

15.1.5.2. Problem-2: Multi-component Distillation***Problem Statement:***

A continuous fractionating column having 17 stages with total condenser and reboiler is to be designed to separate 27522.2 kmol per hr. of a mixture of 28.19 % methanol, 46.26 % n-butane and 25.55 % i-butene on molar basis. A reflux ratio of 10 mol to 1 mol of product is to be used. The feed enters at bubble point at 1172 kPa and at 10th stage. Overhead product rate coming out of the column is 2043.0 kmol per hr. The pressure at condenser and reboiler are 1115 kPa and 1216 kPa respectively. Simulate the distillation column assuming no pressure drop across the reboiler and condenser to find:

1. Conditions of feed, distillate and bottom streams.
2. Properties of feed, distillate and bottom streams.
3. Composition of distillate and bottom products.
4. Temperature, liquid rate and vapor rate profile throughout the column.
5. Composition profiles of all the components throughout the column.
6. Heat duties required for the condenser and reboiler, temperature of condenser and reboiler.

Column Specifications:

Total number of trays:	17
Feed tray location:	10 th tray
Feed flow rate:	2752.2 kmol per hr
Distillate flow rate:	2043.0 kmol per hr
Feed compositions:	
Methanol:	0.2819 (mole fraction)
n-butane:	0.4626 (mole fraction)
i-butene:	0.2555 (mole fraction)
Feed condition:	Saturated liquid at 1172 kPa

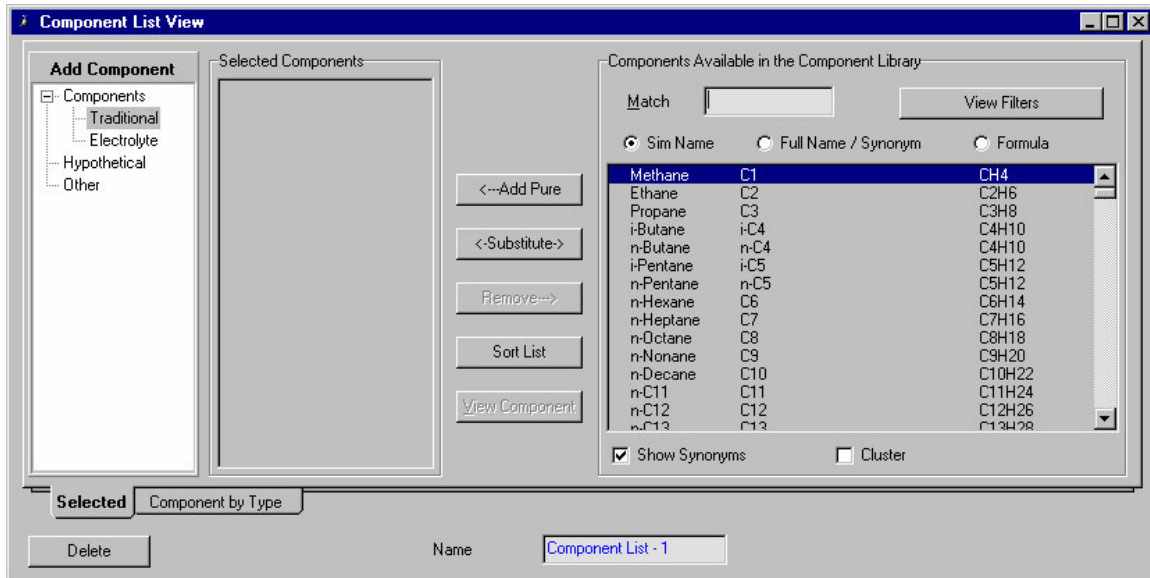
Reflux ratio: 10
Reboiler Pressure: 1216 kPa
Condenser Pressure: 1115 kPa
Pressure drop in condenser: 0 kPa

Solution steps:

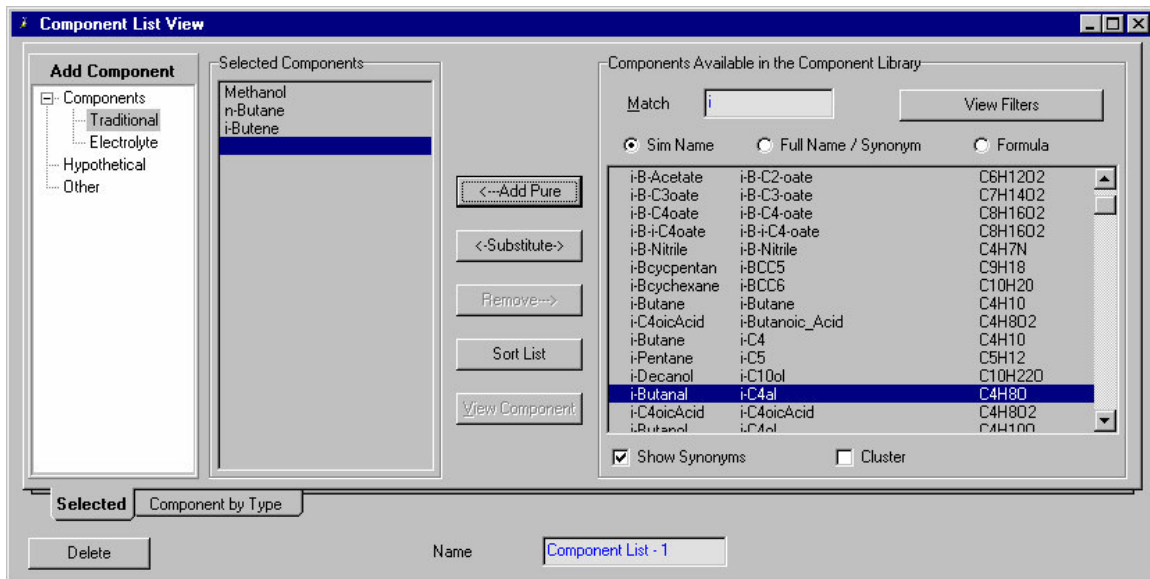
1. Open the file as a new case; the following window named as Simulation Basis Manager will be displayed.



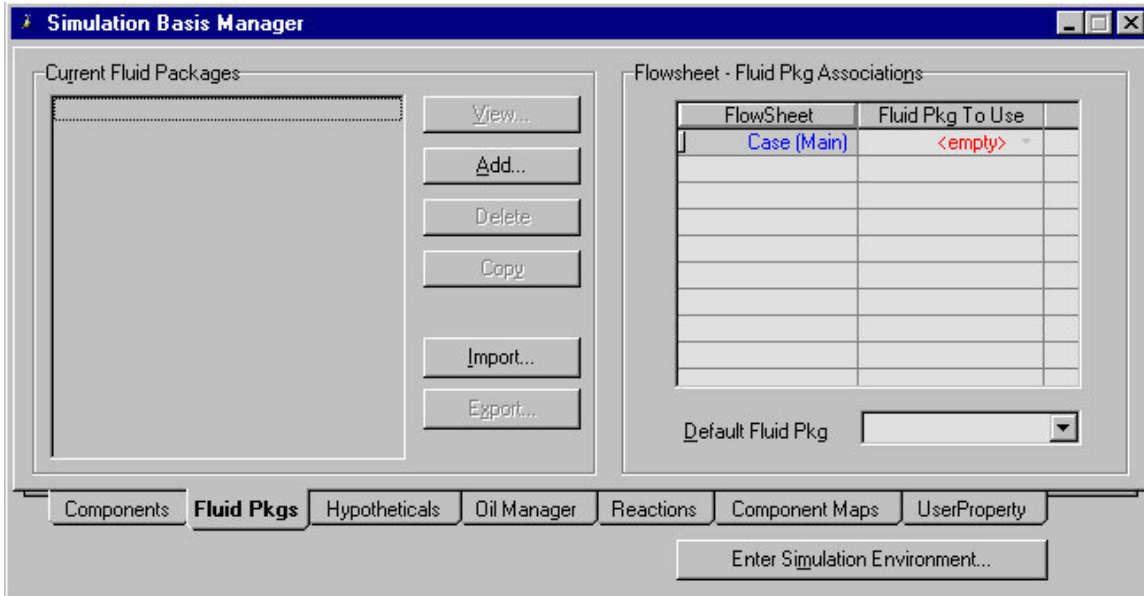
- Click the “add” button to select components and fluid package to be used for the simulation of column.



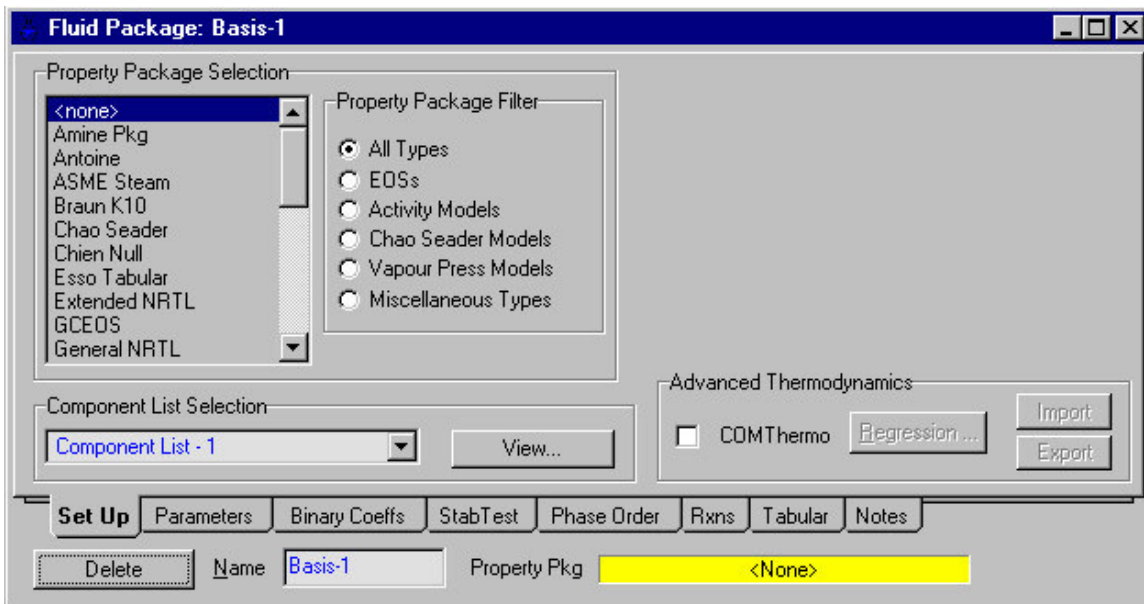
- Select the components and add them from the list by clicking “add pure” button. Here the components selected are methanol, i-butene and n-butane.



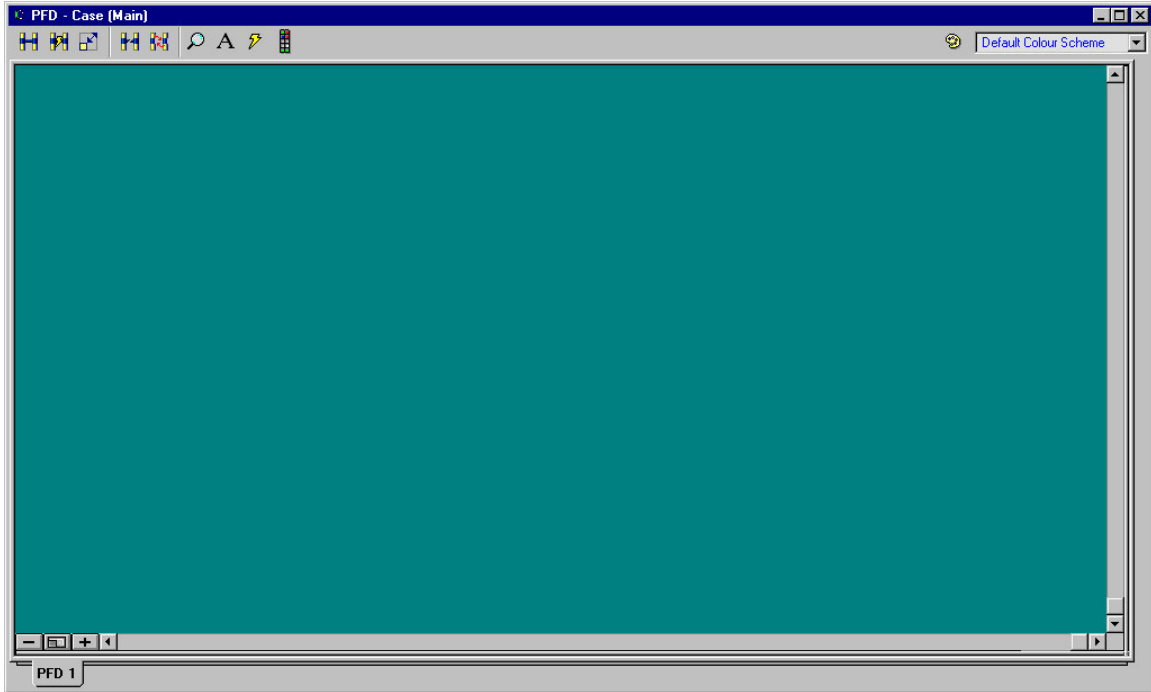
- Close the window and the Simulation Basis Manager window appears. Click on the Fluid Pkgs. The following window is displayed.



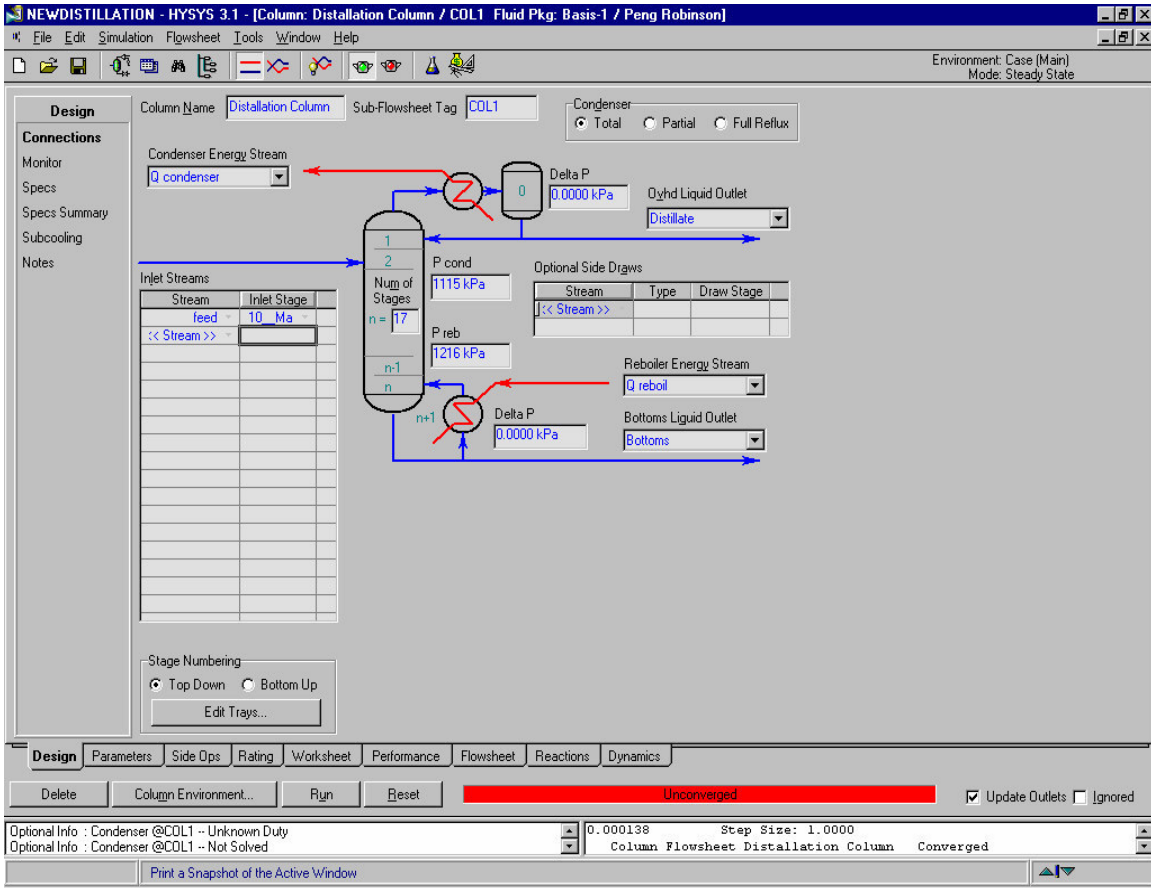
- Click the “Add” button, and select the fluid package to be used for the simulation of column.



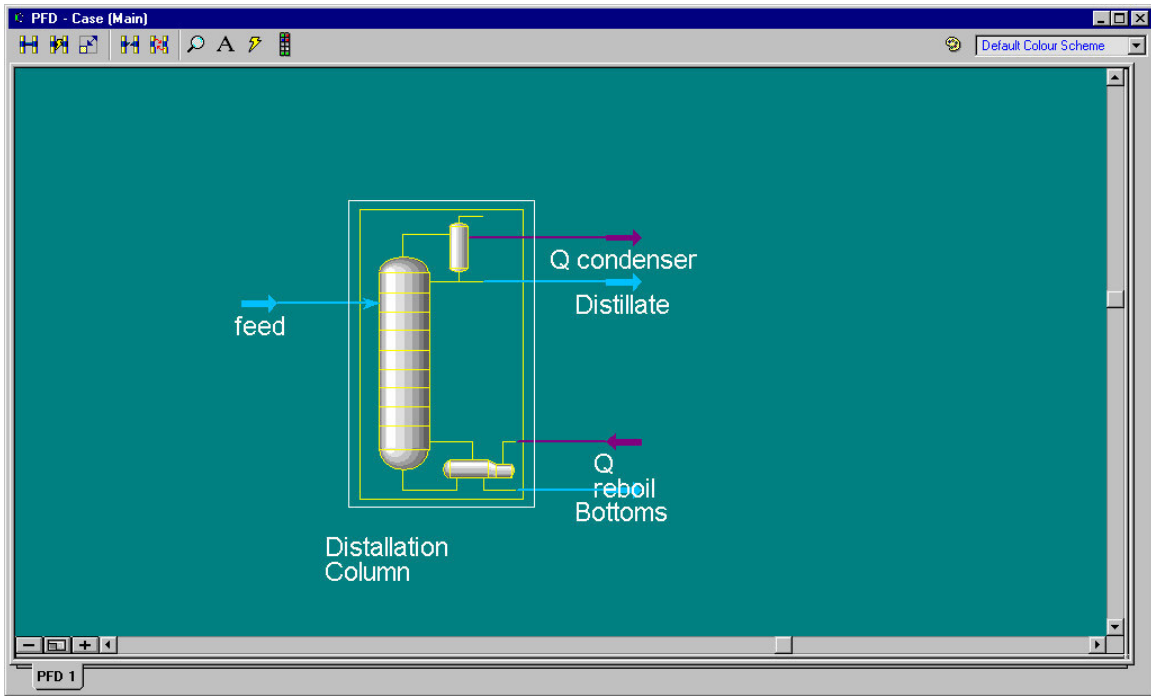
- Click the “Enter Simulation Environment” button. The following window is displayed.



- Select the distillation column by double clicking it at the Case (main) window Give the name to different streams like feed, distillate, bottoms, $Q_{\text{condenser}}$, Q_{reboiler} . Enter the value of number of trays, feed tray location, etc. and then click “Next” button. Then window related to the pressure will be displayed. Enter the Condenser pressure, reboiler pressure and condenser pressure drop values and the click at the “Next” button. The window related to the temperature at condenser and reboiler will be displayed which is optional. Then again after clicking at “Next” button enter the value of reflux ratio and distillate flow rate. Then click at the “Done”. The window showing the whole information about column that we added will be displayed as follows:



10. Close the window; the next window will display the distillation column with Feed, Distillate and Bottom streams.



11. Close the Window and double click at the Feed to specify the various conditions of

Worksheet	Stream Name	Value
Conditions	Vapour / Phase Fraction	<empty>
Properties	Temperature [C]	<empty>
Properties	Pressure [kPa]	<empty>
Composition	Molar Flow [kgmole/h]	<empty>
Composition	Mass Flow [kg/h]	<empty>
K Value	Std Ideal Liq Vol Flow [m3/h]	<empty>
User Variables	Molar Enthalpy [kJ/kgmole]	<empty>
Notes	Molar Entropy [kJ/kgmole-C]	<empty>
Notes	Heat Flow [kJ/h]	<empty>
Cost Parameters	Liq Vol Flow @Std Cond [m3/h]	<empty>
Cost Parameters	Fluid Package	Basis-1

Optional Info : Condenser @COL1 -- Unknown Duty
 Optional Info : Condenser @COL1 -- Not Solved
 Completed.

feed.

12. Select the Composition and add the known compositions for various components in the feed.

Here the molar composition of feed is:

Methanol: 0.2819 n-Butane: 0.4626 i-Butene: 0.2555

The screenshot shows the HYSYS 3.1 software interface. The main window displays a composition table for a feed stream. The table has columns for component names and mole fractions. The components listed are Methanol, n-Butane, and i-Butene. The mole fractions are 0.281900, 0.462600, and 0.255500 respectively. The total mole fraction is 1.00000. The interface also shows a menu bar, a toolbar, and a status bar at the bottom.

Component	Mole Fractions
Methanol	0.281900
n-Butane	0.462600
i-Butene	0.255500
Total	1.00000

Optional Info : Condenser @COL1 -- Unknown Duty
 Optional Info : Condenser @COL1 -- Not Solved
 Completed.

13. Select the Conditions and add the known properties of feed.

Here Feed properties are:

Feed flow rate: 2752.2 kmol per hr

Vapor/Phase Fraction: 0.0 (as feed is saturated liquid)

Pressure: 12 atm

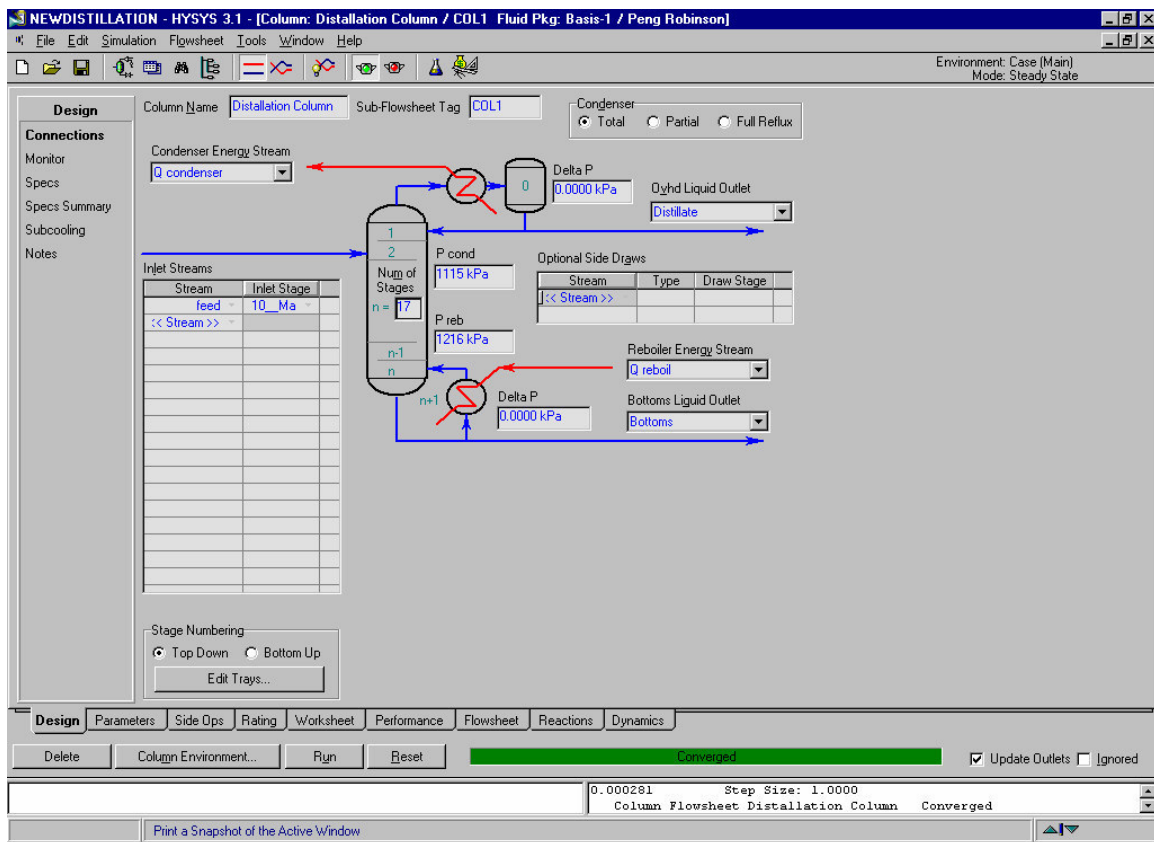
With this information the HYSYS will automatically simulate for rest of the feed properties.

The screenshot shows the HYSYS 3.1 interface with the 'Conditions' worksheet selected. The table below represents the data shown in the worksheet:

Stream Name	feed	Liquid Phase	Vapour Phase
Vapour / Phase Fraction	0.00000	1.00000	0.00000
Temperature [C]	93.055	93.055	93.055
Pressure [kPa]	1215.9	1215.9	1215.9
Molar Flow [kgmole/h]	2752.2	2752.2	0.00000
Mass Flow [kg/h]	1.3832e+005	1.3832e+005	0.00000
Std Ideal Liq Vol Flow [m3/h]	224.68	224.68	0.00000
Molar Enthalpy [kJ/kgmole-C]	-1.344e+005	-1.344e+005	-9.911e+004
Molar Entropy [kJ/kgmole-C]	96.610	96.610	150.79
Heat Flow [kJ/h]	-3.7001e+08	-3.7001e+08	0.0000e-01
Liq Vol Flow @Std Cond [m3/h]	219.09	219.09	0.00000
Fluid Package	Basis-1		

At the bottom of the window, there is a status bar showing 'Optional Info : Condenser @COL1 -- Unknown Duty' and 'Optional Info : Condenser @COL1 -- Not Solved', with a 'Completed.' indicator.

- Close the feed window; double click at the Distillation Column, all the specifications of distillation column will be displayed. At this stage also we can change the specifications if needed. Now click at the “Run” button to simulate the Distillation column.



Results:

1. **Condition of feed, distillates and bottoms:** Click on “work sheet” button, select “Conditions”. This window will display the conditions of Feed, Distillate and Bottom products.

The screenshot shows a software window titled "Column: Distillation Column / COL1 Fluid Pkg: Basis-1 / Peng Robinson". The "Worksheet" tab is active, displaying a table with the following data:

Name	feed @COL1	Distillate @COL	Bottoms @COL
Vapour	0.0000	0.0000	0.0000
Temperature [C]	93.05	81.95	147.1
Pressure [kPa]	1216	1115	1216
Molar Flow [kgmole/h]	2752	2043	709.1
Mass Flow [kg/h]	1.383e+005	1.156e+005	2.272e+004
Std Ideal Liq Vol Flow [m3/h]	224.7	196.1	28.55
Molar Enthalpy [kJ/kgmole]	-1.344e+005	-1.041e+005	-2.267e+005
Molar Entropy [kJ/kgmole-C]	96.61	101.6	58.70
Heat Flow [kJ/h]	-3.700e+008	-2.127e+008	-1.607e+008

At the bottom of the window, there are several tabs: Design, Parameters, Side Ops, Rating, **Worksheet**, Performance, Flowsheet, Reactions, and Dynamics. Below the tabs are buttons for "Delete", "Column Environment...", "Run", and "Reset". A green "Converged" indicator is visible, along with checkboxes for "Update Outlets" (checked) and "Ignored" (unchecked).

2. **Properties of feed, distillate and Bottoms:** Click on the “Properties”, this window will display the properties of feed, distillate and bottom products.

NEWDISTILLATION - HYSYS 3.1 - [Column: Distillation Column / COL1 Fluid Pkg: Basis-1 / Peng Robinson]

Environment: Case (Main)
Mode: Steady State

Name	feed	Distillate	Bottoms
Vapour Fraction	0.00000	0.00000	0.00000
Temperature [C]	93.055	81.949	147.13
Pressure [kPa]	1215.9	1114.6	1215.9
Actual Vol. Flow [m3/h]	262.23	229.20	35.725
Mass Enthalpy [kJ/kg]	-2675.1	-1840.1	-7074.4
Mass Entropy [kJ/kg-C]	1.9224	1.7958	1.8320
Molecular Weight	50.256	56.578	32.042
Molar Density [kgmole/m3]	10.495	8.9139	19.849
Mass Density [kg/m3]	527.45	504.33	636.00
Liq Mass Density @Std Cond [kg/m3]	631.32	594.04	796.39
Molar Heat Capacity [kJ/kgmole-C]	160.86	169.45	145.62
Mass Heat Capacity [kJ/kg-C]	3.2009	2.9949	4.5446
Thermal Conductivity [W/m-K]	8.5556e-002	7.3559e-002	0.12321
Viscosity [cP]	0.10983	9.7996e-002	0.13693
Surface Tension [dyne/cm]	8.5906	6.0993	11.140
Specific Heat [kJ/kgmole-C]	160.86	169.45	145.62
Z Factor	3.8050e-002	4.2351e-002	1.7530e-002
Vap. Frac. (molar basis)	0.00000	0.00000	0.00000
Vap. Frac. (mass basis)	0.00000	0.00000	0.00000
Vap. Frac. (Volume Basis)	0.00000	0.00000	0.00000
Molar Volume [m3/kgmole]	9.5282e-002	0.11218	5.0380e-002
Act. Gas Flow [ACT_m3/h]	<empty>	<empty>	<empty>
Act. Liq. Flow [m3/s]	7.2843e-002	6.3667e-002	9.9236e-003
Liq Vol Flow @Std Cond [m3/h]	219.09	194.59	28.530
Std. Gas Flow [STD_m3/h]	65074	48308	16767
Watson K	12.967	13.345	10.625
Kinematic Viscosity [cSt]	0.20822	0.19431	0.21530
Cp/Cv	1.3206	1.3212	1.0606
Lower Heating Value [kJ/kgmole]	2.0551e+006	2.5470e+006	6.3810e+005
Mass Lower Heating Value [kJ/kg]	40893	45017	19915
Liquid Fraction	1.0000	1.0000	1.0000
Partial Pressure of CO2 [kPa]	0.00000	0.00000	0.00000
Avg. Liq. Density [kgmole/m3]	12.249	10.417	24.834
Heat Of Vap. [kJ/kgmole]	20201	17088	23789

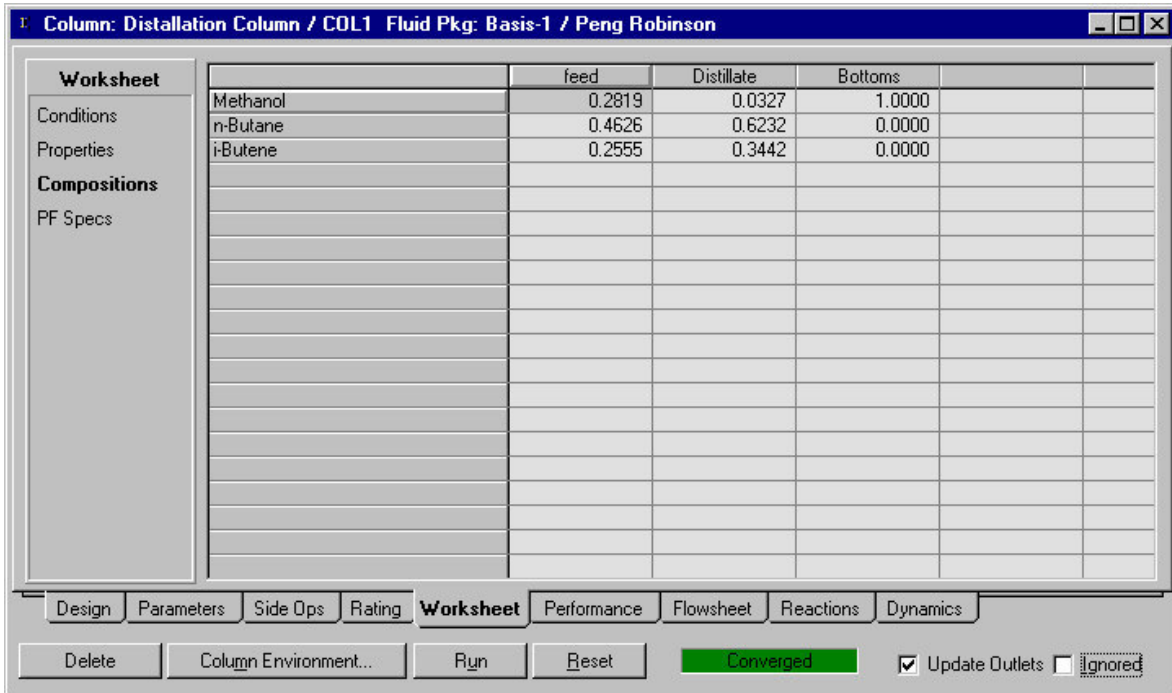
Design Parameters Side Dps Rating **Worksheet** Performance Flowsheet Reactions Dynamics

Delete Column Environment... Run Reset Converged Update Outlets Ignored

0.000281 Step Size: 1.0000
Column Flowsheet Distillation Column Converged

Print a Snapshot of the Active Window

3. **Composition of Distillate and Bottom products:** Click on the “Compositions”, this



window will display the compositions of feed, distillate as well as bottom products.

4. **Temperature, Vapor and Liquid Profiles throughout the column:** Click on “performance” button, select “Column profiles”, this window will display temperature, vapor rate and liquid rate at all trays inside the distillation column.

NEWDISTILLATION - HYSYS 3.1 - [Column: Distillation Column / COL1 Fluid Pkg: Basis-1 / Peng Robinson]

Environment: Case (Main)
Mode: Steady State

Reflux Ratio: 10.00
Reboil Ratio: 18.01

Basis: Molal Mass Liq Vol

	Temperature [C]	Pressure [kPa]	Net Liquid [kgmole/h]	Net Vapour [kgmole/h]	Net Feed [kgmole/h]	Net Draws [kgmole/h]
Condenser	81.95	1115	20430.9			2043.1
1_Main TS	82.85	1115	20087.9	22474.0		
2_Main TS	84.38	1121	19579.9	22131.0		
3_Main TS	86.67	1127	18607.2	21623.0		
4_Main TS	90.93	1134	16455.8	20650.3		
5_Main TS	101.9	1140	12336.3	18498.9		
6_Main TS	125.2	1146	11177.4	14379.4		
7_Main TS	135.2	1153	11206.1	13220.5		
8_Main TS	137.2	1159	11224.2	13249.2		
9_Main TS	137.7	1165	11235.3	13267.3		
10_Main TS	137.9	1172	13295.5	13278.4	2752.2	
11_Main TS	144.6	1178	13391.2	12586.4		
12_Main TS	145.8	1184	13416.5	12682.1		
13_Main TS	146.2	1191	13430.7	12707.4		
14_Main TS	146.5	1197	13443.4	12721.6		
15_Main TS	146.7	1203	13455.9	12734.3		
16_Main TS	146.9	1210	13468.3	12746.7		
17_Main TS	147.1	1216	13482.5	12759.2		
Reboiler	147.1	1216	12773.4			709.11

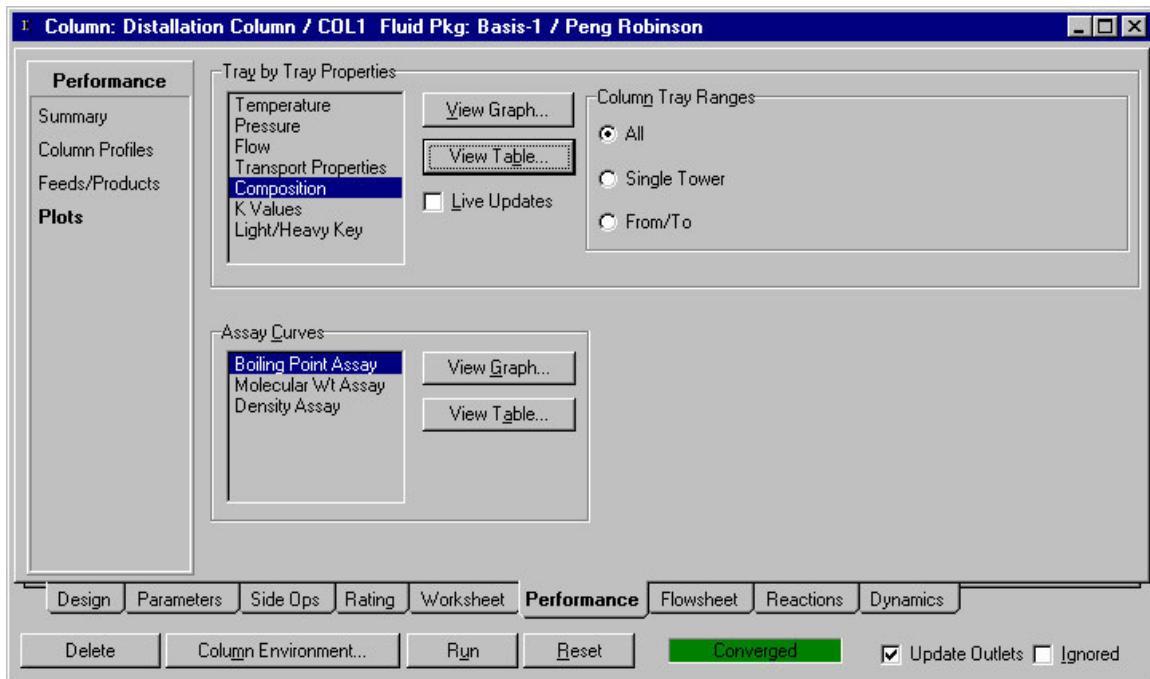
Design Parameters Side Ops Rating Worksheet **Performance** Flowsheet Reactions Dynamics

Delete Column Environment... Run Reset Converged Update Outlets Ignored

0.000281 Step Size: 1.0000
Column Flowsheet Distillation Column Converged

Print a Snapshot of the Active Window

5. **Composition profiles:** Click on “Plot” options, select “Compositions and click on “View Tables” (or on View Graphs), this window will display compositions of all components at each tray inside the column in form of table (or graph).

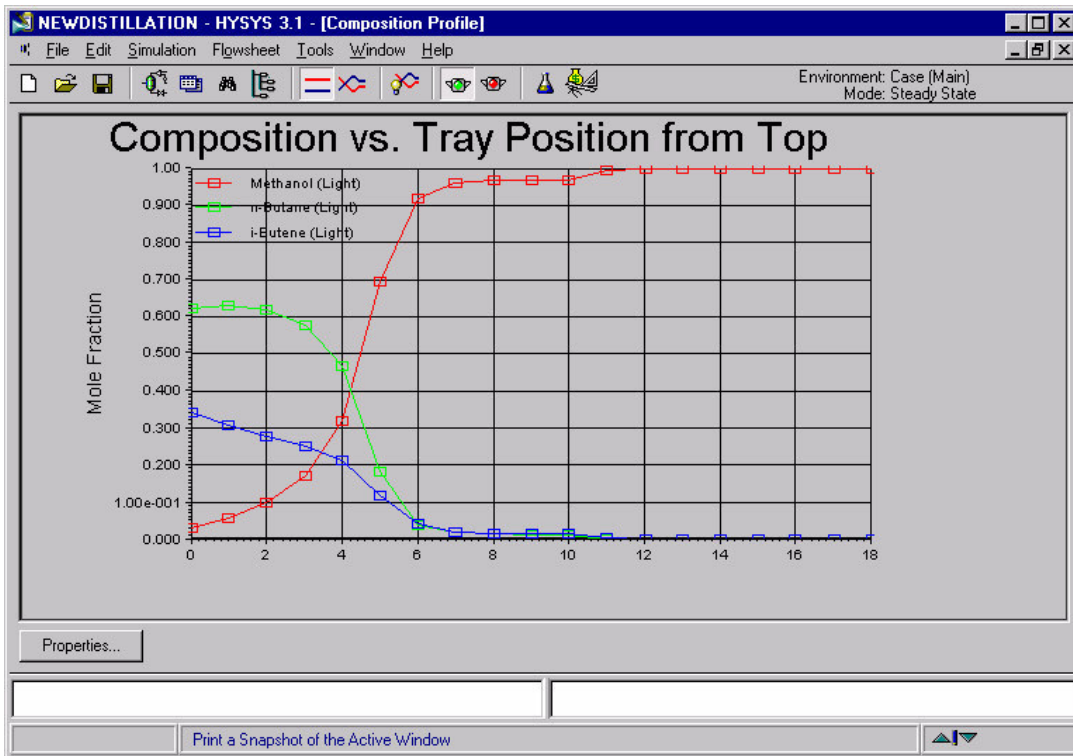


NEWDISTILLATION - HYSYS 3.1 - [Profile Table: Composition Profile]

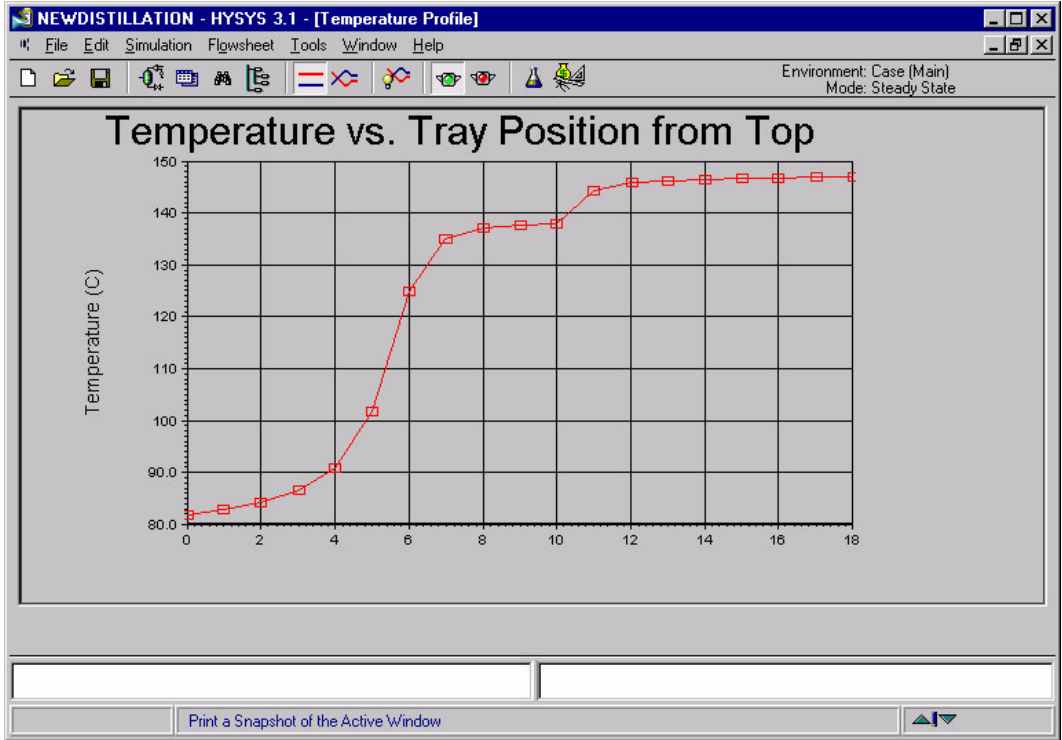
Environment: Case (Main)
Mode: Steady State

	Methanol (Light Liq)	n-Butane (Light Liq)	i-Butene (Light Liq)
Condenser	0.0327	0.6232	0.3442
1_Main TS	0.0576	0.6324	0.3100
2_Main TS	0.0987	0.6221	0.2793
3_Main TS	0.1714	0.5791	0.2495
4_Main TS	0.3211	0.4669	0.2121
5_Main TS	0.6948	0.1855	0.1197
6_Main TS	0.9197	0.0399	0.0404
7_Main TS	0.9628	0.0175	0.0197
8_Main TS	0.9701	0.0145	0.0153
9_Main TS	0.9713	0.0142	0.0145
10_Main TS	0.9714	0.0142	0.0144
11_Main TS	0.9951	0.0018	0.0031
12_Main TS	0.9991	0.0002	0.0006
13_Main TS	0.9998	0.0000	0.0001
14_Main TS	1.0000	0.0000	0.0000
15_Main TS	1.0000	0.0000	0.0000
16_Main TS	1.0000	0.0000	0.0000
17_Main TS	1.0000	0.0000	0.0000
Reboiler	1.0000	0.0000	0.0000

0.000281 Step Size: 1.0000
Column Flowsheet Distillation Column Converged



Similarly we can find the plot for liquid, vapor and temperature profiles throughout the column after clicking at “View Graph” button for respective profiles. For example the result of Temperature profile will be displayed as follows:



- Boiler and Condenser duties and temperatures:** Click on “Feeds/Products”, this window will display all the loads and properties related to the condenser and reboiler.

NEWDISTILLATION - HYSYS 3.1 - [Column: Distillation Column / COL1 Fluid Pkg: Basis-1 / Peng Robinson]

File Edit Simulation Flowsheet Tools Window Help

Environment: Case (Main)
Mode: Steady State

Basis: Molal Mass Liq/Vol

Performance

Summary
Column Profiles
Feeds/Products
Plots

	Stream	Type	Duty [kJ/h]	Phase	Flows [kgmole/h]	Enthalpy [kJ/kgmole]	Temp [C]
Condenser	Q condenser Distillate	Energy Draw	3.8399e+008	Liquid	2043.1	-1.041e+005	81.95
1_Main TS							
2_Main TS							
3_Main TS							
4_Main TS							
5_Main TS							
6_Main TS							
7_Main TS							
8_Main TS							
9_Main TS							
10_Main TS	feed	Feed		Liquid	2752.2	-1.344e+005	93.05
11_Main TS							
12_Main TS							
13_Main TS							
14_Main TS							
15_Main TS							
16_Main TS							
17_Main TS							
Reboiler	Q reboil Bottoms	Energy Draw	3.8049e+008	Liquid	709.11	-2.267e+005	147.1

Design Parameters Side Ops Rating Worksheet **Performance** Flowsheet Reactions Dynamics

Delete Column Environment... Run **Reset** Converged Update Outlets Ignored

0.000281 Step Size: 1.0000
Column Flowsheet Distillation Column Converged

Print a Snapshot of the Active Window