The **pfdicons** Package: Documentation

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Contents

1 Introduction

This package provides Ti*k*Z shapes and a few supporting functions to draw icons and streams for process flow diagrams (PFDs) in chemical engineering, and to a lesser extent process and instrumentation diagrams (PIDs) in the same field. Unit operations provided by this package are expected to cover–in Turton's estimate–about 90% of fluid processing systems.

This package was developed to support students and faculty in undergraduate chemical engineering courses where excessive detail and customization are not necessary to convey meaning, as opposed to professionals who may require more customization than this package currently provides. Examples from several standard textbooks in undergraduate chemical engineering have been reproduced in the Examples section to illustrate the applicability of this package. A visual summary of all process units is provided at the end of this document as a quick reference.

2 Usage

To use this package simply provide

```
\usepackage{tikz}
\usepackage{pfdicons}
```

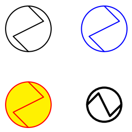
in your preamble. The `tikz` package must be loaded first. The `pfdicons` package automatically loads the `ifthen` package as well as the following Ti*k*Z libraries: `positioning`, `shapes`, `arrows.meta`, and `spath3`. Most shapes provided by the package are drawn within a `tikzpicture` environment using the basic syntax

```
\begin{tikzpicture}
  \node[<shape>] {};
\end{tikzpicture}
```

where `<shape>` is the desired process unit. Like most Ti*k*Z shapes the icons provided by `pfdicons` can be scaled, rotated, and colored in the usual ways:

```
\begin{tikzpicture}
  \node[basic hx] at (0,0) {};
  \node[basic hx, draw=blue] at (1,0) {};
  \node[basic hx, draw=red, fill=yellow] at (0,-1) {};
  \node[basic hx, scale=0.75, rotate=90, anchor=center] at (1,-1) {};

\end{tikzpicture}
```

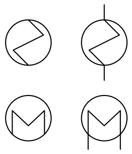


Two additional PGF keys are available for some process units: `unit int` which modifies the interior contents of the process unit, and `unit ext` which modifies the exterior of the process unit.[1] These keys can be used as

```
\node[<shape>, unit int=<intopt>, unit ext=<extopt>] {};
```

where `<intopt>` and `<extopt>` are interior and exterior options specific to the process unit. For most process units both keys can be used to combine effects. For example, the `basic hx` shape drawn above has keys `U tube` and `stems` which can be combined as follows:

```
\begin{tikzpicture}
  \node[basic hx] at (0,0) {};
  \node[basic hx, unit ext=util] at (1,0) {};
  \node[basic hx, unit fill=U tube] at (0,-1) {};
  \node[basic hx, unit fill=U tube, unit ext=util] at (1,-1) {};
\end{tikzpicture}
```



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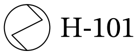
[1] A few other keys are available for drawing streams which are introduced later.

However, unlike “standard” nodes *the curly braces should always be empty*; that is, text cannot be directly included as part of the node (this prohibition includes keys like `label`). Annotations and labels of shapes from `pfdicons` must be included as separate nodes:

```
\begin{tikzpicture}
  % No:
  % \node[basic hx] {H-101};

  % Yes:
  \node[basic hx] (g) {};
  \node[right] at (g.east) {H-101};
\end{tikzpicture}
```



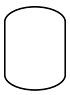
All process units have the standard cardinal and off-cardinal anchors which can be accessed using the standard Ti*k*Z anchor notation such as `f.north` or `mycolumn.south east`. Some units have additional anchors on half-cardinal points (*e.g.*, `north north east` or `east south east`) or special process unit features (*e.g.*, `east jacket` or `actuator`). All compass anchors of custom shapes provided by the `pfdicons` package are **aliased with abbreviated versions** (*e.g.*, `n` for `north`, `ene` for `east north east`) to allow for shortened code. Full anchor names can always be used to provide syntax consistency with core Ti*k*Z.

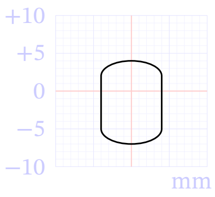
3 Process units

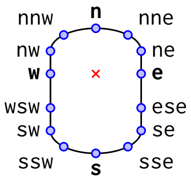
3.1 Reactors

3.1.1 Tank reactor

```
\node[tank reactor] {};
```

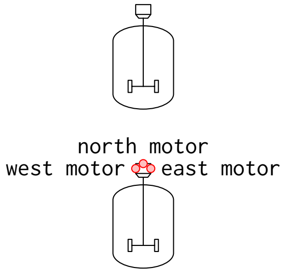
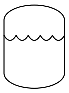
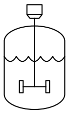
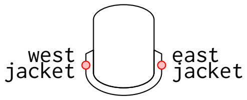
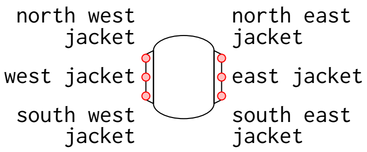






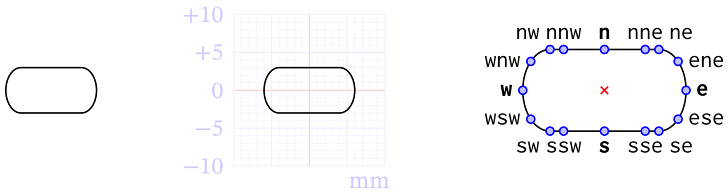
The `tank reactor` shape provides a cylindrical tank reactor, also referred to as a stirred-tank reactor, continuous stirred-tank reactor (CSTRs), or autoclave. The `center` anchor is offset slightly to accommodate fill and interior options as described below. Several key modifiers are available:

Table 1: Key-value pairs for the **`tank reactor`** shape.

key=value	Description	Example
`unit int=stirred`	Adds a rounded stirrer with motor and mixing blade. Three additional anchors are specific to this option: `west motor`, `north motor`, and `east motor`.	
`unit int=liquid`	Adds wavy lines from `west` to `east` to indicate a liquid surface.	
`unit int=stirred liquid`	A combination of `unit int=stirred` and `unit int=liquid`.	
`unit ext=lower jacket`	Adds a jacket around the lower portion of the reactor. Two additional anchors are specific to this option: `west jacket` and `east jacket`.	
`unit ext=side jacket`	Adds a jacket around the side of the reactor. Several additional anchors available: `west jacket`, `north west jacket`, `south west jacket`, `east jacket`, `north east jacket`, and `south east jacket`.	 north west jacket north east jacket west jacket east jacket south west jacket south east jacket

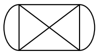
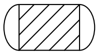
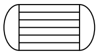
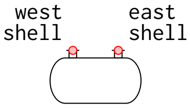
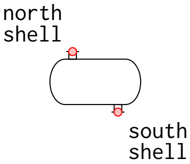
3.1.2 Tube reactor

```
\node[tube reactor] {};
```



The `tube reactor` shape provides a horizontal cylinder with curved sides to be used for such reactors as plug flow reactors, packed bed reactors, fixed bed reactors, tubular reactors, and so forth. Several key-value pairs can be provided to indicate common fills and utility features:

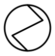
Table 2: Key-value pairs for the **`tube reactor`** shape.

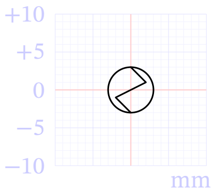
key=value	Description	Example
`unit int=packed`	Adds a cross representing a packed, dumped, or random fill within the reactor.	
`unit int=fixed`	Adds angled lines representing a fixed bed.	
`unit int=tubular`	Adds horizontal lines representing tubes for (*e.g.*) shell-and-tube reactors, double-pipe reactors, and so forth.	
`unit ext=cis shell`	Adds two shell-side stems, both on the north side with anchors `west shell` and `east shell`. Stems can be moved to the south side by rotating (`rotate=180`) or scaling (`yscale=-1`) the node.	
`unit ext=trans shell`	Adds two shell-side stems, one on the north side and one on the south side, with anchors `north shell` and `south shell`. Stem locations can be swapped by scaling the node (`yscale=-1` or `xscale=-1`).	

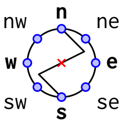
3.2 Heat exchangers

3.2.1 Basic heat exchanger

```
\node[basic hx] {};
```

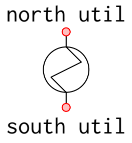
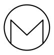


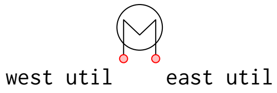




The `basic hx` shape provides a circle with a jagged interior line and represents a generic heat exchange unit. Only the four cardinal and intercardinal anchors are used; the half-cardinals `nnw`, `nne`, `ssw`, and `sse` anchors are not used. Protrusions from the inner "tube" line can be added to provide additional indication of tube-side fluids, typically to indicate utility fluids (hence the `util` value). Additional anchors can be used to place labels at ends of the protrusions.

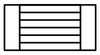
Table 3: Key-value pairs for the **`basic hx`** shape.

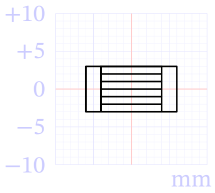
key=value	Description	Example
`unit ext=util`	Adds protrusions from the inner tube, typically to indicate utility fluids. Additional anchors `south util` and `north util` are available at the terminals.	
`unit int=U tube`	Modifies interior to a generic U-tube orientation with both tube points on the same shell side. The `south west` and `south east` anchors are located at these tube points.	

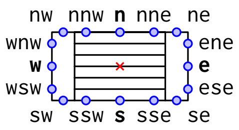
`unit int=U tube,`
`unit ext=util`
	Modifies interior to U-tube orientation and adds protrusions, typically to indicate utility fluids. Additional anchors `west util` and `east util` are available at the terminals.	

3.2.2 Shell and tube heat exchanger

```
\node[shell and tube hx] {};
```







The `shell and tube hx` shape provides a rectangle with an inner set of horizontal lines representing a shell and tube heat exchanger. Keys can modify the appearance to provide shell-side stems or modify the tube ends to represent two-pass or four-pass arrangements.

Table 4: Key-value pairs for the **`shell and tube hx`** shape.

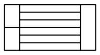
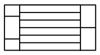
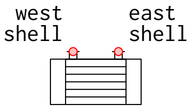
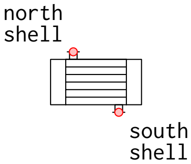
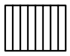
key=value	Description	Example
`unit int=two pass`	Adds a horizontal line on the west shell side to indicate a two-pass heat exchanger.	
`unit int=four pass`	Adds two horizontal line on the west shell side and one on the east to indicate a four-pass heat exchanger.	

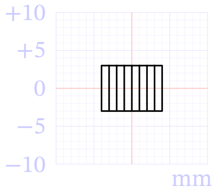
Table 4: Key-value pairs for the **`shell and tube hx`** shape *(cont'd)*

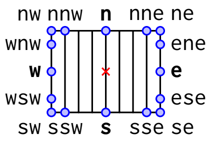
`unit ext=cis shell`	Adds two shell-side stems, both on the north side with anchors `west shell` and `east shell`. Stems can be moved to the south side by rotating (`rotate=180`) or scaling (`yscale=-1`) the node.	
`unit ext=trans shell`	Adds two shell-side stems, one on the north side and one on the south side, with anchors `north shell` and `south shell`. Stem locations can be swapped by scaling the node (`yscale=-1` or `xscale=-1`).	

3.2.3 Plate heat exchanger

```
\node[plate hx] {};
```



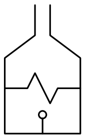


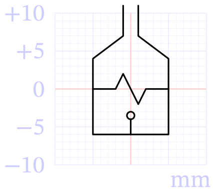


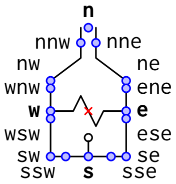
The `plate hx` shape provides a rectangle with an inner set of vertical lines representing a plate-and-frame heat exchanger. This unit has no `key=value` pairs for additional modification.

3.2.4 Fired exchanger

```
\node[fired hx] {};
```

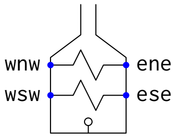
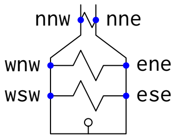






The `fired hx` shape provides a square unit with tapered chimney representing a fired heat exchanger. A horizontal through-line represents the process tube; a small circular icon at the bottom indicates the combustion region of the heat exchanger. The default number of process tubes is one (`unit int=single` or omitted) but additional process tubes can be added using the `unit int` key. Inlets and outlets will shift to correspond to half-cardinal anchors as shown below.

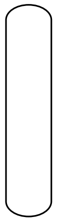
Table 5: Key-value pairs for the **fired hx** shape.

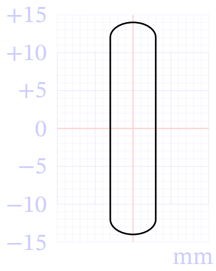
key=value	Description	Example
`unit int=double`	Provides two tubes roughly corresponding to the radiative and convective zones.	
`unit int=triple`	Provides three tubes roughly corresponding to a radiative zone and two convective zones.	

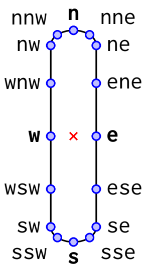
3.3 Separation units

3.3.1 Column

```
\node[column] {};
```







The `column` shape provides a vertical, elongated cylinder as a generic separation column. The default fill is empty but several `key=value` pairs are provided to represent the most common separation units. Several additional anchors and keys are available based on these settings.

Table 6: Key-value pairs for the **column** shape.

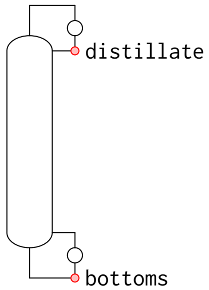
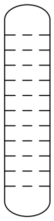
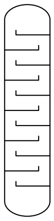
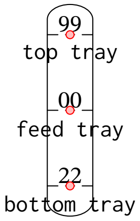
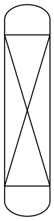
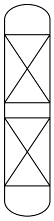
key=value	Description	Example
`unit ext=simple hx`	Provides stylized representation of condenser and reboiler along with anchors `distillate` and `bottoms` for stream connections. These anchors always exist but coincide with `north east` and `south east` when the `simple hx` key is omitted.	

Table 6: Key-value pairs for the **`column`** shape *(cont'd)*

`unit int=tray`
`unit int=dashed tray`
	Dashed, horizontal lines. Dashes will always have three segments and two openings.	

`unit int=weir tray`	Solid, horizontal lines with small risers to represent tray weirs.	

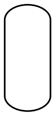
`unit int=numbered tray`
associated keys:
`top tray=99`
`feed tray=00`
`bottom tray=22`
	Dashed, horizontal lines at top, feed, and bottom trays. Associated keys `top tray`, `feed tray` , and `bottom tray` can be used to indicate tray numbers **if column is not transformed**. If column is transformed then associated keys can be omitted and anchors `feed tray`, `top tray`, and `bottom tray` used for placement of additional text nodes.	

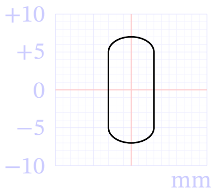
`unit int=packed`	Large cross symbol indicating random or dumped fill (packing).	
`unit int=double packed`	Two sections of random or dumped fill (packing) separated by a small, central gap.	

3.3.2 Vessel

```
\node[vessel] {};
```

The `vessel` shape provides a vertical cylinder as a generic vessel. Such a vessel can be, for example, down-scaled and rotated 90° can represent a product tank or a phase separator after a condenser. The default fill is empty but several `key=value` pairs are provided to represent two common vapor-liquid units as well as liquid accumulation tanks. Several additional anchors are available based on these settings.





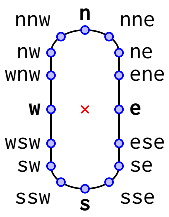
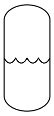
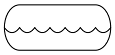
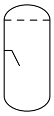
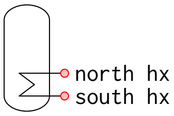


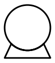
Table 7: Key-value pairs for the **vessel** shape.

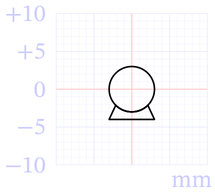
key=value	Description	Example
`unit int=liquid`	Adds wavy lines across the middle of the vessel to indicate a liquid level.	
`unit int=liquid rotated`	Adds wavy lines down the center of the vessel to indicate a liquid level. This key is intended to be used with a rotated node such as `\node[vessel, rotate=90, unit int=liquid rotated] {};`	
`unit int=phase sep`	Adds a knock-down element near the `west` anchor and a dashed, horizontal line near the top of the vessel to indicate a demister pad.	
`unit ext=simple hx`	Adds a simplified heat transfer element to the bottom portion of the vessel. Two additional anchors, `north hx` and `south hx`, are located at the exterior points of the heat exchanger tubes.	

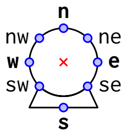
3.4 Fluid transport

3.4.1 Centrifugal pump

```
\node[centrifugal pump] {};
```

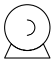
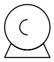
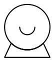
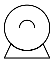
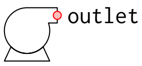
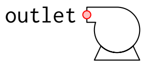
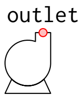
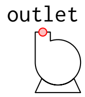






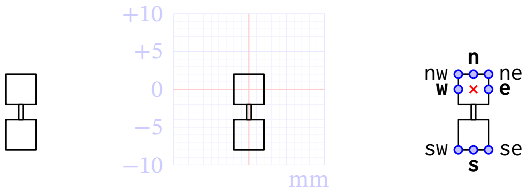
The `centrifugal pump` shape provides a circular element with a triangular base to represent a centrifugal pump. An additional half-circle can be added using the `unit int` key to indicate the pump inlet and a rectangular outlet direction can be added using the `unit ext` key.

Table 8: Key-value pairs for the **`centrifugal pump`** shape.

`key=value`	Description	Example
`unit int=inlet west`	Adds a half-circle around the `center` anchor to accept an inlet stream to enter from the west.	
`unit int=inlet east`	Adds a half-circle around the `center` anchor to accept an inlet stream to enter from the east.	
`unit int=inlet north`	Adds a half-circle around the `center` anchor to accept an inlet stream to enter from the north.	
`unit int=inlet south`	Adds a half-circle around the `center` anchor to accept an inlet stream to enter from the south. Note that there is no means of removing the triangular base; such an inlet stream should be drawn as going through the base.	
`unit ext=outlet east`	Adds a rectangular protrusion facing east to represent an outlet. Also adds the `outlet` anchor in the center of the outlet box.	
`unit ext=outlet west`	Adds a rectangular protrusion facing west to represent an outlet. Also adds the `outlet` anchor in the center of the outlet box.	
`unit ext=outlet north east`	Adds a rectangular protrusion facing north on the east side of the pump to represent an outlet. Also adds the `outlet` anchor in the center of the outlet box.	
`unit ext=outlet north west`	Adds a rectangular protrusion facing north on the west side of the pump to represent an outlet. Also adds the `outlet` anchor in the center of the outlet box.	

3.4.2 Reciprocating pump

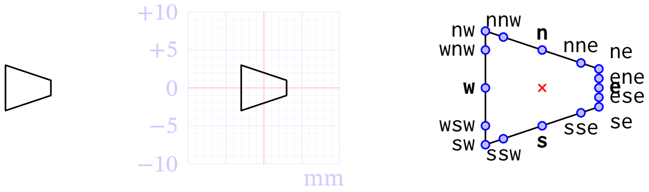
```
\node[reciprocating pump] {};
```



The `reciprocating pump` shape provides two square elements–a pump head and motor–connected by a simple shaft. Most anchors are placed relative to the pump head. This unit has no `key=value` pairs for additional modification.

3.4.3 Compressor

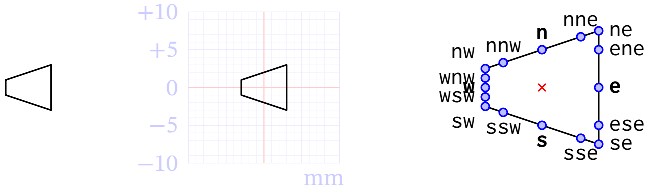
```
\node[compressor] {};
```



The `compressor` shape provides a quadrilateral to represent a gas-phase compressor. This unit has no `key=value` pairs for additional modification. If mirrored along the x-axis (*e.g.*, by using something like `xscale=-1` or `rotate=90`) then the `compressor` shape is identical to the `turbine` shape but with different anchor points.

3.4.4 Turbine

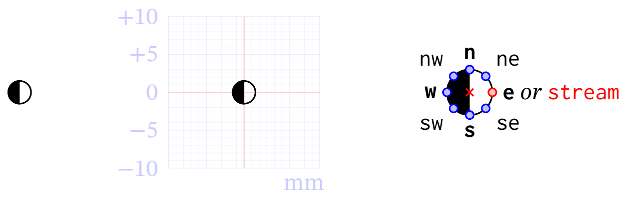
```
\node[turbine] {};
```



The `turbine` shape provides a quadrilateral to represent a gas-phase turbine. This unit has no `key=value` pairs for additional modification. If mirrored along the x-axis (*e.g.*, by using something like `xscale=-1` or `rotate=90`) then the `turbine` shape is identical to the `compressor` shape but with different anchor points.

4 Streams

4.1 Feed terminal

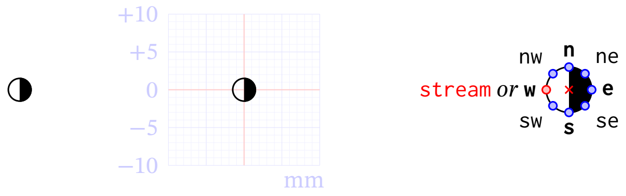


```
\node[feed] {};
```

The `feed` shape provides a half-filled circle representing a process feed point. The special anchor `stream` corresponds to the `east` anchor and is provided as an optional method to define stream starting points. This unit has no `key=value` pairs for additional modification.

4.2 Product terminal

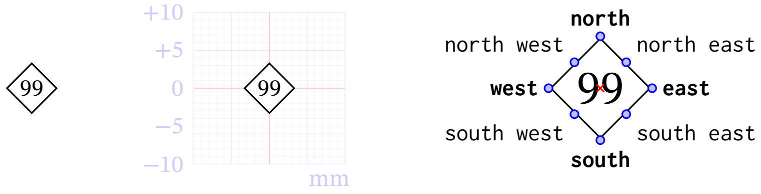
```
\node[product] {};
```



The `product` shape provides a half-filled circle representing a process product point. The special anchor `stream` corresponds to the `west` anchor and is provided as an optional method to define stream ending points. This unit has no `key=value` pairs for additional modification.

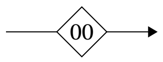
4.3 Stream numbers

```
\node[sid] {99};
```



The `sid` (read "ess eye dee" for "stream identification") shape provides a modified `diamond` shape from the `shapes` library for the purpose of labeling streams. The anchors **are not aliased** with their abbreviations because *(a)* this is not a custom shape of the `pfdicons` package and *(b)* the `sid` shape is typically used within a line (stream) without accessing its anchors. The fill of `sid` is white which allows it to be conveniently placed within a stream-drawing command such as

```
\begin{tikzpicture}
  \draw[->] (0,0) -- node[sid] {00} (2,0);
\end{tikzpicture}
```

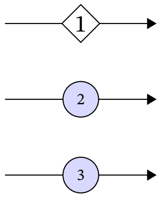


The `sid` shape has no `key=value` pairs to modify its appearance but you can modify the appearance by redefining its `tikzstyle`, which by default is

```
\tikzstyle{sid} = [diamond, draw, solid, fill=white, text badly centered, inner sep=1pt, font=\footnotesize]
```

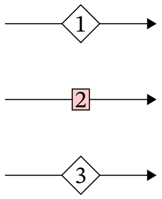
Modifications to this definition can occur either in the preamble (to affect all drawings) or within the document (to affect individual drawings or lines). For example, if you'd like to use circular identifiers with a blue fill and more space around bigger numbers then you could do something like this:

```
\begin{tikzpicture}
  \draw[->] (0,0) -- node[sid] {1} (2,0);

  \tikzstyle{sid} = [circle, draw, solid, fill=blue!15, text badly centered, inner sep=3pt, font=\tiny]

  \draw[->] (0,-1) -- node[sid] {2} (2,-1);

  \draw[->] (0,-2) -- node[sid] {3} (2,-2);
\end{tikzpicture}
```



You can also modify individual parameters while retaining others by passing additional modifiers within the `sid` node usage, like this:

```
\begin{tikzpicture}
  \draw[->] (0,0) -- node[sid] {1} (2,0);

  \draw[->] (0,-1) -- node[sid, rectangle, fill=red!20] {2} (2,-1);

  \draw[->] (0,-2) -- node[sid] {3} (2,-2);
\end{tikzpicture}
```



4.4 Stream arrow tips

The arrow tip is set using the standard TikZ syntax

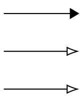
```
\tikzset{>=<tip style>}
```

When loaded the `pfdicons` package sets `<tip style>` to `Triangle` as

```
\tikzset{>=Triangle}
```

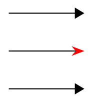
You can change this setting in the preamble or within the document itself to whatever arrow tip you prefer (see §16.5 in the PGF manual for a summary of arrow tips). For example,

```
\begin{tikzpicture}
  \draw[->] (0,0) -- (1,0);

  \tikzset{>=Latex[open]}
  \draw[->] (0,-0.5) -- (1,-0.5);
  \draw[->] (0,-1) -- (1,-1);
\end{tikzpicture}
```



You can also make modifications to individual arrow tips simply by using a different tip for that particular arrow:

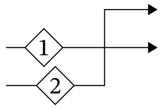
```
\begin{tikzpicture}
  \draw[->] (0,0) -- (1,0);
  \draw[-{Stealth[red]}] (0,-0.5) -- (1,-0.5);
  \draw[->] (0,-1) -- (1,-1);
\end{tikzpicture}
```



4.5 Stream crossings

When two streams cross it's desirable to indicate their status as distinct streams to avoid confusion with junctions or mixing points. Consider the following example:

```
\begin{tikzpicture}
  \draw[->] (0,0.5) -- node[sid, pos=0.25]{1} (2,0.5);
  \draw[->] (0,0) -- node[sid]{2} (1.5,0) -- (1.5,1) -- (2,1);
\end{tikzpicture}
```

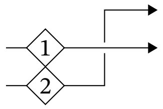


It may not be immediately obvious that the intersection between streams 1 and 2 is not a four-way pipe junction with two inlets and two outlets. To make such distinction a *bridge* can be used, most commonly in the form of a break in one stream, an arc of one stream, or a combination of a break and an arc. The `pfdicons` package provides a `bridge` style which uses the `spath3` package to detect crossings and create bridges. The workflow to use the `bridge` style is as follows:

1. Identify that a crossing has occurred (*e.g.*, by completing a drawing as done above). Determine which stream is to be drawn continuously (the `over` stream) and which stream is to be broken (the `under` stream).
2. Re-define the original streams using the **`path`** operation, removing all decorations.
3. Use the `bridge` key with `tikzset` to set the `over` and `under` paths as `\tikzset{bridge={over}{under}}`.
4. Re-draw the streams with a **`draw`** operation, replacing any previously removed decorations.

To demonstrate this process on the previous example we select stream 1 as the `over` stream (Turton recommends horizontal streams be continuous and vertical streams be broken). The remaining steps are completed as follows:

```
1 \begin{tikzpicture}
2   % \draw[->] (0,0.5) -- node[sid, pos=0.25]{1} (2,0.5);
3   % \draw[->] (0,0) -- node[sid]{2} (1.5,0) -- (1.5,1) -- (2,1);
4   \path[spath/save=over] (0,0.5) -- (2,0.5);
5   \path[spath/save=under] (0,0) -- (1.3,0) -- (1.3,1) -- (2,1);
6   \tikzset{bridge={over}{under}}
7   \draw[->, spath/use=over] node[sid, pos=0.15]{1};
8   \draw[->, spath/use=under] node[sid, pos=0.1]{2};
9 \end{tikzpicture}
```

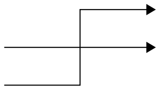
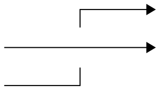


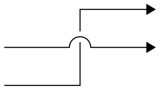
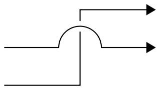
Lines 4 and 5 define the original streams using the **`path`** operation. Line 6 sets the `bridge` key to identify the `over` and `under` stream (the names here could be anything as long as the first input is the "over" path and the second input is the "under" path). Lines 7 and 8 re-draw the streams with an appropriate `draw` operation, adding the stream labels as well. Notice that the positioning of the stream labels must be modified slightly from the original syntax; getting the labels *precisely* where they were before the bridging operation can be challenging (but is usually not necessary).

The bridge style can be modified by using `\tikzset` to set the value of two keys, `bridge gap` and `bridge radius`, as summarized below.

Table 9: Key-value pairs for use with stream crossings

key	Description	Example

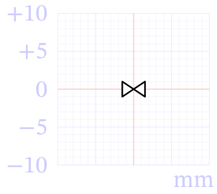
`bridge gap`	Adjusts the amount of space around a stream break. The default value is `4pt`.	`\tikzset{bridge gap=0pt}`
		
		`\tikzset{bridge gap=15pt}`
		

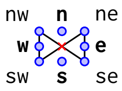
`bridge radius`	Adjusts the radius of an arc bridge. The default value is `0pt` which produces a straight line.	`\tikzset{bridge radius=8pt}`
		
		`\tikzset{bridge radius=20pt}`
		

5 Control elements

5.1 Valve

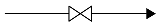
```
\node[valve] {};
```





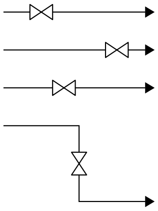
The `valve` shape provides two opposing triangles as a generic valve shape. Unlike most other shapes the fill color of a `valve` shape is white which allows it to be conveniently placed within a line-drawing operation such as

```
\begin{tikzpicture}
  \draw[->] (0,0) -- node[valve] {} (2,0);
\end{tikzpicture}
```



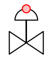
Placement of the valve on the stream can be modified using the standard placement keys (*e.g.*, `middle` or `near start`) or by the `pos=number` key. The valve can also be rotated to an arbitrary angle using the `rotate=degree` key. For example:

```
\begin{tikzpicture}
  \draw[->] (0,0) -- node[valve, near start] {} (2,0);
  \draw[->] (0,-0.5) -- node[valve, near end] {} (2,-0.5);
  \draw[->] (0,-1) -- node[valve, pos=0.4] {} (2,-1);
  \draw[->] (0,-1.5) -- (1,-1.5) -- node[valve, rotate=90] {} (1,-2.5)
      -- ++(1,0);
\end{tikzpicture}
```



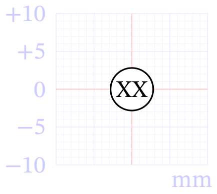
A generic actuator can be added to the `valve` shape by using the `unit ext` key as summarized below.

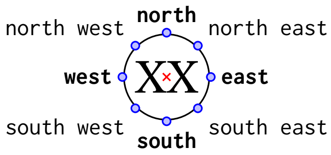
Table 10: Key-value pairs for the **`valve`** shape.

`key=value`	Description	Example
`unit ext=actuator`	Adds a hemisphere-capped protrusion as an indicator of a generic actuation device. The `actuator` anchor is placed at the top of the hemisphere for electrical connections.	

5.2 Electrical instruments

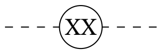
```
\node[elec] {XX};
```





The `elec` shape provides a modified `circle` shape from the `shapes` library for the purpose of labeling streams. The anchors **are not aliased** with their abbreviations because this is not a custom shape of the `pfdicons` package. Like the `valve` and `sid` shapes the fill of `elec` is white which allows it to be conveniently placed within a stream-drawing command such as

```
\begin{tikzpicture}
  \draw[dashed] (0,0) -- node[elec] {XX} (2,0);
\end{tikzpicture}
```

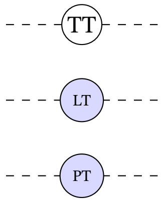


The `elec` shape has no `key=value` pairs to modify its appearance but you can modify the appearance by redefining its `tikzstyle`, which by default is

```
\tikzstyle{elec} = [circle, draw, solid, fill=white, text badly centered, inner sep=1pt, font=
    \footnotesize]
```

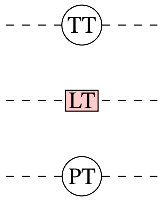
Modifications to this definition can occur either in the preamble (to affect all drawings) or within the document (to subsequent drawings or lines). For example, if you'd like to use circular identifiers with a blue fill and more space around bigger numbers then you could do something like this:

```
\begin{tikzpicture}
  \draw[dashed] (0,0) -- node[elec] {TT} (2,0);

  \tikzstyle{elec} = [circle, draw, solid, fill=blue!15, text badly centered, inner sep=3pt, font=\tiny]

  \draw[dashed] (0,-1) -- node[elec] {LT} (2,-1);

  \draw[dashed] (0,-2) -- node[elec] {PT} (2,-2);
\end{tikzpicture}
```



You can also modify individual parameters while retaining others by passing additional modifiers within the `sid` node usage, like this:

```
\begin{tikzpicture}
  \draw[dashed] (0,0) -- node[elec] {TT} (2,0);

  \draw[dashed] (0,-1) -- node[elec, rectangle, fill=red!20] {LT} (2,-1);

  \draw[dashed] (0,-2) -- node[elec] {PT} (2,-2);
\end{tikzpicture}
```



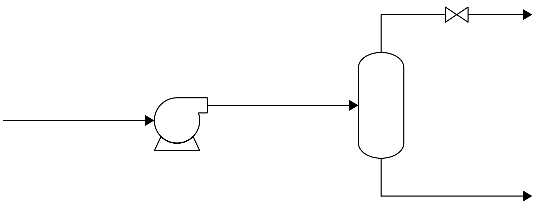
6 Examples

The following examples use the `pfdicons` package to replicate process flow diagrams and other diagrams found in several standard undergraduate textbooks. The examples are generally grouped according to the (approximate) course in which they occur: material and energy balances, thermodynamics, reaction engineering, separations, process controls, and capstone design.

Caution: Sometimes copy/pasting example code will introduce artifacts (mostly whitespaces) into the pasted code which are not apparent in this document. If this occurs you can (1) check and remove any erroneous whitespaces in your pasted code, (2) type out the examples here by hand, or (3) copy the code directly from the `pfdicons-doc.tex` file on the CTAN page for this package.

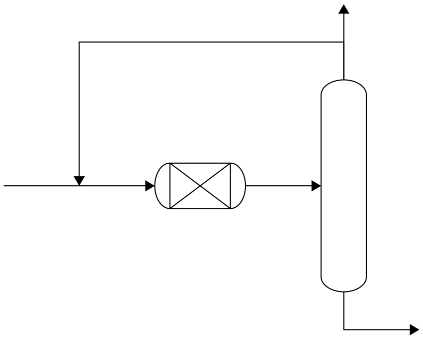
6.1 Material and Energy Balances

Example 1: A basic separation process consisting of a pump, flash unit, and valve. Source: Himmelblau, D.; Riggs, J. *Basic Principles and Calculations in Chemical Engineering*, 8th ed.; Prentice Hall, 2012.



```
\begin{tikzpicture}
  \node[centrifugal pump, unit ext=outlet east] (c) {};
  \node[vessel, right=2cm of c.outlet] (s) {};
  \draw[<-] (c.west) -- ++(-2,0);
  \draw[->] (c.outlet) -- (s.west);
  \draw[->] (s.north) -- ++(0,0.5) -- node[valve] {} ++(2,0);
  \draw[->] (s.south) |- ++(2,-0.5);
\end{tikzpicture}
```

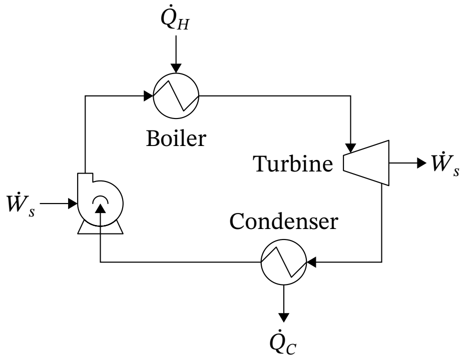
Example 2: A simplified ethylene dichloride synthesis process illustrating the reactor-separator-recycle-purge (RSRP) arrangement. Source: Himmelblau, D.; Riggs, J. *Basic Principles and Calculations in Chemical Engineering*, 8th ed.; Prentice Hall, 2012.



```
\begin{tikzpicture}
  \node[tube reactor, unit int=packed] (r) {};
  \node[column, right=of r] (s) {};
  \coordinate [left=of r] (m);

  \draw[<-] (r.west) -- ++(-2,0);
  \draw[->] (r.east) -- (s.west);
  \draw[->] (s.south) |- ++(1,-0.5);
  \draw[->] (s.north) -- ++(0,1);
  \draw[->] (s.north) -- ++(0,0.5) -| (m);
\end{tikzpicture}
```

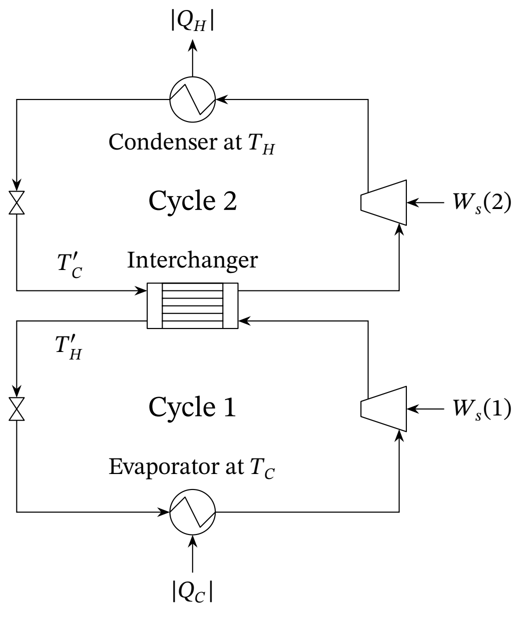
6.2 Thermodynamics

Example 3: A simple steam power plant. Source: Figure 8.1 on pg. 270 in Smith, J.M.; Van Ness, H.C.; Abbot, M.M. *Introduction to Chemical Engineering Thermodynamics*, 6th ed.; McGraw-Hill, 2001.



```
\begin{tikzpicture}[font=\footnotesize]
  % Units
  \node [basic hx, rotate=90] (boiler) {};
  \node [turbine, below right=1cm and 2cm of boiler] (turbine) {};
  \node [basic hx, rotate=90, below left=of turbine] (cond) {};
  \node [centrifugal pump, below left=of boiler, unit int=inlet south, unit ext=outlet north west] (pump) {};

  % Streams
  \draw[->] (boiler.south) -| (turbine.nnw);
  \draw[->] (turbine.sse) |- (cond.south);
  \draw[->] (cond.north) -| (pump.center);
  \draw[->] (pump.outlet) |- (boiler.north);

  % Labels
  \node[below] at (boiler.west) {Boiler};
  \node[above] at (cond.east) {Condenser};
  \node[left] at (turbine.west) {Turbine};
  \draw[<-] (boiler.east) -- node[pos=1.5] {$\dot{Q}_H$} ++(0,5mm);
  \draw[->] (cond.west) -- node[pos=1.5] {$\dot{Q}_C$} ++(0,-5mm);
  \draw[->] (turbine.east) -- node[pos=1.5] {$\dot{W}_s$} ++(5mm,0);
  \draw[<-] (pump.west) -- node[pos=1.5] {$\dot{W}_s$} ++(-5mm,0);
\end{tikzpicture}
```

EXAMPLE 4: A two-stage cascade refrigeration system. Here a `matrix` structure is used for node placement but one could equally use positioning keys (*i.e.*, `above`, `below`, and so forth) to achieve similar placement. Source: Figure 9.3 on pg. 301 in Smith, J.M.; Van Ness, H.C.; Abbot, M.M. *Introduction to Chemical Engineering Thermodynamics*, 6th ed.; McGraw-Hill, 2001.

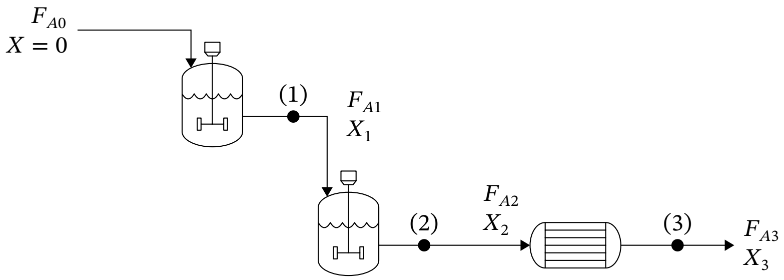


```
\begin{tikzpicture}[font=\footnotesize]
  % \usetikzlibrary{matrix}
  % Units
  \matrix [column sep=1.5cm, row sep=0.75 cm] {
    % Row 1
    & \node[basic hx, rotate=90] (cond) {};
    & \\
    % Row 2
    \node[valve, rotate=90] (v2) {}; &
```

```
      \node{\normalsize Cycle 2}; &
      \node[turbine] (c2) {}; \\
      % Row 3
      & \node[shell and tube hx] (intx) {};
      & \\
      % Row 4
      \node[valve, rotate=90] (v1) {}; &
      \node{\normalsize Cycle 1}; &
      \node[turbine] (c1) {}; \\
      % Row 5
      & \node[basic hx, rotate=90] (evap) {}; & \\
   };

   % Streams
   \tikzset{>=Stealth}
   % Upper loop
   \draw[->] (cond.n) -| (v2.e);
   \draw[->] (v2.w) |- (intx.wnw);
   \draw[->] (intx.ene) -| (c2.sse);
   \draw[->] (c2.nnw) |- (cond.s);
   % Lower loop
   \draw[->] (intx.wsw) -| (v1.e);
   \draw[->] (v1.w) |- (evap.n);
   \draw[->] (evap.s) -| (c1.sse);
   \draw[->] (c1.nnw) |- (intx.ese);

   % Labels
   \node[above] at (intx.north) {Interchanger};
   \node[below] at (cond.w) {Condenser at $T_H$};
   \node[above] at (evap.e) {Evaporator at $T_C$};
   \node[above left=1pt and 7mm of intx.wnw] {$T^{\prime}_C$};
   \node[below left=1pt and 7mm of intx.wsw] {$T^{\prime}_H$};

   \draw[<-] (c2.e) -- node[pos=2] {$W_s(2)$} ++(5mm,0);
   \draw[<-] (c1.e) -- node[pos=2] {$W_s(1)$} ++(5mm,0);
   \draw[->] (cond.e) -- node[pos=1.5] {$\lvert Q_H \rvert$} ++(0,5mm);
   \draw[<-] (evap.w) -- node[pos=1.5] {$\lvert Q_C \rvert$} ++(0,-5mm);
\end{tikzpicture}
```

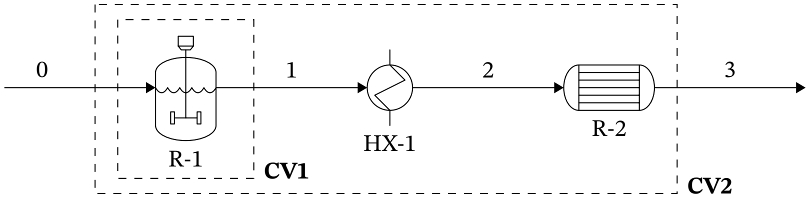
6.3 Reaction Engineering

Example 5: A series of two CSTRs followed by a PFR as part of a discussion regarding Levenspiel plots. Source: Figure 2-10 on pg. 61 in Fogler, H.S. *Elements of Chemical Reaction Engineering*, 4th ed.; Pearson, 2006.



```
\begin{tikzpicture}[font=\footnotesize]
  % Custom point marker
  \tikzstyle{dot} = [circle, draw, fill=black, inner sep=1.5pt]

  % Units
  \node[tank reactor, unit int=stirred liquid] (R1) {};
  \node[tank reactor, unit int=stirred liquid, below right=of R1] (R2) {};
  \node[tube reactor, unit int=tubular, right=2cm of R2.ese] (R3) {};

  % Streams
  \draw[<-] (R1.nnw) |- coordinate[at end] (p0) ++(-1.5,0.5);
  \draw[->] (R1.ese) -| node[dot, pos=0.3] (p1) {} (R2.nnw);
  \draw[->] (R2.ese) -- node[dot, pos=0.3] (p2) {} (R3.w);
  \draw[->] (R3.e) -- node[dot] (p3) {} coordinate[at end] (p4) ++(1.5,0);

  % Labels
  \node[left, align=right] at (p0) {$F_{A0}$\\$X=0$};
  \node[above] at (p1) {(1)};
  \node[right=5mm of p1, align=left] {$F_{A1}$\\$X_1$};
  \node[above] at (p2) {(2)};
  \node[above left, align=left] at (R3.w) {$F_{A2}$\\$X_2$};
  \node[above] at (p3) {(3)};
  \node[right, align=left] at (p4) {$F_{A3}$\\$X_3$};
\end{tikzpicture}
```

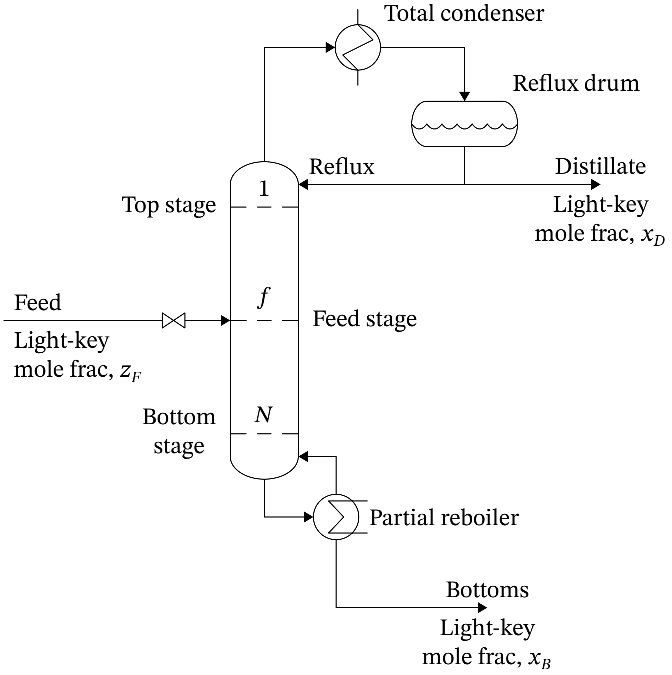
EXAMPLE 6: Two adiabatic reactors separated by a heat exchanger as part of a discussion regarding interstage heating and cooling. Source: Figure 11.2 on pg. 300 in Drews, A. *An Introduction to Chemical Reaction Engineering with MATLAB*; `ceng113.eng.ucsd.edu` (2019).



```
\begin{tikzpicture}[font=\footnotesize]
  % Units
  \node[tank reactor, unit int=stirred liquid] (R1) {};
  \node[basic hx, unit ext=util, right=2cm of R1] (HX1) {};
  \node[tube reactor, unit int=tubular, right=2cm of HX1] (R2) {};

  % Streams
  \draw[<-] (R1.w) -- node[above, near end] {0} ++(-2,0);
  \draw[->] (R1.e) -- node[above] {1} (HX1.w);
  \draw[->] (HX1.e) -- node[above] {2} (R2.w);
  \draw[->] (R2.e) -- node[above] {3} ++(2,0);

  % Control volumes
  \coordinate[above left=7mm and 5mm of R1.nw] (a);
  \coordinate[below right=7mm and 5mm of R1.se] (b);
  \coordinate[above left=9mm and 8mm of R1.nw] (c);
  \coordinate[below right=11mm and 5mm of R2.se] (d);
  \draw[dashed] (a) rectangle (b);
  \draw[dashed] (c) rectangle (d);

  % Labels
  \node[below] at (R1.s) {R-1};
  \node[below] at (HX1.south util) {HX-1};
  \node[below] at (R2.s) {R-2};
  \node[anchor=base west] at (b) {\textbf{CV1}};
  \node[anchor=base west] at (d) {\textbf{CV2}};
\end{tikzpicture}
```

6.4 Separations

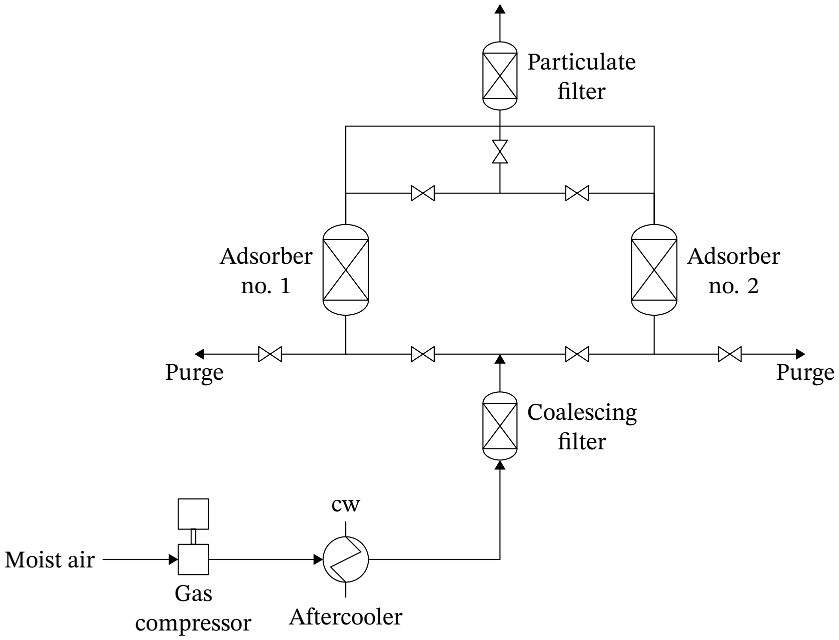
Example 7: A general distillation system using a total condenser and partial reboiler. Some annotations have been excluded for clarity (clarity of this document, not the figure: if so desired it would only be a matter of additional `node` elements to replace the excluded annotations). Source: Figure 7.2 on pg. 261 in Seader, J.D.; Henley, E.J.; Roper, D.K. *Separation Process Principles*, 3rd ed.; John Wiley and Sons, 2011.



```
\begin{tikzpicture}[font=\footnotesize]
  %\usetikzlibrary{decorations.pathmorphing}
  % Units
  \node[column, unit int=numbered tray, scale=1.5] (c) {};
  \node[vessel, rotate=90, unit int=liquid rotated, above right=8mm and 15mm of c, anchor=
      north] (drum) {};
  \node[basic hx, unit ext=util, above left=8mm and 5mm of drum.north] (cond) {};
  \node[basic hx, unit int=U tube, unit ext=util, rotate=90, below right=5mm and 5mm of c,
      anchor=east] (reboil) {};

  % Helpful points
  \coordinate[left=3cm of c.west] (F);
  \coordinate[right=4cm of c.north east] (D);
  \coordinate[below right=2cm and 2.5cm of c.south east] (B);

  % Streams
```

```
   \draw[->] (c.north) |- (cond.west);
   \draw[->] (cond.east) -| (drum.east);
   \draw[->] (drum.west) |- (c.north east);
   \draw[->] (drum.west) |- (D);
   \draw[->] (c.south) |- (reboil.north);
   \draw[->] (reboil.east) |- (c.south east);
   \draw[->] (reboil.west) |- (B);
   \draw[->] (F) -- node[valve, near end] {} (c.west);

   % Distillate labels
   \node[above=0.5pt of c.top tray] {1};
   \node[left=5mm of c.top tray, anchor=east] {Top stage};
   \node[anchor=south west] at (c.ne) {Reflux};
   \node[above] at (D) {Distillate};
   \node[above right] at (cond.ne) {Total condenser};
   \node[above right] at (drum.south east) {Reflux drum};

   % Feed labels
   \node[above=0.5pt of c.feed tray] {$f$};
   \node[anchor=south west] at (F) {Feed};
   \node[right=5mm of c.feed tray, anchor=west] {Feed stage};
   \node[align=left, anchor=north west] at (F) {Light-key\\mole frac, $z_F$};

   % Bottoms labels
   \node[above=0.5pt of c.bottom tray] {$N$};
   \node[above] at (B) {Bottoms};
   \node[right] at (reboil.south) {Partial reboiler};
   \node[left=5mm of c.bottom tray, anchor=east, align=center] {Bottom\\stage};
   \node[below, align=center] at (D) {Light-key\\mole frac, $x_D$};
   \node[below, align=center] at (B) {Light-key\\mole frac, $x_B$};
\end{tikzpicture}
```

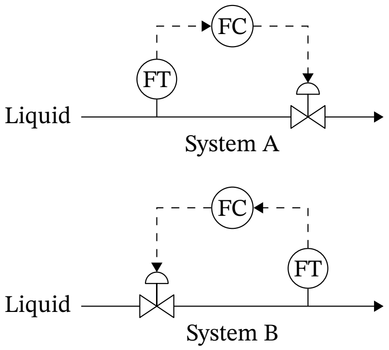
EXAMPLE 8: A schematic of pressure-swing adsorption for the dehydration of air. In this diagram the original authors used approximately the same symbol for a filter as the adsorber, a similarity retained here. A matrix was again used to help with alignment and several `tikzstyle` definitions were used to create “shortcut” shapes for the `filter`, `ads`, and `pump` units. Source: Figure 15.2 on pg. 570 in Seader, J.D.; Henley, E.J.; Roper, D.K. *Separation Process Principles*, 3rd ed.; John Wiley and Sons, 2011.



```
\begin{tikzpicture}[font=\footnotesize]
  % \usetikzlibrary{matrix}

  % Definitions
  \tikzstyle{filter} = [tube reactor, unit int=packed, rotate=90, scale=0.75];
  \tikzstyle{ads} = [tube reactor, unit int=packed, rotate=90];
  \tikzstyle{pump} = [reciprocating pump, yscale=-1];

  % Nodes
  \matrix [column sep=1.5cm, row sep=0.5 cm] {
    % 4 columns: & & & \\
    & & \node[filter] (f1) {}; & \\
    & & & \\
    & & & \\
    & \node[ads] (ads1) {}; & & \node[ads] (ads2) {};\\
    & & & \\
    & & \node[filter] (f2) {}; & \\ % f2
    \node[pump] (p) {}; & \node[basic hx, unit ext=util] (hx) {};& & \\ % pump+cooler
  };

  % Helper points
  \coordinate[above=5mm of f2.e] (v2); % for valves near f2
  \coordinate[below=11mm of f1.w] (v1); % for valves near f1

  % Streams
  \draw[<-] (p.w) -- node[pos=1.7] {Moist air} ++(-1,0);
  \draw[->] (p.e) -- (hx.w);
  \draw[->] (hx.e) -| (f2.w);
  \draw[->] (f2.e) -- (v2);
  \draw (v2) -| node[valve, near start] {} (ads1.w);
  \draw[->] (ads1.w |- v2) -- node[valve] {} node[anchor=north, at end] {Purge} ++(-2,0);
  \draw (v2) -| node[valve, near start] {} (ads2.w);
  \draw[->] (ads2.w |- v2) -- node[valve] {} node[anchor=north, at end] {Purge} ++(2,0);
  \draw (ads1.e) |- node[valve, near end] {} (v1) -| node[valve, near start] {} (ads2.e);
  \draw (v1) -- node[valve, rotate=90] {} (f1.w);
  \draw (ads1.e) -- ++(0,1.3) -| (ads2.e);
  \draw[->] (f1.e) -- ++(0,5mm);

  % Labels
  \node[right, align=center] at (f1.s) {Particulate\\filter};
  \node[right, align=center] at (ads2.s) {Adsorber\\no. 2};
  \node[left, align=center] at (ads1.n) {Adsorber\\no. 1};
  \node[right, align=center] at (f2.s) {Coalescing\\filter};
  \node[below, align=center] at (p.n) {Gas\\compressor};
  \node[below] at (hx.south util) {Aftercooler};
  \node[above] at (hx.north util) {cw};

\end{tikzpicture}
```

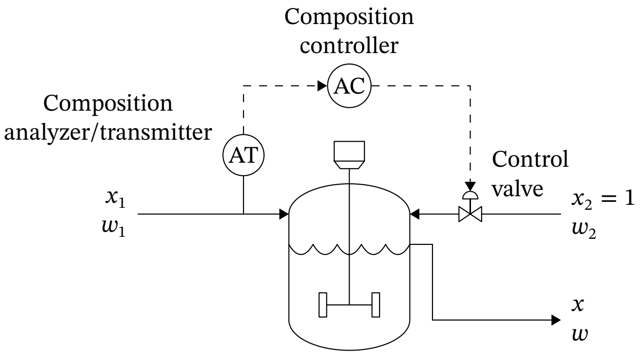
6.5 Process Controls

Example 9: A comparison of feedforward and feedback control systems. This example illustrates the use of absolute positioning (only for variety, not because it's necessary). Source: Figure E1.9 on pg. 13 in Seborg, D.E.; Edgar, T.F.; Mellichamp, D.A.; Doyle III, F.J. *Process Dynamics and Control*, 4th ed.; John Wiley and Sons, 2016.



```
\begin{tikzpicture}[font=\footnotesize]
  % Feedforward system
  \draw[->] (0,0) -- ++(4,0);
  \node[elec] at (1, 0.5) (ft1) {FT};
  \node[elec] at (2, 1.2) (fc1) {FC};
  \node[valve, unit ext=actuator, scale=1.5] at (3,0) (v1) {};
  \node[left] at (0,0) {Liquid};
  \node[below] at (2,-0.1) {System A};
  \draw (1,0) -- (ft1.south);
  \draw[->, dashed] (ft1.north) |- (fc1.west);
  \draw[->, dashed] (fc1.east) -| (v1.actuator);

  % Feedback system
  \draw[->] (0,-2.5) -- ++(4,0);
  \node[valve, unit ext=actuator, scale=1.5] at (1,-2.5) (v2) {};
  \node[elec] at (2, -1.2) (fc2) {FC};
  \node[elec] at (3, -2) (ft2) {FT};

  \node[left] at (0,-2.5) {Liquid};
  \node[below] at (2,-2.6) {System B};
  \draw (3,-2.5) -- (ft2.south);
  \draw[->, dashed] (ft2.north) |- (fc2.east);
  \draw[->, dashed] (fc2.west) -| (v2.actuator);
\end{tikzpicture}
```

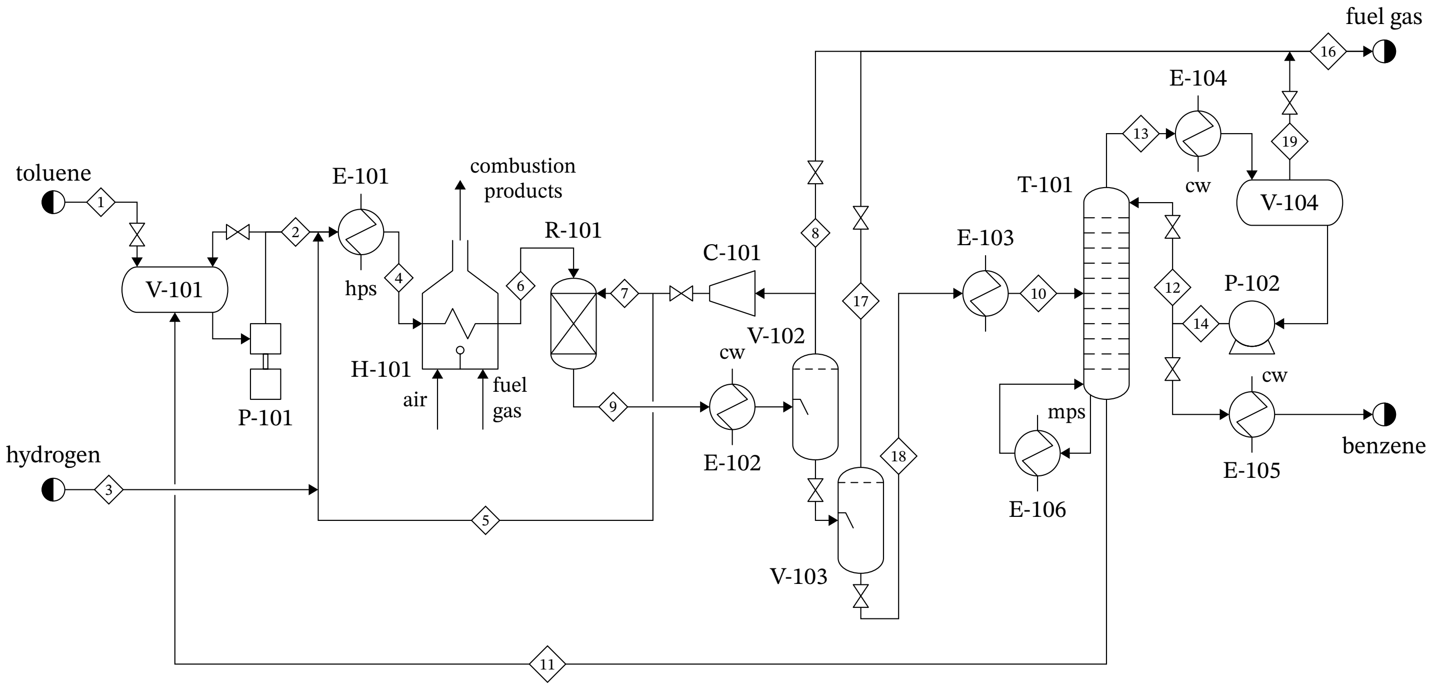
EXAMPLE 10: A blending system controlled by measuring the composition of the stream 1 and adjusting a control valve on stream two. Source: Figure 1.5 on pg. 5 in Seborg, D.E.; Edgar, T.F.; Mellichamp, D.A.; Doyle III, F.J. *Process Dynamics and Control*, 4th ed.; John Wiley and Sons, 2016.



```
\begin{tikzpicture}[font=\footnotesize]
  % Units
  \node[tank reactor, unit int=stirred liquid, scale=2] (r) {};
  \node[elec, above=of r] (ac) {AC};

  % Helpful points
  \coordinate[left=2cm of r.nw] (f1);
  \coordinate[right=2cm of r.ne] (f2);
  \coordinate[right=2cm of r.se] (p);

  % Streams and stream labels
  \draw[->] (f1) -- coordinate[pos=0.7] (s) (r.nw);
  \draw[->] (f2) -- node[valve, unit ext=actuator, pos=0.6] (v) {} (r.ne);
  \draw[->] (r.e) -- ++(3mm,0) |- (p);
  \node[left, align=right] at (f1) {$x_1$\\$w_1$};
  \node[right, align=left] at (f2) {$x_2=1$\\$w_2$};
  \node[right, align=left] at (p) {$x$\\$w$};

  % Control elements
  \node[elec, above=5mm of s] (at) {AT};
  \draw (s) -- (at.south);
  \draw[->, dashed] (at.north) |- (ac.west);
  \draw[->, dashed] (ac.east) -| (v.actuator);

  % Labels
  \node[align=center, anchor=south east] at (at.west) {Composition\\analyzer/transmitter};
  \node[align=center, anchor=south west] at (v.ne) {Control\\valve};
  \node[align=center, above] at (ac.north) {Composition\\controller};
\end{tikzpicture}
```

6.6 Capstone processes

Example 11: Hydrodealkylation of toluene to produce benzene. Source: Figure 1.3 in Turton, R.; Bailie, R.C.; Whiting, W.B.; Shaeiwitz, J.A. *Analysis, Synthesis, and Design of Chemical Processes*, 3rd ed.; Pearson, 2009.

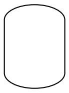
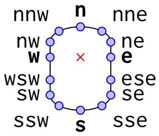
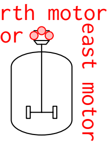
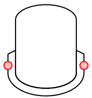
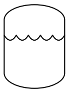
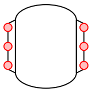
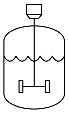
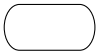
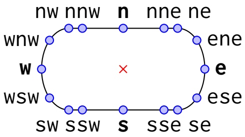
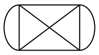
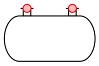
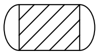
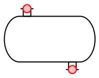
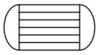
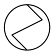
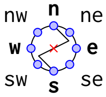
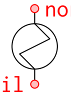
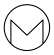
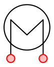
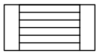
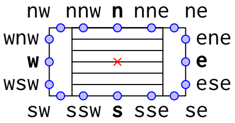
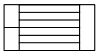
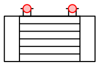
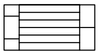
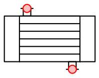
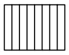
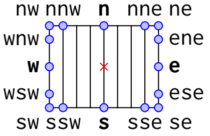
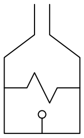
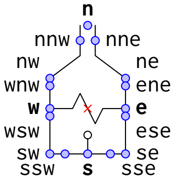
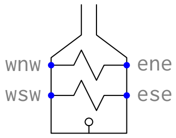
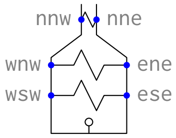


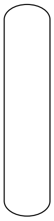
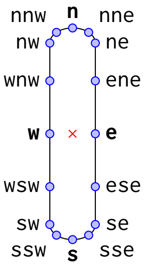
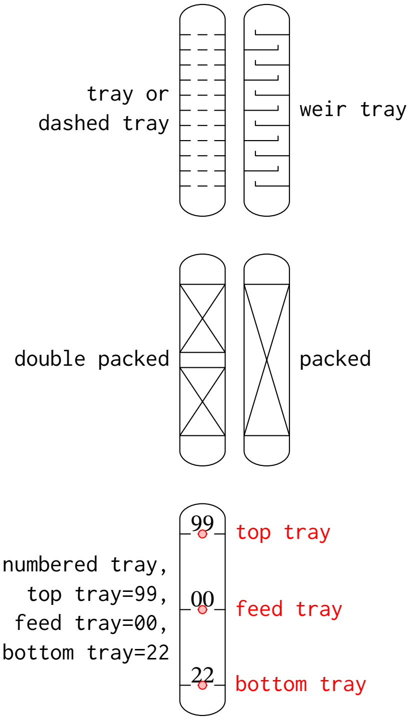
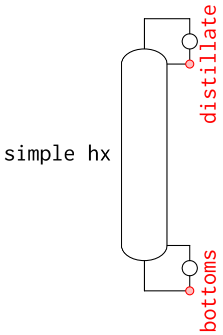
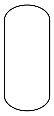
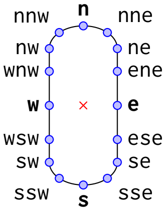
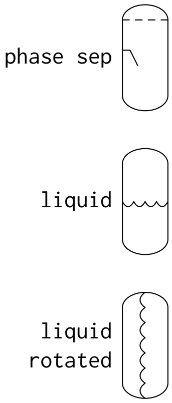
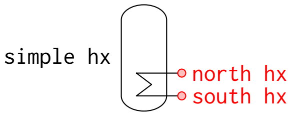
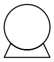
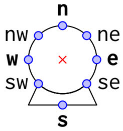
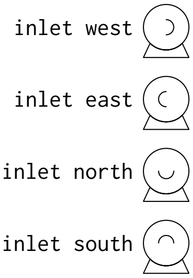
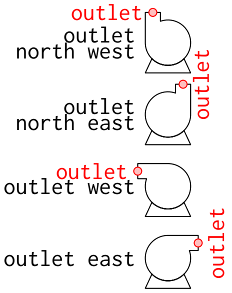
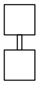
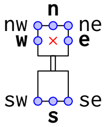
```latex
\begin{tikzpicture}[font=\footnotesize]
  % Reduce stream label sizes
  \tikzstyle{sid} = [diamond, draw, solid, fill=white, text badly centered, inner sep=1pt, font=\tiny]

  % Units
  \node[vessel, rotate=90] (V101) {};
  \node[reciprocating pump, below right=0.75cm and 0.5cm of V101] (P101) {};
  \node[basic hx, unit ext=util, above right=0.25cm and 2.75cm of V101] (E101) {};
  \node[fired hx, below right=1cm and 0.6cm of E101, anchor=west] (H101) {};
  \node[tube reactor, unit int=packed, right=of H101, anchor=center, rotate=90] (R101) {};
  \node[turbine, right=1.5cm of R101.se] (C101) {};
  \node[basic hx, unit ext=util, below=of C101] (E102) {};
  \node[vessel, unit int=phase sep, right=0.5cm of E102] (V102) {};
  \node[vessel, unit int=phase sep, below=of V102.se, anchor=west] (V103) {};
  \node[basic hx, unit ext=util, right=2.75cm of C101] (E103) {};
  \node[column, unit int=tray, right=1cm of E103] (T101) {};
  \node[basic hx, unit ext=util, below left=0.5cm and 0.7cm of T101.s] (E106) {};
  \node[basic hx, unit ext=util, above right=0.5cm and 1cm of T101.n] (E104) {};
  \node[vessel, rotate=90, below right=1cm and 0.5cm of E104] (V104) {};
  \node[centrifugal pump, below=1cm of V104.nw] (P102) {};
  \node[basic hx, unit ext=util, below=0.5cm of P102] (E105) {};
  \node[product, right=1.3cm of E105] (bz) {};
  \node[product, above=4.5cm of bz] (fuel) {};
  \node[feed, above left=0.75cm and 1cm of V101.ne] (tol) {};
  \node[feed, below=3.5cm of tol] (h2) {};

```

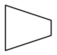
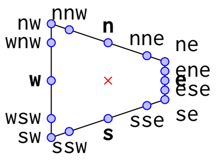
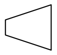
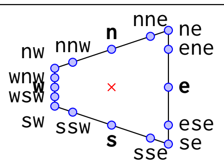
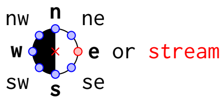
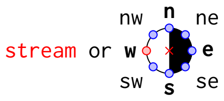
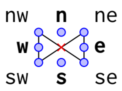
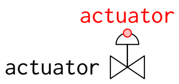
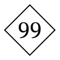
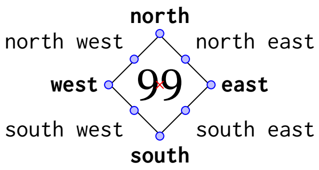
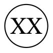
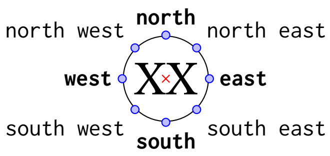
```
% Streams
\draw[->] (tol.e) -| node[sid, near start]{1} node[valve, near end, rotate=90]{} (V101.ne);
\draw[->] (V101.sw) |- (P101.w);
\draw[->] (P101.n) |- (E101.w);
\draw[<-] (V101.se) |- node[valve, pos=0.6]{} node[sid, pos=0.83]{2} (E101.w) node[pos=0.92](n1){} ;
\draw[->] (E101.e) -- ++(0.2,0) |- node[sid, near start]{4} (H101.w);
\draw[->] (H101.e) -| node[sid,near end]{6} ++(0.3,1) -| (R101.e);
\draw[->] (E102.e) -- (V102.w);
\draw[->] (V102.s) |- node[valve, rotate=90, near start]{} (V103.w);
\draw[->] (V103.s) |- node[valve, rotate=90, near start]{} ++(0.5,-0.6) |- node[sid, near start]{18} (E103.w);
\draw[->] (E103.e) -- node[sid, pos=0.4]{10} (T101.w);
\draw[->] (T101.ssw) |- (E106.e);
\draw[->] (E106.w) -- ++(-0.2,0) |- (T101.sw);
\draw[->] (T101.n) |- node[sid,near end]{13} (E104.w);
\draw[->] (E104.e) -| (V104.ne);
\draw[->] (V104.sw) |- (P102.e);
\draw[->] (P102.w) -- ++(-0.75,0) |- node[sid,pos=0.15]{12} node[valve,rotate=90,pos=0.4]{} (T101.ne);
\draw[->] (P102.w) -- node[sid]{14} ++(-0.75,0) |- node[valve,rotate=90,near start]{} (E105.w);
\draw[->] (E105.e) -- (bz.w);
\draw[->] (V103.n) |- node[sid, pos=0.2]{17} node[valve,rotate=90, pos=0.3]{} (fuel.w);
\draw[->] (V102.n) |- node[sid, pos=0.2]{8} node[valve,rotate=90, pos=0.3]{} node[sid, pos=0.96]{16} (fuel.w);
\draw[->] (V104.e) -- node[sid,pos=0.3]{19} node[valve,rotate=90,pos=0.6]{} (V104 |- fuel);
\draw[->] (V102.n) |- (C101.e);
\draw[->] (C101.w) -- node[valve, near start]{} node[sid,near end]{7} (R101.se) node[pos=0.5](n2){};

% Cross stream 9 over 5
\path[spath/save=over1] (R101.w) |- (E102.w);
\path[spath/save=under1] (n2 |- C101) |- (n1 |- V103) -| (n1 |- E101);
\tikzset{bridge={over1}{under1}}
\draw[->, spath/use=over1] node[sid, pos=0.5]{9};
\draw[->, spath/use=under1] node[sid, pos=0.5]{5};

% Cross stream 3 over 11
\path[spath/save=over2] (h2.e) -- (n1 |- h2);
\path[spath/save=under2] (T101.s) -- ++(0,-3.5) -| (V101.w);
\tikzset{bridge={over2}{under2}}
\draw[->, spath/use=over2] node[sid, pos=0.2]{3};
\draw[->, spath/use=under2] node[sid, pos=0.4]{11};

% Unit labels
\node at (V101.center) {V-101};
\node[below] at (P101.s) {P-101};
\node[above] at (E101.north util) {E-101};
\node[left] at (H101.sw) {H-101};
\node[above=4mm of R101.e] {R-101};
\node[above=1mm of C101.n] {C-101};
\node[below] at (E102.south util) {E-102};
\node[left, anchor=south east] at (V102.n) {V-102};
\node[below left, anchor=north east] at (V103.sw) {V-103};
\node[above] at (E103.north util) {E-103};
\node[above left] at (T101.nw) {T-101};
\node[above] at (E104.north util) {E-104};
\node at (V104.center) {V-104};
```

```
  \node[above] at (P102.n) {P-102};
  \node[below] at (E105.south util) {E-105};
  \node[below] at (E106.south util) {E-106};

  % Stream labels
  \node[above] at (tol.n) {toluene};
  \node[above] at (h2.n) {hydrogen};
  \node[below] at (bz.s) {benzene};
  \node[above] at (fuel.n) {fuel gas};

  % Utility labels
  \tikzset{font=\scriptsize}
  \node[right] at (E105.north util) {cw};
  \node[below] at (E104.south util) {cw};
  \node[above] at (E102.north util) {cw};
  \node[right] at (E106.north util) {mps};
  \node[below] at (E101.south util) {hps};

  \draw[->] (H101.n) -- node[at end, right, align=center] {combustion\\products} ++(0,0.8);
  \draw[<-] (H101.sse) -- node[right, align=left] {fuel\\gas} ++(0,-0.8);
  \draw[<-] (H101.ssw) -- node[left] {air} ++(0,-0.8);
\end{tikzpicture}
```

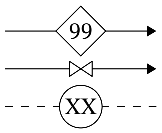
7 Quick reference

shape name	default	anchors	unit int	unit ext
tank reactor		 nnw n nne nw ne w e wsw ese sw se ssw s sse	stirred 	 lower jacket
			liquid 	 north west jacket north east jacket west jacket east jacket south west jacket south east jacket side jacket
			stirred liquid 	
tube reactor		 nw nnw n nne ne wnw ene w e wsw ese sw ssw s sse se	packed 	cis shell 
			fixed 	trans shell 
			tubular 	
basic hx				util 
			U tube 	util 
shell and tube hx		 nw nnw n nne ne wnw ene w e wsw ese sw ssw s sse se	two pass 	cis shell 
			four pass 	trans shell 
plate hx		 nw nnw n nne ne wnw ene w e wsw ese sw ssw s sse se		
fired hx		 n nnw nne nw ne wnw ene w e wsw ese sw se ssw s sse	double 	
			triple 	

shape name	default	anchors	unit int	unit ext
column		 nnw n nne nw ne wnw ene w e wsw ese sw se ssw s sse	 tray or dashed tray weir tray double packed packed numbered tray, top tray=99, feed tray=00, bottom tray=22 99 00 22 top tray feed tray bottom tray	 simple hx distillate bottoms
vessel		 nnw n nne nw ne wnw ene w e wsw ese sw se ssw s sse	 phase sep liquid liquid rotated	 simple hx north hx south hx
centrifugal pump		 n nw ne w e sw se s	 inlet west inlet east inlet north inlet south	 outlet outlet north west outlet outlet north east outlet outlet west outlet outlet east
reciprocating pump		 n nw ne w e sw se s		

shape name	default	anchors	unit int	unit ext
compressor		 nw nnw n wnw nne ne w ene e ese wsw sse se sw s ssw		
turbine		 nne ne n ene nw nnw wnw w wsw e sw ssw ese s se sse		
feed				
product				
valve				
\node[sid] {99};		 north north west north east west 99 east south west south east south		
\node[elec] {XX};		 north west north north east west XX east south west south east south		

```
\begin{tikzpicture}
  \draw[->] (0,0.5) -- node[sid] {99} (2,0.5);
  \draw[->] (0,0) -- node[valve] {} (2,0);
  \draw[dashed] (0,-0.5) -- node[elec] {XX} (2,-0.5);
\end{tikzpicture}
```



```
\begin{tikzpicture}
  \tikzset{bridge radius=8pt} % default 0pt=straight line
  \path[->, spath/save=over] (0,0) -- (2,0);
  \path[->, spath/save=under] (1,-1) -- (1,1);
  \tikzset{bridge={over}{under}}
  \draw[->, spath/use=over] node[sid, pos=0.1]{1};
  \draw[->, spath/use=under] node[sid, pos=0.2]{2};
\end{tikzpicture}
```