NGL Fractionation Train

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04 NGL Fractionation Train.pdf

Workshop

Recovery of natural-gas liquids (NGL) from natural gas is quite common in natural gas processing. Recovery is usually done to:

- produce transportable gas (free from heavier hydrocarbons which may condense in the pipeline).
- meet a sales gas specification.
- maximize liquid recovery (when liquid products are more valuable than gas).

HYSYS can model a wide range of different column configurations. In this simulation, an NGL Plant will be constructed, consisting of three columns:

- De-Methanizer (operated and modelled as a Reboiled Absorber column)
- De-Ethanizer (Distillation column)
- De-Propanizer (Distillation column)

Learning Objectives

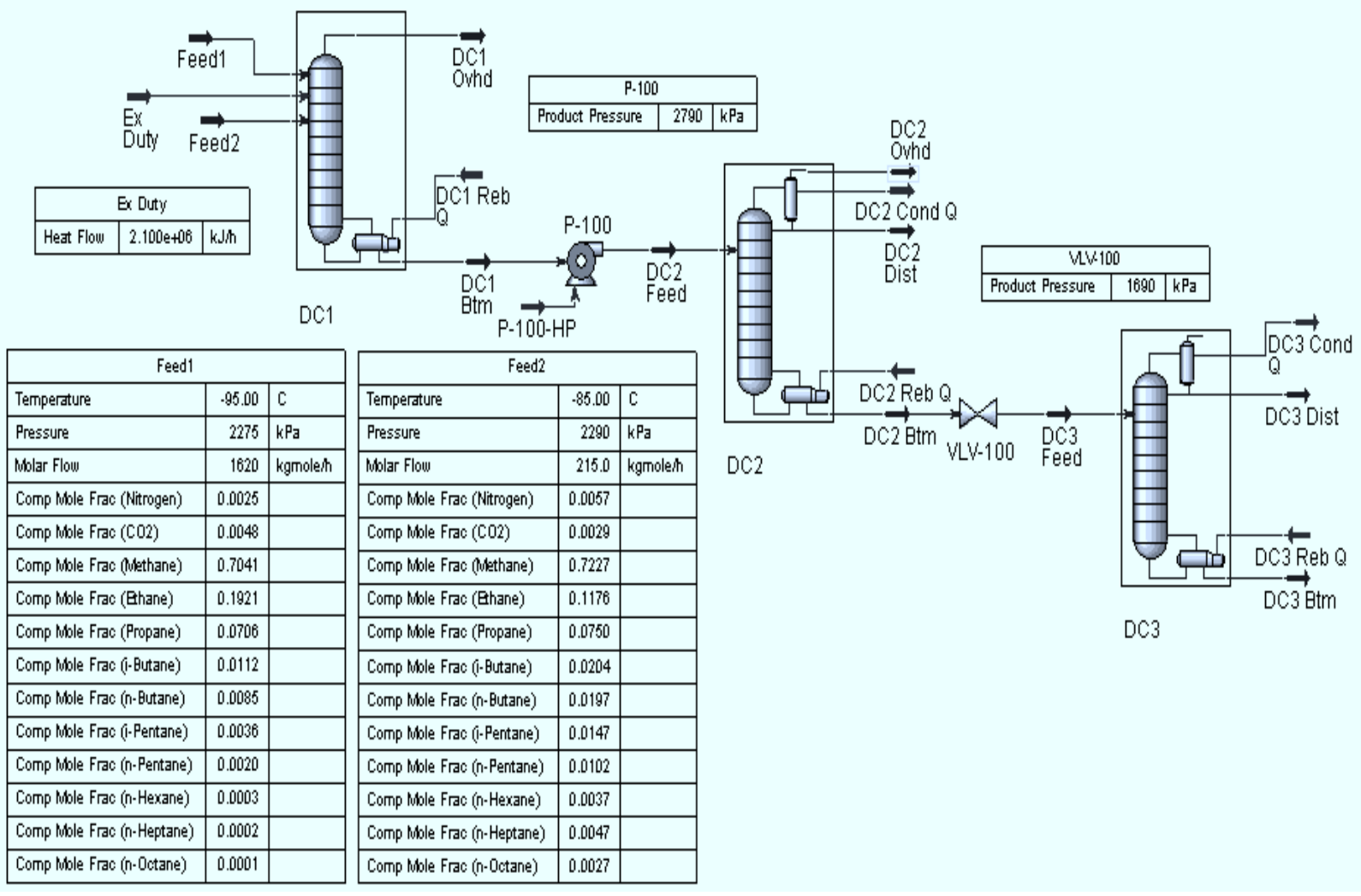
Once you have completed this section, you will be able to:

- Add columns using the Input Experts.
- Add extra specifications to columns.

Prerequisites

Before beginning this module you need to complete modules 1, 2, and 3.

Process Overview



P-100		
Product Pressure	2790	kPa

Ex Duty		
Heat Flow	2.100e+06	kJ/h

VLV-100		
Product Pressure	1690	kPa

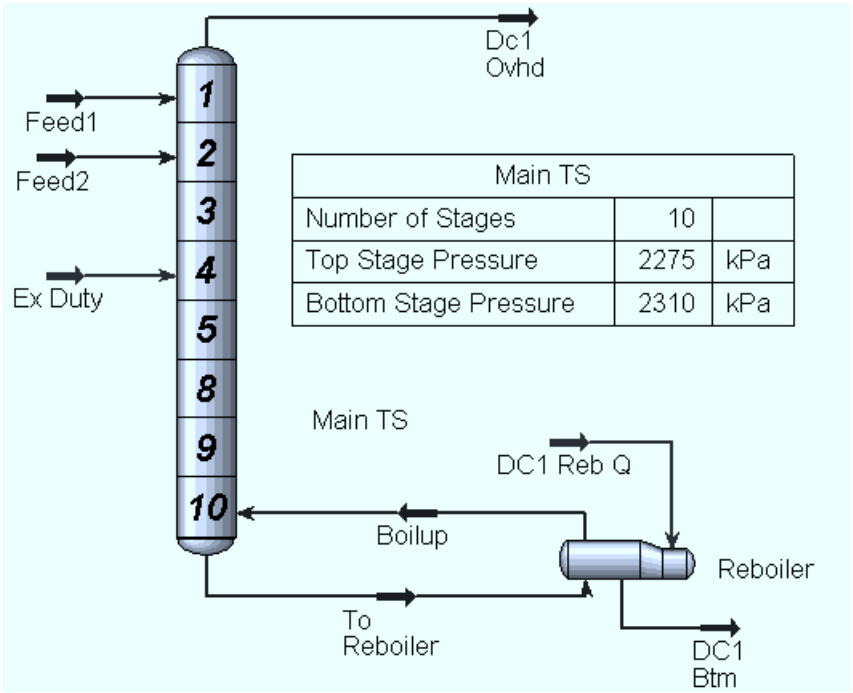
Feed1		
Temperature	-95.00	C
Pressure	2275	kPa
Molar Flow	1620	kgmole/h
Comp Mole Frac (Nitrogen)	0.0025	
Comp Mole Frac (CO2)	0.0048	
Comp Mole Frac (Methane)	0.7041	
Comp Mole Frac (Ethane)	0.1921	
Comp Mole Frac (Propane)	0.0706	
Comp Mole Frac (i-Butane)	0.0112	
Comp Mole Frac (n-Butane)	0.0085	
Comp Mole Frac (i-Pentane)	0.0036	
Comp Mole Frac (n-Pentane)	0.0020	
Comp Mole Frac (n-Hexane)	0.0003	
Comp Mole Frac (n-Heptane)	0.0002	
Comp Mole Frac (n-Octane)	0.0001	

Feed2		
Temperature	-85.00	C
Pressure	2290	kPa
Molar Flow	215.0	kgmole/h
Comp Mole Frac (Nitrogen)	0.0057	
Comp Mole Frac (CO2)	0.0029	
Comp Mole Frac (Methane)	0.7227	
Comp Mole Frac (Ethane)	0.1176	
Comp Mole Frac (Propane)	0.0750	
Comp Mole Frac (i-Butane)	0.0204	
Comp Mole Frac (n-Butane)	0.0197	
Comp Mole Frac (i-Pentane)	0.0147	
Comp Mole Frac (n-Pentane)	0.0102	
Comp Mole Frac (n-Hexane)	0.0037	
Comp Mole Frac (n-Heptane)	0.0047	
Comp Mole Frac (n-Octane)	0.0027	

Column Overviews

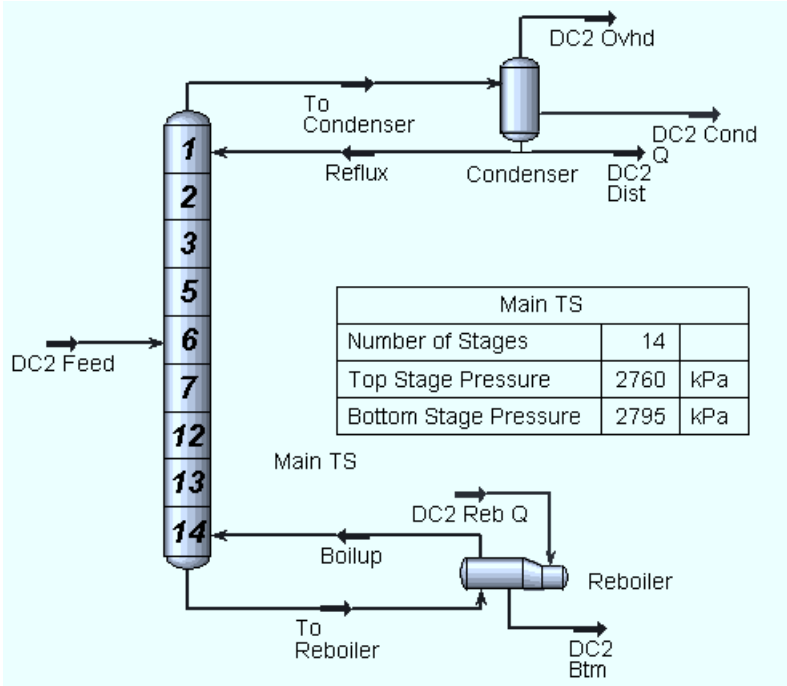
DC1: De-Methanizer

Figure 1



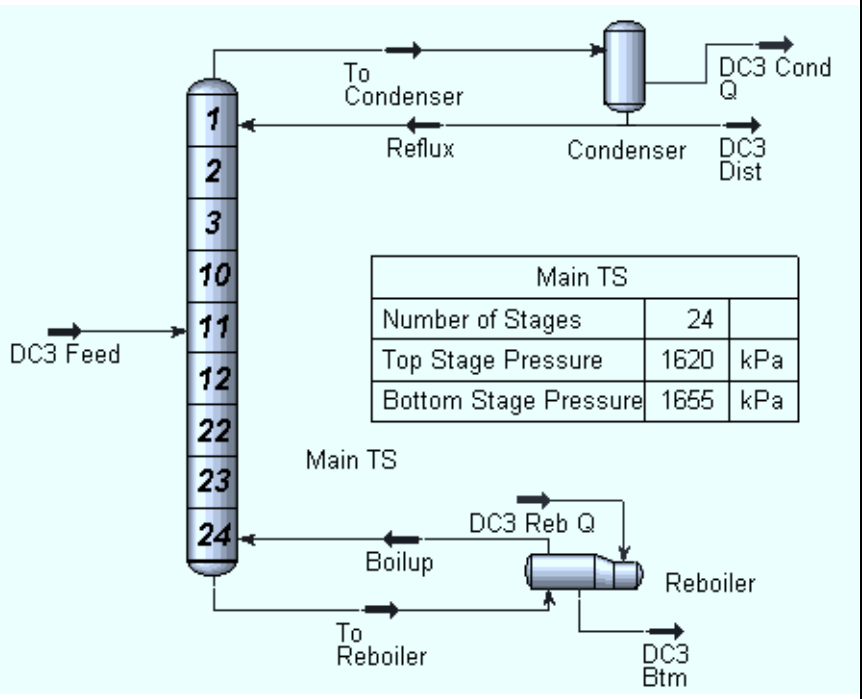
DC2: De-Ethanizer

Figure 2



DC3: De-Propanizer

Figure 3



Building the Simulation

Defining the Simulation Basis

1. Start a new case.
2. Select the **Peng Robinson** EOS.
3. Add the components: N_2, CO_2, C_1 - C_8.
4. Enter the **Simulation Environment**.

Adding the Feed Streams

1. Add a **Material Stream** with the following data:

In this cell...	Enter...
Name	Feed1
Temperature	-95°C (-140°F)
Pressure	2275 kPa (330 psia)
Flowrate	1620 kgmole/h (3575 lbmole/hr)
Component	**Mole Fraction**
N_2	0.0025
CO_2	0.0048
C_1	0.7041
C_2	0.1921
C_3	0.0706
i-C_4	0.0112
n-C_4	0.0085
i-C_5	0.0036
n-C_5	0.0020
C_6	0.0003
C_7	0.0002
C_8	0.0001

2. Add a **Material Stream** with the following data:

In this cell...	Enter...
Name	Feed2
Temperature	-85°C (-120°F)
Pressure	2290 kPa (332 psia)
Flowrate	215 kgmole/h (475 lbmole/hr)
Component	**Mole Fraction**
N_2	0.0057
CO_2	0.0029
C_1	0.7227
C_2	0.1176
C_3	0.0750
i-C_4	0.0204
n-C_4	0.0197
i-C_5	0.0147
n-C_5	0.0102
C_6	0.0037
C_7	0.0047
C_8	0.0027

Adding the Unit Operations

De-Methanizer

The De-Methanizer is modelled as a reboiled absorber operation, with two feed streams and an energy stream feed, which represents a side heater on the column.

1. Add an **Energy** stream with the following values:

In this cell...	Enter...
Name	Ex Duty
Energy Flow	2.1e+06 kJ/h (2.0e+06Btu/hr)



Reboiled Absorber Column icon

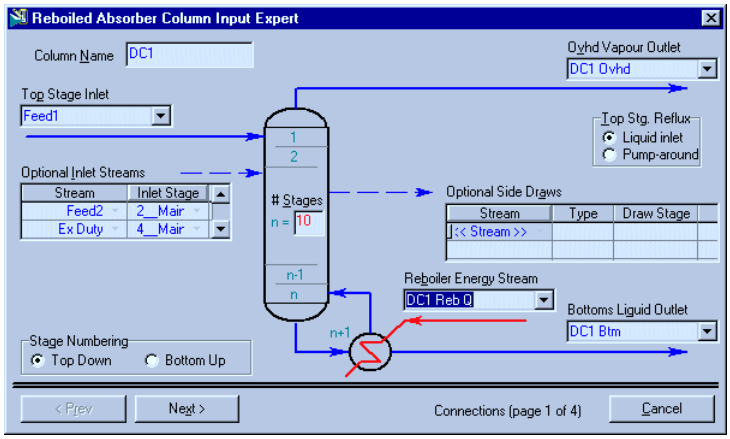
2. Double-click on the **Reboiled Absorber** icon on the Object Palette. The first Input Expert view appears.

3. Complete the view as shown below:



The Input Experts provide the new user with step by step instruction for defining a column.

Figure 4

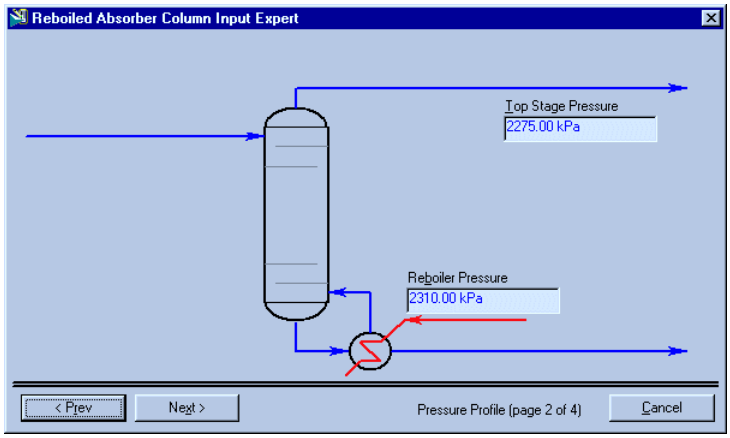


4. Click the **Next** button to proceed to the next page.
5. Supply the following information to the Pressure Estimates page. If you are using field units, the values will be **330 psia** and **335 psia**, for the Top Stage Pressure and Reboiler Pressure, respectively.



The Next button is only available when all of the necessary information has been supplied.

Figure 5



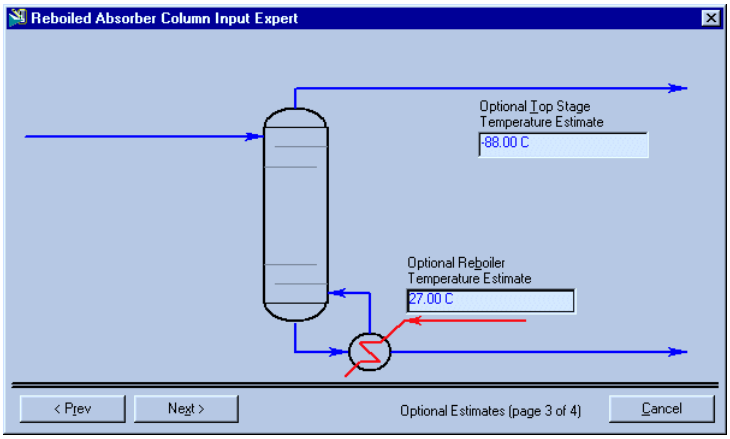
6. Click the **Next** button to proceed to the next page.

7. Enter the temperature estimates shown below. In field units, the top stage temperature estimate will be **-125°F**, and the reboiler temperature estimate will be **80°F**.



Temperature estimates are not required for the column to solve but they will aid in convergence.

Figure 6

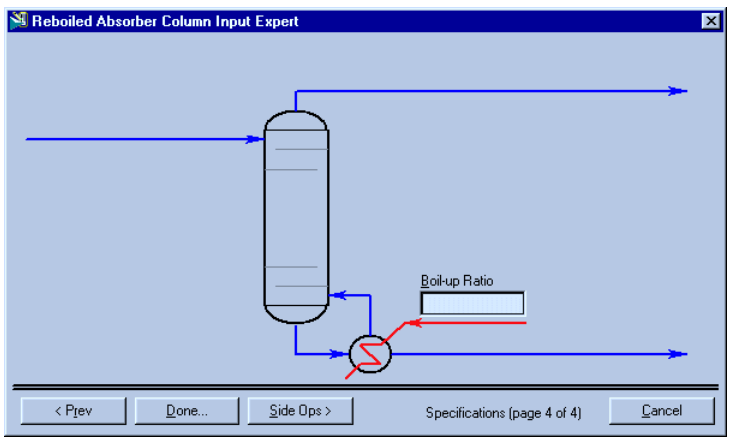


8. Click the **Next** button to continue.
9. For this case, no information is supplied on the last page of the Input Expert, so click the **Done** button.



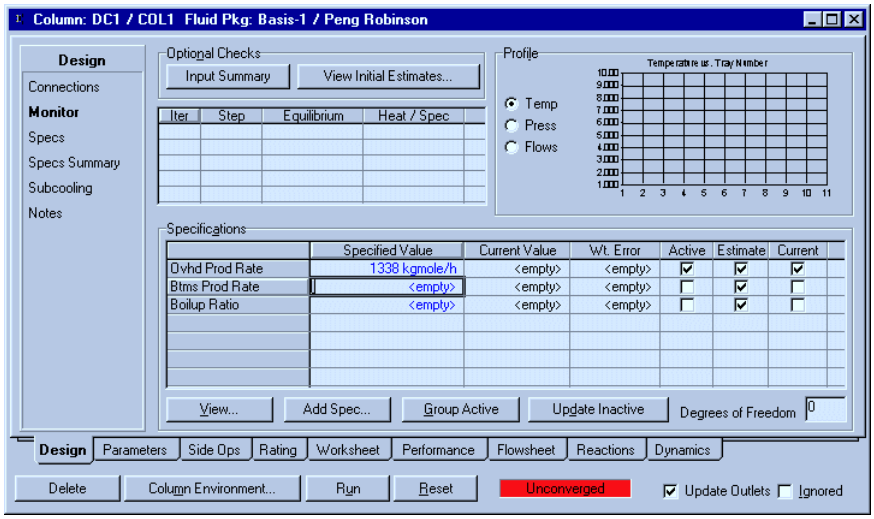
The basic Reboiled Absorber has a single DOF.

Figure 7



When you click the **Done** button, HYSYS will open the Column property view. Access the **Monitor** page on the **Design** tab.

Figure 8



Before you converge the column, make sure that the specifications are as shown above. You will have to enter the value for the Ovhd Prod Rate specification. The specified value is **1338 kgmole/h** (2950 lbmole/hr).

10. Click the RUN button to run the column.



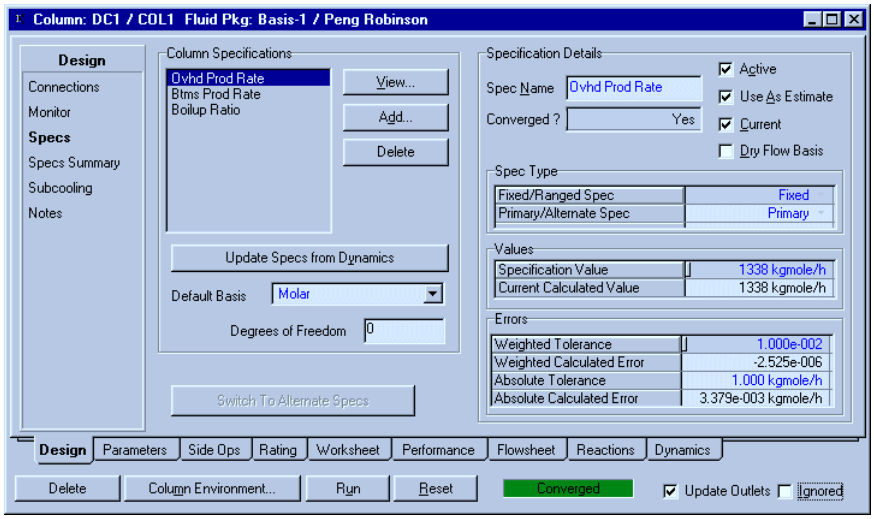
What is the mole fraction of Methane in DC1 Ovhd? _____

Although the column is converged, it is not always practical to have flow rate specifications. These specifications can result in columns which cannot be converged or that produce product streams with undesirable properties if the column feed conditions change.

An alternative approach is to specify either component fractions or component recoveries for the column product streams.

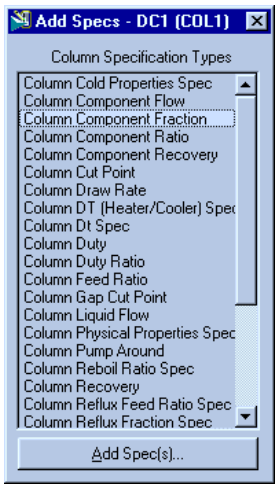
1. Go to the **Specs** page on the **Design** tab of the Column property view.

Figure 9



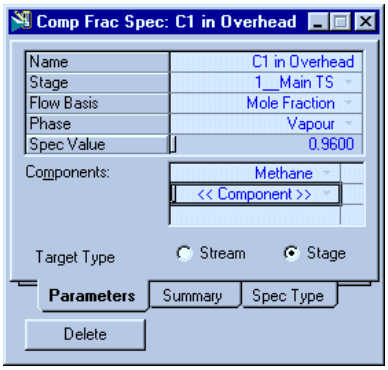
2. Click the **Add** button in the Column Specifications group to create a new specification.
3. Select **Column Component Fraction** from the list that appears.

Figure 10



4. Click the **Add Spec(s)** button.
5. Complete the spec as shown in the following figure.

Figure 11



6. When you are done, close the view.

The Monitor page of the Column property view shows 0 Degrees of Freedom even though you have just added another specification. This is due to the fact that the specification was added as an estimate, not as an active specification.

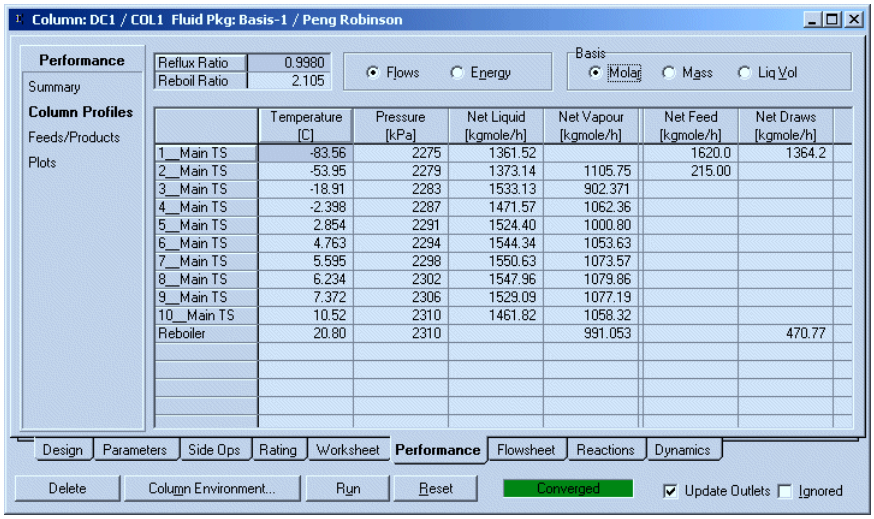
7. Go to the **Monitor** page. Deactivate the **Ovhd Prod Rate** as an active specification and activate the **Comp Fraction** specification which you created.



What is the flowrate of the overhead product, DC1 Ovhd? _____

Once the column has converged, you can view the results on the **Performance** tab.

Figure 12



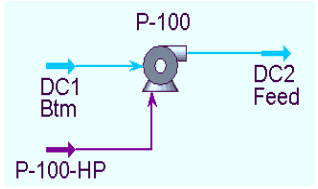
Adding a Pump



Pump icon

The pump is used to move the De-Methanizer bottom product to the De-Ethanizer.

Install a pump and enter the following information:



P-100		
Product Pressure	2790	kPa

In this cell...	Enter...
Connections	
Inlet	DC1 Btm
Outlet	DC2 Feed
Energy	P-100-HP
Worksheet	
DC2 Feed Pressure	2790 kPa (405 psia)

De-Ethanizer

The De-Ethanizer column is modeled as a distillation column, with 16 stages, 14 trays in the column, plus the reboiler and condenser. It operates at a pressure of 2760 kPa (400 psia). The objective of this column is to produce a bottom product that has a ratio of ethane to propane of 0.01.



Distillation Column icon

1. Double-click on the **Distillation Column** button on the Object Palette and enter the following information.

In this cell...	Enter...
Connections	
Name	DC2
No. of Stages	14
Feed Stream/Stage	DC2 Feed/6
Condenser Type	Partial
Overhead Vapour Product	DC2 Ovhd
Overhead Liquid Product	DC2 Dist
Bottom Liquid Outlet	DC2 Btm
Reboiler Duty	DC2 Reb Q
Condenser Duty	DC2 Cond Q
Pressures	
Condenser	2725 kPa (395 psia)
Condenser Delta P	35 kPa (5 psi)
Reboiler	2792 kPa (405 psia)
Temperature Estimates	
Condenser	-4°C (25°F)
Reboiler	95°C (200°F)
Specifications	
Overhead Vapour Rate	320 kgmole/h (700 lbmole/hr)
Distillate Rate	0 kgmole/h
Reflux Ratio	2.5 (Molar)

2. Click the **Run** button to run the column.



What is the flowrate of C_2 and C_3 in DC2 Btms?

C_2 _____, ***C_3*** _____, ***Ratio of C_2/C_3*** _____

3. On the **Specs** page, click the **Add** button to create a new specification.

4. Select **Column Component Ratio** as the specification type and provide the following information:

In this cell...	Enter...
Name	C2/C3
Stage	Reboiler
Flow Basis	Mole Fraction
Phase	Liquid
Spec Value	0.01
Numerator	Ethane
Denominator	Propane

5. On the **Monitor** tab, deactivate the **Ovhd Vap Rate** specification and activate the **C2/C3** specification which you created.



What is the flowrate of DC2 Ovhd? _____

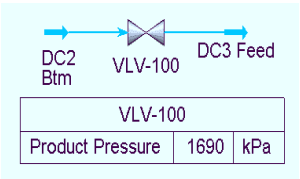
Adding a Valve



Valve icon

A valve is required to reduce the pressure of the stream DC2 Btm before it enters the final column, the De-Propanizer.

Add a Valve operation and provide the following information:



In this cell...	Enter...
Connections	
Inlet	DC2 Btm
Outlet	DC3 Feed
Worksheet	
DC3 Feed Pressure	1690 kPa (245 psia)

De-Propanizer


Distillation Column icon

The De-Propanizer column is represented by a distillation column consisting of 25 stages, 24 trays in the column plus the reboiler. (Note that a total condenser does not count as a stage). It operates at 1620 kPa (235 psia). There are two process objectives for this column. One is to produce an overhead product that contains no more than 1.50 mole percent of i-C4 and n-C4 and the second is that the concentration of propane in the bottom product should be less than 2.0 mole percent.

1. Add a distillation column and provide the following information:

In this cell...	Enter...
Connections	
Name	DC3
No. of Stages	24
Feed Streams/Stage	DC3 Feed/11
Condenser Type	Total
Ovhd Liquid Outlet	DC3 Dist
Bottom Liquid Outlet	DC3 Btm
Reboiler Duty	DC3 Reb Q
Condenser Duty	DC3 Cond Q
Pressures	
Condenser	1585 kPa (230 psia)
Condenser Delta P	35 kPa (5 psi)
Reboiler	1655 kPa (240 psia)
Temperature Estimates	
Condenser	38°C (100°F)
Reboiler	120°C (250°F)
Specifications	
Liquid Rate	110 kgmole/h (240 lbmole/hr)
Reflux Ratio	1.0 Molar

2. Run the column.



What is the mole fraction of C3 in the overhead and bottoms products?
_____ and _____

3. Create two new Component Fraction specifications for the column.

In this cell...	Enter...
i-C4 and n-C4 in Distillate	
Name	iC4 and nC4
Stage	Condenser
Flow Basis	Mole Fraction
Phase	Liquid
Spec Value	0.015
Components	i-C4 and n-C4
C3 in Reboiler Liquid	
Name	C3
Stage	Reboiler
Flow Basis	Mole Fraction
Phase	Liquid
Spec Value	0.02
Component	C3

4. Deactivate the **Distillate Rate** and **Reflux Ratio** specifications.
5. Activate the **iC4, and nC4**, and **C3** specifications which you created.

Save your case!

Optional

Convert your case to a template and save!

Advanced Modelling

The column is a special type of sub-flowsheet in HYSYS. Sub-flowsheets contain equipment and streams, and exchange information with the parent flowsheet through the connected streams. From the main environment, the column appears as a single, multifeed multiproduct operation. In many cases, you can treat the column in exactly that manner.

The column subflowsheet provides a number of advantages:

- **Isolation of the Column Solver**. The Column Build Environment allows you to make changes and focus on the column without the re-calculation of the entire flowsheet.
- **Optional use of different fluid packages**. HYSYS allows you to specify a unique (different from the main environment) fluid package for the column subflowsheet. This is useful when a different fluid package is better suited to the column (Gas Plant using PR may contain an Amine Contactor that needs to use the Amines Property Package), or the column does not use all of the components used in the main flowsheet and so by decreasing the number of components in the column you may speed up column convergence.
- **Construction of custom templates**. In addition to the default column configurations which are available as templates, you may define column setups with varying degrees of complexity. Complex custom columns and multiple columns may be simulated within a single subflowsheet using various combinations of subflowsheet equipment. Custom column examples include, replacement of the standard condenser with a heat exchanger, or the standard kettle reboiler with a thermosyphon reboiler.
- **Ability to solve multiple towers simultaneously**. The column subflowsheet uses a simultaneous solver whereby all operations within the subflowsheet are solved simultaneously. The simultaneous solver permits the user to install multiple interconnected columns within the subflowsheet without the need for recycle blocks.



Enter Parent Simulation Environment icon

You can enter the column subflowsheet by clicking the **Column Environment** icon on the Column property view. Once inside the column environment, you can return to the parent environment by clicking either the **Parent Environment** button on the Column runner view or the **Enter Parent Simulation Environment** icon in the tool bar.



The presence of the green "Up Arrow" icon in the tool bar and the Environment: Name (COL1) indicates that you are in the column subflowsheet.

Exploring the Simulation

Challenge

After simulating your DeMethanizer, you have to use HYSYS to determine the UA for the DeMethanizer Reboiler. Assume that you have 1000 kgmole/h of saturated 100 psi steam available for the shell side and there is a 5 psi pressure drop on the steam side. Your overhead Methane spec of 0.96 (mole) must still be met.

Remember, you will need to add water to your component list. Instead of changing the configuration of the column (changing the solver type to Modified HYSIM Inside-Out), you can create an internal stream (on the Flowsheet tab). This stream represents the liquid that flows from the bottom tray to the reboiler, which can then be added to a heat exchanger in the Main Flowsheet. Use steam to exchange heat with the process stream.