Part 8

Utilities in Aspen Plus

Objectives:

1.Learn to use different pressure change elements such as pumps, valves, pipe segments.
2.Become familiar with pages and Tabs of each element and how to fill in the required inputs.
3.Get to know the critical conditions and its causes for each pressure change elements.
4.Learn to use Sensitivity in Aspen Plus
5.Learn to use Design Specs in Aspen Plus
6.Understand pressure level heuristics for compressors and turbines
7.Understand the difference between heat, material, and work streams

UTILITIES

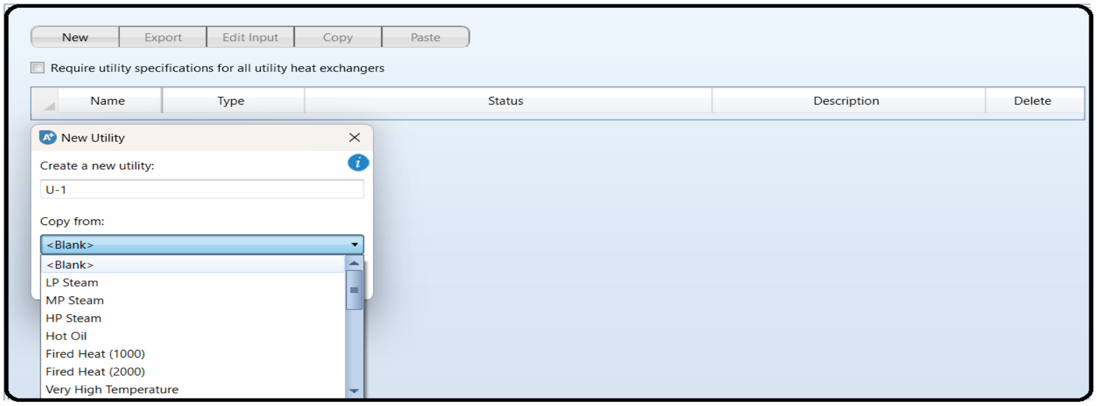
In this tutorial, you will use the Utilities feature. This is basically a convenient way of tracking the costs and amounts of utilities that your plant requires. These include electricity, different types of steam, different types of cooling, fuels, refrigerants, and others. Basically, you create your own list of utilities available to your plant, along with appropriate temperature ranges and costs of use. Then, for units such as heat exchangers, pumps, compressors, etc., you simply select in each block which utility you are going to use. Then, Aspen Plus will figure out how much of that utility you need and how much it costs.

What Are Utilities?

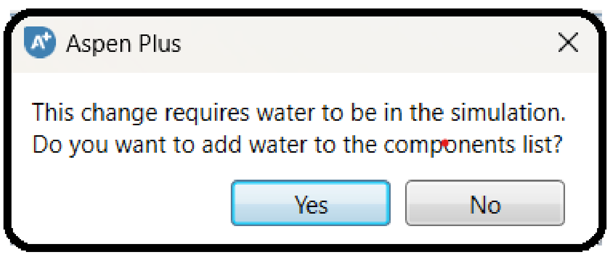
Most everyday people understand what “utilities” are since they routinely pay utility bills as a part of living expenses. The term has a very similar meaning in a chemical engineering context. When a chemical process consumes a utility, it is essentially “purchasing” heating, cooling, refrigeration, or electricity from some other provider, even though that provider may just be another business unit of the same company. In practice, other services may be considered utilities, such as waste removal, water treatment, pressurized air, high-purity oxygen, process water, or solvents of various kinds. However, in Aspen Plus, “utilities” refer only to energy services: heating, cooling, and electricity. Conceptually, utilities are provided “on demand” and are not directly integrated into your chemical process. A chemical process designer is not often concerned with exactly how those utilities are provided; the designer instead determines what utility is needed and how much. It is important to understand that when you are purchasing utilities like steam, cooling water, or refrigeration, you are not actually purchasing the actual steam, water, or refrigerant—you instead purchase the heating or cooling service they provide. For example, when you purchase highpressure steam as a utility, you are really only purchasing the latent heat it carries. In fact, your chemical plant would normally have a condensate return line where the used, condensed steam (still hot and at high pressure) returns to the steam generation plant. If you buy refrigeration utility, you are only buying the service of removing low-temperature thermal energy from your plant (making it colder). This is why utility accounting uses a cost-per-unit-energy framework, because you are only purchasing the energy.

Defining Utilities

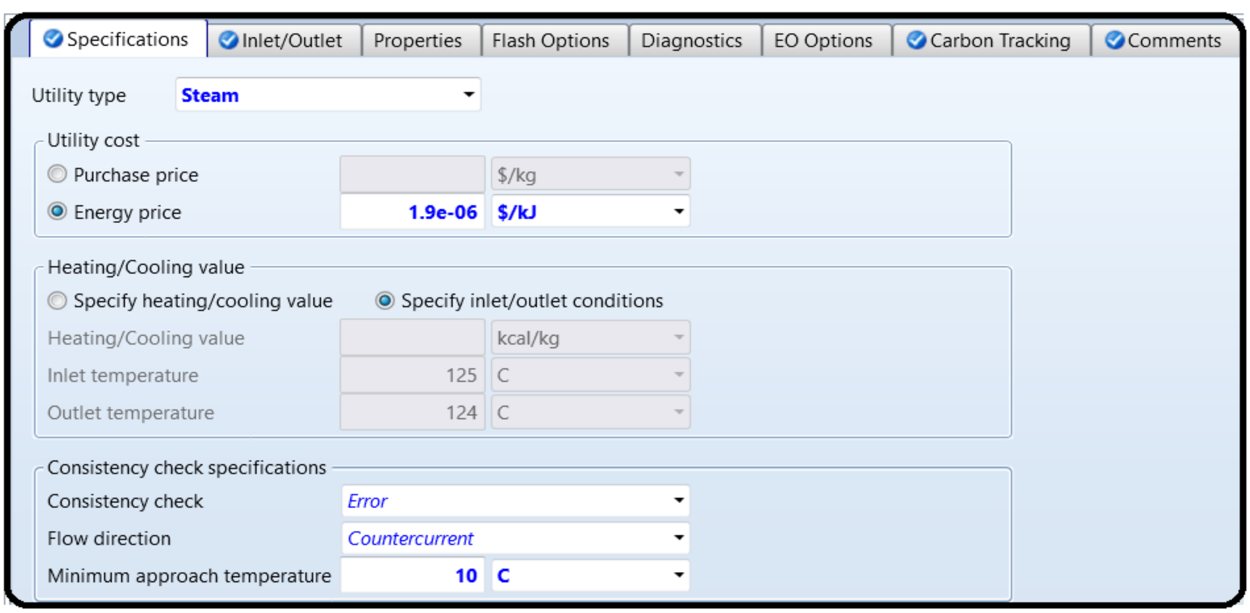
To use utilities in Aspen Plus, you must first define what utilities are available for you to purchase. Start with a blank simulation in Aspen Plus, preferably with the Chemicals with Metric Units template. You can define a utility in the Utilities folder under the Simulation tab (or click Process Utilities in the Economics ribbon). Click New to make a new utility, and call it something meaningful (see Figure 6.1). Let’s make LPS (low-pressure steam).

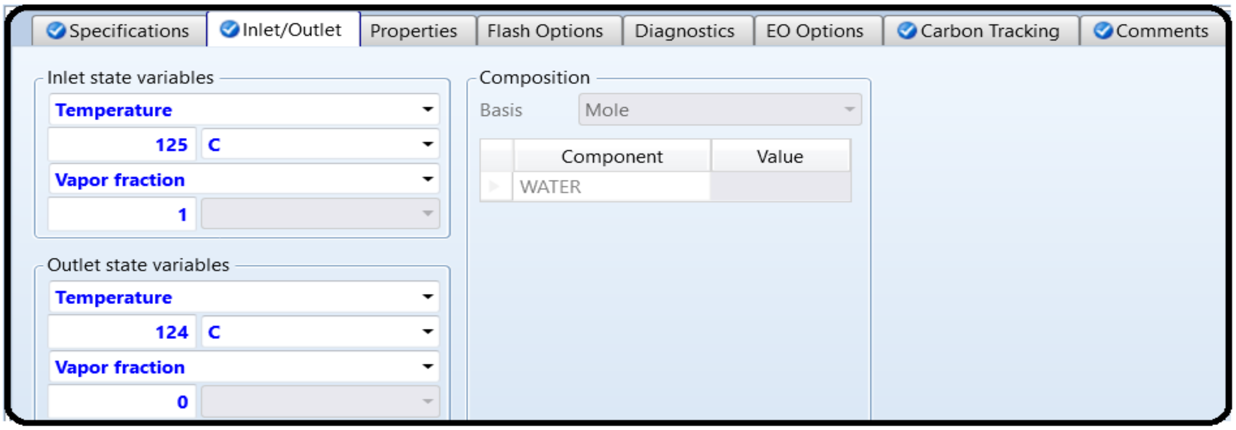


In the Copy Form, choose LP Steam. Aspen Plus comes with default prices and settings for LPS. These are heuristics which may or may not be correct for your plant, and you'll see the actual numbers show up in the Specifications and Inlet/Outlet tab once you choose LP Steam and select OK. Note also that if you have not added water to your components list, you will be prompted to do so (do it).



These numbers are very convenient, but are they right? The energy prices given here are \$1.9×10-6 per kJ, which is \$1.9 per GJ.



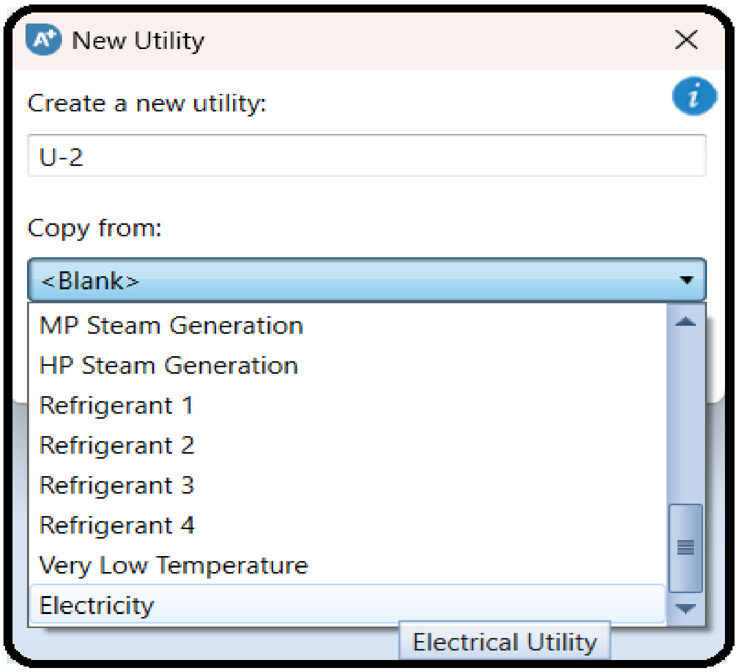


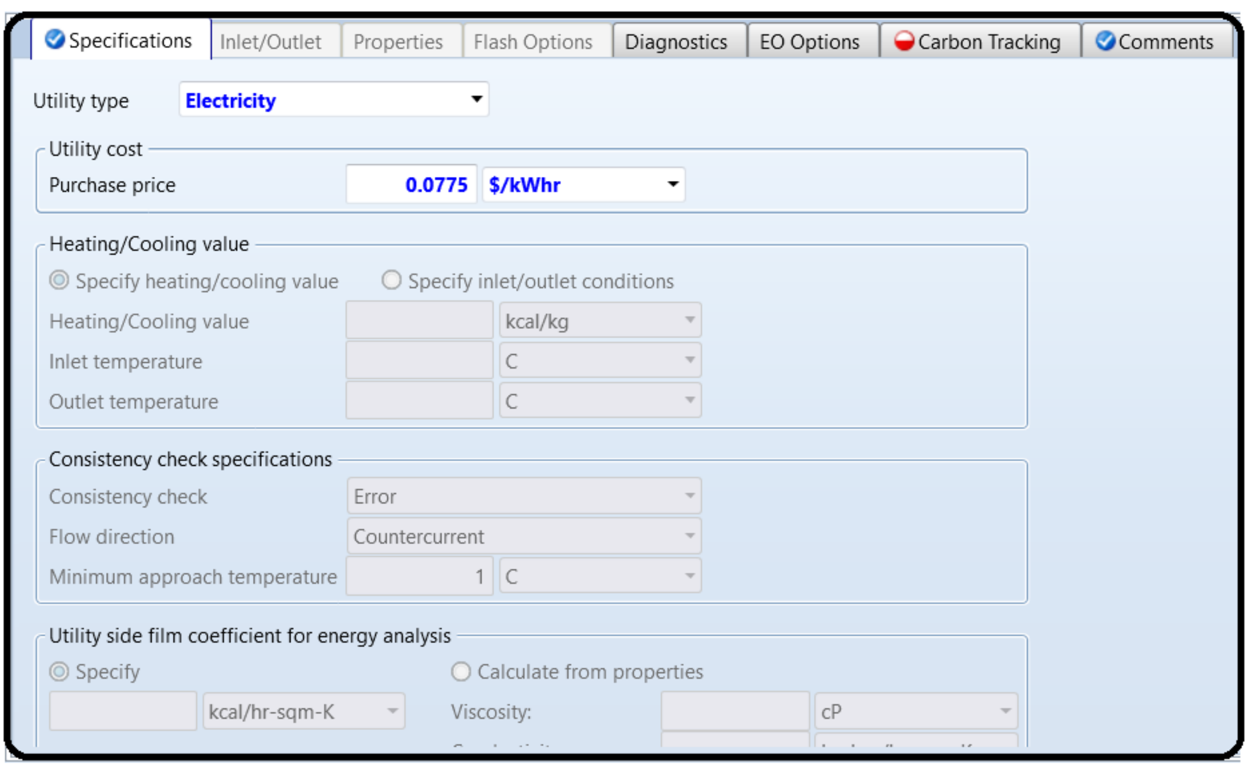
AspenTech sometimes updates these numbers, but of course the prices will be different for each specific circumstance and point in time.[3] The bottom line is that it will vary with the price of energy. At the same time, there are differences in the temperature/pressure ranges of the steams between Aspen Plus's default and heuristics given in other sources. There is no standard! Essentially, each plant will have access to steam levels depending on the other plants that sit nearby. For example, a company with lots of different processes on-site may have standard steam lines for that location. Or, individual plants may have custom steam pressure lines which are optimized to some particular values. My point is, don't just blindly go with the default numbers.

Now I've said that, let's blindly go with the default numbers since we're just learning how to use the tool and are less concerned about what the numbers actually are. In the Inlet/Outlet tab, you'll notice that the vapor fraction is defined as 1 for the inlet and 0 for the outlet. This means that heat is provided by condensing steam (this is normal). As mentioned in earlier tutorials, Aspen Plus uses a convention that if you *specify* vapor fraction = 1 or vapor fraction = 0 in an input form, that means you are defining that the inlet is exactly saturated vapor at the dew point or the outlet is exactly saturated liquid at the bubble point. The temperatures are given, so the pressures will be computed from this information. The outlet is defined to have a slightly lower temperature than the inlet so that the outlet will have a slightly lower pressure than the inlet. In the event that you wanted superheated steam or subcooled liquid, you would enter the temperature and pressure combination instead of a temperature and vapor pressure combination. Usually, real systems superheat and subcool by a few degrees as a safety margin.

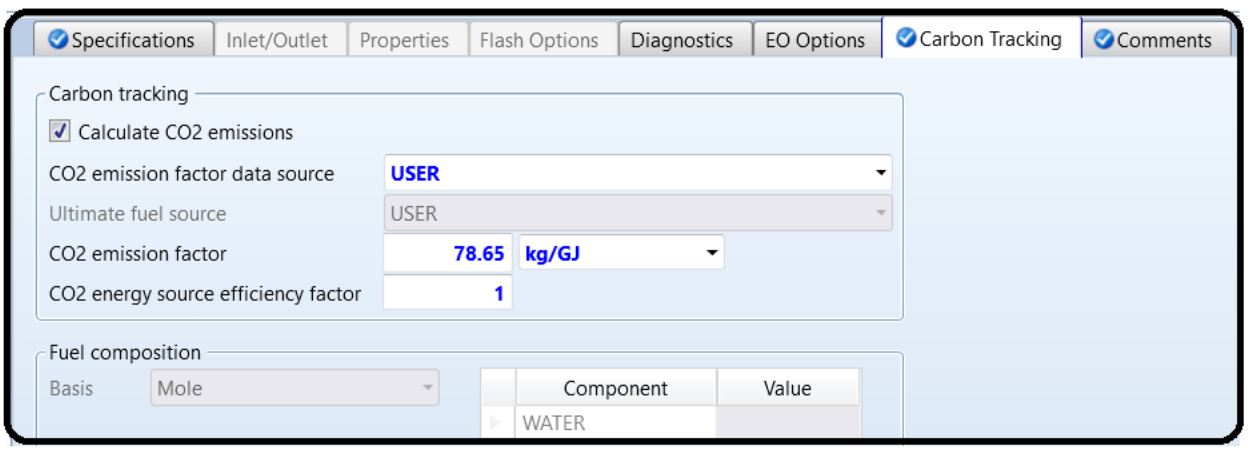
Notice that there is a Carbon Tracking tab. This is a new feature that can help with sustainability analyses. On this tab, you'll see that by default it chose a U.S. Environmental Protection Agency rule for computing the amount of global warming potential (measured in CO_2 equivalents). It also selected natural gas combustion to produce the heat to make the steam, and an efficiency of 85%. Aspen Plus has a default number for the average composition of natural gas and its heat of combustion. It takes the amount of steam duty you need and then divides that by 0.85 to determine the total natural gas combustion duty that is required to produce it (so only 85% of the chemical energy from the natural gas is used to make steam via combustion, the rest is assumed lost as waste heat). Then it assumes that all the carbon atoms in the natural gas end up as CO_2, and then outputs that number. So Aspen Plus computes the *total direct emissions* for this utility, but does not account for the CO_2 that was emitted in order to produce the natural gas and pipeline it across the country and into your plant.

Now, go ahead and add a utility for electricity, using the default. We are going to add our own electric utility that assumes the electric power is produced by a coal power plant with a solvent-based CO_2 capture system on it.





The default electricity setting in Aspen Plusassumes classic power plants with no CO_2 capture, at a rather typical price of about 8 cents per kWh. However, there is a power plant by SaskPower in Saskatchewan, Canada which is the first of its kind to implement CO_2 capture at a meaningful scale from coal, which has about 80% lower emissions per kWh than traditional pulverized coal. Of course, it is more expensive than classic power plants without CO_2 capture. According to the U.S. Department of Energy (document DOE/NETL-2007/1281), we can predict that the prices for this type are higher, at 13.2 cents per kWh (in the United States), after adjusting for inflation. So make the change in the Specifications tab. Similarly, the CO_2 emissions should also be changed since they are much lower. A recent life cycle analysis study[4] determined that the total cradle-to-grave life cycle emissions for a power plant of this new type should be about 78.65 kg of CO_2 equivalent per GJ of electricity. That includes the construction of the power plant, the mining and transport of the coal, the construction and use of the CO_2 capture, pipeline and storage system, and even the electricity transmission losses from connecting the power plant to your plant. So it's a much better number to use than what Aspen Plus has because it includes more of the life cycle. Anyway, enter this number by setting the CO_2 emission data factor source to USER, typing the number into the CO_2 emissions factor box, and setting the efficiency factor to 1.0 since the efficiency factor is already included in the 78.65 kg/GJ number.



Finally, add utilities for medium- and high-pressure steam, and for boiler feedwater (BFW) streams at low, medium, and high pressure,using the defaults in Aspen Plus. Note that the BFW defaults are "Steam Generation" items. They are basically backward versions of the corresponding steam utility and actually make money and "consume" CO_2 instead of costing money because the energy price and CO_2 efficiency is negative. It is an accounting trick. The idea is that it prevents the cost of steam and the emission of CO_2 somewhere else by making it here. Also, note the temperature ranges of these utilities for later. For example, cooling water comes in at 20°C and comes out at 25°C, which is rather generous but we'll go with it. It also has a temperature approach maximum of 5°C by default. That means that for countercurrent flow, the coldest anything can get is 25°C (cold in = 20°C + 5°C = 25°C). If you violate this by assigning the utility where it shouldn't be used (your heat exchanger comes too close to temperature crossover or actually does crossover, as discussed in Tutorial 4), Aspen Plus will throw you an error.[5]

Using Utilities

Ok, let's see how utilities are used in the software. In this example, we are going to separate a 100 kmol/hr mixture of acetone (27 mol%, *T*bp = 56°C), methanol (38 mol%, *T*bp = 65°C), and *n*-butanol (35 mol%, *T*bp = 117°C) at 25°C and 1 bar that we get after a biofuel production process. Acetone and methanol form a low boiling azeotrope at 55°C, so we're going to use pressure swing distillation again (see Tutorial 2).

The process shown in Figure 6.2 can be used, with all of the remaining design parameters given. Simulate this process in Aspen Plus. You should be able to do this, given what you already know. Remember, it is better to get one block working at a time before adding another one, and get all three columns working without recycle first before connecting the final recycle stream. When it is finished, you should be able to get at least 98 mol% purity in each of the three product streams. Assume the distillation columns and their supporting reboilers and condensers are at constant pressure throughout. Use RADFRAC for the distillation columns of course and the NRTL-RK property package. Remember the best practices we learned from earlier tutorials: *change the property package first before adding the chemicals!* (butanol is *n*-butanol). Go back to check and make sure that the binary parameters come from the VLERK database and not the VLE-IG one! Do this by looking at the Source drop-downs of the different chemical pairs under the Input tab of the Properties | Parameters | Binary Interaction | NRTL-1 form.

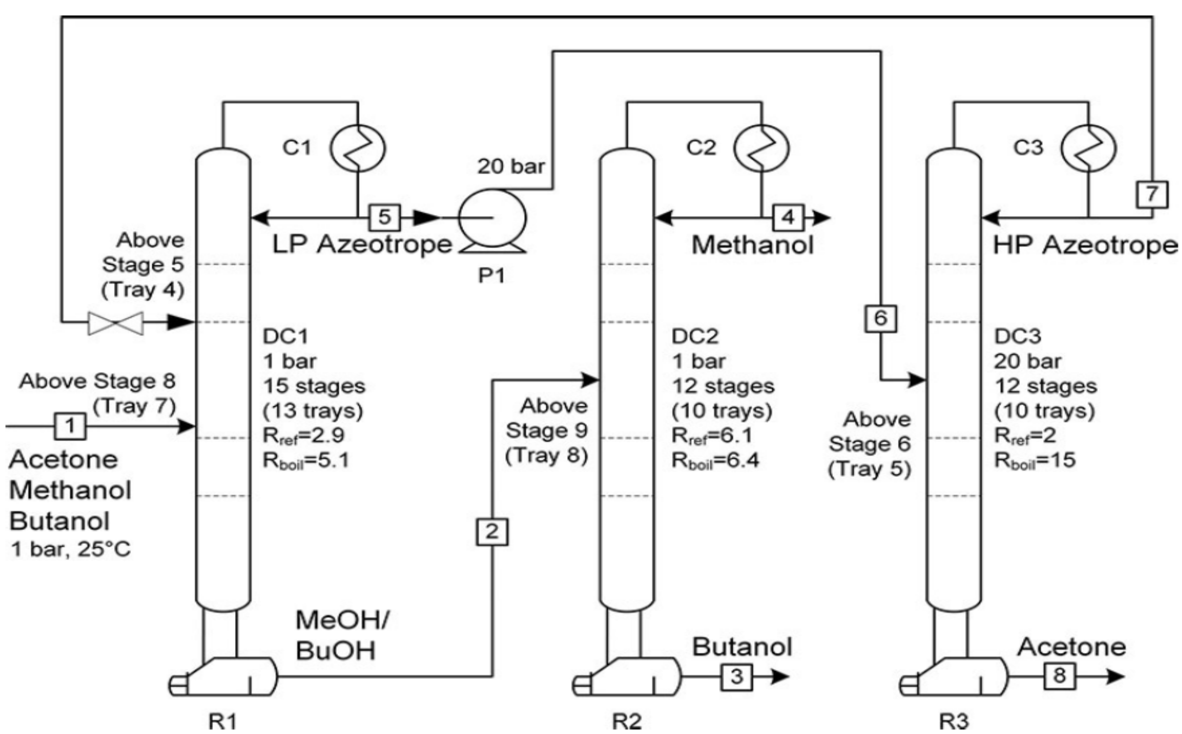


Figure 6.2 A process to separate a mixture of acetone, methanol, and butanol using pressure swing distillation.

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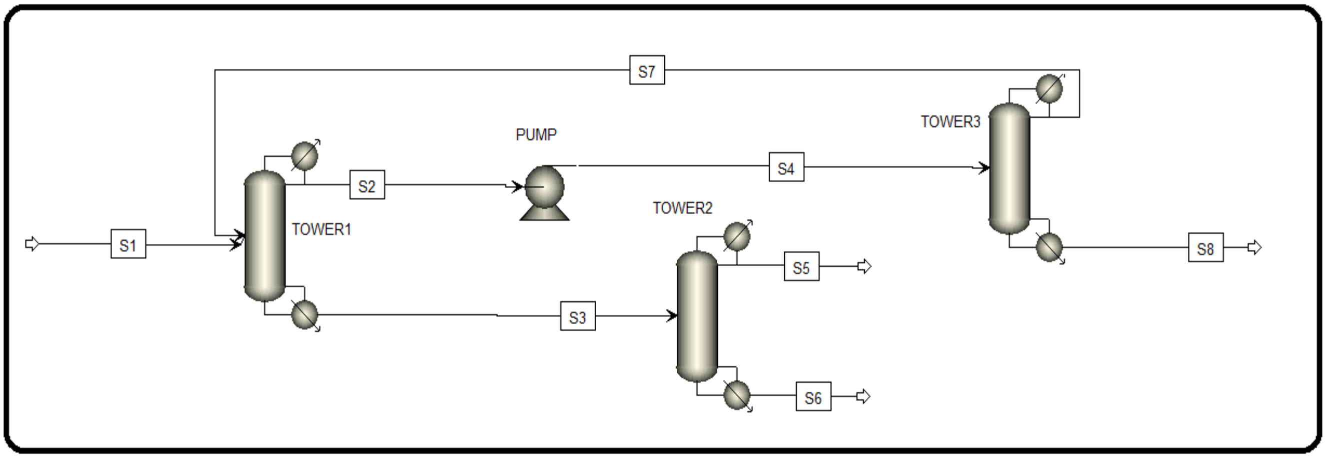
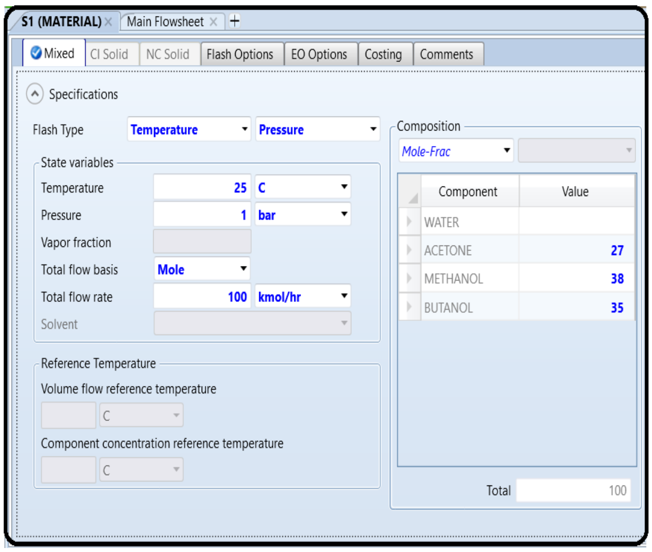
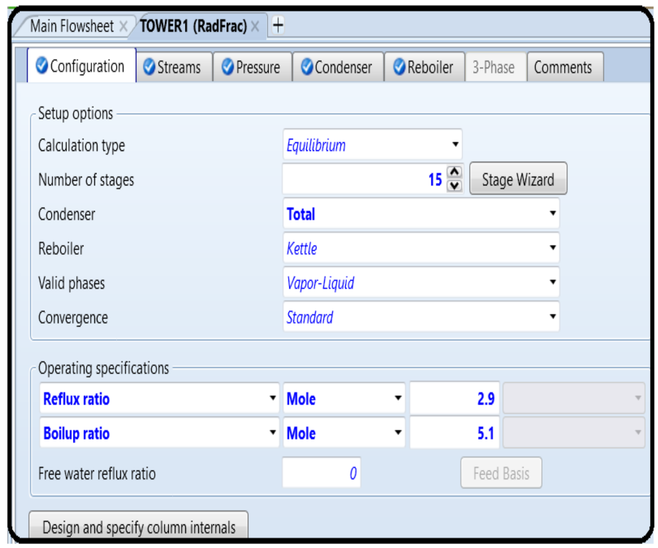
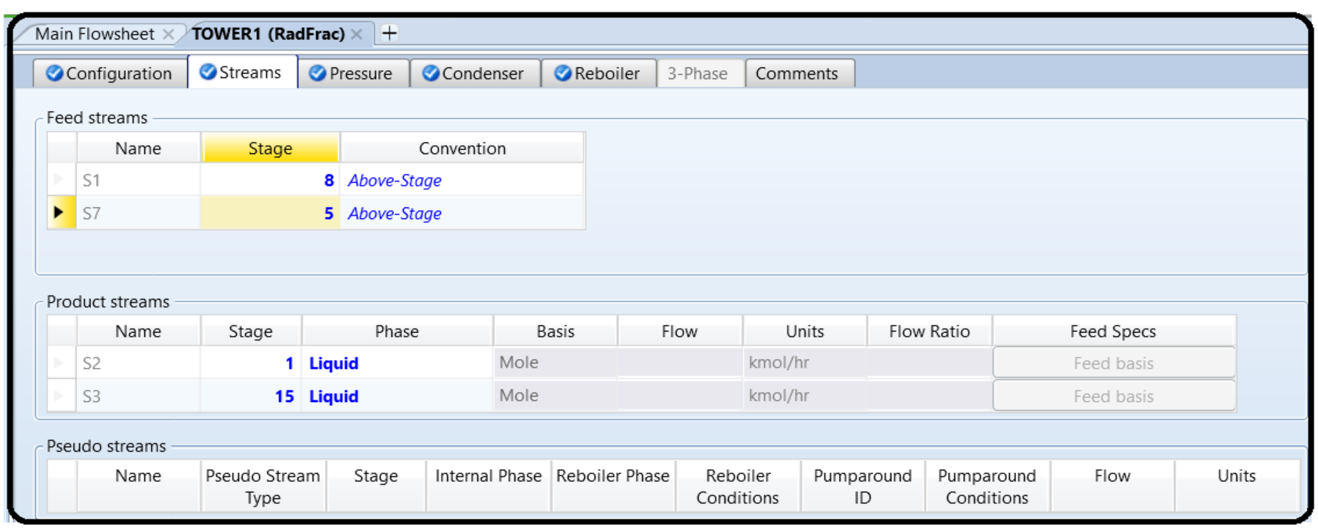
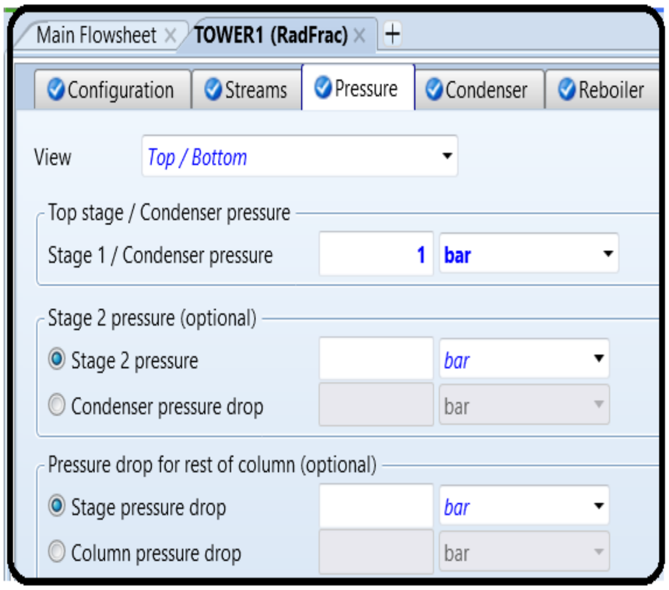
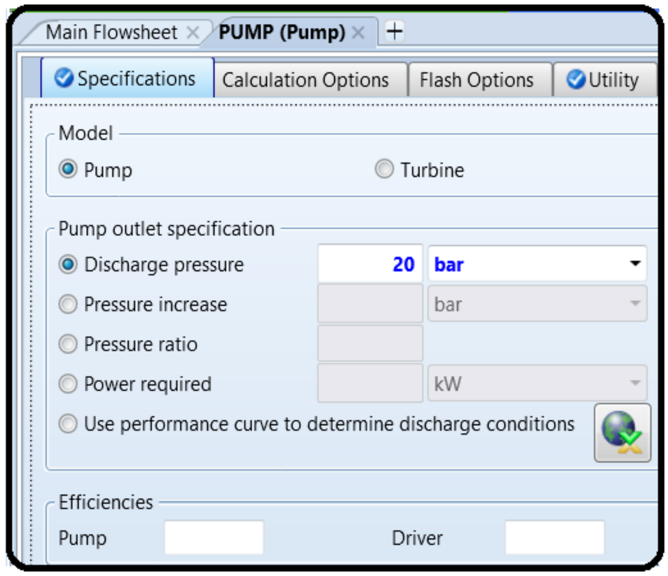

S7
TOWER3
PUMP
S2
S4
TOWER1
TOWER2
S1
S5
S8
S3
S6

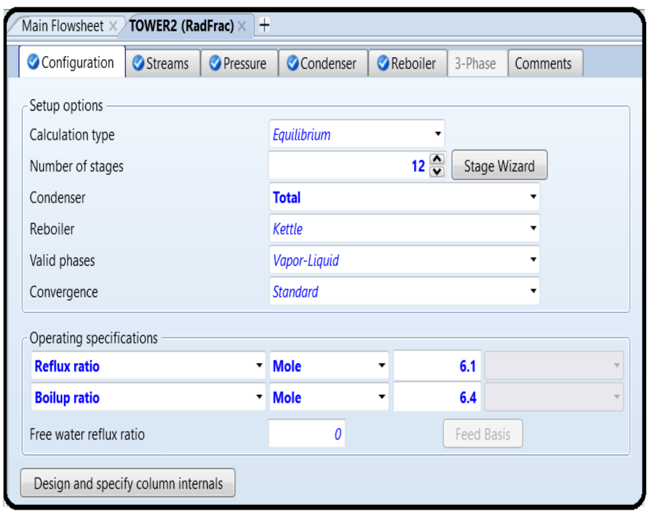

S1 (MATERIAL)
Main Flowsheet
Mixed
CI Solid
NC Solid
Flash Options
EO Options
Costing
Comments
Specifications
Flash Type
Temperature
Pressure
State variables
Temperature 25 C
Pressure 1 bar
Vapor fraction
Total flow basis Mole
Total flow rate 100 kmol/hr
Solvent
Reference Temperature
Volume flow reference temperature
C
Component concentration reference temperature
C
Composition
Mole-Frac
Component Value
WATER
ACETONE 27
METHANOL 38
BUTANOL 35
Total 100

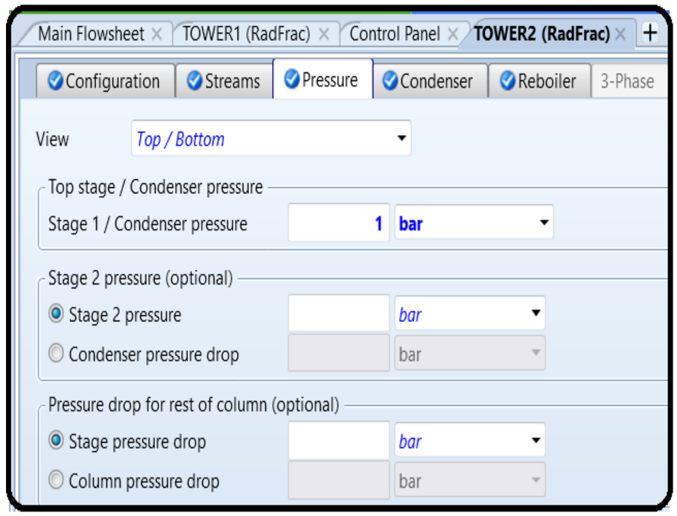

Main Flowsheet
TOWER1 (RadFrac)
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Comments
Setup options
Calculation type Equilibrium
Number of stages 15
Stage Wizard
Condenser Total
Reboiler Kettle
Valid phases Vapor-Liquid
Convergence Standard
Operating specifications
Reflux ratio Mole 2.9
Boilup ratio Mole 5.1
Free water reflux ratio 0
Feed Basis
Design and specify column internals

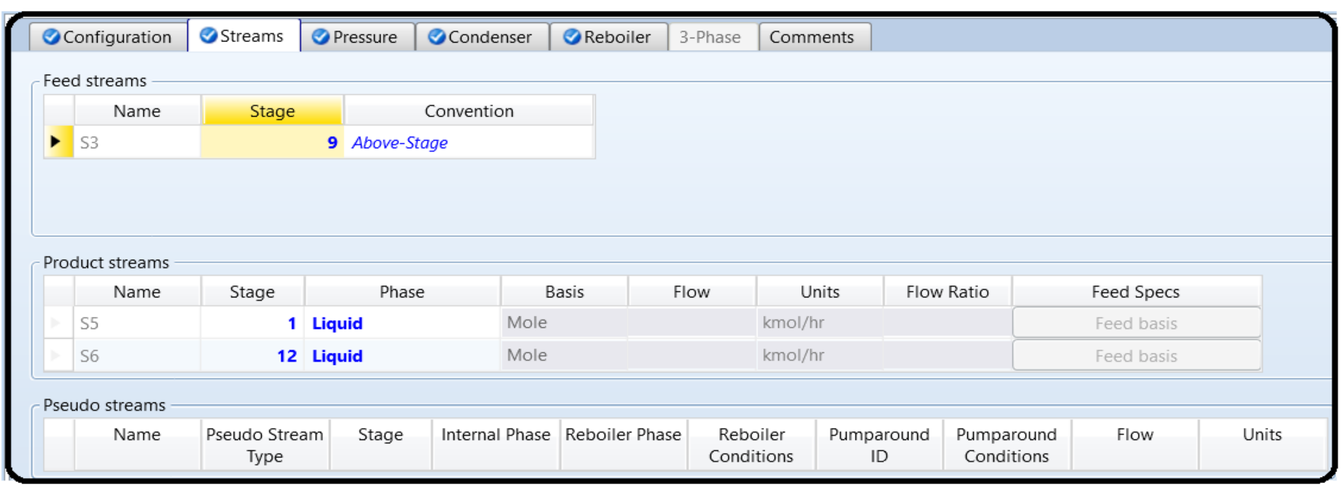

Main Flowsheet
TOWER1 (RadFrac)
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Comments
Feed streams
Name Stage Convention
S1 8 Above-Stage
S7 5 Above-Stage
Product streams
Name Stage Phase Basis Flow Units Flow Ratio Feed Specs
S2 1 Liquid Mole kmol/hr Feed basis
S3 15 Liquid Mole kmol/hr Feed basis
Pseudo streams
Name
Pseudo Stream Type
Stage
Internal Phase
Reboiler Phase
Reboiler Conditions
Pumparound ID
Pumparound Conditions
Flow
Units

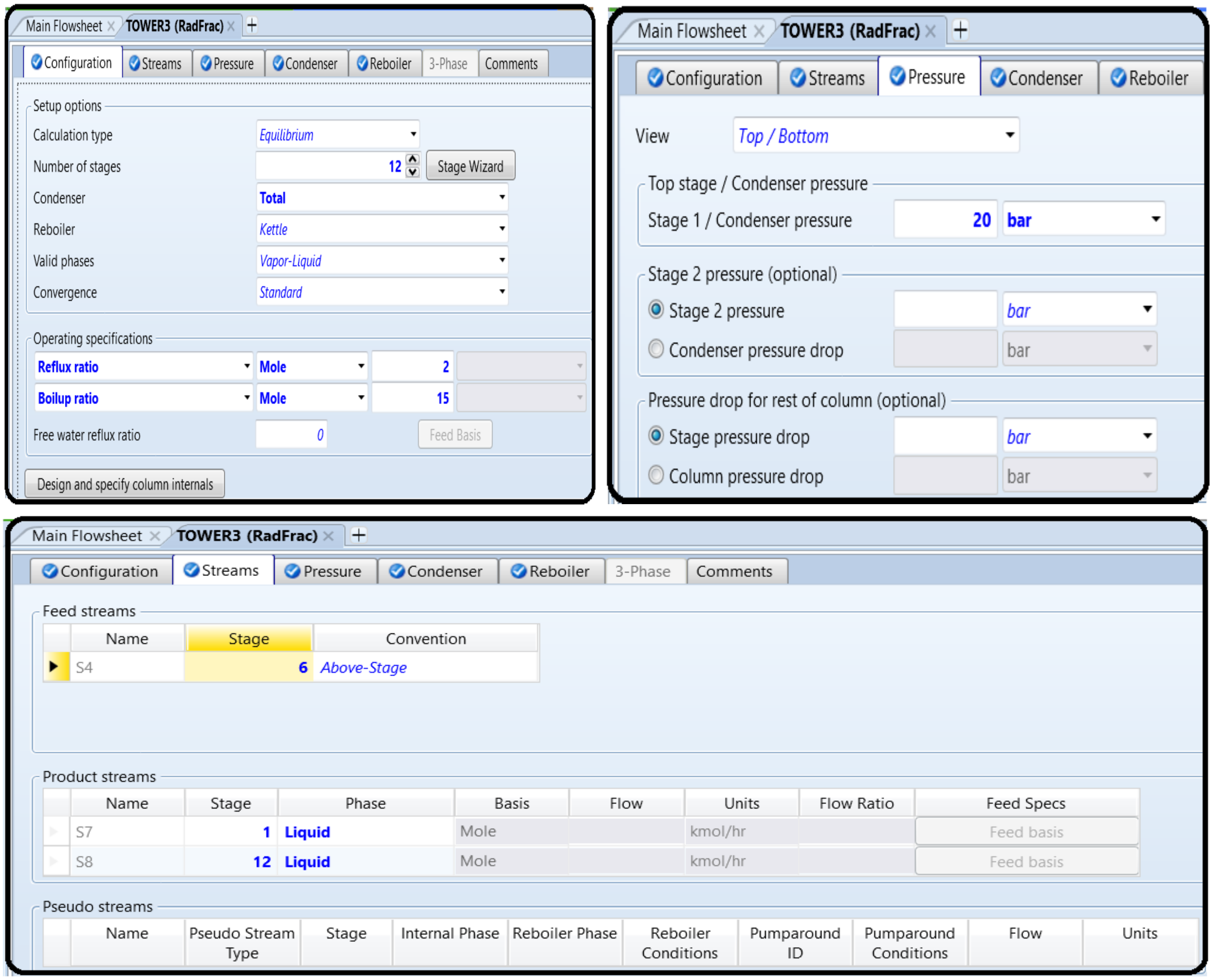

Main Flowsheet
TOWER1 (RadFrac)
Configuration
Streams
Pressure
Condenser
Reboiler
View
Top / Bottom
Top stage / Condenser pressure
Stage 1 / Condenser pressure
1
bar
Stage 2 pressure (optional)
Stage 2 pressure
bar
Condenser pressure drop
bar
Pressure drop for rest of column (optional)
Stage pressure drop
bar
Column pressure drop
bar


Main Flowsheet
PUMP (Pump)
Specifications
Calculation Options
Flash Options
Utility
Model
Pump
Turbine
Pump outlet specification
Discharge pressure
20
bar
Pressure increase
bar
Pressure ratio
Power required
kW
Use performance curve to determine discharge conditions
Efficiencies
Pump
Driver


Main Flowsheet
TOWER2 (RadFrac)
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Comments
Setup options
Calculation type
Equilibrium
Number of stages
12
Stage Wizard
Condenser
Total
Reboiler
Kettle
Valid phases
Vapor-Liquid
Convergence
Standard
Operating specifications
Reflux ratio
Mole
6.1
Boilup ratio
Mole
6.4
Free water reflux ratio
0
Feed Basis
Design and specify column internals


Main Flowsheet
TOWER1 (RadFrac)
Control Panel
TOWER2 (RadFrac)
Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
View
Top / Bottom
Top stage / Condenser pressure
Stage 1 / Condenser pressure
1
bar
Stage 2 pressure (optional)
Stage 2 pressure
bar
Condenser pressure drop
bar
Pressure drop for rest of column (optional)
Stage pressure drop
bar
Column pressure drop
bar

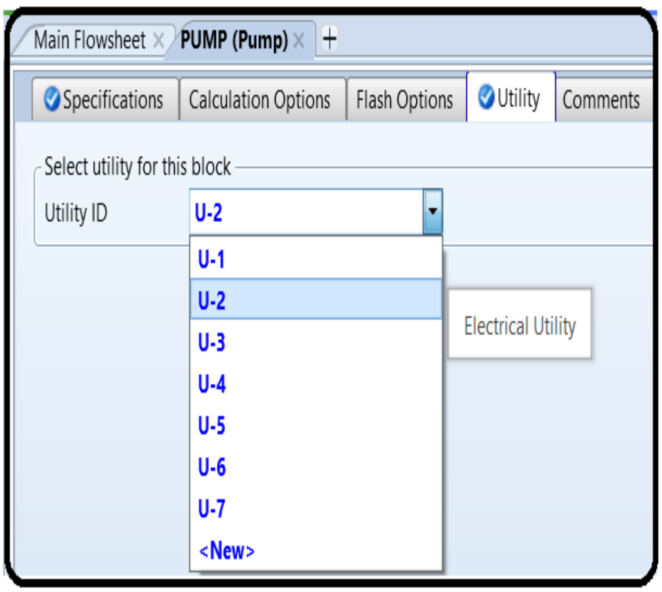

Configuration
Streams
Pressure
Condenser
Reboiler
3-Phase
Comments
Feed streams
Name
Stage
Convention
S3
9
Above-Stage
Product streams
Name
Stage
Phase
Basis
Flow
Units
Flow Ratio
Feed Specs
S5
1
Liquid
Mole
kmol/hr
Feed basis
S6
12
Liquid
Mole
kmol/hr
Feed basis
Pseudo streams
Name
Pseudo Stream Type
Stage
Internal Phase
Reboiler Phase
Reboiler Conditions
Pumparound ID
Pumparound Conditions
Flow
Units

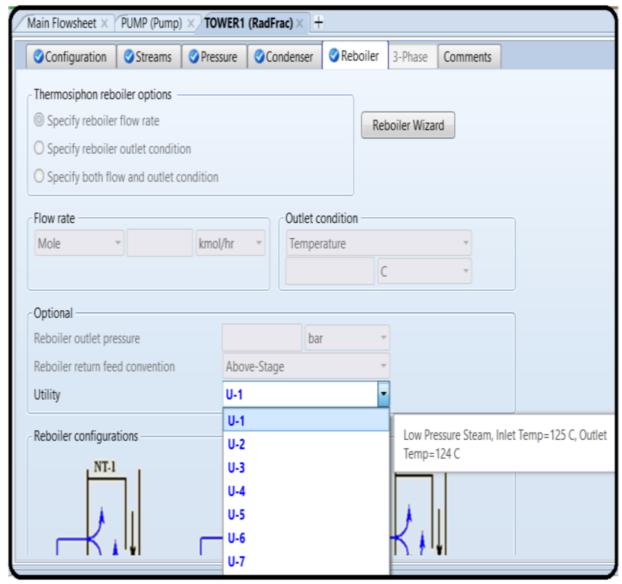


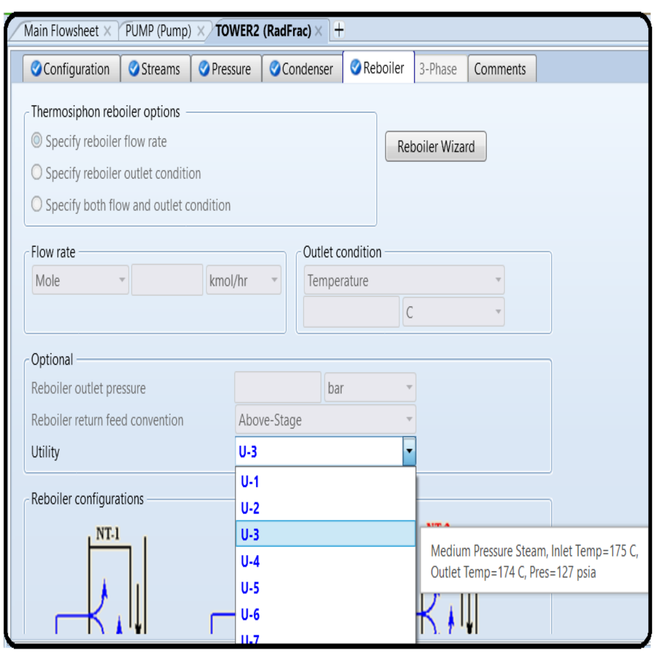
Ok, let's go back and assign utilities to the process units. Each block has a different way of doing this. For example, in the Pump, there is a Utility tab, where you select which of the utilities that you created to be used with it (see Figure 6.3). In the RADFRAC blocks, you can find the utility specification in the Condenser (see Figure 6.4) and Reboiler tabs (Figure 6.5), respectively, at the bottom.

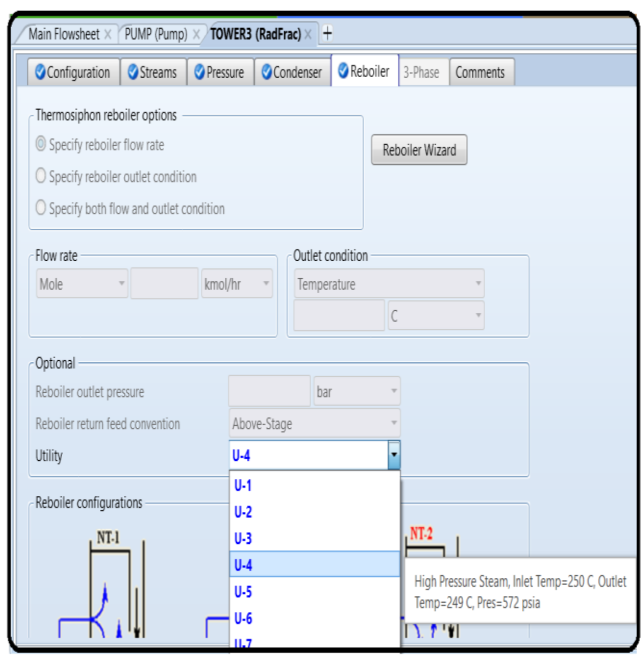
Go through and choose the correct utilities for each. You can use your simulation results to help you select. Remember not to violate the second law of thermodynamics! Remember, use BFW for cooling whenever you can because you'll generate steam instead of paying for cooling! Rerun the simulation. You can check the utility results in the block's results form, in the Utility tab or similarly named. Note: When selecting utilities, you generally want to choose the cheapest utility that does the job. Suppose for example, you need to deliver 1.2 GJ/hr of heat to a stream that you want to heat up to 150°C. Your choices may include LPS (available at 125°C), MPS (175°C), HPS (250°C), and Fired Heat (e.g., inside a furnace with a minimum of 400°C). In this case, you cannot use LPS because it is not hot enough, so rule that out. MPS will work because it is 25°C hotter than your maximum needed heating temperature, which is well above the 5–10°C approach temperature we often assume (see Tutorial 4 for more about approach temperatures). HPS and Fired Heat are even hotter and can also be used, but they are more expensive per GJ. (The default in Aspen Plus for HPS is $2.5/GJ but MPS is only $2.2/GJ.) So we select MPS because it is cheaper, with a total cost of $2.64/hr.

Note: Although Aspen Plus lets you select Electricity as the utility for almost any heat exchanger, this is very rarely the actual utility used in practice. Electric heaters (e.g., using resistors or actually shocking the target directly) are usually special cases only.

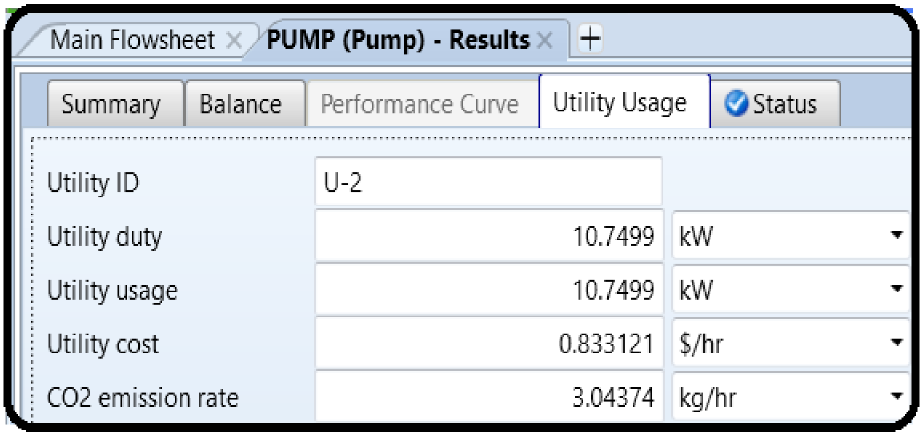


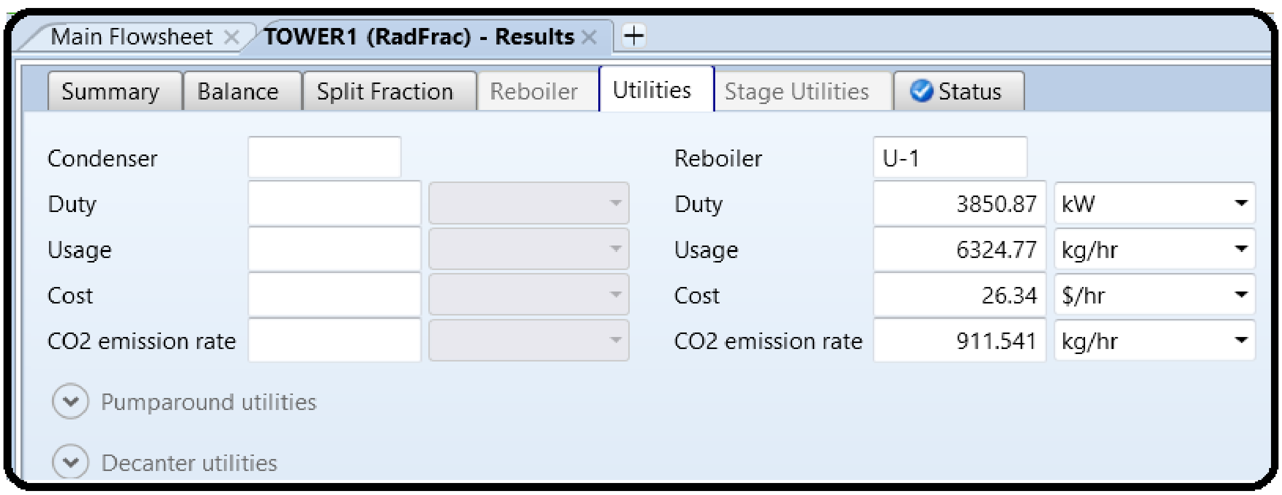


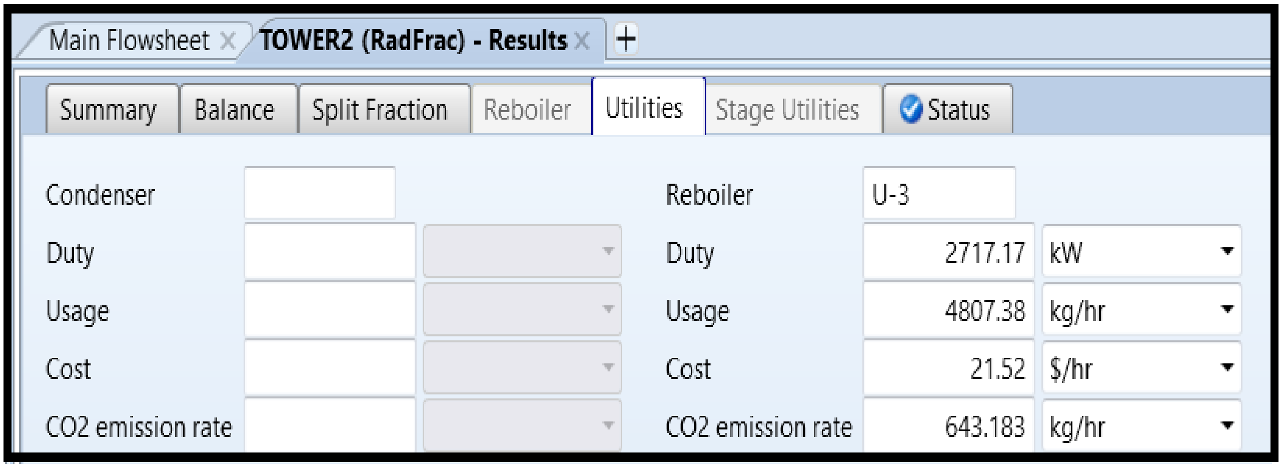




Results


Main Flowsheet
PUMP (Pump) - Results
Summary
Balance
Performance Curve
Utility Usage
Status
Utility ID
U-2
Utility duty
10.7499
kW
Utility usage
10.7499
kW
Utility cost
0.833121
$/hr
CO2 emission rate
3.04374
kg/hr


Main Flowsheet
TOWER1 (RadFrac) - Results
Summary
Balance
Split Fraction
Reboiler
Utilities
Stage Utilities
Status
Condenser
Duty
Usage
Cost
CO2 emission rate
Reboiler
U-1
Duty
3850.87
kW
Usage
6324.77
kg/hr
Cost
26.34
$/hr
CO2 emission rate
911.541
kg/hr
Pumparound utilities
Decanter utilities


Main Flowsheet
TOWER2 (RadFrac) - Results
Summary
Balance
Split Fraction
Reboiler
Utilities
Stage Utilities
Status
Condenser
Duty
Usage
Cost
CO2 emission rate
Reboiler
U-3
Duty
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kW
Usage
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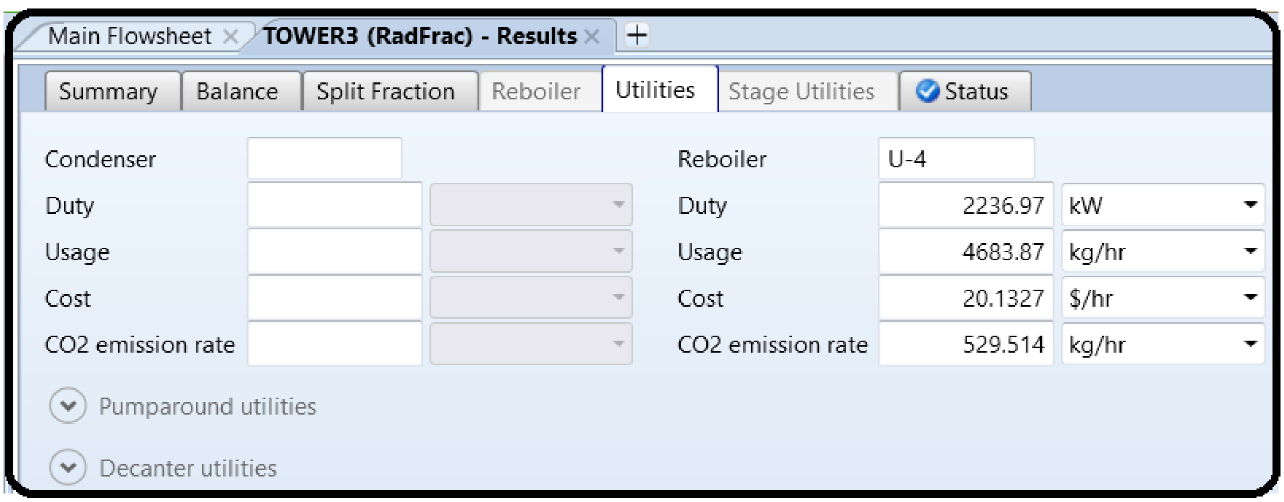
kg/hr
Cost
21.52
$/hr
CO2 emission rate
643.183
kg/hr


Main Flowsheet
TOWER3 (RadFrac) - Results
Summary
Balance
Split Fraction
Reboiler
Utilities
Stage Utilities
Status
Condenser
Duty
Usage
Cost
CO2 emission rate
Reboiler
U-4
Duty
2236.97
kW
Usage
4683.87
kg/hr
Cost
20.1327
$/hr
CO2 emission rate
529.514
kg/hr
Pumparound utilities
Decanter utilities