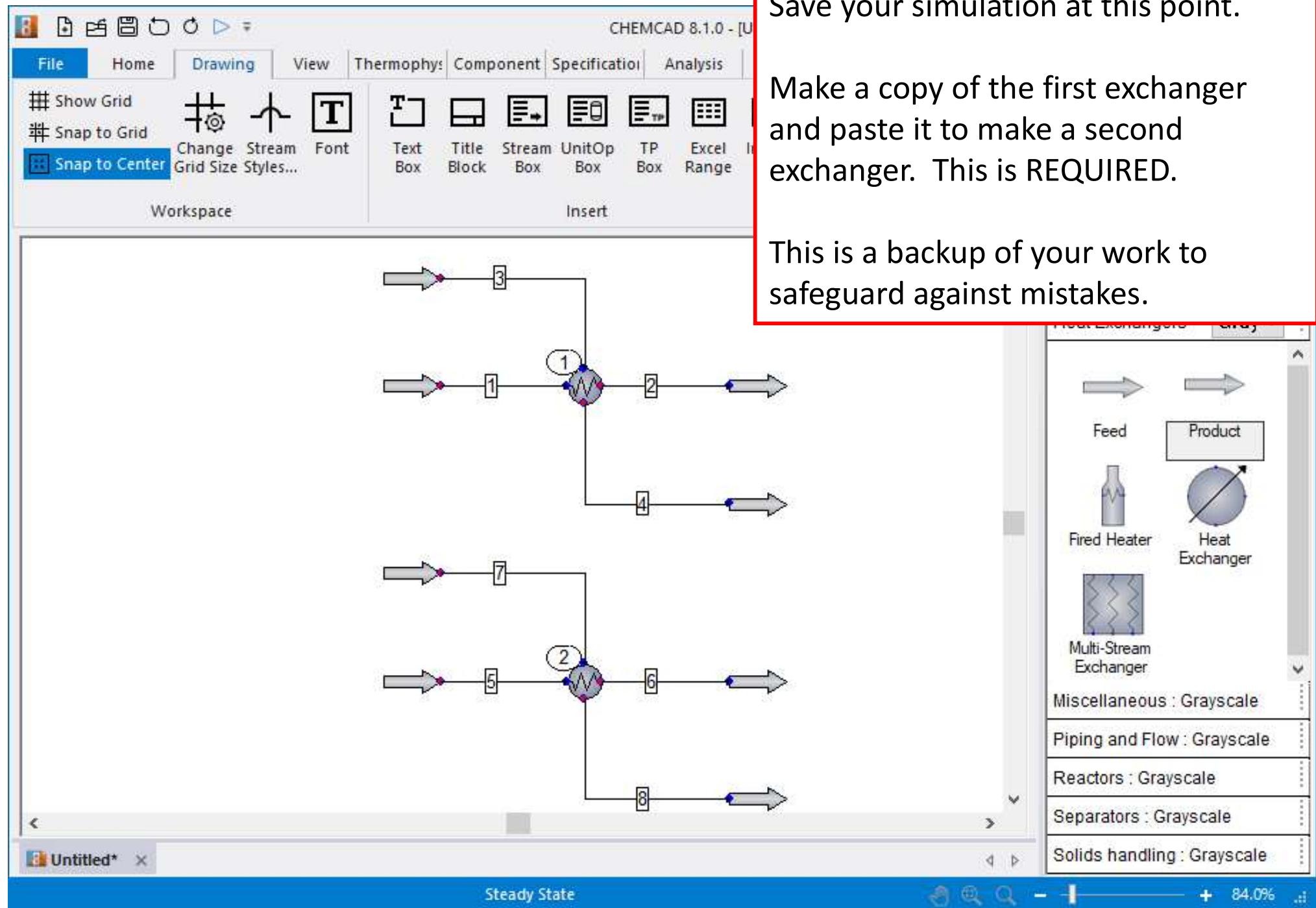
Numbers in gray fields were calculated by CHEMCAD

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.

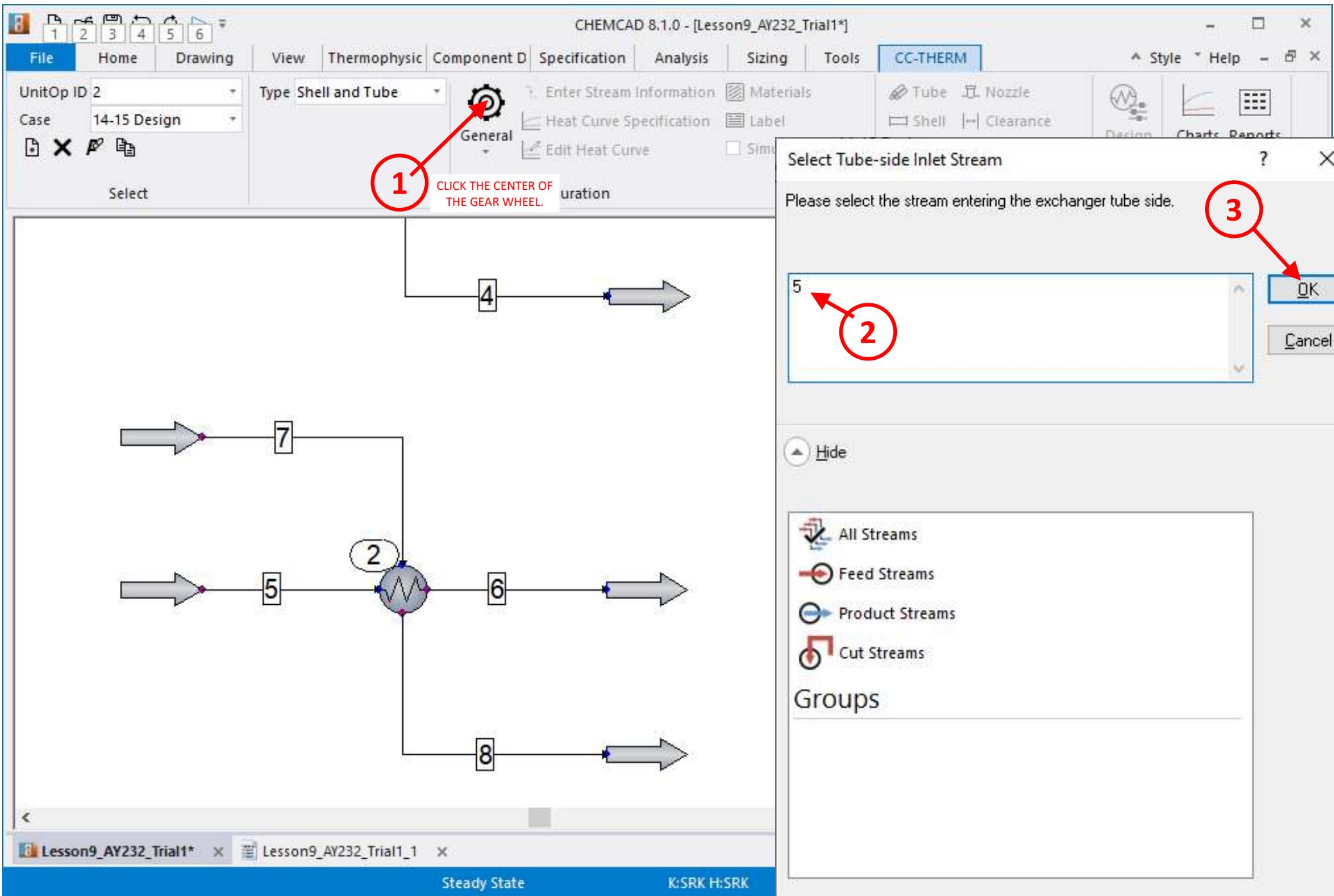


Click "Sizing," then "Shell-and-tube."

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 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 flow direction.
- Select UnitOps Dialog:** A modal dialog titled "Select UnitOps". It contains a text input field with the placeholder "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 containing "2" and "3" (circled with red arrow 3), and buttons for OK (circled with red arrow 4) and Cancel.
- New CC-THERM Case Dialog:** A modal dialog titled "New CC-THERM Case". It has a checked checkbox for "All UnitOps" and a text input field containing "14-15 Design" (circled with red arrow 5). It includes "Cancel" and "OK" buttons.
- Status Bar:** Untitled*, Steady State.



TEMA Type AEL Exchanger. Take all defaults.

General Specifications

General Information Modeling Methods

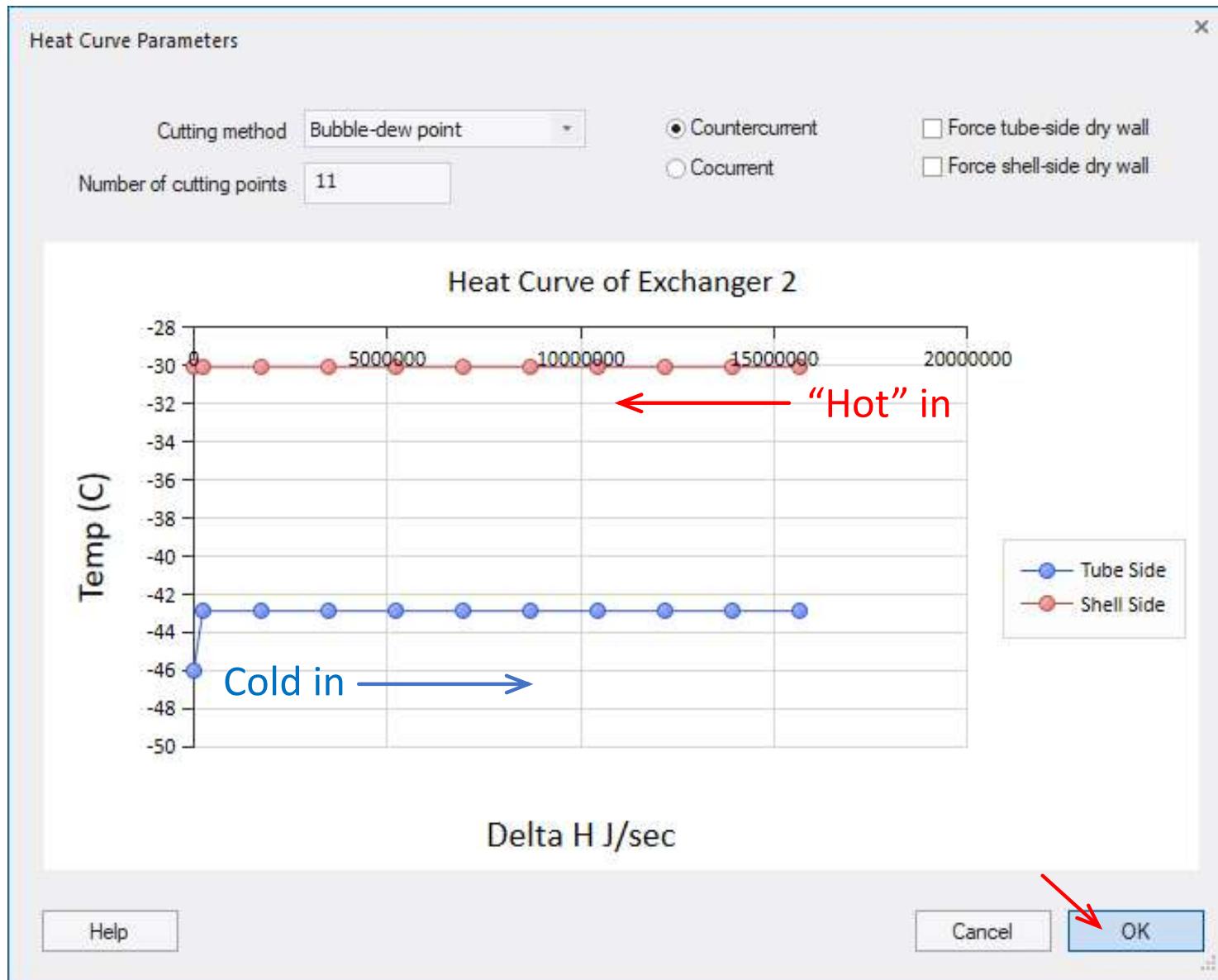
TEMA class/ standard	TEMA R
Orientation	Horizontal
TEMA front end head	A - Channel Removable Cover
TEMA shell type	E - One Pass
TEMA rear end head type	L - Fixed Tubesheet (A head)
Stream name	Tube Side
Process type	Forced Evaporation
Fouling factor	0.00017610948 m ² -K/W
Optional h Coeff.	W/m ² -K
Shell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

Geometry Run Results

Palette

1 2 3 4 5 6 7 8

dropdown

1. Design Constraints

2. Lower Limits

3. Upper Limits

4. 6

5. OK

6. 3.1

7. 0.1524

8. 45

9. 3.175

10. Percent of diameter

11. Optimize number of tube passes

12. Help Cancel OK

13. Steady State

14. Lesson9_AY232_Trial1* Lesson9_AY232_Trial1_1

Diagram Description: A process flow diagram showing a shell-and-tube heat exchanger. Stream 1 enters at the top left, stream 2 enters at the bottom left, stream 4 exits at the top right, stream 5 enters at the bottom right, stream 6 exits at the top right, stream 7 exits at the top left, and stream 8 exits at the bottom right. A valve component is located between streams 2 and 6.

Design Constraints Dialog:

Design Criteria

- Allowable tube pressure drop: 34.473801 kPa
- Allowable shell pressure drop: 34.473801 kPa
- Allowable tube velocity: 76.199997 m/sec
- Allowable shell velocity: 76.199997 m/sec
- Prefer tube length/shell diameter ratio: 12
- Minimum excess %: [empty]

Limits of Design Variables

	Lower Limits	Upper Limits
Tube Length	3	3.1 m
Shell Diameter	0.1524	6 m
Baffle Cut	15	45 Percent of diameter
Baffle Spacing	0.050799999	3.175 m

Optimize number of tube passes:

Help Cancel OK

Steady State

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%

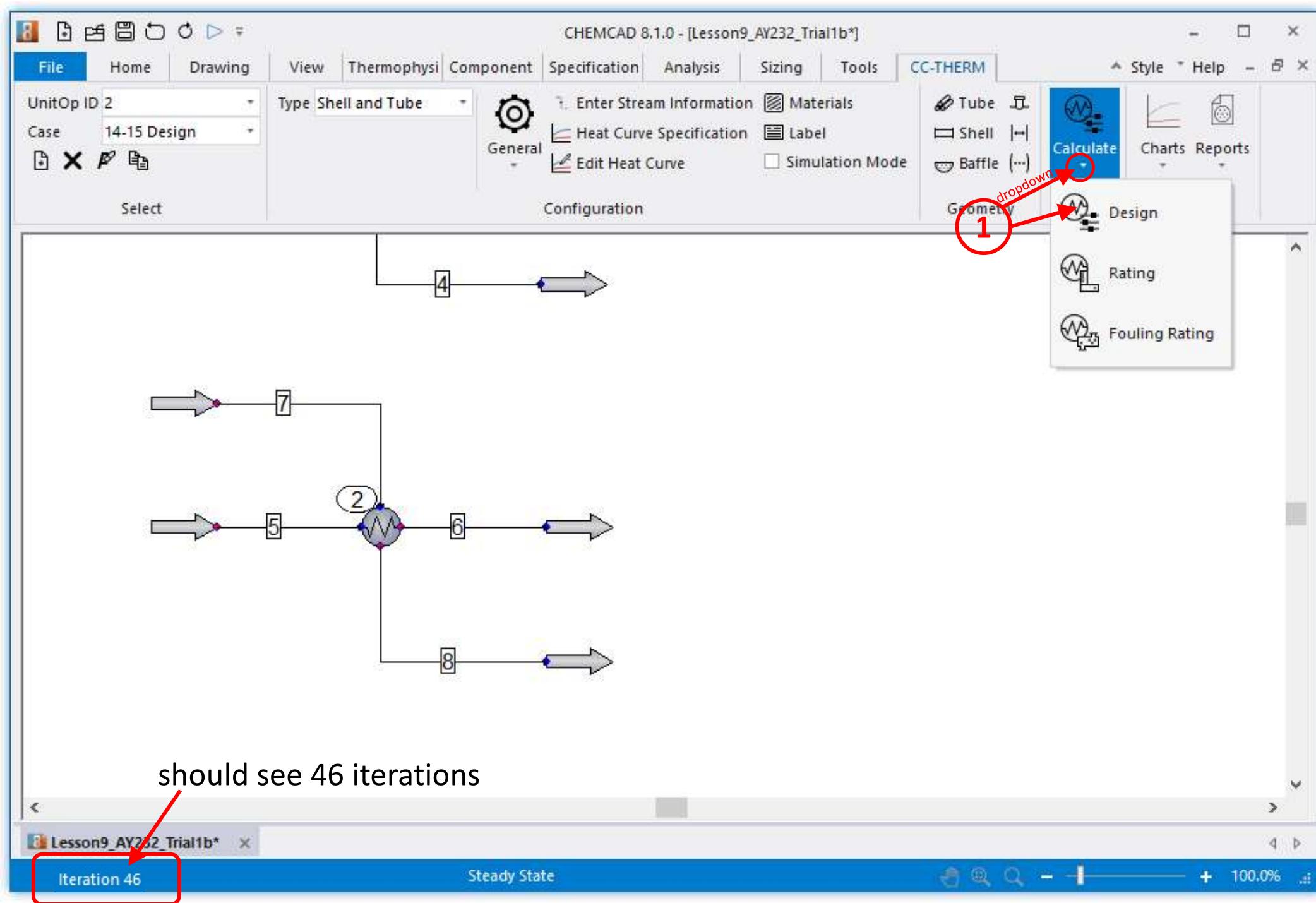
1

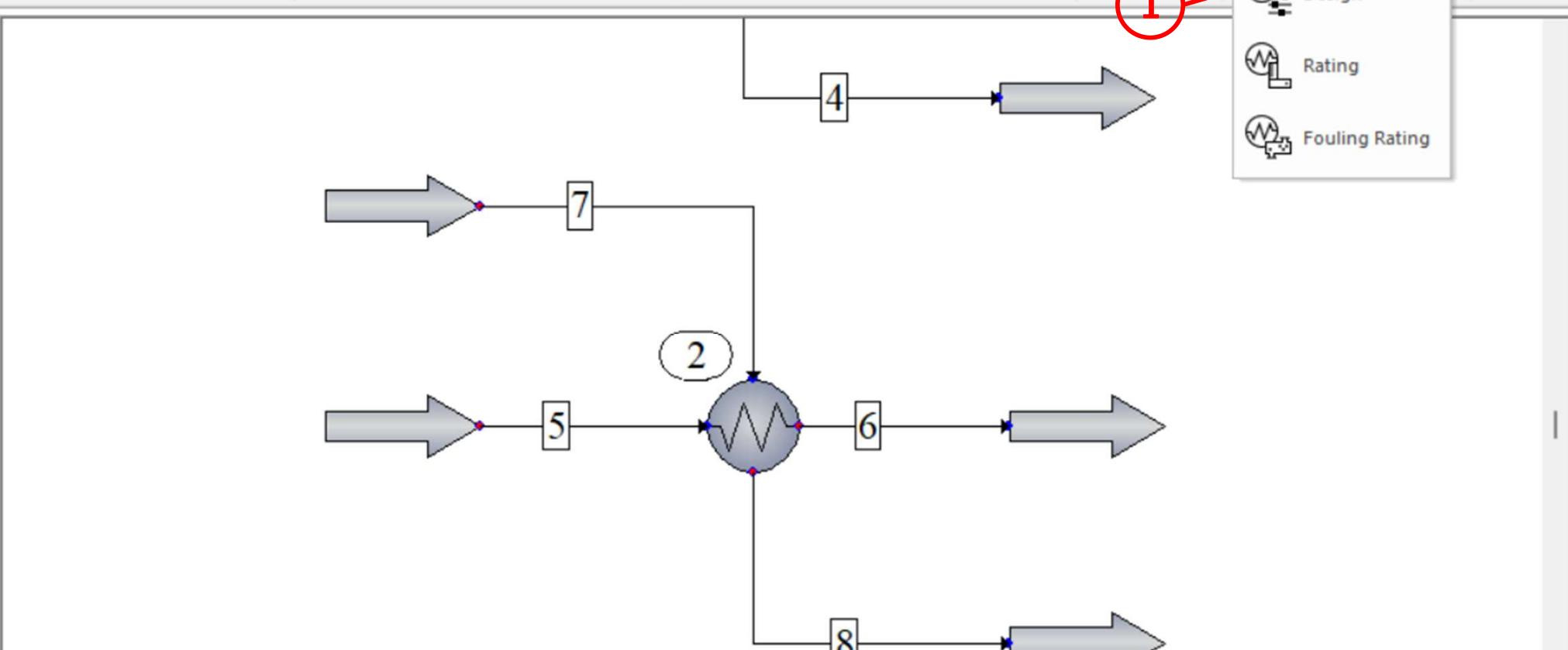
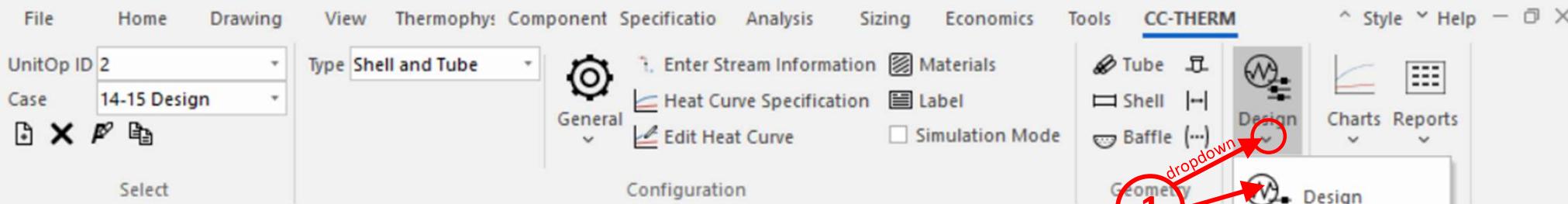
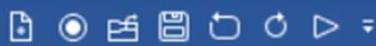
2

3

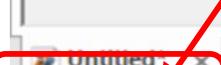
4

5





should see 44 iterations



Iteration 44

Steady State

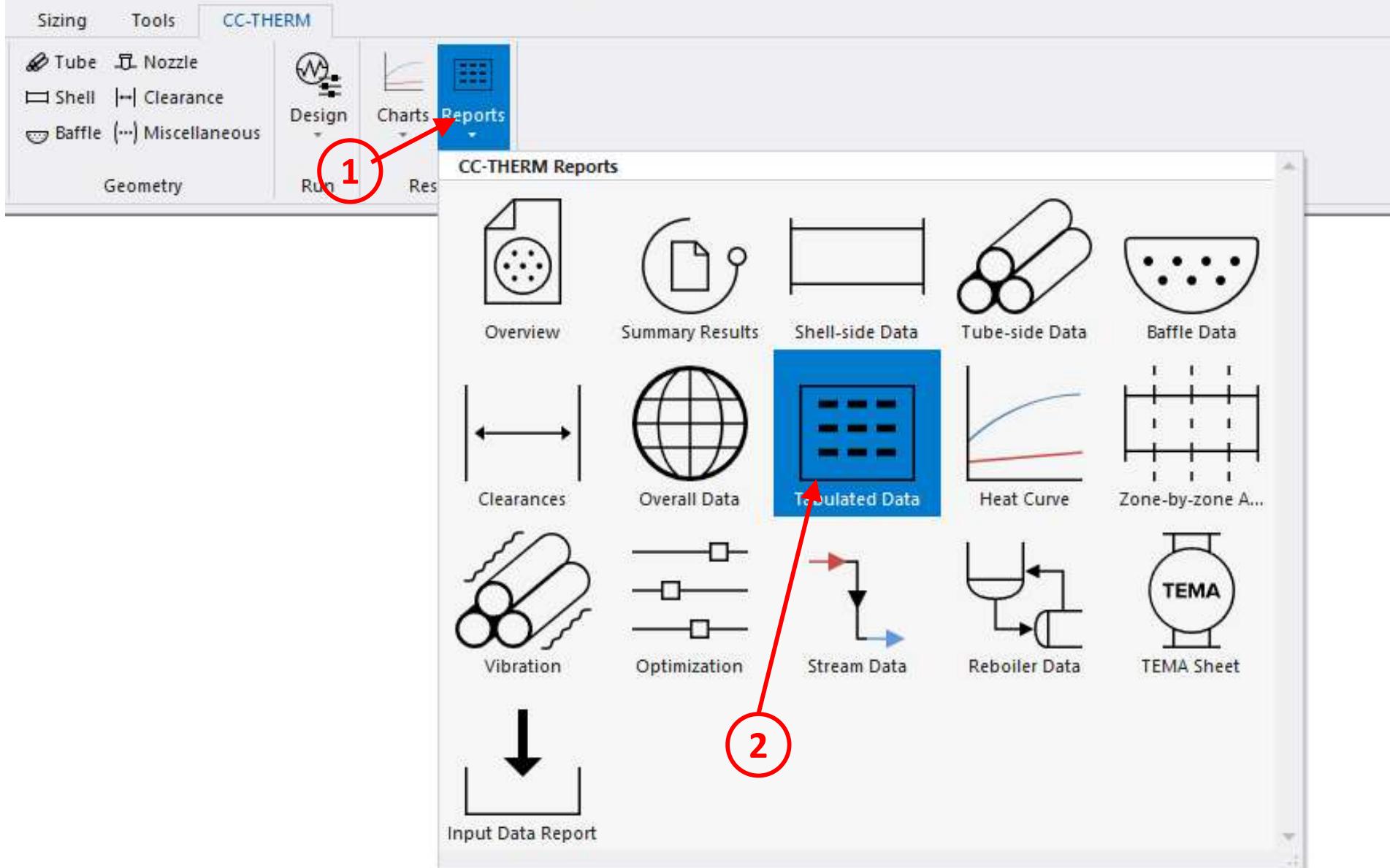
K:SRK H:SRK



- +

196.0%

CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]



Design Results – CHEMCAD NXT 1.2.0

TABULATED ANALYSIS

Overall Data:

Area Total	m ²	2348.77	% Excess	6.13
Area Required	m ²	2157.83	U Calc. W/m ² -K	566.94
Area Effective	m ²	2290.05	U Service W/m ² -K	534.21
Area Per Shell	m ²	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 ² -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 ²	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 ² -K/W	0.00068
Shell-side Fouling	m ² -K/W	0.00018
Tube Wall	m ² -K/W	0.00004
Tube-side Fouling	m ² -K/W	0.00018
Tube-side Film	m ² -K/W	0.00047
Reference Factor (Total outside area/inside area based on tube ID)		1.351

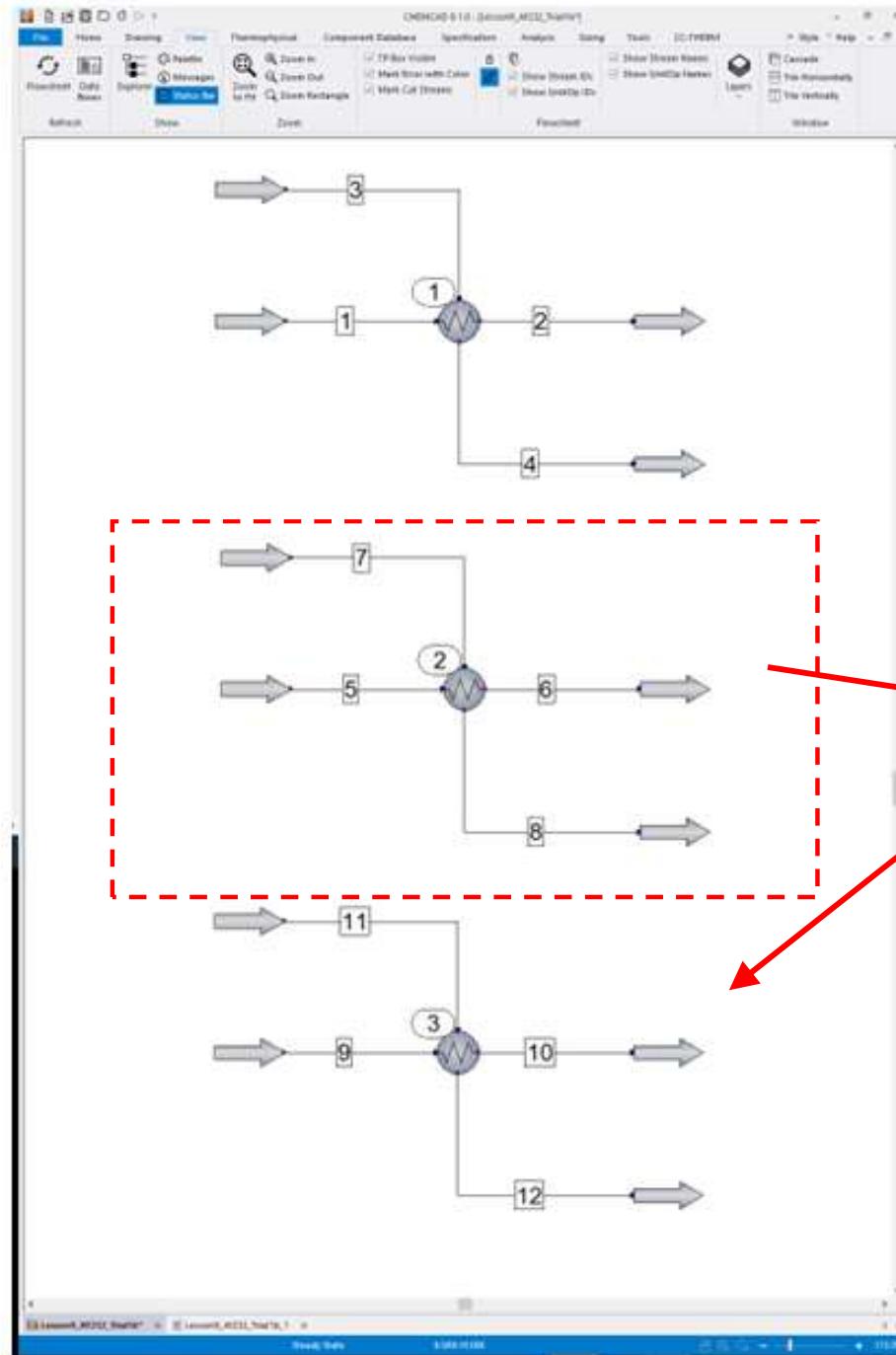
Answers to first three questions are found here. How many tubes? Shell diameter? Largest resistance?

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.

copy this and paste here

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)

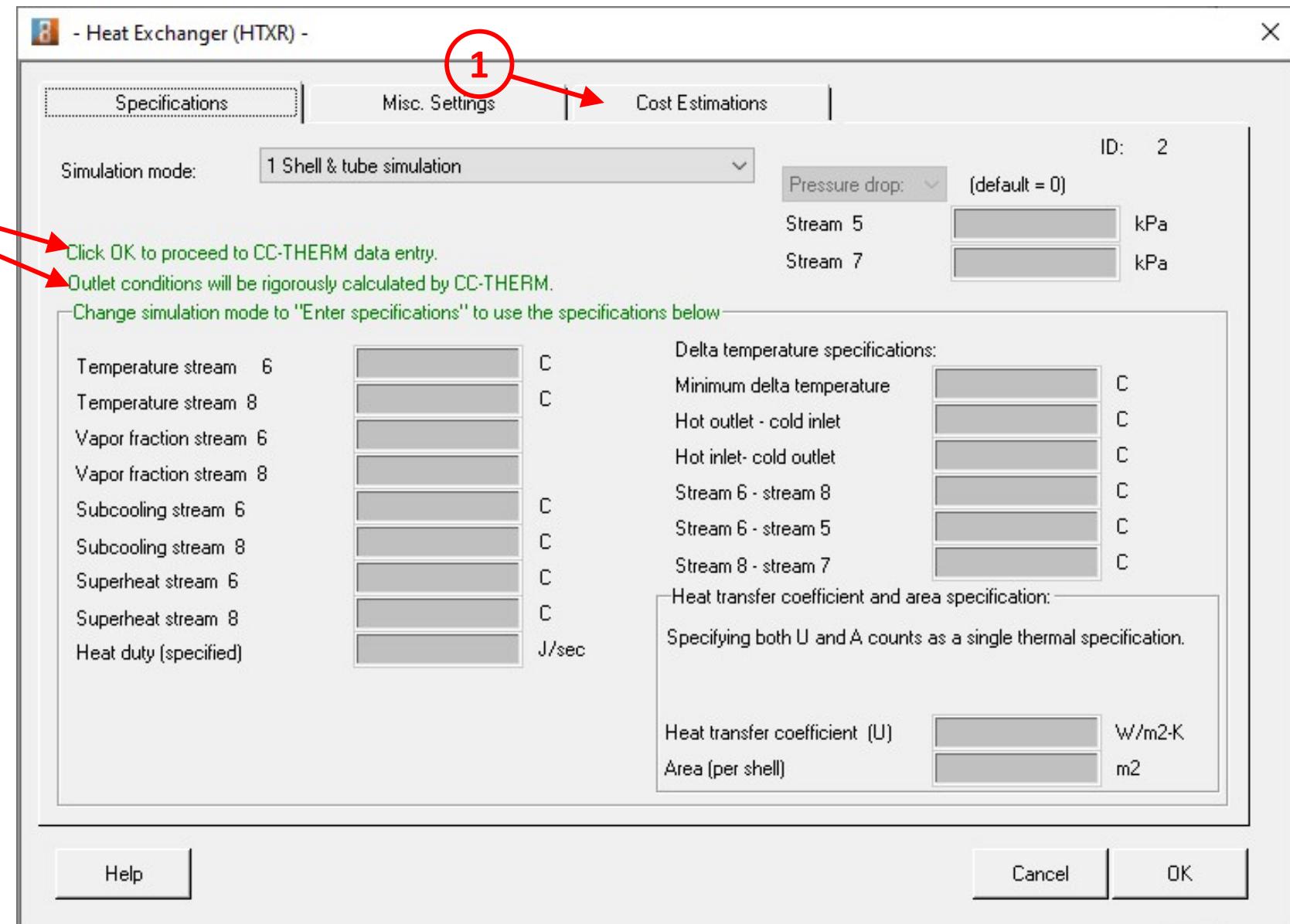
Help Cancel OK

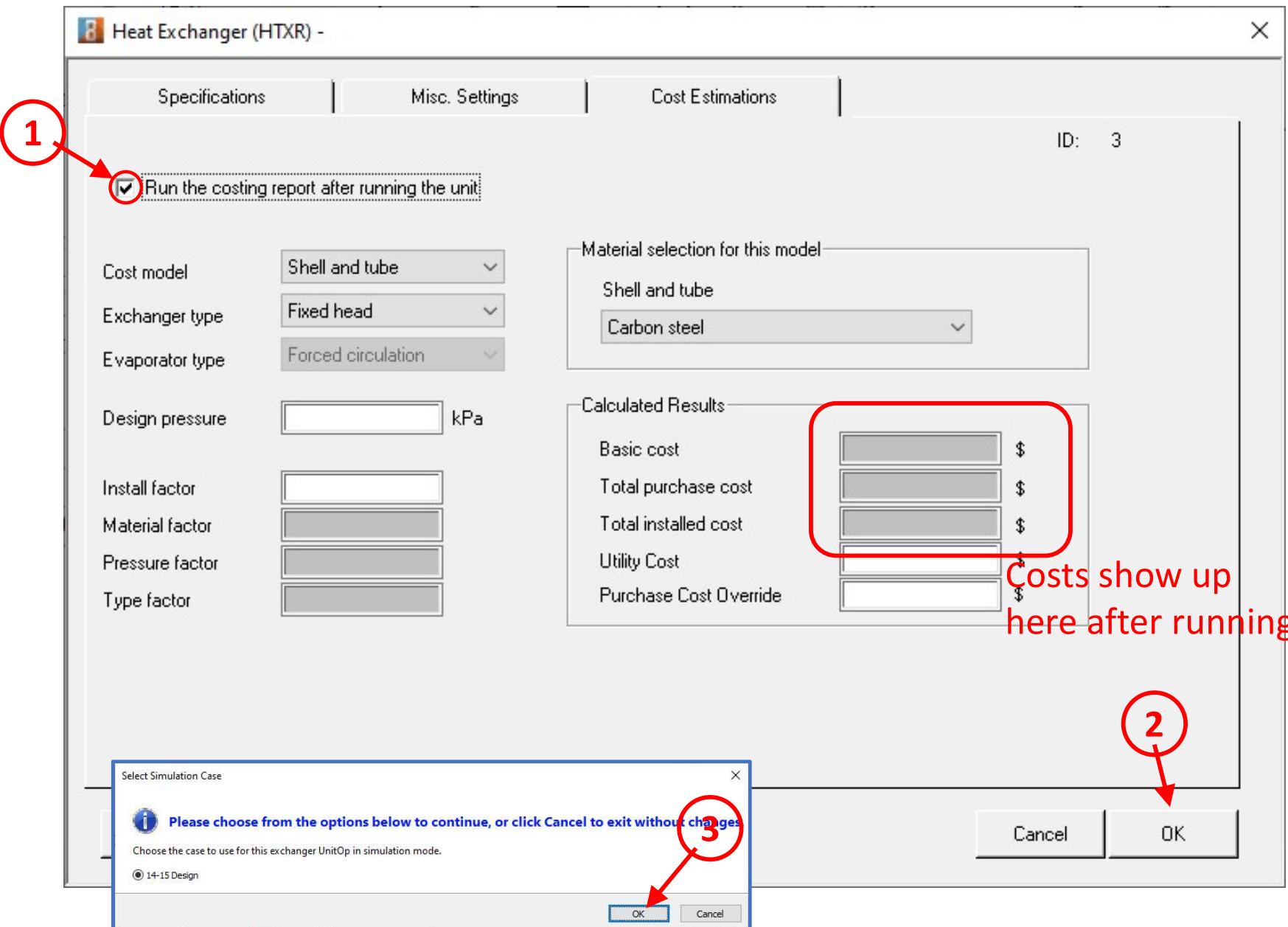
Steady State

double-click 1 2

The 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, and Status Bar. The main window displays a flow diagram of a heat exchanger. On the left, stream 9 enters a shell-and-tube heat exchanger (represented by a wavy pipe icon). Stream 11 enters from the top. Stream 10 exits to the right, and stream 12 exits downwards. A callout bubble labeled '1' points to the wavy pipe icon. Another callout bubble labeled '2' points to the '1 Shell & tube simulation' dropdown in a dialog box titled '- Heat Exchanger (HTXR) -'. This dialog box also contains sections for Specifications, Misc. Settings, and Cost Estimations. The Specifications section lists various parameters like Temperature streams, Vapor fractions, Subcooling, Superheat, and Heat duty, each with a corresponding input field. A note at the bottom says 'Click OK to proceed to CC-THERM data entry.' The status bar at the bottom shows 'Steady State'.

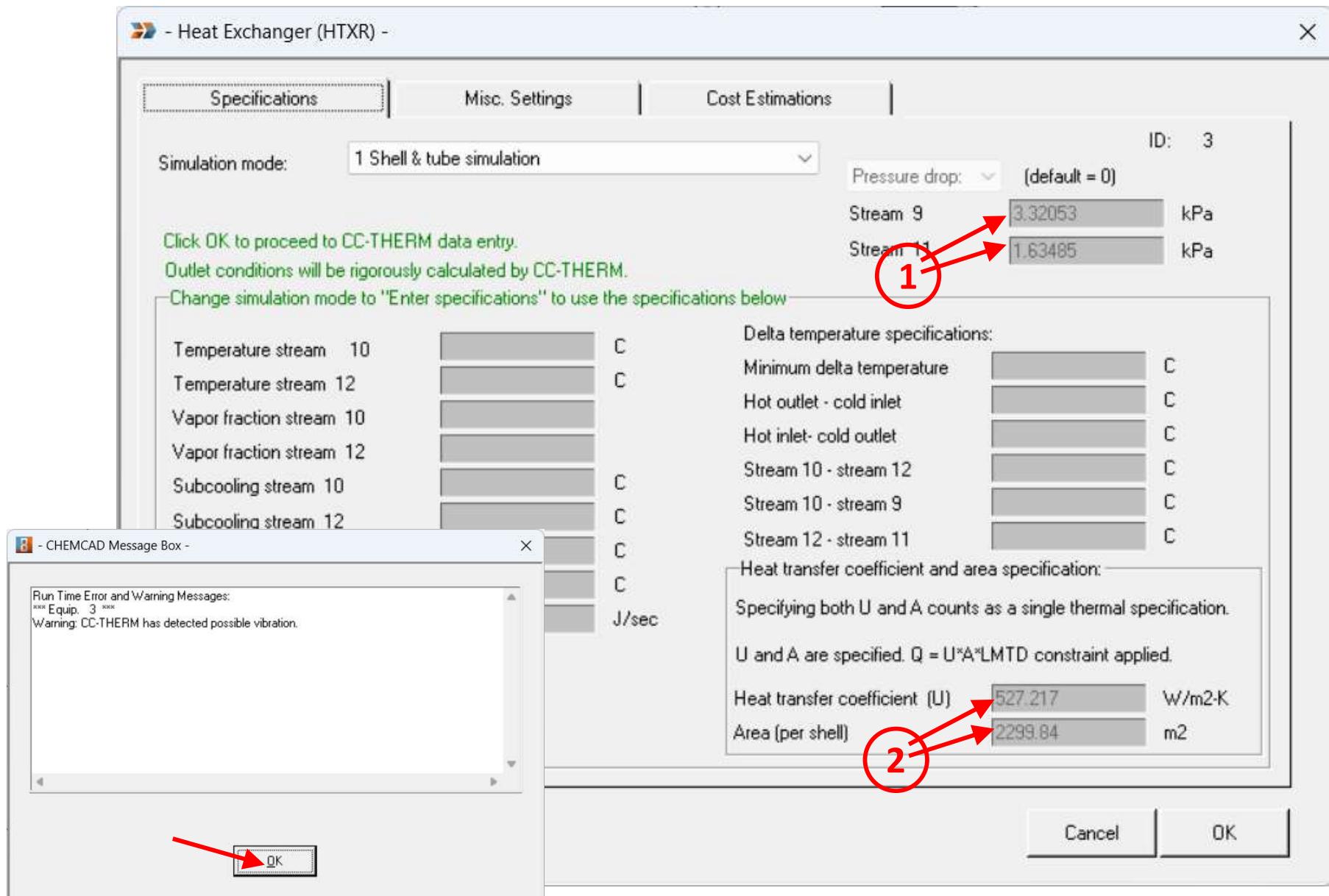
Heat Exchanger Before Running





Click OK then run the simulation.

Heat Exchanger After Running



Click “Run All” in the Home tab



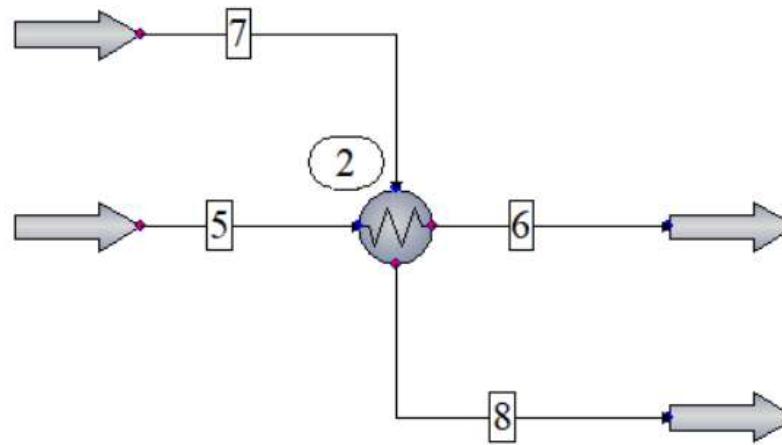
File Home Drawing View Thermophysical Component Database Specification Analysis Sizing Economics Tools CC-THERM ^ Style Help

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

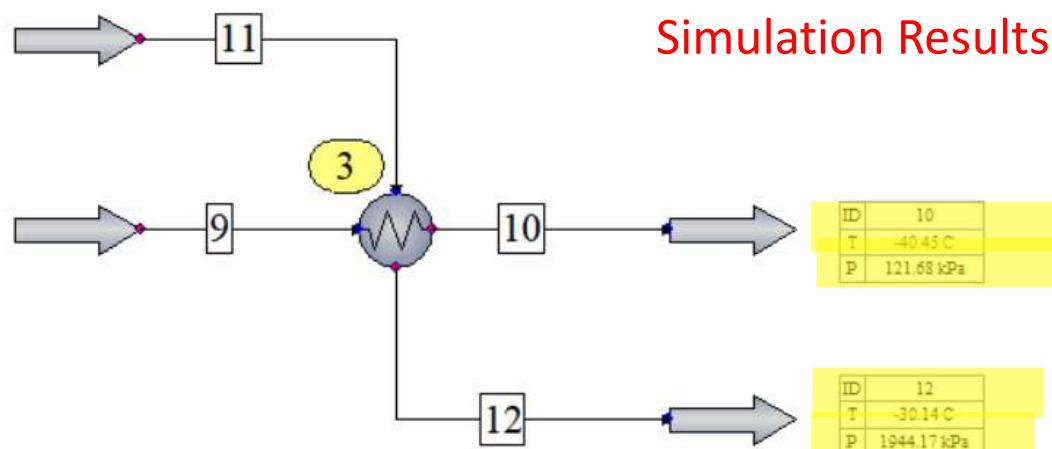


ID	6
T	-42.88 C
P	125.00 kPa

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 Execution Rules \$ Select Simple Calculator
Save Data Map As New Edit Cost Economics Units Visual Basic Editor
Import... Costing Index Execute Parser Converter Reaction Rate Regression
CO2 Solid Environmental Report...
Hydrates TOC/COD...

Data Map Chemical Engineering Plant Cost Index

Year/Month Selection for the Cost Index

Year: 2026 Month: February Source: Database

ID T P

11	-30.10 C	1945.81 kPa
----	----------	-------------

ID T P

9	-46.00 C	125.00 kPa
---	----------	------------

ID T P

10	-40.45 C	121.68 kPa
----	----------	------------

ID T P

12	-30.14 C	1944.17 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

Help Cancel OK

14-15 Practice Trial4 - NXT* 14-15 Practice Trial4 - NXT_1

Steady State K:SRK H:SRK

196.0%

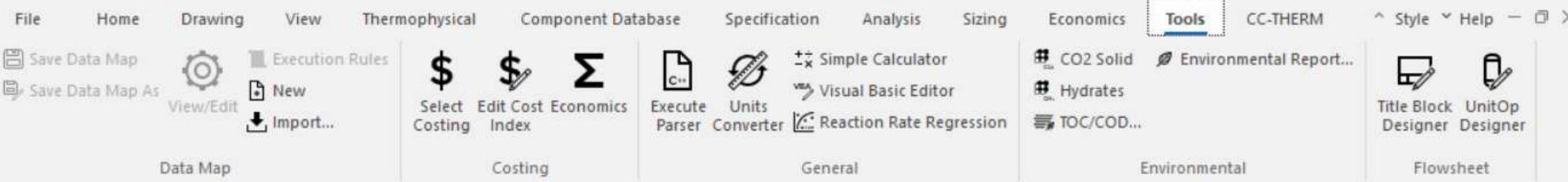
1

2

3

4

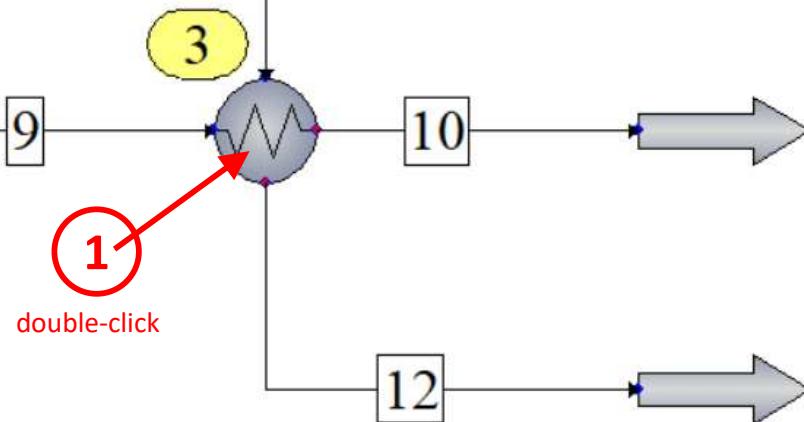
make sure to set this to February 2026



ID	11
T	-30.10 C
P	1945.81 kPa



ID	9
T	-46.00 C
P	125.00 kPa



ID	8
T	-30.11 C
P	1945.81 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 317634 \$
Material factor	1	Total purchase cost 810750 \$
Pressure factor	1.28102	Total installed cost 1.6215e+06 \$
Type factor	0.819535	Utility cost _____ \$/sec
		Purchase cost override _____ \$
		317634 \$
		767912 \$
		1.53582e+06 \$

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