

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

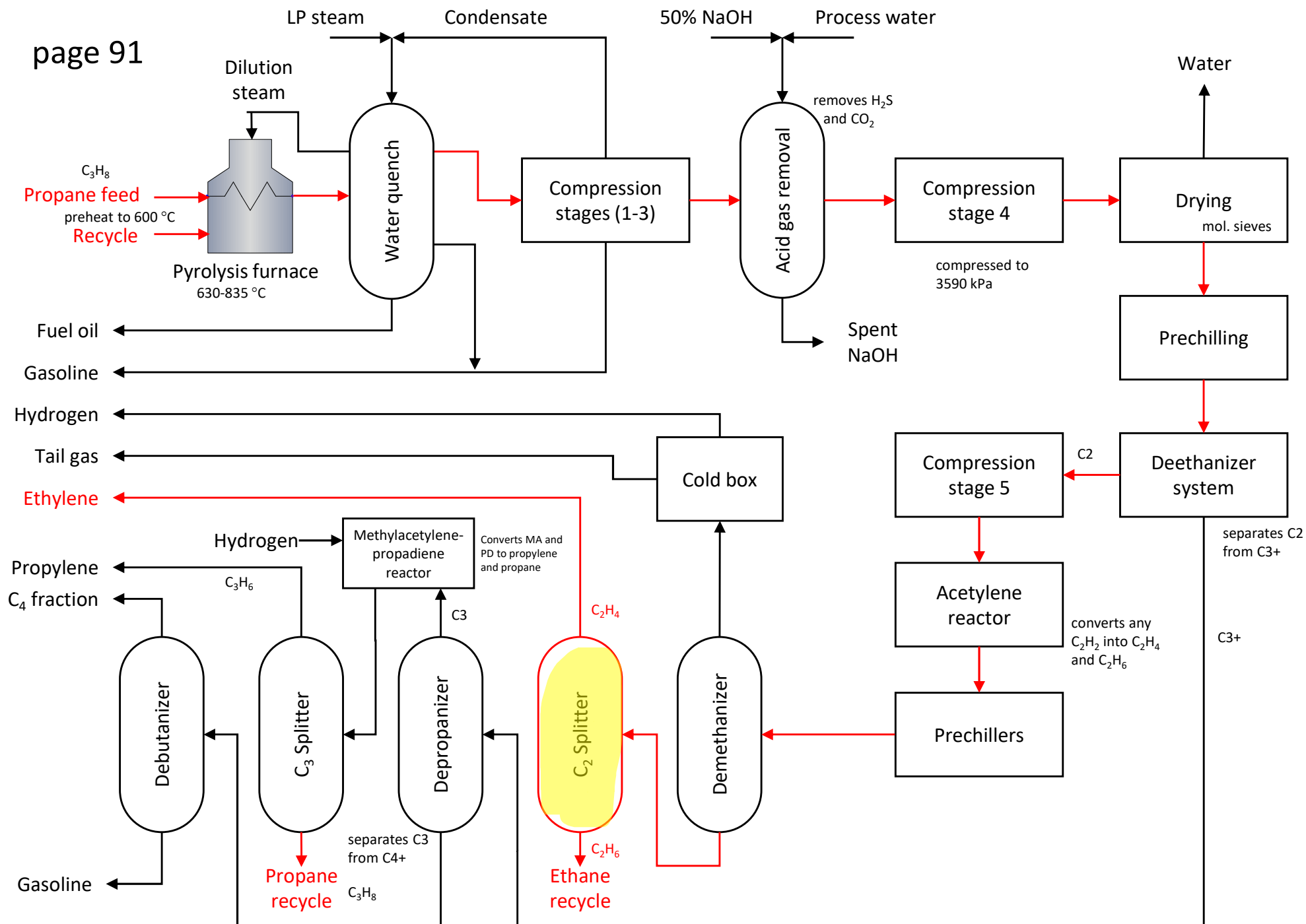


Figure 3-13. Product Separation Section

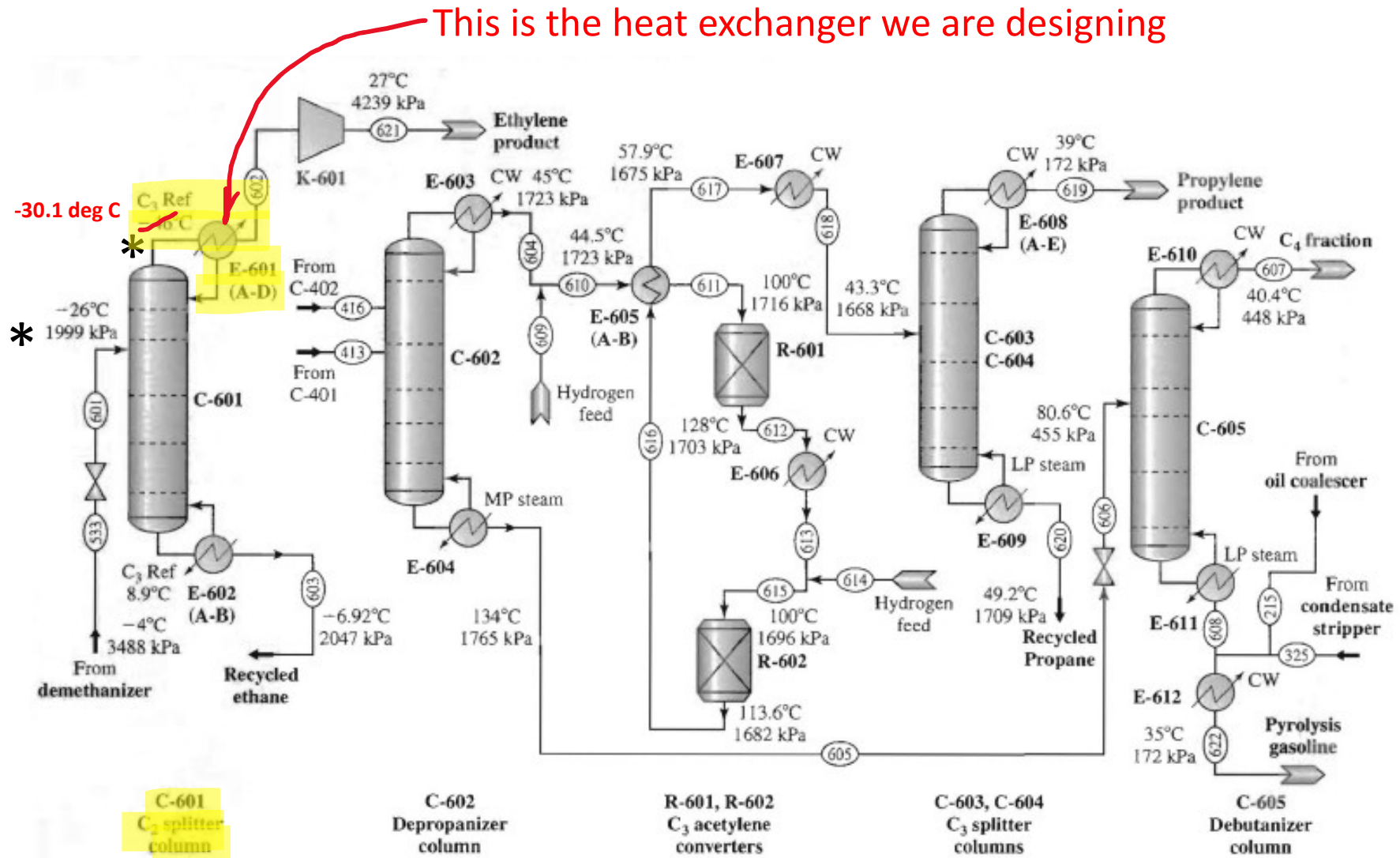


Figure 3-13. Product separation section.

Change engineering units

Change CEPCI to Feb 2026 for PS5

Steady State

Dynamic

Run All

Run from Initial State

Charts

Reports

Property Set

Stream Property

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: m3/h

Vapor Volume Rate: m3/h

Vapor Density: kg/m3

Liquid Density/Con...: kg/m3

Crude Flow Rate: m3/h

Velocity: m/sec

Fluid Properties

Heat Capacity: kJ/kg-K

Specific Heat: kJ/kg

Heat Transfer Coef...: W/m2-K

Thermal Conductivity: W/m-K

Viscosity: N-s/m2

Surface Tension: N/m

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, Onifice, and line sizing tool.

ASME (B36.10M-2015, B36.19M-2004)

Misc

Solubility Parameter: (J/m3)**0.5

Dipole Moment: C.m

Cake Resistance: m/kg

Packing dP: mm-water/m

Currency: \$

Currency Factor: 1.0000000

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

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

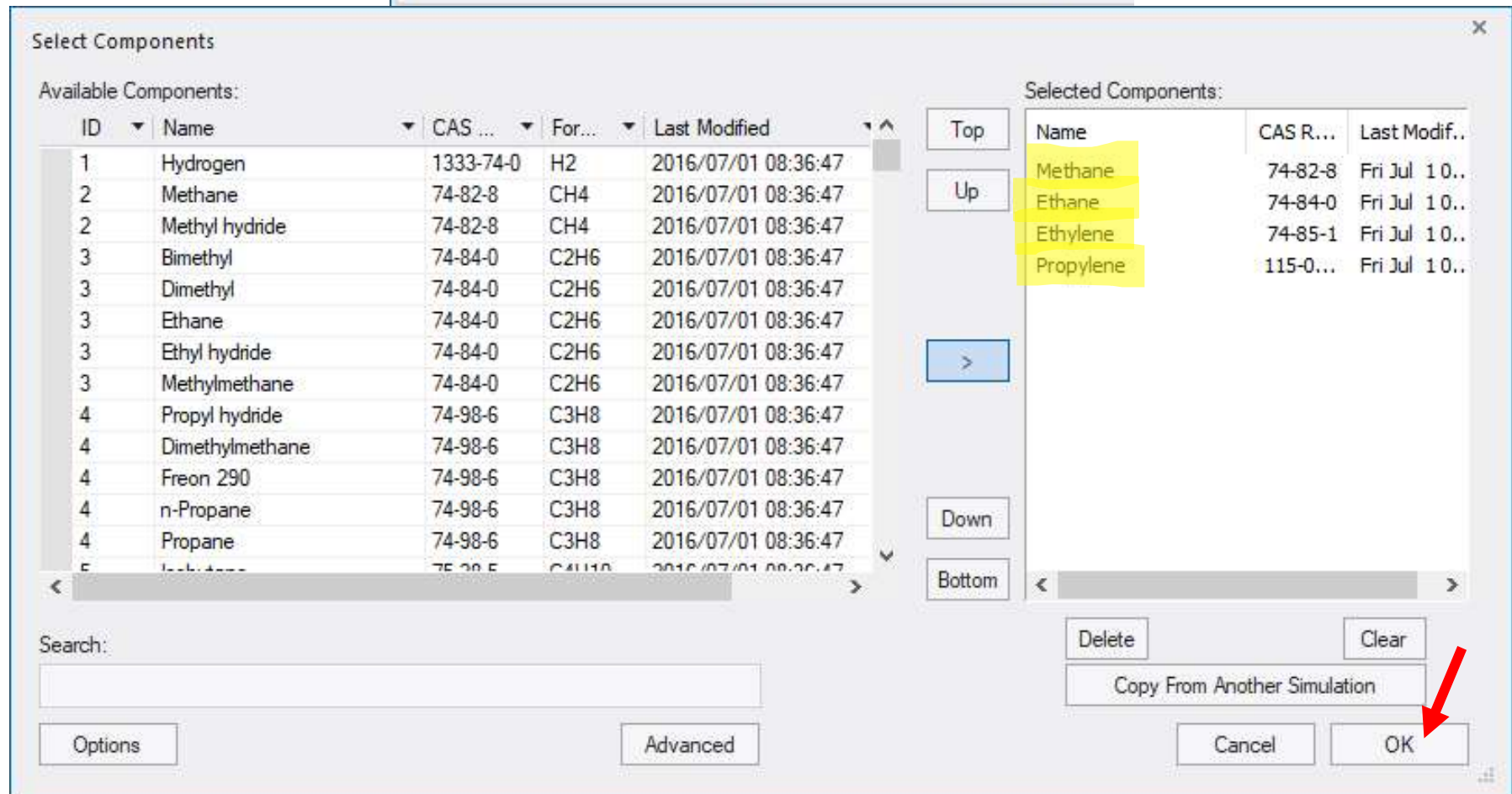
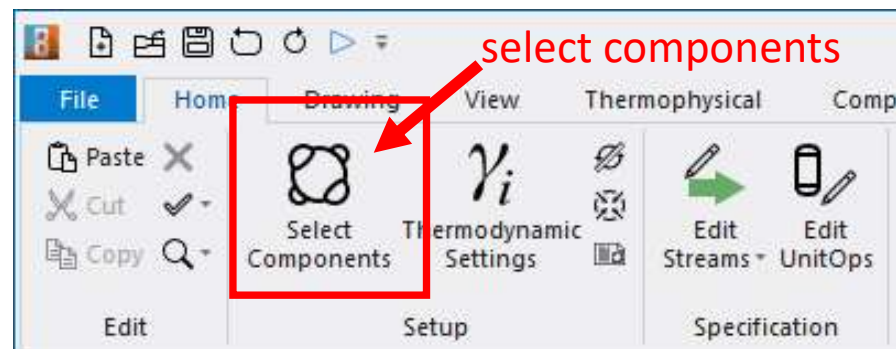
Separators : Grayscale

Solids handling : Grayscale

Steady State

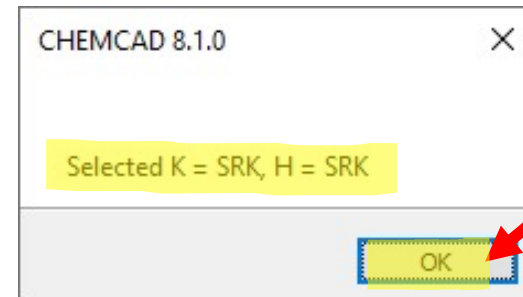
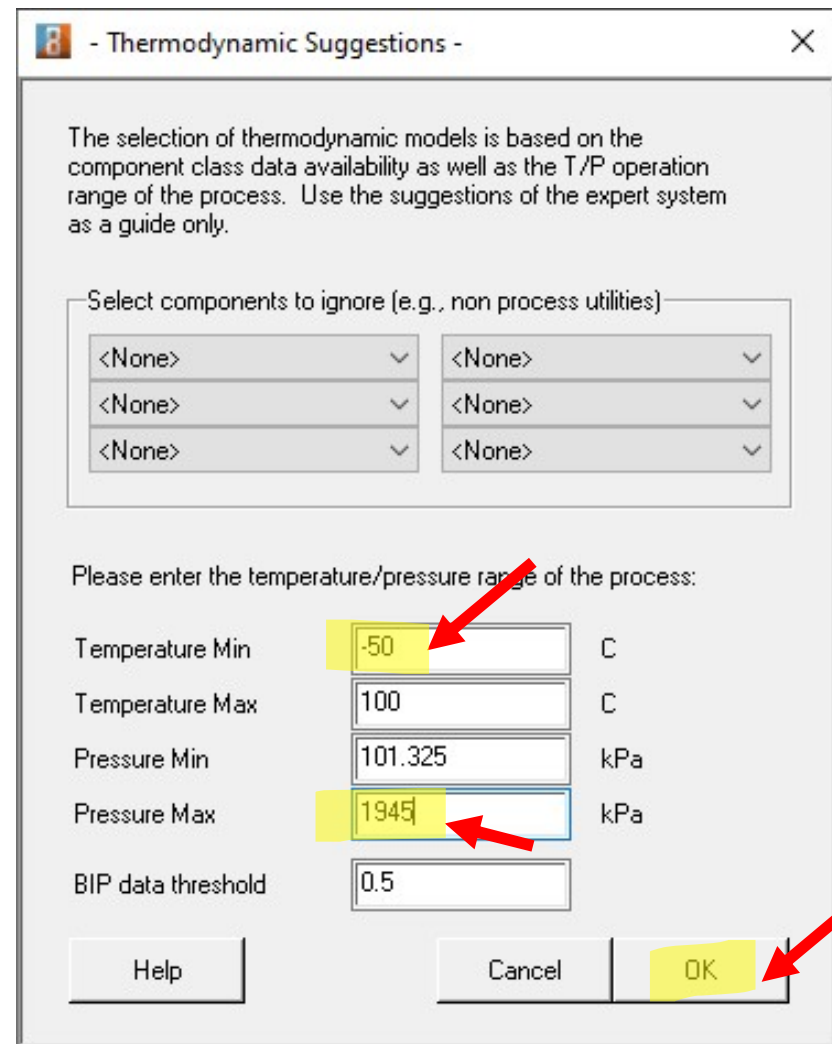
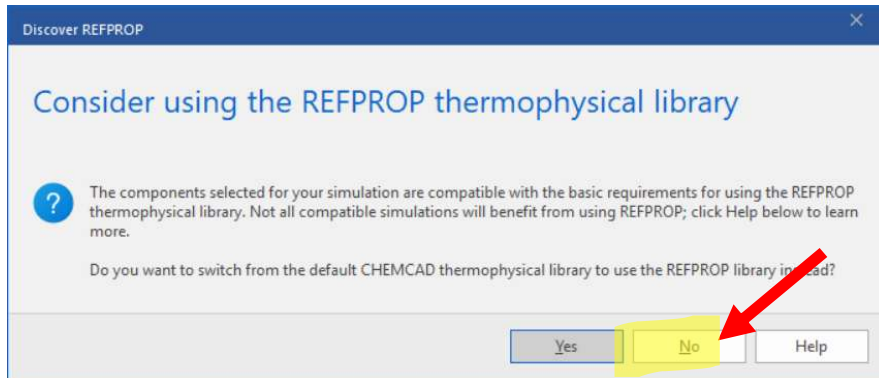
100.0%

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



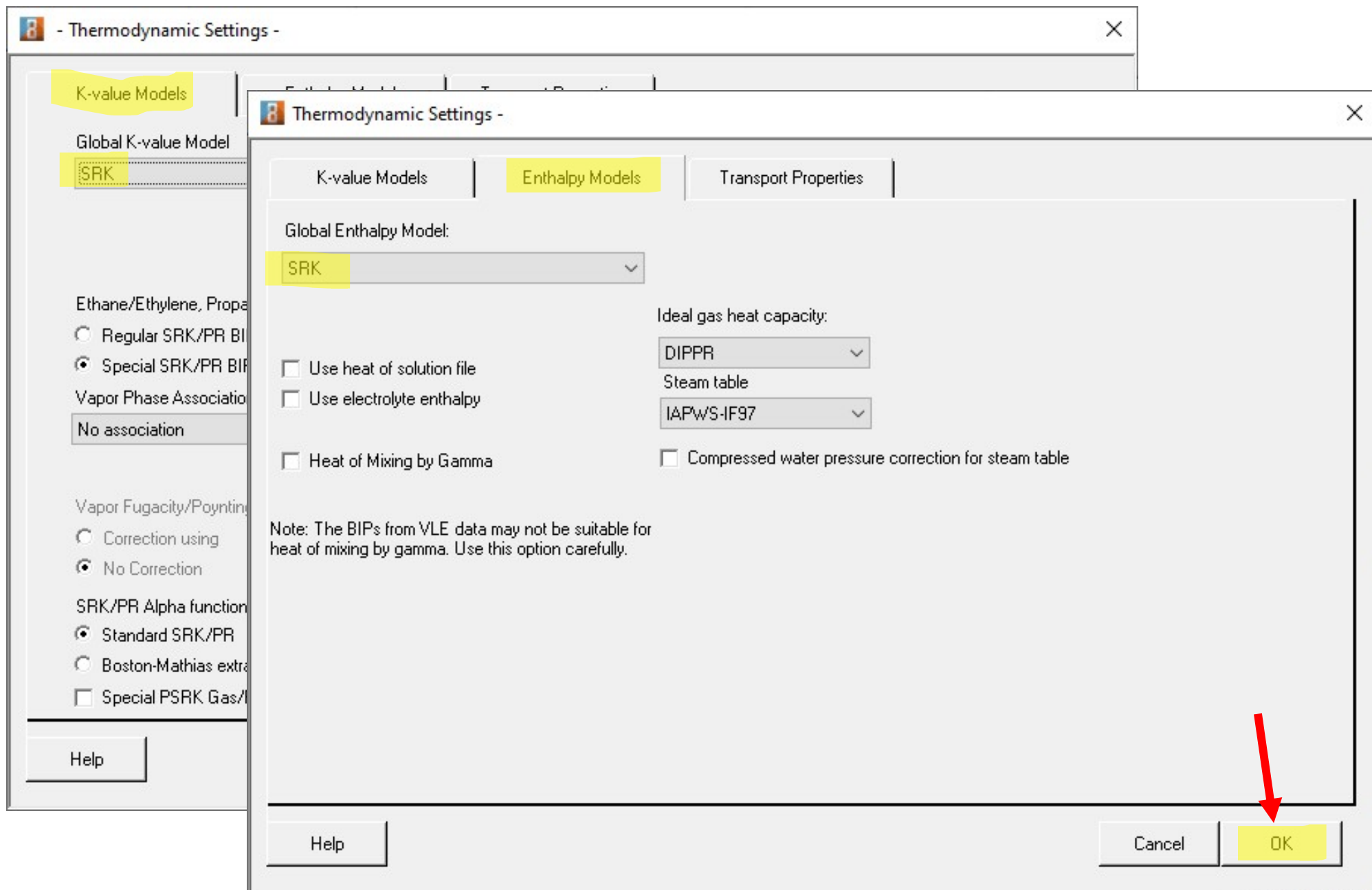
“Thermodynamic Suggestions” window launches automatically when you click OK.

Thermodynamic Suggestions



SRK is good!

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



Draw flowchart and solve m/e balances.

Step 1 – Lesson 8, slide 3.

Overhead vapor

Coolant – tube side

Heat Exchanger #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.

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.

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

CHEMCAD will solve for the actual flow rate later.

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

The screenshot shows the 'Heat Exchanger (HTXR)' dialog box with the 'Specifications' tab selected. The 'Simulation mode' is set to '0 Enter specifications (CHEMCAD simulation)'. The 'Utility option' is set to '3 Calculate flow of stream 1', which is highlighted by a red box with the text 'Switch this to "3"'. The 'Pressure drop' is set to '(default = 0)'. The 'Stream 1' and 'Stream 3' pressure fields are empty. The 'Delta temperature specifications' section includes fields for 'Minimum delta temperature', 'Hot outlet - cold inlet', 'Hot inlet - cold outlet', 'Stream 2 - stream 4', 'Stream 2 - stream 1', and 'Stream 4 - stream 3'. The 'Heat transfer coefficient and area specification' section includes fields for 'Heat transfer coefficient (U)' and 'Area (per shell)'. The 'Heat duty (specified)' field is highlighted by a red box with the text 'Given (see slide 2)'. The 'Temperature stream 4' field is highlighted by a red box with the text 'Assume! (see note 1)'. The 'Vapor fraction stream 2' and 'Vapor fraction stream 4' fields are set to 0.995 and 0.265, respectively. The 'Subcooling stream 2' field is empty. The 'Superheat stream 4' field is empty. The 'Heat duty (specified)' field is highlighted by a red box with the text 'Given (see slide 2)'. The 'Help', 'Cancel', and 'OK' buttons are at the bottom.

Heat Exchanger (HTXR) -

Specifications | Misc. Settings | Cost Estimations

Simulation mode: 0 Enter specifications (CHEMCAD simulation)

Utility option: 3 Calculate flow of stream 1

Pressure drop: (default = 0)

Stream 1 kPa

Stream 3 kPa

ID: 1

Temperature stream 4 C

Vapor fraction stream 2 0.995

Vapor fraction stream 4 0.265

Subcooling stream 2 C

Superheat stream 4 C

Heat duty (specified) J/sec

Delta temperature specifications:

Minimum delta temperature C

Hot outlet - cold inlet C

Hot inlet - cold outlet C

Stream 2 - stream 4 C

Stream 2 - stream 1 C

Stream 4 - stream 3 C

Heat transfer coefficient and area specification:

Specifying both U and A counts as a single thermal specification.

Heat transfer coefficient (U) W/m²-K

Area (per shell) m²

Help Cancel OK

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 main window displays a process flow diagram with four streams (1, 2, 3, 4) and a unit operation (a circle with a wavy line). Stream 1 is highlighted with a red circle. A red arrow points to the 'Run All' button in the 'Steady State' tab. A text box with a red border contains the instruction: 'Double-click stream 1 to check results'.

The 'Edit Streams' dialog box is open, showing the following data:

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 'Propylene' row in the 'Edit Streams' dialog box.

Confirm Results (2/3)

Heat Exchanger (HTXR) -

Specifications | Misc. Settings | Cost Estimations

Simulation mode: 0 Enter specifications (CHEMCAD simulation)

Utility option: 3 Calculate flow of stream 1

Pressure drop: (default = 0)

Stream 1 kPa

Stream 3 kPa

Enter two specifications, the flowrate of stream 1 will be recalculated

Temperature stream 2		C
Temperature stream 4		C
Vapor fraction stream 2	0.995	
Vapor fraction stream 4	0.265	
Subcooling stream 2		C
Subcooling stream 4		C
Superheat stream 2		C
Superheat stream 4		C
Heat duty (specified)		J/sec

Delta temperature specification

Minimum delta temperature

Hot outlet - cold inlet

Hot inlet - cold outlet

Stream 2 - stream 4

Stream 2 - stream 1

Stream 4 - stream 3

Heat transfer coefficient and area specification:

Specifying both U and A count

Heat transfer coefficient (U) W/m²-K

Area (per shell) m²

Help

Cancel OK

Note: there is no P-drop

Note: there is no A or U

Double-click heat exchanger to confirm results

Confirm Results (3/3)

Heat Exchanger (HTXR) -

Specifications | Misc. Settings | Cost Estimations

ID: 1

Type: 0 Countercurrent

No. of Zones

Max. Percent of Pressure Drop

Percent

For evaporator utility side operating temp:

Utility operating T

C

Shells in Series

No. of SS Passes

No. of TS Passes

☐ Include holdup in dynamic calculation

Stream 1-2 holdup

m3

Stream 3-4 holdup

m3

Backcalc mode (for Autocalc): 0 No back calculation

Calculated Results

Calc Ht Duty	1.56566e+07	J/sec	Pinch Flag		
LMTD (End points)	14.2801	C	Wt. LMTD		C
LMTD Corr Factor	1				m2
Calc U				125	kPa
Calc Area (Total)				1945.81	kPa
Tube fouling					
Shell fouling		m2-K/W			

For more comprehensive heat exchanger design and rating, please contact us regarding our CC-THERM program.

Help Cancel OK

$$\ln[2] := \frac{(-30.1084 - (-46)) - (-30.1 - (-42.8813))}{\text{Log} \left[\frac{(-30.1084 - (-46))}{(-30.1000 - (-42.8813))} \right]}$$

$$\text{out}[2] = 14.28004$$

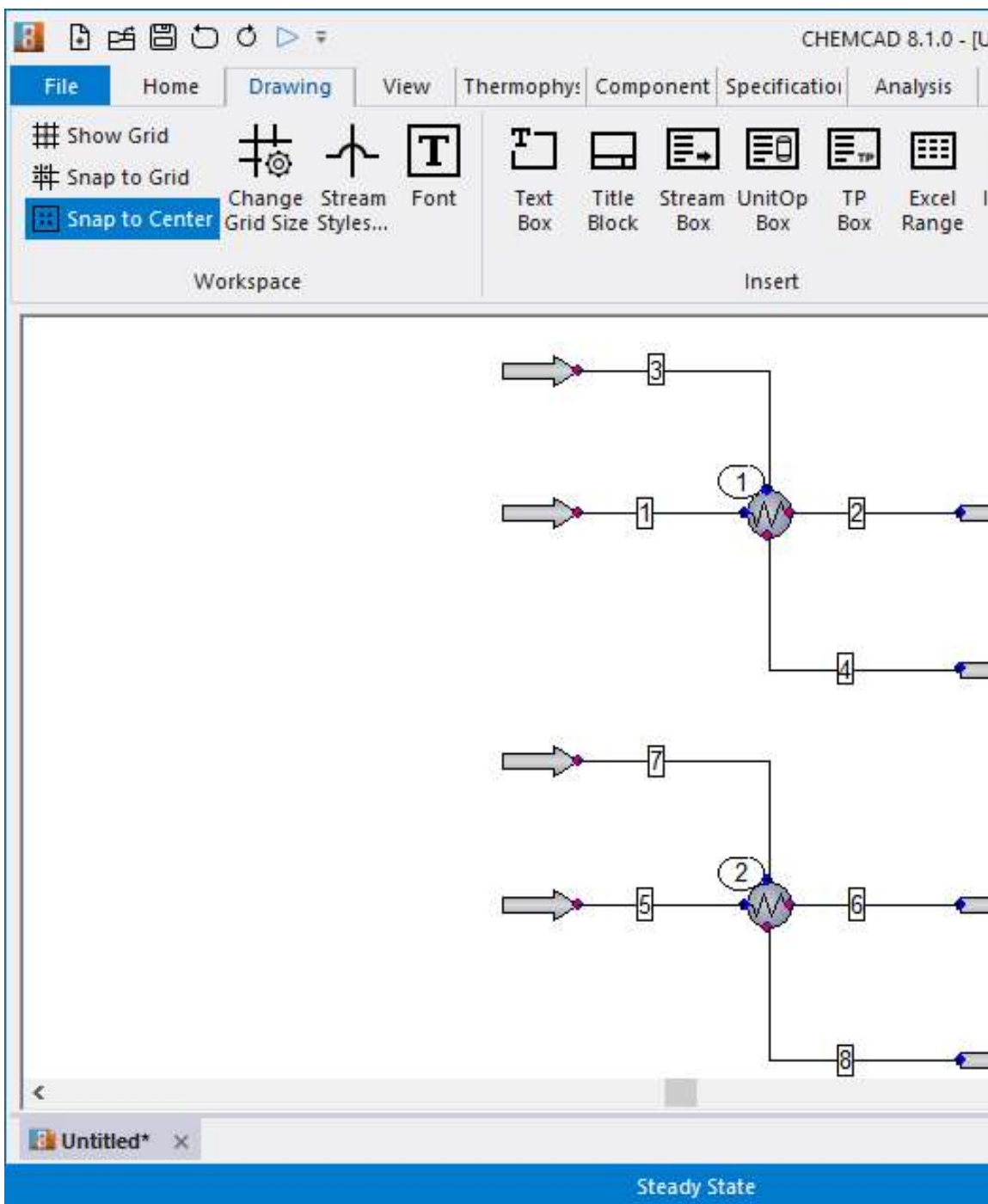
Numbers in gray fields were calculated by CHEMCAD

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.

The screenshot shows the CHEMCAD 8.1.0 software interface. The 'Sizing' tab is selected in the top menu bar. The 'Shell and Tube' icon in the 'Heat Exchanger' group is highlighted with a red circle and the number 2. The 'Sizing' tab itself is also highlighted with a red circle and the number 1. Below the menu bar, a tooltip for 'Shell and Tube' is visible, stating 'Perform shell and tube heat exchanger sizing'. The main workspace displays a process flowsheet with two heat exchangers, labeled 1 and 2, and various streams numbered 1 through 8. The status bar at the bottom indicates 'Steady State'.

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

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

The screenshot shows two dialog boxes. The top dialog box is titled 'Select UnitOps' and contains a text input field with the number '2' entered, highlighted with a red circle and the number 3. The 'OK' button is highlighted with a red circle and the number 4. The bottom dialog box is titled 'New CC-THERM Case' and contains a text input field with the text '14-15 Design' entered, highlighted with a red circle and the number 5. The 'OK' button is also visible in this dialog box.

CHEMCAD 8.1.0 - [Lesson9_AY232_Trial1*]

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

UnitOp ID 2 Type Shell and Tube

Case 14-15 Design

Select

General

Enter Stream Information Materials
Heat Curve Specification Label
Edit Heat Curve

Tube Nozzle
Shell Clearance

Design Charts Reports

1 CLICK THE CENTER OF THE GEAR WHEEL.

2

3

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

Lesson9_AY232_Trial1* Lesson9_AY232_Trial1_1

Steady State K:SRK H:SRK

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)

Tube Side

Stream name:

Process type: Forced Evaporation

Fouling factor: 0.0001761094 m²-K/W

Optional h Coeff.: W/m²-K

Shell Side

Horiz Condensation

0.0001761094 m²-K/W

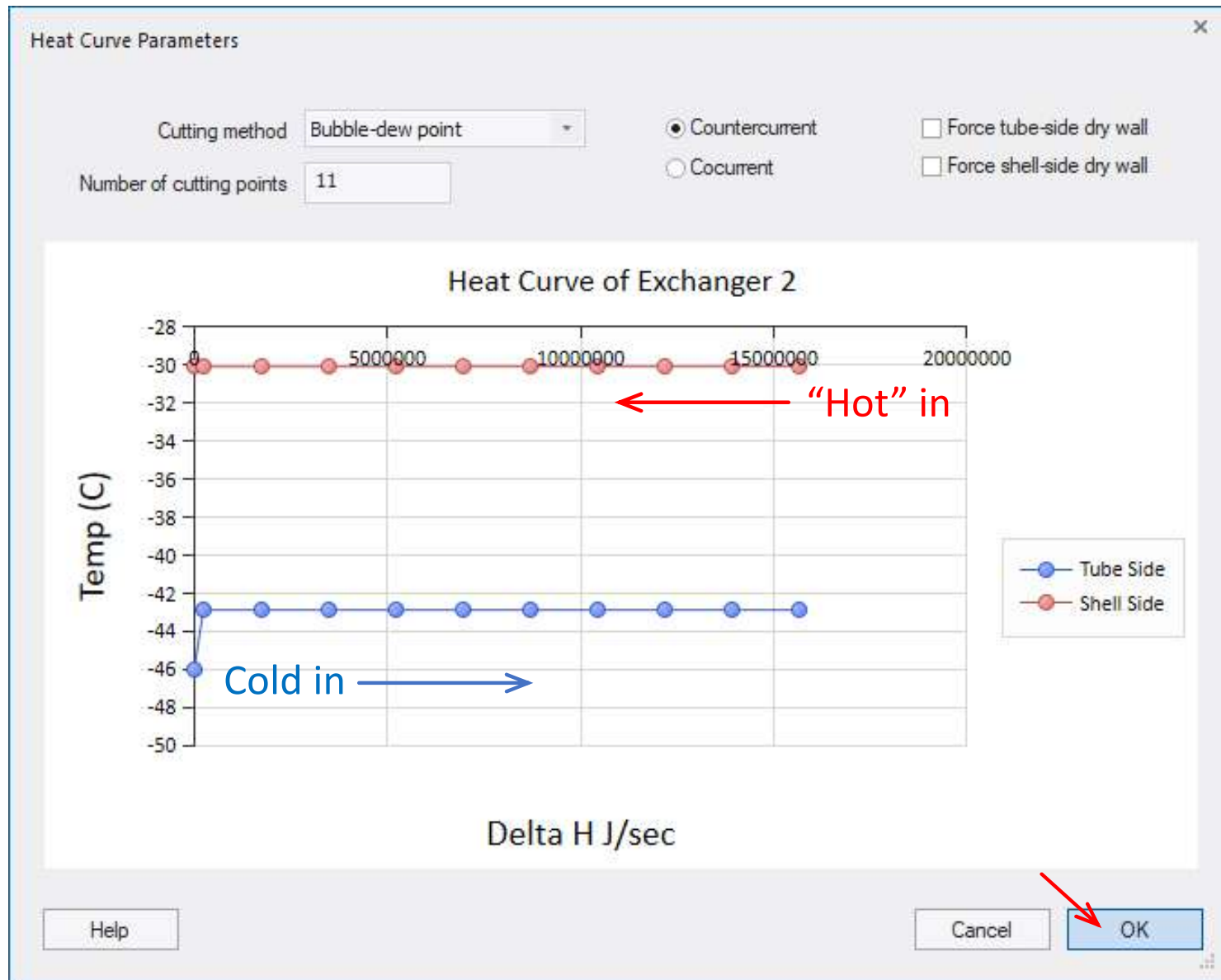
W/m²-K

For fouling rating calculations: Calculate tube-side fouling only

Help Cancel OK

3

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



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*]

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

UnitOp ID 2 Type Shell and Tube

Case 14-15 Design

Select

General

Enter Stream Information Materials

Heat Curve Specification Label

Edit Heat Curve Simulation Mode

Design Constraints

Reboiler Spec

Tube Nozzle

Shell Clearance

Baffle Miscellaneous

Design Charts Reports

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 Variable

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

Lesson9_AY232_Trial1* Lesson9_AY232_Trial1_1 Steady State

CH EMCAD 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 Case 14-15 Design

General Enter Stream Information Materials Heat Curve Specification Label Simulation Mode

Configuration Edit Heat Curve

Tube Nozzle Shell Clearance Baffle Miscellaneous Geometry Run Results

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 128.0%

Tube Specifications

Number of tubes *	1396
Number of tube passes *	1
Tube outer diameter	.0127 m
Tube wall thickness	.00165 m
Tube length *	6.0960002 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

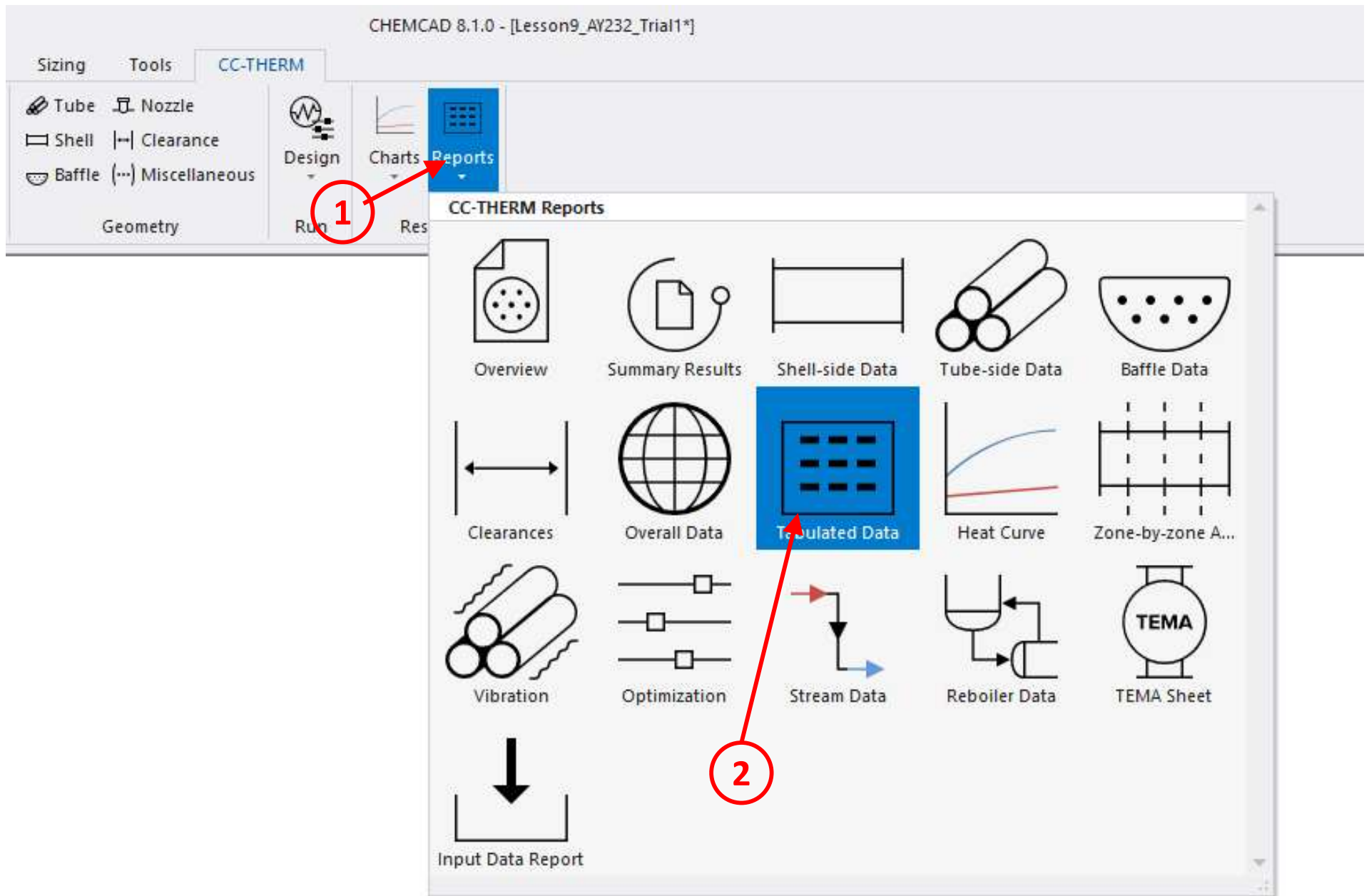
1

2

3

4

5



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
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
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?

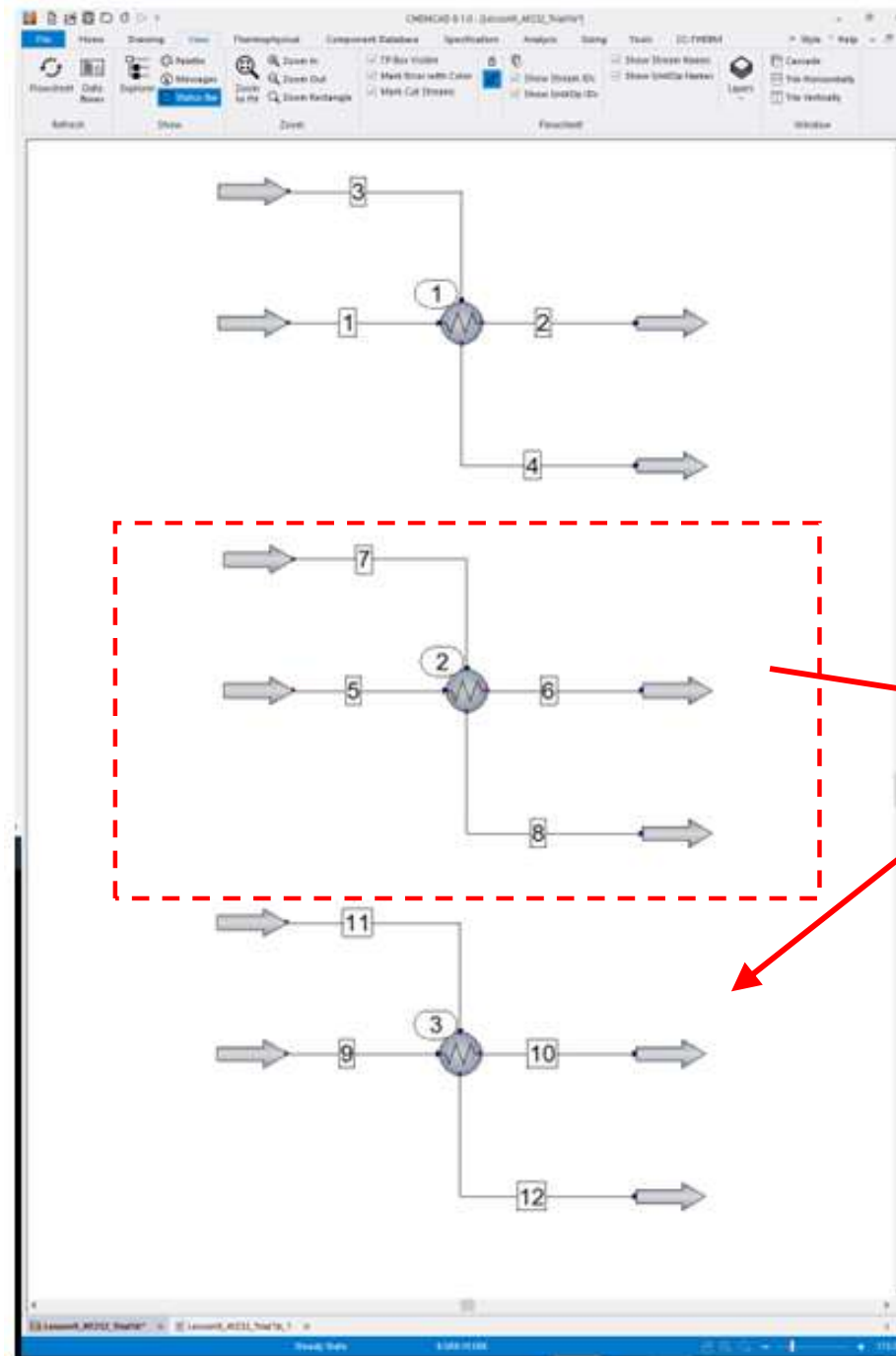
STOP HERE

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.

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

CH EMCAD 8.1.0 - [Lesson9_AY232_Trial3*]

File Home Drawing View Thermophys Component Specification Analysis Sizing Tools

Flowsheet Data Boxes Explorer Palette Messages Status Bar

Refresh Show Zoom

TP Box Visible
Mark Error with Color
Mark Cut Streams

Show Stream IDs
Show UnitOp IDs

Flowsheet Window

double-click

1

2

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			Hot outlet - cold inlet
Vapor fraction stream	12			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 area
Heat duty (specified)			J/sec	Specifying both U and A count

Heat transfer coefficient (U)
Area (per shell)

Help Cancel OK

Lesson9_AY232_Trial3* Lesson9_AY232_Trial1b_1

Steady State

Heat Exchanger Before Running

8 - Heat Exchanger (HTXR) -

Specifications Misc. Settings Cost Estimations

Simulation mode: 1 Shell & tube simulation ID: 2

Pressure drop: (default = 0)

Stream 5 kPa

Stream 7 kPa

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 6		C
Temperature stream 8		C
Vapor fraction stream 6		
Vapor fraction stream 8		
Subcooling stream 6		C
Subcooling stream 8		C
Superheat stream 6		C
Superheat stream 8		C
Heat duty (specified)		J/sec

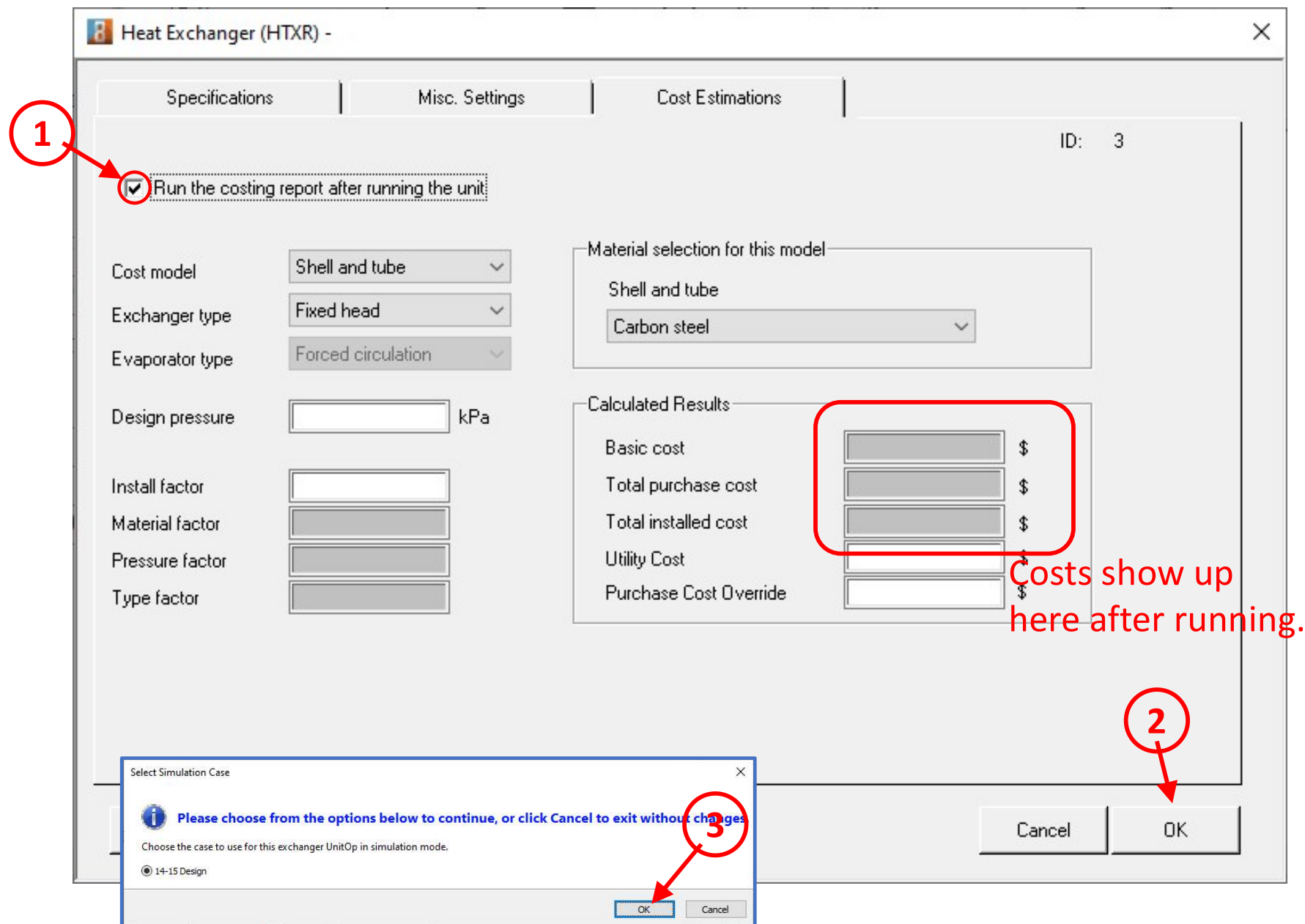
Delta temperature specifications:

Minimum delta temperature		C
Hot outlet - cold inlet		C
Hot inlet - cold outlet		C
Stream 6 - stream 8		C
Stream 6 - stream 5		C
Stream 8 - stream 7		C

Heat transfer coefficient and area specification:
Specifying both U and A counts as a single thermal specification.

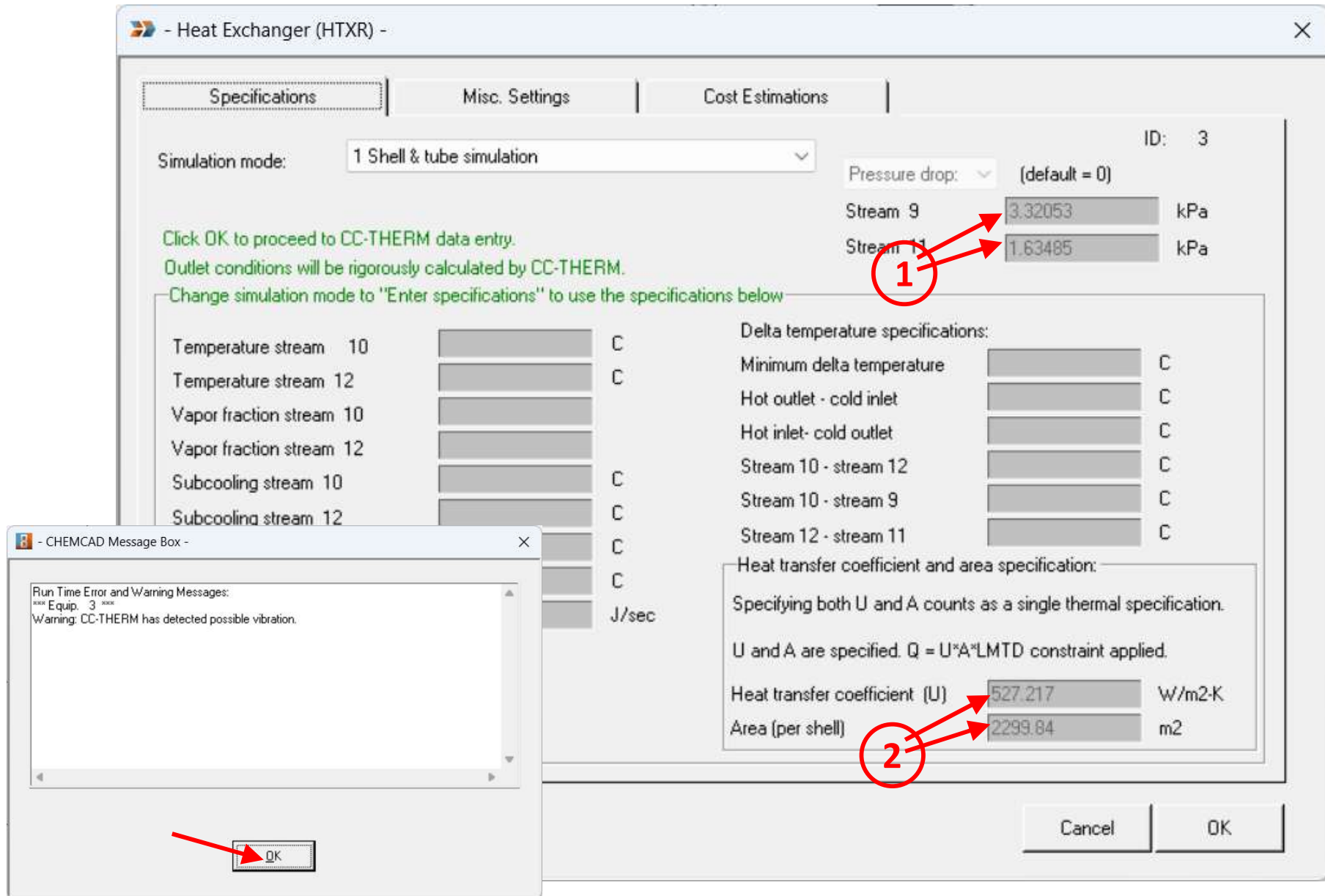
Heat transfer coefficient (U)		W/m ² -K
Area (per shell)		m ²

Help Cancel OK

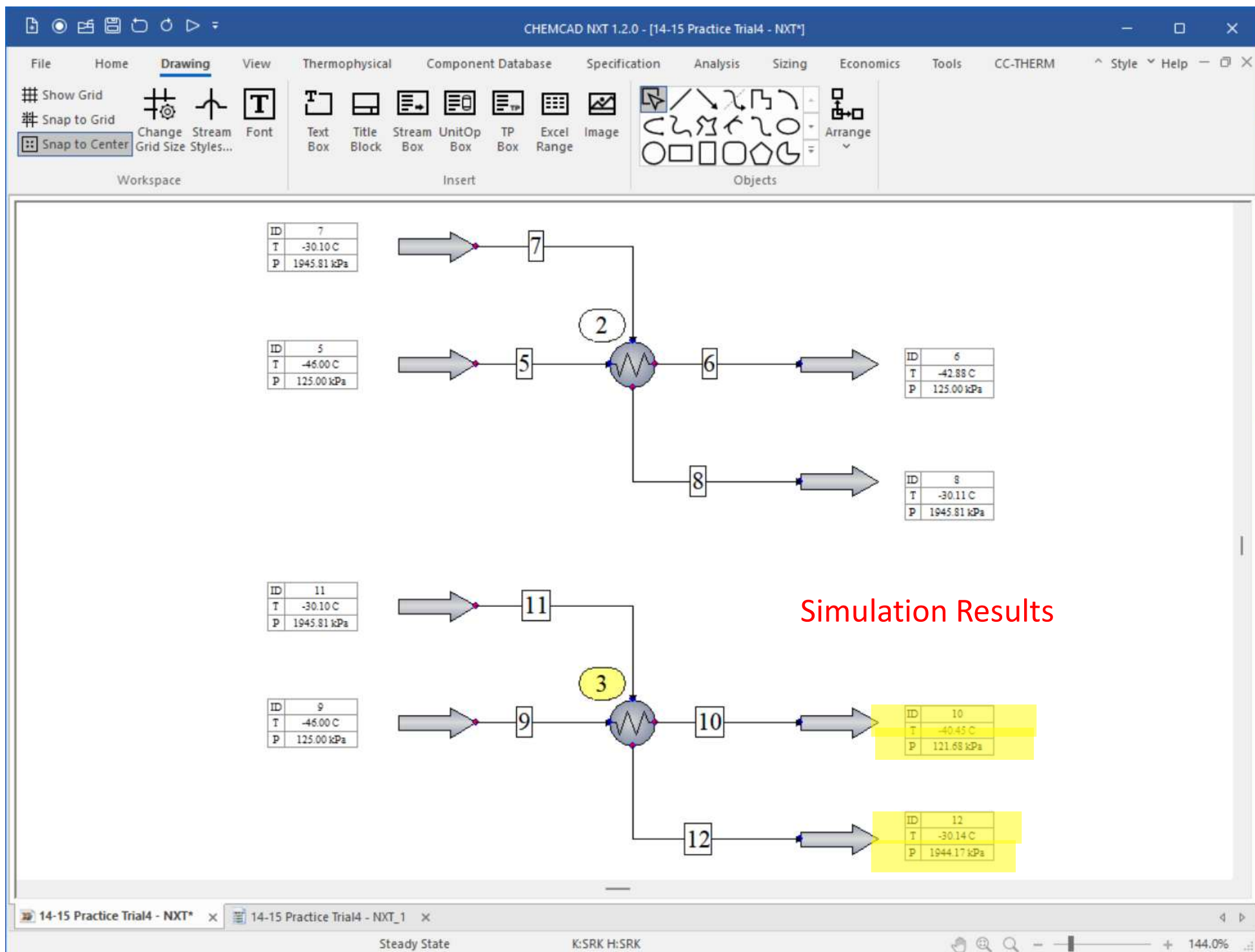


Click OK then run the simulation.

Heat Exchanger After Running



Click "Run All" in the Home tab



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 Costing Edit Cost Index Economics Execute Parser Units Converter Reaction Rate Regression CO2 Solid Hydrates Environmental Report... Title Block Designer UnitOp Designer

Data Map

Chemical Engineering Plant Cost Index

Year/Month Selection for the Cost Index

Year 2026 Source Database

Month February } make sure to set this to February 2026

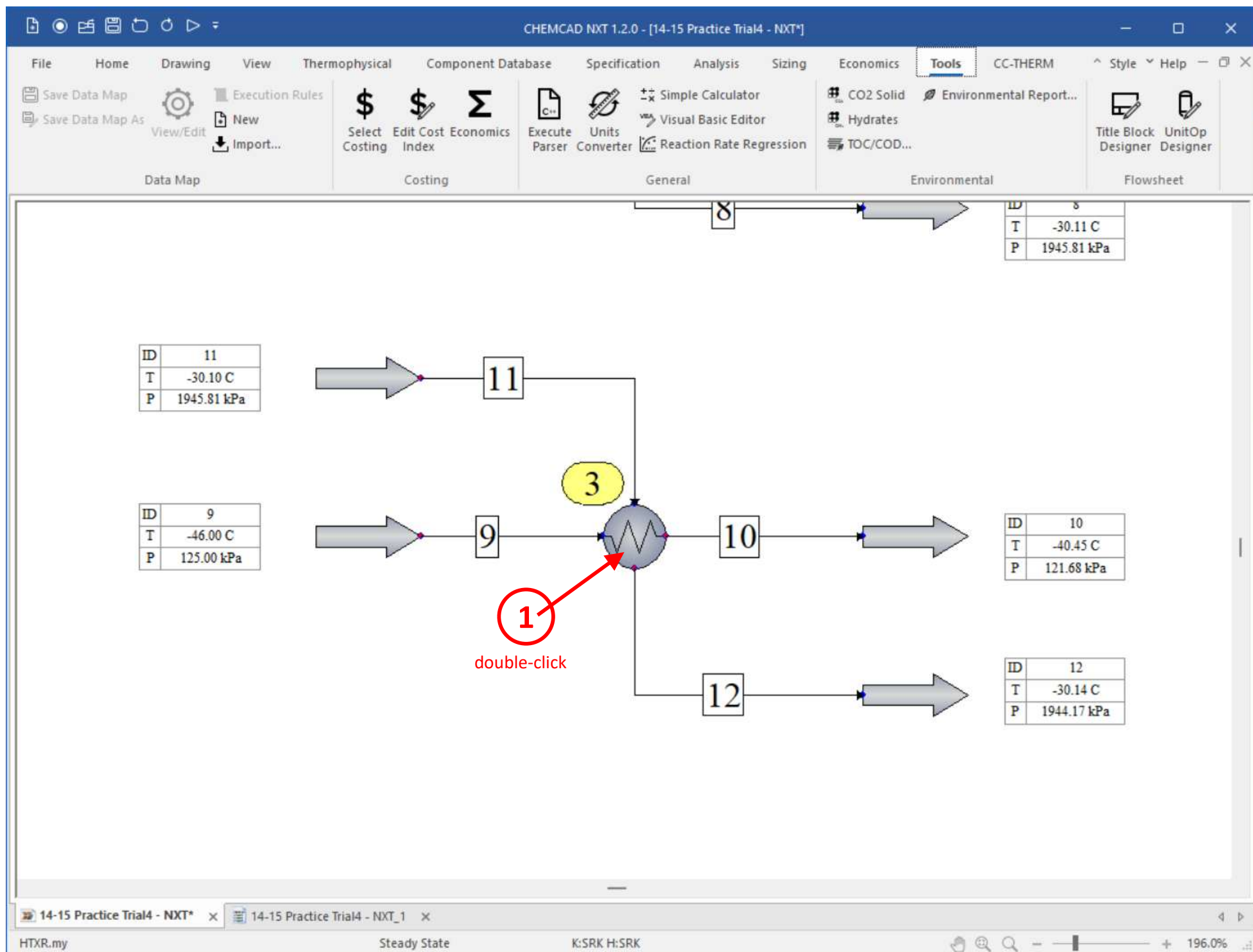
Type	Cost Index
CE Index	830.50
Equipment	1045.80
Heat exchangers and tanks	815.70
Process machinery	1057.50
Pipes, valves, and fittings	1410.40
Process instruments	620.50
Pumps and compressors	1677.10
Electrical equipment	917.90
Structural supports and misc.	1142.00
Construction labor	390.30
Buildings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

Help Cancel OK

Steady State K:SRK H:SRK

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

196.0%



Cost Results

Heat Exchanger (HTXR) -

Specifications | Misc. Settings | Cost Estimations

ID: 3

☒ Run the costing report after running the unit

Cost model: Shell and tube

Exchanger type: Fixed head

Evaporator type: Forced circulation

Design pressure: kPa

Install factor: 2

Material factor: 1

Pressure factor: 1.28102

Type factor: 0.819535

Material selection for this model

Shell and tube

Carbon steel

Calculated Results

Basic cost	317634	\$
Total purchase cost	810750	\$
Total installed cost	1.6215e+06	\$
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