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 to have v8.1 on laptop)

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*

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

Species Flow rates, kg/s

CH_4	0.003
C_2H_6	0.0626
C_2H_4	64.53

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. 2024.

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

page 91

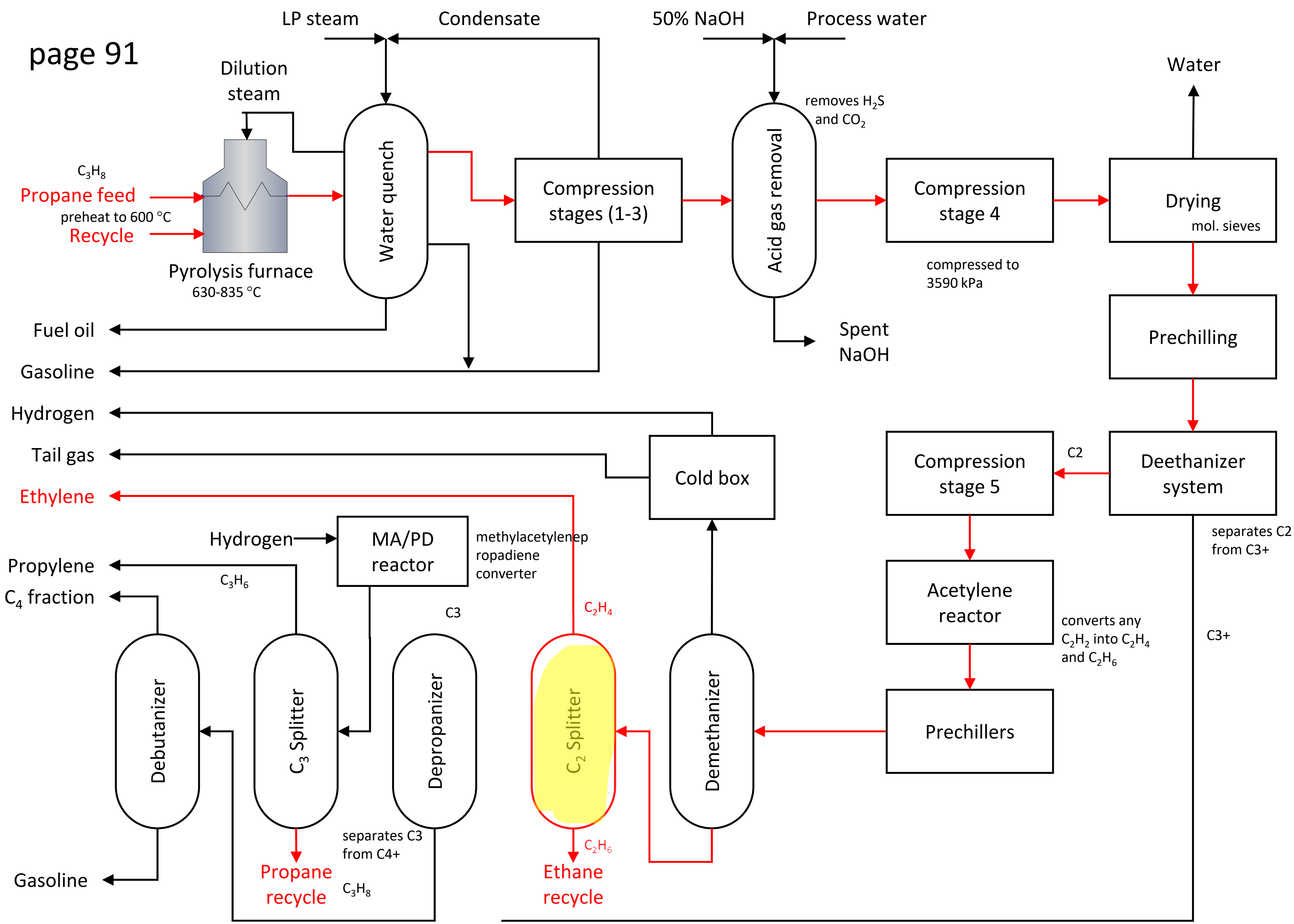


Figure 3-13. Product Separation Section

This is the heat exchanger we are designing

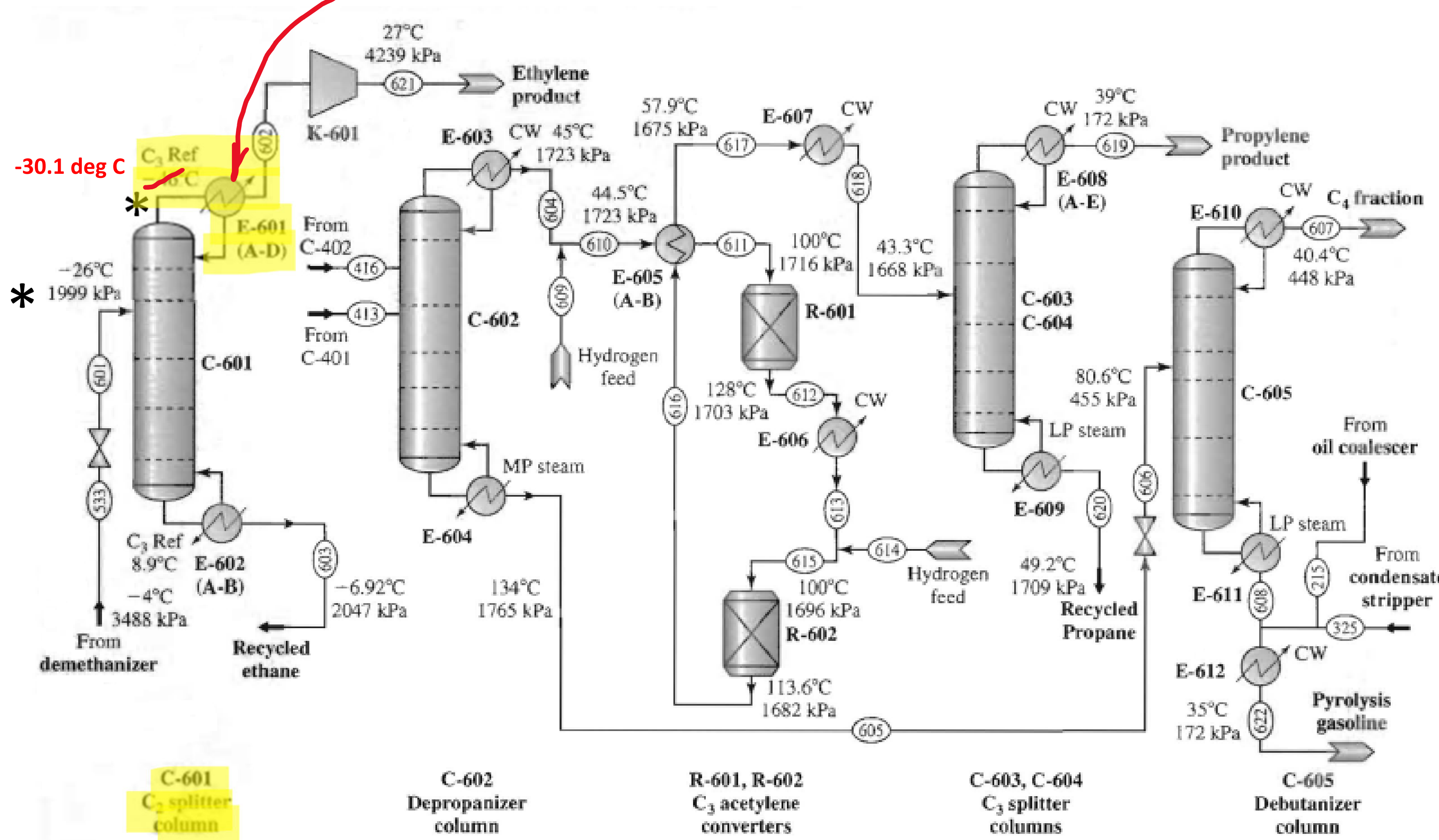
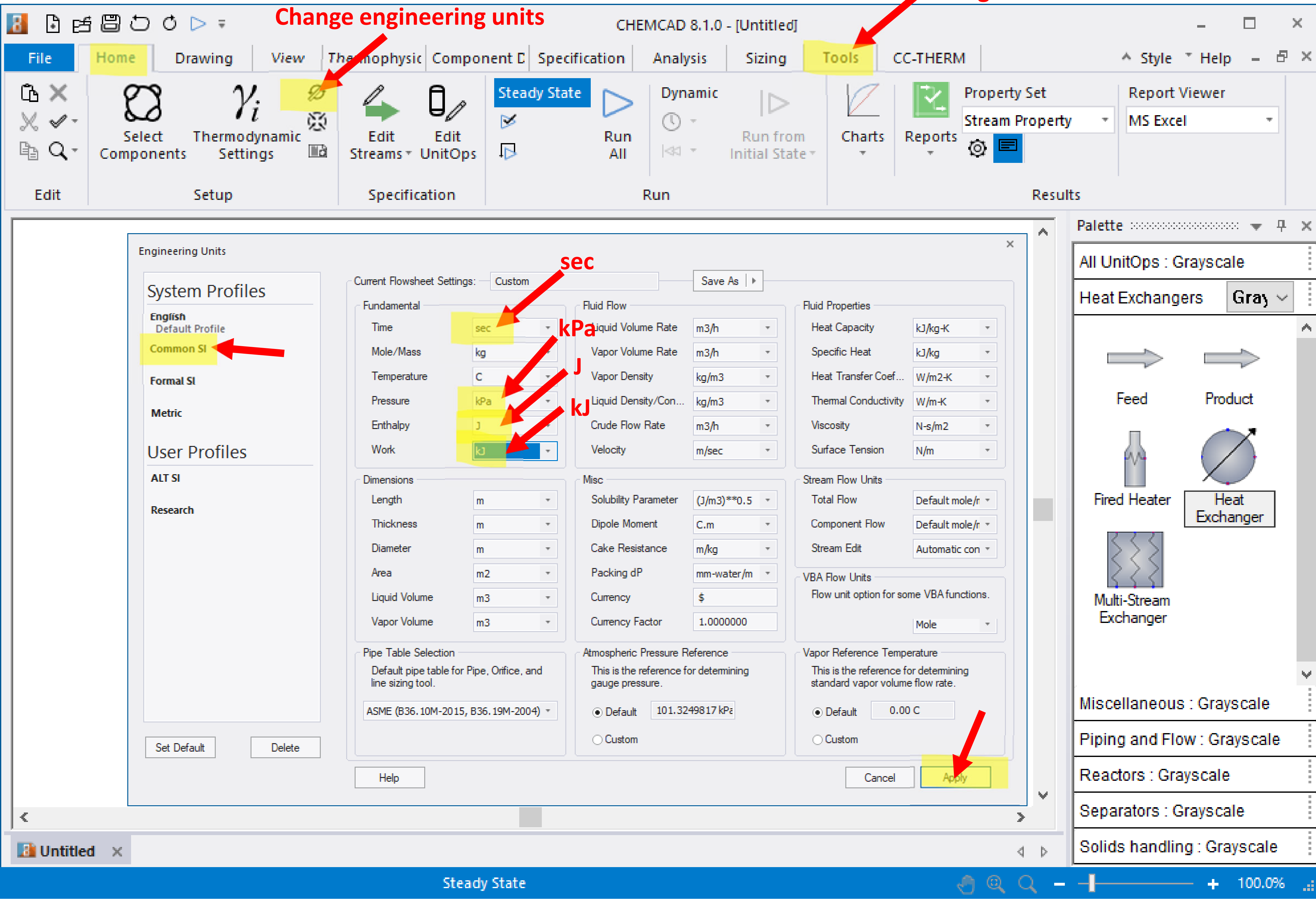
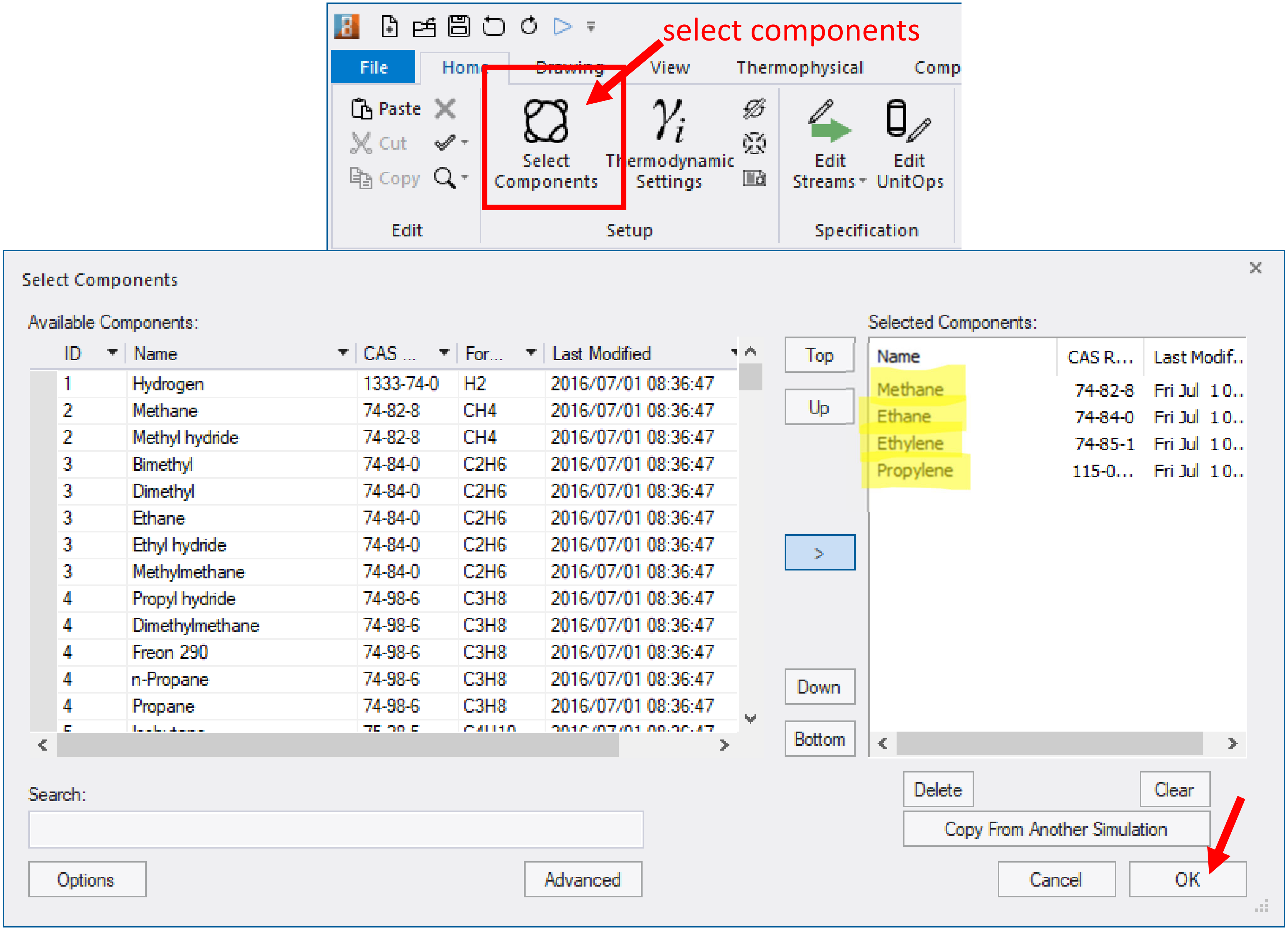


Figure 3-13. Product separation section.

Change CEPCI to Feb 2024 for PS4

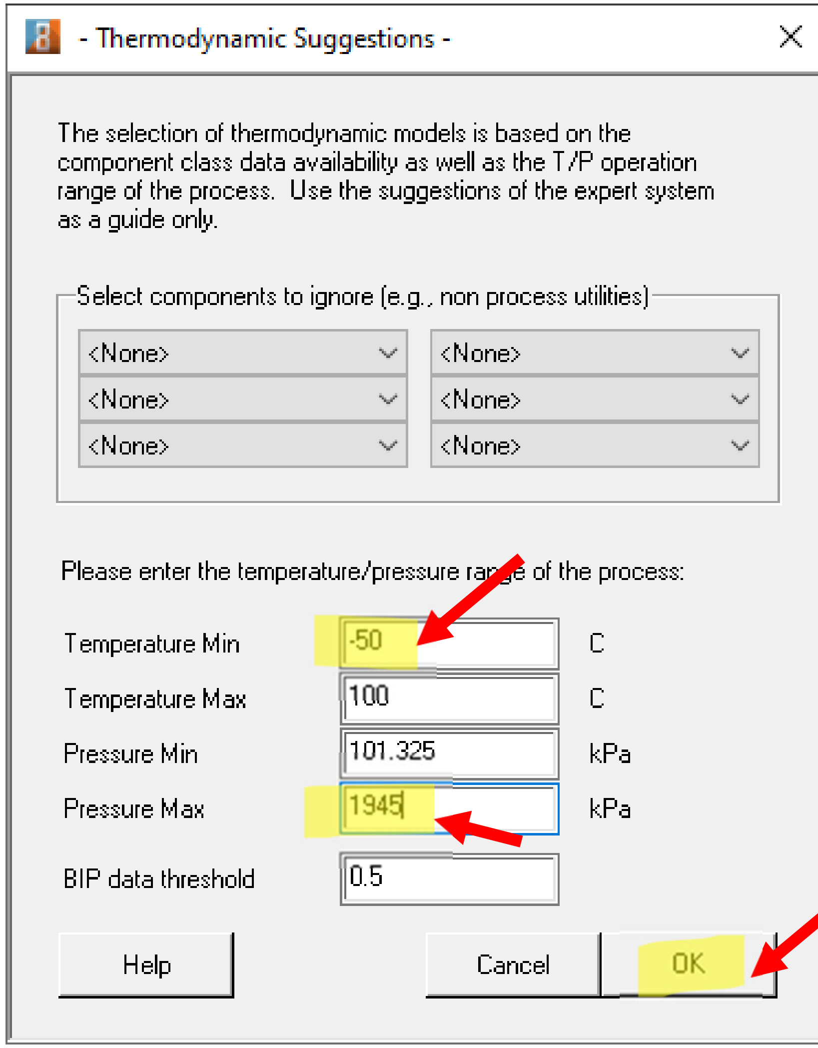


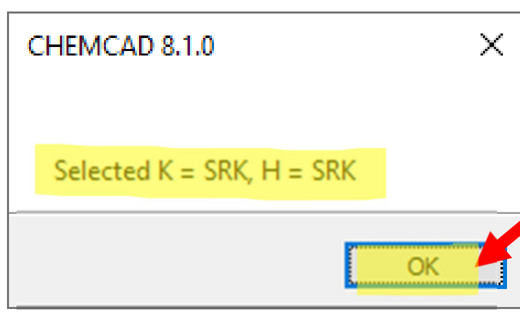
On my computer, I have Common SI set as the default.



“Thermodynamic Suggestions” window launches automatically when you click OK.

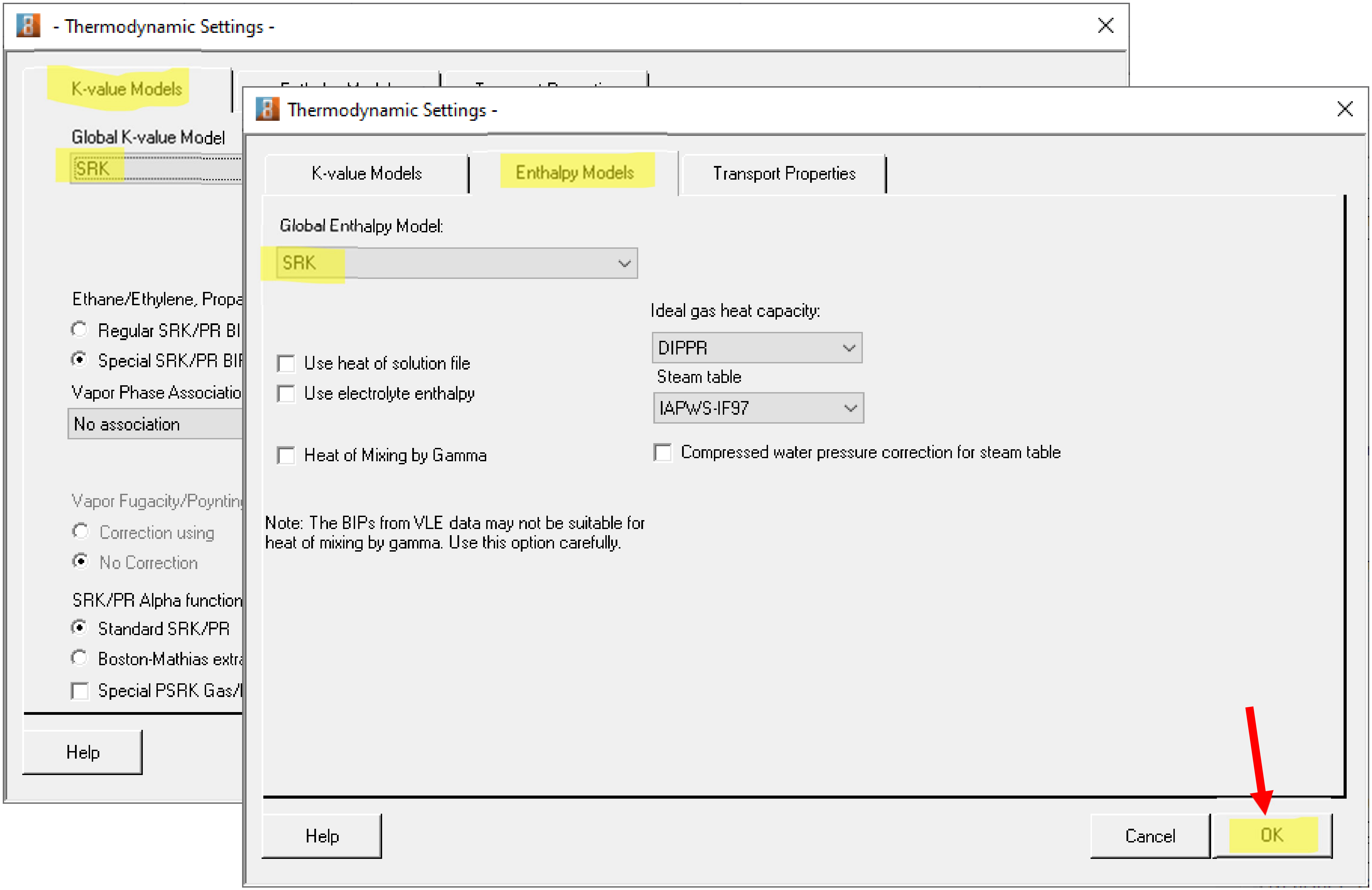
Thermodynamic Suggestions

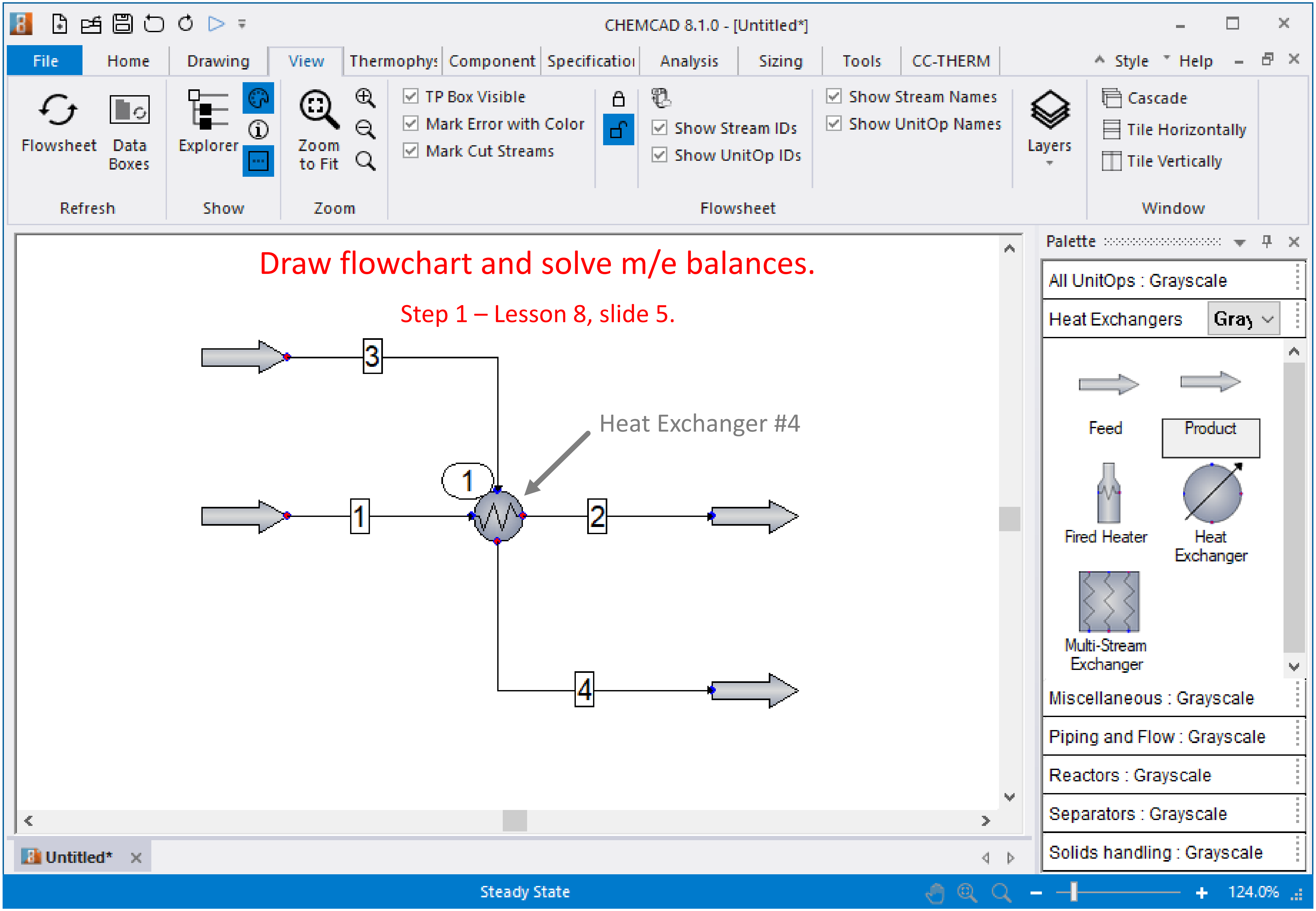




SRK is good!

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





CHEMCAD 8.1.0 - [Untitled*]
File
Home
Drawing
View
Thermophys
Component
Specificatio
Analysis
Sizing
Tools
CC-THERM
Style
Help
Flowsheet
Data Boxes
Refresh
Explorer
Show
Zoom to Fit
Zoom
TP Box Visible
Mark Error with Color
Mark Cut Streams
Show Stream IDs
Show UnitOp IDs
Show Stream Names
Show UnitOp Names
Flowsheet
Layers
Cascade
Tile Horizontally
Tile Vertically
Window
Draw flowchart and solve m/e balances.
Step 1 – Lesson 8, slide 5.
Heat Exchanger #4
3
1
1
2
4
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
124.0%

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 Cancel OK

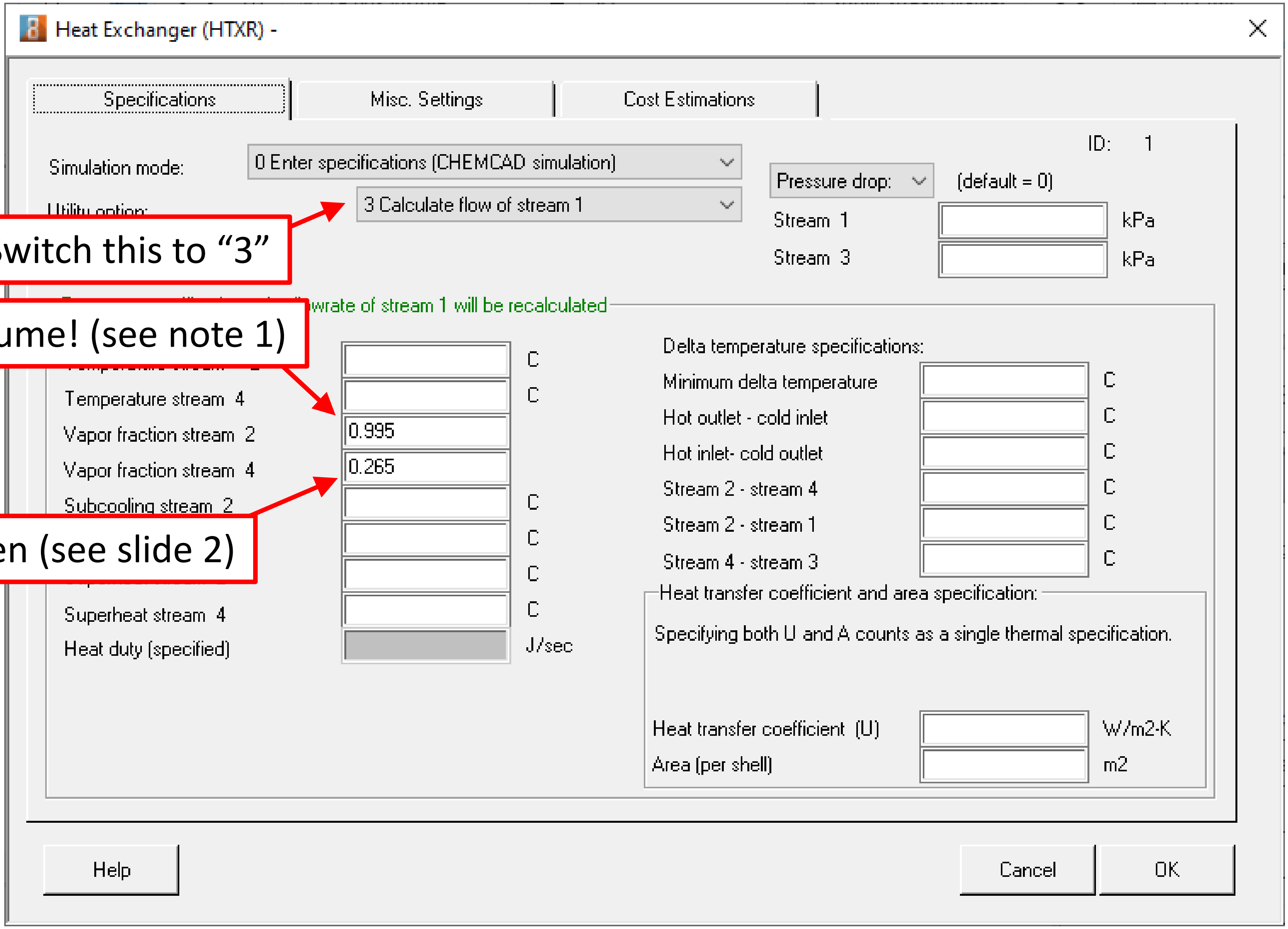
Stream No.	1	3
Stream Name		
Temp C	-46	-30.1
Pres kPa	125	1945.806
Vapor Fraction	0	1
Enthalpy J/sec	-77463.29	1.114613e+08
Total flow	1	64.5956
Total flow unit	kg/sec	kg/sec
Comp unit	kg/sec	kg/sec
Methane	0	0.003
Ethane	0	0.0626
Ethylene	0	64.53
Propylene	1	0

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.

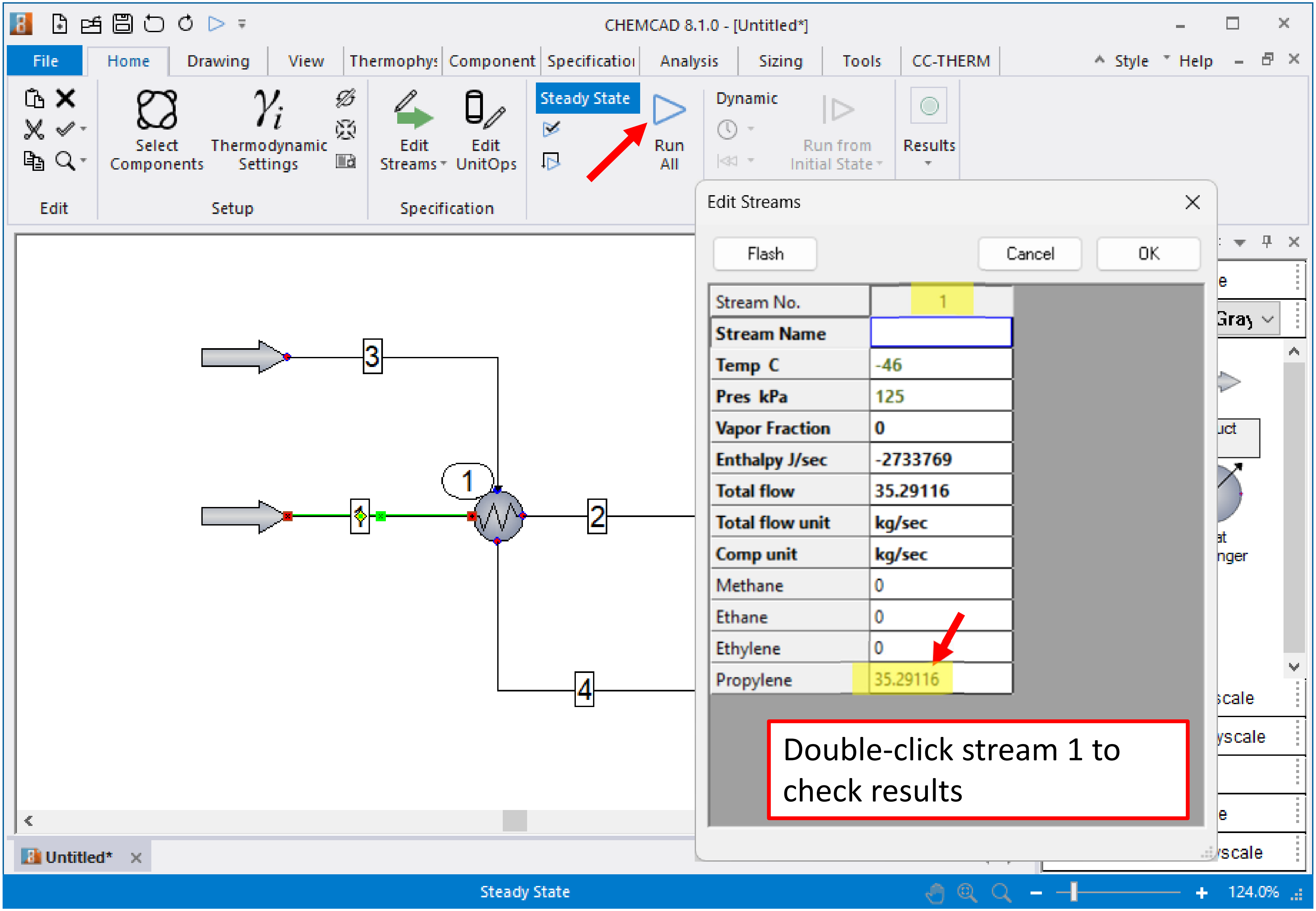
Complete Specs on Heat Exchanger and Coolant Flow Rate



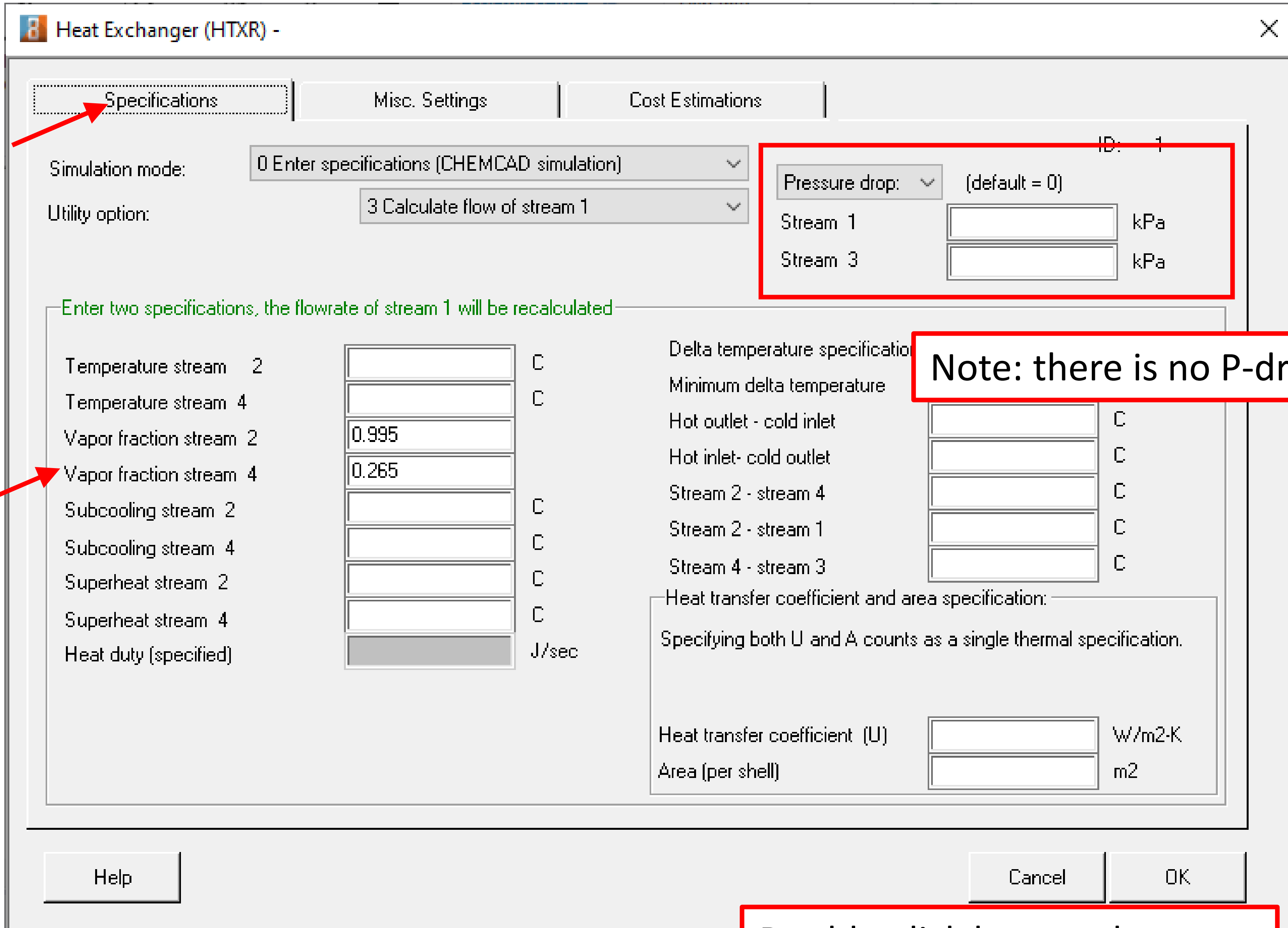
Note 1: The largest “thermal reservoir” in the coolant is the latent heat of the phase transition. Any further warming of the coolant will involve relatively small enthalpy changes.

Click OK, then Run

Run the Simulation and Confirm Results (1/3)



Confirm Results (2/3)

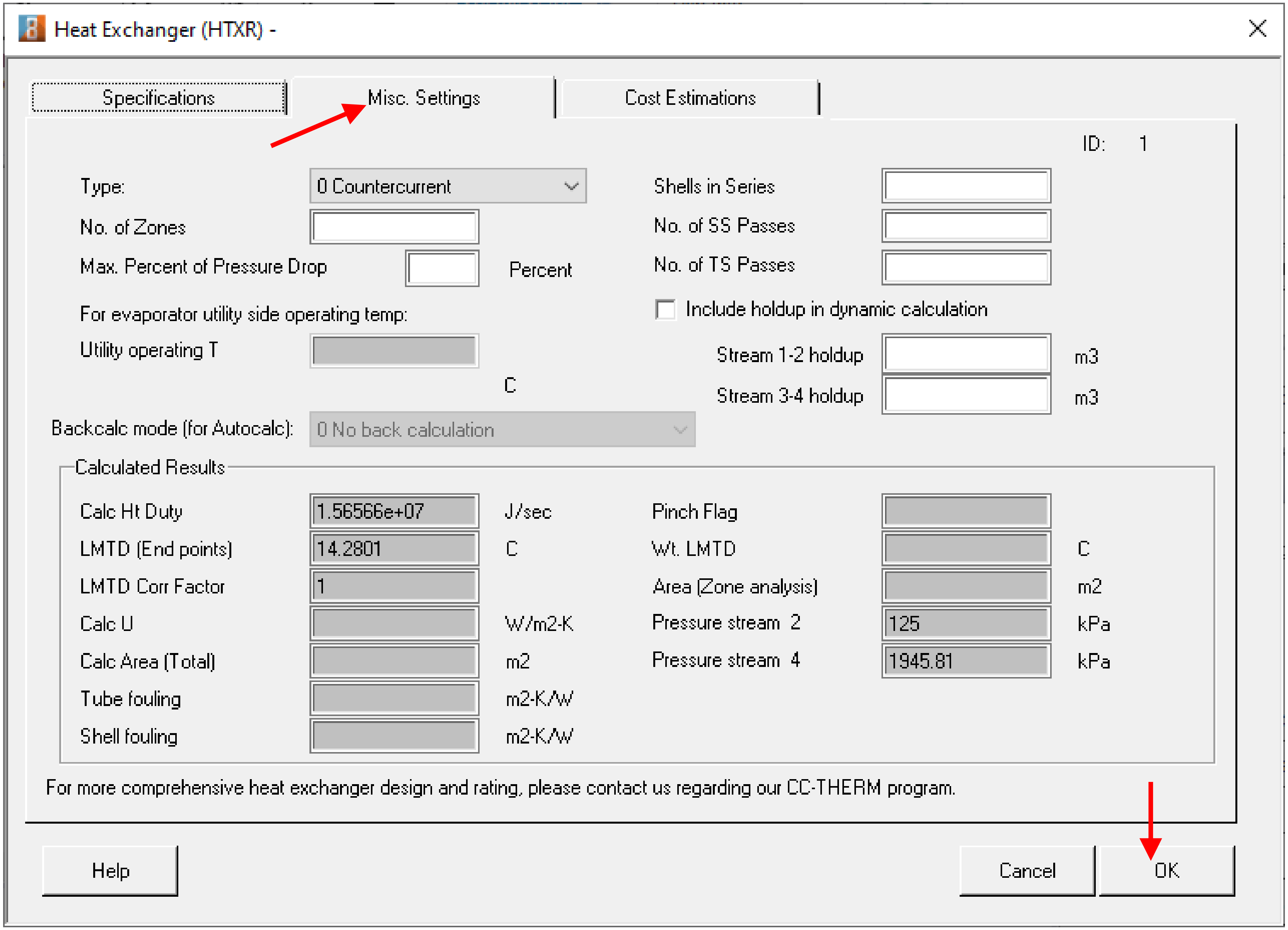


Given

Note: there is no P-drop

Double-click heat exchanger to confirm results

Confirm Results (3/3)



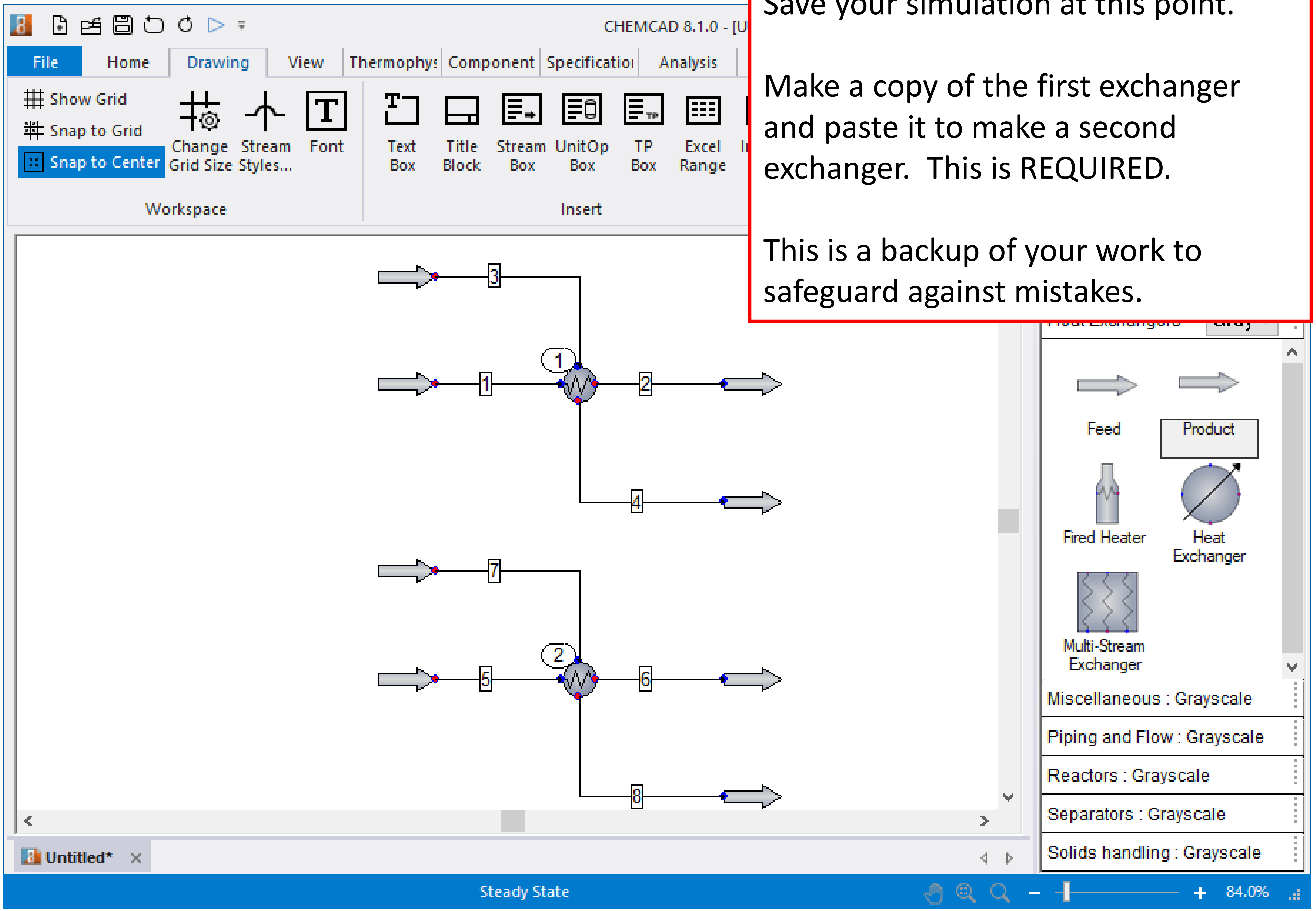
Numbers in gray fields were calculated by CHEMCAD

STOP HERE

Confirm results in slides 12 to 14 before proceeding

Step 1 (L8 Slide 5) is complete:

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



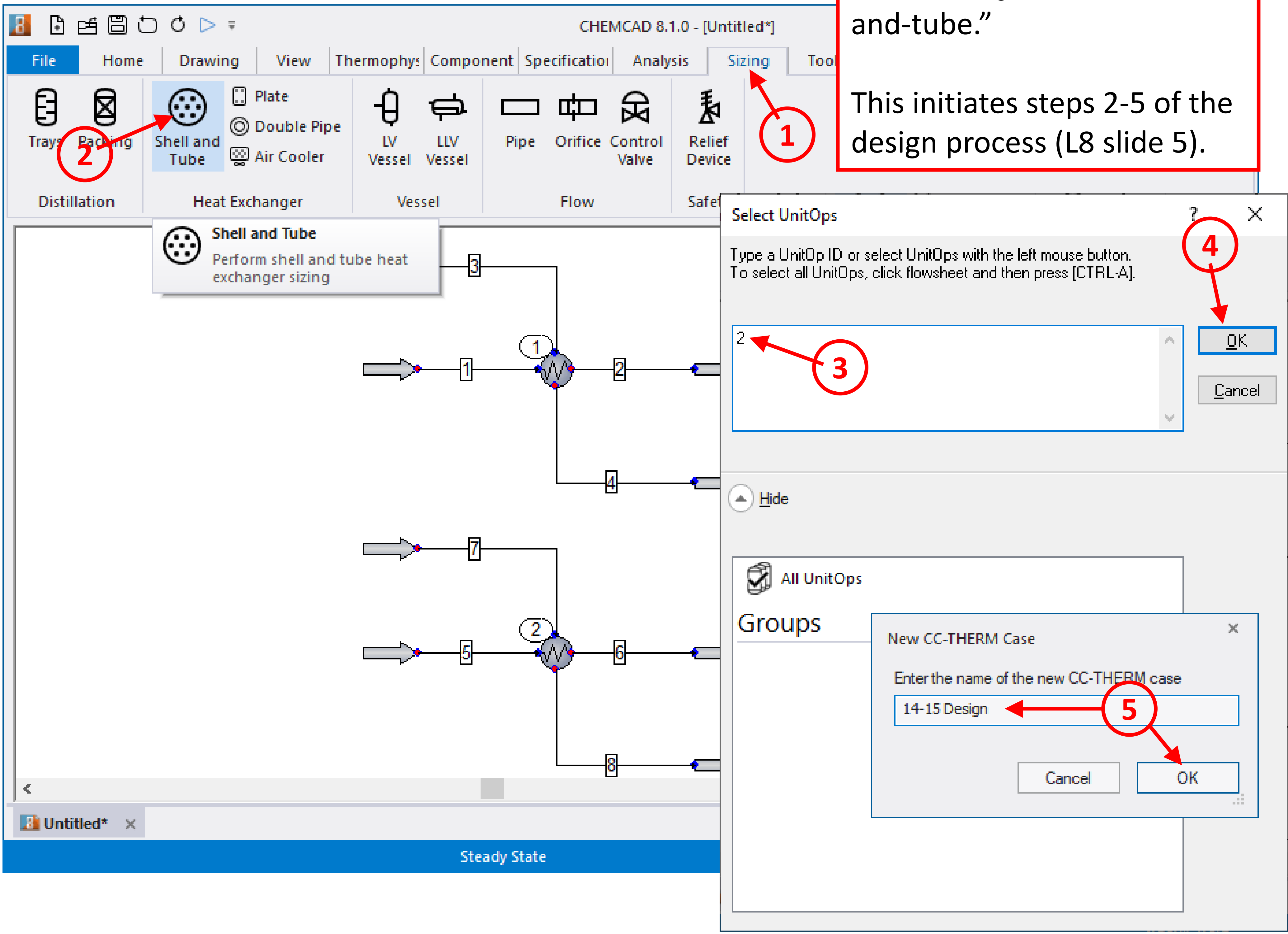
Save your simulation at this point.

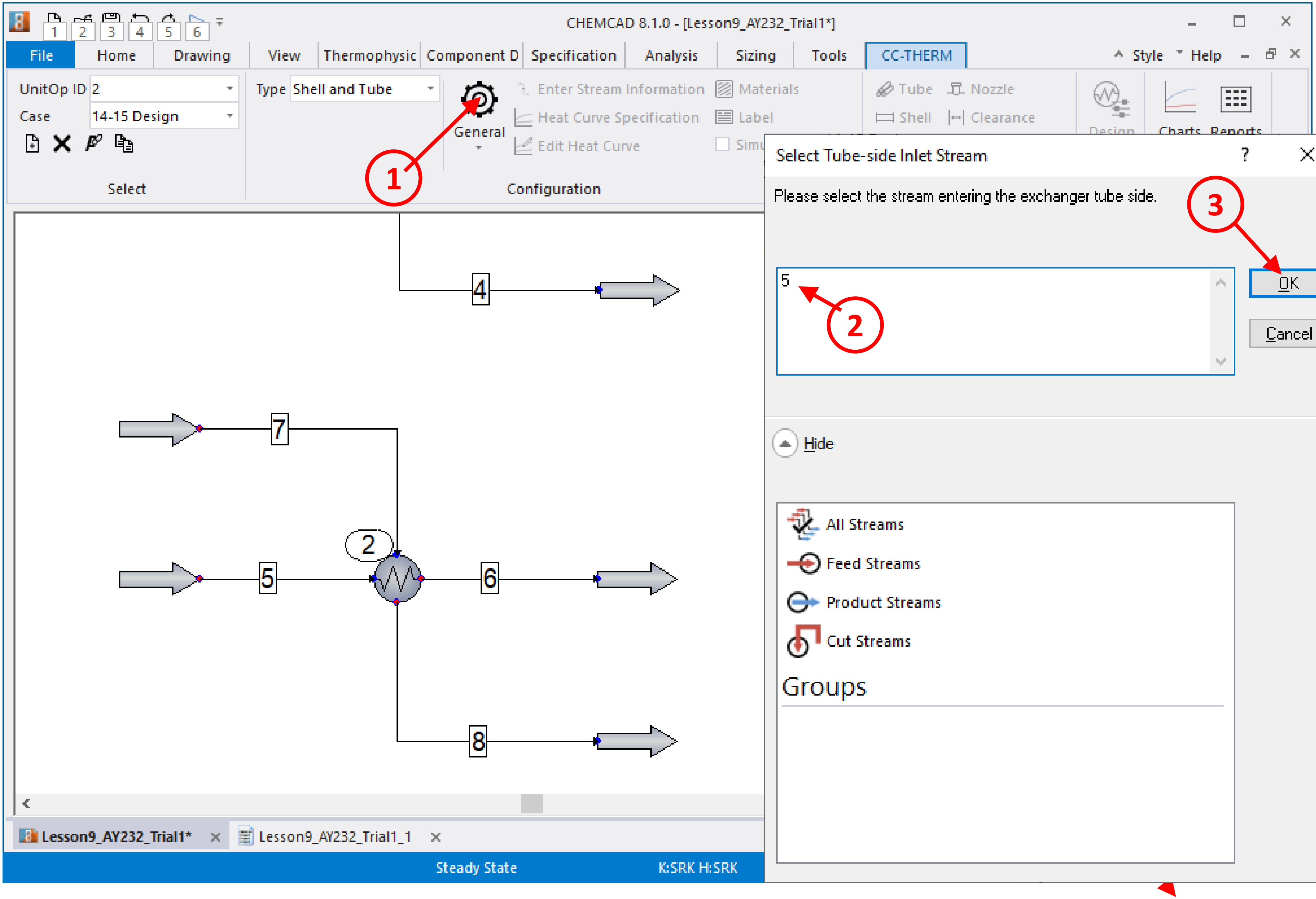
Make a copy of the first exchanger and paste it to make a second exchanger. This is REQUIRED.

This is a backup of your work to safeguard against mistakes.

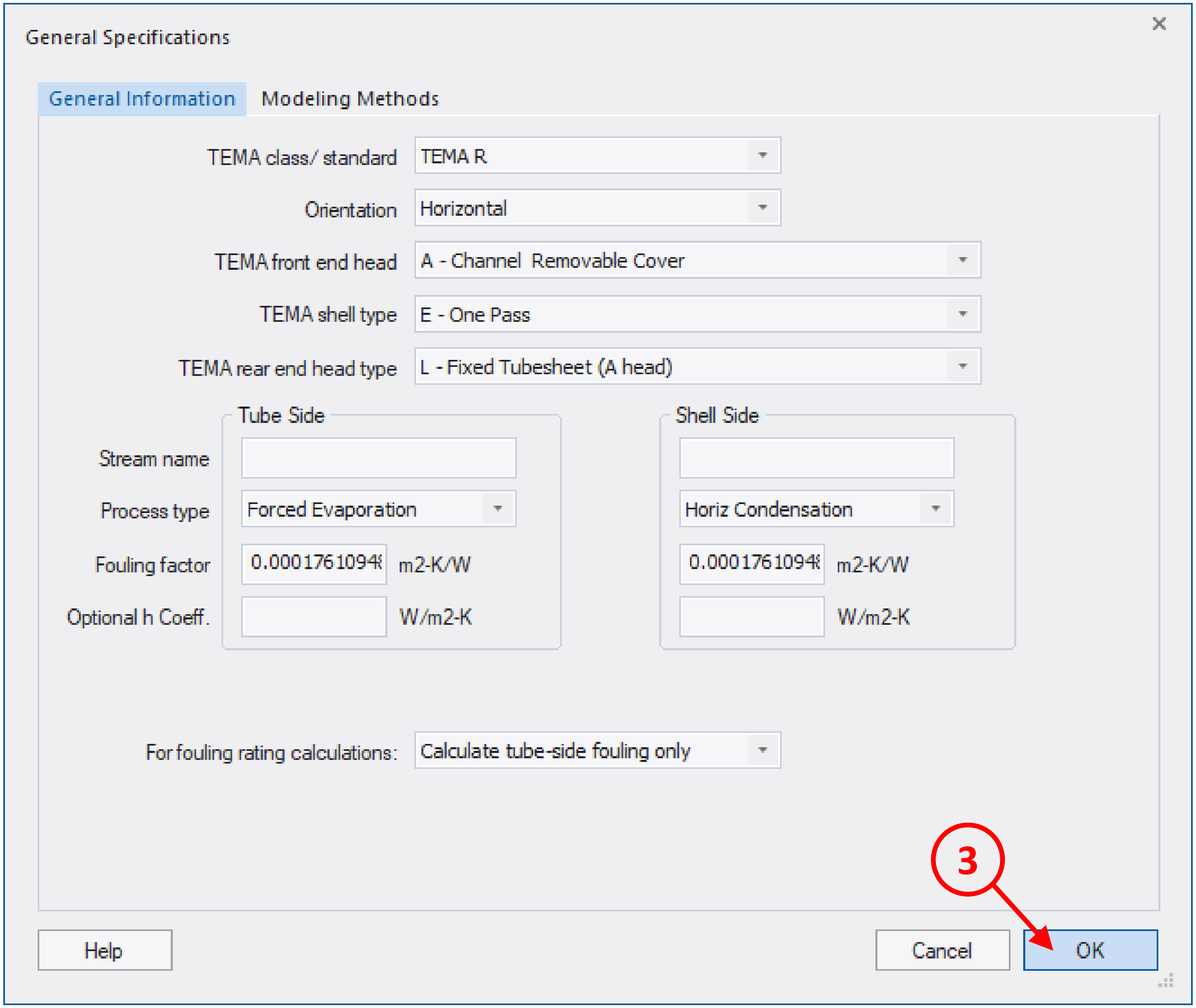
Click “Sizing,” then “Shell-and-tube.”

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

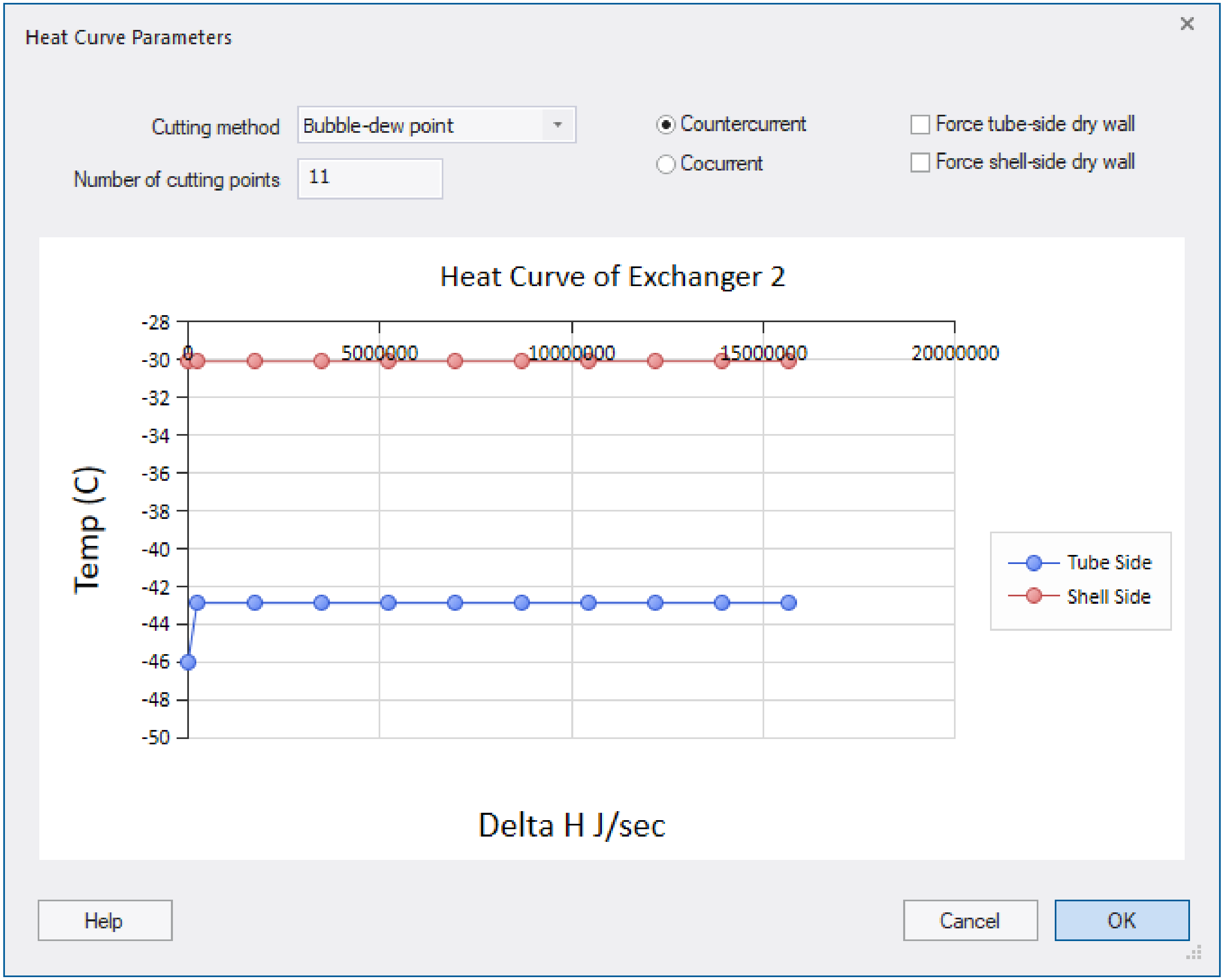


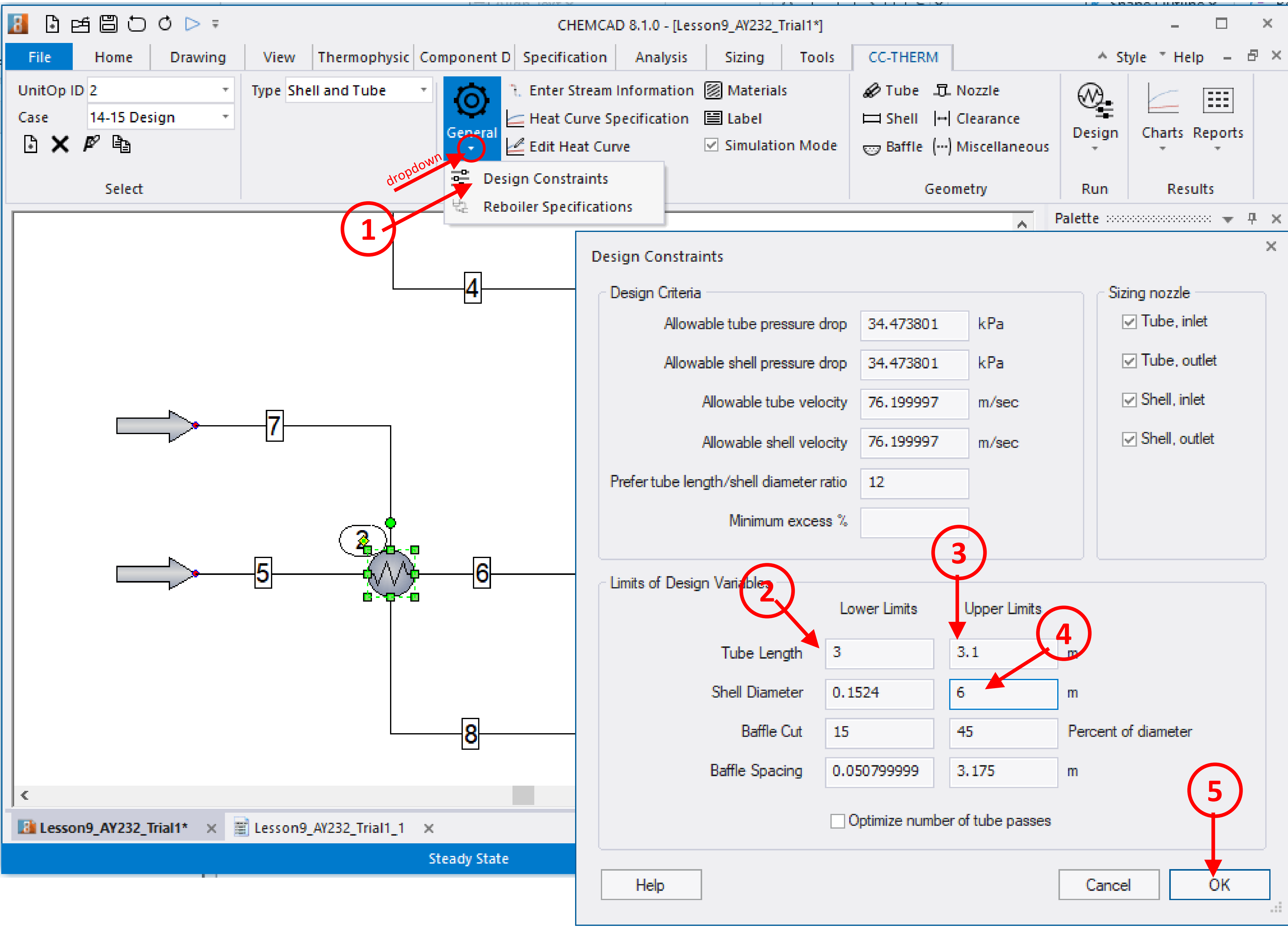

CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]
File
Home
Drawing
View
Thermophysic
Component D
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
UnitOp ID 2
Case 14-15 Design
Select
Type Shell and Tube
General
Enter Stream Information
Heat Curve Specification
Edit Heat Curve
Materials
Label
Configuration
Tube
Nozzle
Shell
Clearance
Design
Charts
Reports
Select Tube-side Inlet Stream
Please select the stream entering the exchanger tube side.
5
OK
Cancel
Hide
All Streams
Feed Streams
Product Streams
Cut Streams
Groups
1
2
3
4
5
6
7
8
Lesson9_AY232_Trial1*
Lesson9_AY232_Trial1_1
Steady State
K:SRK H:SRK

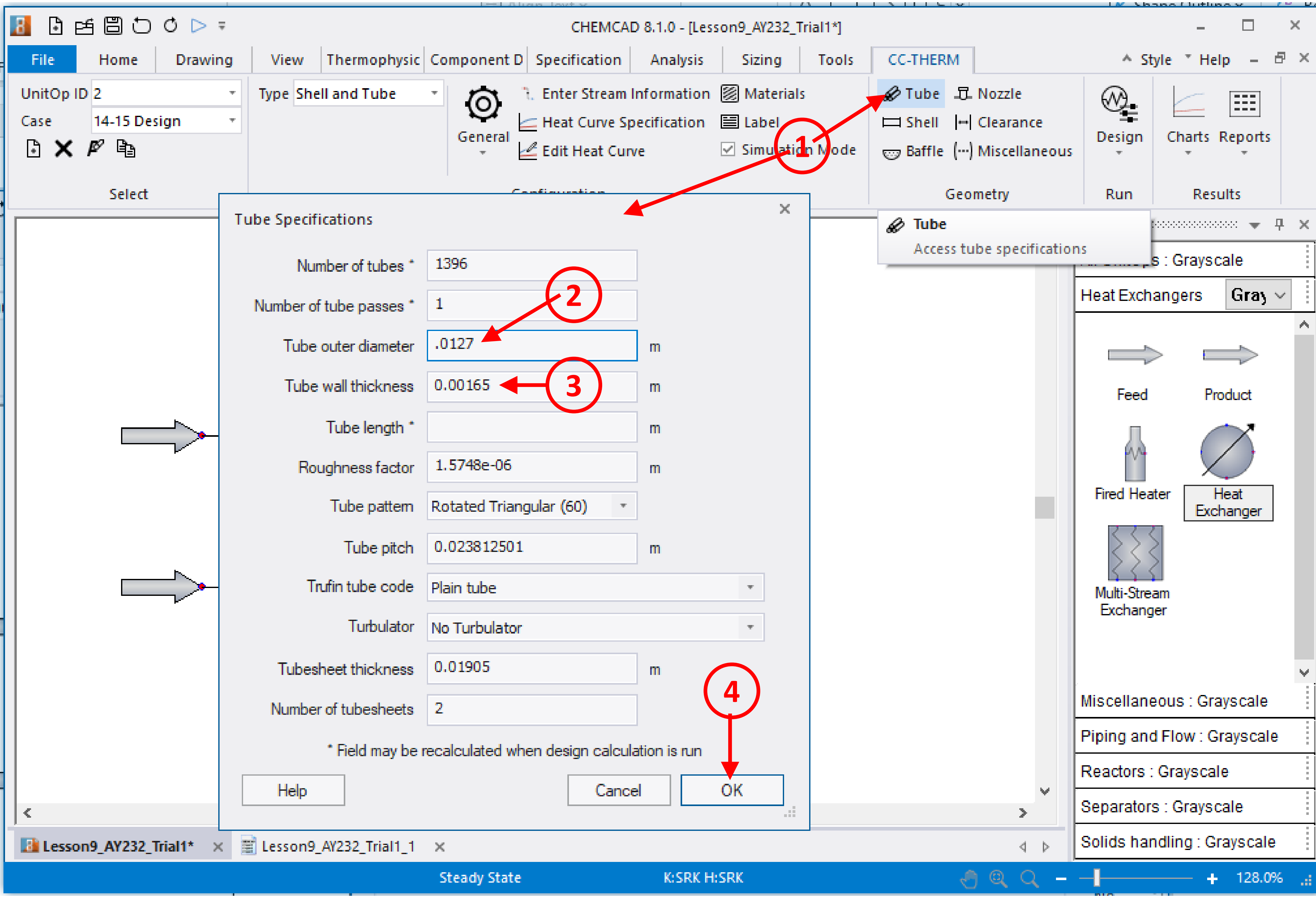
TEMA Type AEL Exchanger. Take all defaults.



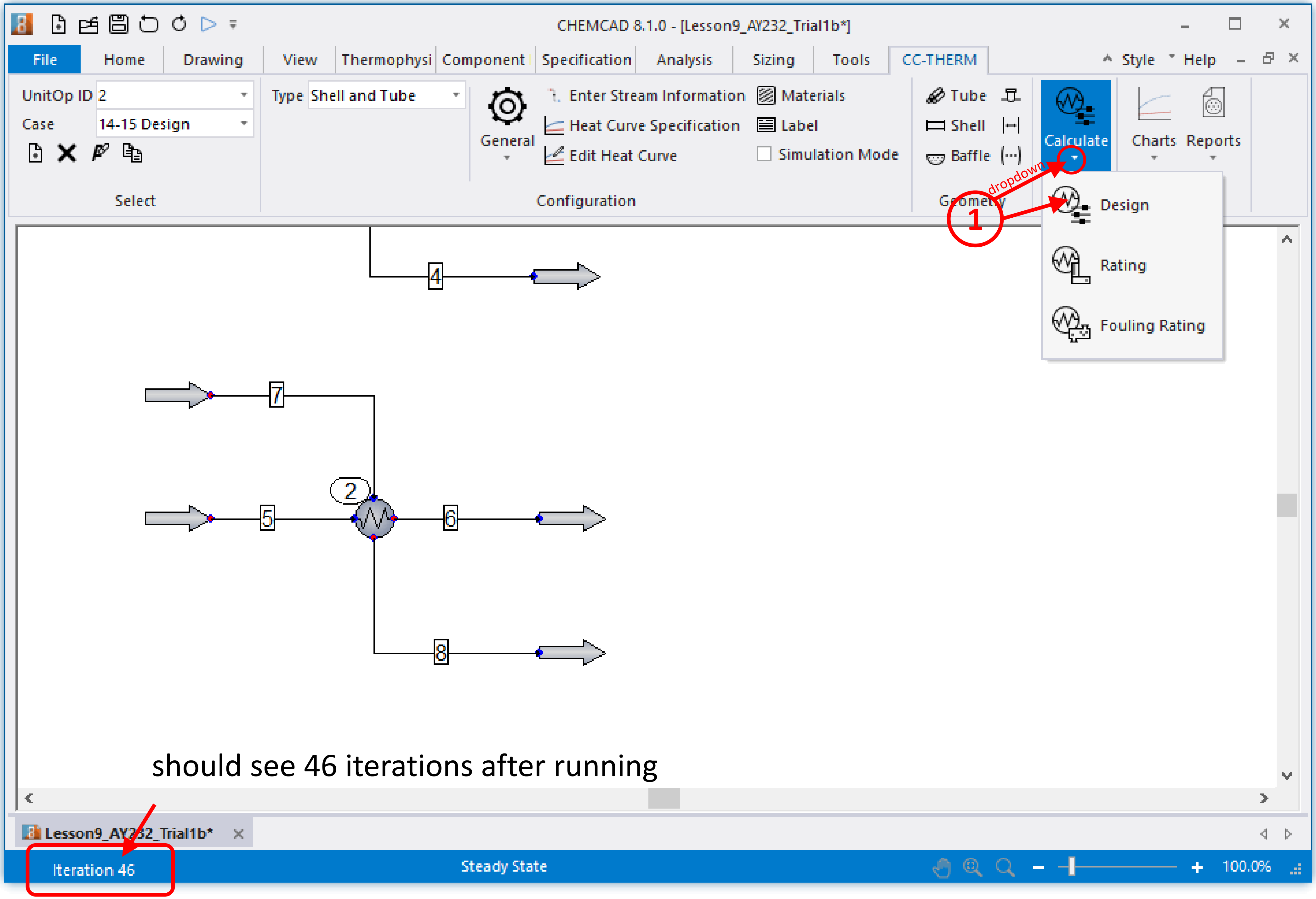
Heating-cooling curve can be seen by clicking "Heat Curve Specification."



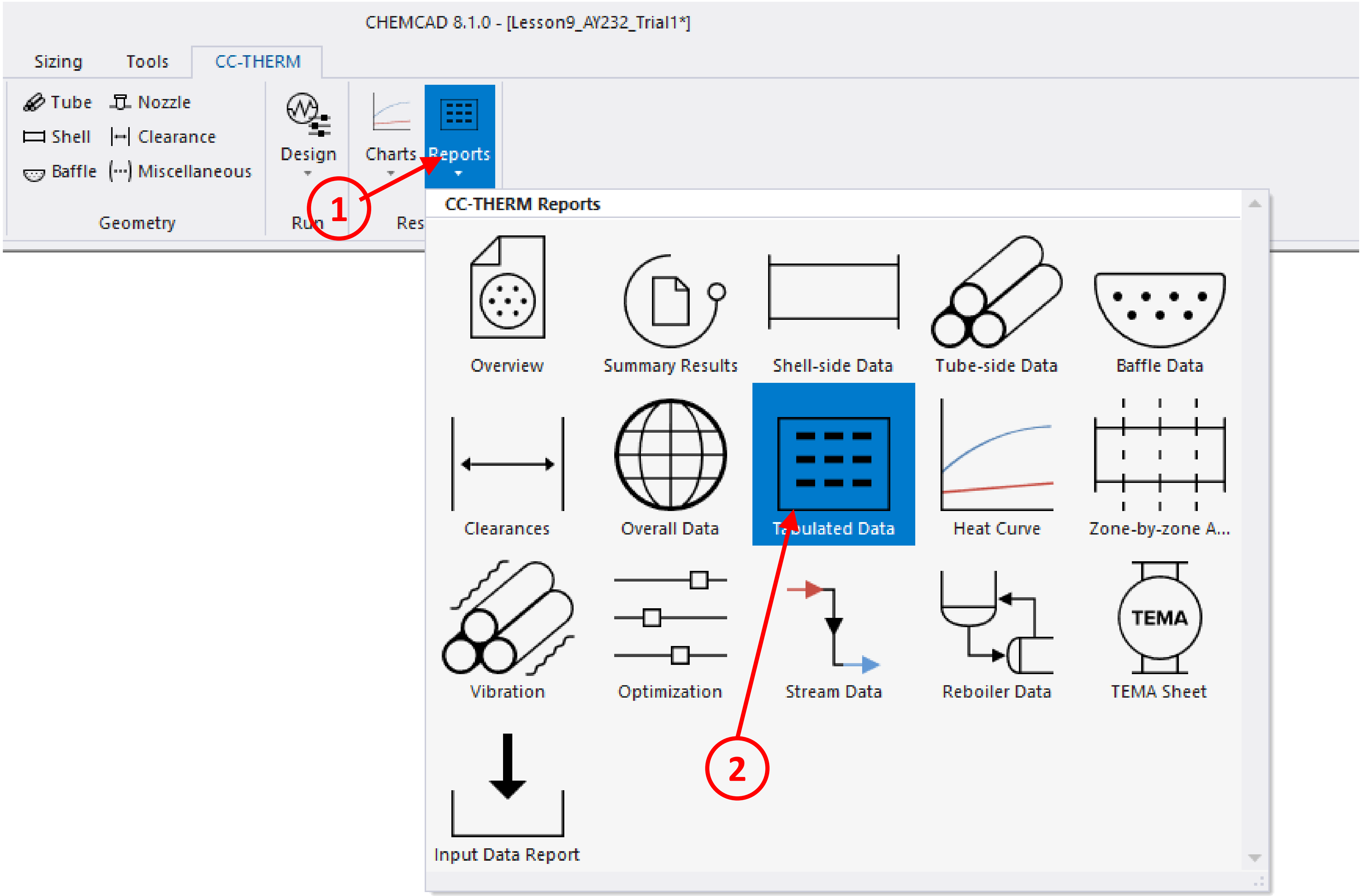

CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]
File
Home
Drawing
View
Thermophysic
Component D
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
UnitOp ID 2
Case 14-15 Design
Type Shell and Tube
General
Enter Stream Information
Heat Curve Specification
Edit Heat Curve
Materials
Label
Simulation Mode
Tube
Shell
Baffle
Nozzle
Clearance
Miscellaneous
Geometry
Design
Run
Charts
Reports
Results
Select
dropdown
Design Constraints
Reboiler Specifications
Palette
1
4
7
5
2
6
8
Lesson9_AY232_Trial1*
Lesson9_AY232_Trial1_1
Steady State
Design Constraints
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 %
Sizing nozzle
Tube, inlet
Tube, outlet
Shell, inlet
Shell, outlet
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
3
4
5
Help
Cancel
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
Heat Curve Specification
Edit Heat Curve
Materials
Label
Simulation Mode
Tube
Nozzle
Shell
Clearance
Baffle
Miscellaneous
Design
Charts
Reports
Select
Geometry
Run
Results
Tube
Access tube specifications
1
2
3
4
Tube Specifications
Number of tubes * 1396
Number of tube passes * 1
Tube outer diameter .0127 m
Tube wall thickness 0.00165 m
Tube length * m
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
Heat Exchangers
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%



CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1b*]
File
Home
Drawing
View
Thermophysi
Component
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
UnitOp ID 2
Case 14-15 Design
Select
Type Shell and Tube
General
Enter Stream Information
Heat Curve Specification
Edit Heat Curve
Materials
Label
Simulation Mode
Configuration
Tube
Shell
Baffle
Geometry
Calculate
Charts
Reports
dropdown
1
Design
Rating
Fouling Rating
4
7
2
5
6
8
should see 46 iterations after running
Lesson9_AY232_Trial1b*
Iteration 46
Steady State
100.0%


CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]
Sizing
Tools
CC-THERM
Tube
Nozzle
Shell
Clearance
Baffle
Miscellaneous
Geometry
Design
Run
Charts
Reports
Res
1
CC-THERM Reports
Overview
Summary Results
Shell-side Data
Tube-side Data
Baffle Data
Clearances
Overall Data
Tabulated Data
Heat Curve
Zone-by-zone A...
Vibration
Optimization
Stream Data
Reboiler Data
TEMA
TEMA Sheet
Input Data Report
2

Design Results

TABULATED ANALYSIS

Overall Data:

Area Total	m2	2758.72	% Excess		8.57
Area Required	m2	2482.72	U Calc.	W/m2-K	492.75
Area Effective	m2	2695.50	U Service	W/m2-K	453.85
Area Per Shell	m2	2695.50	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	3.99	Orientation		H
Shell I.D.	m	3.96	Shell in Series		1
Bonnet I.D.	m	3.96	Shell in Parallel		1
Type		AEL	Max. Heat Flux	Btu/ft2-hr	0.00
Imping. Plate		Impingement Plate	Sealing Strip		5

Tubes:

Number		22685	Tube Type		Bare
Length	m	3.05	Free Int. Fl Area	m2	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	m2-K/W	0.00091
Shell-side Fouling	m2-K/W	0.00018
Tube Wall	m2-K/W	0.00004
Tube-side Fouling	m2-K/W	0.00018
Tube-side Film	m2-K/W	0.00050

Answers to first three questions are found here.

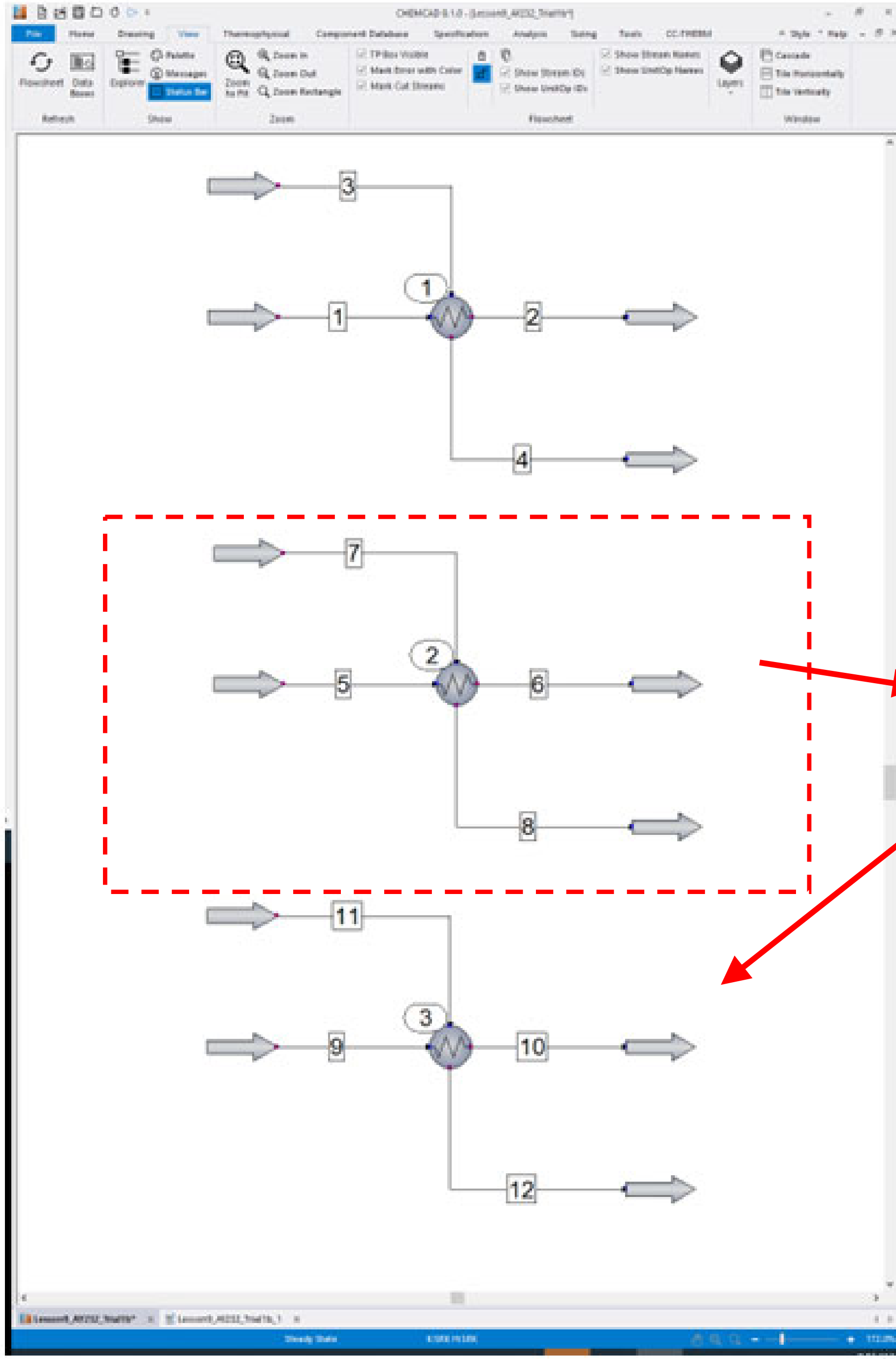
STOP HERE

Confirm results in slide 12 before proceeding

Steps 2-5 of L8 Slide 5 are complete:

Type of exchanger, geometric details, overall U, thermal driving force, area, and P-drops.

Exchanger Simulation

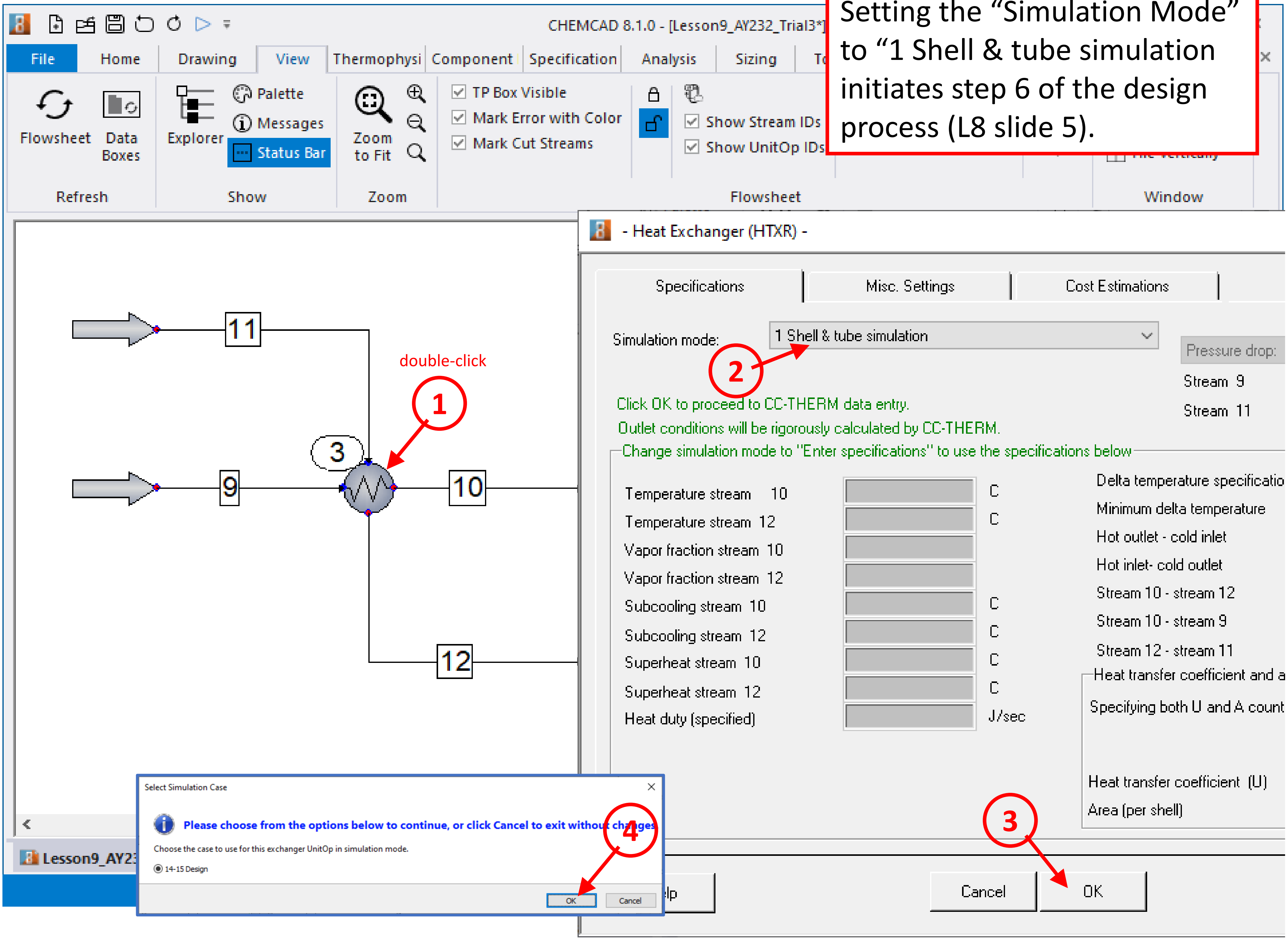


Copying and pasting is an important step.

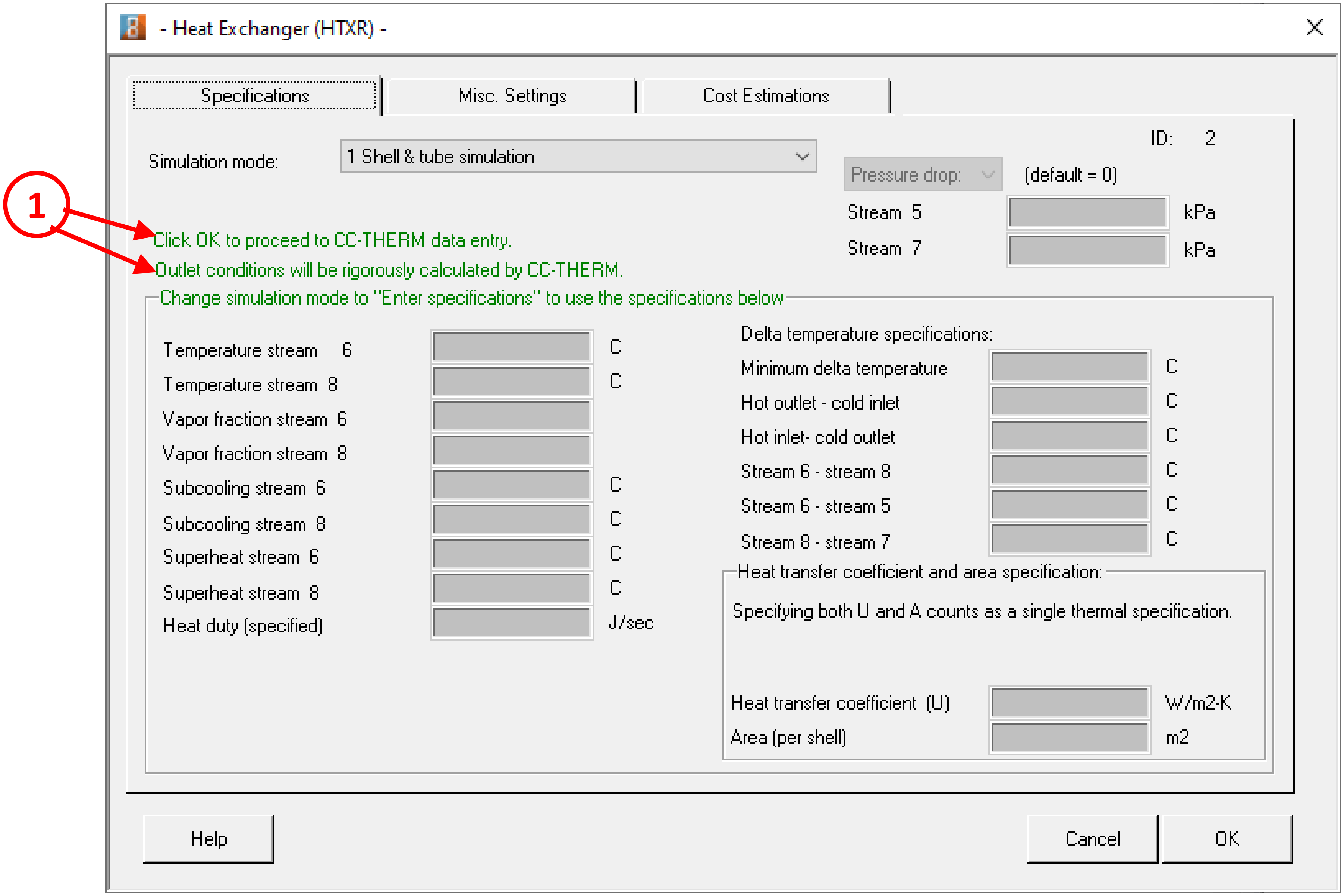
It preserves the design work down in exchanger 2 as a backup.

copy this and paste here

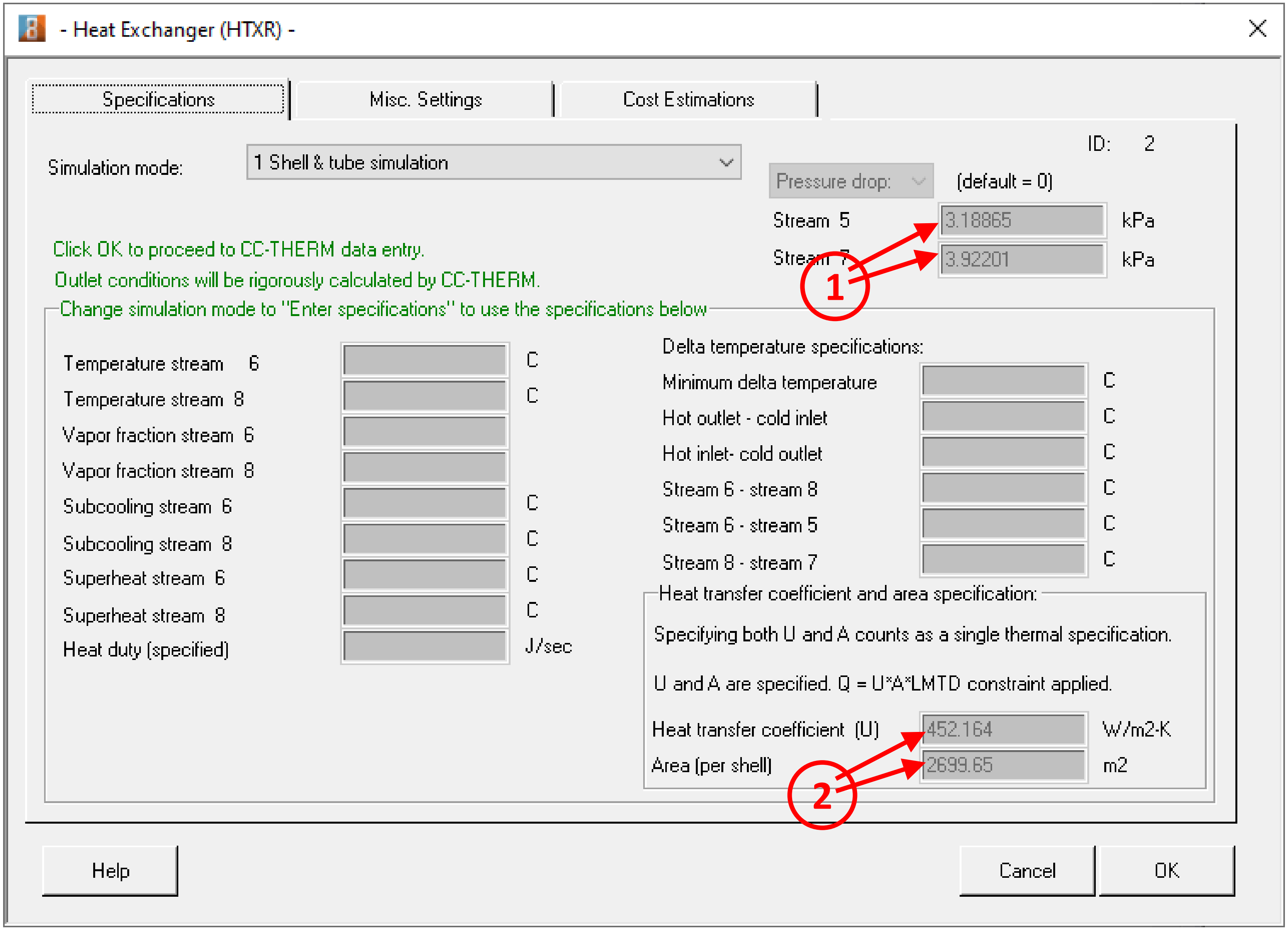
Setting the “Simulation Mode” to “1 Shell & tube simulation initiates step 6 of the design process (L8 slide 5).



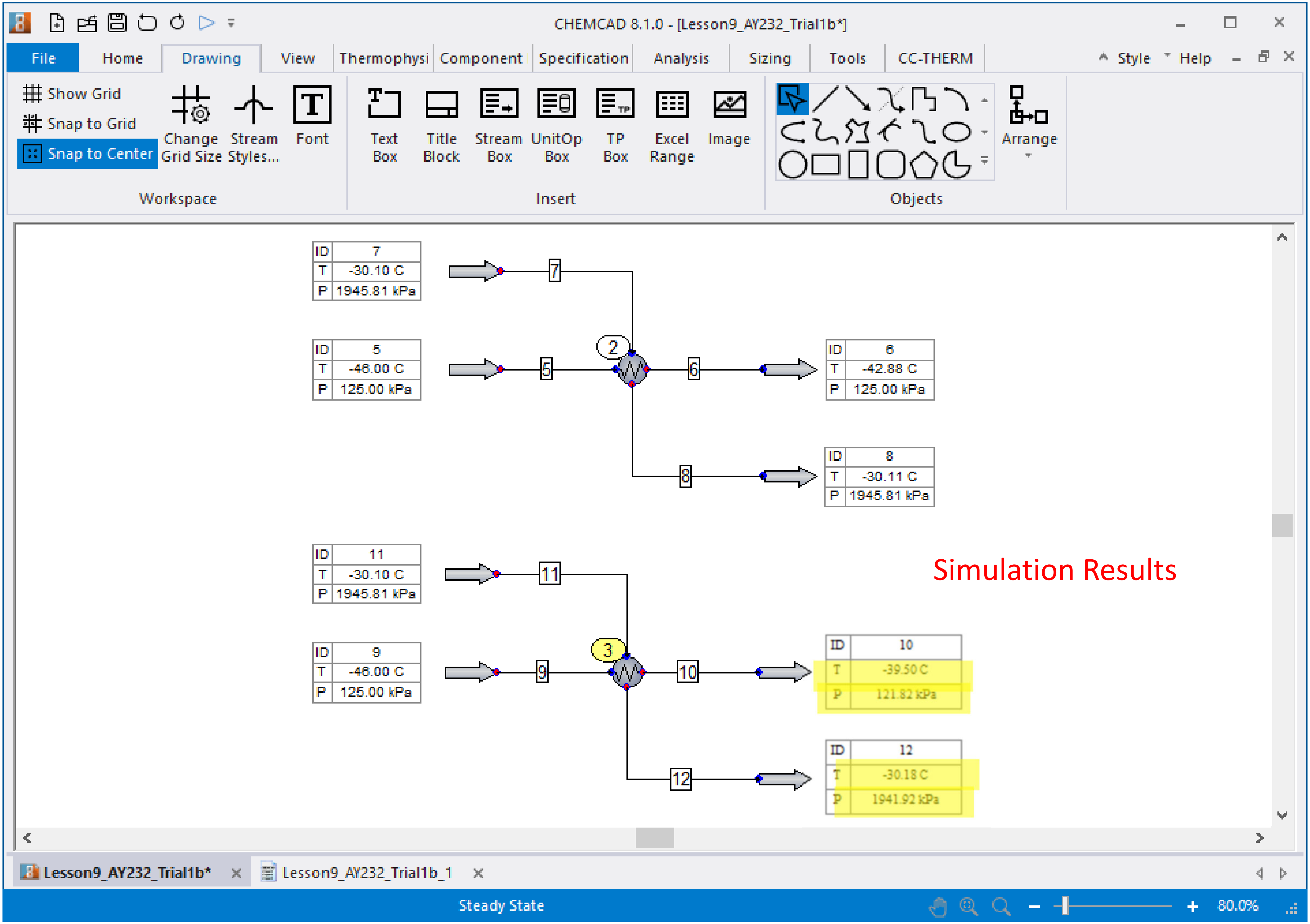
Heat Exchanger Before Running

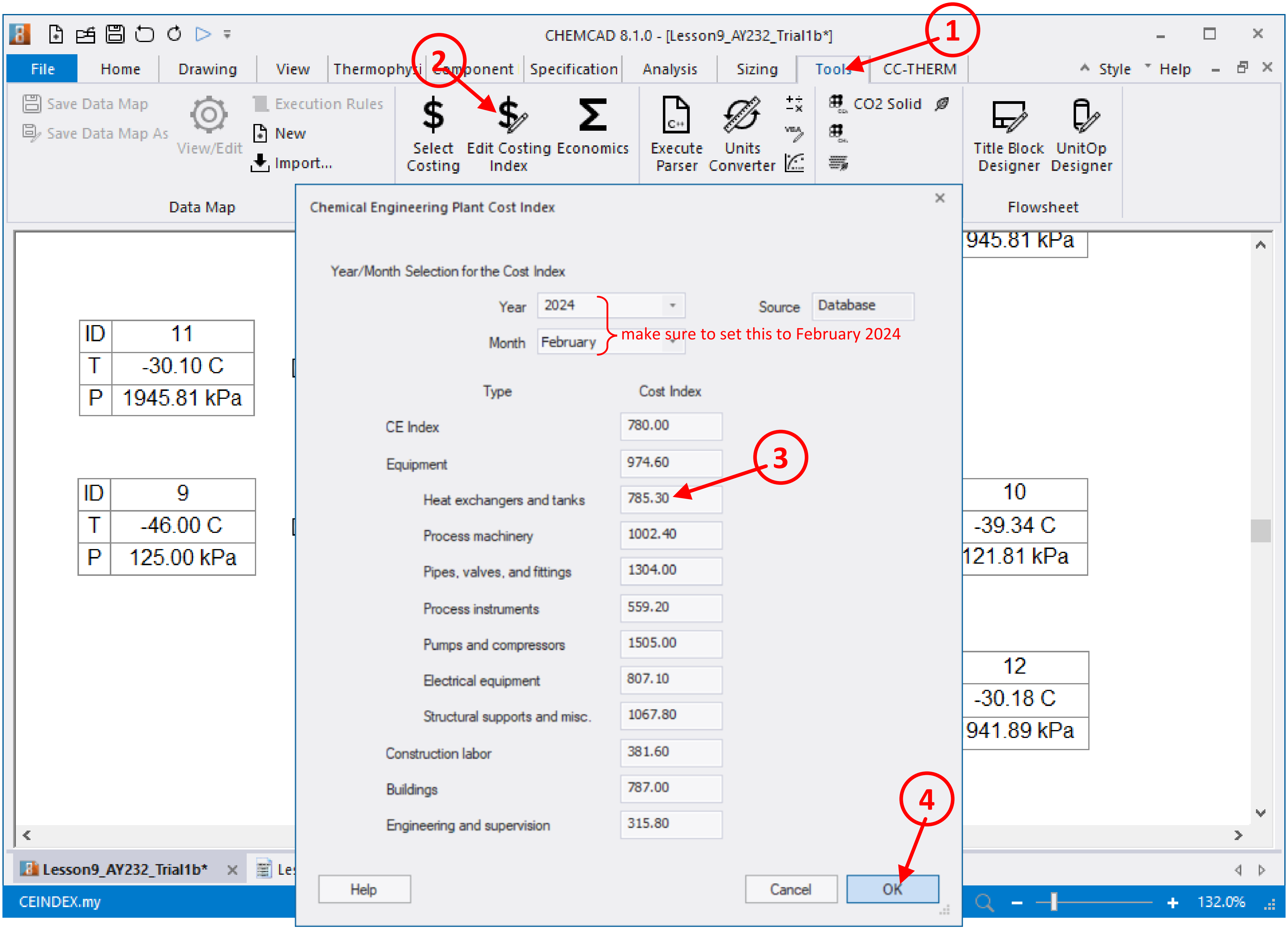


Heat Exchanger After Running

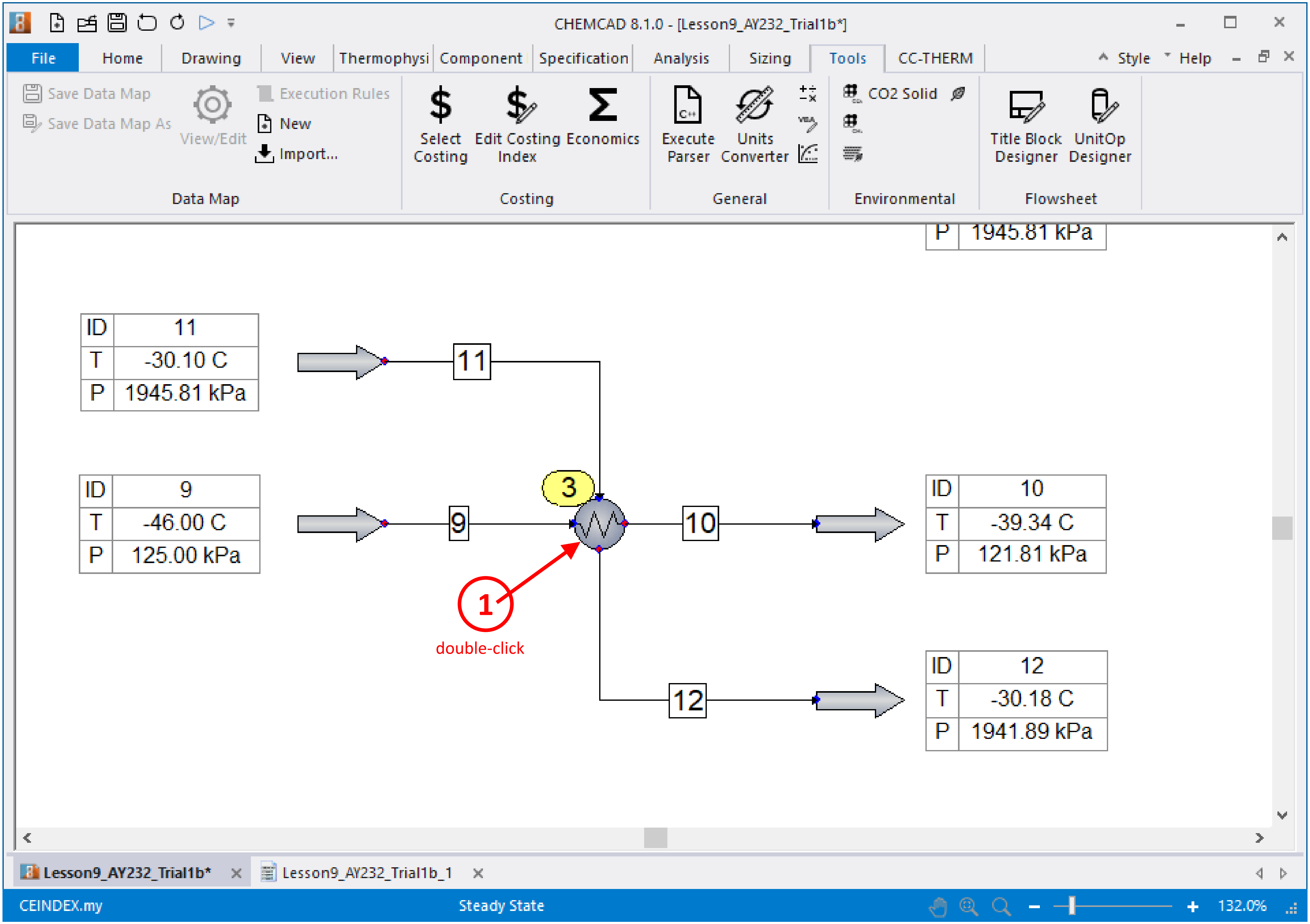


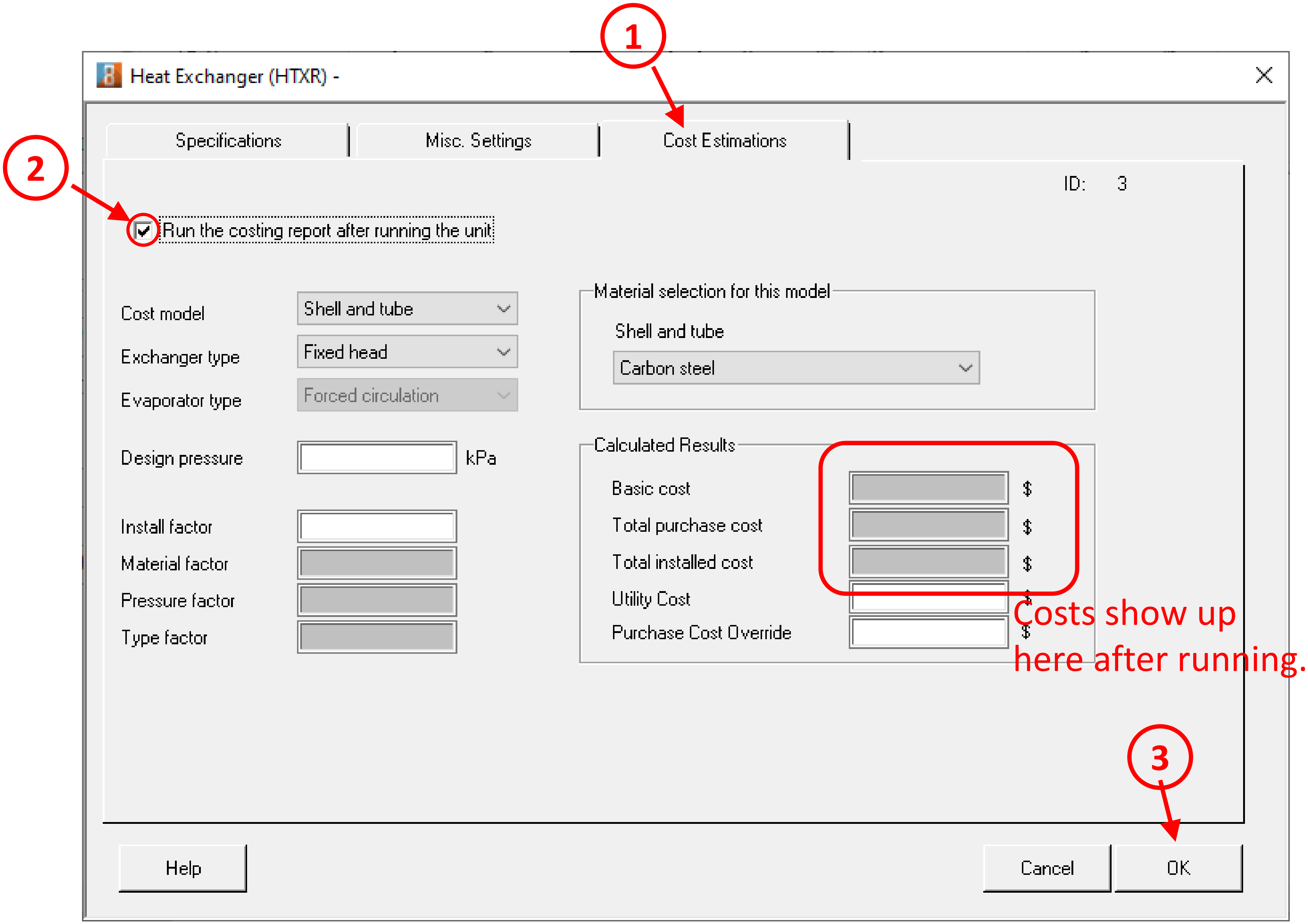
Click "Run All" in the Home tab


CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1b*]
File
Home
Drawing
View
Thermophysi
Component
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
Show Grid
Snap to Grid
Snap to Center
Change Grid Size
Stream Styles...
Font
Workspace
Text Box
Title Block
Stream Box
UnitOp Box
TP Box
Excel Range
Image
Insert
Objects
Arrange
ID 7
T -30.10 C
P 1945.81 kPa
ID 5
T -46.00 C
P 125.00 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 -46.00 C
P 125.00 kPa
ID 10
T -39.50 C
P 121.82 kPa
ID 12
T -30.18 C
P 1941.92 kPa
Simulation Results
Lesson9_AY232_Trial1b*
Lesson9_AY232_Trial1b_1
Steady State
80.0%



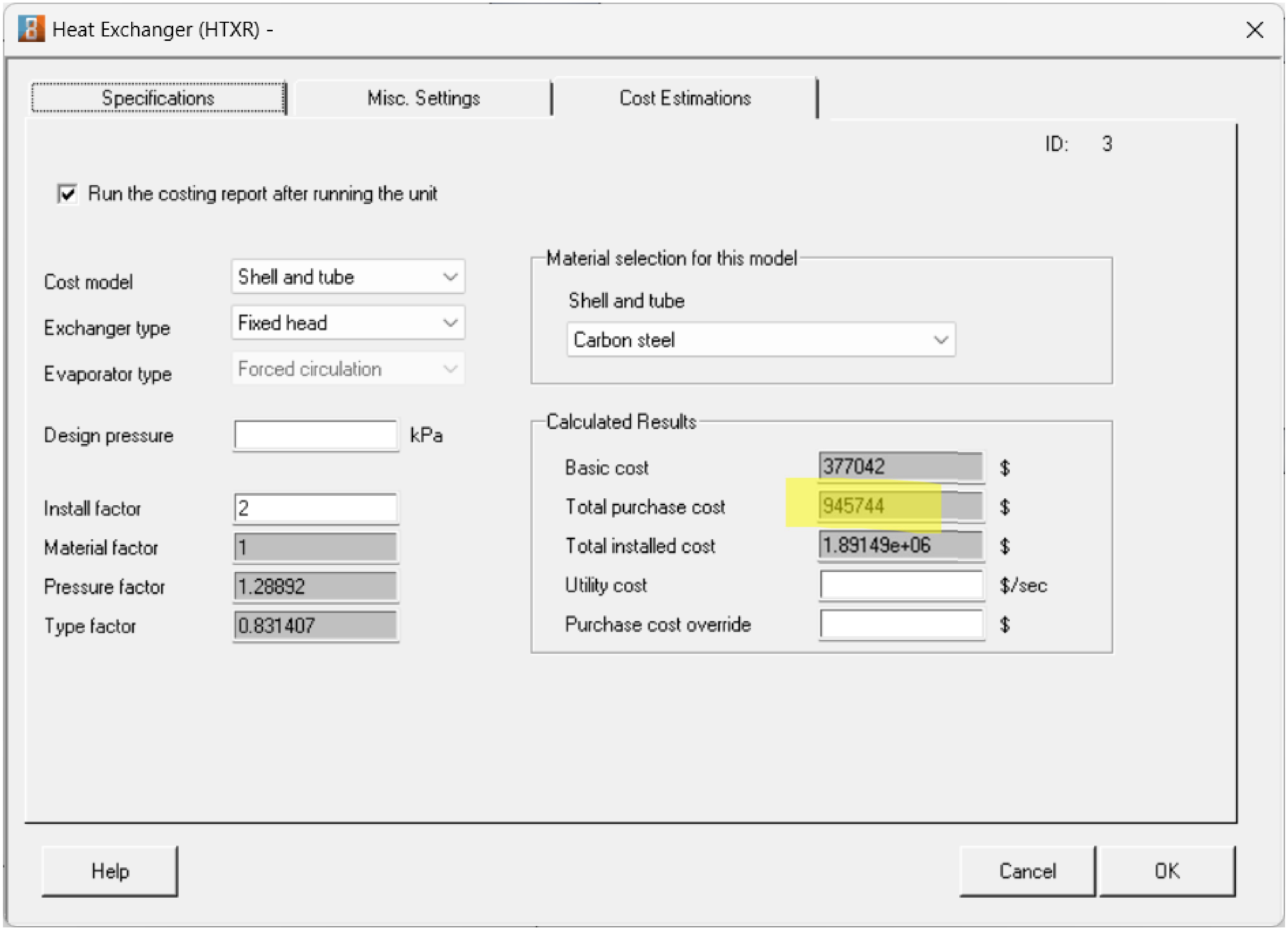
CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1b*]
File
Home
Drawing
View
Thermophysical
Component
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
Save Data Map
Save Data Map As
View/Edit
Execution Rules
New
Import...
Data Map
Select Costing
Edit Costing Index
Economics
Execute Parser
Units Converter
CO2 Solid
Title Block Designer
UnitOp Designer
Flowsheet
1
2
3
4
Chemical Engineering Plant Cost Index
Year/Month Selection for the Cost Index
Year 2024
Source Database
Month February
make sure to set this to February 2024
Type
Cost Index
CE Index 780.00
Equipment 974.60
Heat exchangers and tanks 785.30
Process machinery 1002.40
Pipes, valves, and fittings 1304.00
Process instruments 559.20
Pumps and compressors 1505.00
Electrical equipment 807.10
Structural supports and misc. 1067.80
Construction labor 381.60
Buildings 787.00
Engineering and supervision 315.80
Help
Cancel
OK
ID 11
T -30.10 C
P 1945.81 kPa
ID 9
T -46.00 C
P 125.00 kPa
945.81 kPa
10
-39.34 C
121.81 kPa
12
-30.18 C
941.89 kPa
Lesson9_AY232_Trial1b*
CEINDEX.my
132.0%


CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1b*]
File
Home
Drawing
View
Thermophysi
Component
Specification
Analysis
Sizing
Tools
CC-THERM
Style
Help
Save Data Map
Save Data Map As
View/Edit
Execution Rules
New
Import...
Data Map
Select Costing
Edit Costing Index
Economics
Costing
Execute Parser
Units Converter
General
CO2 Solid
Environmental
Title Block Designer
UnitOp Designer
Flowsheet
P 1945.81 kPa
ID 11
T -30.10 C
P 1945.81 kPa
11
ID 9
T -46.00 C
P 125.00 kPa
9
3
10
ID 10
T -39.34 C
P 121.81 kPa
1
double-click
12
ID 12
T -30.18 C
P 1941.89 kPa
Lesson9_AY232_Trial1b*
Lesson9_AY232_Trial1b_1
CEINDEX.my
Steady State
132.0%



Click OK then run the simulation.

Cost Results



Answer to last question is found here.

STOP HERE

Finished.

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