

Problem on optimization of distillation column

By: Hemang Tailor

3700 kg/hr mixture of Tetrahydrofuran (THF) and Toluene (44 mass % of THF) at 10 degrees Celsius and 140 Kpa is to be separated by distillation to get each of them with purity of 99.5 mass % of THF and 94% mass % of Toluene.

Fluid package - Wilson

Condenser and reboiler pressure - 103 Kpa and 107 Kpa

Condenser - Total Condenser

Number of stages - 10

Feed cost - 0.05 \$/kg

Pure toluene selling price - 0.136 \$/kg

Pure THF selling price - 0.333 \$/kg

Cooling cost - 0.471 \$/Kw.hr

Heating Cost - 0.737 \$/kw.hr

Use a range of 0.99 to 0.999 for THF limit and 0.9 to 0.99 for Toluene to optimize distillation unit

CALCULATE

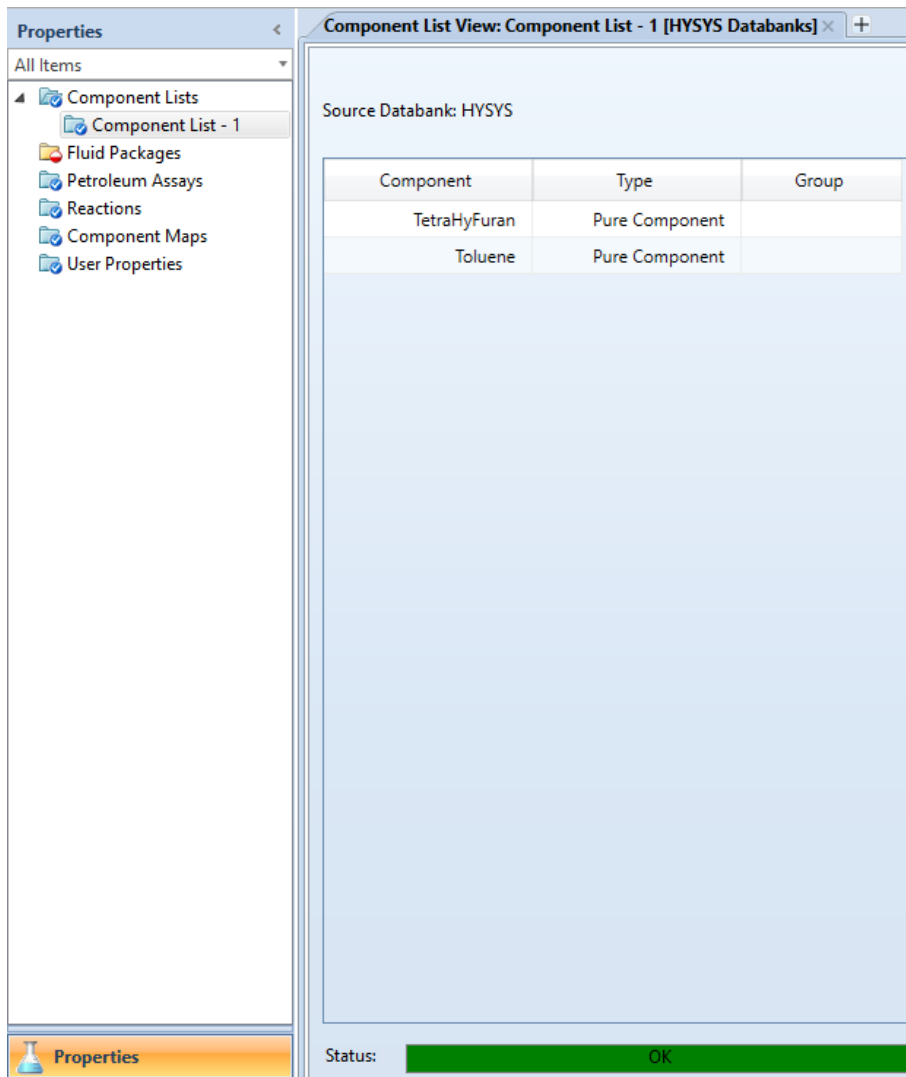
- Reflux Ratio

- Distillate Rate

Under the condition that we have maximum profit

We are using **Aspen Hysys** to optimize the distillation column and will find reflux ratio and distillate rate at maximum profit condition.

1. We start with choosing the components:

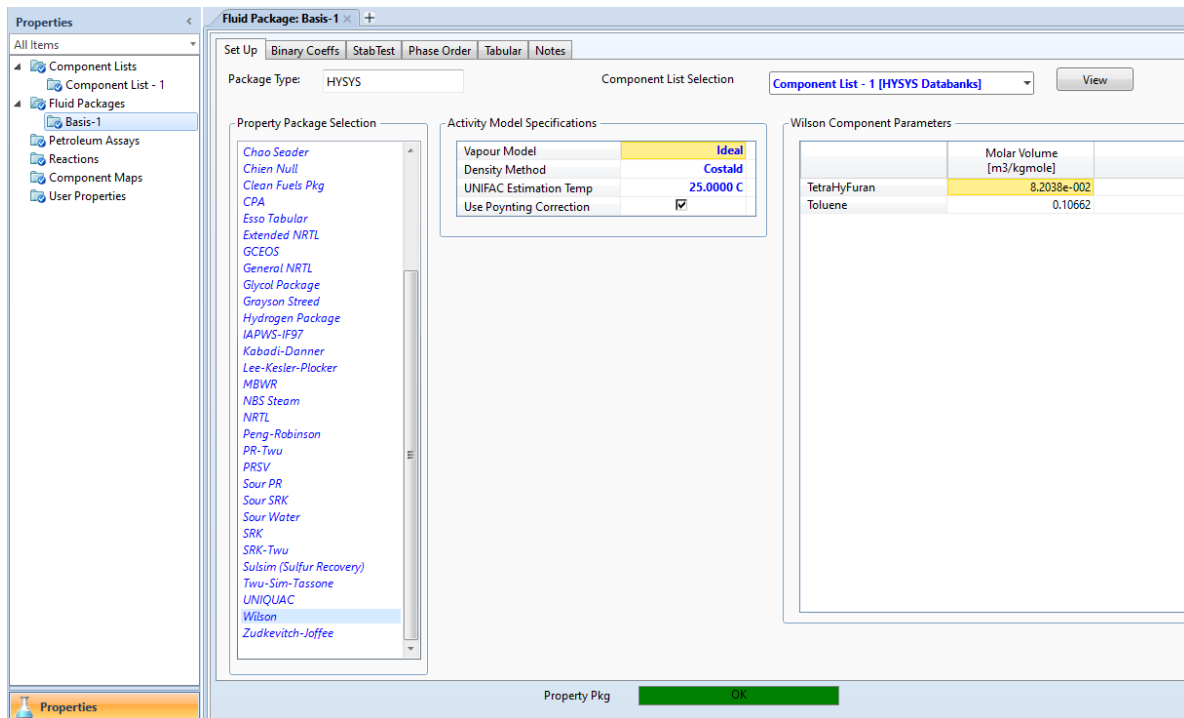


The screenshot shows the Aspen Hysys software interface. On the left, the 'Properties' pane is open, showing a tree view of 'Component Lists' with 'Component List - 1' selected. The main window is titled 'Component List View: Component List - 1 [HYSYS Databanks]'. It displays 'Source Databank: HYSYS' and a table of components.

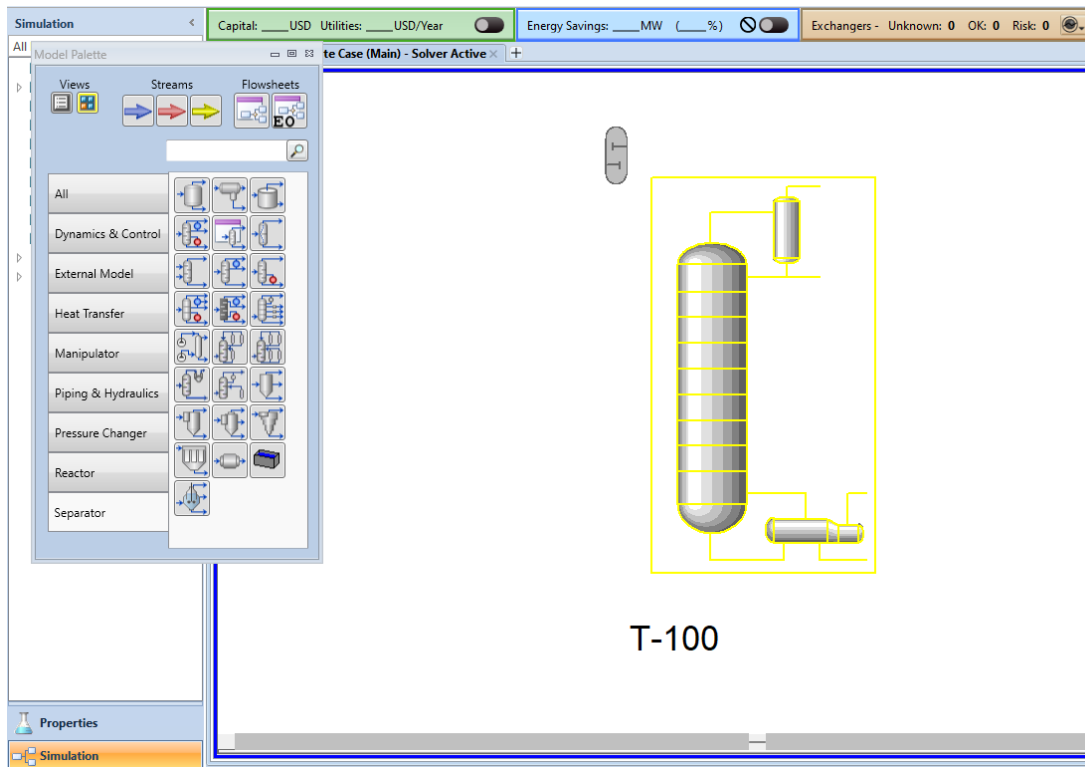
Component	Type	Group
TetraHyFuran	Pure Component	
Toluene	Pure Component	

At the bottom of the window, there is a 'Status:' label and a green bar with the text 'OK'.

2. We choose the Wilson fluid package, then start simulation.



3. We brought out a distillation column.



4. Set the initial conditions at feed, composition of feed etc.

Material Stream: Feed

Worksheet Attachments Dynamics

Worksheet

- Conditions
- Properties
- Composition
- Oil & Gas Feed
- Petroleum Assay
- K Value
- User Variables
- Notes
- Cost Parameters
- Normalized Yields
- Emissions

	Mass Fractions	Liquid Phase
TetraHyFuran	0.4400	0.4400
Toluene	0.5600	0.5600

Material Stream: Feed

Worksheet Attachments Dynamics

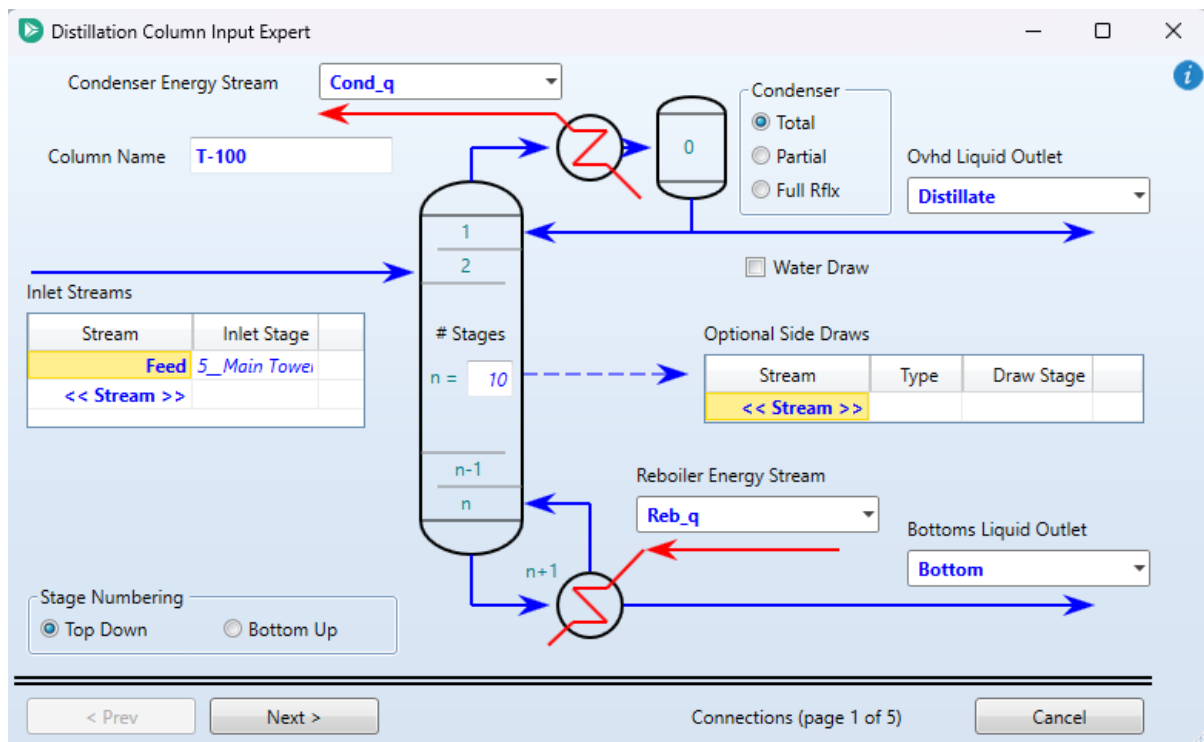
Worksheet

- Conditions
- Properties
- Composition
- Oil & Gas Feed
- Petroleum Assay
- K Value
- User Variables
- Notes
- Cost Parameters
- Normalized Yields
- Emissions

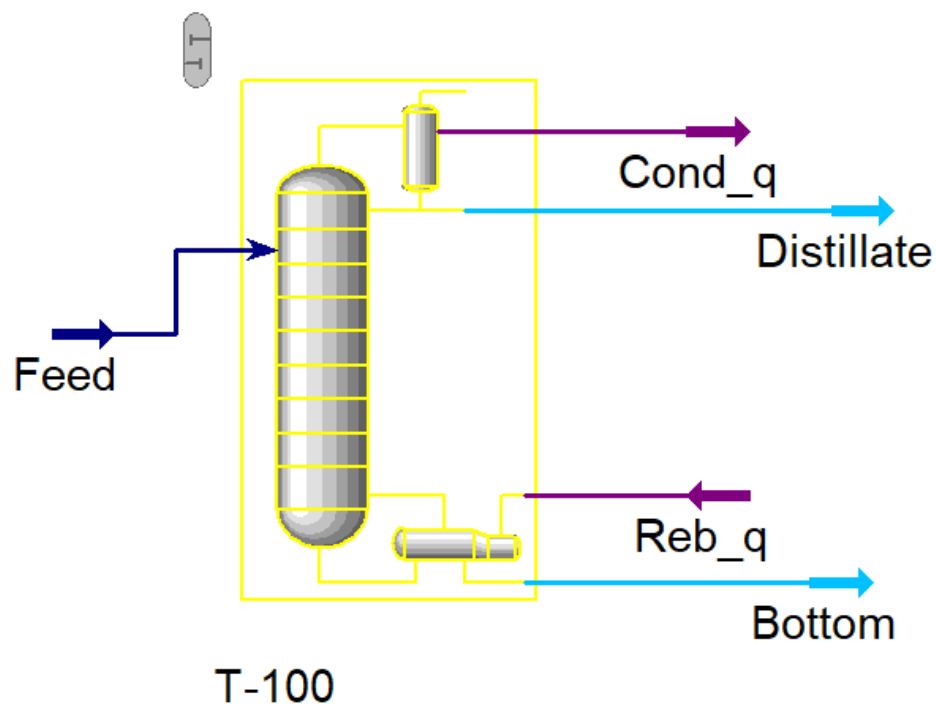
Stream Name	Feed	Liquid Phase
Vapour / Phase Fraction	0.0000	1.0000
Temperature [C]	10.00	10.00
Pressure [kPa]	140.0	140.0
Molar Flow [kgmole/h]	45.06	45.06
Mass Flow [kg/h]	3700	3700
Std Ideal Liq Vol Flow [m3/h]	4.213	4.213
Molar Enthalpy [kJ/kgmole]	-1.042e+005	-1.042e+005
Molar Entropy [kJ/kgmole-C]	51.94	51.94
Heat Flow [kJ/h]	-4.696e+006	-4.696e+006
Liq Vol Flow @Std Cond [m3/h]	4.193	4.193
Fluid Package	Basis-1	

OK

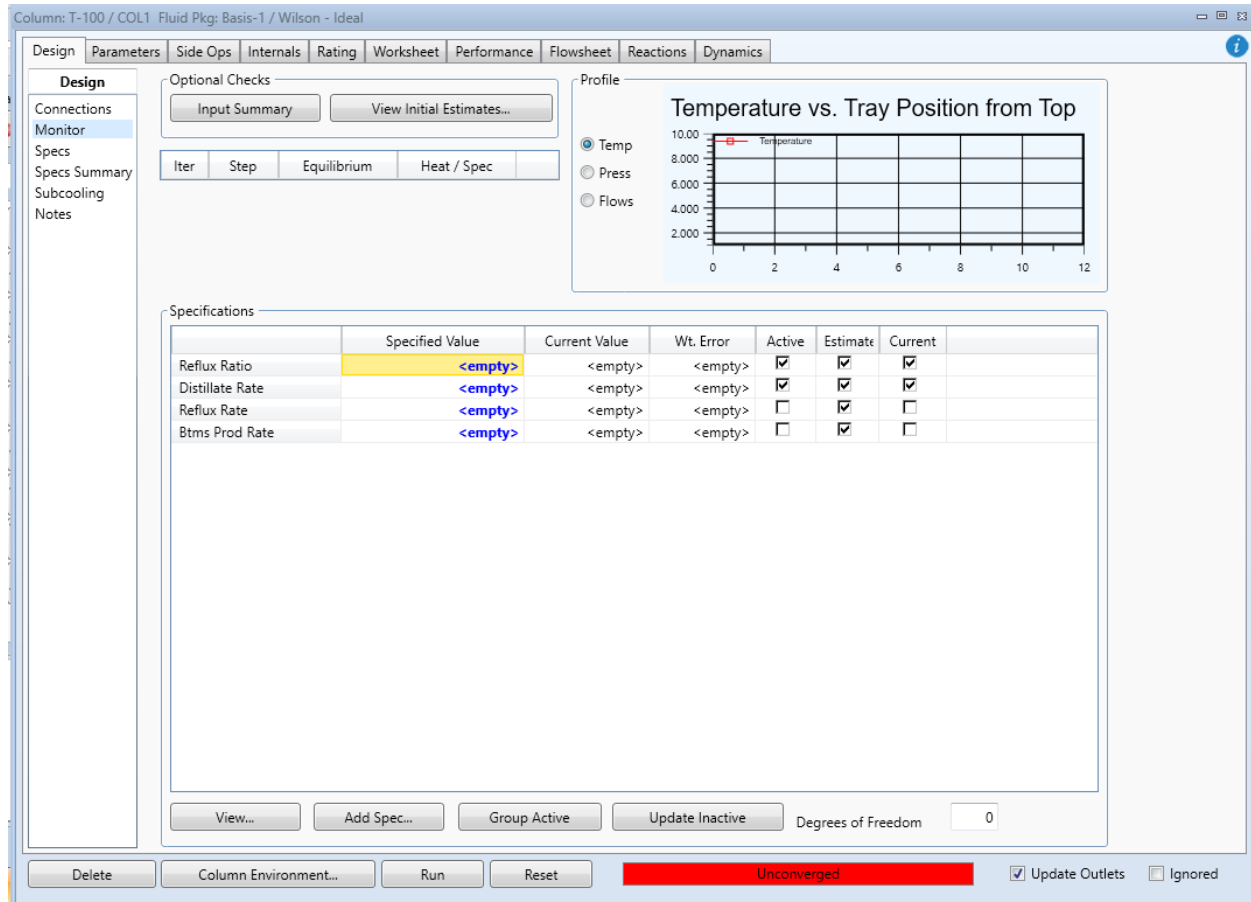
5. We are using 10 trays and total condenser here.



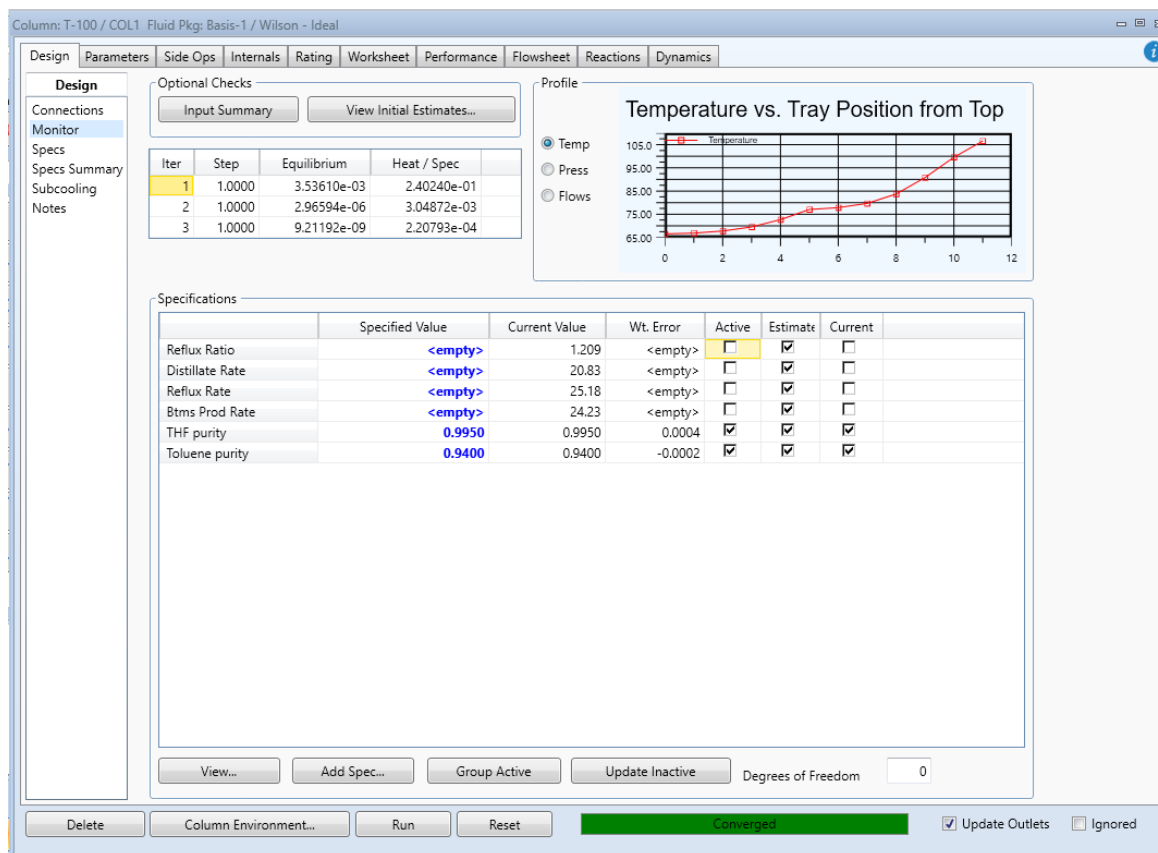
6. This is how our distillation column will look like with feed stream, distillate stream, bottom stream, condenser energy stream and reboiler energy stream.



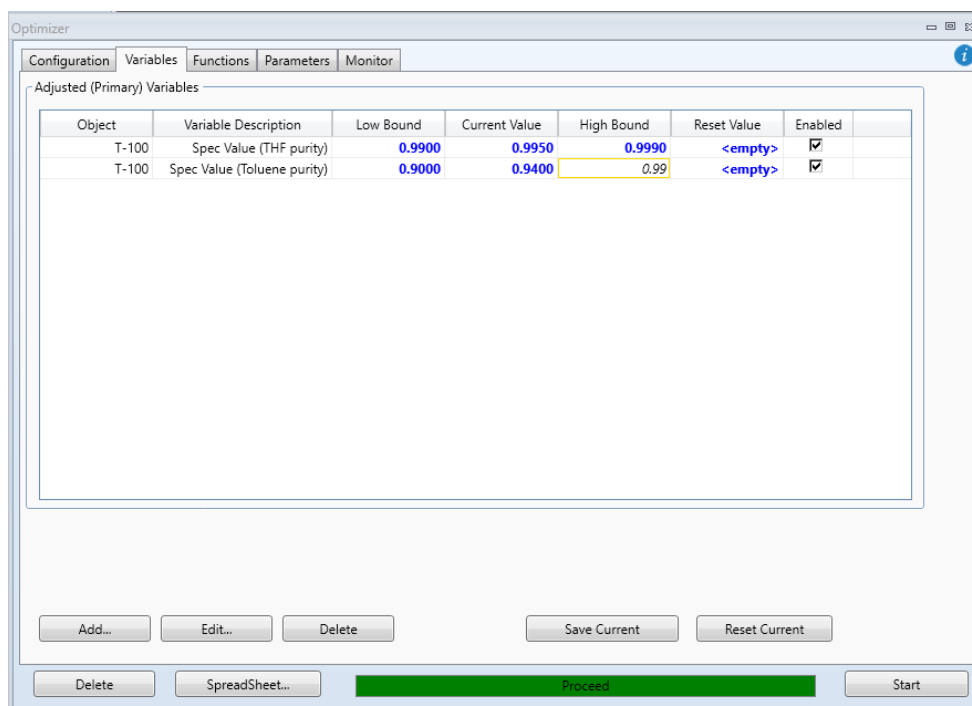
7. Initially we don't have reflux ratio, distillate rate, etc. So we need to calculate that.



8. We add 2 new specifications i.e. the THF purity and Toluene purity which is given at 0.995 and 0.94 respectively.



9. We set the upper and lower bounds for purity in optimizer.



10. We form a spreadsheet with all necessary variables.

Spreadsheet: OptimizerSpreadsheet

Connections Parameters Formulas Spreadsheet Calculation Order User Variables Notes

Current Cell: D10 Exportable ☐ Angles in:

Edit Rows/Columns

	A	B	C	D
1	Condensory duty		Cooling cost	
2	Reboiler duty		Heating cost	
3	Overhead Product			
4	THF purity		Pure THF price	
5	Bottom product			
6	Toluene purity		Pure Toluene price	
7	Feed flow rate		Feed cost	
8			Profit	
9				
10				

Function Help... Spreadsheet Only... Ignored

11. Exported the values of all variables.

Spreadsheet: OptimizerSpreadsheet

Connections Parameters Formulas Spreadsheet Calculation Order User Variables Notes

Current Cell: D8 Exportable ☐ Angles in:

Edit Rows/Columns

	A	B	C	D
1	Condensory duty	378.9 kW	Cooling cost	0.4710
2	Reboiler duty	548.5 kW	Heating cost	0.7370
3	Overhead Product	1504 kg/h		
4	THF purity	0.9950	Pure THF price	0.3330
5	Bottom product	2196 kg/h		
6	Toluene purity	0.9400	Pure Toluene price	0.1360
7	Feed flow rate	3700 kg/h	Feed cost	5.000e-002
8			Profit	
9				
10				

Function Help... Spreadsheet Only... Ignored

12. Calculate the profit by selling the pure THF and Toluene produced from distillation minus the cost of feed and hot utility and cold utility.

Spreadsheet: OptimizerSpreadsheet

Connections Parameters Formulas Spreadsheet Calculation Order User Variables Notes

Current Cell: Variable Type: **Cost Index** Exportable ☒ D8 Variable: Angles in: **Rad** Edit Rows/Columns

$$= ((D6*B6*B5) + (D4*B4*B3)) - ((D7*B7) + (D2*B2) + (D1*B1))$$

	A	B	C	D
1	Condensory duty	378.9 kW	Cooling cost	0.4710
2	Reboiler duty	548.5 kW	Heating cost	0.7370
3	Overhead Product	1504 kg/h		
4	THF purity	0.9950	Pure THF price	0.3330
5	Bottom product	2196 kg/h		
6	Toluene purity	0.9400	Pure Toluene price	0.1360
7	Feed flow rate	3700 kg/h	Feed cost	5.000e-002
8			Profit	11.30 Cost
9				
10				

Function Help... Spreadsheet Only... ☐ Ignored

Initially the cost is coming out to be 11.3 \$/hr.

13. Then we go to the optimizer selected the profit cell and maximise it.

Optimizer

Configuration Variables Functions Parameters Monitor

Cell: D8
Current Value: 11.3033947

☐ Minimize
☒ Maximize

Constraint Functions

Num	LHS Cell	Current Value	Cond	RHS Cell	Current Value	Penalty Value
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Add
Delete

Delete Spreadsheet... Proceed Start

Optimizer

Configuration Variables Functions Parameters Monitor

Cell: D8
Current Value: 65.6436762

☐ Minimize
☒ Maximize

Constraint Functions

Num	LHS Cell	Current Value	Cond	RHS Cell	Current Value	Penalty Value
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Add
Delete

Delete Spreadsheet... Optimum found (SmallDeltaX) Start

14. On maximizing the profit, the purity of THF and Toluene changes accordingly to give maximum profit.

Now the profit becomes **65.64 \$/hr** from 11.3 \$/hr initially.

Spreadsheet: OptimizerSpreadsheet

Connections Parameters Formulas Spreadsheet Calculation Order User Variables Notes

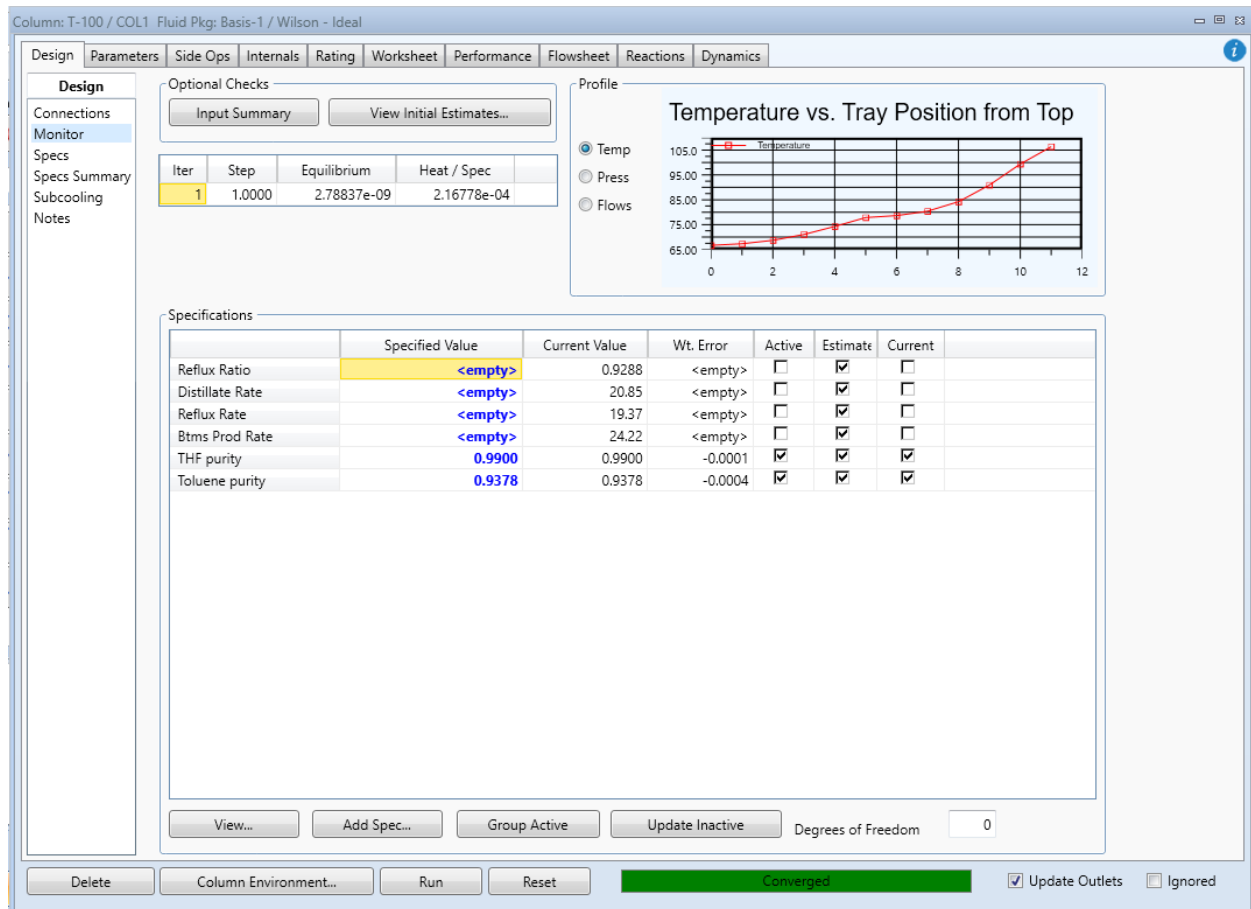
Current Cell: Variable Type: **Cost Index** Exportable ☒ Angles in: **Rad** Edit Rows/Columns

D8 Variable: = ((D6*B6*B5)+(D4*B4*B3))-((D7*B7)+(D2*B2)+(D1*B1))

	A	B	C	D
1	Condensory duty	331.9 kW	Cooling cost	0.4710
2	Reboiler duty	501.3 kW	Heating cost	0.7370
3	Overhead Product	1507 kg/h		
4	THF purity	0.9900	Pure THF price	0.3330
5	Bottom product	2193 kg/h		
6	Toluene purity	0.9378	Pure Toluene price	0.1360
7	Feed flow rate	3700 kg/h	Feed cost	5.000e-002
8			Profit	65.64 Cost
9				
10				

Function Help... Spreadsheet Only... ☐ Ignored

15. Now we can take the values of reflux ratio, distillate rate at maximum profit condition.



At maximum profit condition:

- Reflux ratio = 0.9288
- Distillate rate = 20.85

THANK YOU