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*

* 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. 2026.

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

page 91

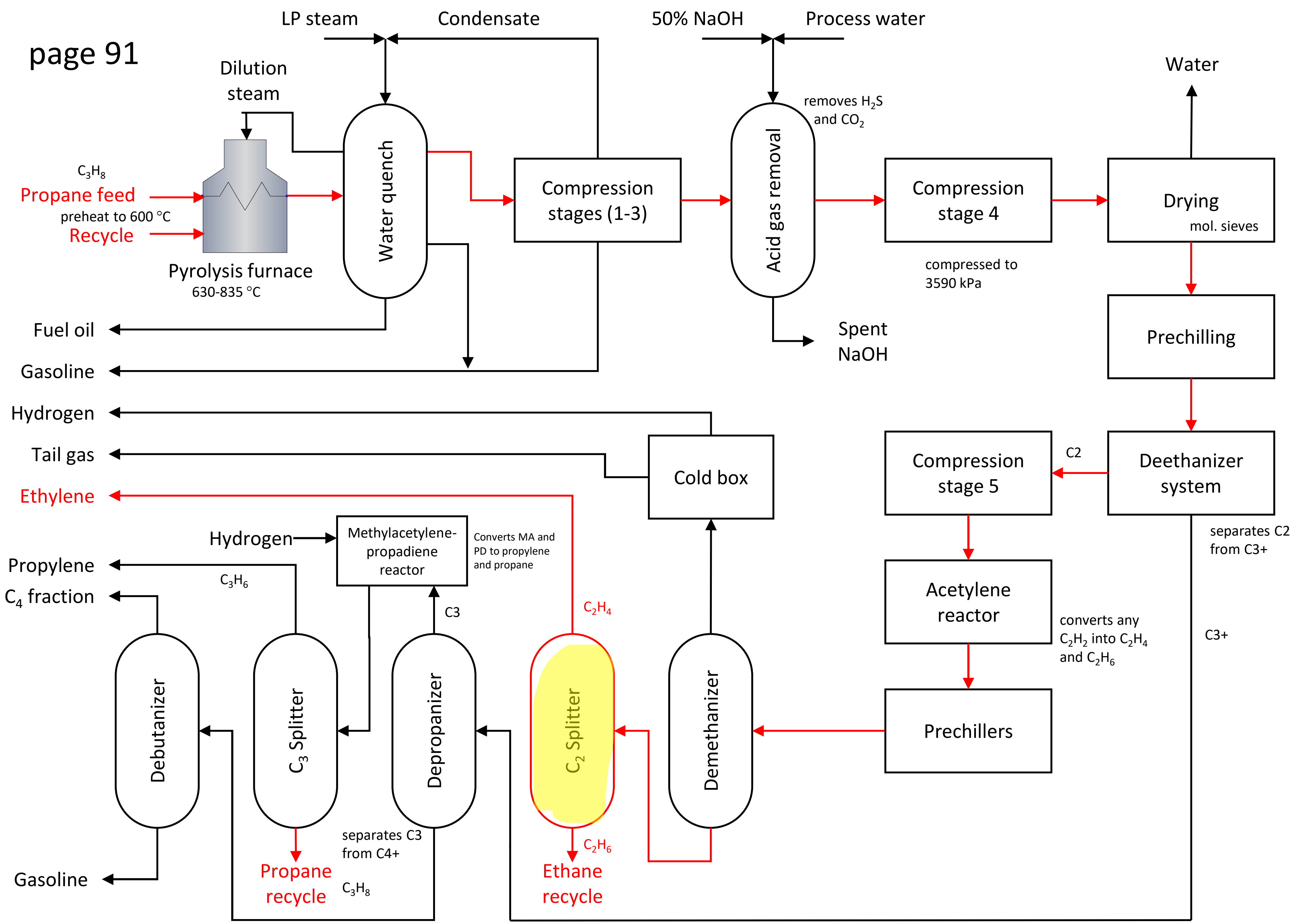


Figure 3-13. Product Separation Section

This is the heat exchanger we are designing

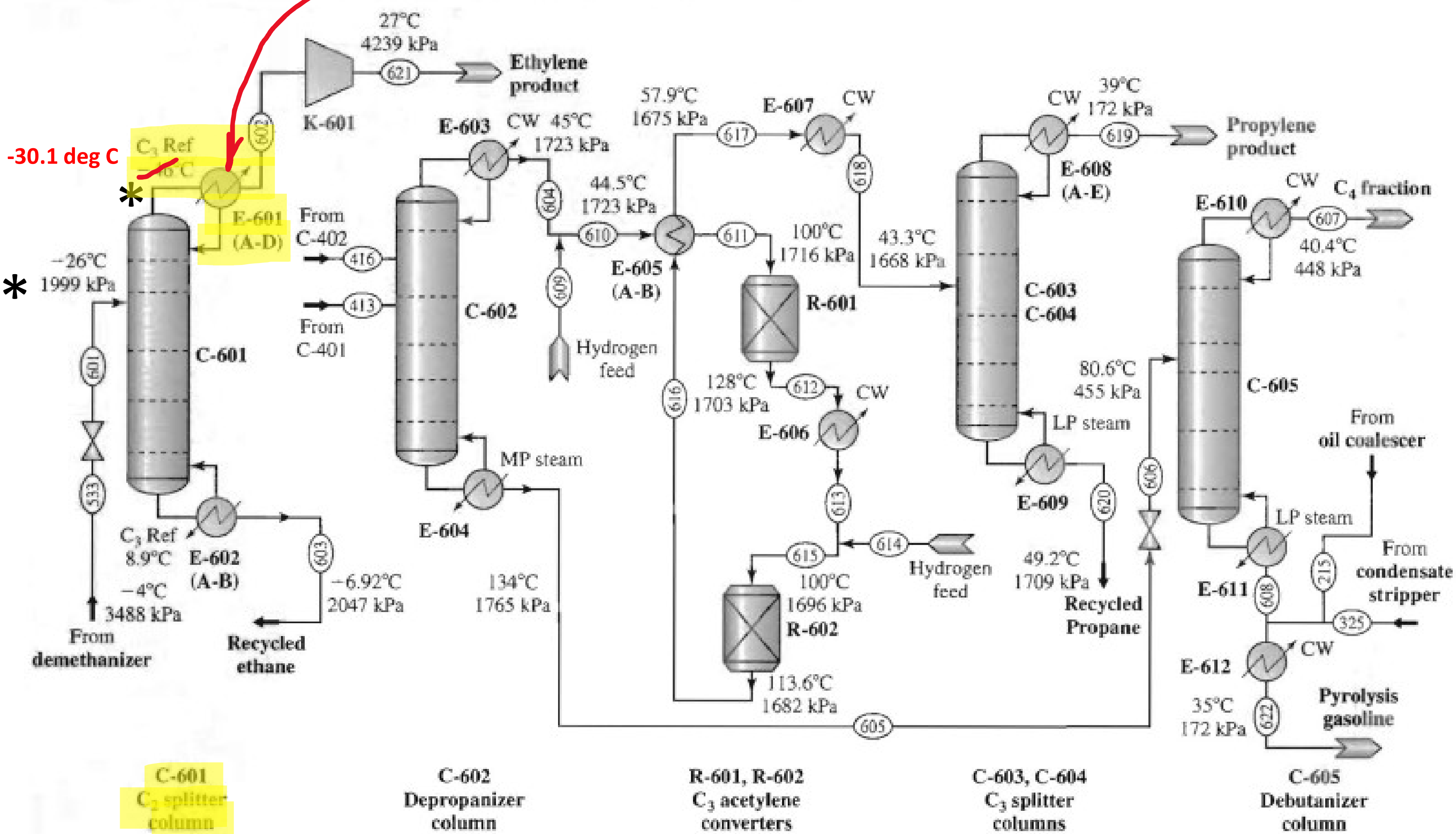
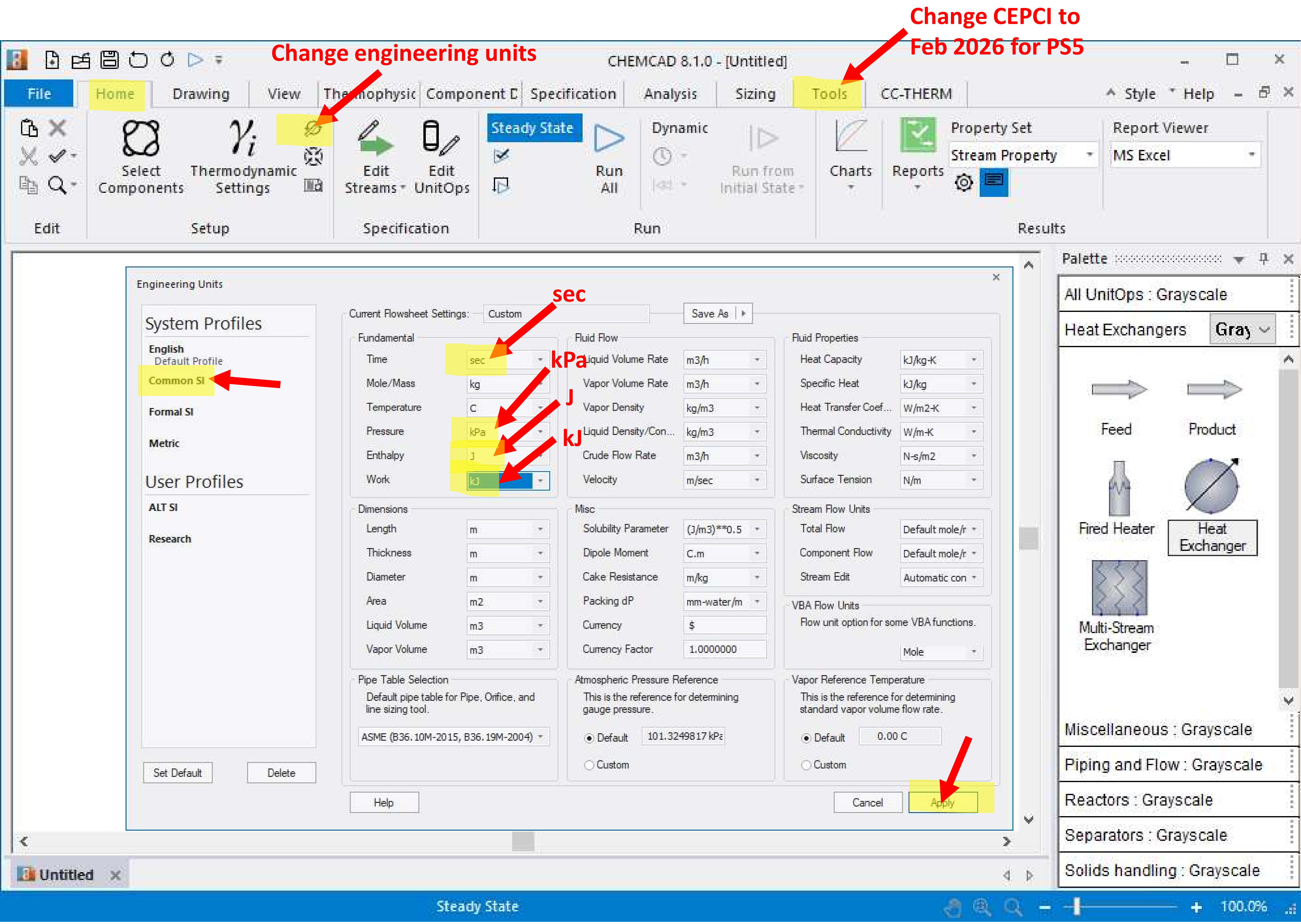
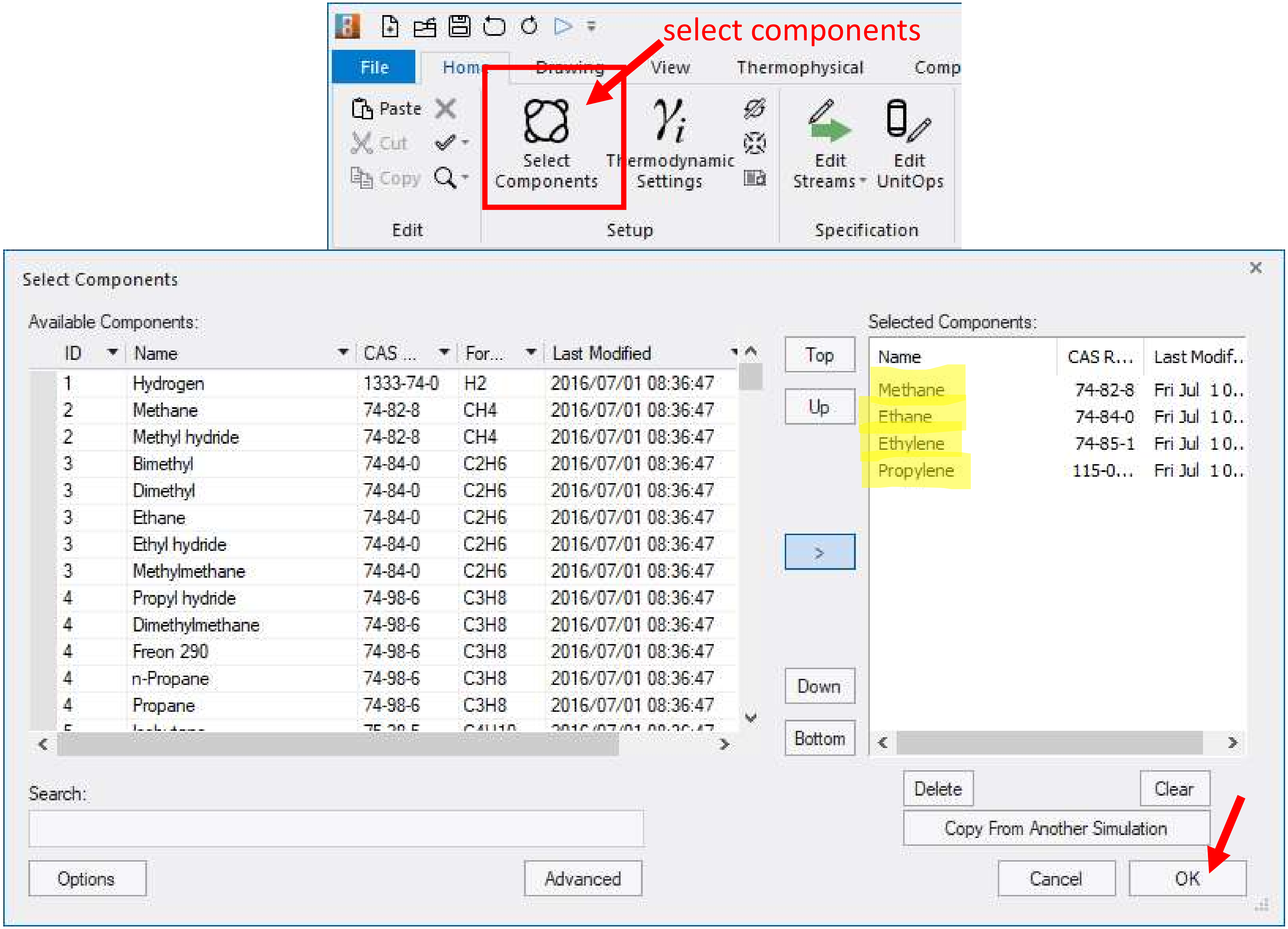


Figure 3-13. Product separation section.

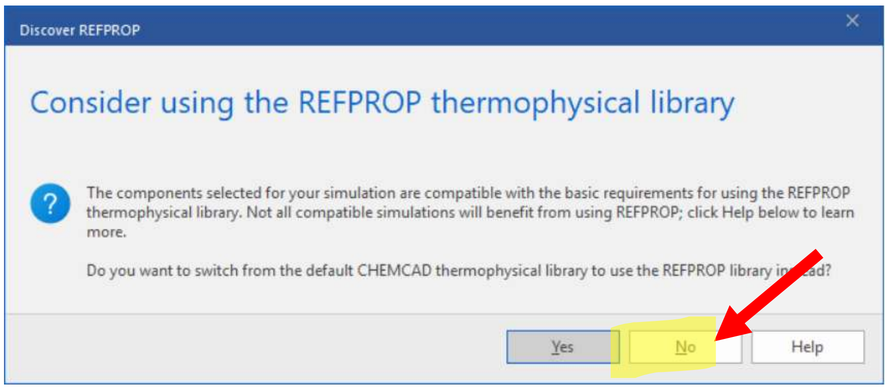


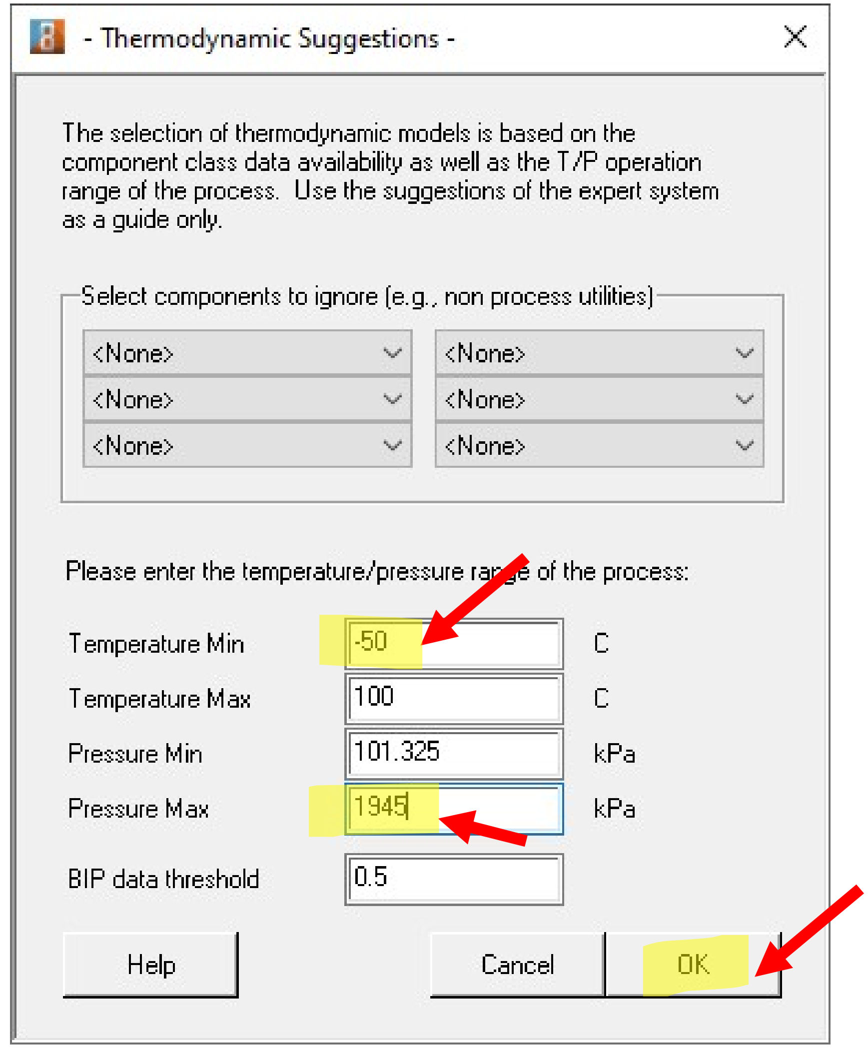
On my computer, I have Common SI set as the default.

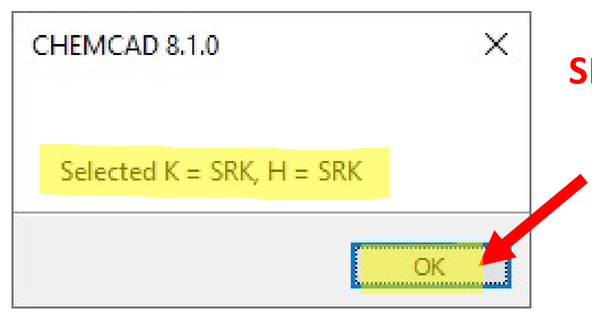


"Thermodynamic Suggestions" window launches automatically when you click OK.

Thermodynamic Suggestions

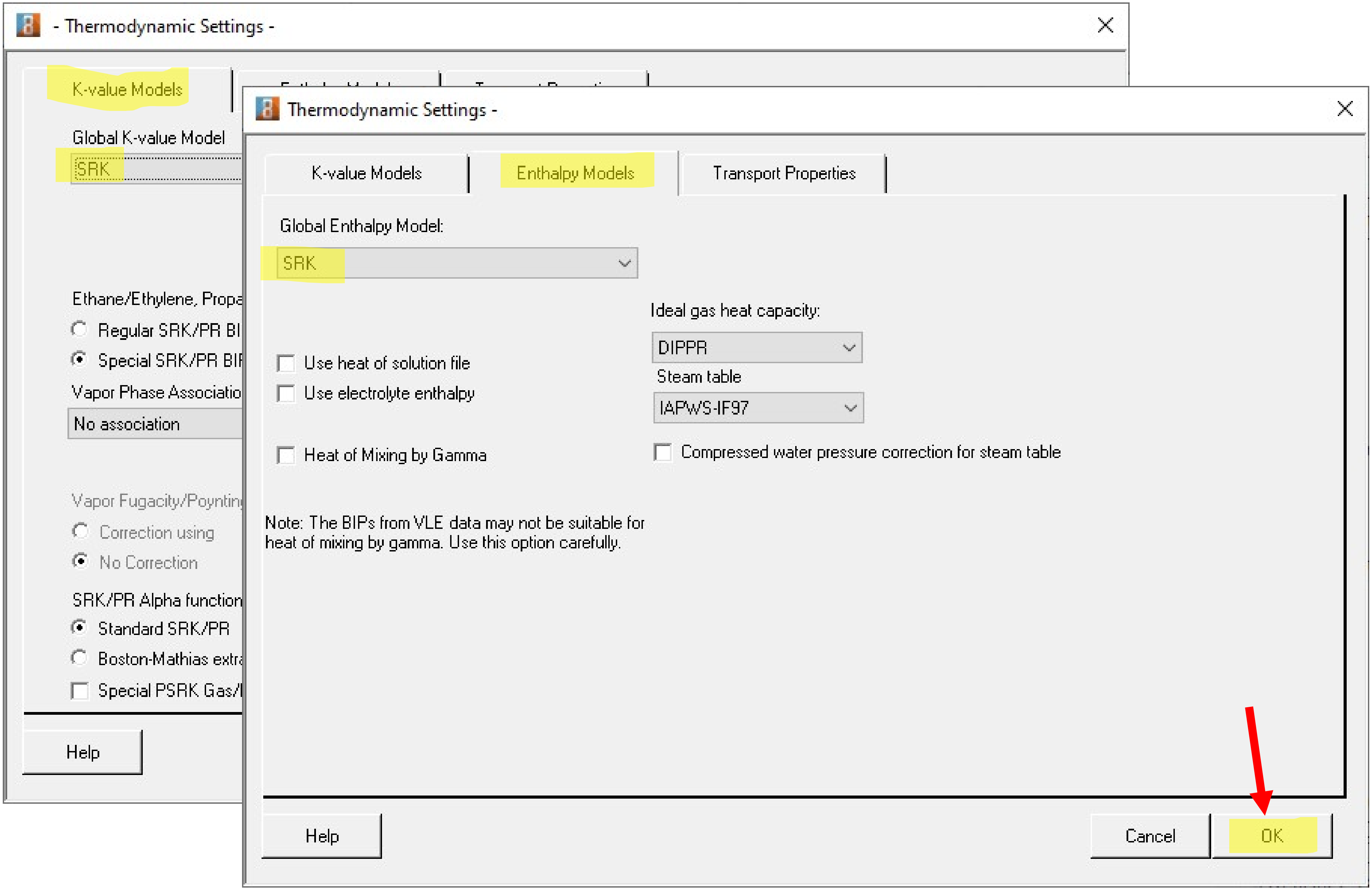


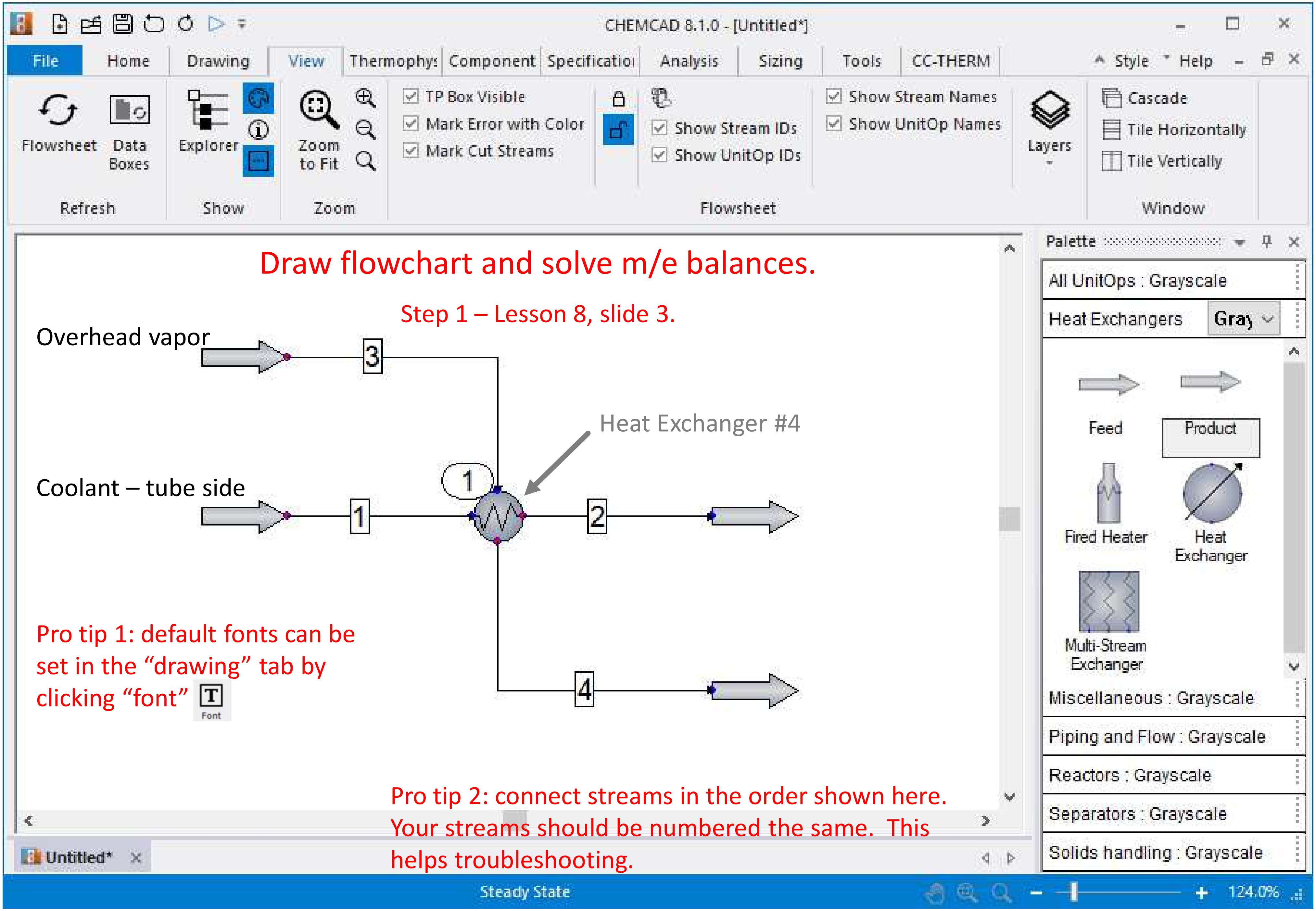




SRK is good!

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




CHEMCAD 8.1.0 - [Untitled*]
File
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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 3.
Overhead vapor
3
Heat Exchanger #4
Coolant – tube side
1
1
2
4
Pro tip 1: default fonts can be set in the “drawing” tab by clicking “font”
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
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.

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.

Edit Streams

Flash Cancel OK

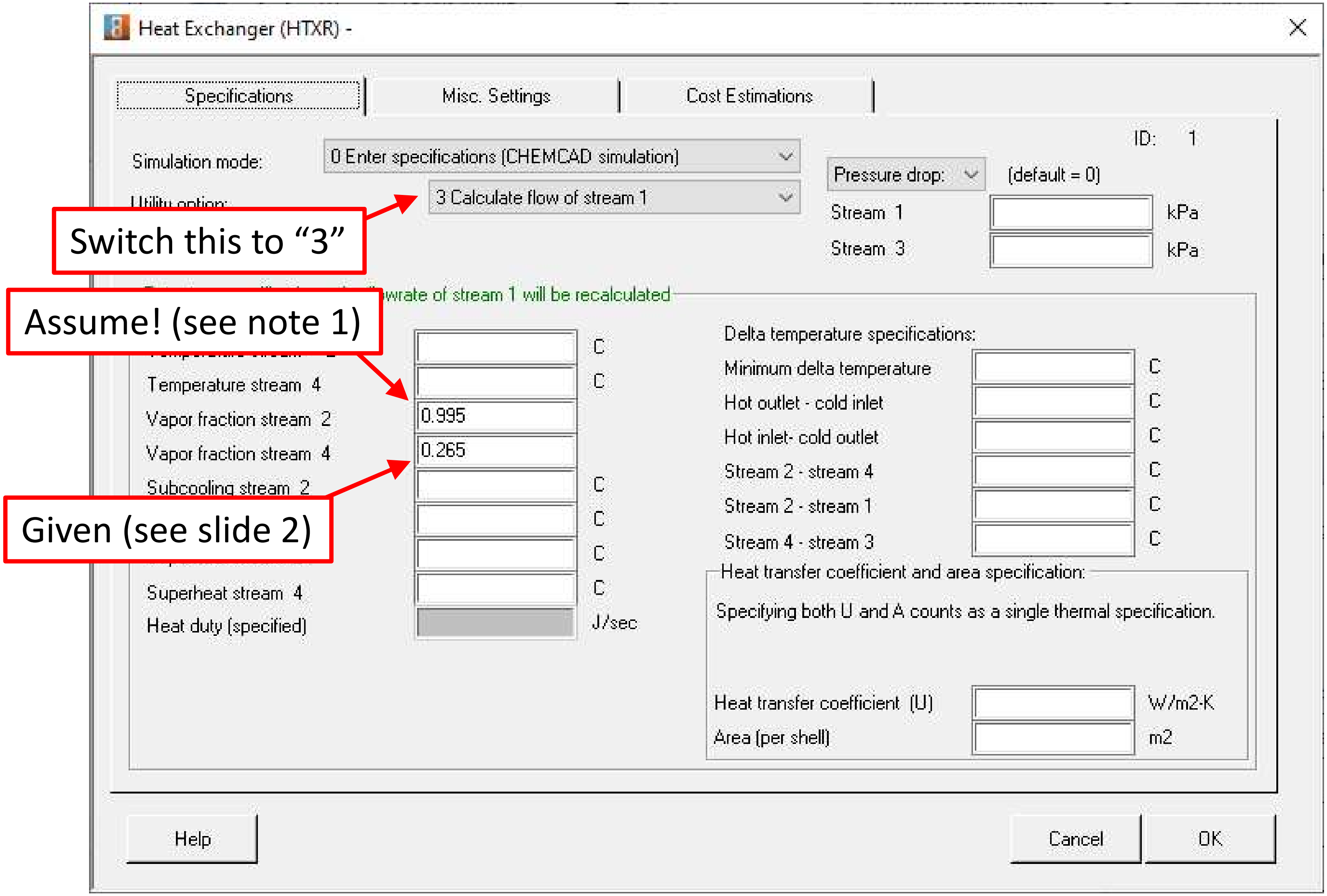
Stream No.	1	3
Stream Name		
Temp C	-46	-30.1
Pres kPa	125	1945.806
Vapor Fraction	0	1
Enthalpy J/sec	-77463.29	1.114613e+08
Total flow	1	64.5956
Total flow unit	kg/sec	kg/sec
Comp unit	kg/sec	kg/sec
Methane	0	0.003
Ethane	0	0.0626
Ethylene	0	64.53
Propylene	1	0

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.

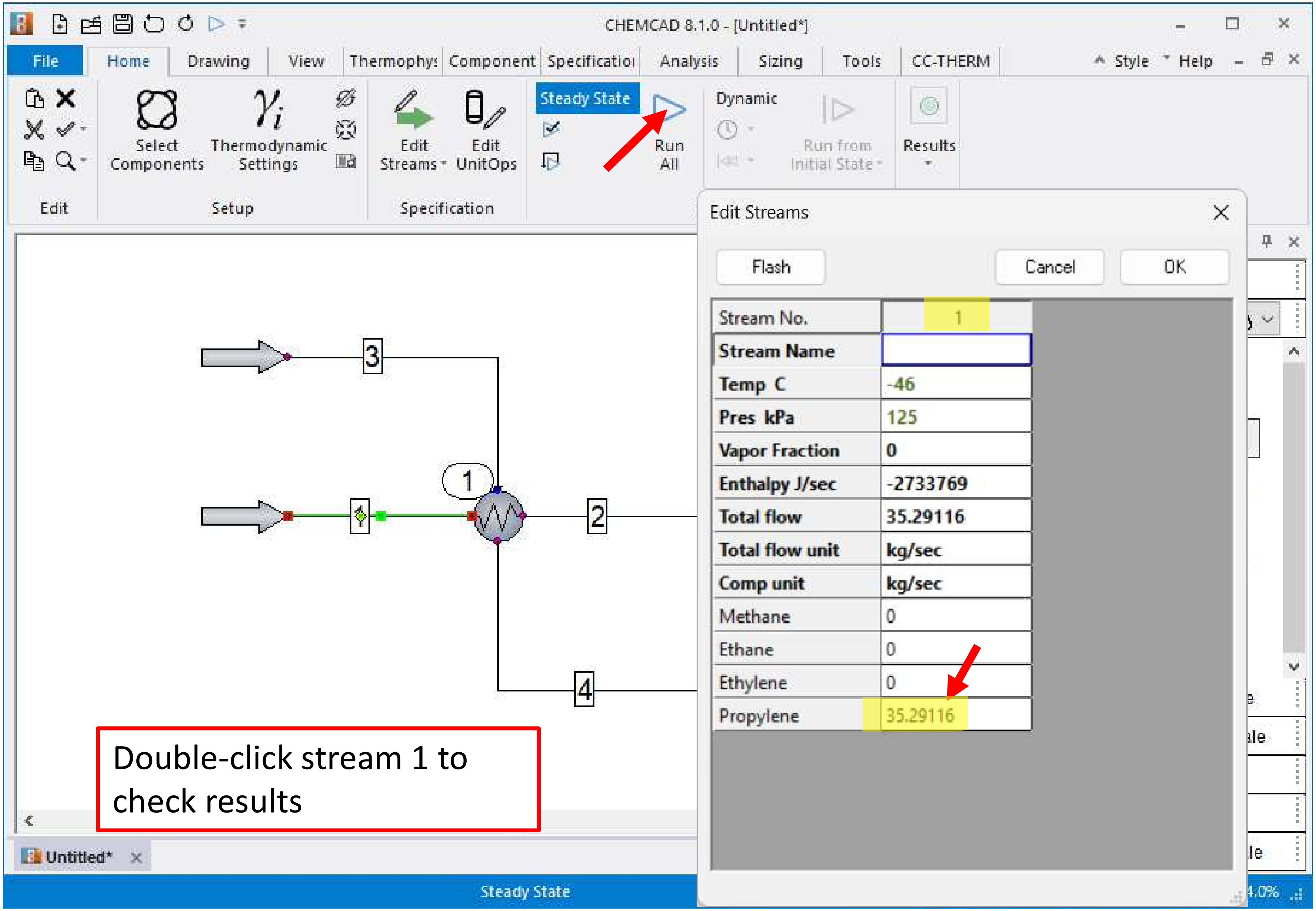
Complete Specs on Heat Exchanger and Coolant Flow Rate



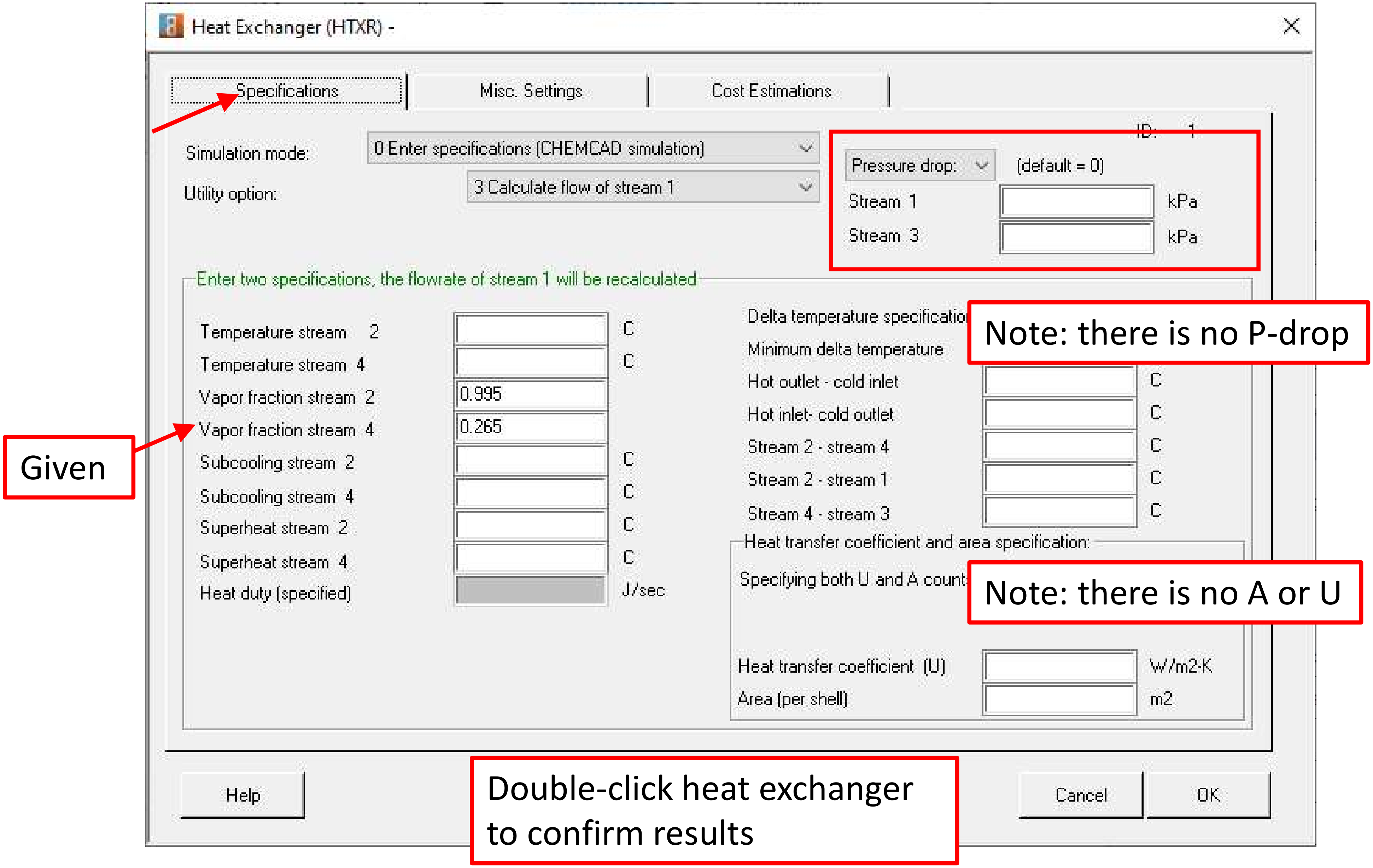
Note 1: The largest “thermal reservoir” in the coolant is the latent heat of the phase transition. Any further warming of the coolant beyond the phase change will involve relatively small enthalpy changes.

Click OK, then Run

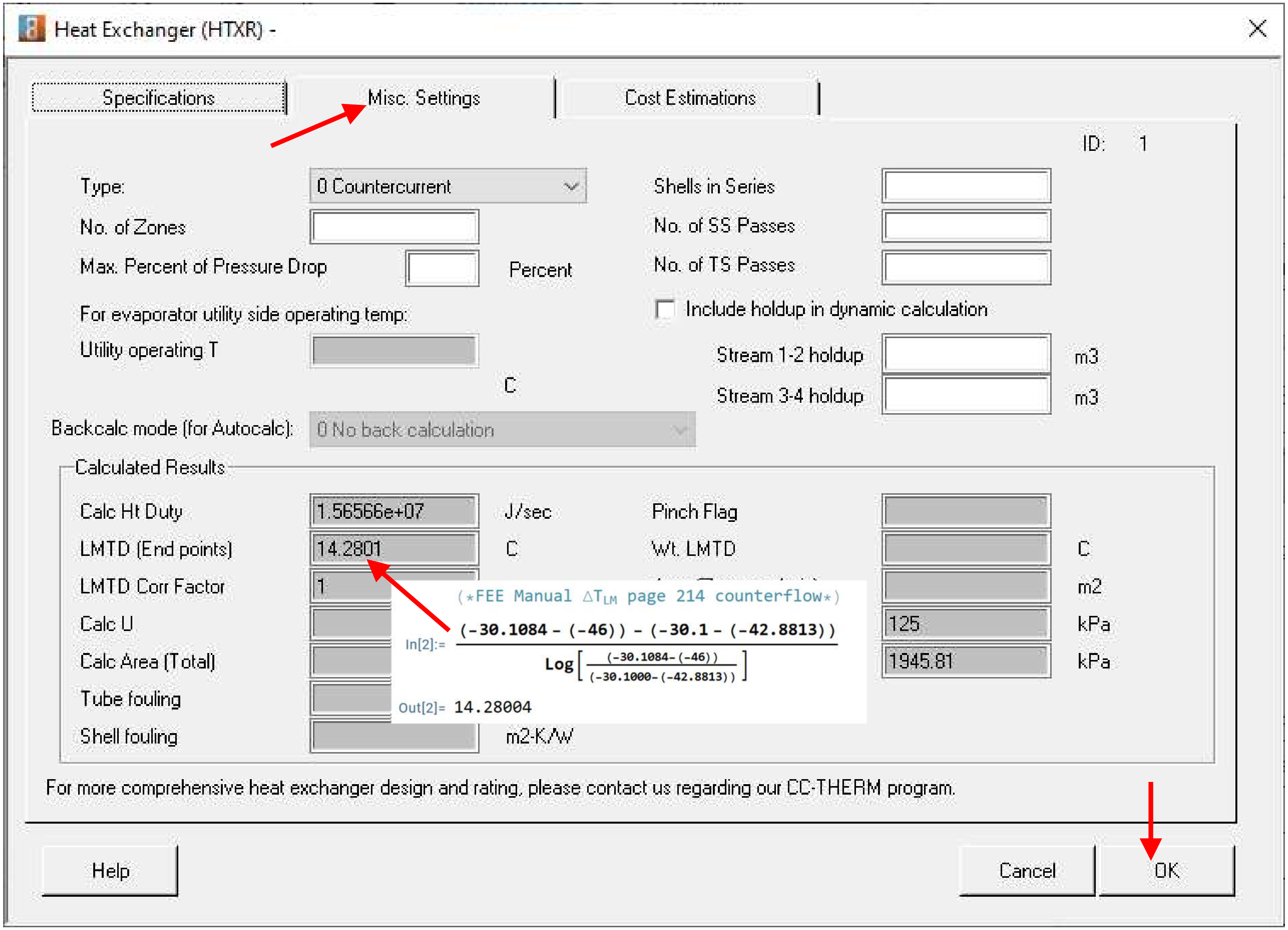
Run the Simulation and Confirm Results (1/3)



Confirm Results (2/3)



Confirm Results (3/3)



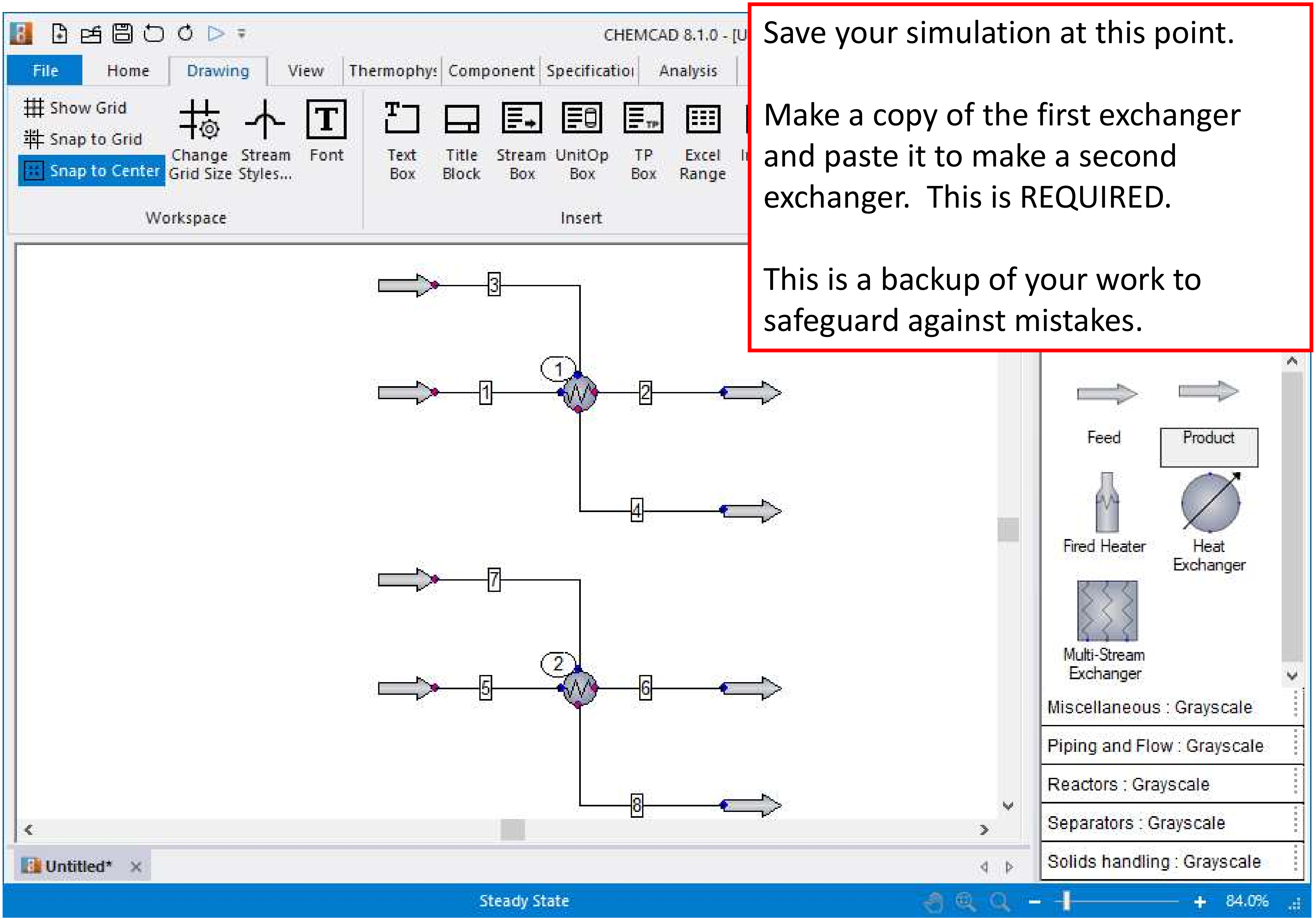
Numbers in gray fields were calculated by CHEMCAD

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.



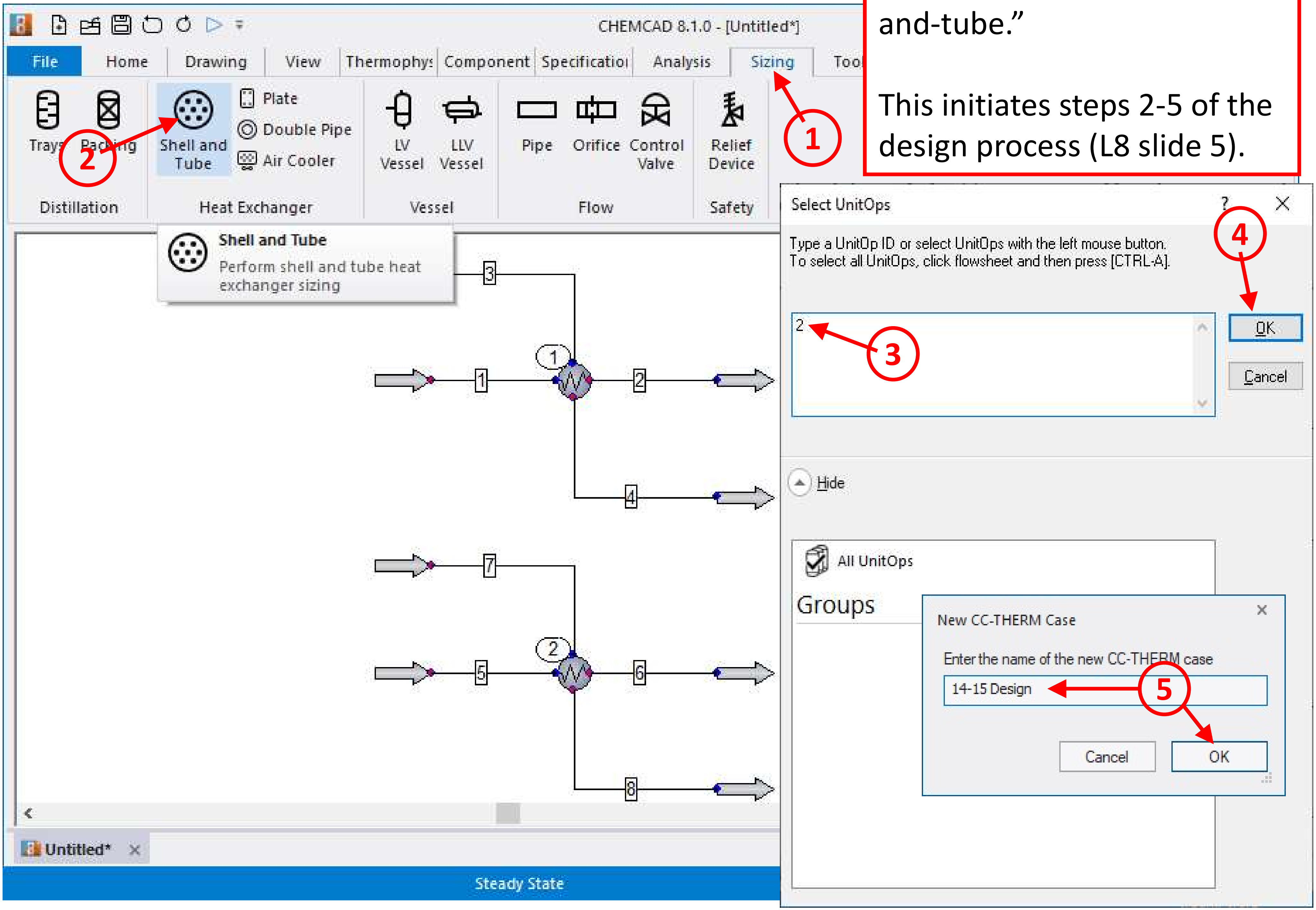
Save your simulation at this point.

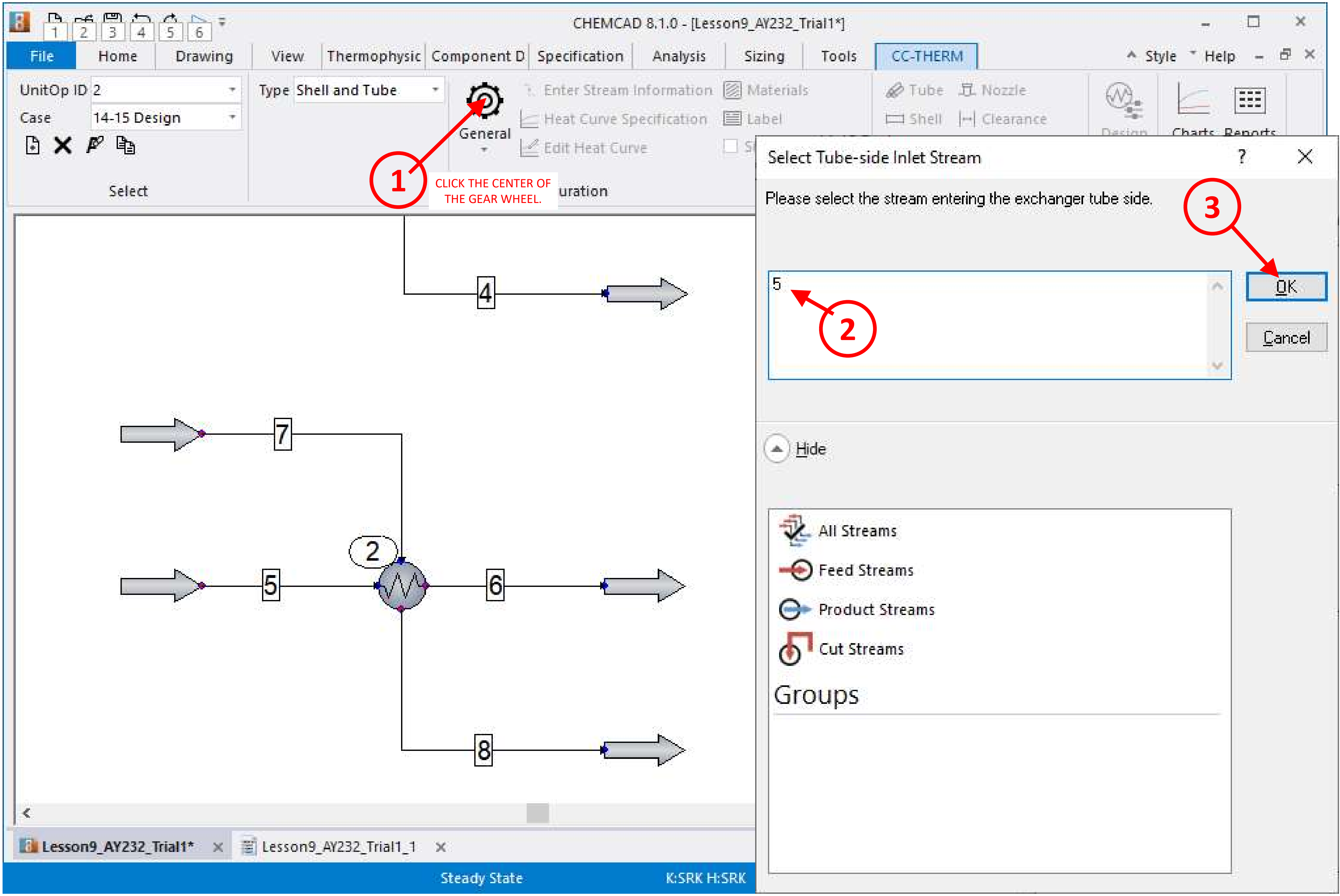
Make a copy of the first exchanger and paste it to make a second exchanger. This is REQUIRED.

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*]
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Help
UnitOp ID 2
Case 14-15 Design
Type Shell and Tube
General
Enter Stream Information
Heat Curve Specification
Edit Heat Curve
Materials
Label
Tube
Nozzle
Shell
Clearance
Design
Charts
Reports
Select
uration
1
CLICK THE CENTER OF THE GEAR WHEEL.
Select Tube-side Inlet Stream
Please select the stream entering the exchanger tube side.
5
2
3
OK
Cancel
Hide
All Streams
Feed Streams
Product Streams
Cut Streams
Groups
4
7
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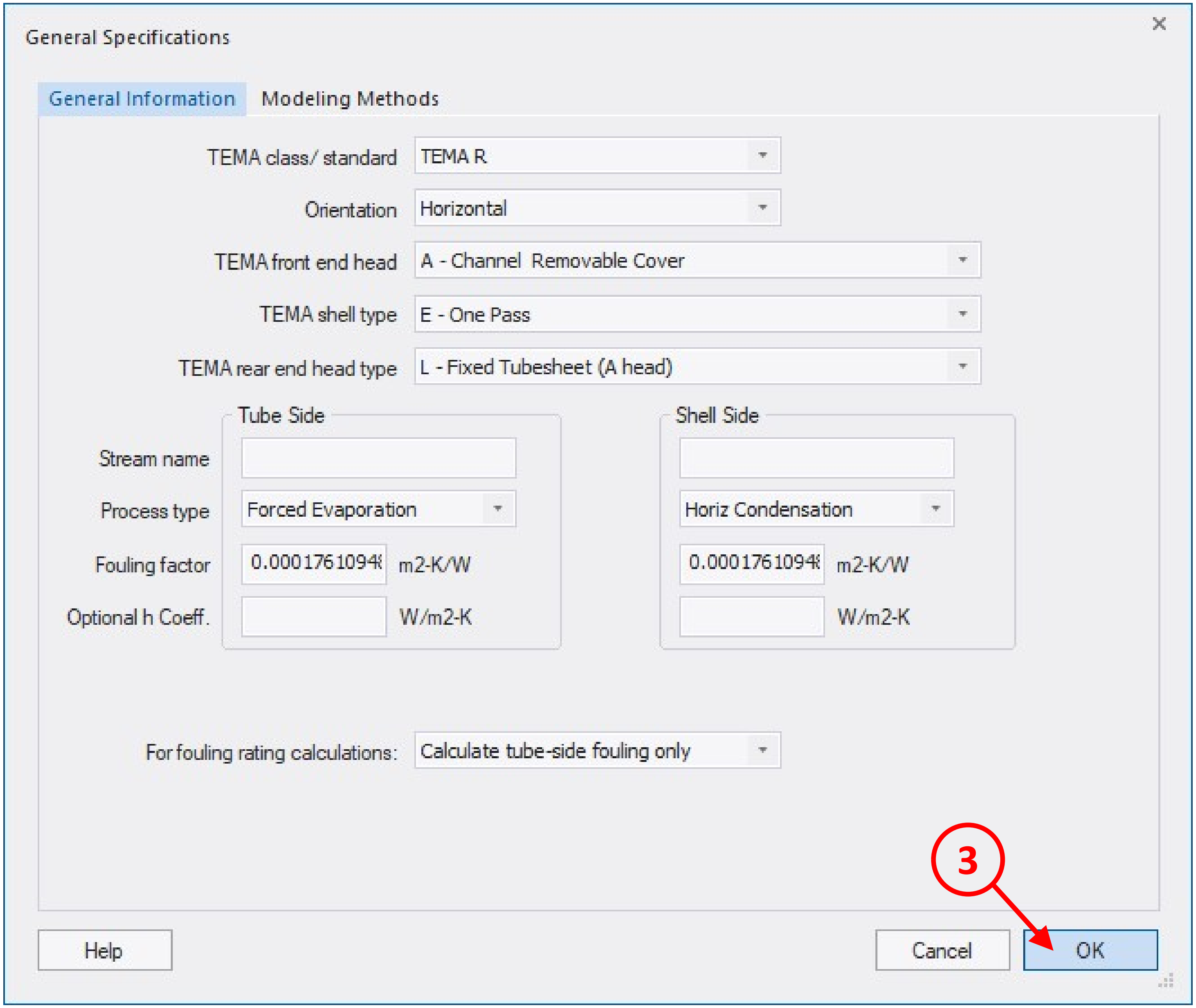
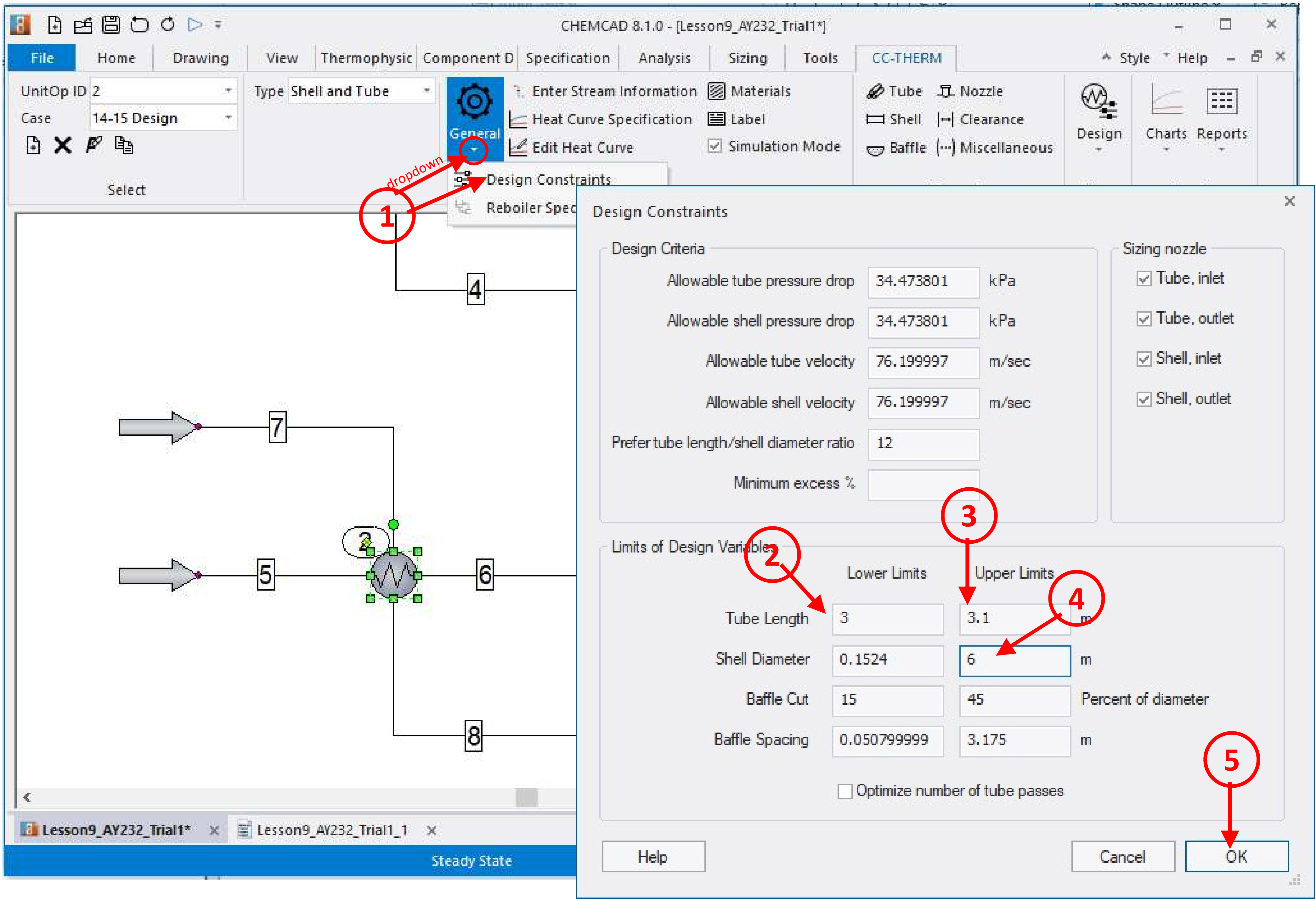
Lesson9_AY232_Trial1*
Lesson9_AY232_Trial1_1
Steady State
K:SRK H:SRK

TEMA Type AEL Exchanger. Take all defaults.



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

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


CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]
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Case 14-15 Design
Type Shell and Tube
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Heat Curve Specification
Edit Heat Curve
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Nozzle
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Miscellaneous
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Design Constraints
Reboiler Spec
4
7
5
2
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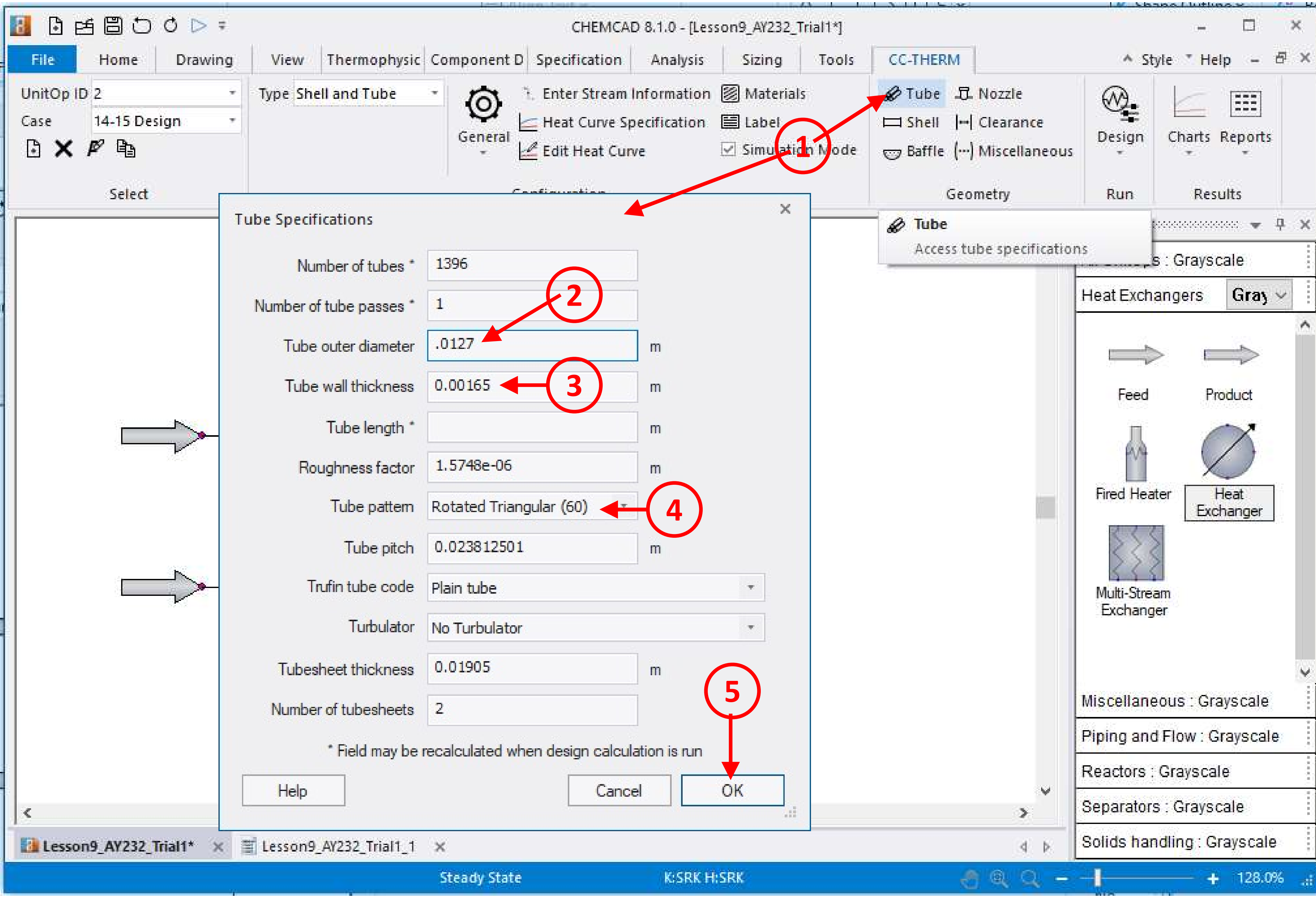
Lesson9_AY232_Trial1*
Lesson9_AY232_Trial1_1
Steady State
Design Constraints
Design Criteria
Allowable tube pressure drop 34.473801 kPa
Allowable shell pressure drop 34.473801 kPa
Allowable tube velocity 76.199997 m/sec
Allowable shell velocity 76.199997 m/sec
Prefer tube length/shell diameter ratio 12
Minimum excess %
Sizing nozzle
Tube, inlet
Tube, outlet
Shell, inlet
Shell, outlet
Limits of Design Variables
2
3
4
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
5
Help
Cancel
OK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Case 14-15 Design
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Heat Curve Specification
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Simulation Mode
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Nozzle
Shell
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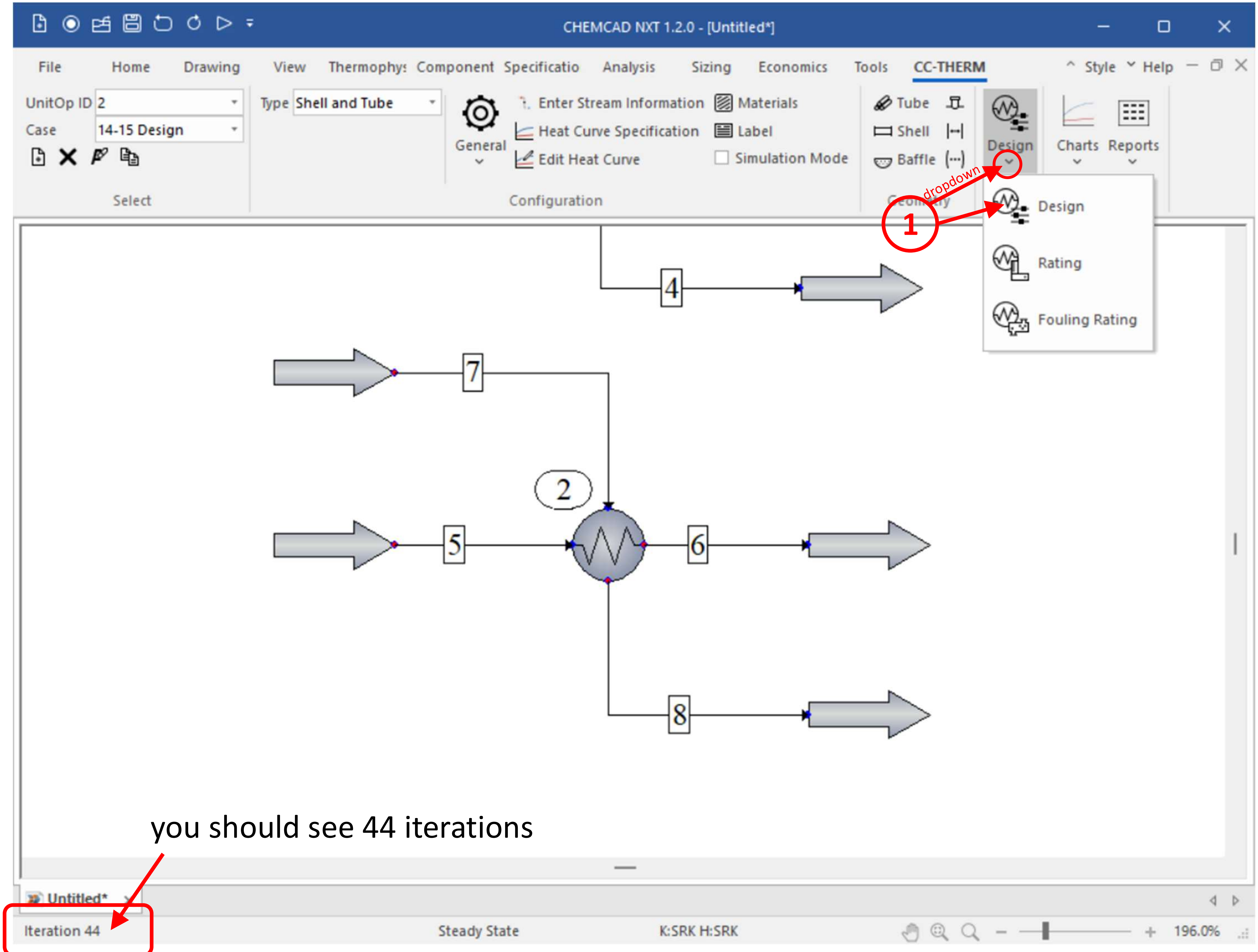
Baffle
Miscellaneous
Geometry
Design
Run
Charts
Reports
Results
Select
Tube
Access tube specifications
Tube Specifications
Number of tubes * 1396
Number of tube passes * 1
Tube outer diameter .0127 m
Tube wall thickness 0.00165 m
Tube length * m
Roughness factor 1.5748e-06 m
Tube pattern Rotated Triangular (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
1
2
3
4
5
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%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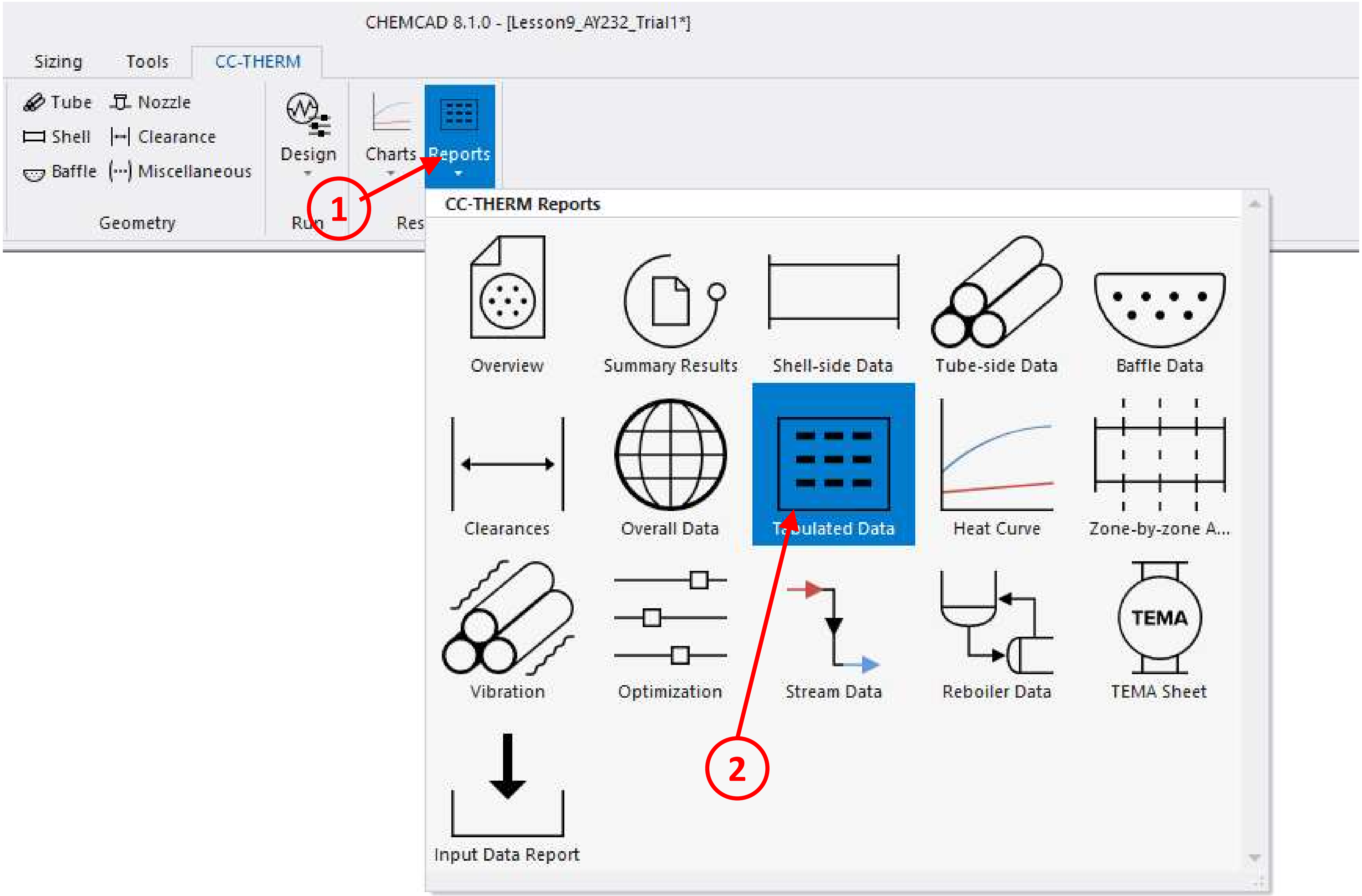
UnitOp ID 2
Case 14-15 Design
Type Shell and Tube
General
Enter Stream Information
Heat Curve Specification
Edit Heat Curve
Materials
Label
Simulation Mode
Tube
Shell
Baffle
Design
Charts
Reports
Select
Configuration
dropdown
1
Design
Rating
Fouling Rating
4
7
2
5
6
8
you should see 44 iterations
Untitled*
Iteration 44
Steady State
K:SRK H:SRK
196.0%


CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]
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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
2
Input Data Report

Design Results – CHEMCAD NXT 1.2.0

```
                         TABULATED ANALYSIS
                         ------------------
Overall Data:
 Area Total         m2       2348.77  % Excess                     6.13
 Area Required      m2       2157.83  U Calc.     W/m2-K         566.94
 Area Effective     m2       2290.05  U Service   W/m2-K         534.21
 Area Per Shell     m2       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/ft2-hr   0.00
 Imping. Plate     Impingement Plate    Sealing Strip                 5
```

```
Tubes:
 Number                        19314    Tube Type                  Bar
 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         0.00068
 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         0.00047
 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?

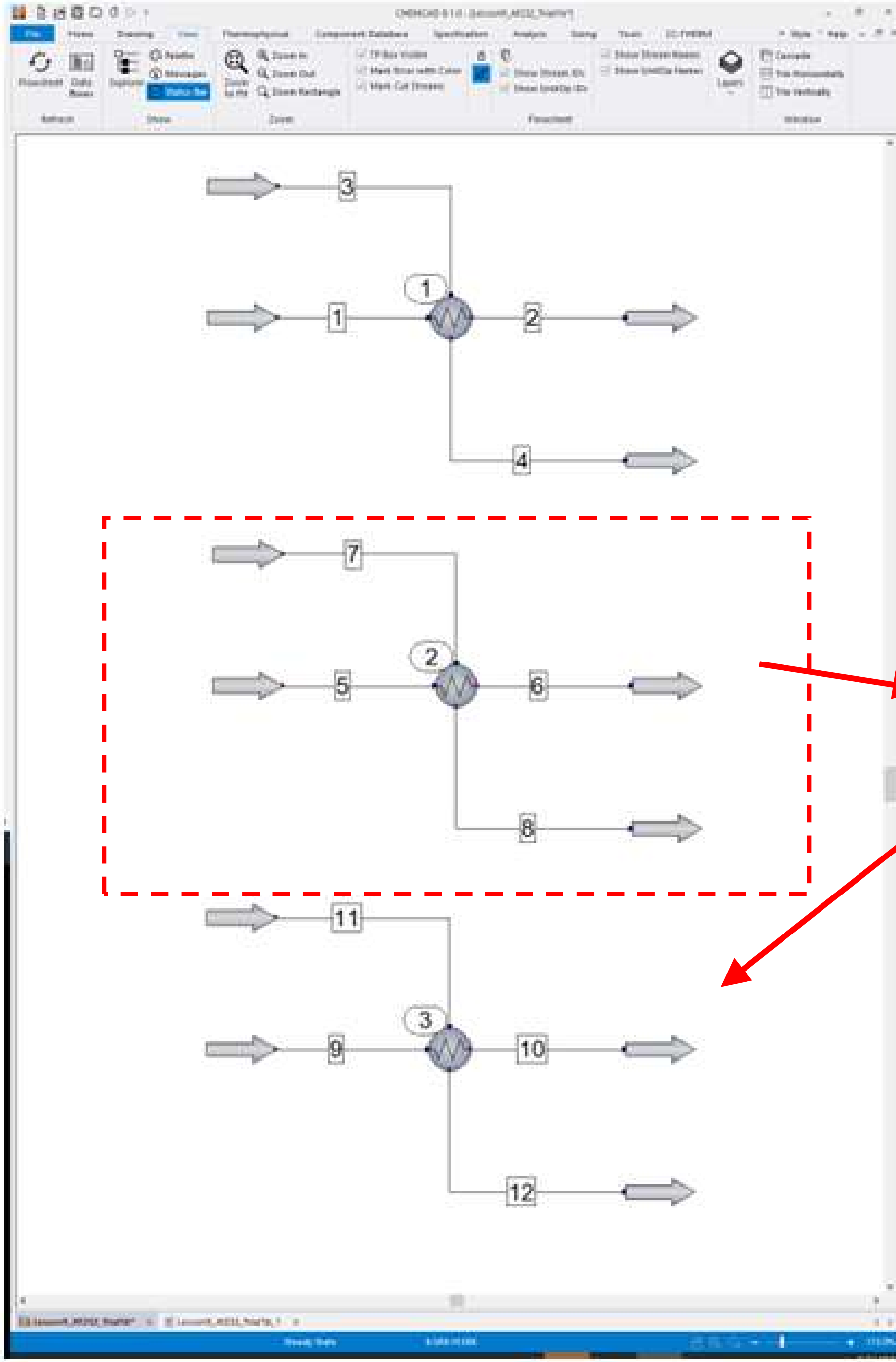
STOP HERE

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

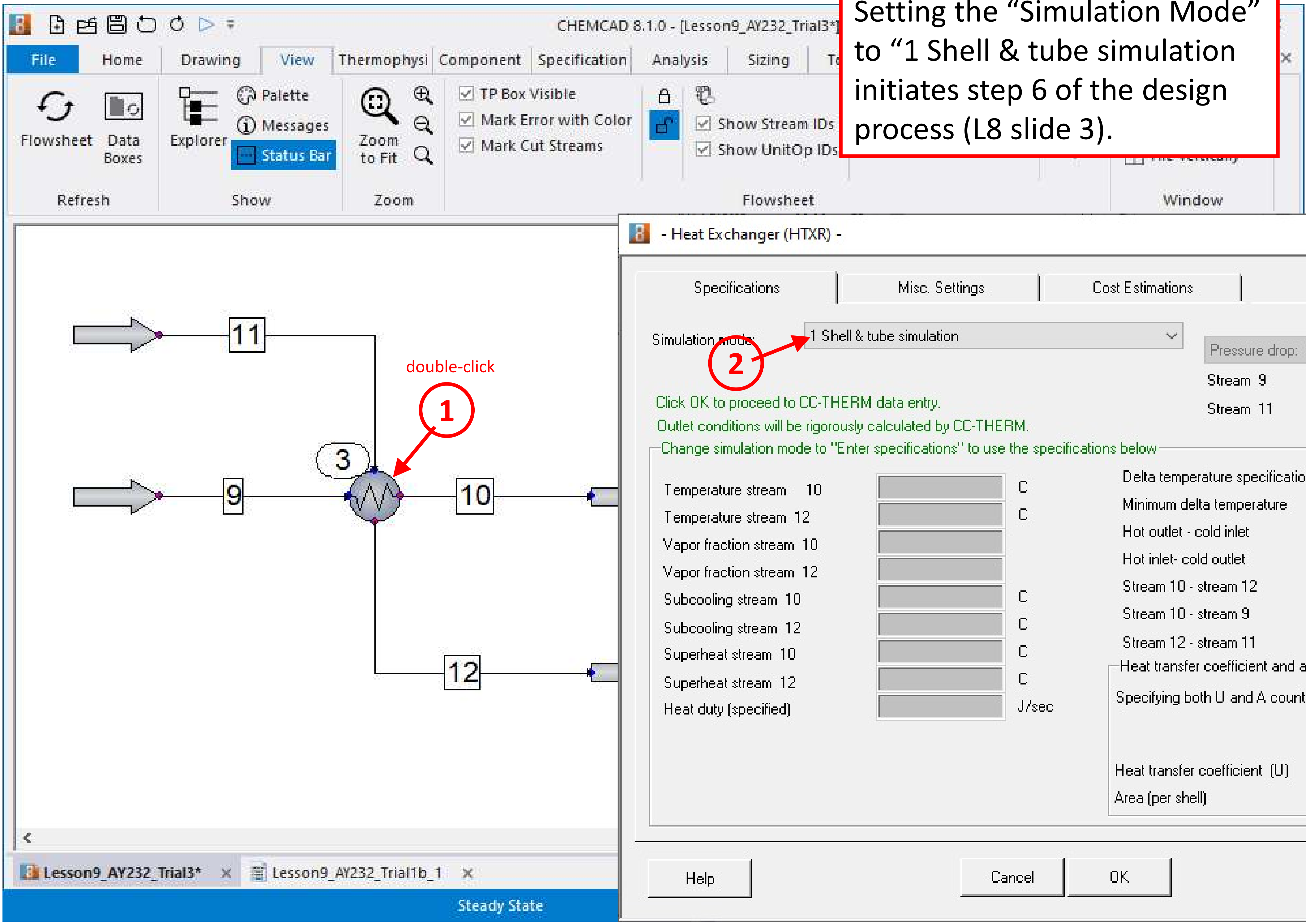


Copying and pasting is an important step.

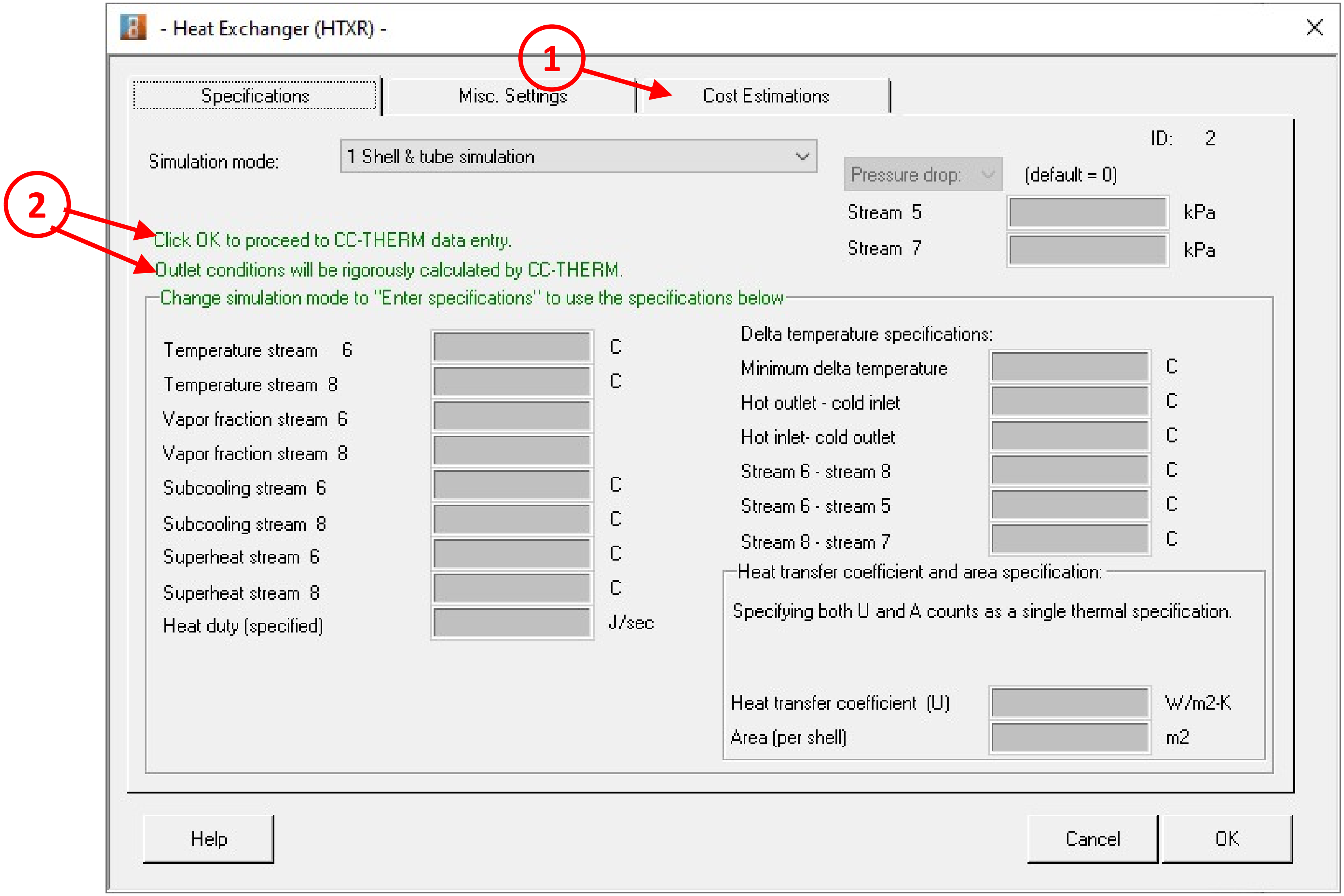
It preserves the design work down in exchanger 2 as a backup.

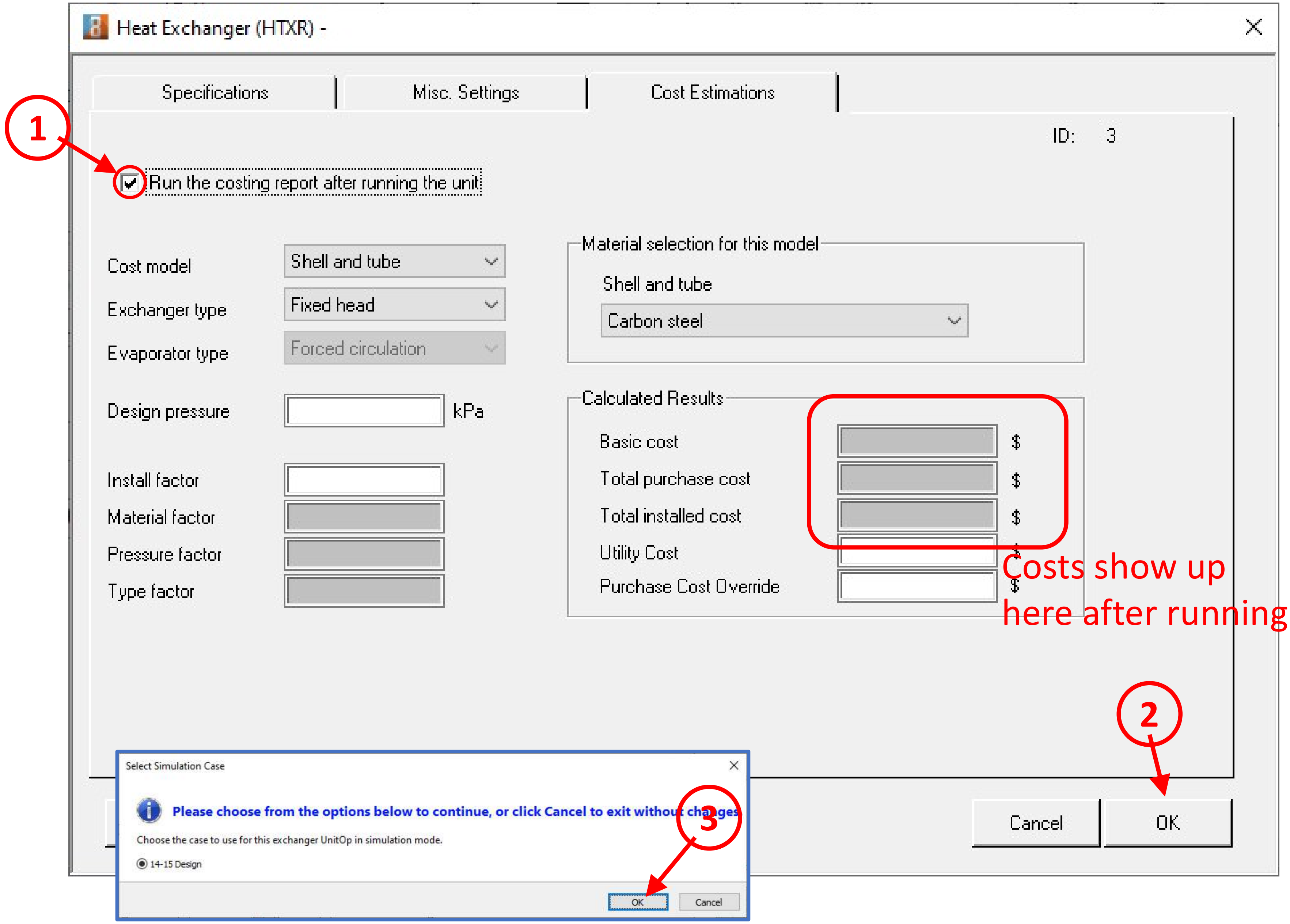
copy this and paste here

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



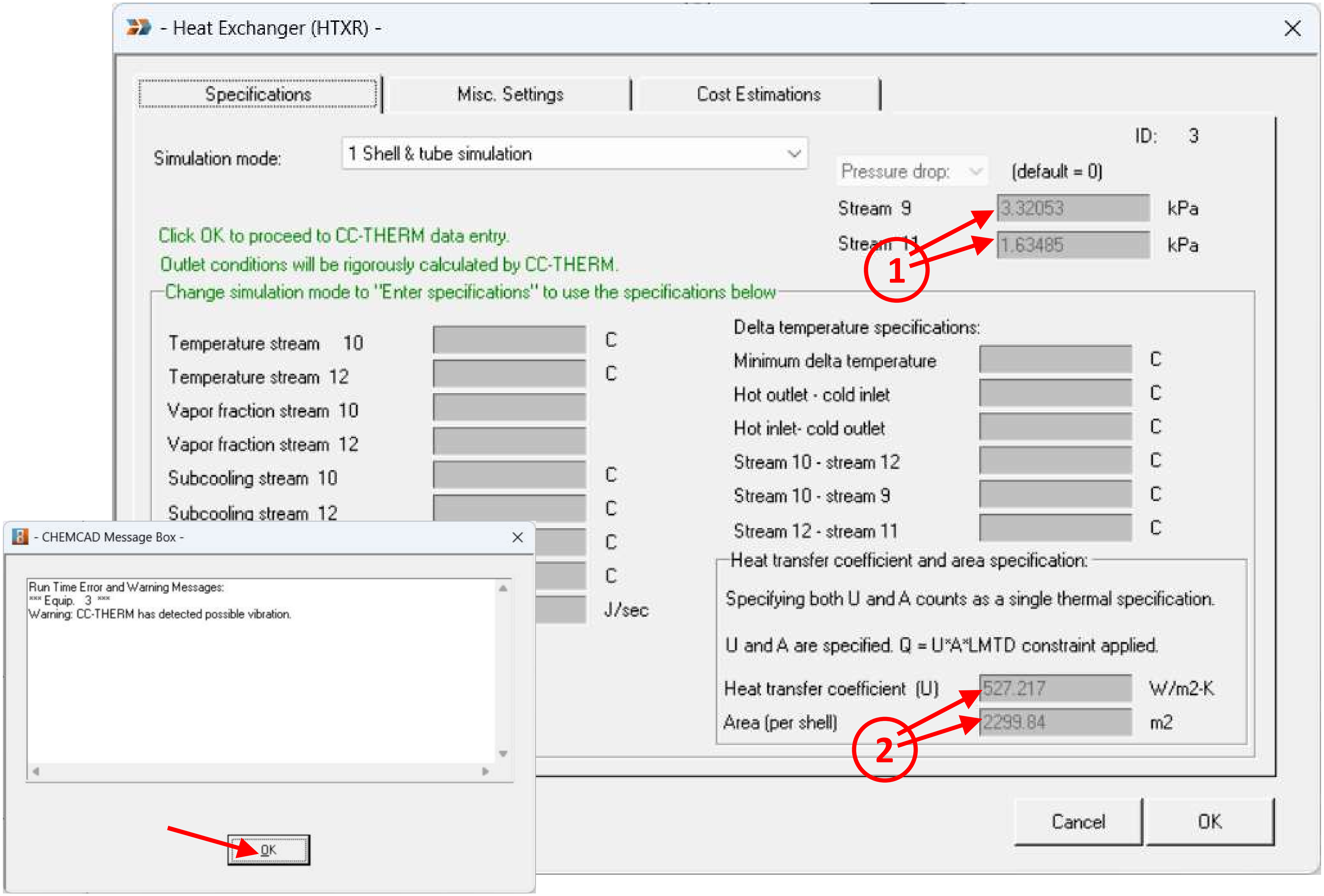
Heat Exchanger Before Running



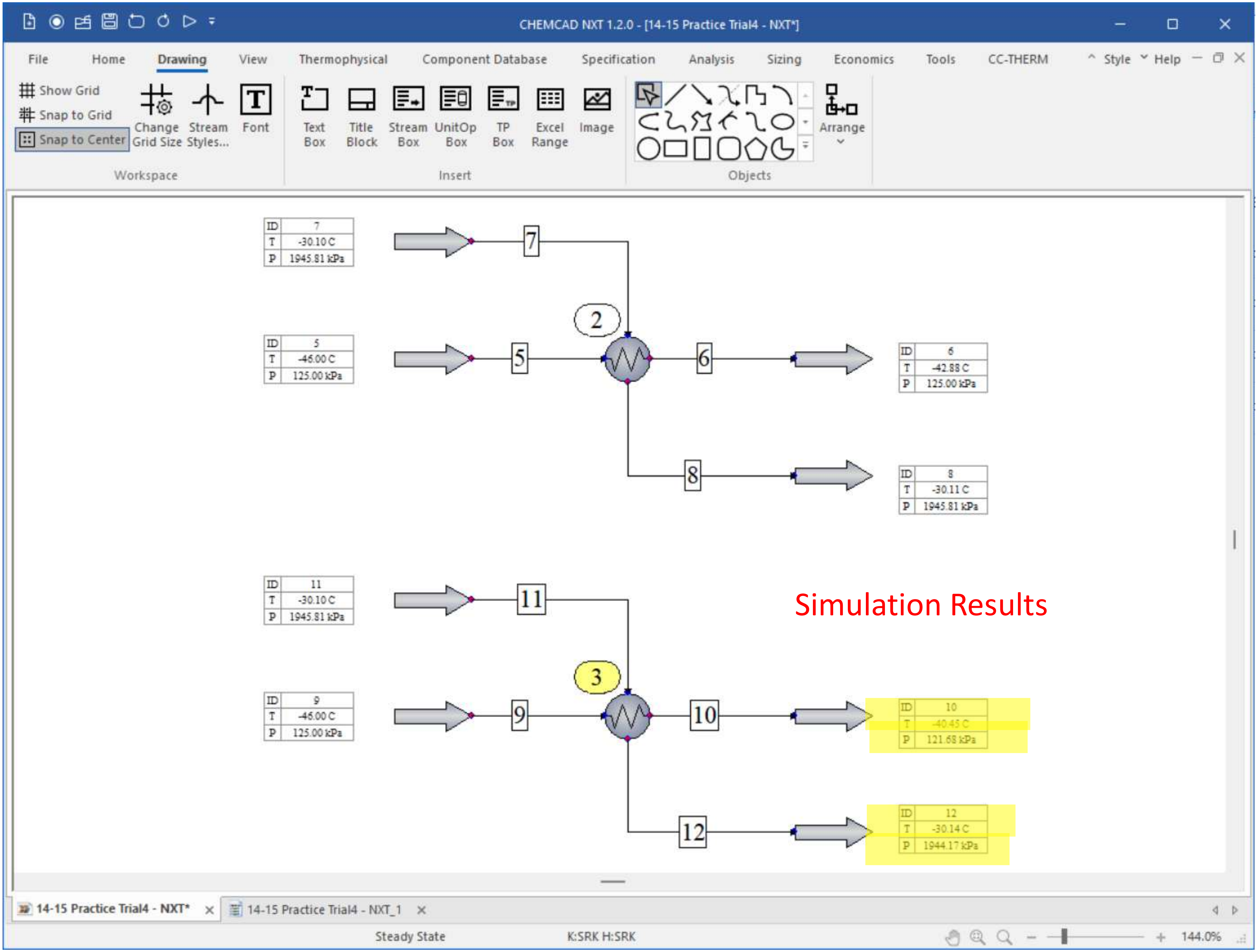


Click OK then run the simulation.

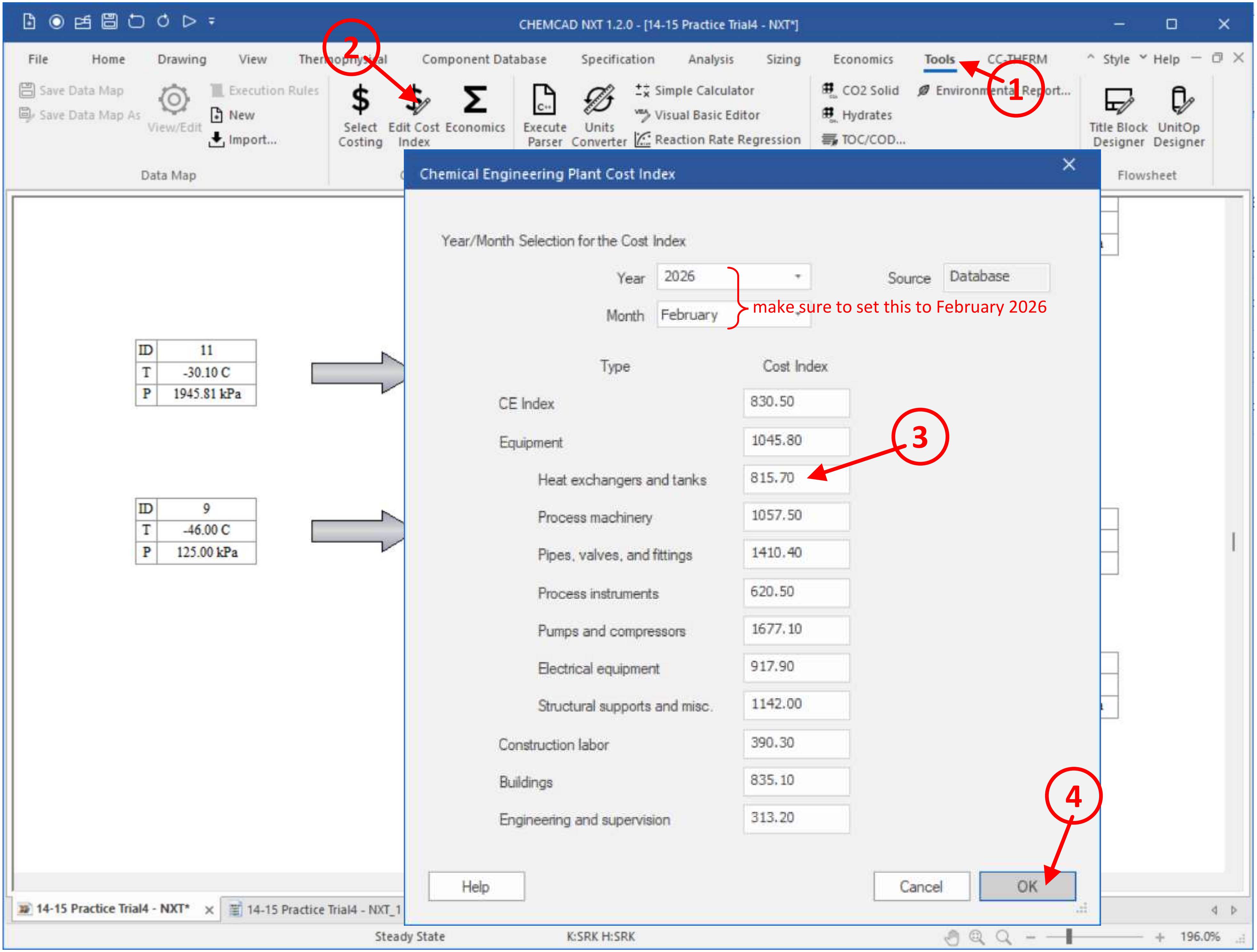
Heat Exchanger After Running

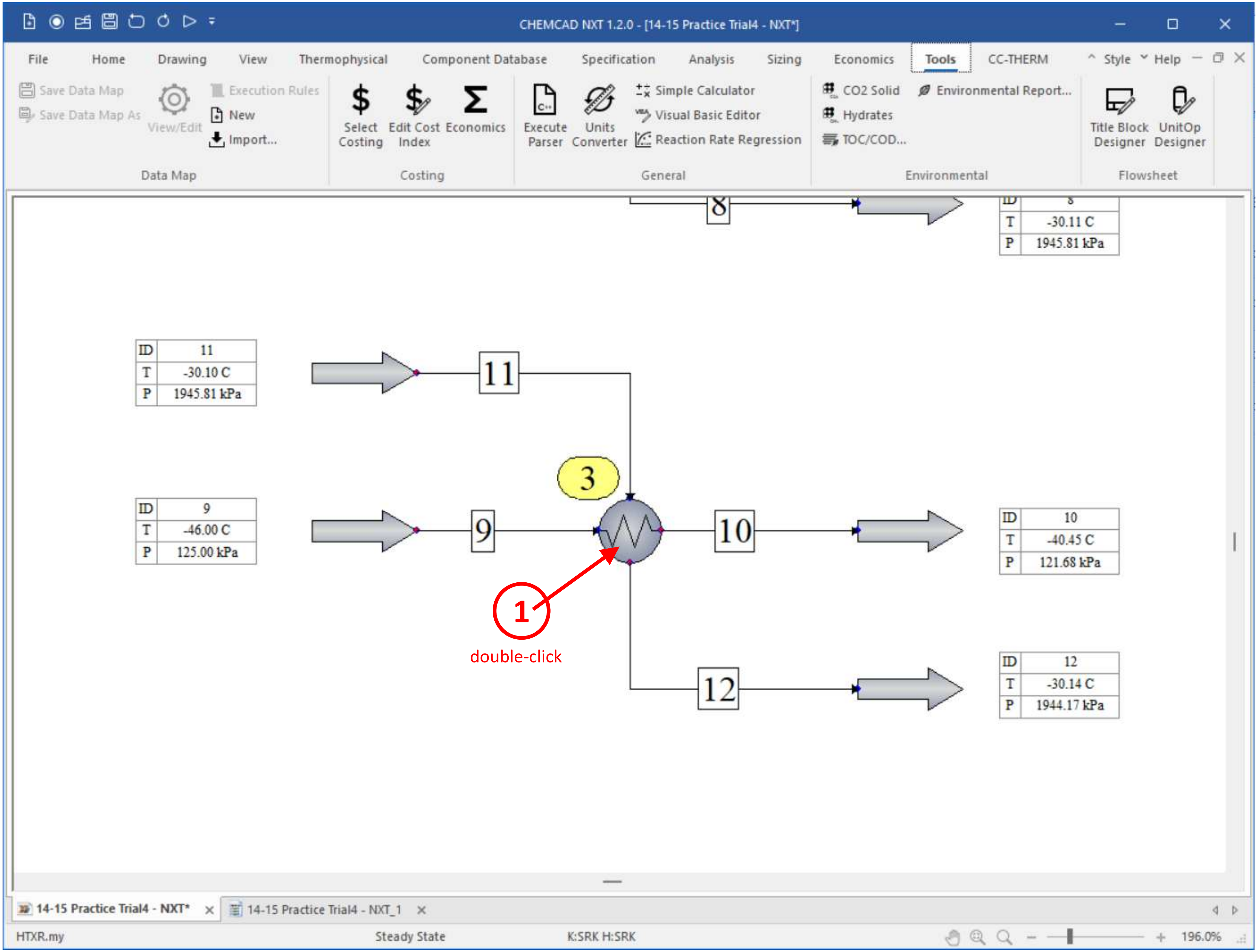


Click “Run All” in the Home tab



Simulation Results


CHEMCAD NXT 1.2.0 - [14-15 Practice Trial4 - NXT*]
File Home Drawing View Thermophysical Component Database Specification Analysis Sizing Economics Tools CC-THERM
Select Costing
Edit Cost Index
Economics
Execute Parser
Units Converter
Simple Calculator
Visual Basic Editor
Reaction Rate Regression
CO2 Solid
Hydrates
TOC/COD...
Environmental Report...
Title Block Designer
UnitOp Designer
1
2
3
4
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
Help
Cancel
OK
Steady State
K:SRK H:SRK


CHEMCAD NXT 1.2.0 - [14-15 Practice Trial4 - NXT*]
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Thermophysical
Component Database
Specification
Analysis
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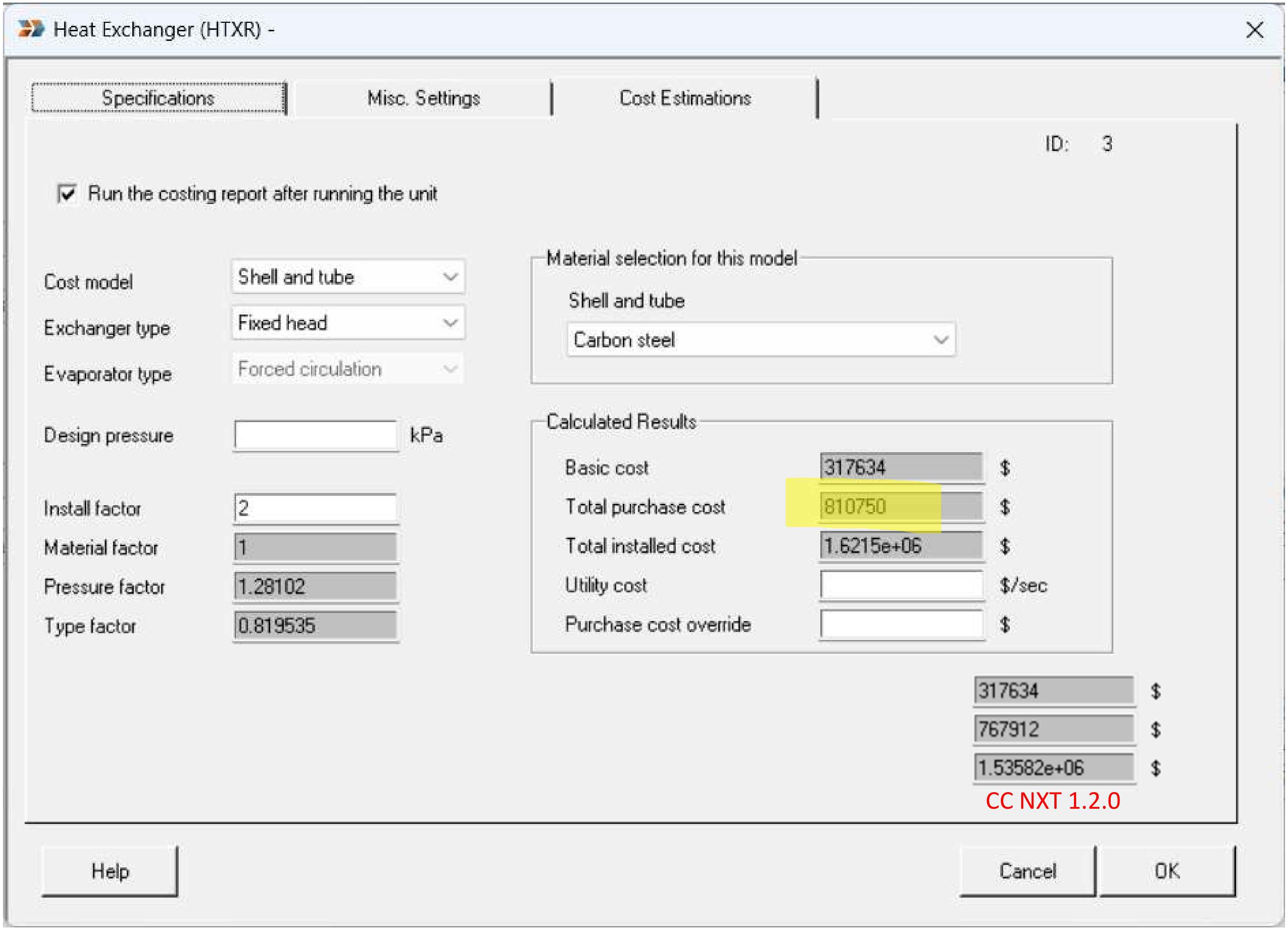
Economics
Tools
CC-THERM
Style
Help
Save Data Map
Save Data Map As
View/Edit
Execution Rules
New
Import...
Data Map
Select Costing
Edit Cost Index
Economics
Costing
Execute Parser
Units Converter
Simple Calculator
Visual Basic Editor
Reaction Rate Regression
General
CO2 Solid
Hydrates
TOC/COD...
Environmental Report...
Environmental
Title Block Designer
UnitOp Designer
Flowsheet
ID 11
T -30.10 C
P 1945.81 kPa
ID 9
T -46.00 C
P 125.00 kPa
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
8
11
9
3
10
12
1
double-click
14-15 Practice Trial4 - NXT*
14-15 Practice Trial4 - NXT_1
HTXR.my
Steady State
K:SRK H:SRK
196.0%

Cost Results



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