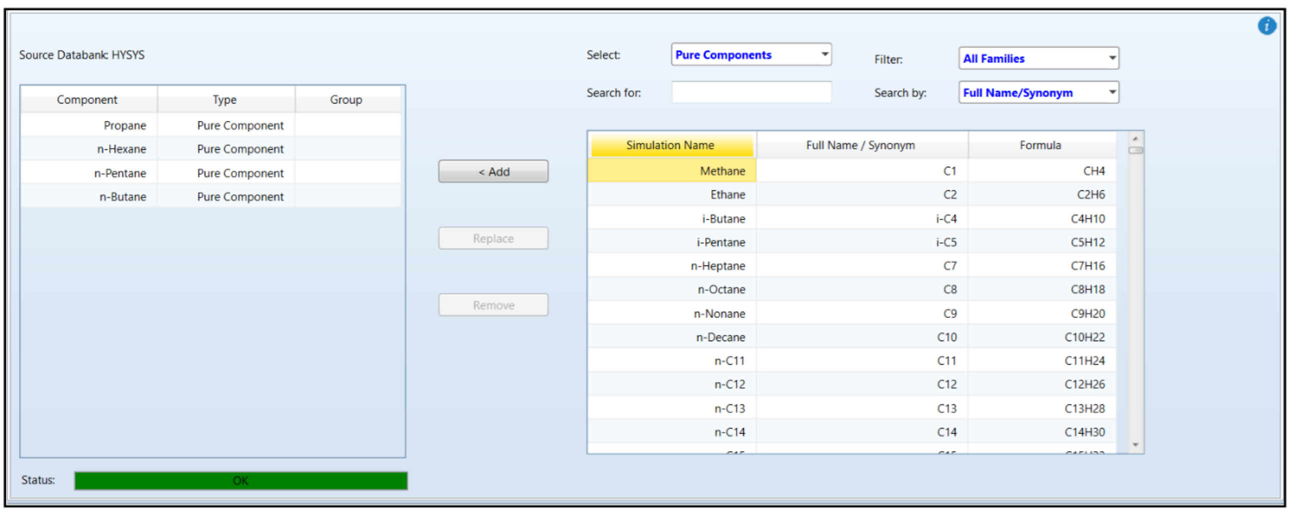
Distillation Column Simulation

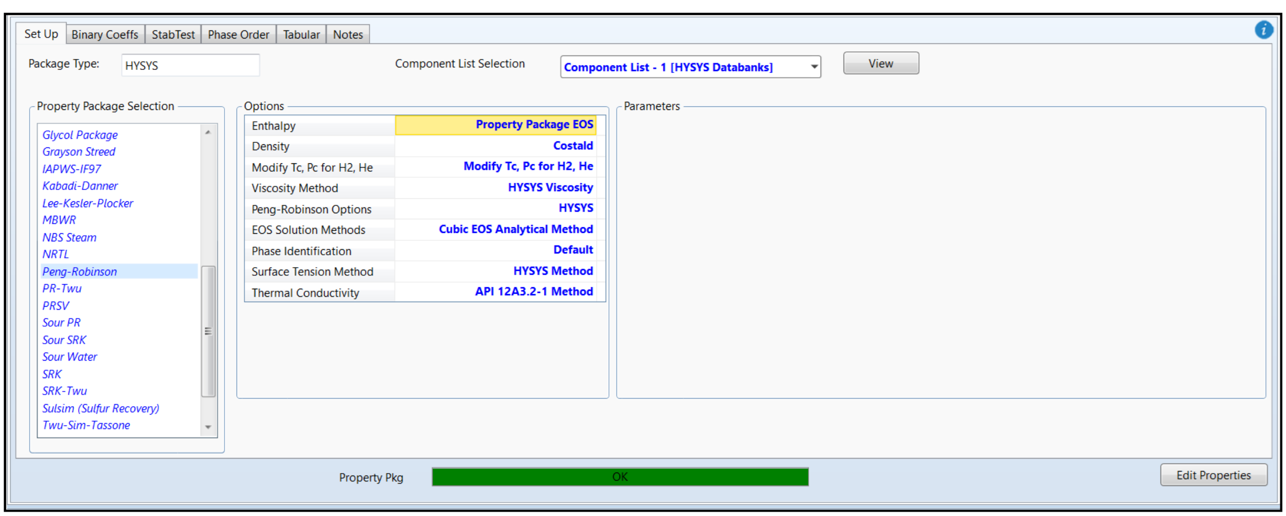
Example: 100 kmol·h−1 of a mixture containing 10, 20, 30, and 40 mol% of propane, *n*-butane, *n*-pentane, and *n*-hexane, respectively, is preheated before entering a distillation tower. Initial temperature of the mixture is 25 ◦C, and the pressure drop can be neglected. The preheated vapor fraction is 0.2. The preheated mixture has to be separated in a distillation tower. The mole fraction of *n*-pentane in the distillate product is 0.05 and that of *n*-butane in the bottom product is also 0.05. Using the Fenske–Underwood–Gilliland method, calculate the minimum reflux ratio and the minimum number of theoretical stages needed. Assuming a reflux ratio 1.5 times higher than the minimum reflux ratio, calculate the actual number of trays, optimal feed stage, condenser and reboiler temperature, and distribution of non-key components into the distillate and bottom. Consider a uniform pressure in the column of 700 kPa.

How to simulate:

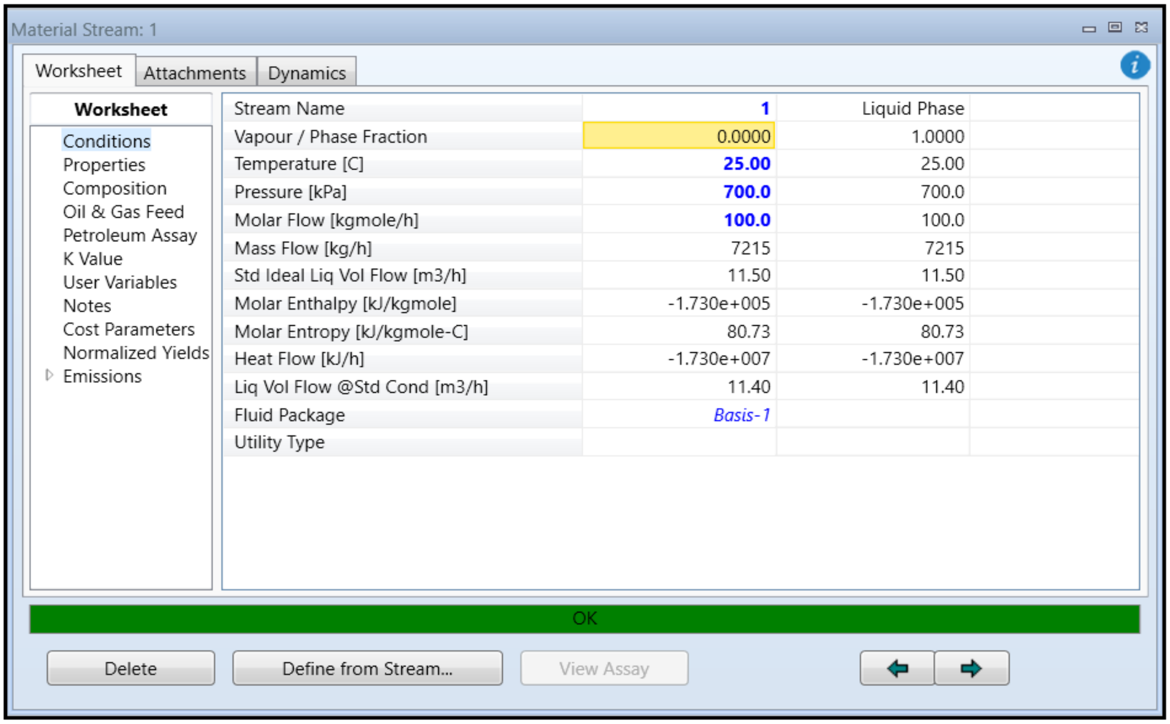
1.Add components to the component list.

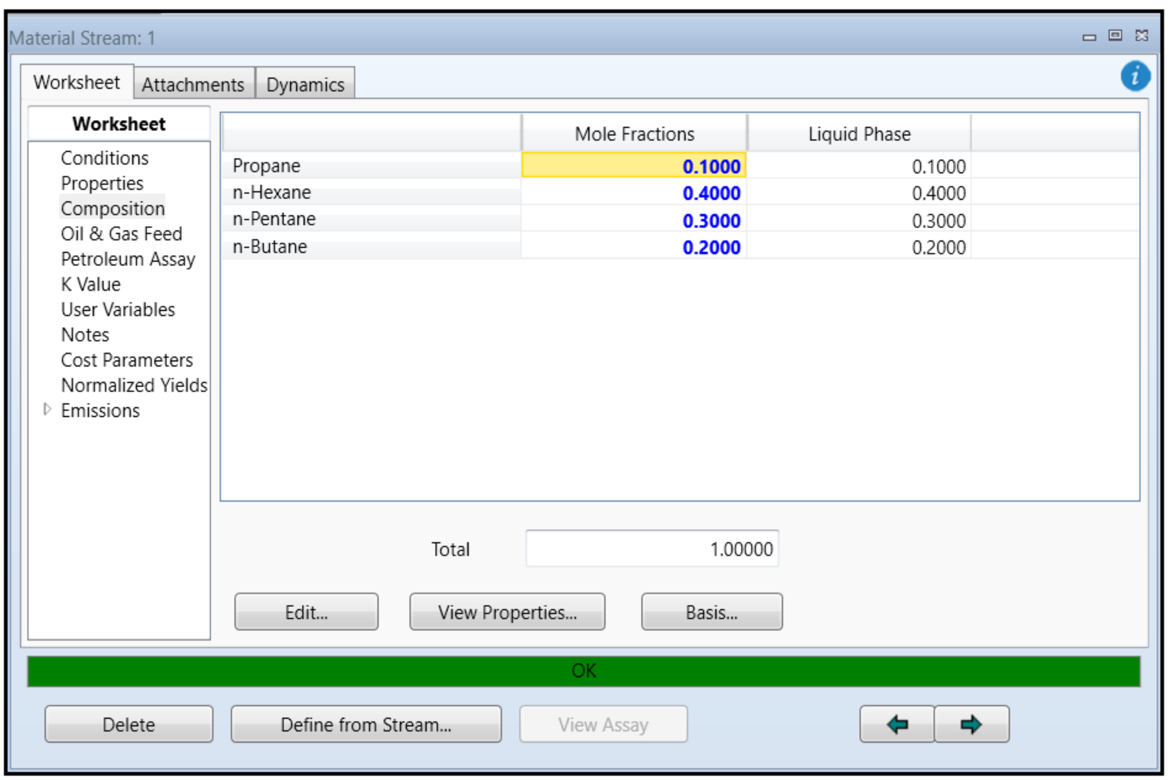


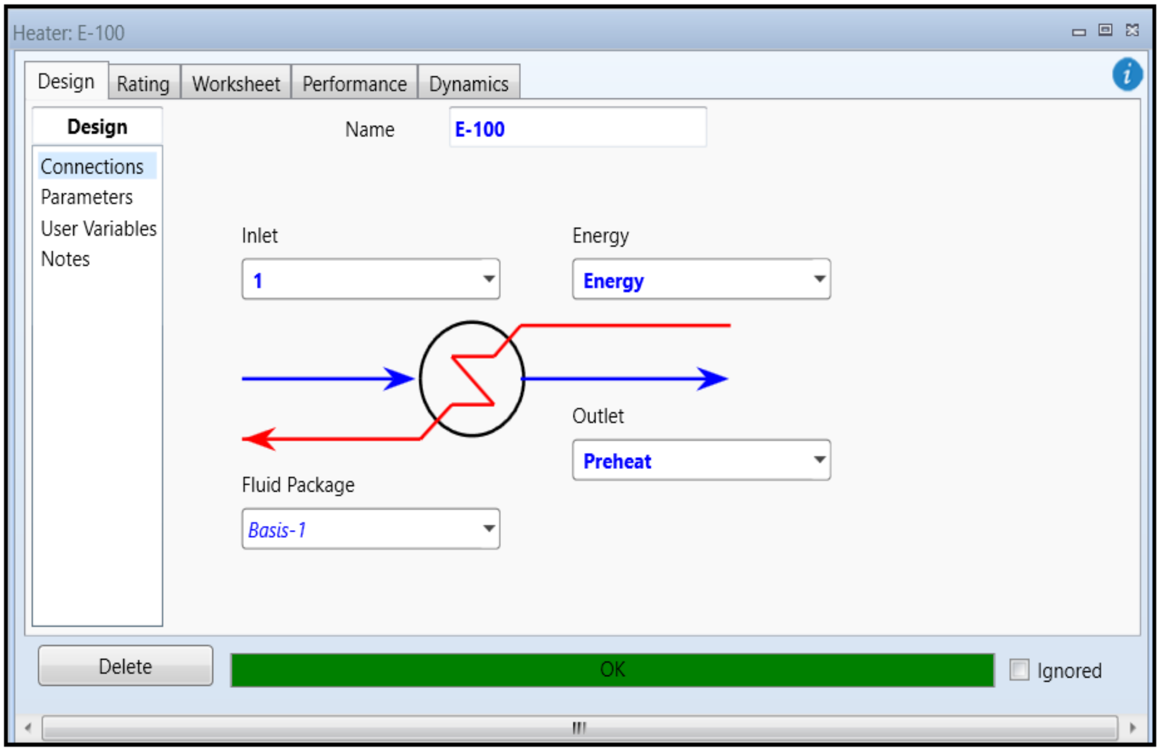
2.Select Peng-Robinson as the Fluid Package.

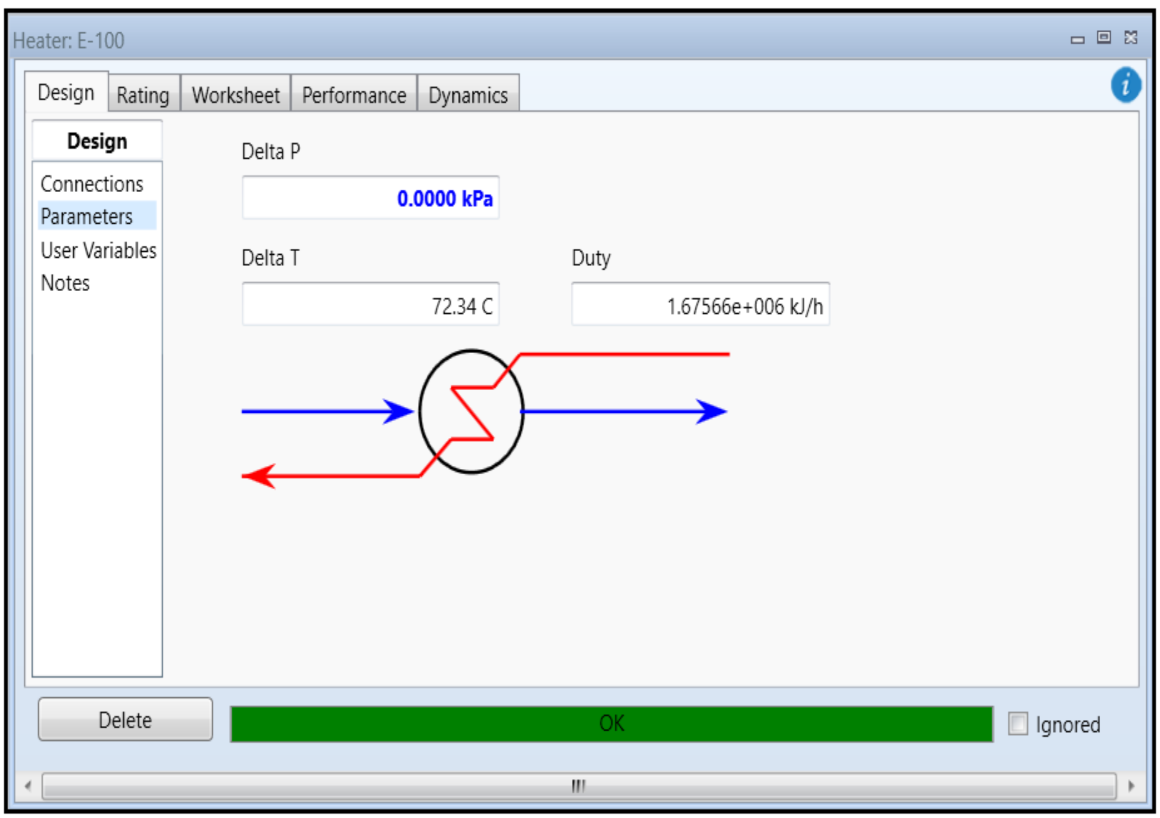


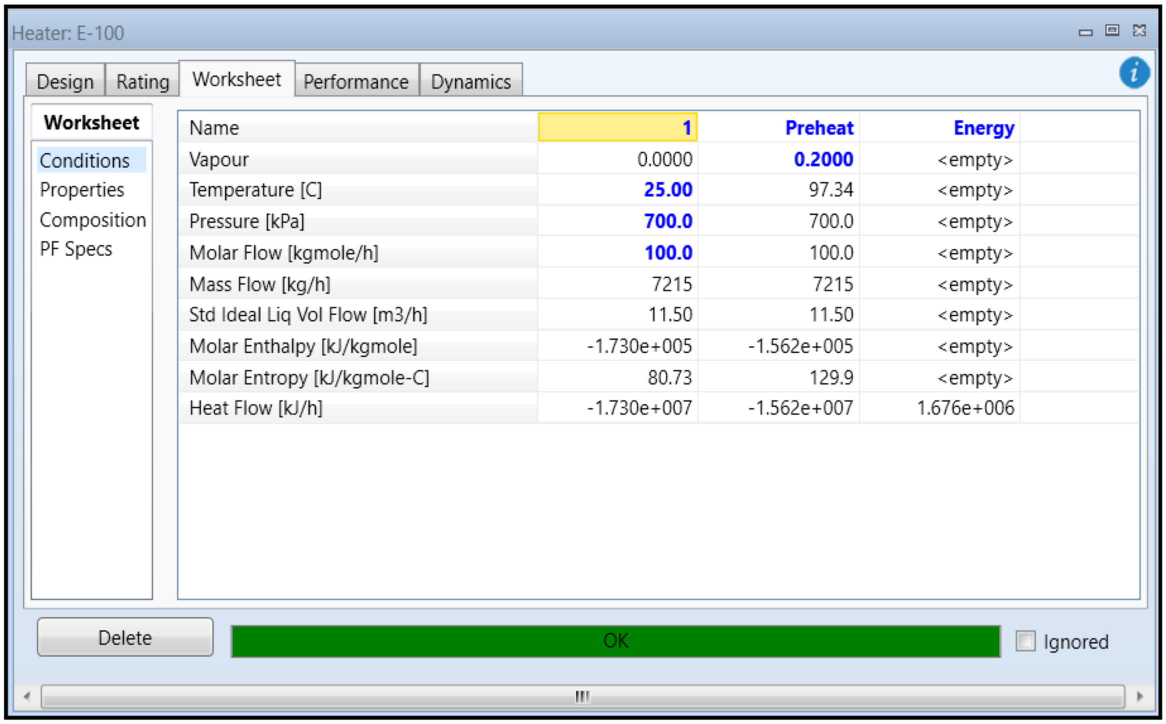
3.Enter Simulation Environment and define streams and set-up the heater.






Heater: E-100
Design
Rating
Worksheet
Performance
Dynamics
Design
Connections
Parameters
User Variables
Notes
Name
E-100
Inlet
1
Energy
Energy
Outlet
Preheat
Fluid Package
Basis-1
Delete
OK
Ignored


Heater: E-100
Design
Rating
Worksheet
Performance
Dynamics
Design
Connections
Parameters
User Variables
Notes
Delta P
0.0000 kPa
Delta T
72.34 C
Duty
1.67566e+006 kJ/h
Delete
OK
Ignored



Heater: E-100

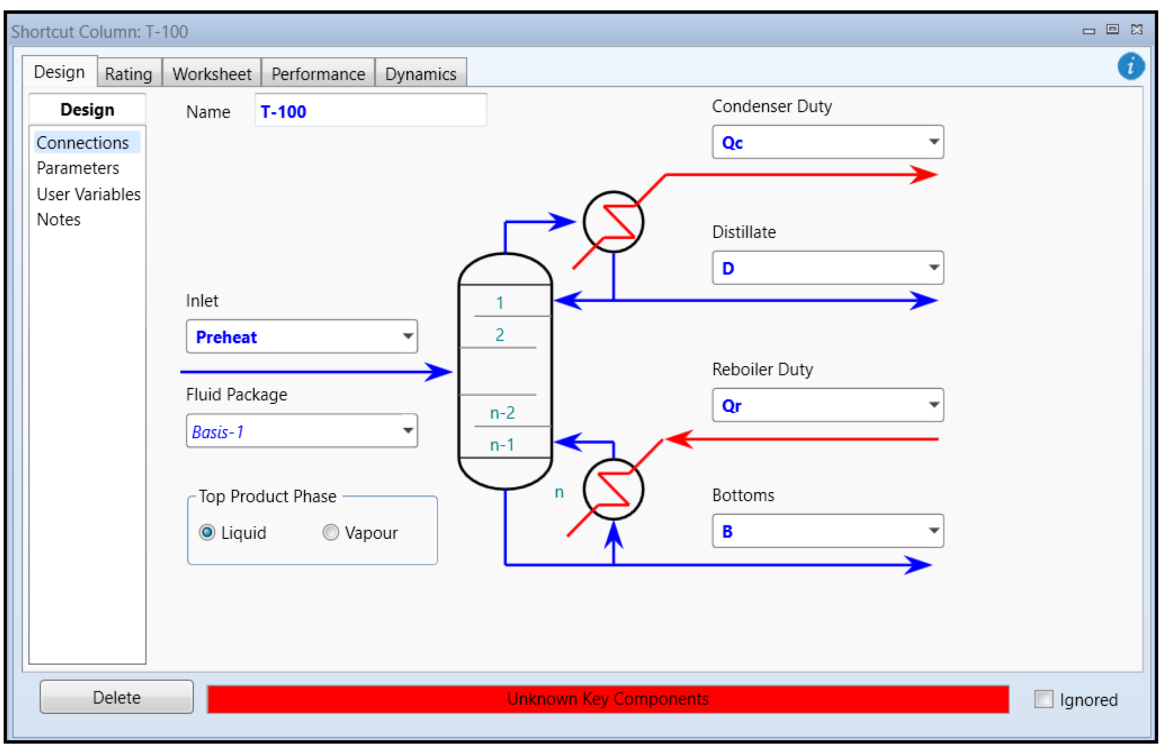
Design | Rating | Worksheet | Performance | Dynamics

Worksheet: Conditions, Properties, Composition, PF Specs

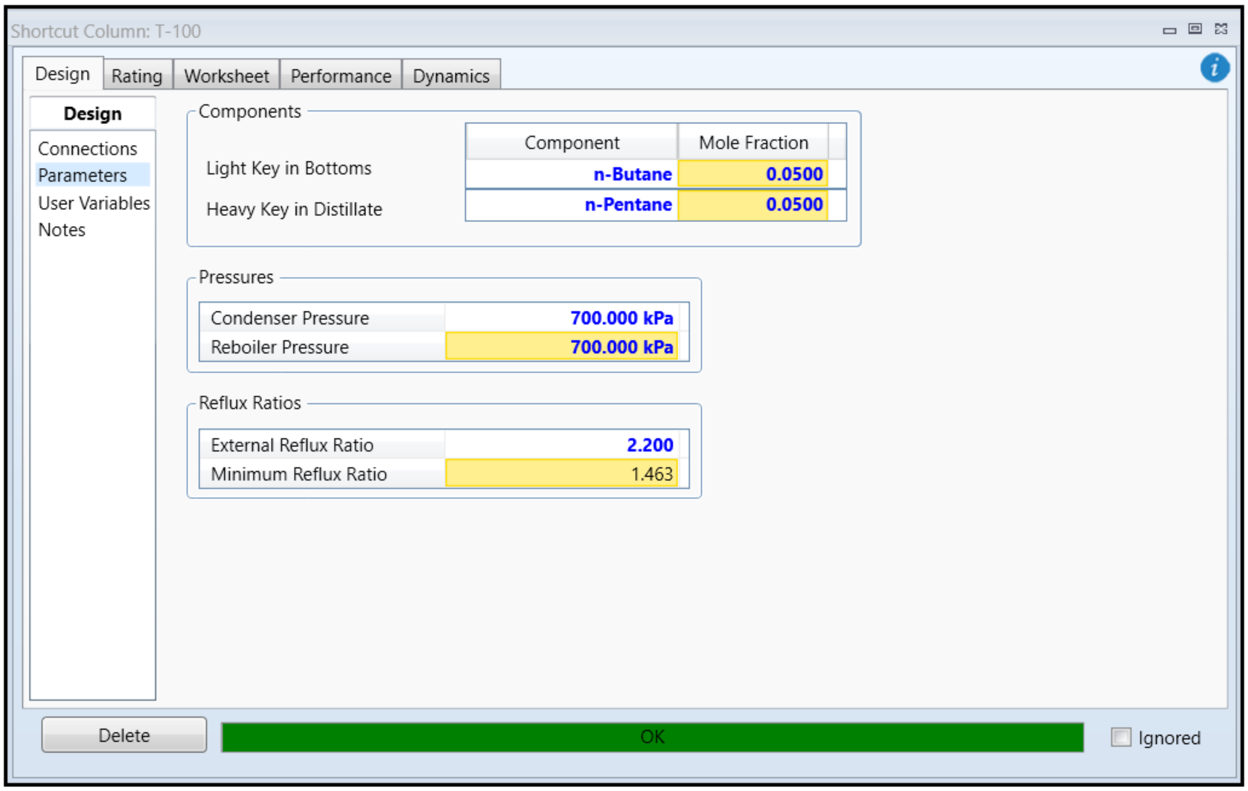
Name	1	Preheat	Energy
Vapour	0.0000	0.2000	<empty>
Temperature [C]	25.00	97.34	<empty>
Pressure [kPa]	700.0	700.0	<empty>
Molar Flow [kgmole/h]	100.0	100.0	<empty>
Mass Flow [kg/h]	7215	7215	<empty>
Std Ideal Liq Vol Flow [m3/h]	11.50	11.50	<empty>
Molar Enthalpy [kJ/kgmole]	-1.730e+005	-1.562e+005	<empty>
Molar Entropy [kJ/kgmole-C]	80.73	129.9	<empty>
Heat Flow [kJ/h]	-1.730e+007	-1.562e+007	1.676e+006

Delete | OK | Ignored

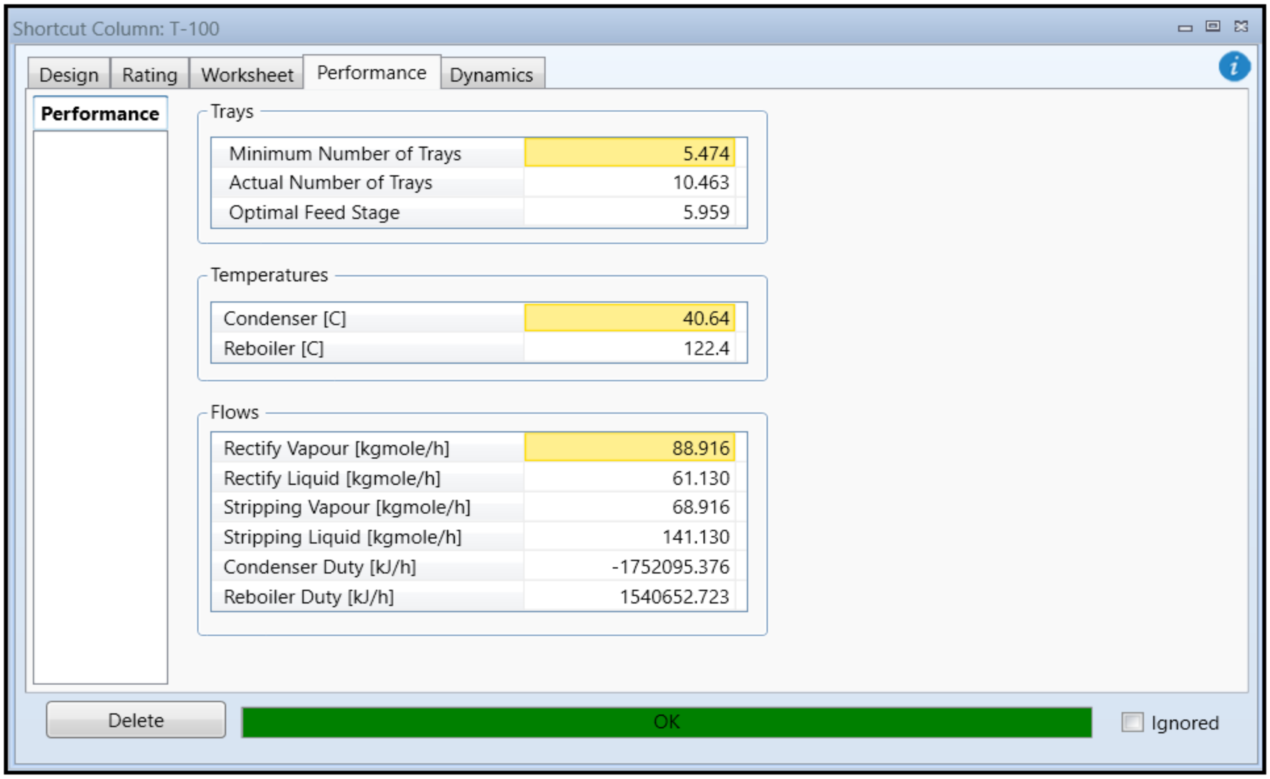
4.Select a Short-cut from Model Pallete/Separators. Act like below:

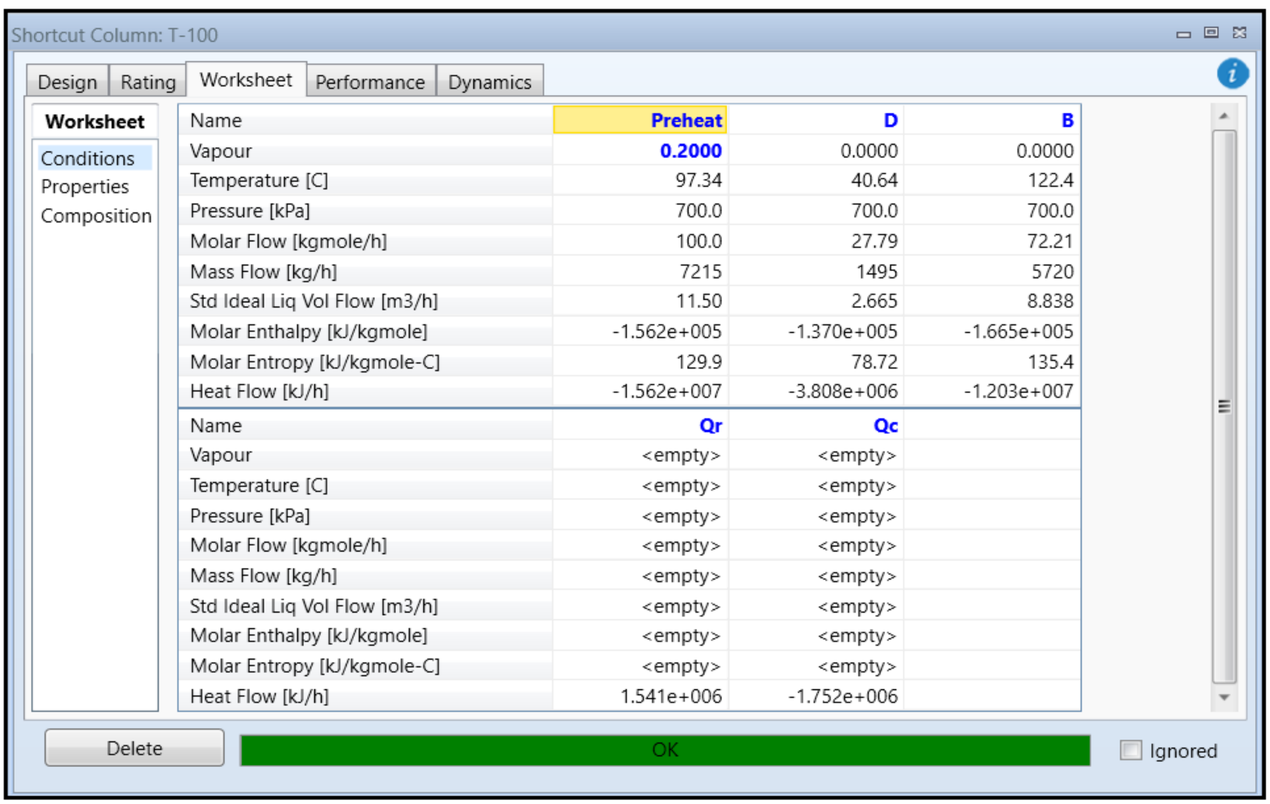


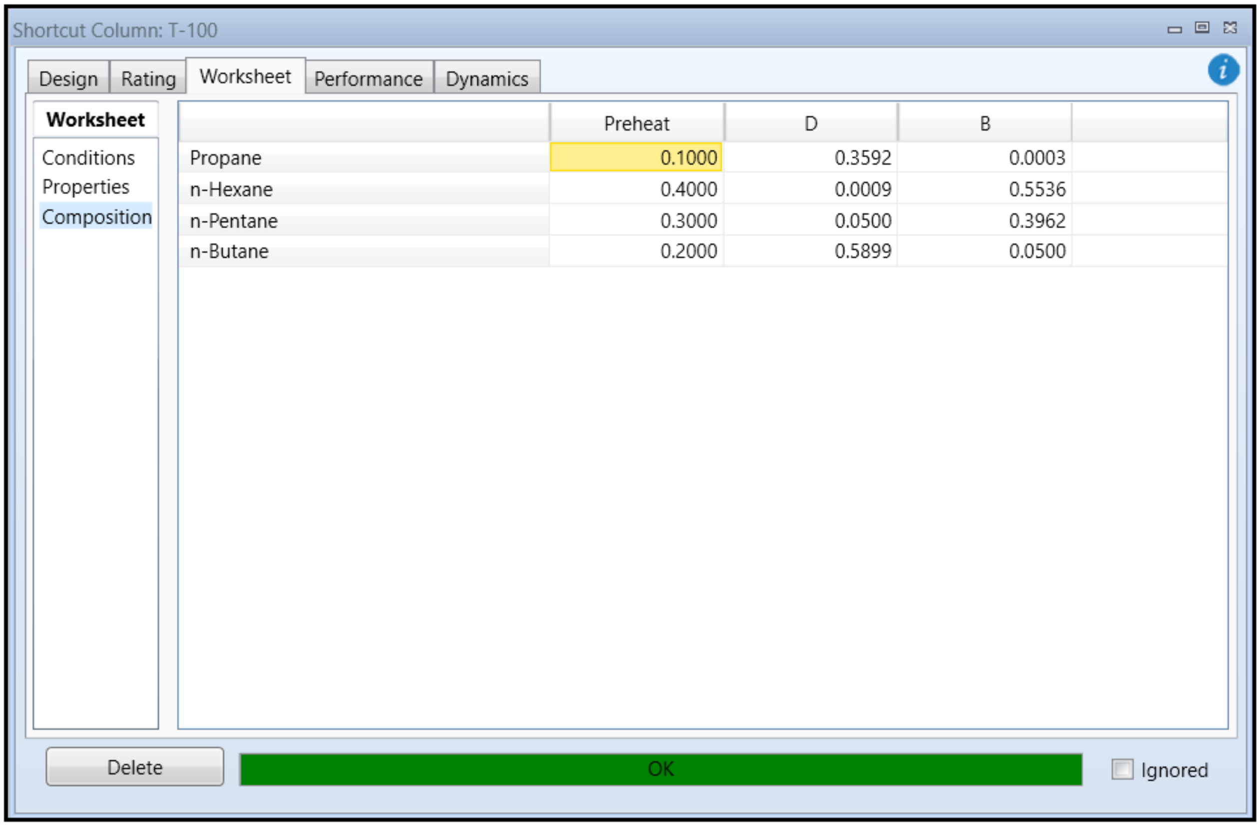
5. On the Parameters tab, under Design, complete the requirements for key component distribution and column pressure; when these parameters are specified, HYSYS calculates the minimum reflux ration. Calculate the value of the external reflux ratio by multiplication of this value with the given coefficient and enter it as value of External Reflux Ratio.



6. On the Performance page, check the distillation column parameters; on the Composition tab, under Worksheet, check the composition of products.


Shortcut Column: T-100
Design
Rating
Worksheet
Performance
Dynamics
Performance
Trays
Minimum Number of Trays 5.474
Actual Number of Trays 10.463
Optimal Feed Stage 5.959
Temperatures
Condenser [C] 40.64
Reboiler [C] 122.4
Flows
Rectify Vapour [kgmole/h] 88.916
Rectify Liquid [kgmole/h] 61.130
Stripping Vapour [kgmole/h] 68.916
Stripping Liquid [kgmole/h] 141.130
Condenser Duty [kJ/h] -1752095.376
Reboiler Duty [kJ/h] 1540652.723
Delete
OK
Ignored

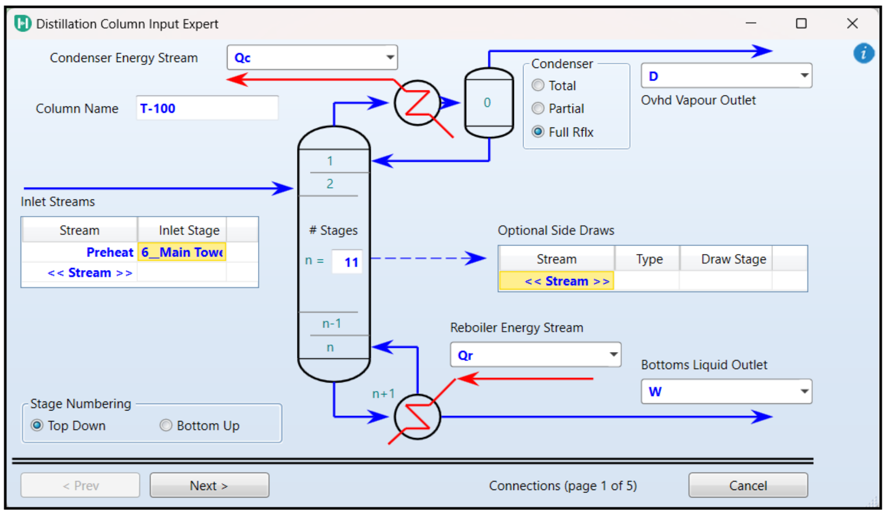

Shortcut Column: T-100
Design
Rating
Worksheet
Performance
Dynamics
Worksheet
Conditions
Properties
Composition
Name Preheat D B
Vapour 0.2000 0.0000 0.0000
Temperature [C] 97.34 40.64 122.4
Pressure [kPa] 700.0 700.0 700.0
Molar Flow [kgmole/h] 100.0 27.79 72.21
Mass Flow [kg/h] 7215 1495 5720
Std Ideal Liq Vol Flow [m3/h] 11.50 2.665 8.838
Molar Enthalpy [kJ/kgmole] -1.562e+005 -1.370e+005 -1.665e+005
Molar Entropy [kJ/kgmole-C] 129.9 78.72 135.4
Heat Flow [kJ/h] -1.562e+007 -3.808e+006 -1.203e+007
Name Qr Qc
Vapour <empty> <empty>
Temperature [C] <empty> <empty>
Pressure [kPa] <empty> <empty>
Molar Flow [kgmole/h] <empty> <empty>
Mass Flow [kg/h] <empty> <empty>
Std Ideal Liq Vol Flow [m3/h] <empty> <empty>
Molar Enthalpy [kJ/kgmole] <empty> <empty>
Molar Entropy [kJ/kgmole-C] <empty> <empty>
Heat Flow [kJ/h] 1.541e+006 -1.752e+006
Delete
OK
Ignored


Shortcut Column: T-100
Design
Rating
Worksheet
Performance
Dynamics
Worksheet
Conditions
Properties
Composition
Preheat
D
B
Propane 0.1000 0.3592 0.0003
n-Hexane 0.4000 0.0009 0.5536
n-Pentane 0.3000 0.0500 0.3962
n-Butane 0.2000 0.5899 0.0500
Delete
OK
Ignored

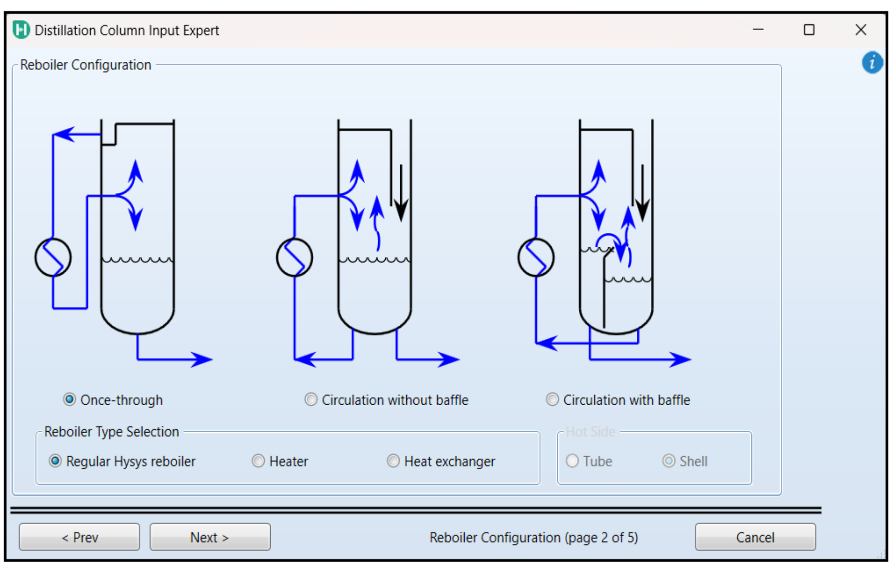
Example 2: Using the rigorous inside-out method, calculate the dependence between the number of theoretical stages and the reflux ratio, if the preheated mixture from Example 1 is separated in a distillation tower, the distillate contains 99 mol% of light components (propane and n-butane) and at the same time common recovery of propane and n-butane is more than 99%. Use the Full Reflux condenser type and neglect the pressure drop in the column and heat exchangers.

How to simulate:

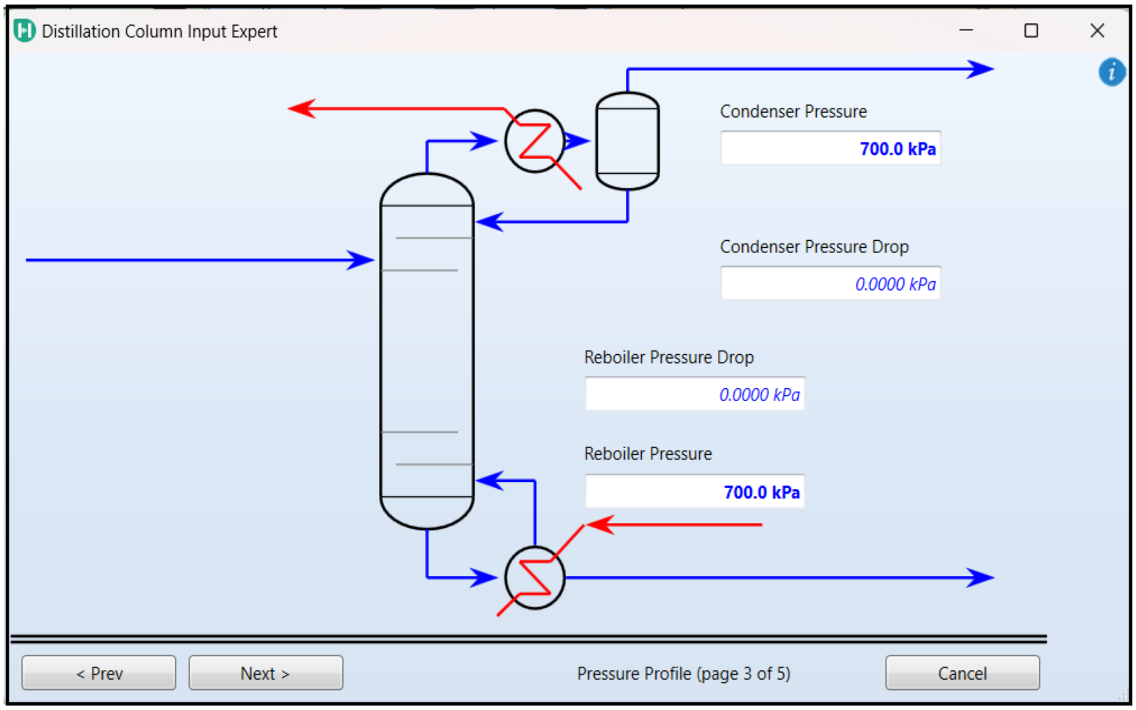
1.Connect Preheat stream as the inlet, define D and W as the outlet streams and Qc and Qr as the energy required for condenser and reboiler. Then click Next.



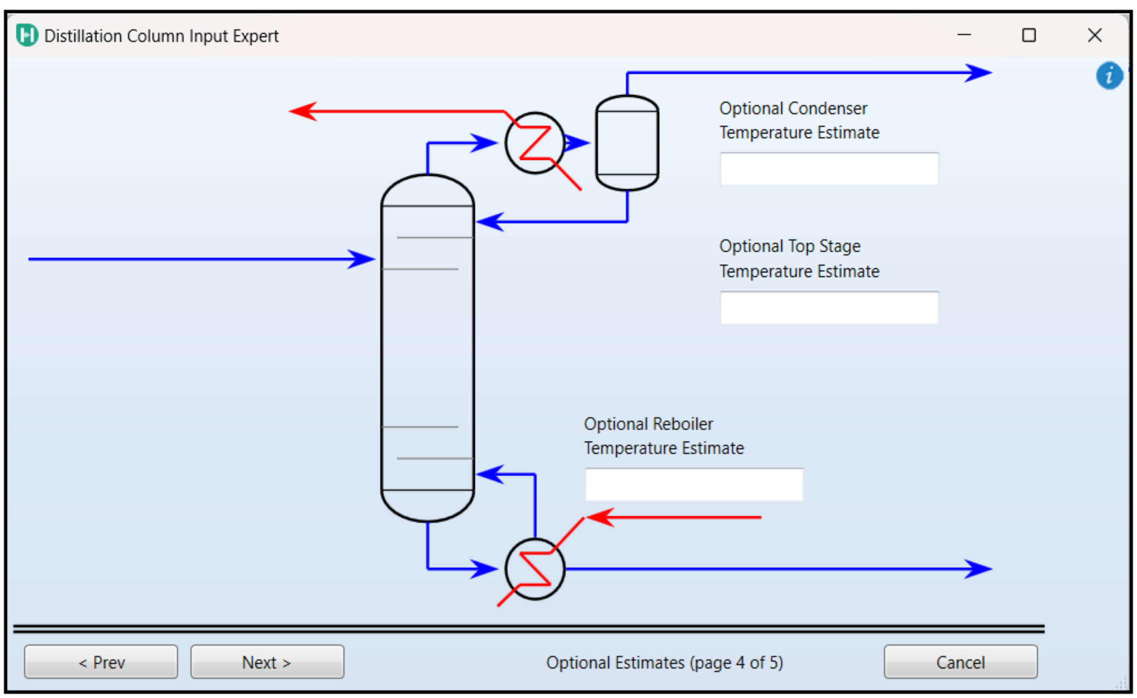
2. Select the reboiler configuration, you can use the default selected reboiler type.



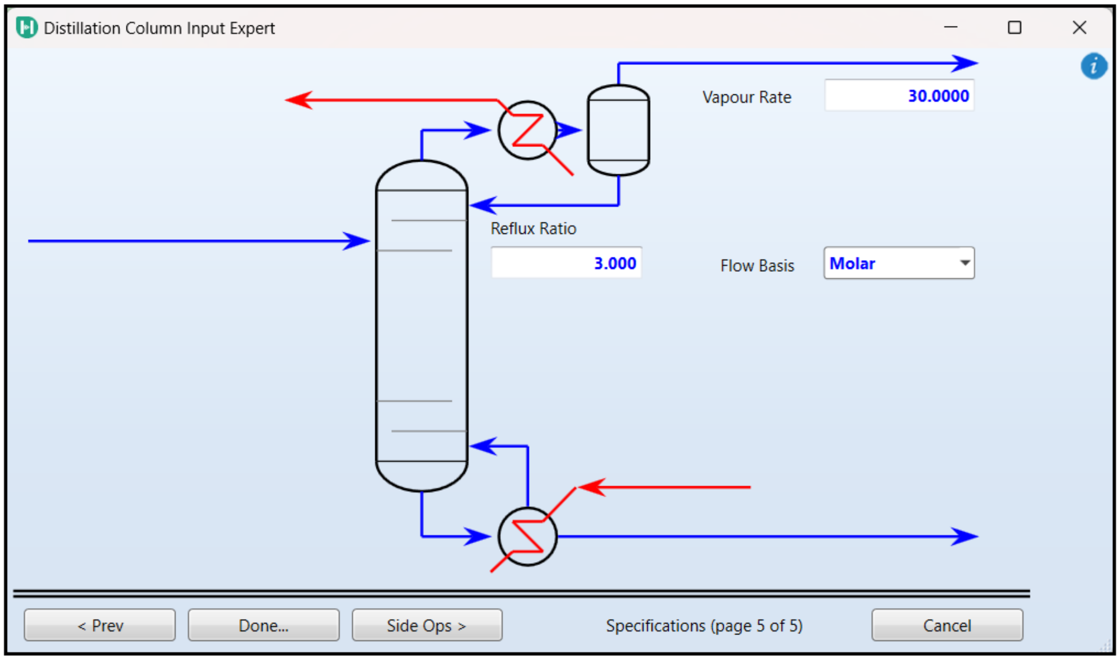
3. Enter condenser and reboiler pressure of 700 kPa for both equipment.



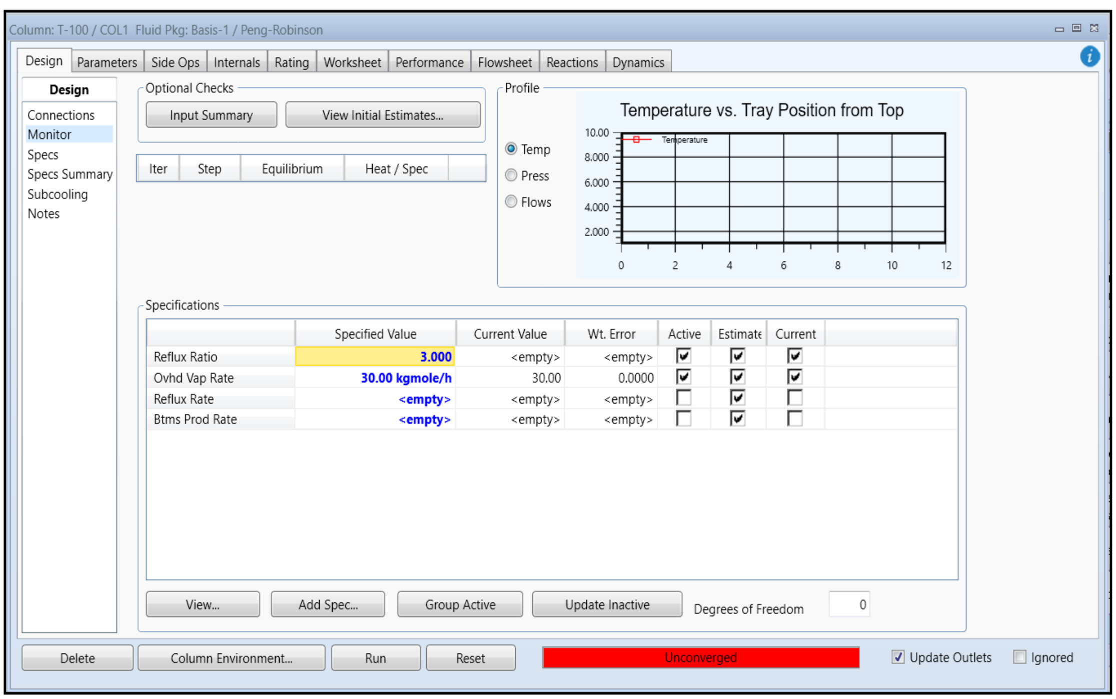
4. On the next page, the condenser and reboiler optimum temperature can be specified, but it is not mandatory, click Next and allow HYSYS to estimate the condenser and reboiler temperature.



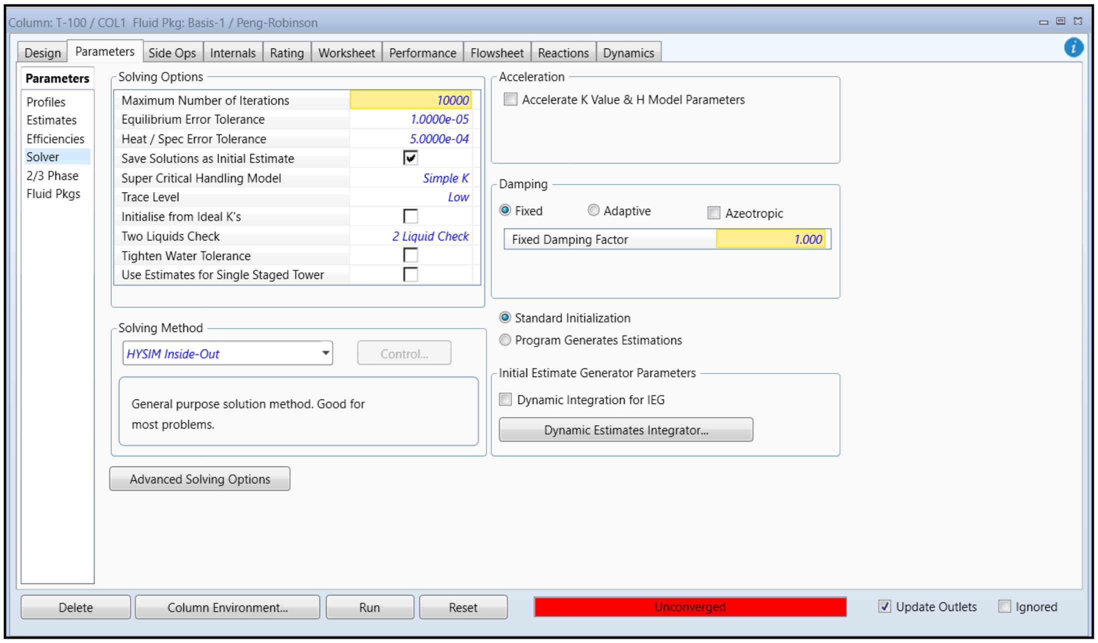
5. On the next page, check if flow basis is set to Molar and enter the initial values of the distillation rate (vapor rate) and the reflux ratio. The total amount of propane and n-butane in the feed is 30 kmol·h−1, so this value can be chosen as the vapor rate. Finally click Done.



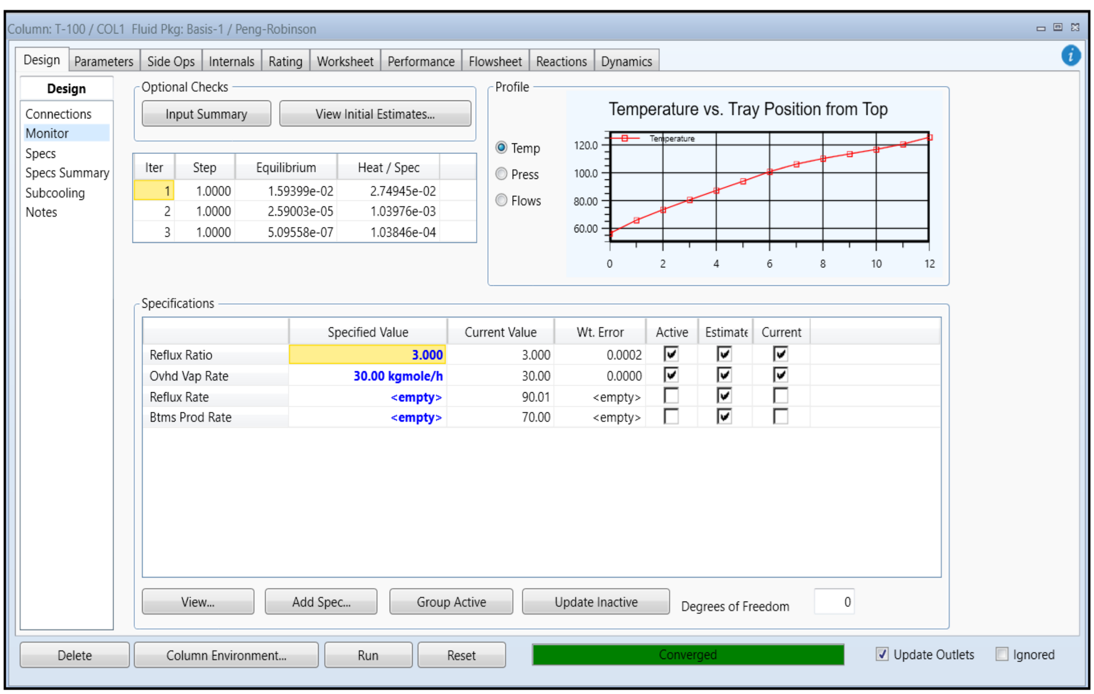
6. Before running the column, check if the value of the degrees of freedom is zero and the values of activated specifications are specified.



7. Move to the Solver tab, under Parameters, and check if the HISIM inside-out method is set as the solving method;



8. Run the column; if the calculations converge, HYSYS indicates it by green color and converged.



9.Result:

Name	Preheat @COL1	D @COL1	W @COL1
Vapour	0.2000	1.0000	0.0000
Temperature [C]	97.34	56.34	125.6
Pressure [kPa]	700.0	700.0	700.0
Molar Flow [kgmole/h]	100.0	30.00	70.00
Mass Flow [kg/h]	7215	1621	5594
Std Ideal Liq Vol Flow [m3/h]	11.50	2.883	8.620
Molar Enthalpy [kJ/kgmole]	-1.562e+005	-1.177e+005	-1.669e+005
Molar Entropy [kJ/kgmole-C]	129.9	138.5	137.7
Heat Flow [kJ/h]	-1.562e+007	-3.532e+006	-1.169e+007

	Preheat	D	W
Propane	0.1000	0.3332	0.0000
n-Hexane	0.4000	0.0001	0.5714
n-Pentane	0.3000	0.0421	0.4105
n-Butane	0.2000	0.6246	0.0180

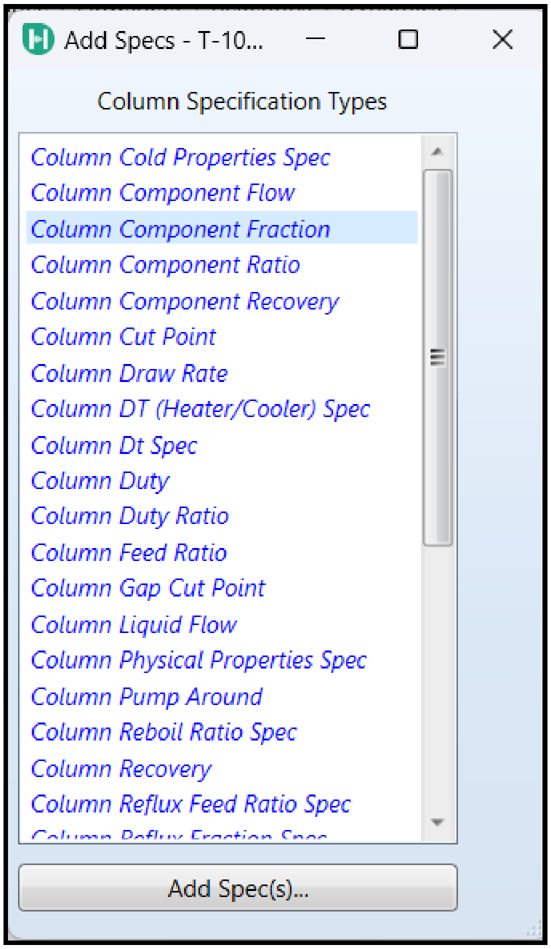
Condenser

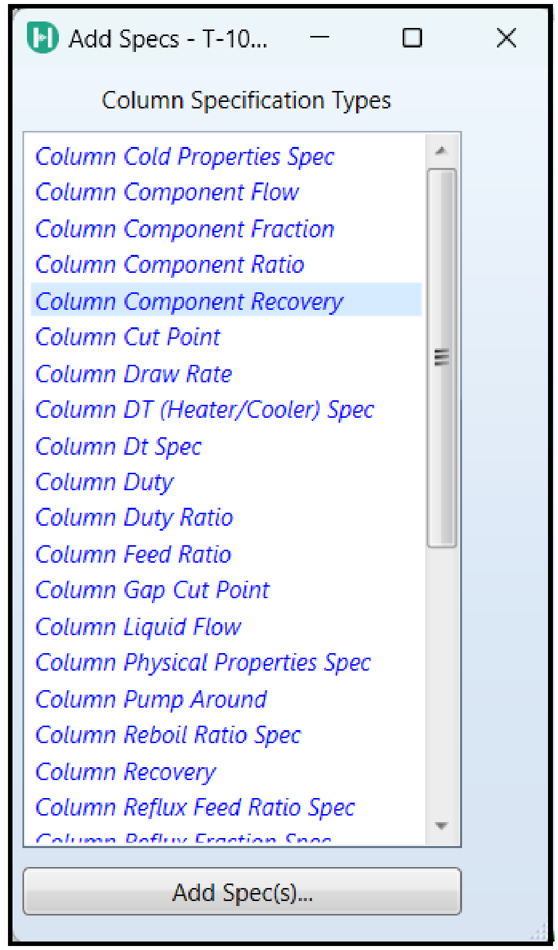
Type	Total reflux
Temperature	56.34 C
Pressure	700.0 kPa
Duty	1.822e+006 kJ/h
Reflux Flowrate	90.01 kgmole/h

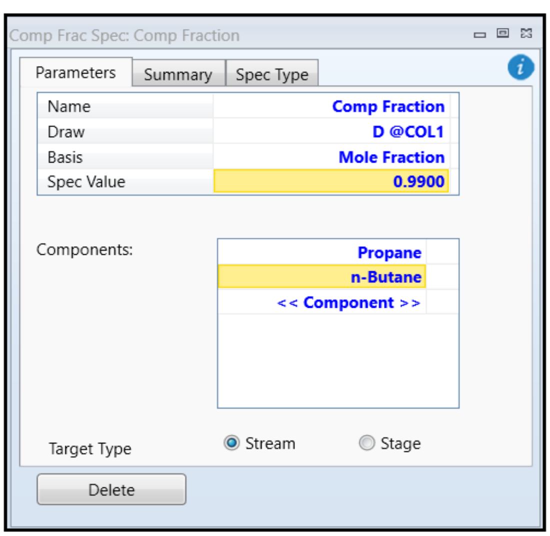
Reboiler

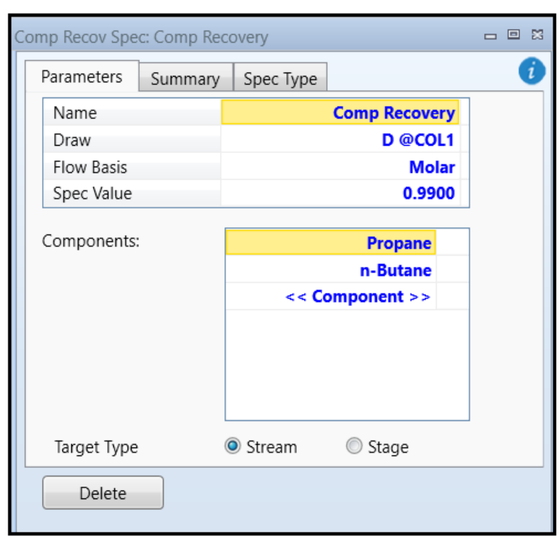
Type	Regular
Temperature	125.6 C
Pressure	700.0 kPa
Duty	2.227e+006 kJ/h
Outlet Flowrate	70.00 kgmole/h

10.Changing the specs.









	Preheat	D	W
Propane	0.1000	0.3333	0.0000
n-Hexane	0.4000	0.0000	0.5714
n-Pentane	0.3000	0.0100	0.4243
n-Butane	0.2000	0.6567	0.0043