

Advanced Columns

Workshop

Most users are familiar with the prebuilt columns that are available in the main HYSYS Environment. This module will introduce the concept of custom columns. HYSYS allows users to build columns without using the prebuilt configurations. This is useful for simulating columns that do not fit into the usual configurations.

Building custom columns allows users to replace reboilers with heat exchangers; the heat exchangers can then be rated and sized. Likewise, thermosyphon reboilers can be used in place of generic reboilers.

HYSYS also includes a Column Sizing utility that can size and rate column tray sections.

Learning Objectives

After completing this module, you will be able to:

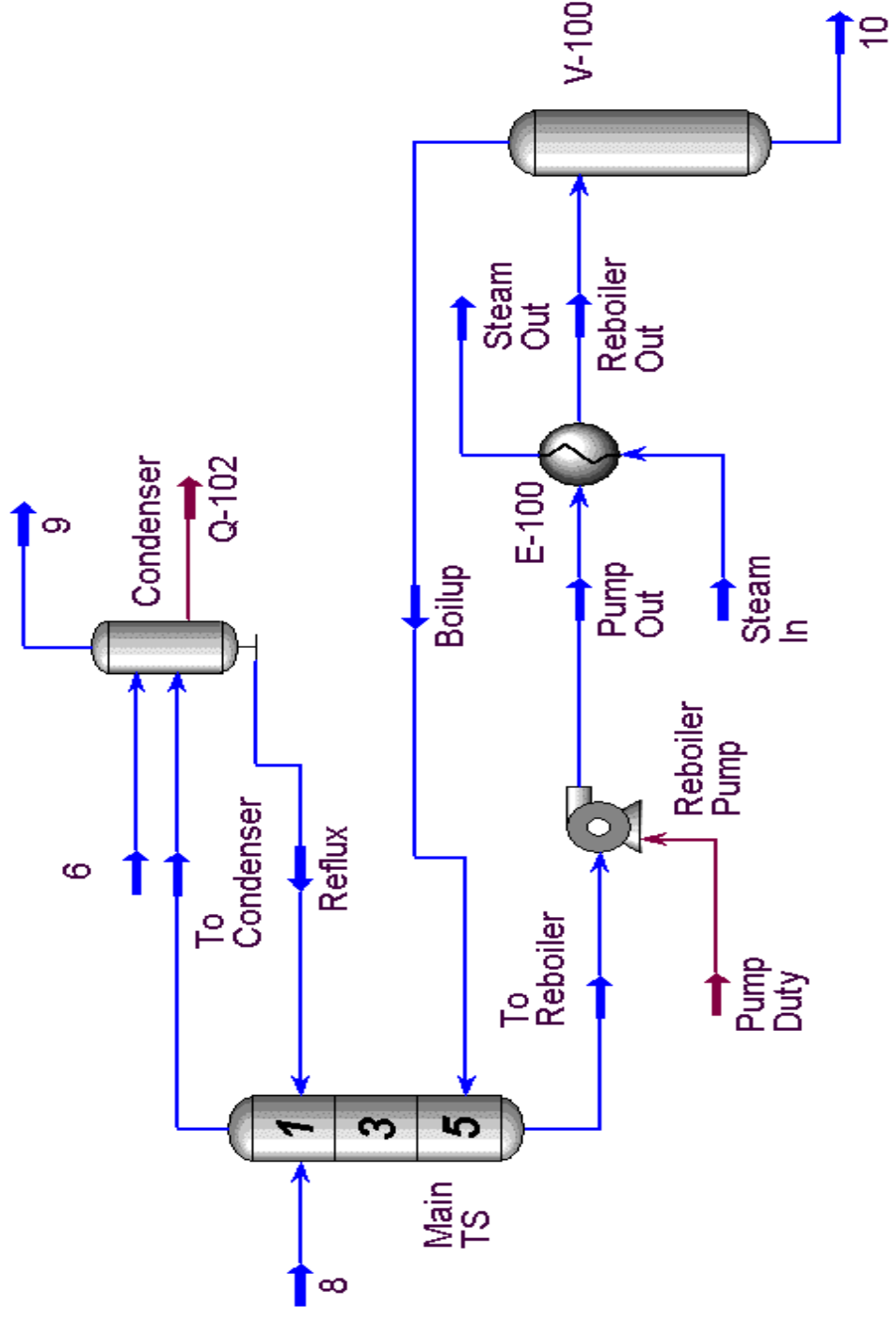
- Build custom columns in HYSYS
- Replace generic reboilers with sizable heat exchangers
- Perform Tray Sizing and Rating calculations

Prerequisites

Before beginning this module, you should be able to:

- Navigate the Main Simulation
- Add unit operations to the PFD
- Add, and converge, a generic prebuilt column

Column Overview



Custom Columns

The most common way of adding a column to a simulation is to use the prebuilt columns that HYSYS offers. There are four prebuilt columns available:

- **Absorber** - the simplest of all towers, no reboiler or condenser.
- **Refluxed Absorber** - an absorber tower with a condenser on the top stage that allows for a refluxing stream in the column.
- **Reboiled Absorber** - an absorber tower with a reboiler at its base, and no condenser at the top.
- **Distillation Column** - an absorber tower with both a condenser and a reboiler.

Customising a Column gives the user greater control over the simulation. For example, replacing the reboiler with a Heat Exchanger allows the user to use steam as a heating medium and size the exchanger based on the required duty.

Custom Columns can be built in two ways, either by modifying a prebuilt column, or by constructing a new column from the beginning. In this module, a prebuilt LPG recovery column will be modified.

The Column Sub-Flowsheet

Whenever a column is added to a HYSYS simulation, a **Column Sub-flowsheet** is created. The sub-flowsheet is essentially another layer in the HYSYS simulation. It is located under the Main layer, and can be seen by selecting **Tools-PFDs** in the main menu bar, or by pressing the hot-key **CTRL P**. The nature of the layering scheme can be seen in the displayed list as the Column's PFD is indented under the Main PFD. Selecting the desired PFD and clicking the **View** button will open that particular layer for viewing.



In HYSYS Version 3.1+ it is not necessary to enter the Column Environment to edit it. Changes can be made by opening the PFD and editing it, although it is still recommended to enter the Column Environment.

Alternatively the PFD of a particular column can be seen by right clicking on the column PFD icon and choosing **Open PFD**.

In order to edit the column, i.e. to add and modify operations, it is best to enter the Column Environment. The Column Environment is accessed through the Column Property View. To bring up the Column

Property View, double click the column icon on the PFD. With the Column Property View as the active view, click the Column Environment button. This will make HYSYS enter the Column Environment. The operations within the column can be deleted, modified, replaced, and controlled just like ordinary unit operations in the Main Environment.



Enter Parent Environment icon

When in the Column Environment, returning to the Main Environment can be accomplished by clicking the Enter Parent Simulation Environment icon located on the Main Menu Bar.

Adding operations to the column is very similar to adding operations in the Main Environment. The choice of operations is reduced, but the method of installation is identical.



Don't worry if you haven't built the Turbo Expander plant case. The file "ADV1_GettingStarted_Soln.hsc" contains this case.

Building the Simulation

This module will continue with the column built in the Getting Started module. This column is an LPG Recovery unit for a Turbo Expander plant.

This column was constructed as a generic distillation column. The condenser is a "Total Reflux" type; this means that there is no liquid product from the condenser, rather all of the condensed liquid is sent back into the column to provide a refluxing liquid stream.

The reboiler on this column is also of the generic type. An energy stream is supplied and the liquid product from the last stage is boiled up. The vapours return to the column and the liquid leaves the column as a liquid product.

Replacing the Reboiler

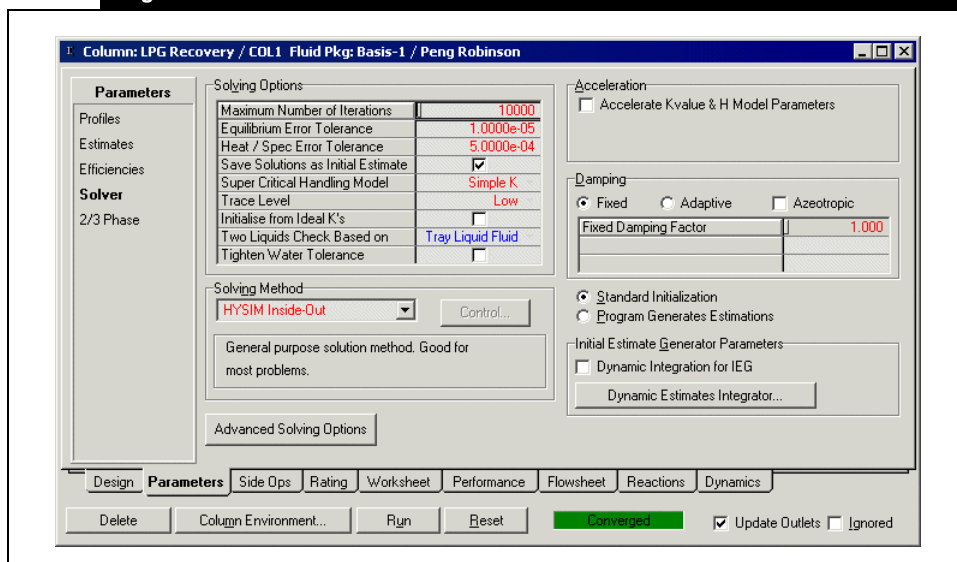


Modified HTSIM Inside-Out is a general-purpose solver that allows Heat Exchangers and other operations in the Column Environment.

The generic reboiler will be replaced with a shell and tube heat exchanger. This will allow the user to supply steam to the column as the energy stream, and size, or rate, the heat exchanger.

1. Before modifying the column, it is necessary to change the Column Solving Method to **Modified HYSIM Inside-Out**. The Solving method is accessed through the **Solver** page (on the **Parameters** tab) of the Column Property View.

Figure 1



2. In the Basis Environment, add **Water** to the list of components.
3. If necessary click the **Run** button to recalculate the column.
4. Enter the Column Environment and delete the existing reboiler and energy stream from the PFD.

Because the generic reboiler that had no pressure drop is being replaced with a heat exchanger that will have a pressure drop, a pump must be added to the simulation to “push” the fluid through the exchanger.

5. Add a **Pump** to the Column Environment with the following parameters:

In This Cell...	Enter...
Name	Reboiler Pump
Inlet	To Reboiler
Outlet	Pump Out
Energy	Pump Duty
Delta P (on Design... Parameters page)	75 kPa (10.9 psia)



Heat Exchanger icon

6. After the newly created pump, add a **Heat Exchanger** to the Column's PFD, with the following parameters:

In This Cell...	Enter
Name	E-100
Heat Exchanger Model	Calculated by Column (default)
Tube Side Inlet	Steam In
Tube Side Outlet	Steam Out
Shell Side Inlet	Pump Out
Shell Side Outlet	Reboiler Out
Tube Side Pressure Drop	50 kPa (7.25 psia)
Shell Side Pressure Drop	75 kPa (10.9 psia)

7. Define the **Steam In** stream as saturated pure steam at **200°C** (392°F). The mass flow rate is 2500 kg/h (5511 lb/hr).

Normally when the reboiler is deleted from the column Sub-flowsheet the pressure that was specified at the bottom will be lost, and hence must be added back on the **Parameters** page in **Profiles** tab.

However in this case the pressure at the bottom of the column is set by the pressure in the bottoms liquid product stream (10), which is linked to the Turbo Expander outlet pressure.



Be sure to pick the Separator operation from the object palette, rather than one of the Condensers which have similar icons.

8. Add a **Separator** after the Heat Exchanger, with the vapour product returning to the bottom stage of the column, and the liquid product leaving the Column Environment as stream 10. (See the Column Overview at the beginning of the module for the column PFD).

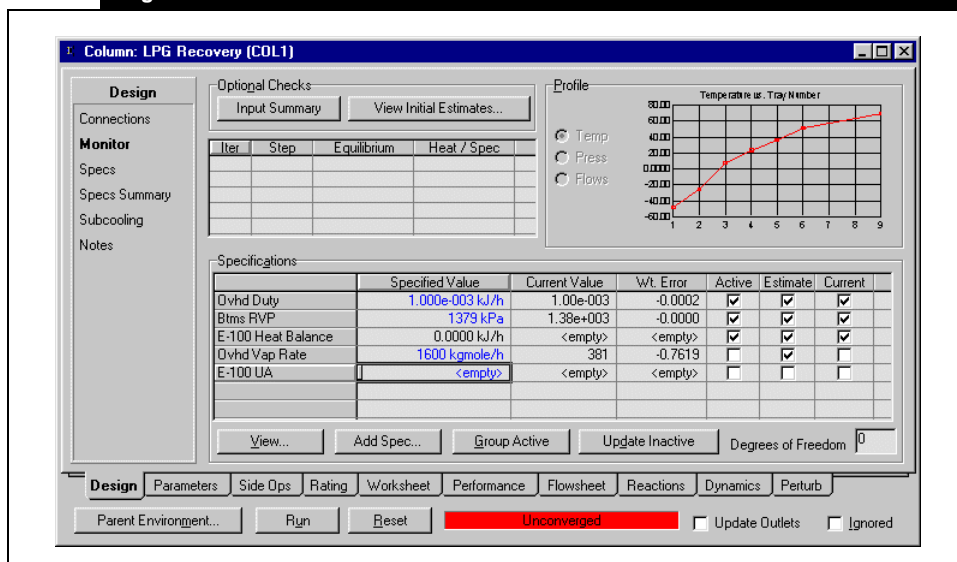
9. Because the Reboiler was deleted, HYSYS removed the Reboiler liquid RVP spec. Add this spec back:

RVP Spec...	
Type	Column Vapour Pressure Spec
Name	Btms RVP
Stage	V-100
Type	Reid Vapour Pressure
Phase	Liquid
Spec Value	200 psia

Since the Heat Exchanger was installed in the Column Environment it's specifications appear on the **Monitor** page along with the specifications of the column. Heat Exchanger specifications can be activated and deactivated just like Column specifications; they can also be added in exactly the same manner as Column specifications.

10. Return to the Main Flowsheet and ensure that the three active specifications for the column are: Ohvd Duty, Btms RVP, and E-100 Heat Balance.

Figure 2



11. Run the column; after it has converged, answer these questions:



What is the UA of the Heat Exchanger?

What is the LMTD for this exchanger?

What is the vapour fraction of the outlet steam?

Save your case!

Connecting Streams Between Flowsheets

1. Look at the Main PFD. Notice the streams **Steam In** and **Steam Out** are not visible here. This is because they were created in the Column Sub-flowsheet, and have not been connected to the Main Flowsheet.
2. Streams are connected between the Main and Sub-flowsheet on the **Connections** page on the **Design** tab. Notice that there are two types of streams listed here, **Internal** and **External**. Internal streams are those on the Column Sub-flowsheet. External streams are the corresponding streams on the main Flowsheet. Currently **Steam In** and **Steam Out** do not have any linked external streams.

- Internal streams are connected to the Main Flowsheet by typing a name in the **External Stream** column. Add the appropriate names to the **External Streams** column, and check to make sure that these streams appear in the Main PFD.



As this is now a Custom Column, the Connections page of the Design tab no longer shows a Distillation Column.

Figure 3

Design Column Name Sub-Flowsheet Tag

Connections

Inlet Streams

Internal Stream	External Stream	Inlet Stage	Transfer Basis	Split
8	8	1_Main TS	P-H Flash	<input type="checkbox"/>
6	6	Condenser	P-H Flash	<input type="checkbox"/>
Pump Duty	<< Stream >>	P-100	None Req'd	<input type="checkbox"/>
Steam In	Stream In	Tube_E-100	P-H Flash	<input type="checkbox"/>
** New **	<< Stream >>			

Outlet Streams

Internal Stream	External Stream	Outlet Stage	Type	Transfer Basis
Q-102	Q-102	Condenser	Q	None Req'd
9	9	Condenser	V	P-H Flash
10	10	V-100	L	P-H Flash
Steam Out	Steam Out	Tube_E-100		P-H Flash
** New **	<< Stream >>			

Stage Numbering
 Top Down
 Bottom Up

Split Inlets

dP Top:
P Top:
dP Bot:
P Bot:

Design Parameters Side Ops Rating Worksheet Performance Flowsheet Reactions Dynamics

Update Outlets Ignored

The **Steam In** flow rate was defined in the Column Environment, therefore, it is not a specifiable parameter in the Main Environment. Some users prefer to have all the feed streams visible and editable in the Main Environment.

- Delete the flow rate of **Steam In** in the Column Environment, and enter the same value as a flow rate for **Steam In** in the Main Environment. The column will automatically resolve.
- Delete the other **Steam In** specifications on the column sub-flowsheet (Vapour Fraction, Temperature and Composition) and transfer them to the main flowsheet.

Save your case!

Exercise - Simulating the Reboiler on the Main Flowsheet Using Internal Streams

Another method of simulating the reboiler with a Heat Exchanger is to use the Internal Stream feature of the column to make a copy of the reboiler on the main flowsheet. Here this will be added to the case where a rigorous heat exchanger has already been added to the column sub-flowsheet. However this technique works just as well with columns using the standard Reboiler operation.

This way of modelling the reboiler is just as accurate as adding the heat exchanger to the column sub-flowsheet although it does not look quite as good.

An 'Internal Stream' is a special HYSYS stream that represents a fluid inside the column, for example the vapour leaving the top tray, or the liquid leaving the bottom tray. Internal Streams show with a cyan colour on the column sub-flowsheet.

Pump Name	Reboiler Pump
Shell Side Outlet	Reboiler Out
Heat Exchanger Model	Exchanger Design (Weighted)
Tube Side Pressure Drop	50 kPa
Shell Side Pressure Drop	75 kPa
Steam In 2 conditions	Saturated pure steam at 200°C. Mass flow 2500 kg/h.

- Use a Set operation to specify the Reboiler Out stream temperature to be the same as the column bottom product stream.

Save your case!

Column Sizing

HYSYS contains a Tray Sizing utility that greatly simplifies the mechanical design of a distillation column. A user can size full towers, or sections of towers, by specifying information related to the trays, tower internals, the downcomers, and the weirs.

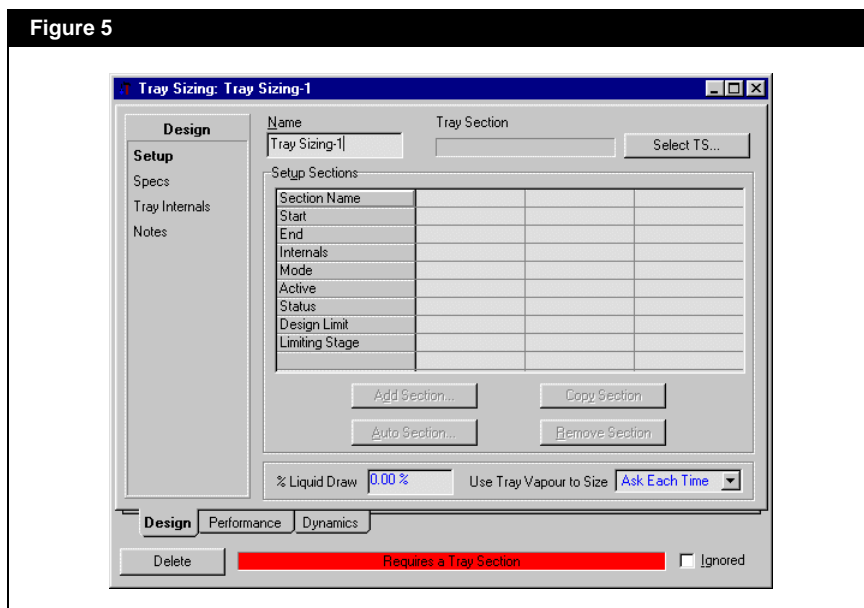
The most common use of the Tray Sizing utility is to identify a tray section, and then make HYSYS size the tower into sections based on your input, then if desired, perform a rating analysis on the column.

While HYSYS is able to size and rate tray sections, the values that it provides are only rough estimates and should be treated as such.

Column Sizing in Design Mode

- Select **Tools/Utilities** from the Main Menu bar, or press the hot key **CTRL U**.

2. Select **Tray Sizing** from the list of available utilities and click the **Add Utility** button.



3. Click the **Select TS...** button, and select LPG Recovery as the Flowsheet and Main TS as the Object.

HYSYS allows users to select Tray Sections instead of entire columns so that users may size Side Strippers independently from the Main Column.

4. Click the **Add Section...** button. Accept all of the default values that are presented.

HYSYS will calculate the dimensions of the column using preset values for the column internals and for the various parameters.

On the Performance tab a summary of the calculations are presented. A brief explanation of the terms follows:

- **Number of Flow Paths.** The number of times liquid crosses the tray, most trays are single-pass or have NFP of 1.
- **Maximum Downcomer Backup.** Represents the maximum amount of liquid hold-up in the downcomer that can be tolerated by the column before flooding occurs.
- **Maximum Weir Loading.** Measures the amount of liquid flowing over the weir.
- **Pressure Drops.** Estimates the total pressure drop over the section and the maximum pressure drop per tray.



What is the maximum pressure drop per tray in the Distillation Column?

Over which tray does this pressure drop occur?

What is the diameter of the trays inside the column?

What is the total section height?

Column Sizing in Rating Mode

In rating mode, HYSYS allows you to perform rating calculations based on a specified tower diameter and fixed tray configuration.

Exercise

Head office is desperate to build a distillation column, but the fabrication mill is working overtime and there are very lengthy delays for special orders. The mill has the following trays in stock:

Diameter, m (ft.)	NFP (Passes)
0.75 (2.5)	1
1.0 (3.3)	1
1.25 (4.1)	1

Obtain the flow parameters and pressure drops for a column that uses the trays as given above. The following requirements must be met in order for the column to be constructed.

- Maximum% Flood = 85
- Maximum weir loading = $80 \text{ m}^3/\text{h}\cdot\text{m}$ ($860 \text{ ft}^3/\text{h}\cdot\text{ft}$)
- Maximum downcomer backup = 50%

For each case, follow these steps:

1. On the **Design** tab, click on the **Specs** page and set the Mode to Rating.
2. Set the diameter and number of flow paths, and move to the **Performance** tab.
3. Leave all the other specs at the default values.

4. Complete this table with the information provided by HYSYS.

Case Number	1	2	3
Diameter, m (ft.)	0.75 (2.5)	1.0 (3.3)	1.25 (4.1)
NFP	1	1	1
Weir Load			
Flood			
DC Back Up			
Total Delta P			



Compare the table above with the specifications on the previous page; which set of trays will best meet the restrictions? Remember that smaller trays will be less expensive.

Save your case!

Challenge

The Export Pressures button on the Tray Sizing Utility Performance tab allows the calculated pressure drops to be exported to the column pressure profile.

Use this feature to supply the LPG Recovery Column with the rigorously calculated pressure profile.

Hint: Currently the condenser, reboiler, top and bottom tray pressures appear as calculated (black) numbers. You will need to make them specified (blue) before the Export Pressures function will work.

