Control Valve Sourcebook — Chemical Unit Operations

Distillation Column

EMERSON™
Process Management

Distillation Column

Other Names

tower, stripper, stabilizer, splitter, demethanizer, deethanizer, depropanizer, debutanizer, fractionator

I. How It Operates

Distillation columns are a basic building block for many industrial processes. The objective for any distillation column is to separate a feed stream into light-component and heavy-component product streams. The distillation process is a physical separation process, not a chemical reaction. Industrial distillation is commonly performed in large, vertical cylindrical columns with diameters ranging from 100 centimeters to 6 meters (39.4 inches to 19.7 feet) and heights from 6 to 60 meters (19.7 to 196.9 feet.

The distillation process relies on the relative volatility between the components that make up the feed stream. The high-volatility (lighter) components will boil at a lower temperature than will the low-volatility (heavier) components. Therefore, when heat is added to the column through a bottom reboiler, the lighter materials are vaporized and rise to the top of the column. The overhead vapors are cooled until they condense and become a liquid again.

The efficiency of the distillation depends on the amount of contact between the vapor rising and the liquid falling down through a column. Therefore, some of the overhead liquid product is sent back (refluxed) to the top of the column. Increasing the reflux will improve the purity of the overhead product. However, it also requires more heat from the reboiler to re-vaporize the lighter components in the reflux stream. The operation of a distillation column is a balancing act between product purity and energy use.

If the amount of vapor and liquid traveling through the column (often referred to as traffic) becomes too great, the column can “flood.” Too much reflux flow or reboil heat can result in too much vapor and cause flooding. When flooding occurs, the efficiency of the distillation column is dramatically reduced, with corresponding drops in product purities.

II. Where Distillation Columns are Used

Distillation columns are used to separate a mixed feed into lighter and heavier products, which means that columns are used in virtually every process industry.

- Air separation
- Ammonia
- Biofuels or ethanol
- Desalination
- Olefins
- Petroleum refining

Figure 1. Distillation columns

III. Distillation Column Application Review

Since distillation columns are used in many chemical processes, control valve selection is dependent on the process fluid being distilled. However, across many process units, the control valve function in distillation columns is similar. A summary of each critical control valve and common solution can be found in the following section. Figure 2 show the typical layout of a distillation column with associated critical control valves.

Feed Valve

This valve controls the feed going into the distillation column. Feed valves are usually set up as flow or level control loops. An upstream unit or process often controls the valve.

Unstable feed flow will make the distillation column difficult to control. A problem valve will often cause the feed flow to oscillate. As a result, the column will alternate between too little and too much reboil heat. Depending on the size and number of trays in the column, the effect of a swing in the feed will take anywhere from several minutes to more than an hour to reach the ends of the column. Sometimes, the reboil and reflux controls will amplify the swings. As a result,

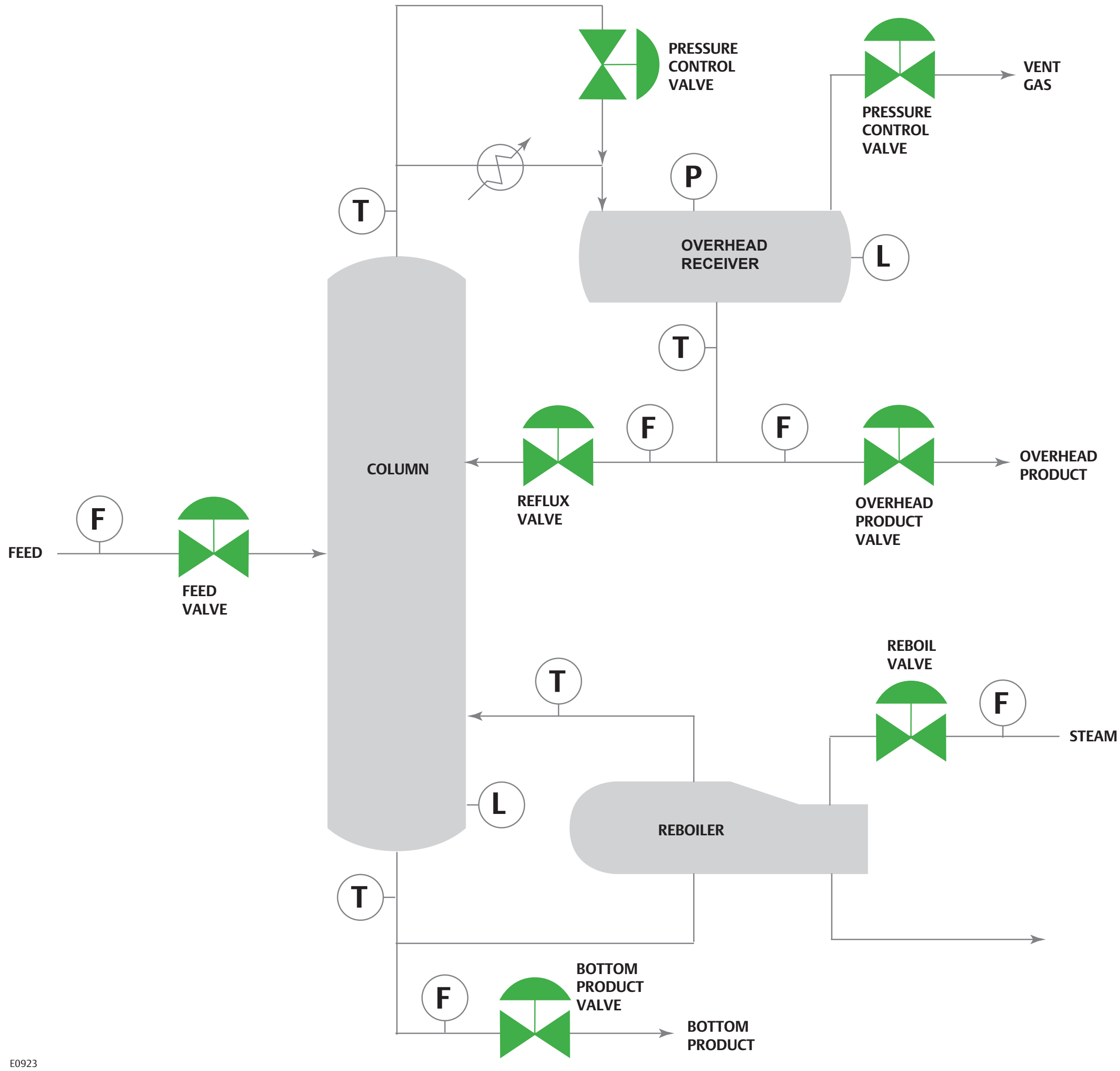

Figure 2. Distillation Column Process Flow Diagram

it is difficult to meet product purity targets. Operations will normally respond by over-purifying the products, wasting energy to compensate for the problematic feed valve.

- **Typical process conditions:**
  - — P1/P2 = dependent on process design
  - — T = dependent on process design
  - — Q = dependent on process design
  - — Flashing may be present depending on process variables
- **Typical valve selection:**
  - — Lower flow rates: NPS 1 to NPS 4 Fisher® EZ, ED, ET, or GX valve
  - — Higher flow rates: NPS 6 to NPS 12 Fisher EWD or NPS 6 to NPS 12 Fisher Vee-Ball™ valve
  - — Materials of construction: WCC or CF8M with standard trim (400-series stainless or 300-series stainless)

Reflux Valve

The reflux valve is typically either a flow or column temperature-control loop. It is used to adjust the purity of the overhead product. The higher the reflux rate, the purer the overhead product will become. However, raising the reflux rate will also require more reboil heat and eventually will flood the tower.

A poorly operating reflux valve will have the same effects as a bad feed valve. Product purities will oscillate, and the column will be difficult to control. This valve has a direct impact on the efficiency of the column.

- **Typical process conditions:**
  - — Fluid = reflux fluid
  - — P1/P2 = dependent on process design
  - — T = dependent on process design
  - — Q = dependent on process design
- **Typical valve selection:**
  - — Lower flow rates: NPS 1 to NPS 4 Fisher EZ or GX valve
  - — Higher Flow Rates: NPS 3 to NPS 12 Fisher Control-Disk™ or Vee-Ball valve
  - — Materials of construction are dependent on the process design

Bottom Product Valve

The bottom product valve is typically used to control the level in the bottom of the column. It normally has no effect on column operation unless it causes the level to change quickly and dramatically.

- **Typical process conditions:**
  - Fluid = distillation bottoms
  - P1/P2 = dependent on process design
  - T = dependent on process design
  - Q = dependent on process design
- **Typical Valve Selection**
  - Lower flow rate, clean fluids: NPS 1 to NPS 4 Fisher EZ, ED, or ET valve
  - Higher flow rate: NPS 3 to NPS 12 Fisher Vee-Ball valve
  - Viscous or dirty fluid: NPS 1 to NPS 8 Fisher V500 valve
  - Materials of construction is dependent on process design, may require stellite or ceramic trim

Pressure Control Valves

Pressure control valves are used to control the column pressure. Higher column pressures will yield better product purities, but require more energy to operate. Normal operating procedure is to minimize the pressure to lower energy costs while maintaining product specifications. There is a low limit because lower pressures reduce the amount of vapor or liquid traffic the column can handle and can make it more likely to flood.

The simplest way to control pressures is to continuously vent gas from the system. This sizing of this valve is critical. If the valve is too large, a small valve movement will cause a large pressure swing. If the valve is too small, the pressure response will be very sluggish. It is likely that a valve that is too small will operate from completely closed to completely open. In either scenario, oscillating column pressure and difficult column control result. A sticking pressure control valve presents the same problem. A sticking valve is a common concern on vent gas service because the valve packing is normally tight to prevent fugitive emissions.

Many distillation columns also use what is known as a “hot vapor bypass” valve to control pressure. In these instances, some of the hot overhead vapors are bypassed around the overhead condenser heat exchanger. The amount of bypass will control the pressure. This eliminates the constant venting of process gas. Unfortunately, the pressure response on a hot vapor bypass valve is normally very sluggish due to slow process response time. Like the vent gas valve, this valve is a concern for fugitive emissions, and the packing is likely to be tight. A sticking valve causes wide, slow oscillations in column pressure, and product purities likewise swing widely and slowly. The response of operations personnel is usually to over purify.

A majority of columns with hot vapor bypass valves also utilize a vent gas valve. In these cases, a single pressure control loop manipulates both valves. At lower pressures, the hot vapor bypass valve is used. As the pressure rises, there is a transition point where the hot vapor bypass valve closes fully and the vent gas valve starts to open.

At high pressures, the vent gas valve controls the pressure. This configuration often leads to pressure control problems, since the hot vapor bypass and vent gas valves have different control characteristics. Also, it is unlikely that one valve will close precisely at the same time the other valve opens. If the column is constantly making a transition between using the hot vapor bypass and vent gas valves, the pressure will normally oscillate. This is a tuning rather than a valve problem, but it should be kept in mind for column design or valve resizing. The FIELDVUE™ DVC6200 digital valve controller with Performance Diagnostics is recommended for both of these valves to alert users to any required maintenance in these valves.

Vent gas valves are very important to control the stability of the distillation column. Many columns use tray temperature to control overhead composition, thus stable pressure is required to ensure that temperature changes reflect composition changes, not pressure changes.

- **Typical process conditions:**
  - Fluid = dependent on process design
  - P1/P2 = dependent on process design
  - T = dependent on process design
  - Q = dependent on process design
- **Typical valve construction:**
  - Lower flow rate: NPS 1 to NPS 4 Fisher EZ, ED, or ET valve
  - Higher rlow rate: NPS 3 to NPS 12 Fisher Vee-Ball valve
  - ENVIRO-SEAL™ PTFE or ENVIRO-SEAL Graphite packing, depending on process design conditions
  - Materials of construction are dependent on the process design—if gas is acidic, special materials may be required

Overhead Product Valve

The overhead product valve is typically used to control the level in the overhead receiver. It normally has no effect on column operation unless it causes the level to change quickly and dramatically.

- **Typical process conditions:**
  - Fluid = dependent on process design
  - P1/P2 = dependent on process design
  - T = dependent on process design
  - Q = dependent on process design
- **Typical valve construction:**
  - Lower flow rate: NPS 1 to NPS 4 Fisher EZ, ED, or ET valve
  - Higher flow rate: NPS 3 to NPS 12 Fisher Vee-Ball valve
  - Materials of construction are dependent on the process design

Reboil Valve

The reboil valve controls the amount of heat put into the column by the reboiler. In many cases, steam is used as a heat source. The service is very clean, and fugitive emissions are not a concern. Steam valves are usually very reliable. However, a problematic valve will make the column difficult to control precisely. This will be especially true if the column feed is subject to frequent changes.

Not all reboilers use steam as a heat source. To save energy, some plants have integrated their units so that high-temperature process streams are used to provide heat for low-temperature processes. In these cases, the reboil valve will foul more easily and might create fugitive emission concerns.

This valve is important because it drives the vapor back up through the column. Vapor through the column affects column efficiency. Reboiler steam will have a direct effect on overhead reflux flow.

- **Typical process conditions:**
  - Fluid = steam
  - P1 = dependent on process design, typically 10.3 bar (150 psig) saturated steam
  - T = dependent on process design
  - Q = dependent on process design
- **Typical valve construction:**
  - NPS 1 to NPS 6 Fisher ET or ES valve
  - Class V shutoff may be utilized to minimize leakage
  - Materials of construction: Steam application materials or materials compatible with the process gas

http://www.Facebook.com/FisherValves

http://www.Twitter.com/FisherValves

http://www.YouTube.com/user/FisherControlValve

http://www.LinkedIn.com/groups/Fisher-3941826

To find the Emerson sales contact in your area, scan or click the QR code.

Emerson Process Management
Marshalltown, Iowa 50158 USA
Sorocaba, 18087 Brazil
Chatham, Kent ME4 4QZ UK
Dubai, United Arab Emirates
Singapore 128461 Singapore
www.Fisher.com

FISHER

EMERSON
Process Management