CAPE Lab Report

Assignment - 2

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Project Title: Heat Exchanger Design for Heating Benzene using Toluene

Objective :

To design a shell-and-tube heat exchanger in Aspen HYSYS to heat **benzene** from **70°F** to **140°F** using **toluene** as the heating medium, with outlet temperature of **toluene** at **150°F**. The simulation includes thermal design, rating, and creation of an EDR file.

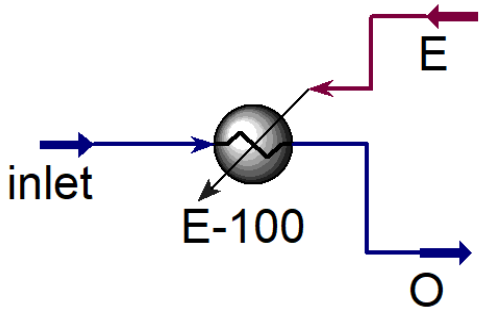
Problem Statement :

- **Cold Fluid (Benzene):**
  - Flow rate: **80,000 lb/hr**
  - Inlet temperature: **70°F**
  - Outlet temperature: **140°F**
  - Inlet pressure: **45 psia**
  - Allowable pressure drop: **5 psia**
- **Hot Fluid (Toluene):**
  - Inlet temperature: **235°F**
  - Outlet temperature: **150°F**
  - Inlet pressure: **40 psia**
  - Allowable pressure drop: **5 psia**
- **Heat Exchanger Details:**
  - Type: **Shell and Tube**
  - Configuration: **Multi-pass (2 pass)**
  - Hot fluid: **Tube side**
  - Cold fluid: **Shell side**
  - Fouling factors: **0.0015 ft^2·hr·°F/BTU** (both sides)

Q1. Flowrate Check & Heat Duty Estimation

Approach:

A **simple heater block** was used in HYSYS to simulate the benzene heating process with toluene as the heat source. This step helps in estimating the **required heat duty**.

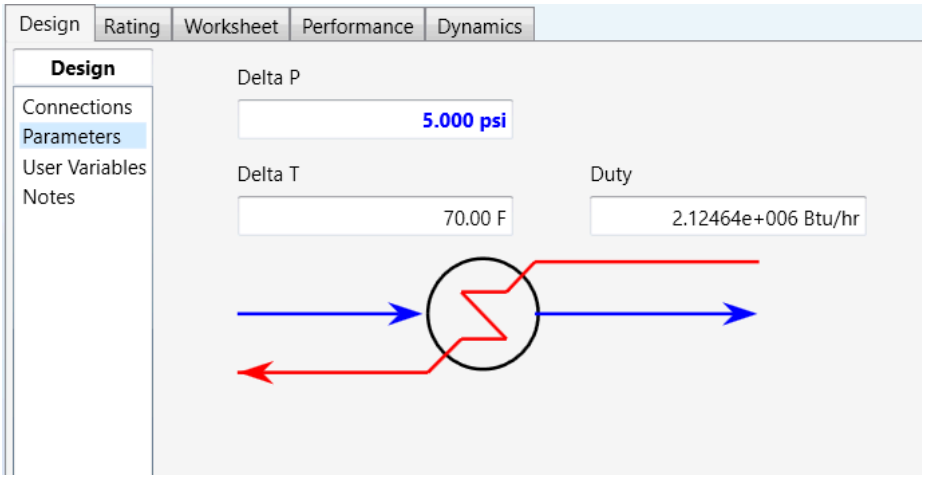


Design | Rating | Worksheet | Performance | Dynamics

Worksheet

- Conditions
- Properties
- Composition
- PF Specs

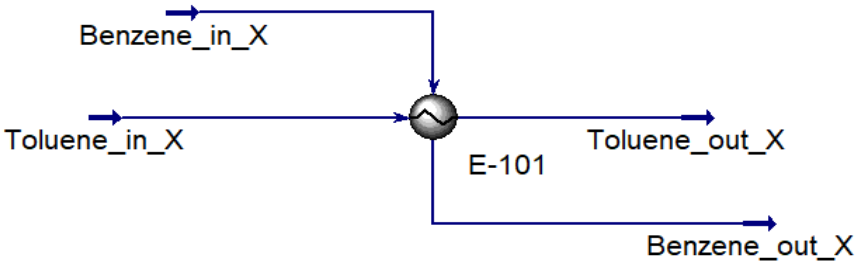
Name	inlet	O	E
Vapour	0.0000	0.0000	<empty>
Temperature [F]	**70.00**	**140.0**	<empty>
Pressure [psia]	**45.00**	40.00	<empty>
Molar Flow [lbmole/hr]	1024	1024	<empty>
Mass Flow [lb/hr]	**8.000e+004**	8.000e+004	<empty>
Std Ideal Liq Vol Flow [barrel/day]	6209	6209	<empty>
Molar Enthalpy [Btu/lbmole]	2.137e+004	2.345e+004	<empty>
Molar Entropy [Btu/lbmole-F]	-35.16	-31.48	<empty>
Heat Flow [Btu/hr]	2.189e+007	2.402e+007	2.125e+006

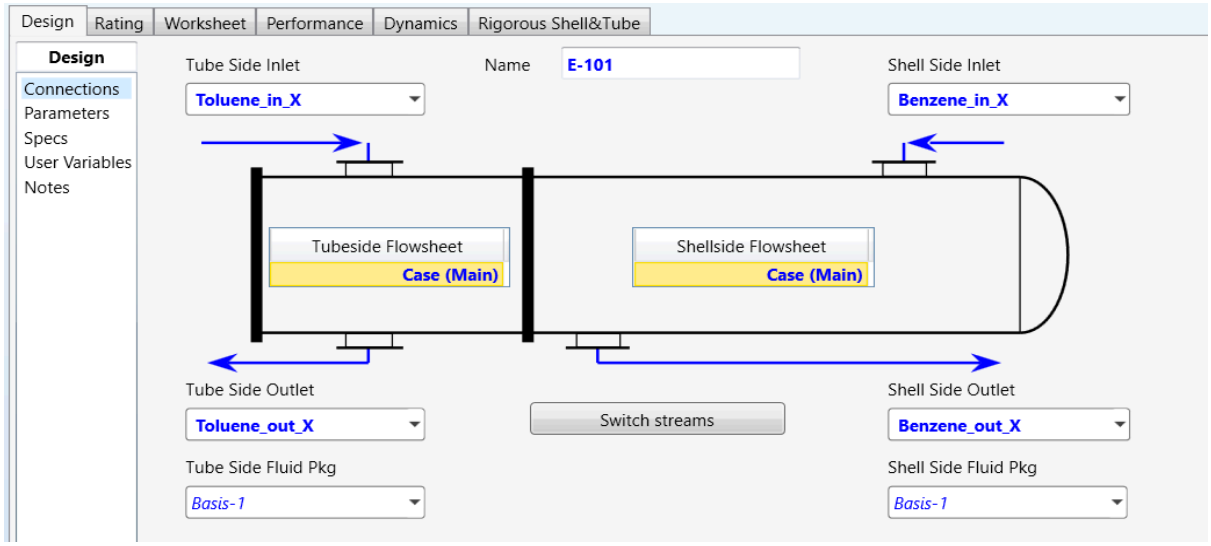


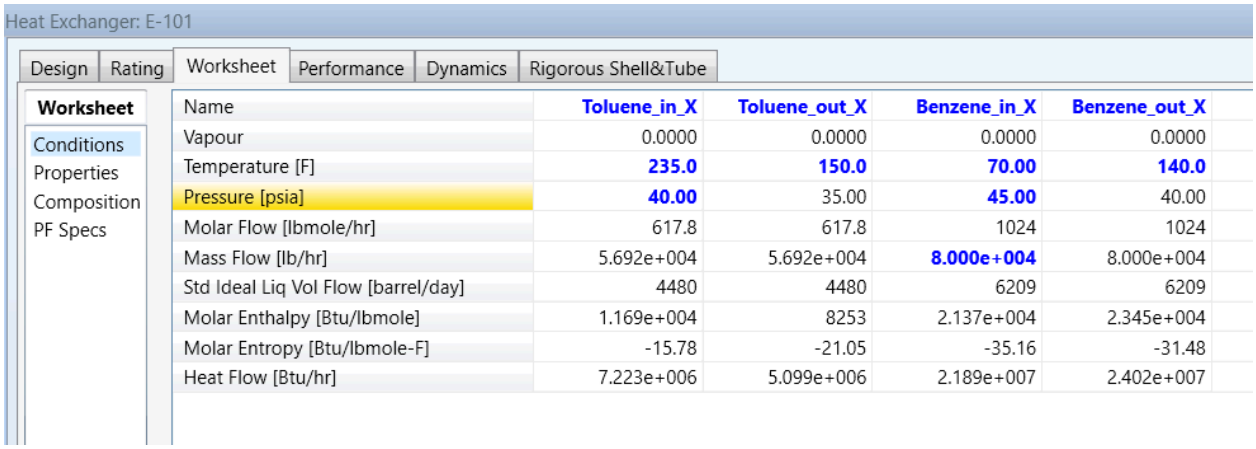
Results:

- Heat Duty (Q): **21,24,640 BTU/hr.**

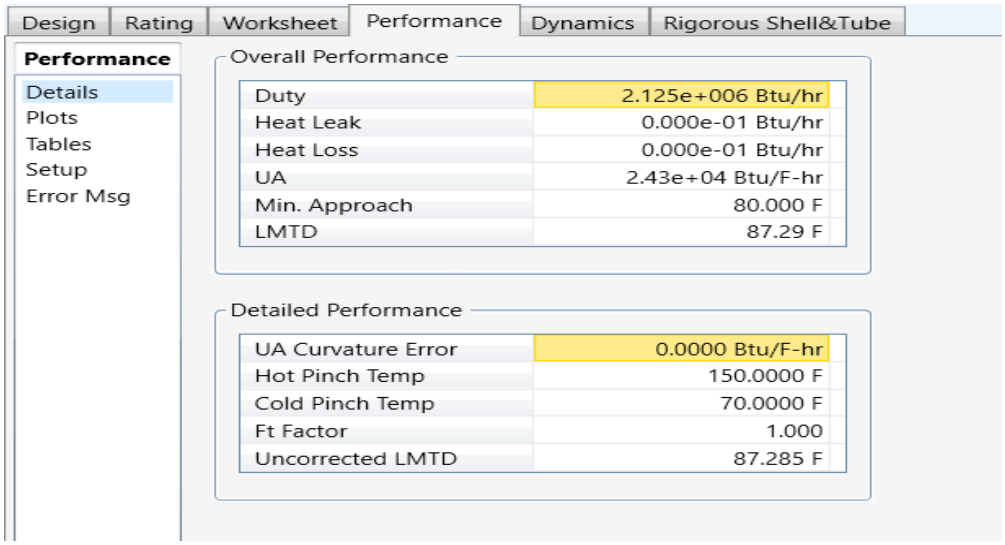
Q2. Thermal Design using Aspen HYSYS - Heat Exchanger Modeler



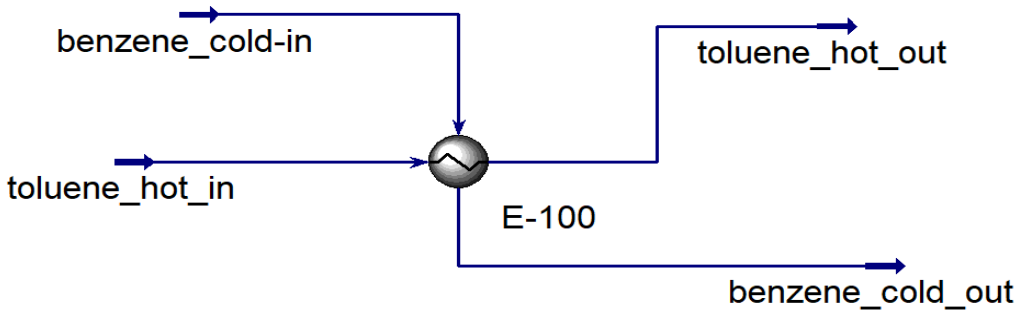


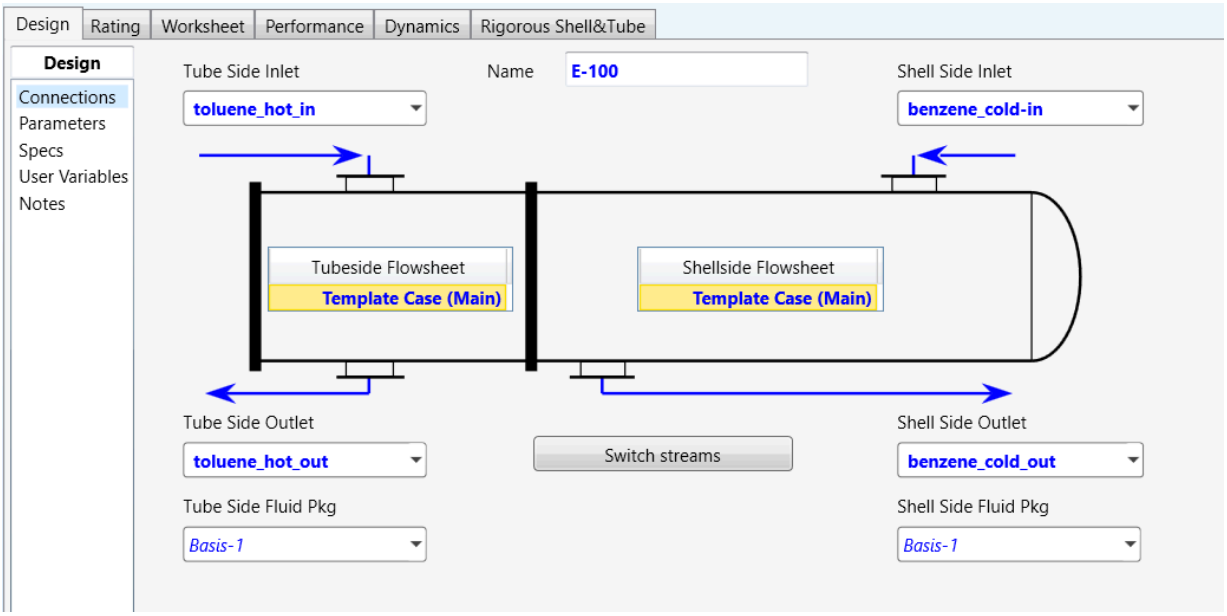


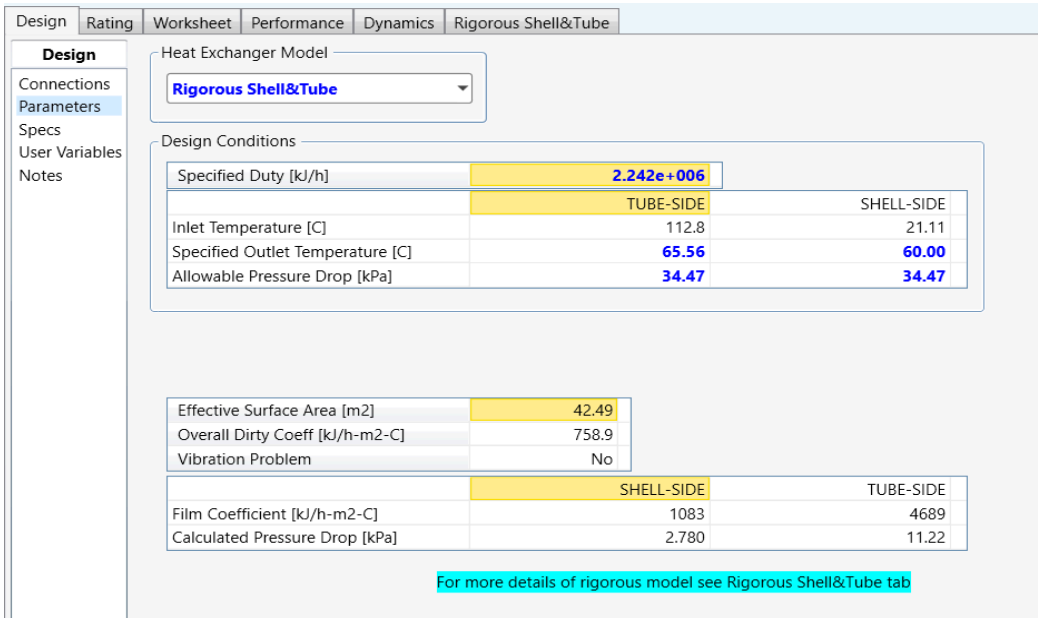
Name	Toluene_in_X	Toluene_out_X	Benzene_in_X	Benzene_out_X
Vapour	0.0000	0.0000	0.0000	0.0000
Temperature [F]	**235.0**	**150.0**	**70.00**	**140.0**
Pressure [psia]	**40.00**	35.00	**45.00**	40.00
Molar Flow [lbmole/hr]	617.8	617.8	1024	1024
Mass Flow [lb/hr]	5.692e+004	5.692e+004	**8.000e+004**	8.000e+004
Std Ideal Liq Vol Flow [barrel/day]	4480	4480	6209	6209
Molar Enthalpy [Btu/lbmole]	1.169e+004	8253	2.137e+004	2.345e+004
Molar Entropy [Btu/lbmole-F]	-15.78	-21.05	-35.16	-31.48
Heat Flow [Btu/hr]	7.223e+006	5.099e+006	2.189e+007	2.402e+007

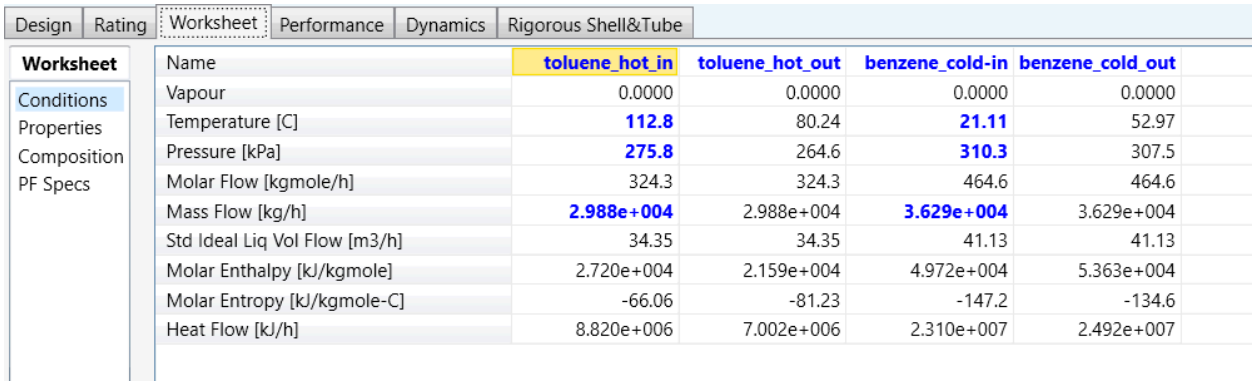


Q3. Thermal Design using Aspen HYSYS - Heat Exchanger Modeler

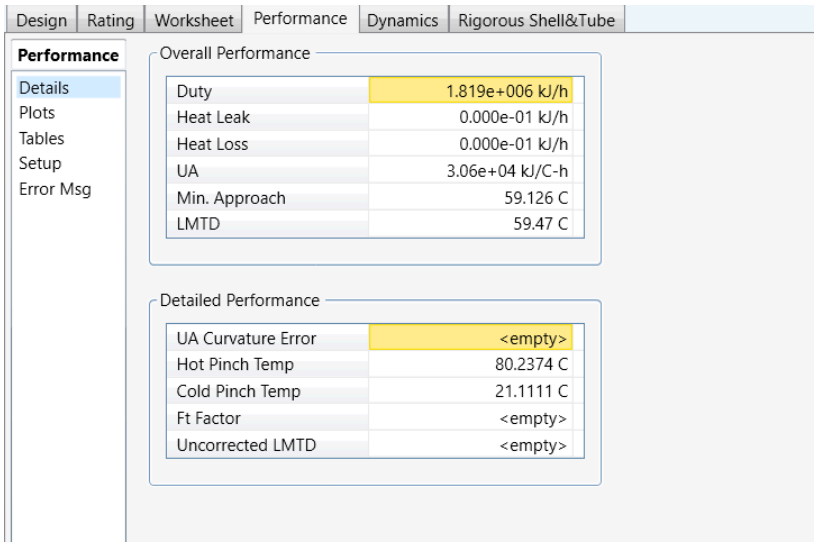








Name	toluene_hot_in	toluene_hot_out	benzene_cold-in	benzene_cold_out
Vapour	0.0000	0.0000	0.0000	0.0000
Temperature [C]	112.8	80.24	21.11	52.97
Pressure [kPa]	275.8	264.6	310.3	307.5
Molar Flow [kgmole/h]	324.3	324.3	464.6	464.6
Mass Flow [kg/h]	2.988e+004	2.988e+004	3.629e+004	3.629e+004
Std Ideal Liq Vol Flow [m3/h]	34.35	34.35	41.13	41.13
Molar Enthalpy [kJ/kgmole]	2.720e+004	2.159e+004	4.972e+004	5.363e+004
Molar Entropy [kJ/kgmole-C]	-66.06	-81.23	-147.2	-134.6
Heat Flow [kJ/h]	8.820e+006	7.002e+006	2.310e+007	2.492e+007

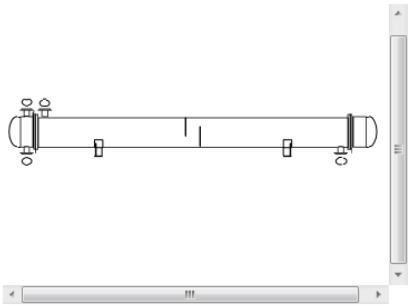


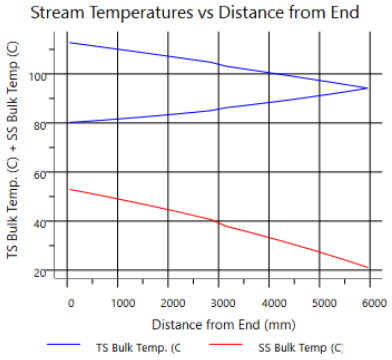
Geometry | Process | Errors & Warnings | Run Status

Calculation mode: Simulation

		Recent	Previous
Configuration			
TEMA Type	B - / E - / M -	BEM	
Tube layout option	New (optimum) layout	New (optimum) layout	
Location of hot fluid	Tube side	Tube side	
Tube OD / Pitch	mm: 19.05 / 23.81	19.05 / 23.81	/
Tube pattern	30-Triangular	30	
Tubes are in baffle window	Yes	Yes	
Baffle type	Single segmental	Single segmental	
Baffle cut orientation	Horizontal	H	
Default exchanger material	Carbon Steel / 1	Carbon Steel	
Size			
Specify some sizes for Design	Set default		
Shell ID / OD	mm: 580 / 599.05	580 / 599.05	/
Tube length	mm: 6000	6000	
Baffle spacing center-center (Bc)	mm: 300	300	
Number of baffles	2	2	
Number of tubes / Tube passes	120 / 2	120 / 2	/
Shells in series	1	1	
Shells in parallel	1	1	
Overall Results			
Excess surface (%)		0	
Dp-ratio Shellside / Tubeside		0.0806 / 0.3254	/
Total cost (all shells)	Dollar(US)	27895	

Setting Plan | Tube Layout





Design | Rating | Worksheet | Performance | Dynamics | Rigorous Shell&Tube

Rating

- Sizing
- Parameters
- Nozzles
- Heat Loss

Sizing Data

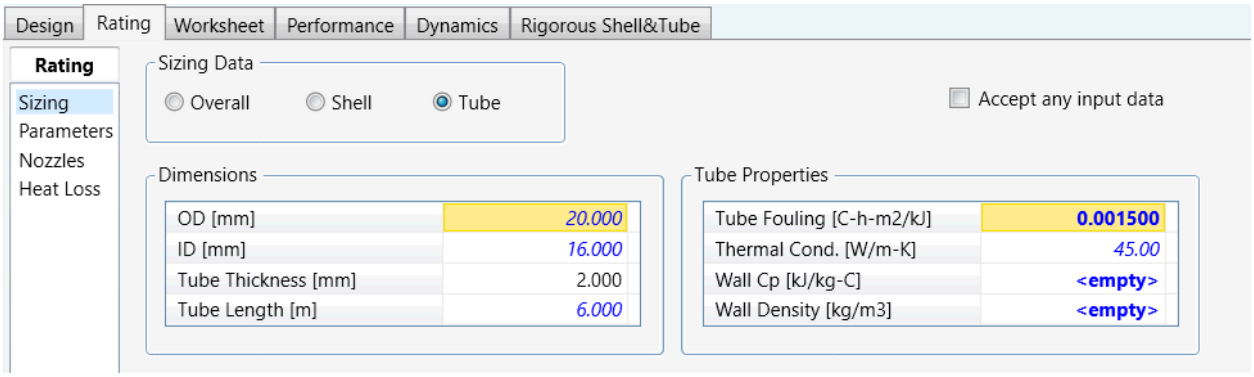
Overall | Shell | Tube

Shell and Tube Bundle Data

Shell Diameter [mm]	739.05
Number of Tubes per Shell	160
Tube Pitch [mm]	50.00
Tube Layout Angle	Triangular (30 degrees)
Shell Fouling [C-h-m2/kJ]	0.000073

Shell Baffles

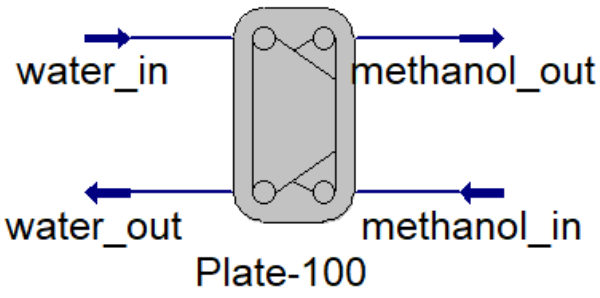
Shell Baffle Type	Single
Shell Baffle Orientation	Horizontal
Baffle Cut (%Height) [%]	20.00
Baffle Spacing [mm]	800.00



Situation 2 :

1. Objective:

This addendum evaluates the **existing shell and tube heat exchanger**, initially designed for heating benzene with toluene, for a **new service**: heating **methanol using high-temperature water**. The same **heat duty (10.5 MMBTU/hr)** is maintained. The goal is to **rate** and **retune** the exchanger and assess its performance under the new operating conditions.



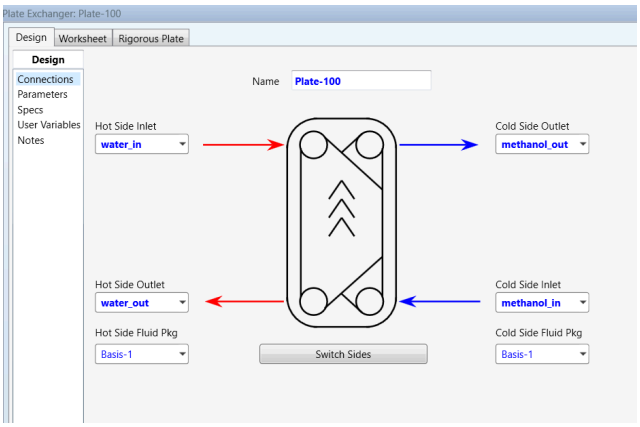


Plate Exchanger: Plate-100

Design | Worksheet | Rigorous Plate

Worksheet

- Conditions
- Properties
- Composition

Name	water_in	methanol_in	water_out	methanol_out
Vapour	1.0000	0.0000	1.0000	0.0000
Temperature [F]	**500.0**	**60.00**	**422.4**	72.90
Pressure [psia]	**100.0**	**100.0**	95.00	95.00
Molar Flow [lbmole/hr]	1443	2809	1443	2809
Mass Flow [lb/hr]	**2.600e+004**	**9.000e+004**	2.600e+004	9.000e+004
Std Ideal Liq Vol Flow [barrel/day]	1784	7745	1784	7745
Molar Enthalpy [Btu/lbmole]	-1.006e+005	-1.044e+005	-1.013e+005	-1.041e+005
Molar Entropy [Btu/lbmole-F]	42.37	3.059	41.74	3.712
Heat Flow [Btu/hr]	-1.452e+008	-2.933e+008	-1.461e+008	-2.924e+008

Plate Exchanger: Plate-100

Design | Worksheet | Rigorous Plate

Design

- Connections
- Parameters
- Specs
- User Variables
- Notes

Rating Method

Simple End Point

Overall UA	2446 Btu/F-hr
Area	*1076 ft2*
Heat Transfer Coefficient	2.273 Btu/hr-ft2-F

	Hot Side	Cold Side
Pressure Drop [psi]	**5.000**	**5.000**