CL-402: Chemical Process Technology

July-November session, 2018

7th semester, Department of Chemical Engineering

Indian Institute of Technology Guwahati, Guwahati

Tutorial 3

Use Aspen Plus V8.8 to solve all the problems.

Problem-1: Shortcut Distillation Calculation: DSTWU

An equimolar mixture of benzene and toluene is to be separated by distillation to produce a distillate containing 90 mol% benzene and a bottom product that contains 89% toluene. The distillation column is to operate at 1 atm pressure and the feed to column is a saturated liquid. Use the DSTWU programme and the NRTL model to estimate:

a. the minimum reflux ration and the minimum number of stages to accomplish the separation.

b. the actual number of stages and the location of the feed stage if the column is operated at 1.2 times the minimum reflux ratio.

Problem-2: Rigorous Distillation Calculations: RadFrac

An equimolar mixture of benzene and toluene is to be separated by distillation to produce a distillate containing 90 mol% benzene and a bottom product that contains 98% toluene. The distillation column is to operate at 1 atm pressure and the feed to the column is a saturated liquid. Use the RADFRAC programme and the NRTL model to estimate

a. the minimum reflux ratio and the minimum number of stages to accomplish the separation;

b. the actual number of stages and the location of the feed stage if the column is operated at 1.2 times the minimum reflux ratio.

Problem 1

DSTWU

- DSTWU performs ***shortcut design calculations for single-feed, two-product distillation columns*** with a partial or total condenser.
- DSTWU assumes constant molar overflow and constant relative volatilities.

DSTWU uses this method/correlation	To estimate
Winn	*Minimum number of stages* and optimum feed location at total reflux
Underwood	*Minimum reflux ratio*
Gilliland	Required reflux ratio and optimum feed location for the specified number of stages, or the required number of stages and optimum feed location for the specified reflux ratio

For the specified recovery of light and heavy key components, DSTWU estimates:

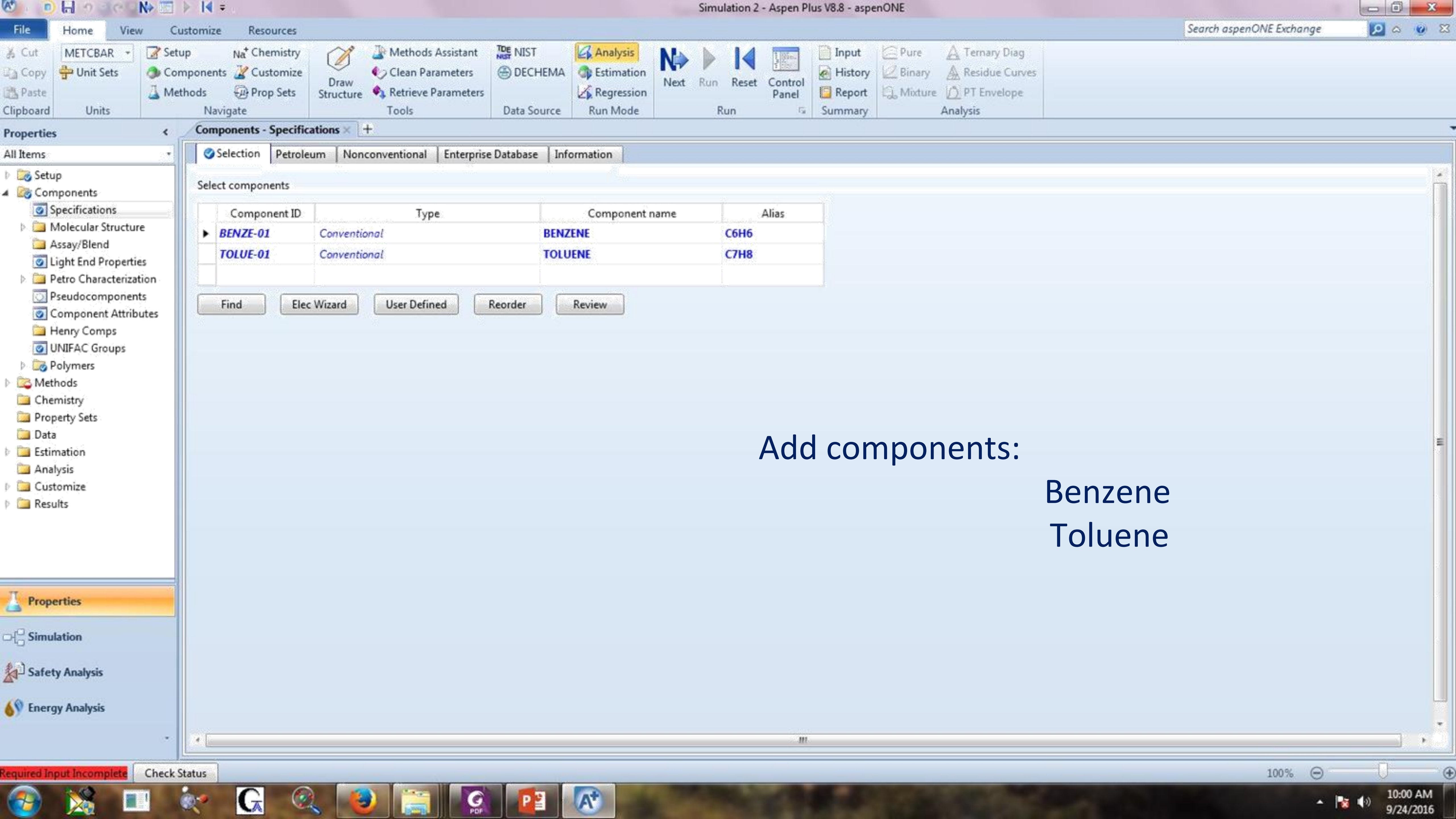
- *Minimum reflux ratio*
- *Minimum number of theoretical stages*

DSTWU then estimates one of the following:

- *Required reflux ratio for the specified number of theoretical stages*
- *Required number of theoretical stages for the specified reflux ratio*

DSTWU also estimates the optimum feed stage location & the condenser & reboiler duties.

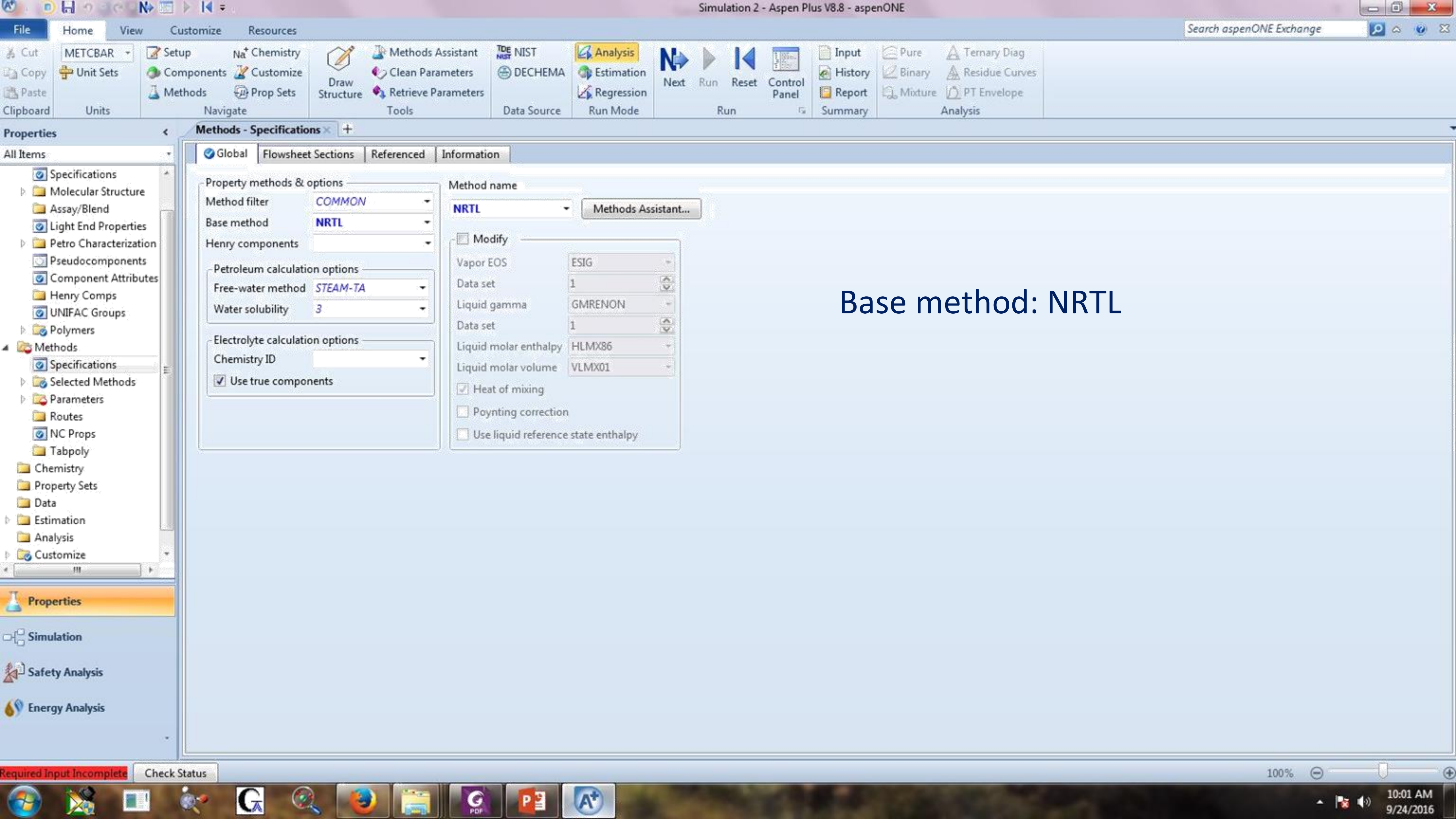
DSTWU can produce tables and plots of reflux ratio versus number of stages.



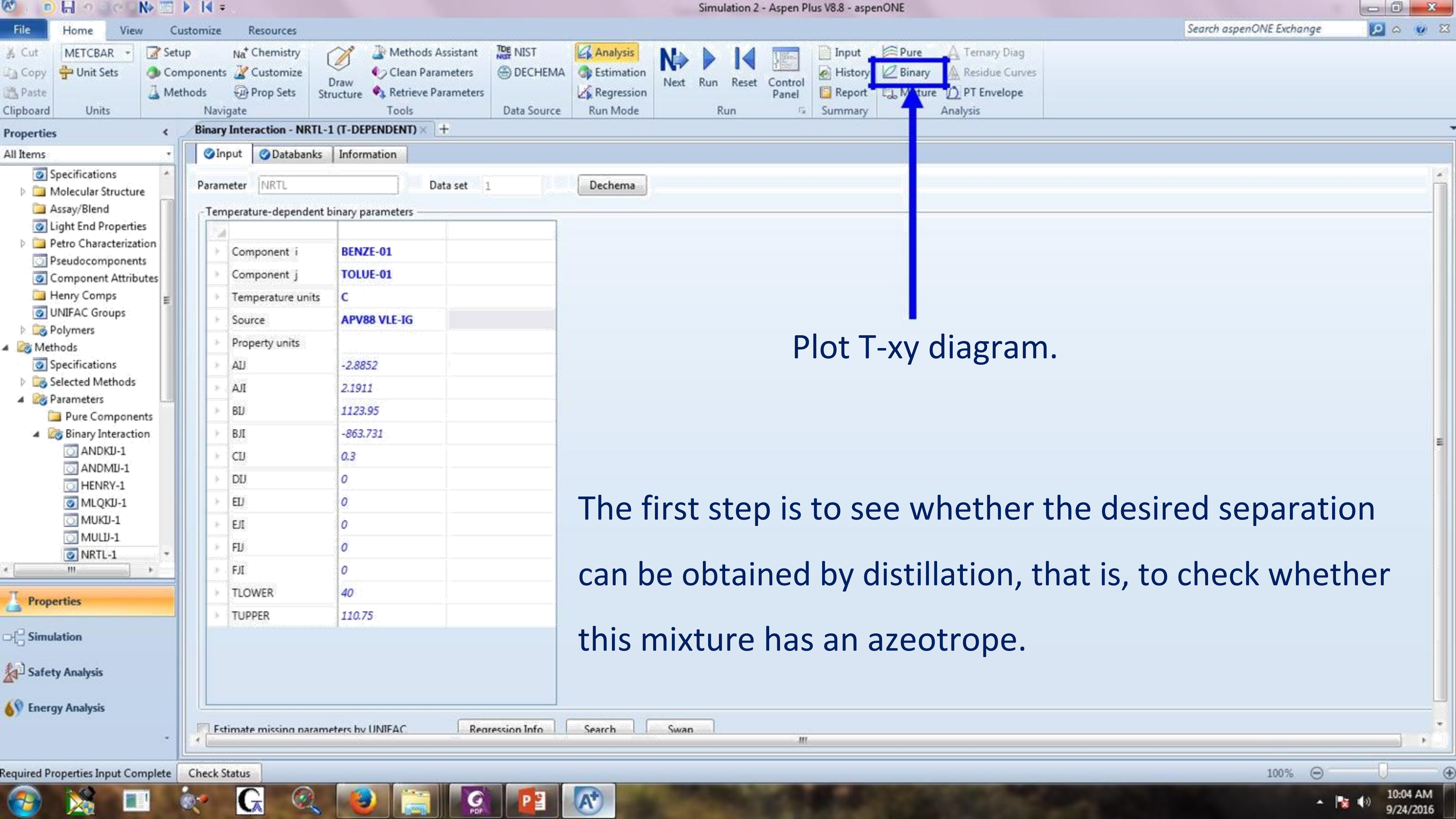
Add components:

Benzene

Toluene

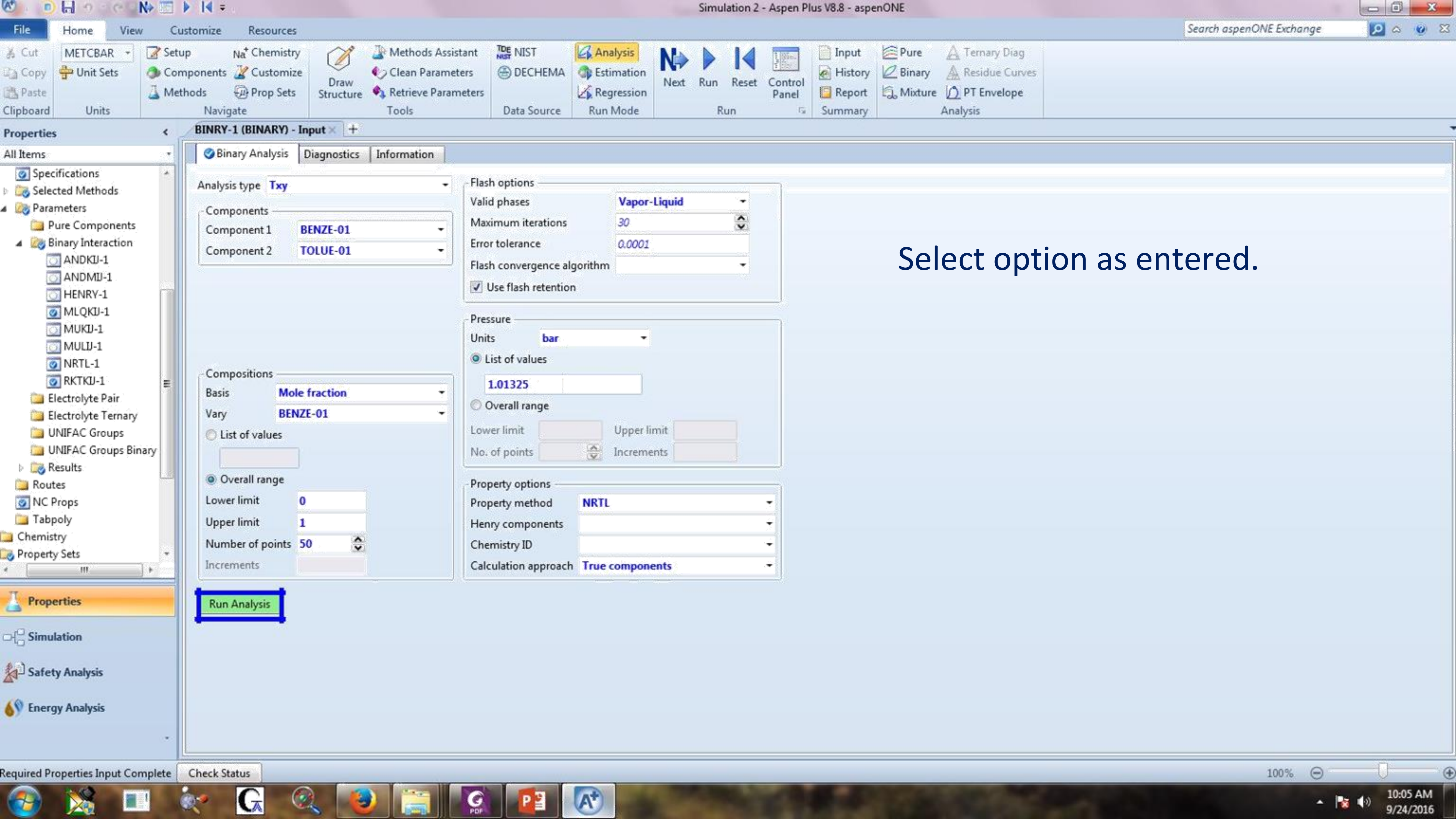


Base method: NRTL



Plot T-xy diagram.

The first step is to see whether the desired separation can be obtained by distillation, that is, to check whether this mixture has an azeotrope.


Simulation 2 - Aspen Plus V8.8 - aspenONE
File
Home
View
Customize
Resources
Search aspenONE Exchange
Cut
Copy
Paste
Clipboard
METCBAR
Unit Sets
Units
Setup
Components
Methods
Chemistry
Customize
Prop Sets
Navigate
Draw Structure
Methods Assistant
Clean Parameters
Retrieve Parameters
Tools
NIST
DECHEMA
Data Source
Analysis
Estimation
Regression
Run Mode
Next
Run
Reset
Control Panel
Run
Input
History
Report
Summary
Pure
Binary
Mixture
Ternary Diag
Residue Curves
PT Envelope
Analysis
Properties
All Items
Specifications
Selected Methods
Parameters
Pure Components
Binary Interaction
ANDKIJ-1
ANDMIJ-1
HENRY-1
MLQKIJ-1
MUKIJ-1
MULIJ-1
NRTL-1
RKTKIJ-1
Electrolyte Pair
Electrolyte Ternary
UNIFAC Groups
UNIFAC Groups Binary
Results
Routes
NC Props
Tabpoly
Chemistry
Property Sets
Properties
Simulation
Safety Analysis
Energy Analysis
BINRY-1 (BINARY) - Input
Binary Analysis
Diagnostics
Information
Analysis type Txy
Components
Component 1 BENZE-01
Component 2 TOLUE-01
Compositions
Basis Mole fraction
Vary BENZE-01
List of values
Overall range
Lower limit 0
Upper limit 1
Number of points 50
Increments
Flash options
Valid phases Vapor-Liquid
Maximum iterations 30
Error tolerance 0.0001
Flash convergence algorithm
Use flash retention
Pressure
Units bar
List of values
1.01325
Overall range
Lower limit
Upper limit
No. of points
Increments
Property options
Property method NRTL
Henry components
Chemistry ID
Calculation approach True components
Run Analysis
Select option as entered.
Required Properties Input Complete
Check Status
100%
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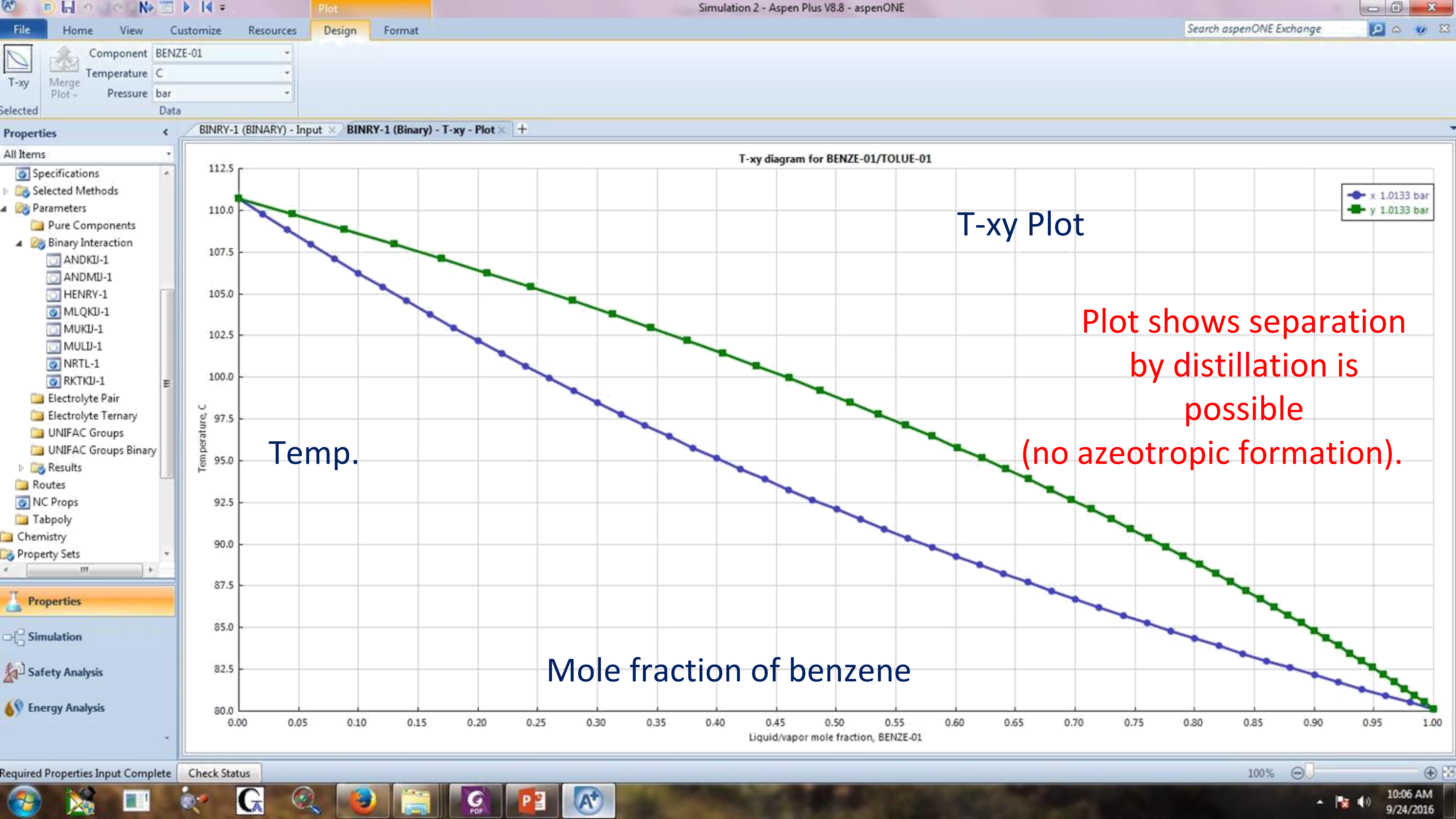
9/24/2016

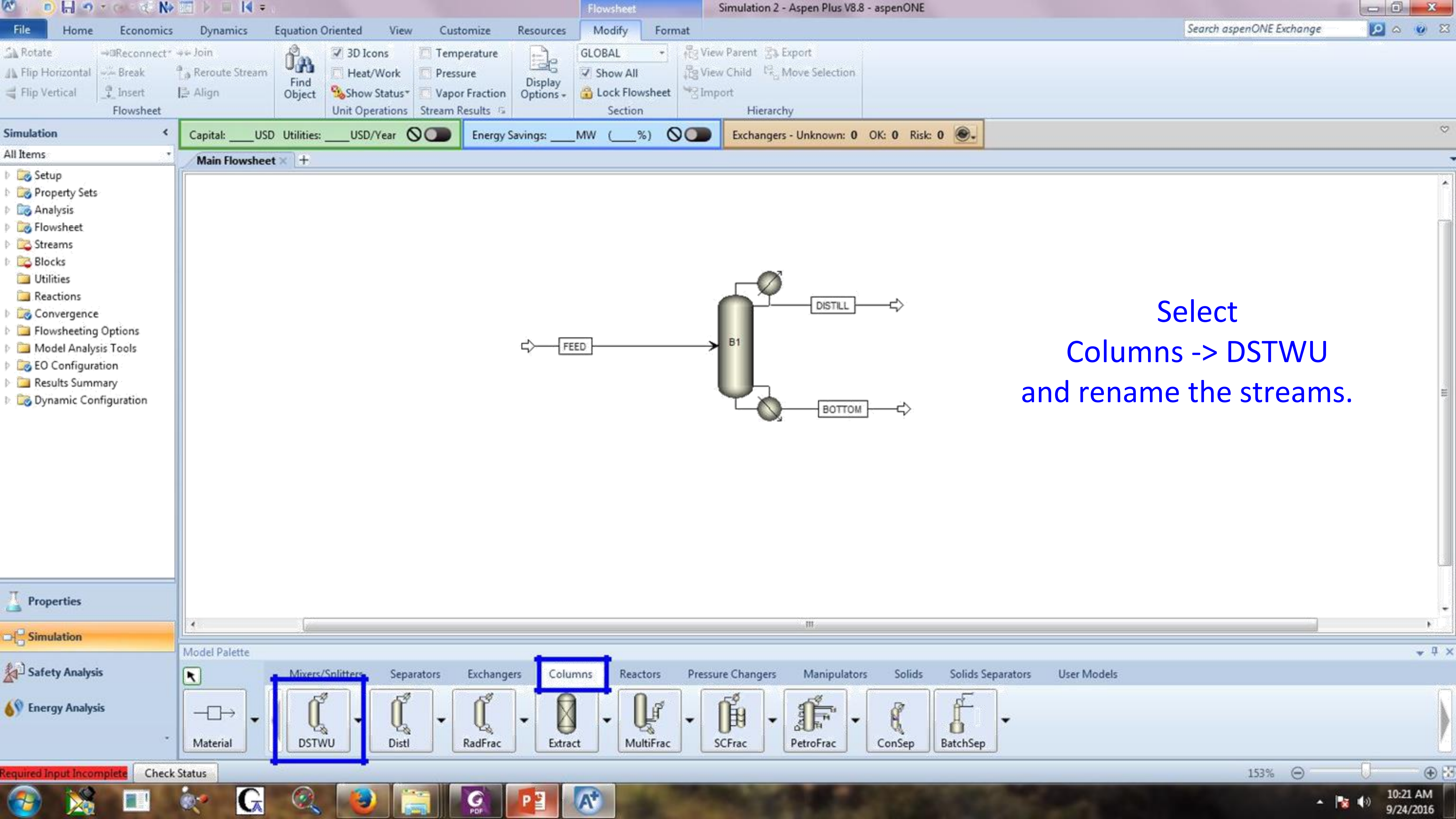

Simulation 2 - Aspen Plus V8.8 - aspenONE
T-xy diagram for BENZE-01/TOLUE-01
x 1.0133 bar
y 1.0133 bar
Temperature, C
Liquid/vapor mole fraction, BENZE-01
T-xy Plot
Temp.
Mole fraction of benzene
Plot shows separation
by distillation is
possible
(no azeotropic formation).

PRES (bar)	MOLEFRAC BENZE-01	TOTAL TEMP (C)	TOTAL KVL BENZE-01	TOTAL KVL TOLUE-01	LIQUID GAMMA BENZE-01	LIQUID GAMMA TOLUE-01	VAPOR MOLEFRAC BENZE-01	VAPOR MOLEFRAC TOLUE-01	LIQUID MOLEFRAC BENZE-01	LIQUID MOLEFRAC TOLUE-01
1.01325	0.14	104.584	1.99521	0.83799	0.994309	0.999856	0.279329	0.720671	0.14	0.86
1.01325	0.16	103.773	1.95501	0.818094	0.995366	0.999839	0.312801	0.687199	0.16	0.84
1.01325	0.18	102.976	1.91597	0.798934	0.996322	0.99983	0.344874	0.655126	0.18	0.82
1.01325	0.2	102.194	1.87807	0.780482	0.997183	0.99983	0.375614	0.624386	0.2	0.8
1.01325	0.22	101.427	1.84129	0.762713	0.997955	0.999842	0.405084	0.594916	0.22	0.78
1.01325	0.24	100.674	1.8056	0.745599	0.998644	0.999866	0.433345	0.566655	0.24	0.76
1.01325	0.26	99.9352	1.77098	0.729115	0.999256	0.999903	0.460455	0.539545	0.26	0.74
1.01325	0.28	99.2104	1.7374	0.713236	0.999796	0.999956	0.48647	0.51353	0.28	0.72
1.01325	0.3	98.4992	1.70482	0.697936	1.00027	1.00003	0.511445	0.488556	0.3	0.7
1.01325	0.32	97.8015	1.67322	0.683193	1.00068	1.00011	0.535429	0.464572	0.32	0.68
1.01325	0.34	97.1169	1.64256	0.668983	1.00104	1.00022	0.558471	0.441529	0.34	0.66
1.01325	0.36	96.4451	1.61283	0.655284	1.00134	1.00035	0.580618	0.419382	0.36	0.64
1.01325	0.38	95.786	1.58398	0.642075	1.00159	1.0005	0.601914	0.398086	0.38	0.62
1.01325	0.4	95.1391	1.556	0.629334	1.00179	1.00067	0.6224	0.3776	0.4	0.6
1.01325	0.42	94.5043	1.52885	0.617042	1.00196	1.00086	0.642116	0.357884	0.42	0.58
1.01325	0.44	93.8811	1.5025	0.60518	1.00208	1.00108	0.661099	0.338901	0.44	0.56
1.01325	0.46	93.2694	1.47693	0.59373	1.00218	1.00133	0.679386	0.320614	0.46	0.54
1.01325	0.48	92.6689	1.4521	0.582675	1.00223	1.0016	0.697009	0.302991	0.48	0.52
1.01325	0.5	92.0791	1.428	0.571997	1.00226	1.0019	0.714001	0.285999	0.5	0.5
1.01325	0.52	91.5	1.4046	0.561683	1.00227	1.00223	0.730392	0.269608	0.52	0.48
1.01325	0.54	90.9312	1.38187	0.551715	1.00225	1.00259	0.746211	0.253789	0.54	0.46
1.01325	0.56	90.3724	1.35979	0.542081	1.0022	1.00298	0.761485	0.238516	0.56	0.44

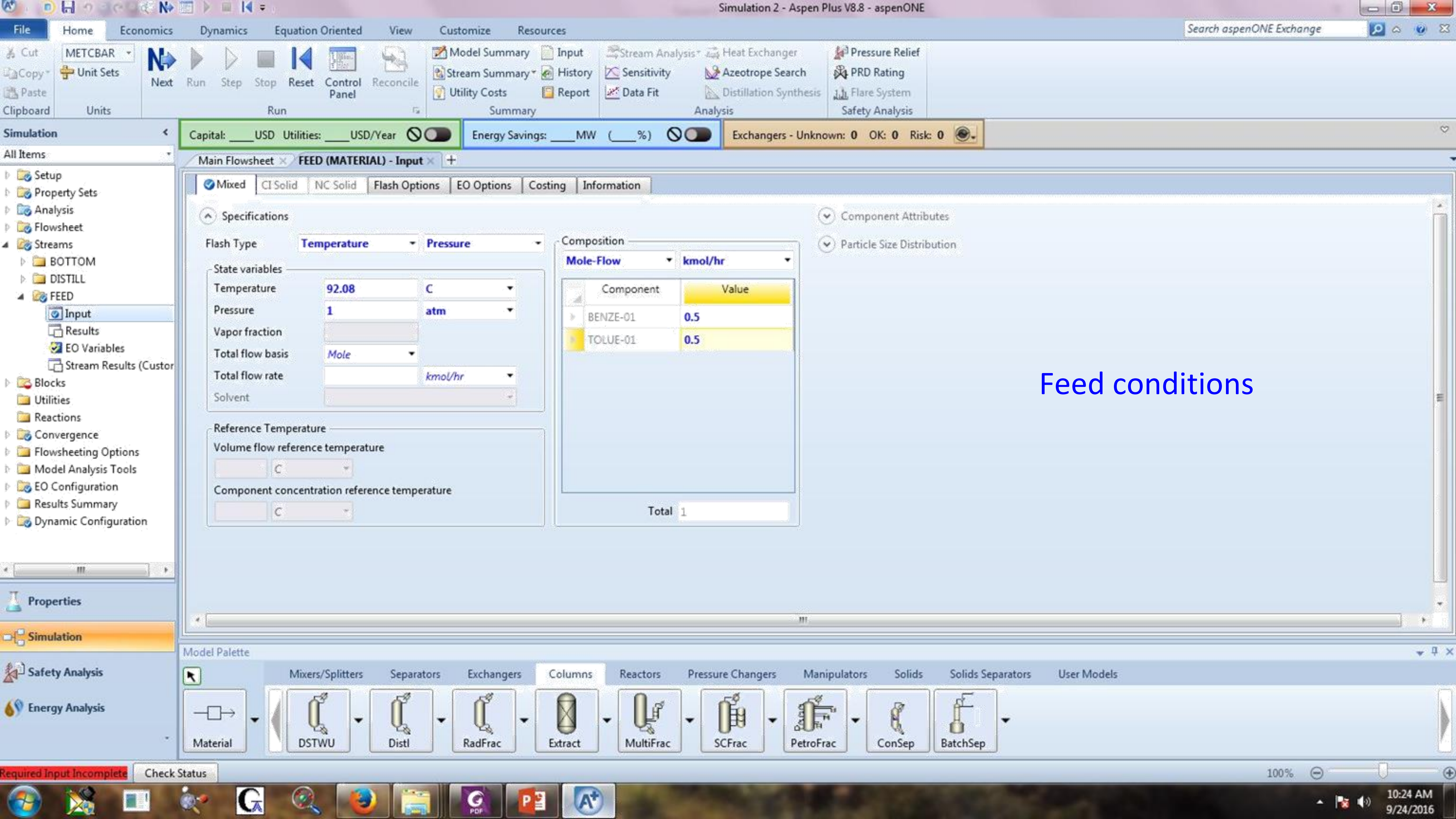
T-xy data

For equimolar mixture of Benzene and Toluene

Saturated liquid Temp = 92.08 °C



Select
Columns -> DSTWU
and rename the streams.


Simulation 2 - Aspen Plus V8.8 - aspenONE
File
Home
Economics
Dynamics
Equation Oriented
View
Customize
Resources
Search aspenONE Exchange
Cut
Copy
Paste
Clipboard
METCBAR
Unit Sets
Units
Next
Run
Step
Stop
Reset
Control Panel
Reconcile
Run
Model Summary
Stream Summary
Utility Costs
Input
History
Report
Summary
Stream Analysis
Sensitivity
Data Fit
Heat Exchanger
Azeotrope Search
Distillation Synthesis
Analysis
Pressure Relief
PRD Rating
Flare System
Safety Analysis
Capital: ___USD Utilities: ___USD/Year
Energy Savings: ___MW (___%)
Exchangers - Unknown: 0 OK: 0 Risk: 0
Simulation
All Items
Setup
Property Sets
Analysis
Flowsheet
Streams
BOTTOM
DISTILL
FEED
Input
Results
EO Variables
Stream Results (Custom
Blocks
Utilities
Reactions
Convergence
Flowsheeting Options
Model Analysis Tools
EO Configuration
Results Summary
Dynamic Configuration
Properties
Simulation
Safety Analysis
Energy Analysis
Main Flowsheet
FEED (MATERIAL) - Input
Mixed
CI Solid
NC Solid
Flash Options
EO Options
Costing
Information
Specifications
Flash Type
Temperature
Pressure
State variables
Temperature 92.08 C
Pressure 1 atm
Vapor fraction
Total flow basis Mole
Total flow rate kmol/hr
Solvent
Reference Temperature
Volume flow reference temperature
C
Component concentration reference temperature
C
Composition
Mole-Flow
kmol/hr
Component
Value
BENZE-01 0.5
TOLUE-01 0.5
Total 1
Component Attributes
Particle Size Distribution
Feed conditions
Model Palette
Mixers/Splitters
Separators
Exchangers
Columns
Reactors
Pressure Changers
Manipulators
Solids
Solids Separators
User Models
Material
DSTWU
Distl
RadFrac
Extract
MultiFrac
SCFrac
PetroFrac
ConSep
BatchSep
Required Input Incomplete
Check Status
100%
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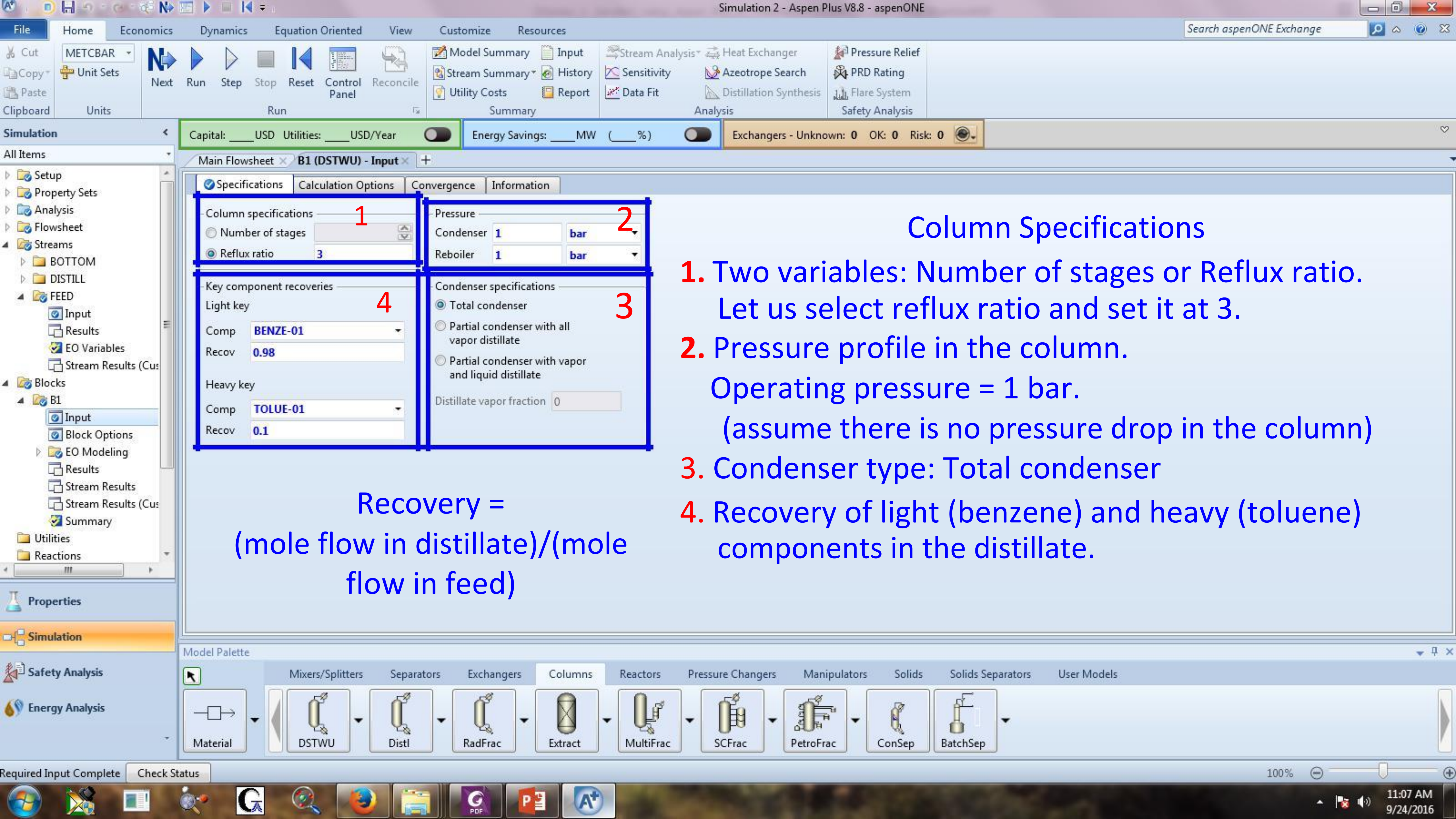


Column Specifications

1. Two variables: Number of stages or Reflux ratio. Let us select reflux ratio and set it at 3.
2. Pressure profile in the column. Operating pressure = 1 bar. (assume there is no pressure drop in the column)
3. Condenser type: Total condenser
4. Recovery of light (benzene) and heavy (toluene) components in the distillate.

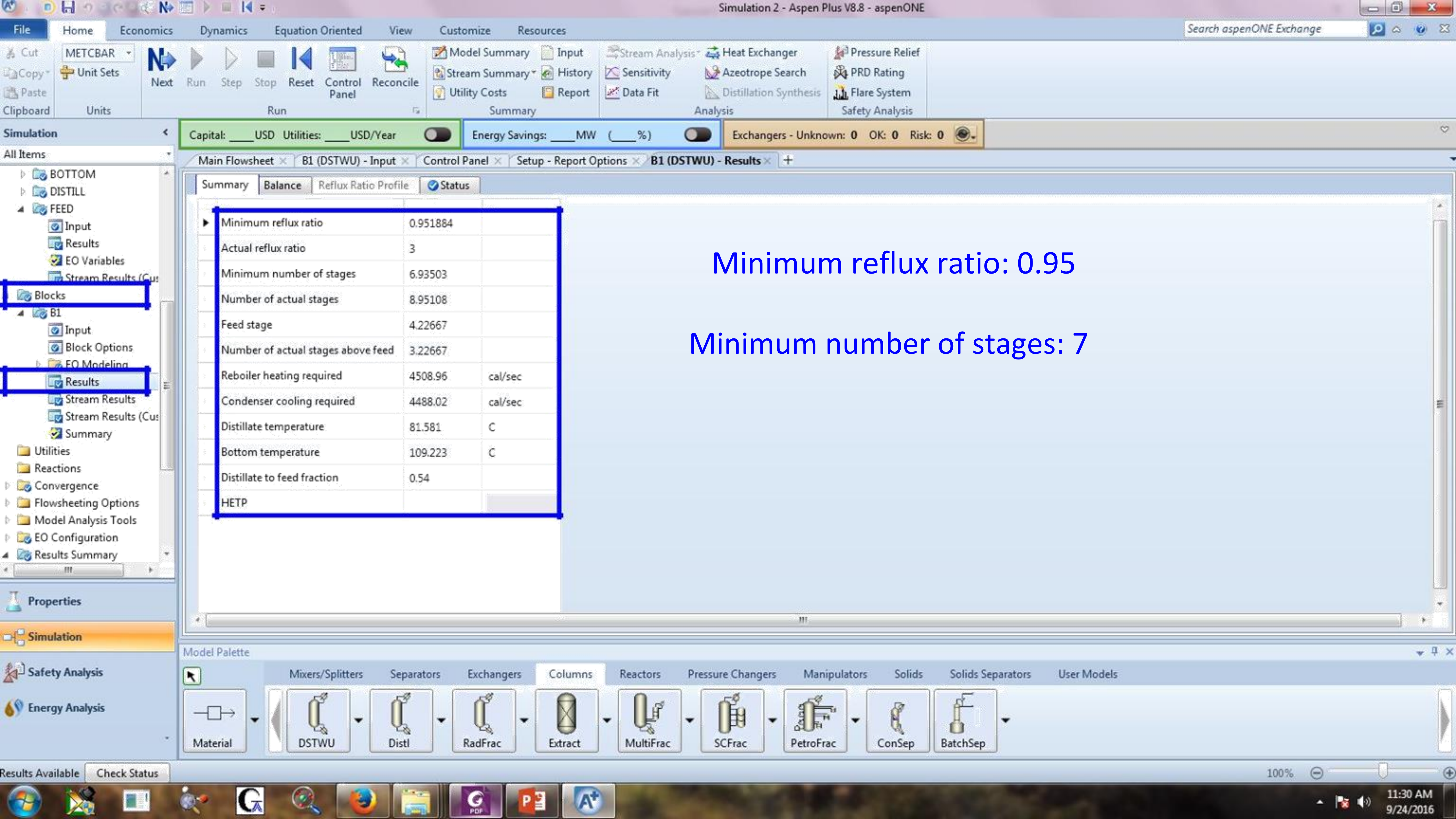
Recovery = (mole flow in distillate)/(mole flow in feed)

Stream results

	Units	FEED	DISTILL	BOTTOM
From			B1	B1
To		B1		
Substream: MIXED				
Phase:		Mixed	Liquid	Liquid
Component Mole Flow				
BENZE-01	KMOL/HR	0.5	0.49	0.01
TOLUE-01	KMOL/HR	0.5	0.05	0.45
Component Mole Fraction				
BENZE-01		0.5	0.907407	0.0217391
TOLUE-01		0.5	0.0925925	0.978261
Component Mass Flow				
BENZE-01	KG/HR	39.0568	38.2757	0.781136
TOLUE-01	KG/HR	46.0703	4.60703	41.4632
Component Mass Fraction				
BENZE-01		0.458806	0.892567	0.0184909
TOLUE-01		0.541194	0.107433	0.981509
Mole Flow	KMOL/HR	1	0.54	0.46

90% Benzene in distillate

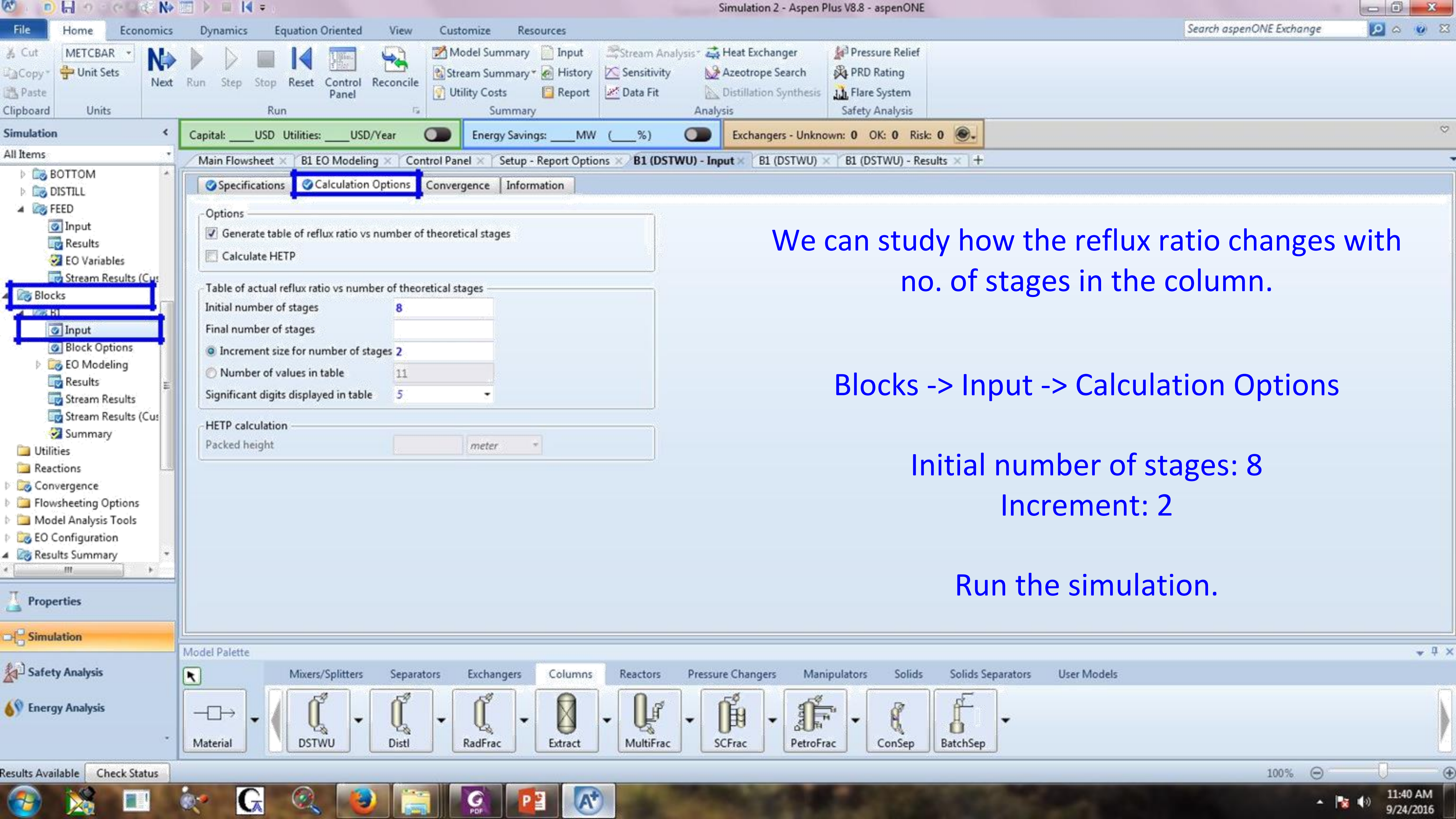
98% Toluene in bottom



Minimum reflux ratio	0.951884	
Actual reflux ratio	3	
Minimum number of stages	6.93503	
Number of actual stages	8.95108	
Feed stage	4.22667	
Number of actual stages above feed	3.22667	
Reboiler heating required	4508.96	cal/sec
Condenser cooling required	4488.02	cal/sec
Distillate temperature	81.581	C
Bottom temperature	109.223	C
Distillate to feed fraction	0.54	
HETP		

Minimum reflux ratio: 0.95

Minimum number of stages: 7



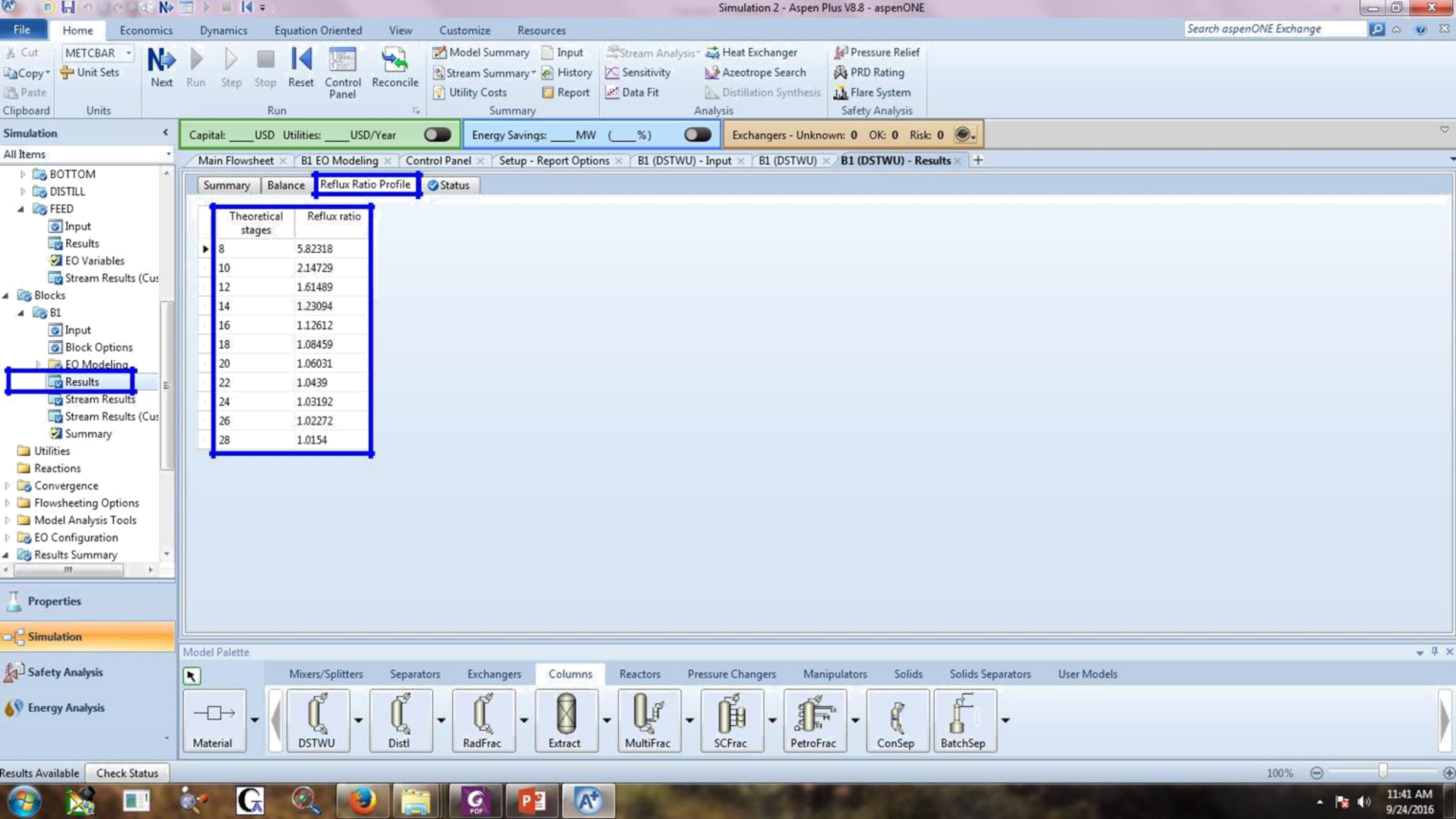
We can study how the reflux ratio changes with no. of stages in the column.

Blocks -> Input -> Calculation Options

Initial number of stages: 8

Increment: 2

Run the simulation.


Simulation 2 - Aspen Plus V8.8 - aspenONE
File
Home
Economics
Dynamics
Equation Oriented
View
Customize
Resources
Search aspenONE Exchange
Cut
Copy
Paste
Clipboard
METCBAR
Unit Sets
Units
Next
Run
Step
Stop
Reset
Control Panel
Reconcile
Run
Model Summary
Stream Summary
Utility Costs
Input
History
Report
Summary
Stream Analysis
Sensitivity
Data Fit
Heat Exchanger
Azeotrope Search
Distillation Synthesis
Analysis
Pressure Relief
PRD Rating
Flare System
Safety Analysis
Simulation
All Items
Capital: ___USD Utilities: ___USD/Year
Energy Savings: ___MW (___%)
Exchangers - Unknown: 0 OK: 0 Risk: 0
Main Flowsheet
B1 EO Modeling
Control Panel
Setup - Report Options
B1 (DSTWU) - Input
B1 (DSTWU)
B1 (DSTWU) - Results
BOTTOM
DISTILL
FEED
Input
Results
EO Variables
Stream Results (Cus
Blocks
B1
Input
Block Options
EO Modeling
Results
Stream Results
Stream Results (Cus
Summary
Utilities
Reactions
Convergence
Flowsheeting Options
Model Analysis Tools
EO Configuration
Results Summary
Summary
Balance
Reflux Ratio Profile
Status
Theoretical stages
Reflux ratio
8
5.82318
10
2.14729
12
1.61489
14
1.23094
16
1.12612
18
1.08459
20
1.06031
22
1.0439
24
1.03192
26
1.02272
28
1.0154
Properties
Simulation
Safety Analysis
Energy Analysis
Model Palette
Mixers/Splitters
Separators
Exchangers
Columns
Reactors
Pressure Changers
Manipulators
Solids
Solids Separators
User Models
Material
DSTWU
Distl
RadFrac
Extract
MultiFrac
SCFrac
PetroFrac
ConSep
BatchSep
Results Available
Check Status
100%
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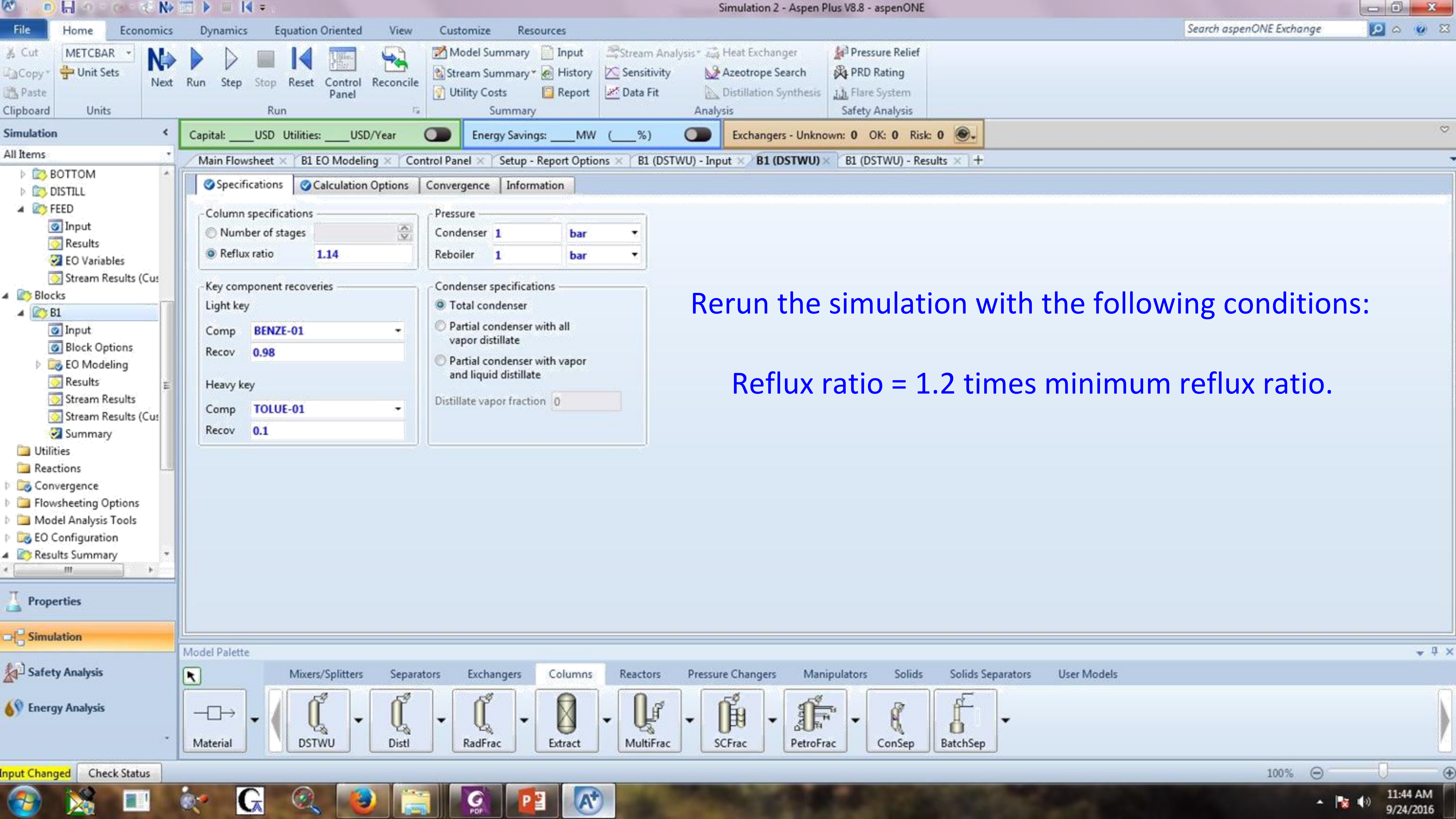
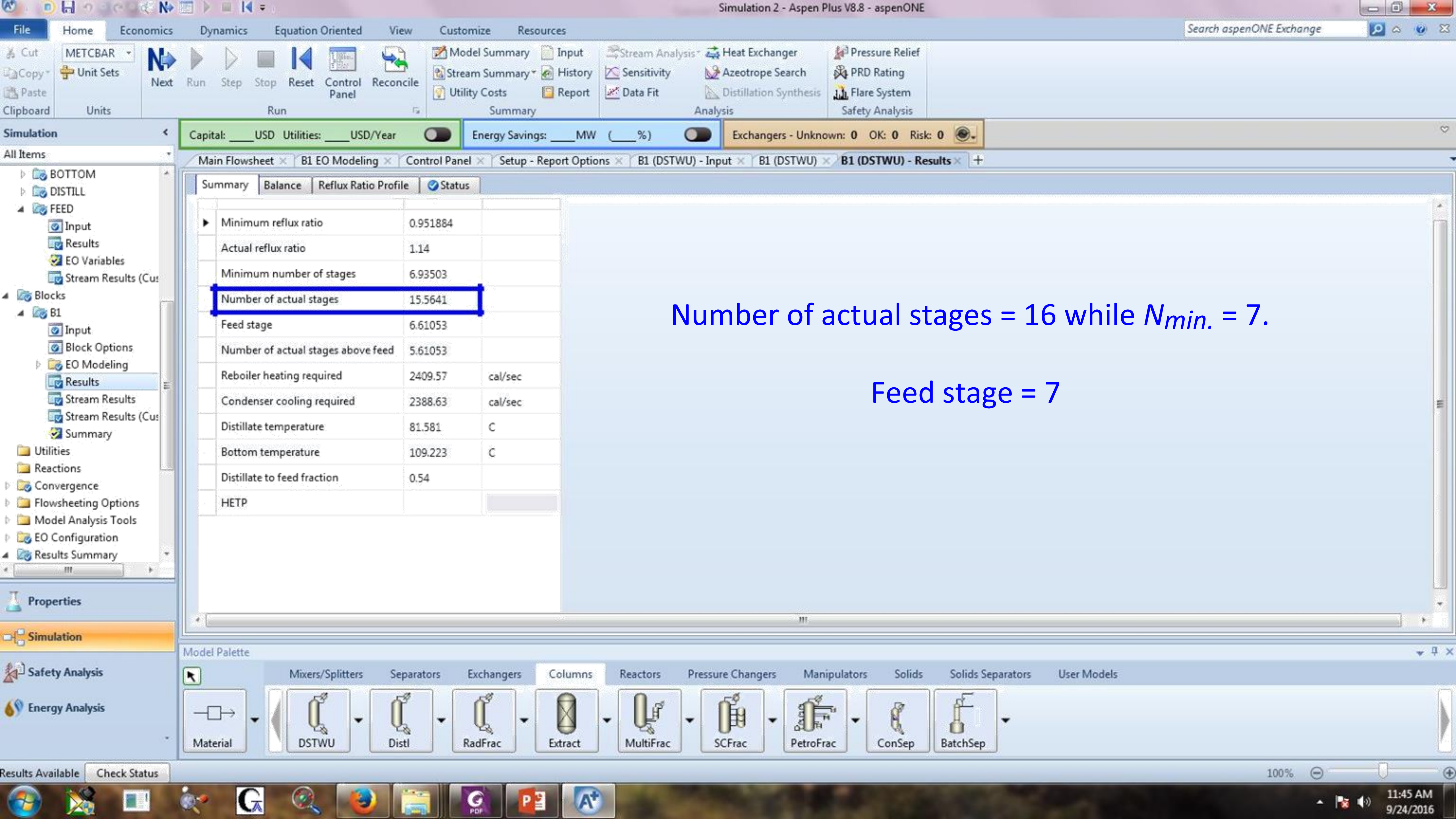


Rerun the simulation with the following conditions:

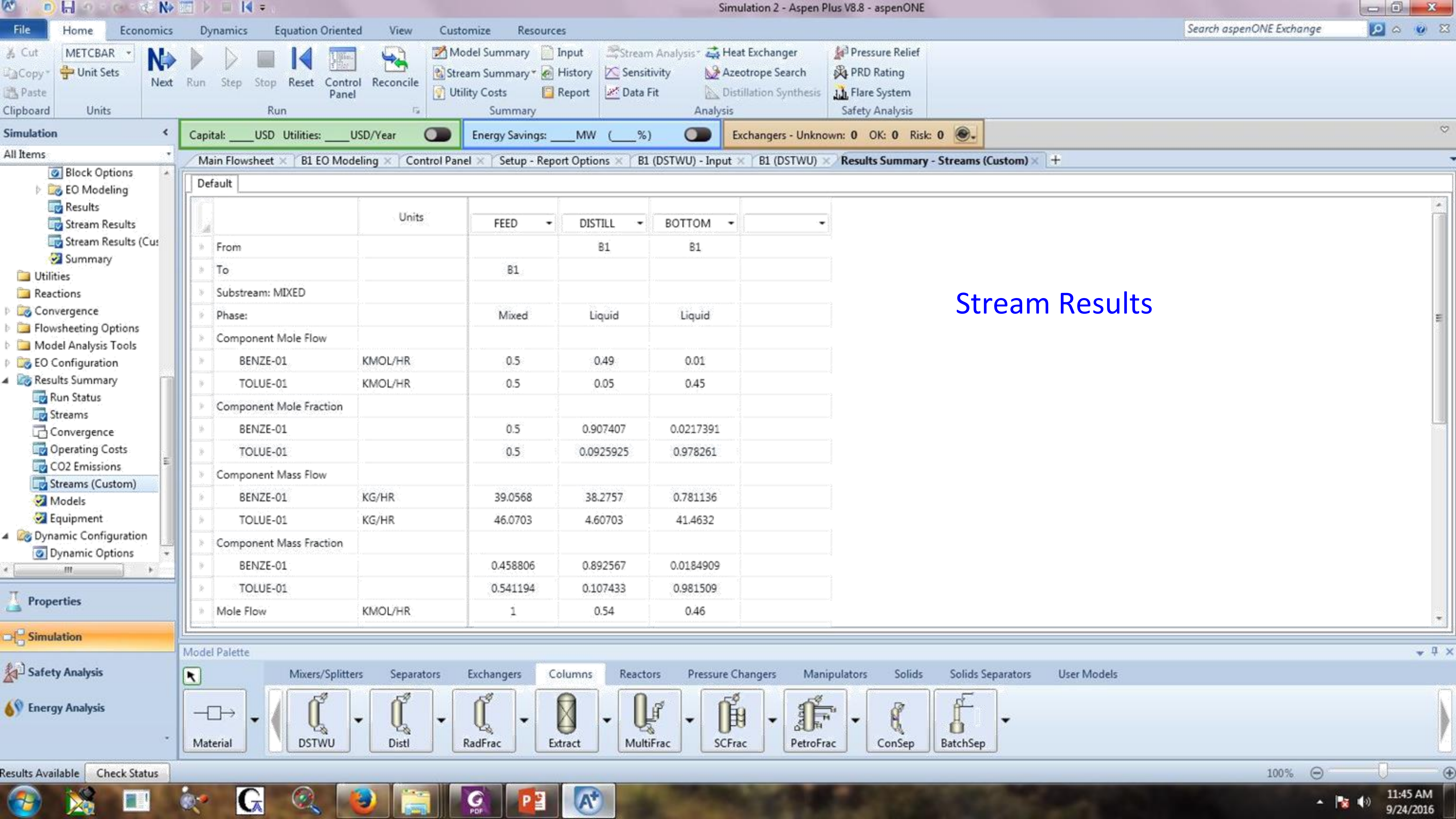
Reflux ratio = 1.2 times minimum reflux ratio.



Number of actual stages = 16 while $N_{min.}$ = 7.

Feed stage = 7

Stream Results



	Units	FEED	DISTILL	BOTTOM	
From			B1	B1	
To		B1			
Substream: MIXED					
Phase:		Mixed	Liquid	Liquid	
Component Mole Flow					
BENZE-01	KMOL/HR	0.5	0.49	0.01	
TOLUE-01	KMOL/HR	0.5	0.05	0.45	
Component Mole Fraction					
BENZE-01		0.5	0.907407	0.0217391	
TOLUE-01		0.5	0.0925925	0.978261	
Component Mass Flow					
BENZE-01	KG/HR	39.0568	38.2757	0.781136	
TOLUE-01	KG/HR	46.0703	4.60703	41.4632	
Component Mass Fraction					
BENZE-01		0.458806	0.892567	0.0184909	
TOLUE-01		0.541194	0.107433	0.981509	
Mole Flow	KMOL/HR	1	0.54	0.46	

Problem 2

A Rigorous Distillation Calculation: RadFrac

RadFrac is a rigorous model for simulating all types of multistage vapour-liquid fractionation operations.

These operations include:

- *Ordinary distillation*
- *Absorption*
- *Reboiled absorption*
- *Stripping*
- *Reboiled stripping*
- *Extractive and azeotropic distillation*

RadFrac is suitable for:

- Two-phase systems
- Three-phase systems (only in equilibrium mode)
- Narrow and wide-boiling systems
- Systems exhibiting strong liquid phase nonideality

RadFrac can handle solids on every stage.

RadFrac can handle pumparounds leaving any stage & returning to the same stage or to a different stage.

RadFrac can model columns in which chemical reactions are occurring. Reactions can have fixed conversions, or they can be:

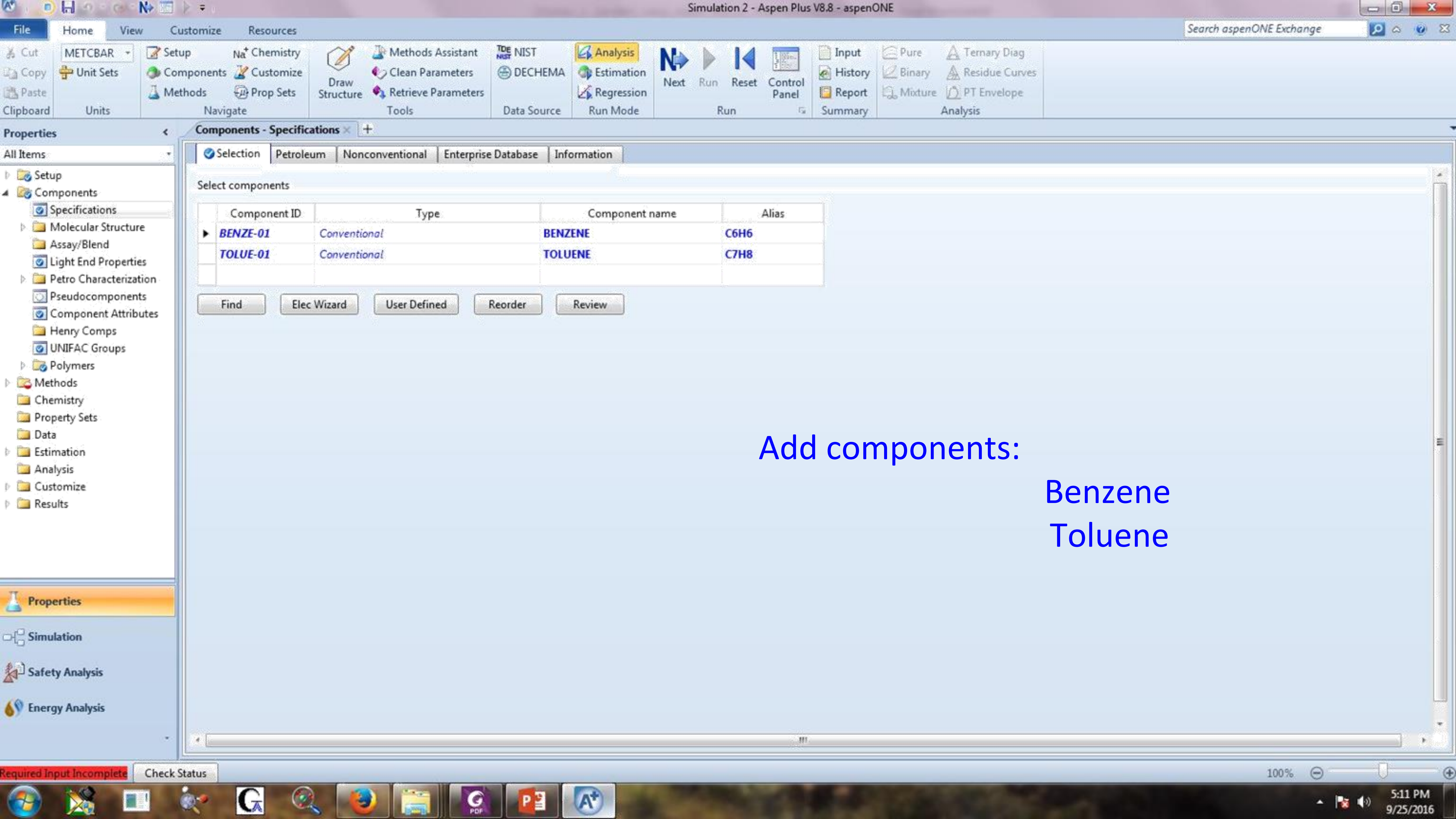
- Equilibrium
- Rate-controlled
- Electrolytic

RadFrac (in equilibrium mode) can also model columns in which two liquid phases and chemical reactions occur simultaneously, using different reaction kinetics for the two liquid phases. In addition, RadFrac (in equilibrium mode) can model salt precipitation.

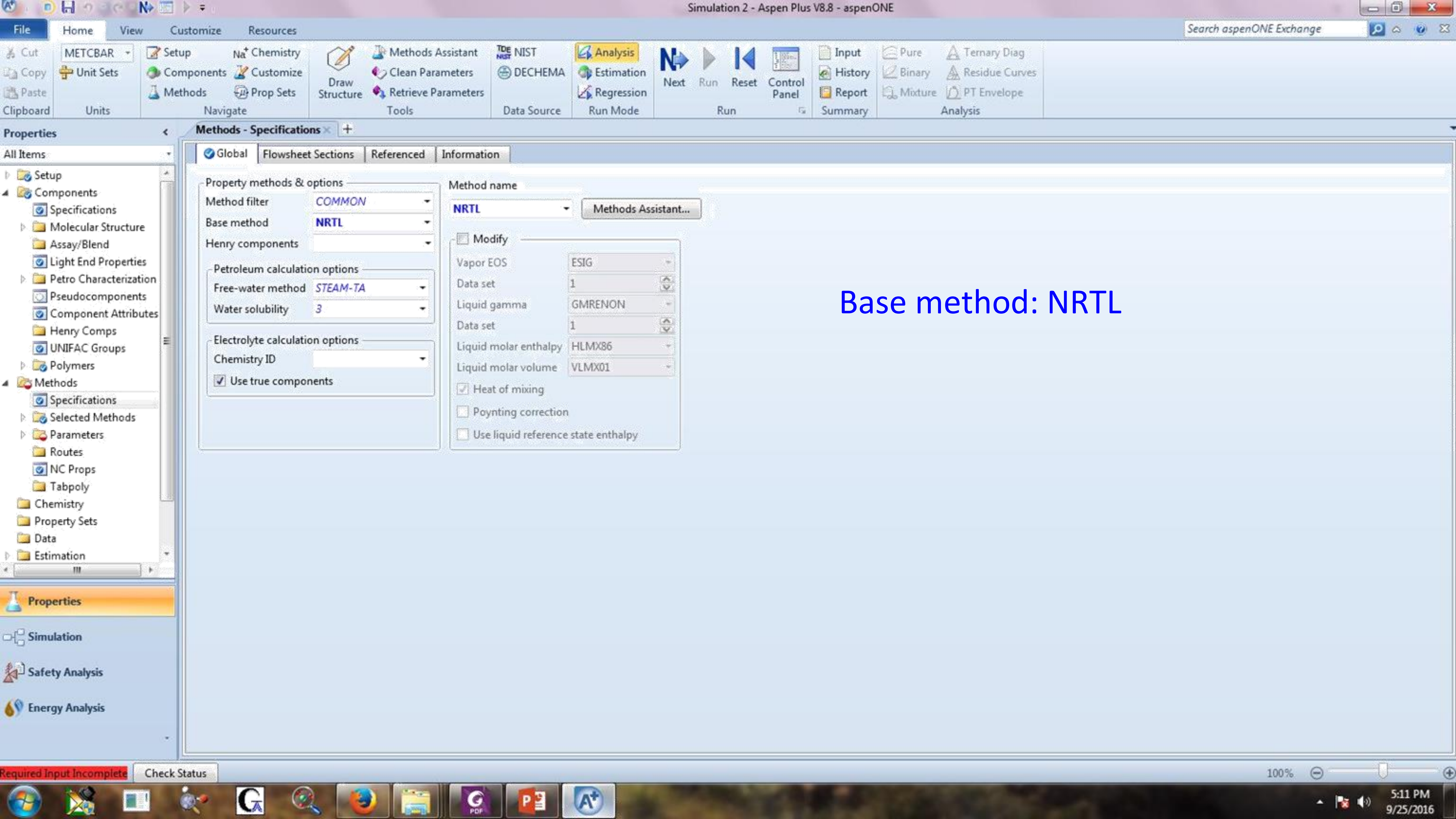
In equilibrium mode, RadFrac assumes equilibrium stages, but you can specify either Murphree or vaporization efficiencies. You can manipulate Murphree efficiencies to match plant performance.

In rate-based mode, RadFrac uses rate-based non-equilibrium calculations to model actual tray and packed columns, based on the underlying mass and heat transfer processes, and does not use empirical factors such as efficiencies and the Height Equivalent to a Theoretical Plate (HETP).

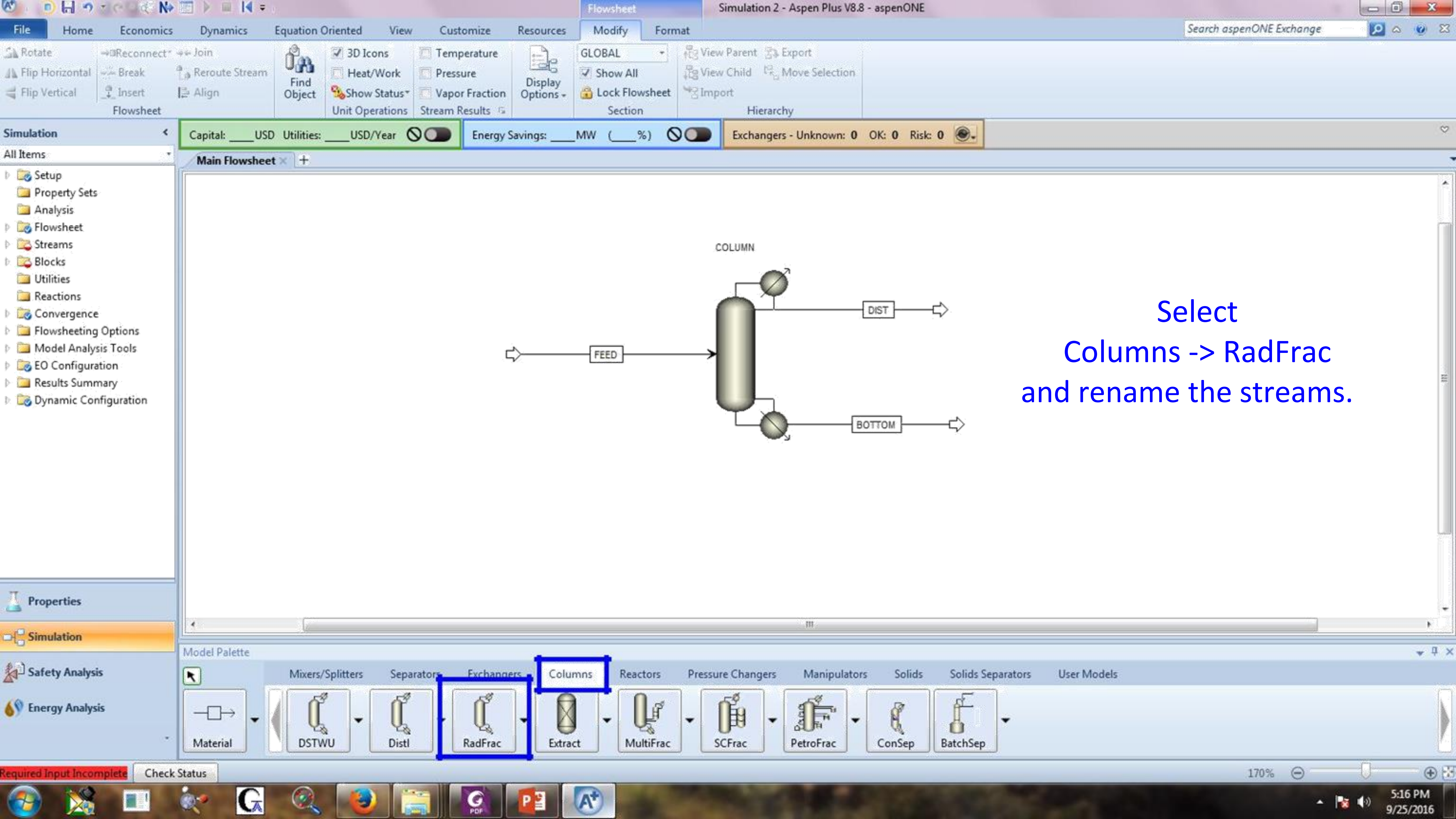
You can use RadFrac to size and rate columns consisting of trays and/or packings. RadFrac can model both random and structured packings.



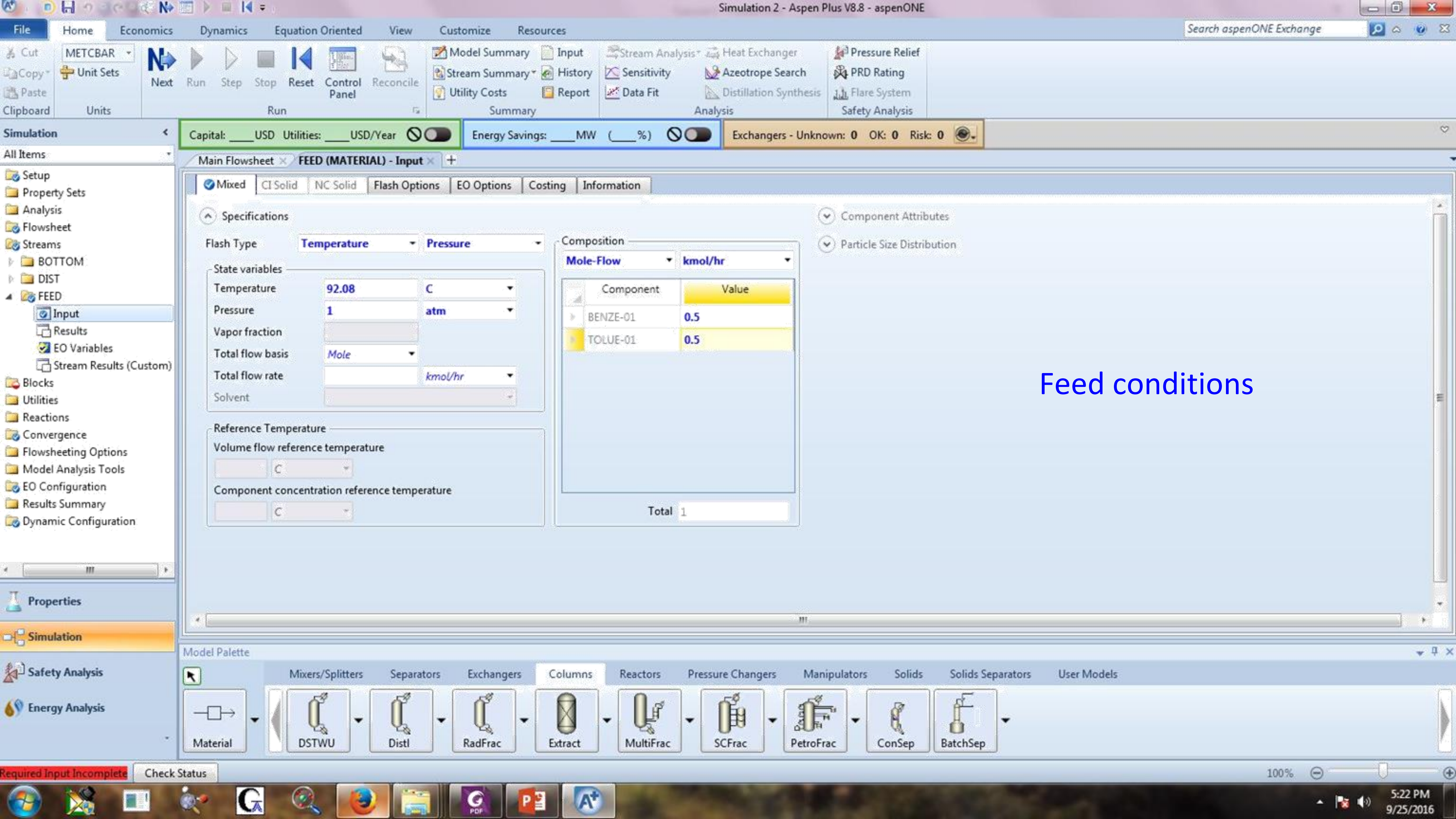
Simulation 2 - Aspen Plus V8.8 - aspenONE
Components - Specifications
Selection
Petroleum
Nonconventional
Enterprise Database
Information
Select components
Component ID
Type
Component name
Alias
BENZE-01
Conventional
BENZENE
C6H6
TOLUE-01
Conventional
TOLUENE
C7H8
Find
Elec Wizard
User Defined
Reorder
Review
Required Input Incomplete
Check Status
Add components:
Benzene
Toluene

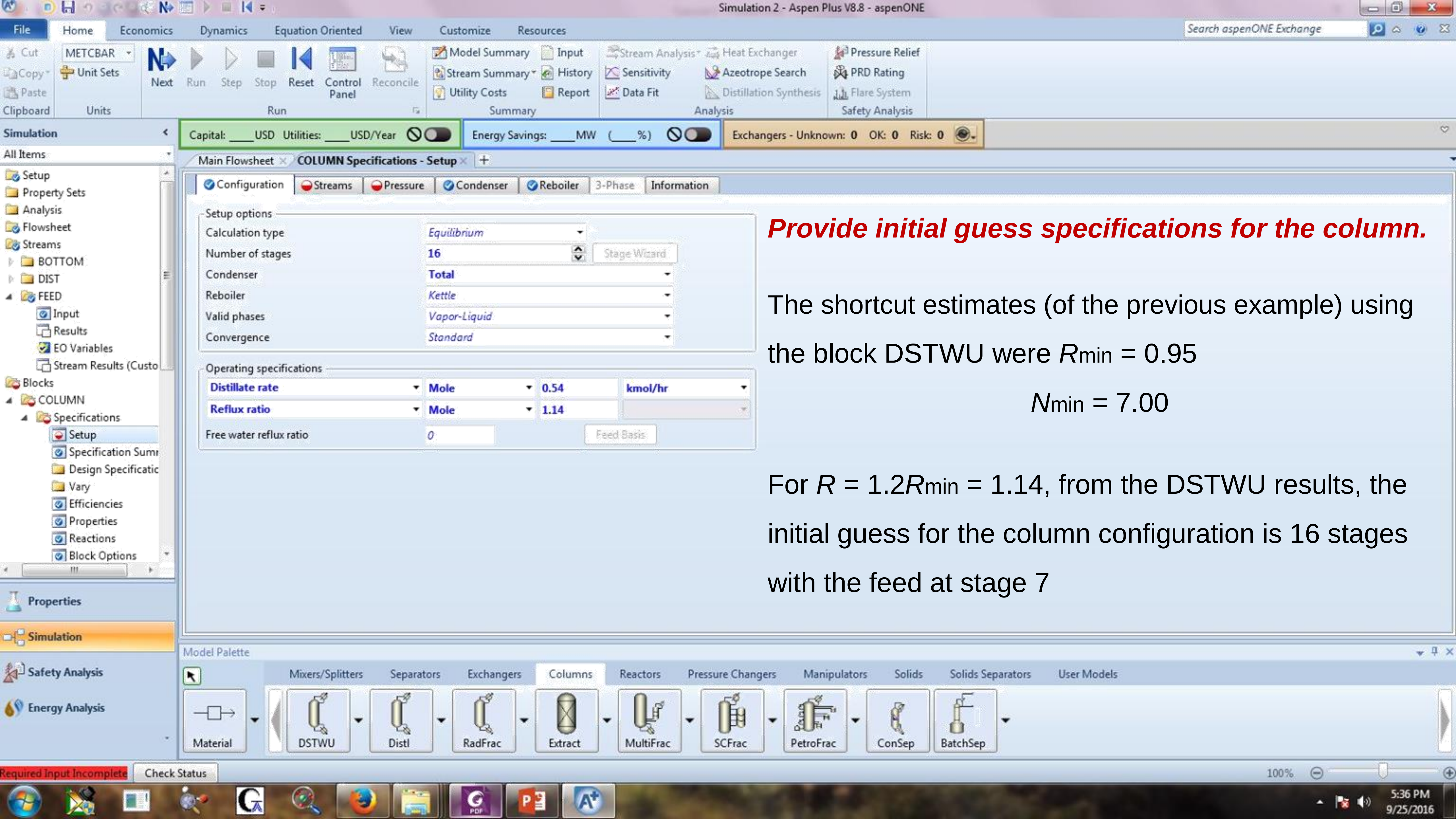


Base method: NRTL



Select
Columns -> RadFrac
and rename the streams.


Simulation 2 - Aspen Plus V8.8 - aspenONE
Main Flowsheet
FEED (MATERIAL) - Input
Mixed
CI Solid
NC Solid
Flash Options
EO Options
Costing
Information
Specifications
Flash Type
Temperature
Pressure
State variables
Temperature 92.08 C
Pressure 1 atm
Vapor fraction
Total flow basis Mole
Total flow rate kmol/hr
Solvent
Reference Temperature
Volume flow reference temperature
Component concentration reference temperature
Composition
Mole-Flow
kmol/hr
Component
Value
BENZE-01 0.5
TOLUE-01 0.5
Total 1
Component Attributes
Particle Size Distribution
Feed conditions
Required Input Incomplete
Check Status

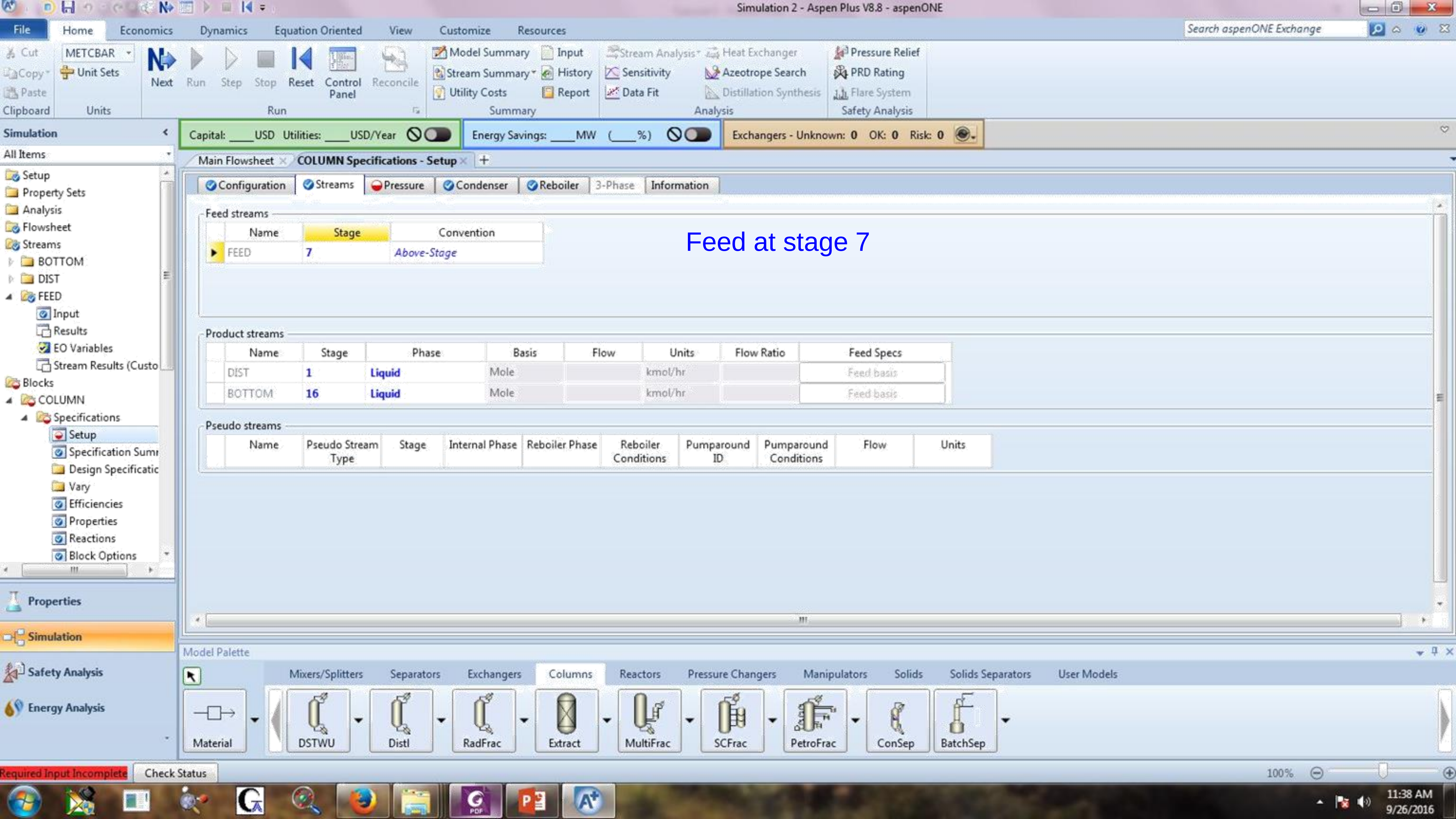


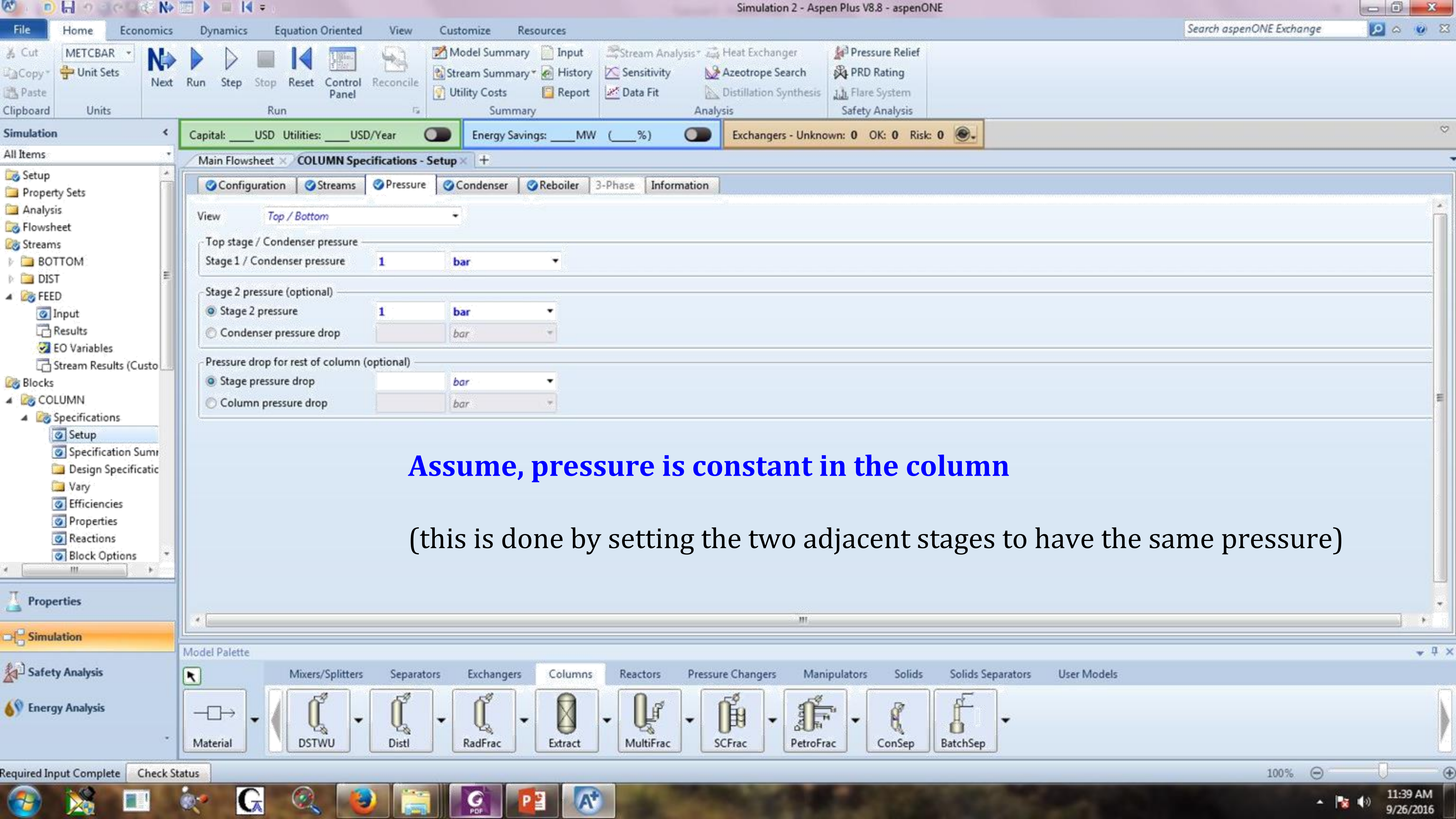
Provide initial guess specifications for the column.

The shortcut estimates (of the previous example) using the block DSTWU were $R_{min} = 0.95$

$N_{min} = 7.00$

For $R = 1.2R_{min} = 1.14$, from the DSTWU results, the initial guess for the column configuration is 16 stages with the feed at stage 7


Simulation 2 - Aspen Plus V8.8 - aspenONE
COLUMN Specifications - Setup
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Information
Feed streams
Name
Stage
Convention
FEED
7
Above-Stage
Feed at stage 7
Product streams
Name
Stage
Phase
Basis
Flow
Units
Flow Ratio
Feed Specs
DIST
1
Liquid
Mole
kmol/hr
Feed basis
BOTTOM
16
Liquid
Mole
kmol/hr
Feed basis
Pseudo streams
Required Input Incomplete
Check Status



Assume, pressure is constant in the column

(this is done by setting the two adjacent stages to have the same pressure)

Stream Results

	FEED	DIST	BOTTOM
Substream: MIXED			
Mole Flow kmol/hr			
BENZE-01	0.5	0.489132	0.0108684
TOLUE-01	0.5	0.0508684	0.449132
Mole Frac			
BENZE-01	0.5	0.905799	0.0236269
TOLUE-01	0.5	0.0942007	0.976373
Mass Flow kg/hr			
BENZE-01	39.0568	38.2079	0.848971
TOLUE-01	46.0703	4.68704	41.3832
Mass Frac			
BENZE-01	0.458806	0.890732	0.0201024
TOLUE-01	0.541194	0.109268	0.979898
Total Flow kmol/hr	1	0.54	0.46
Total Flow kg/hr	85.1271	42.8949	42.2322

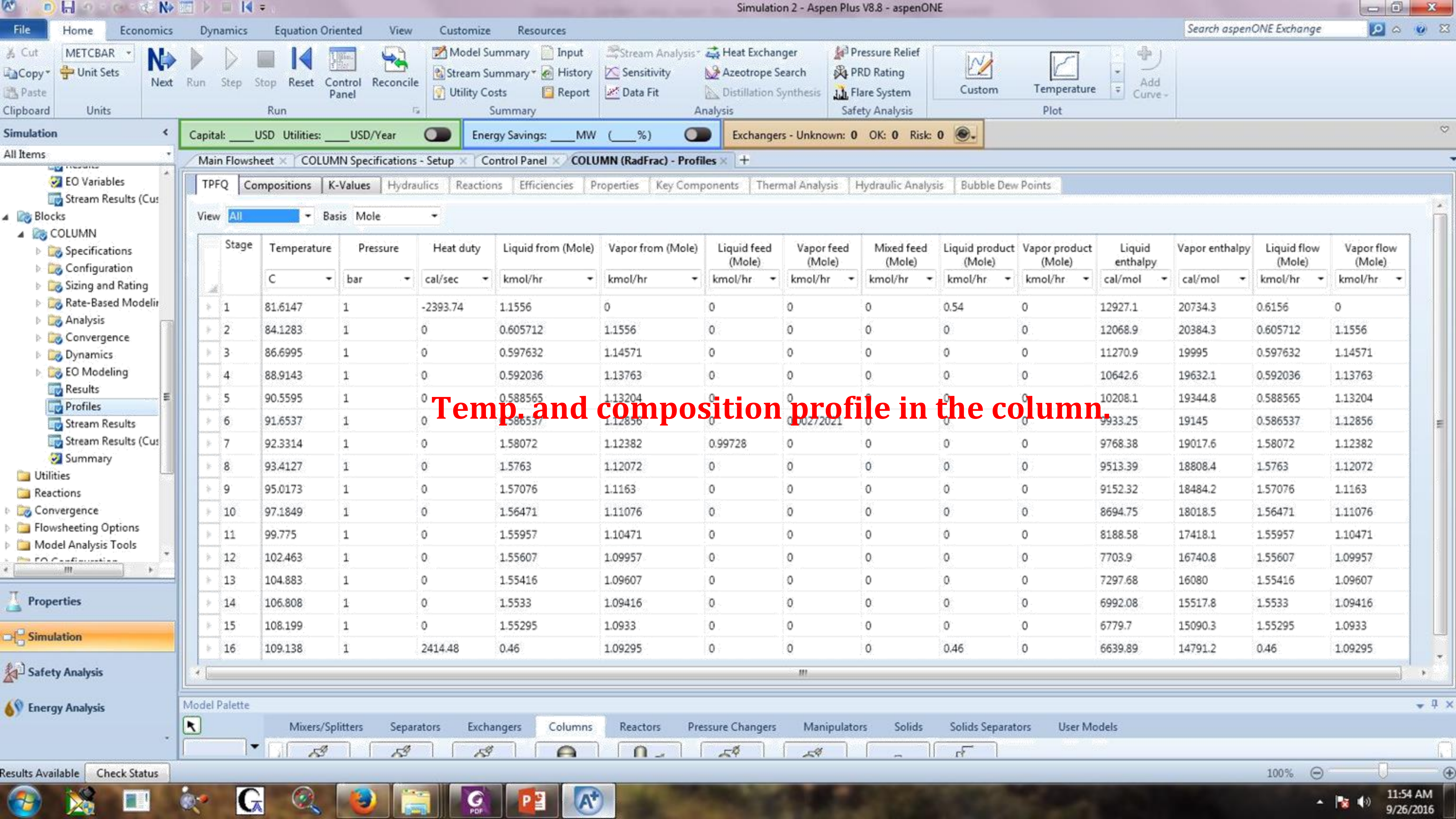
Simulation 2 - Aspen Plus V8.8 - aspenONE

COLUMN (RadFrac) - Summary

EO Model components	
Calculated molar reflux ratio	1.14
Calculated bottoms rate [kmol/hr]	0.46
Calculated boilup rate [kmol/hr]	1.09295
Calculated distillate rate [kmol/hr]	0.54
Condenser / top stage temperature [C]	81.6147
Condenser / top stage pressure [bar]	1
Condenser / top stage heat duty [cal/sec]	-2393.74
Condenser / top stage subcooled duty	
Condenser / top stage reflux rate [kmol/hr]	0.6156
Condenser / top stage free water reflux ratio	
Reboiler pressure [bar]	1
Reboiler temperature [C]	109.138
Reboiler heat duty [cal/sec]	2414.48
Total feed stream CO2e flow [kg/hr]	0
Total product stream CO2e flow [kg/hr]	0

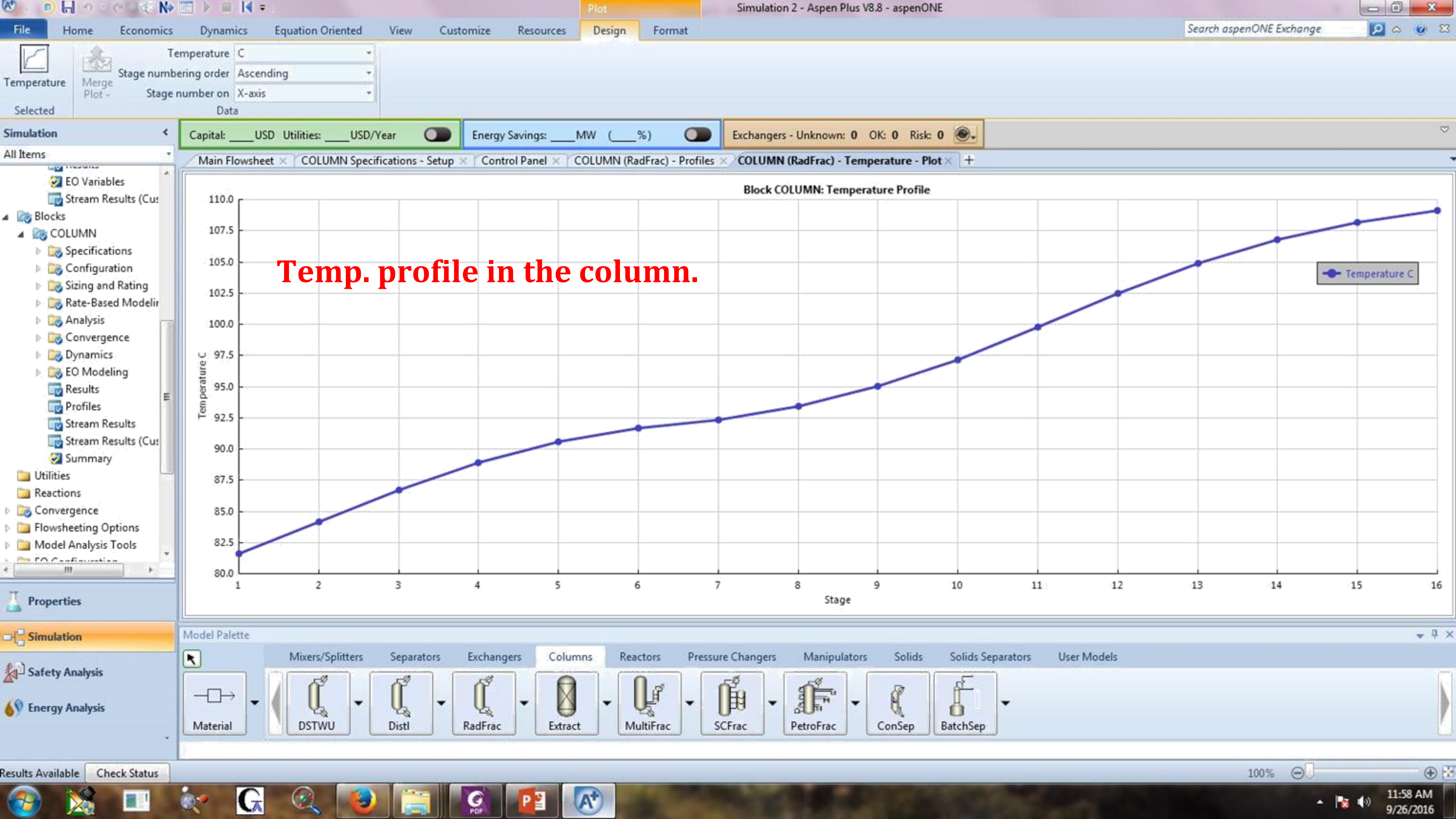
For a flow of 1 kmol/hr

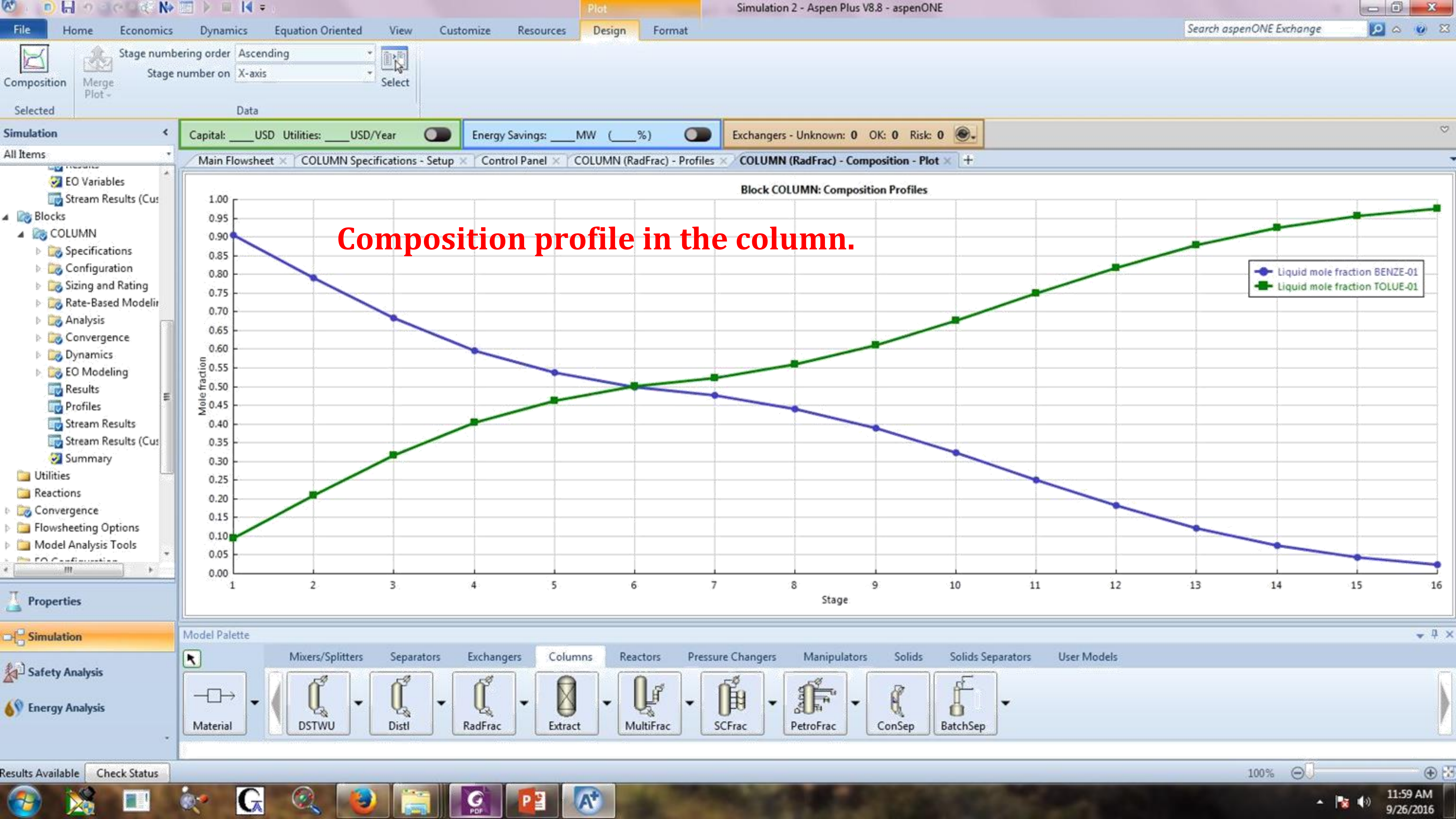
the reboiler heat duty = 2393 cal/sec,
condenser cooling duty = 2414 cal/sec.

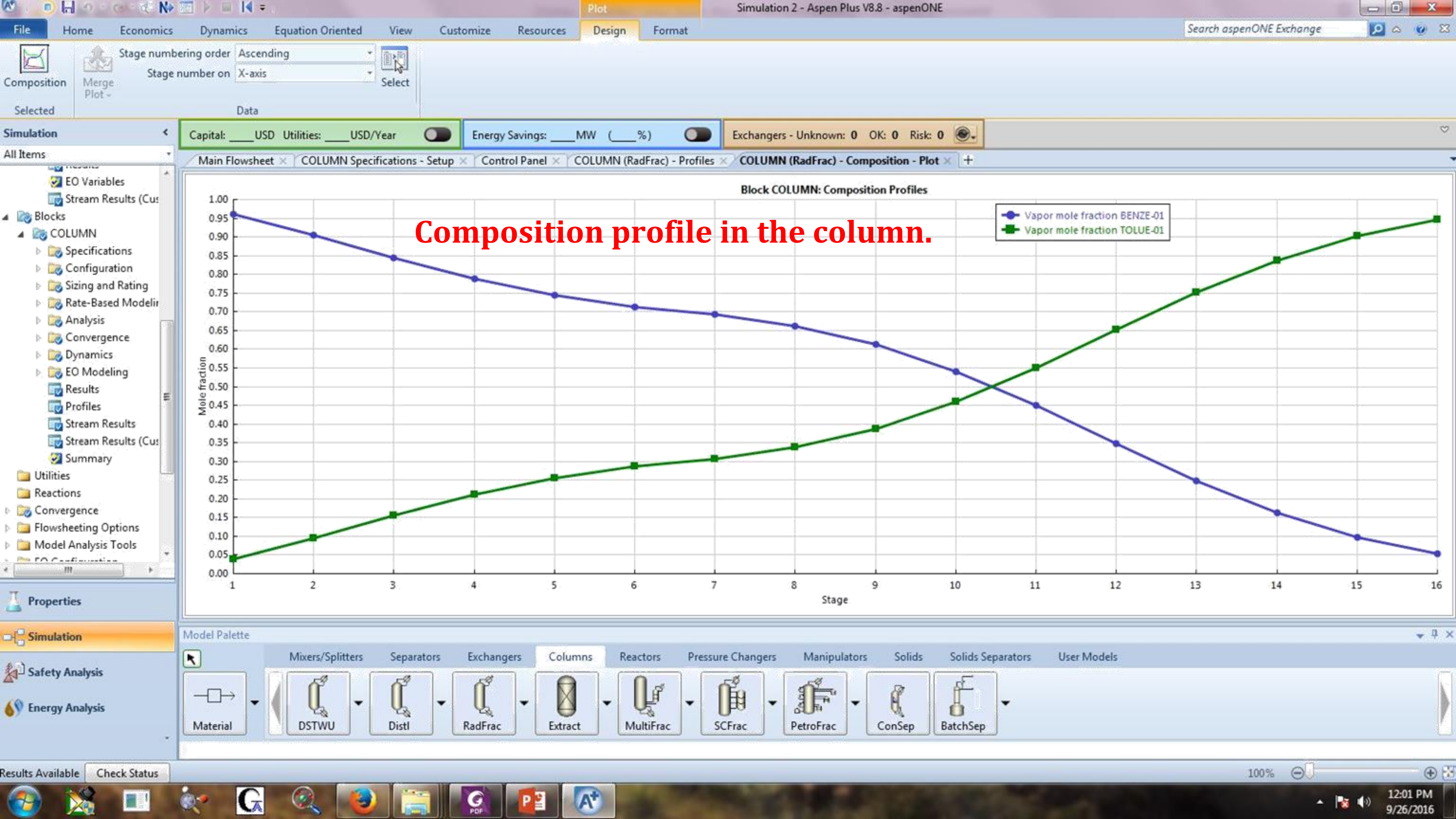


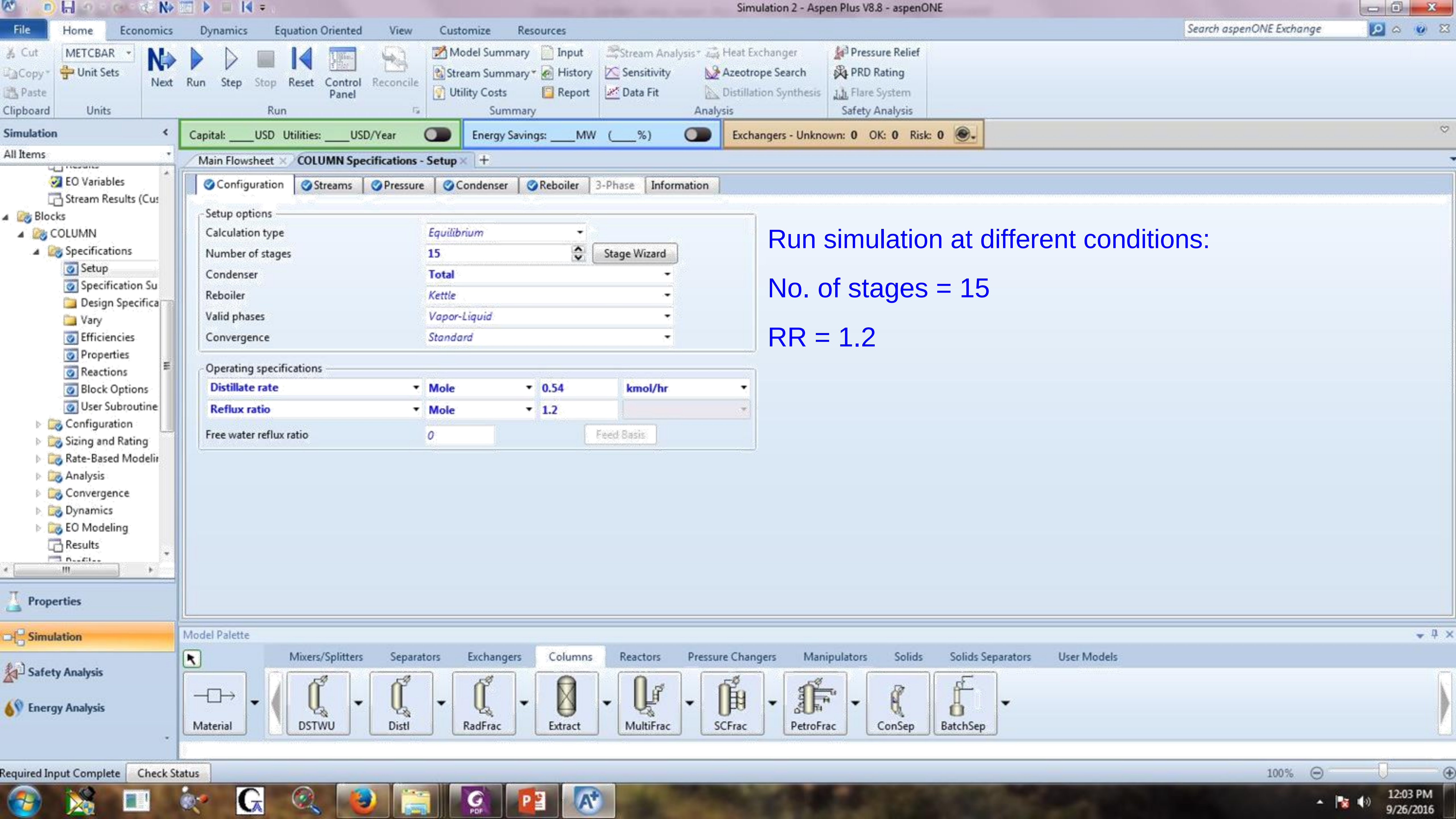
Stage	Temperature (C)	Pressure (bar)	Heat duty (cal/sec)	Liquid from (Mole) (kmol/hr)	Vapor from (Mole) (kmol/hr)	Liquid feed (Mole) (kmol/hr)	Vapor feed (Mole) (kmol/hr)	Mixed feed (Mole) (kmol/hr)	Liquid product (Mole) (kmol/hr)	Vapor product (Mole) (kmol/hr)	Liquid enthalpy (cal/mol)	Vapor enthalpy (cal/mol)	Liquid flow (Mole) (kmol/hr)	Vapor flow (Mole) (kmol/hr)
1	81.6147	1	-2393.74	1.1556	0	0	0	0	0.54	0	12927.1	20734.3	0.6156	0
2	84.1283	1	0	0.605712	1.1556	0	0	0	0	0	12068.9	20384.3	0.605712	1.1556
3	86.6995	1	0	0.597632	1.14571	0	0	0	0	0	11270.9	19995	0.597632	1.14571
4	88.9143	1	0	0.592036	1.13763	0	0	0	0	0	10642.6	19632.1	0.592036	1.13763
5	90.5595	1	0	0.588565	1.13204	0	0	0	0	0	10208.1	19344.8	0.588565	1.13204
6	91.6537	1	0	0.586537	1.12856	0	0.00272021	0	0	0	9933.25	19145	0.586537	1.12856
7	92.3314	1	0	1.58072	1.12382	0.99728	0	0	0	0	9768.38	19017.6	1.58072	1.12382
8	93.4127	1	0	1.5763	1.12072	0	0	0	0	0	9513.39	18808.4	1.5763	1.12072
9	95.0173	1	0	1.57076	1.1163	0	0	0	0	0	9152.32	18484.2	1.57076	1.1163
10	97.1849	1	0	1.56471	1.11076	0	0	0	0	0	8694.75	18018.5	1.56471	1.11076
11	99.775	1	0	1.55957	1.10471	0	0	0	0	0	8188.58	17418.1	1.55957	1.10471
12	102.463	1	0	1.55607	1.09957	0	0	0	0	0	7703.9	16740.8	1.55607	1.09957
13	104.883	1	0	1.55416	1.09607	0	0	0	0	0	7297.68	16080	1.55416	1.09607
14	106.808	1	0	1.5533	1.09416	0	0	0	0	0	6992.08	15517.8	1.5533	1.09416
15	108.199	1	0	1.55295	1.0933	0	0	0	0	0	6779.7	15090.3	1.55295	1.0933
16	109.138	1	2414.48	0.46	1.09295	0	0	0	0.46	0	6639.89	14791.2	0.46	1.09295

Temp. and composition profile in the column.


Temp. profile in the column.
Simulation 2 - Aspen Plus V8.8 - aspenONE
File
Home
Economics
Dynamics
Equation Oriented
View
Customize
Resources
Design
Format
Plot
Temperature
Merge Plot
Stage numbering order
Ascending
Stage number on
X-axis
Selected
Data
Capital: ____USD Utilities: ____USD/Year
Energy Savings: ____MW (____%)
Exchangers - Unknown: 0 OK: 0 Risk: 0
Main Flowsheet
COLUMN Specifications - Setup
Control Panel
COLUMN (RadFrac) - Profiles
COLUMN (RadFrac) - Temperature - Plot
Simulation
All Items
EO Variables
Stream Results (Cus
Blocks
COLUMN
Specifications
Configuration
Sizing and Rating
Rate-Based Modelir
Analysis
Convergence
Dynamics
EO Modeling
Results
Profiles
Stream Results
Stream Results (Cus
Summary
Utilities
Reactions
Convergence
Flowsheeting Options
Model Analysis Tools
Block COLUMN: Temperature Profile
Temperature C
Stage
110.0
107.5
105.0
102.5
100.0
97.5
95.0
92.5
90.0
87.5
85.0
82.5
80.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Properties
Simulation
Safety Analysis
Energy Analysis
Model Palette
Mixers/Splitters
Separators
Exchangers
Columns
Reactors
Pressure Changers
Manipulators
Solids
Solids Separators
User Models
Material
DSTWU
Distl
RadFrac
Extract
MultiFrac
SCFrac
PetroFrac
ConSep
BatchSep
Results Available
Check Status
100%
11:58 AM
9/26/2016


Simulation 2 - Aspen Plus V8.8 - aspenONE
Composition profile in the column.
Block COLUMN: Composition Profiles
Liquid mole fraction BENZE-01
Liquid mole fraction TOLUE-01
Mole fraction
Stage

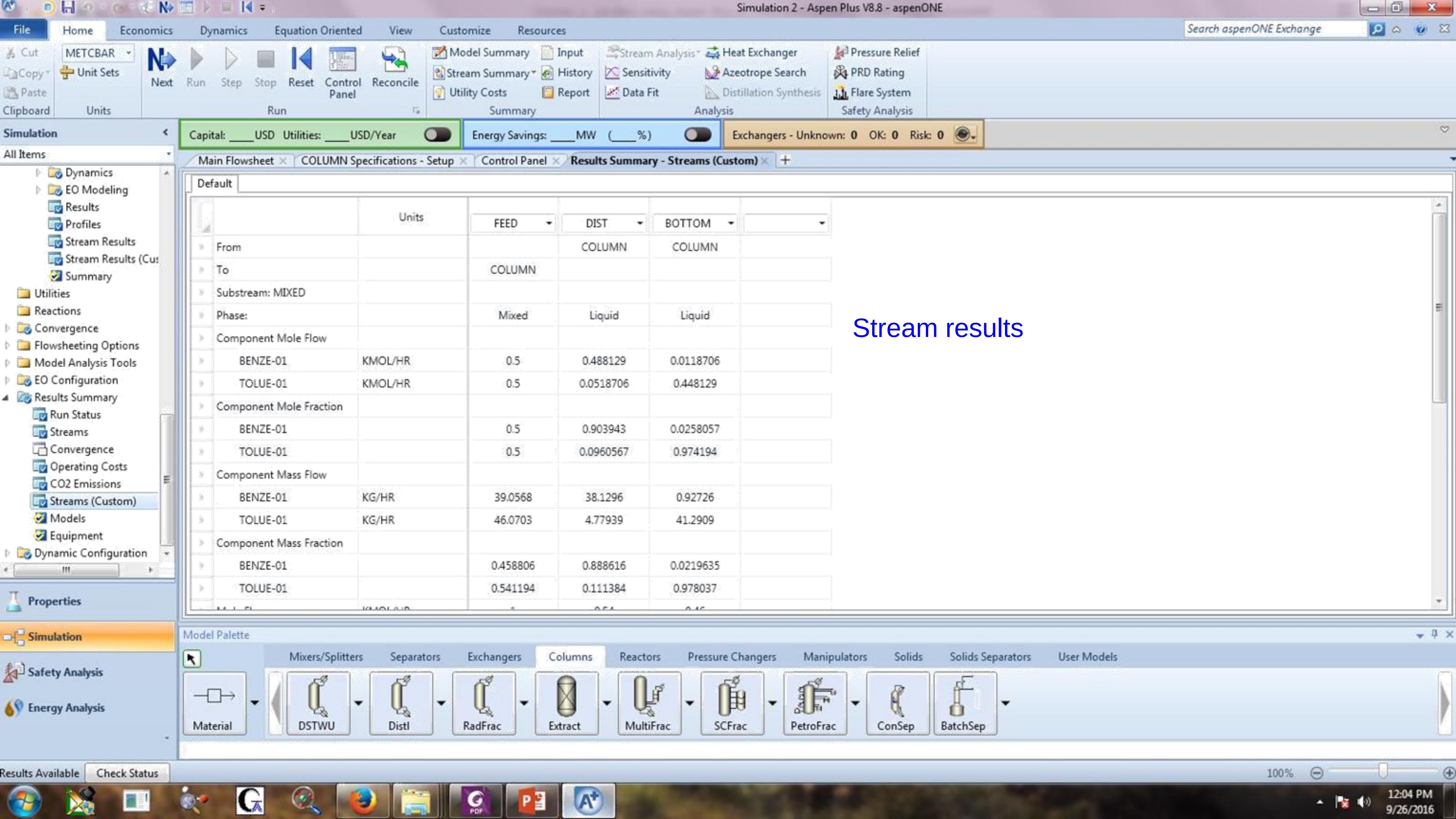

Simulation 2 - Aspen Plus V8.8 - aspenONE
COLUMN (RadFrac) - Composition - Plot
Block COLUMN: Composition Profiles
Composition profile in the column.
Vapor mole fraction BENZE-01
Vapor mole fraction TOLUE-01
Mole fraction
Stage
Model Palette



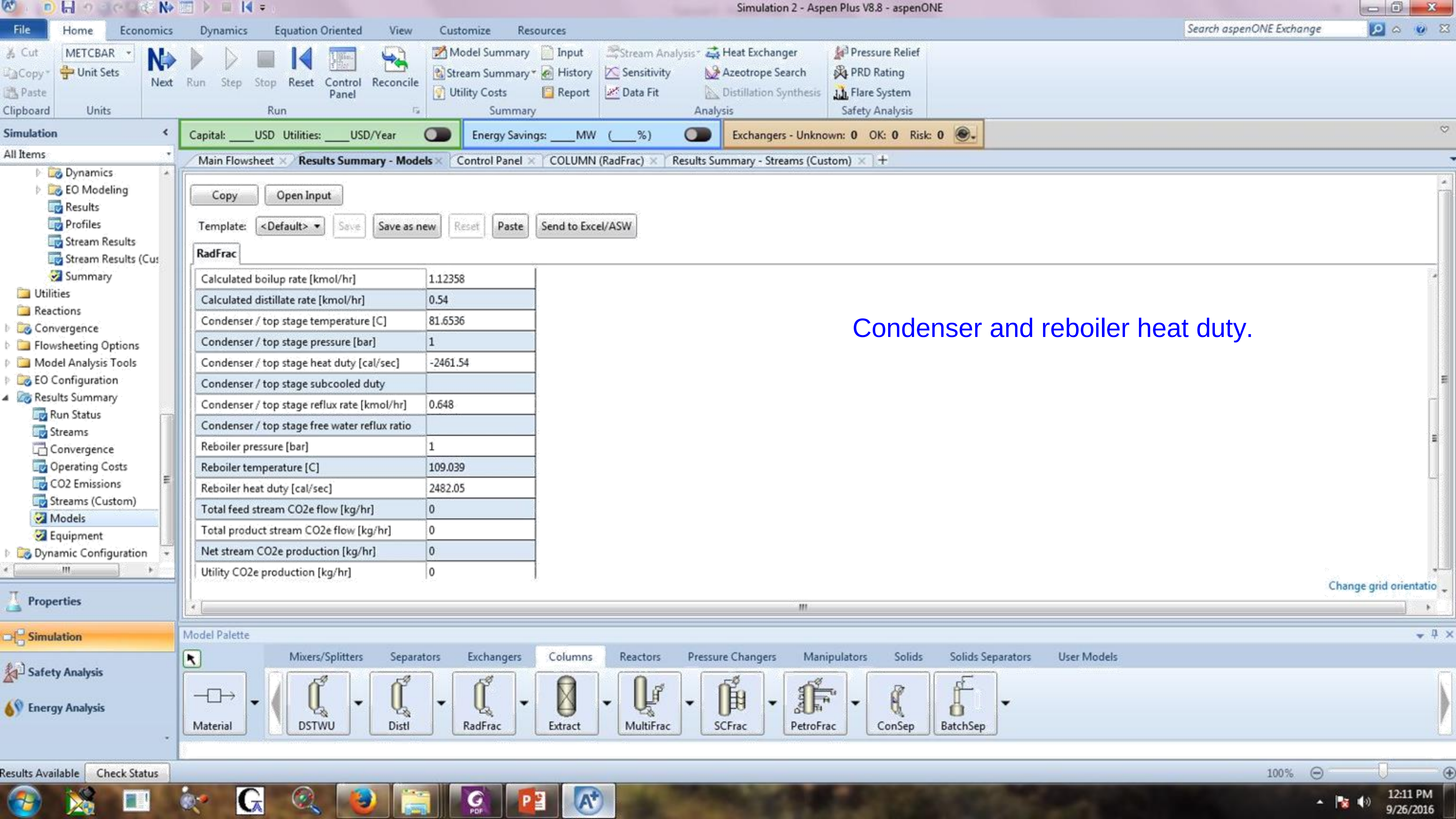
Run simulation at different conditions:

No. of stages = 15

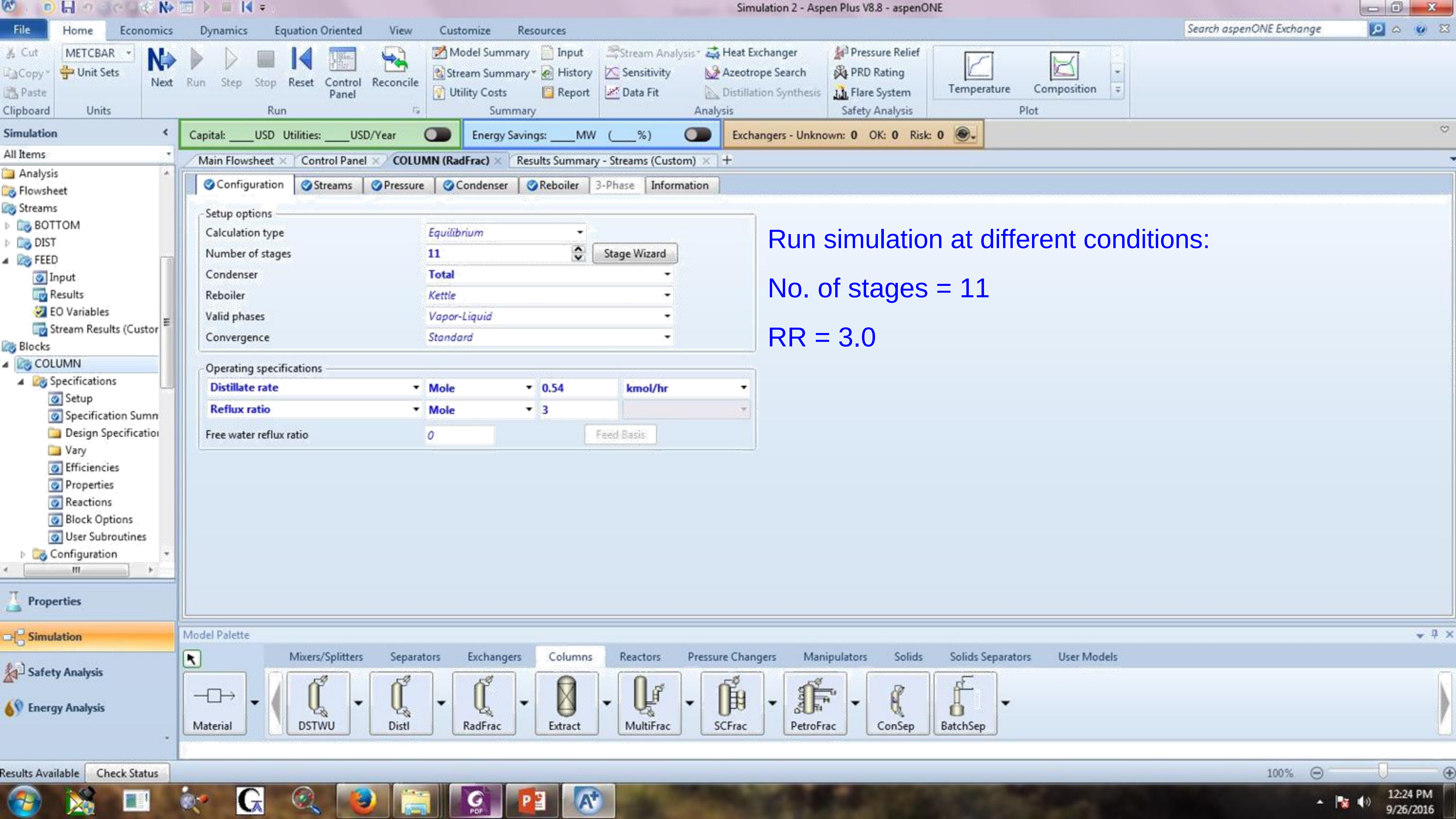
RR = 1.2



	Units	FEED	DIST	BOTTOM
From			COLUMN	COLUMN
To		COLUMN		
Substream: MIXED				
Phase:		Mixed	Liquid	Liquid
Component Mole Flow				
BENZE-01	KMOL/HR	0.5	0.488129	0.0118706
TOLUE-01	KMOL/HR	0.5	0.0518706	0.448129
Component Mole Fraction				
BENZE-01		0.5	0.903943	0.0258057
TOLUE-01		0.5	0.0960567	0.974194
Component Mass Flow				
BENZE-01	KG/HR	39.0568	38.1296	0.92726
TOLUE-01	KG/HR	46.0703	4.77939	41.2909
Component Mass Fraction				
BENZE-01		0.458806	0.888616	0.0219635
TOLUE-01		0.541194	0.111384	0.978037



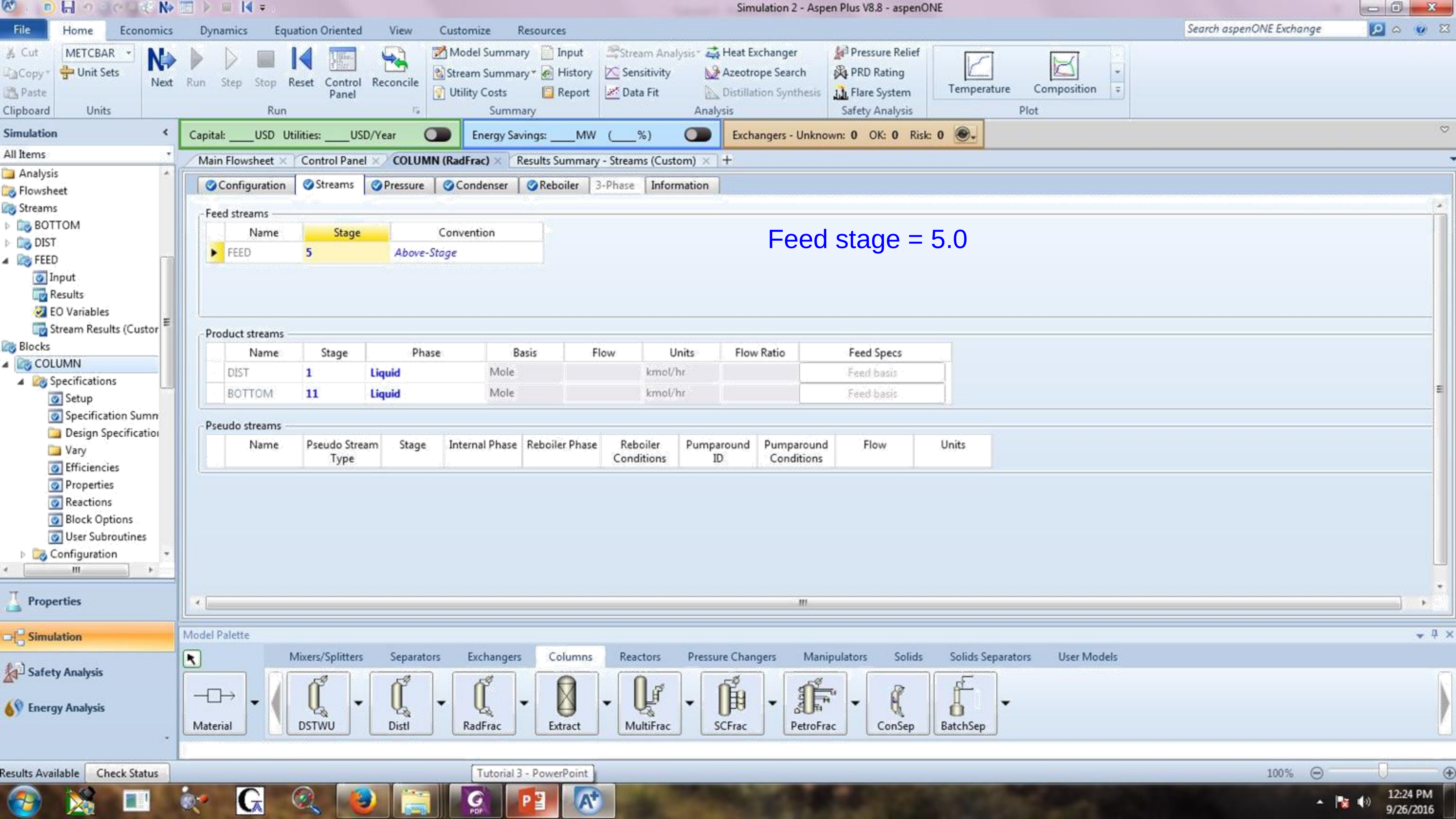
Condenser and reboiler heat duty.



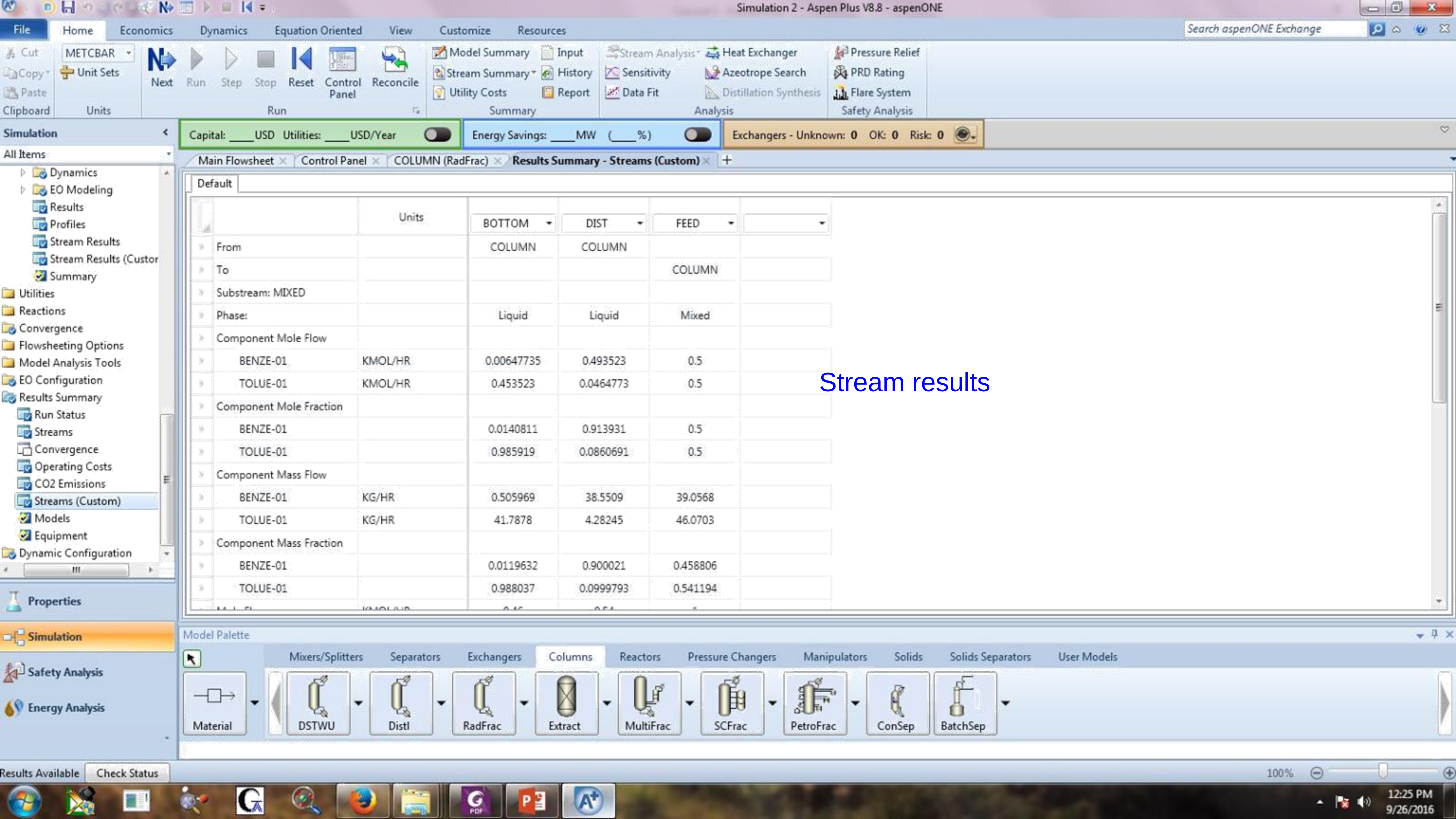
Run simulation at different conditions:

No. of stages = 11

RR = 3.0

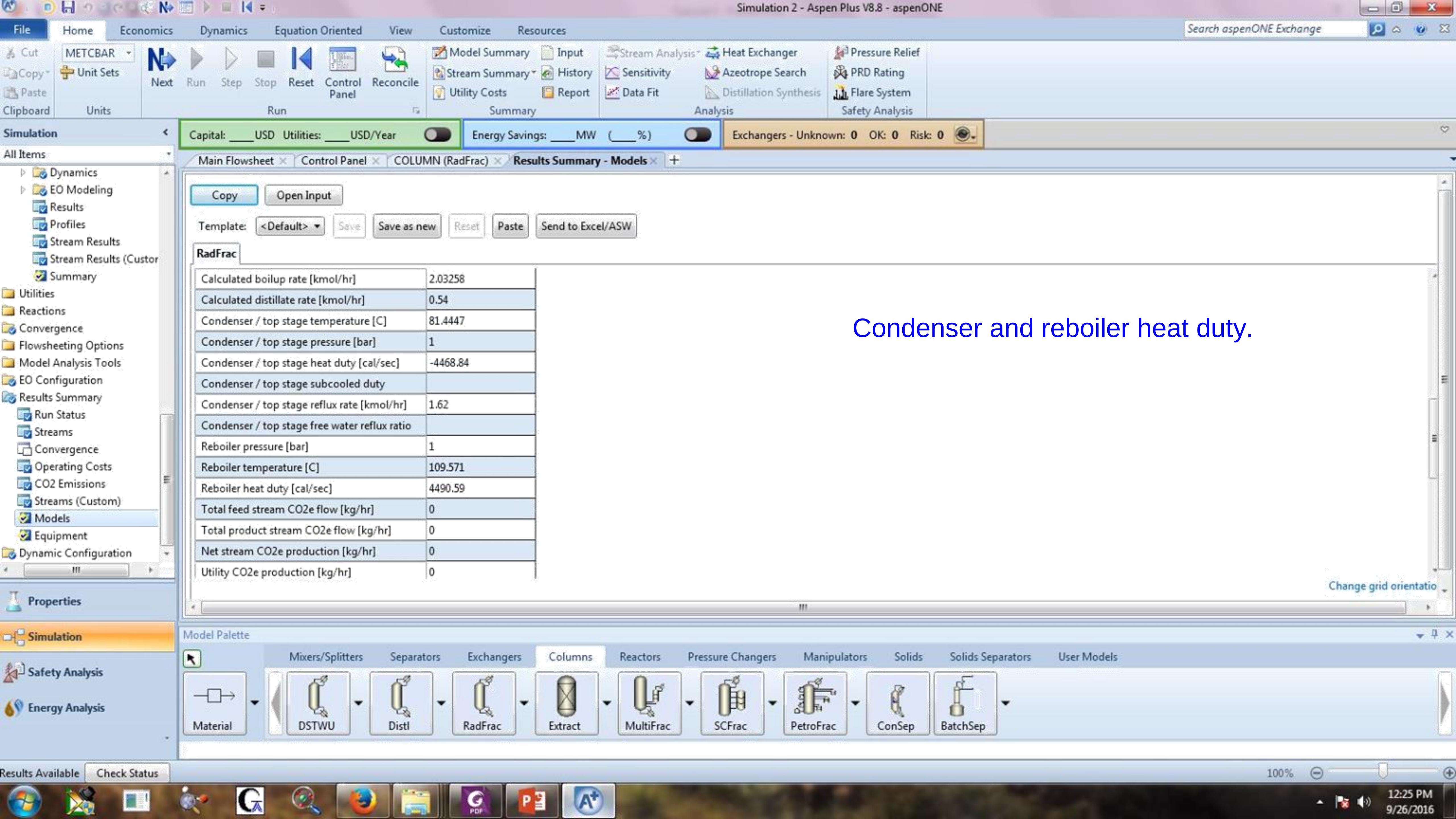


Simulation 2 - Aspen Plus V8.8 - aspenONE
Main Flowsheet
Control Panel
COLUMN (RadFrac)
Results Summary - Streams (Custom)
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Information
Feed stage = 5.0
Feed streams
Name
Stage
Convention
FEED
5
Above-Stage
Product streams
Name
Stage
Phase
Basis
Flow
Units
Flow Ratio
Feed Specs
DIST
1
Liquid
Mole
kmol/hr
Feed basis
BOTTOM
11
Liquid
Mole
kmol/hr
Feed basis
Pseudo streams
Name
Pseudo Stream Type
Stage
Internal Phase
Reboiler Phase
Reboiler Conditions
Pumparound ID
Pumparound Conditions
Flow
Units
Model Palette
Material
DSTWU
Distl
RadFrac
Extract
MultiFrac
SCFrac
PetroFrac
ConSep
BatchSep



	Units	BOTTOM	DIST	FEED
From		COLUMN	COLUMN	
To				COLUMN
Substream: MIXED				
Phase:		Liquid	Liquid	Mixed
Component Mole Flow				
BENZE-01	KMOL/HR	0.00647735	0.493523	0.5
TOLUE-01	KMOL/HR	0.453523	0.0464773	0.5
Component Mole Fraction				
BENZE-01		0.0140811	0.913931	0.5
TOLUE-01		0.985919	0.0860691	0.5
Component Mass Flow				
BENZE-01	KG/HR	0.505969	38.5509	39.0568
TOLUE-01	KG/HR	41.7878	4.28245	46.0703
Component Mass Fraction				
BENZE-01		0.0119632	0.900021	0.458806
TOLUE-01		0.988037	0.0999793	0.541194

Stream results



Condenser and reboiler heat duty.

We have found three column designs that meet the required composition specifications.

Their parameters are shown in the following table:

Reflux ratio	1.14	1.2	3
No. of stages	16	15	11
Feed stage	7	7	5
Reboiler heat duty (cal/sec)	2414	2482	4490
condenser heat duty (cal/sec)	2393	2461	4468

Summary

In a similar fashion, we can find other choices of column parameters that would meet the composition specifications. So the question is which one of the many possible configurations should be used. To answer that question, one has to bring other factors. If costs were the only consideration, then there would be a trade-off between capital costs and operating (heat and cooling) costs.

From the table above, we can see that as the reflux ratio increases, the number of stages (and therefore column height) decreases, thereby reducing that part of the capital cost. However, the vapor and liquid flow rates increase, so a larger diameter column is needed, which increases the capital cost. Also as the reflux ratio increases, the amount of liquid per unit of product that needs to be boiled in the reboiler increases, as does the amount of vapor that needs to be condensed. These increase the capital costs of these two heat exchangers, and more importantly the ongoing energy costs of both units. [Note that increasing the reflux ratio to 3 from 1.25 almost doubled the energy requirements.]

In next Tutorial, we will Perform the steady-state economic optimization of the distillation column based on total annual cost (TAC).

THE END