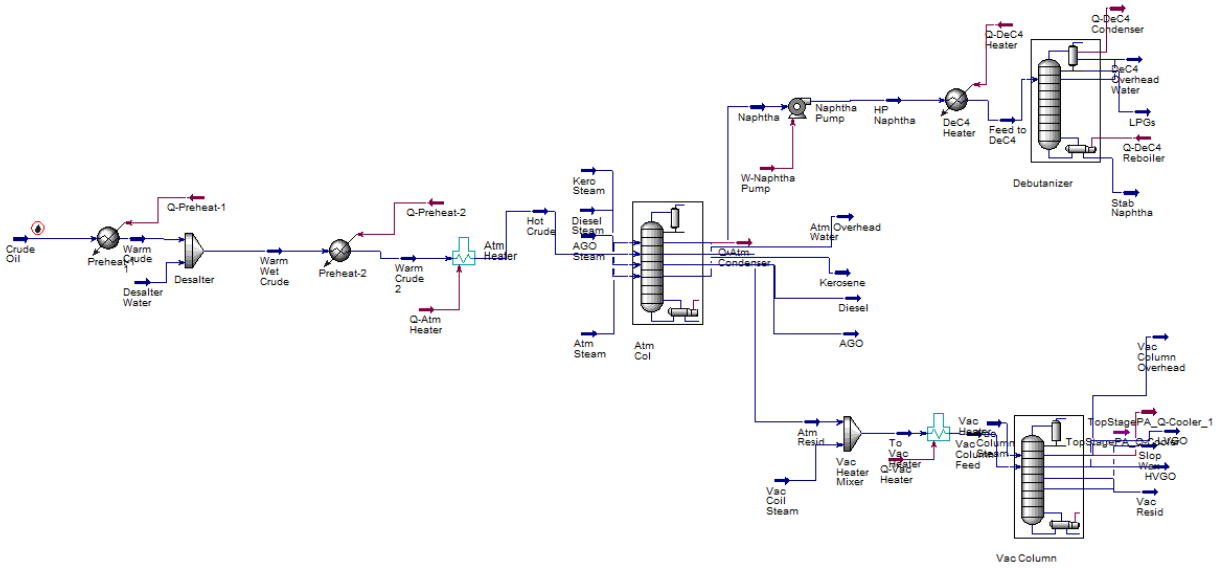
Crude Tower Simulation – HYSYS v10

Steps to set up a simulation in HYSYS v10 to model a crude tower system consisting of:

- Crude Oil Preheat Train
- Atmospheric Crude Tower
- Vacuum Crude Tower
- Debutanizer to stabilize the overhead naphtha stream from the Atmospheric Crude Tower

The feedstock to the crude system will be an equal mix of Light, Medium, & Heavy Crude oils.

When the simulation is set up the overall PFD should look like the following figure.



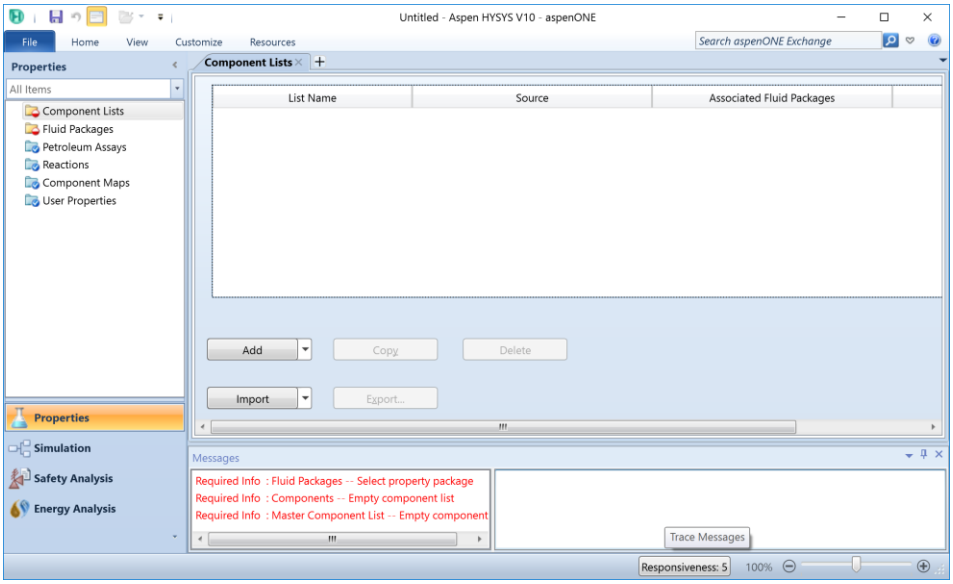
The steps to set up this simulation in previous versions of HYSYS (back to v8.6) are essentially the same, though some of the screen options may be slightly different.

Create new simulation file

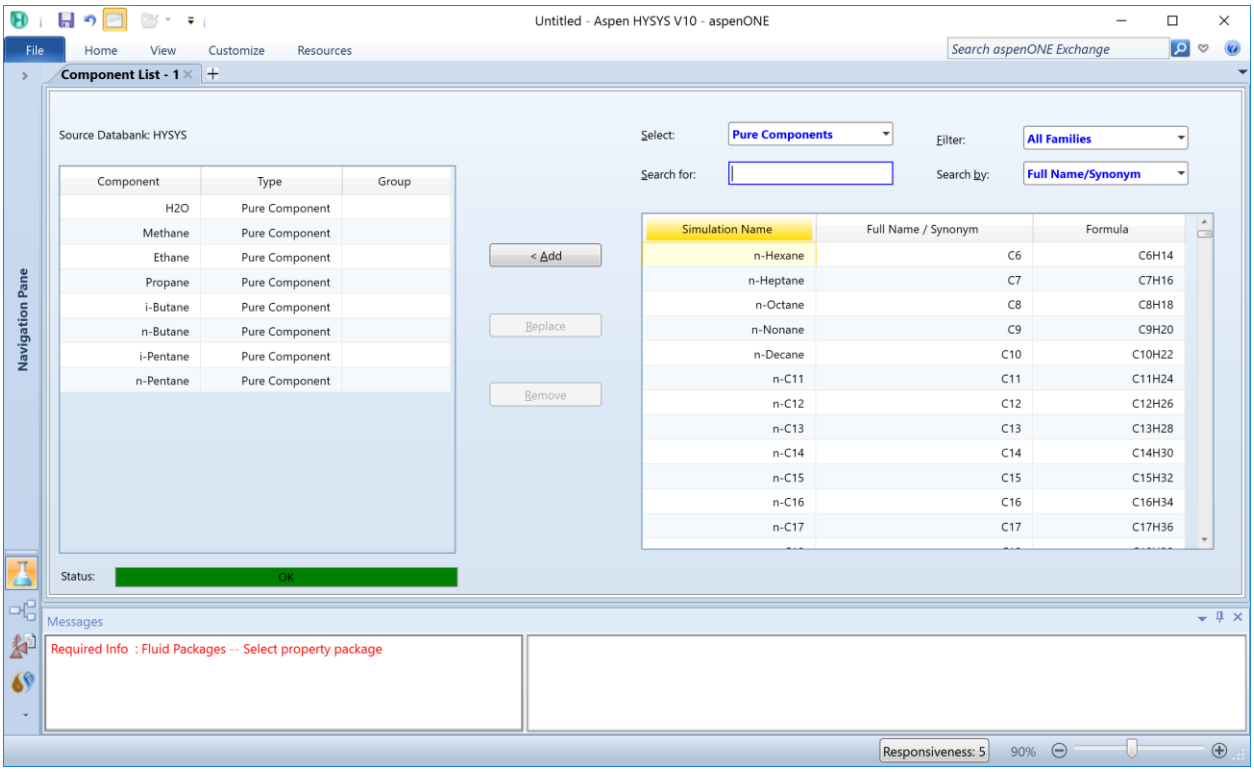
When running under Windows 10 you can start the program from *Start*, the all programs list, *Aspen HYSYS*, *Aspen HYSYS V10*. When the program opens choose the *New* button.

Define the Components & the Property Models

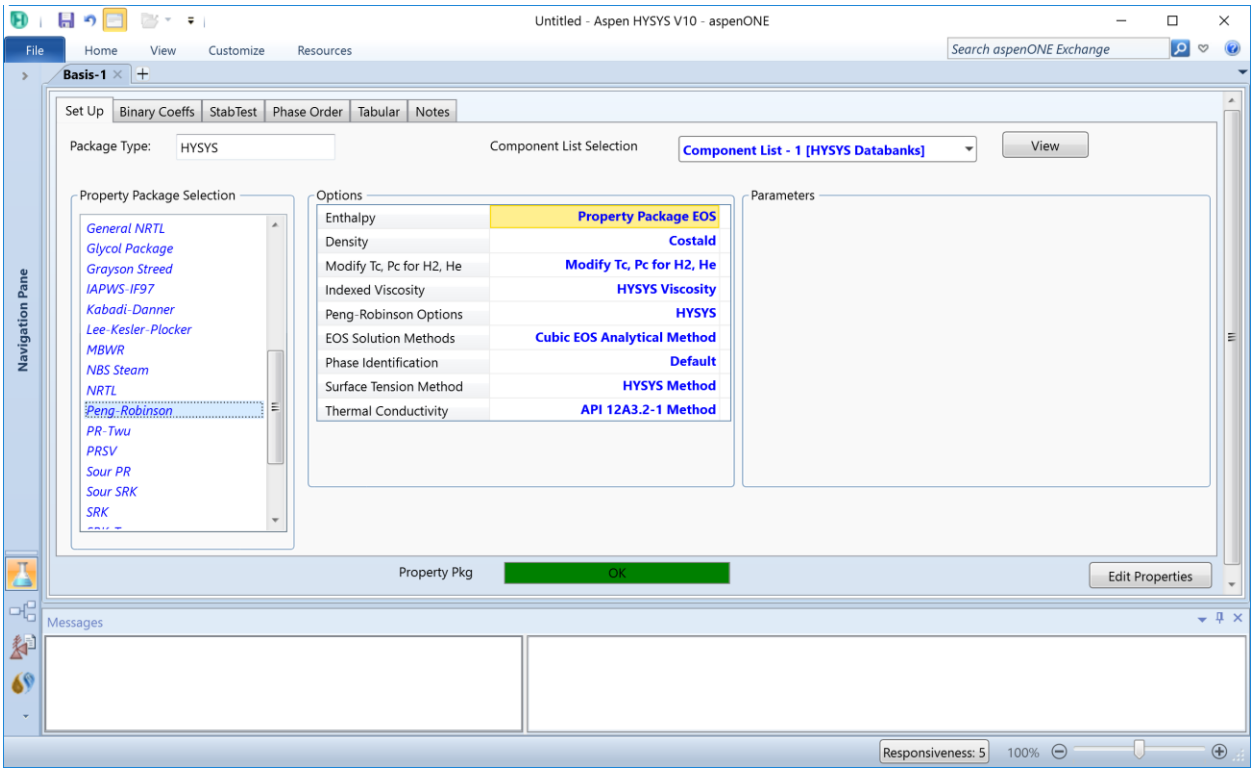
Specify components, fluid property packages, & crude oil assays



The first step is to add a set of pure chemical species to represent the light components of the crude oils. With *Component Lists* highlighted click on the *Add* button. From the list of pure components pick water, methane, ethane, propane, i-butane, n-butane, i-pentane, & n-pentane. Note that you can pick a single component at a time or highlight components & add at the same time. You can also reorder the components in the list & drag to a new position.



The next step is to pick a fluid property package. From the *Fluid Packages* screen click the *Add* button. Choose the *Peng-Robinson* option and make sure it is associated with *Component List – 1*.



We now want to add assay data for the three crude oils: Light Crude, Medium Crude, & Heavy Crude. The data to be added is shown in the following tables.

Table 1. Assay Data for Light Crude

Light Crude							
		Cumulative Yield [wt%]		Density	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3[1]	wt%		[wt%]
Whole Crude				53.27	1.77	Ethane	0.000
31	160	0	2.5	42.75	0.019	Propane	0.146
160	236	5	7.5	45.40	0.031	i-Butane	0.127
236	347	10	15	48.33	0.060	n-Butane	0.702
347	446	20	25	50.46	0.379	i-Pentane	0.654
446	545	30	35	52.38	1.064	n-Pentane	1.297
545	649	40	45	54.18	1.698		
649	758	50	55	56.04	2.159		
758	876	60	65	57.92	2.554		
876	1015	70	75	60.05	3.041		
1015	1205	80	85	62.84	3.838		
1205	1350	90	92.5	64.92	4.503		
1350	FBP	95	97.5	70.64	6.382		

[1] Note that HYSYS uses a water density to convert to specific gravity of 62.3024 lb/ft^3 =8.32862 lb/gal = 997.989 kg/m^3.

Table 2. Assay Data for Medium Crude

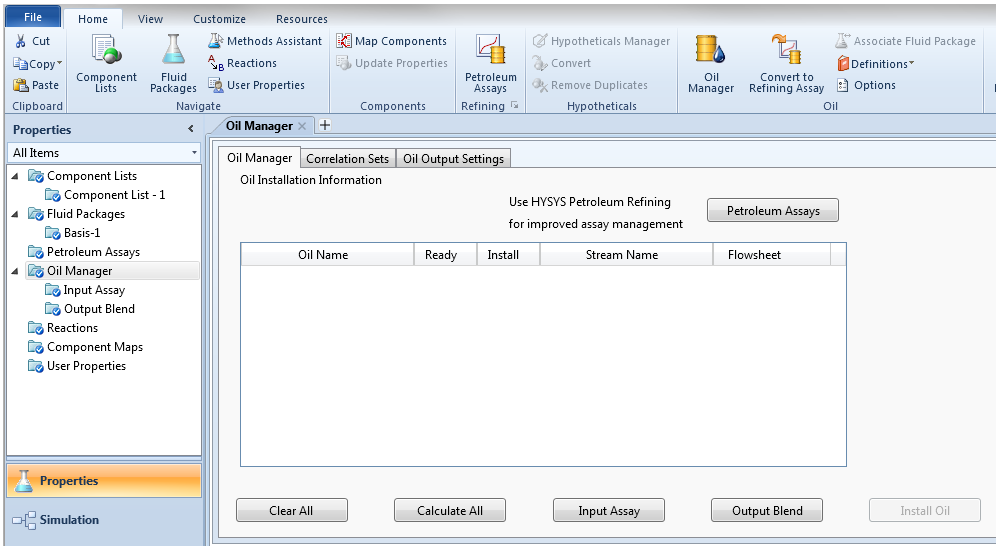
Medium Crude							
		Cumulative Yield [wt%]		Density	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3	wt%		[wt%]
Whole Crude				55.00	2.83	Ethane	0.000
88	180	0	2.5	43.47	0.022	Propane	0.030
180	267	5	7.5	47.14	0.062	i-Butane	0.089
267	395	10	15	49.42	0.297	n-Butane	0.216
395	504	20	25	51.83	1.010	i-Pentane	0.403
504	611	30	35	54.08	2.084	n-Pentane	0.876
611	721	40	45	55.90	2.777		
721	840	50	55	57.73	3.284		
840	974	60	65	59.77	3.857		
974	1131	70	75	62.30	4.706		
1131	1328	80	85	65.74	5.967		
1328	1461	90	92.5	68.08	6.865		
1461	FBP	95	97.5	73.28	8.859		

Table 3. Assay Data for Heavy Crude

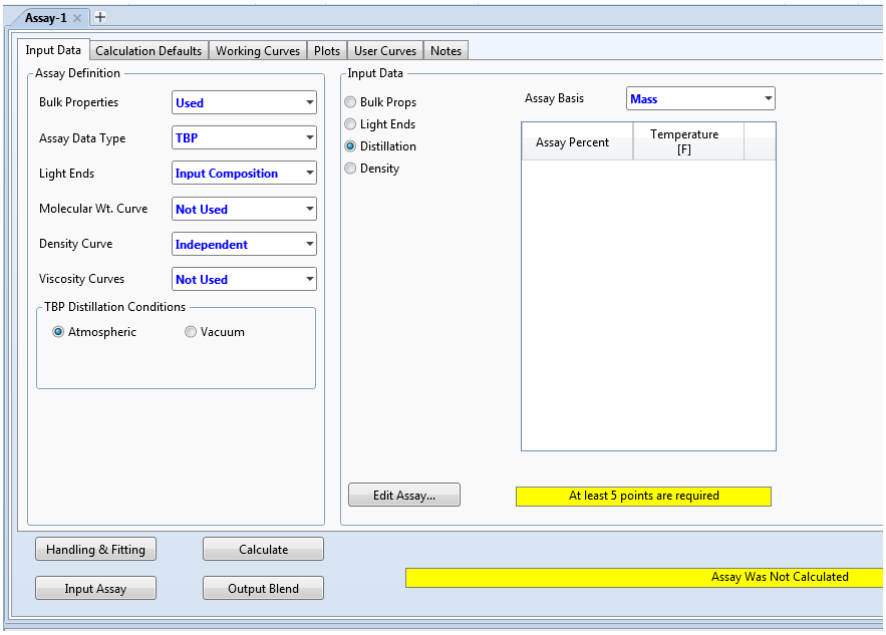
Heavy Crude							
		Cumulative Yield [wt%]		Density	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3	wt%		[wt%]
Whole Crude				55.20	2.8	Ethane	0.039
27	154	0	2.5	42.92	0.005	Propane	0.284
154	255	5	7.5	45.75	0.041	i-Butane	0.216
255	400	10	15	49.44	0.341	n-Butane	0.637
400	523	20	25	52.23	1.076	i-Pentane	0.696
523	645	30	35	54.49	1.898	n-Pentane	1.245
645	770	40	45	56.62	2.557		
770	902	50	55	58.77	3.185		
902	1044	60	65	61.09	3.916		
1044	1198	70	75	63.61	4.826		
1198	1381	80	85	66.63	5.990		
1381	1500	90	92.5	68.71	6.775		
1500	FBP	95	97.5	73.10	8.432		

The following steps show how to enter the data for Light Crude. Similar steps should be used for the other crude oils. The steps will be shown using the *Oil Manager*[2].

- Click on the *Oil Manager* button in the *Home* tab. You will have the options to install individual crude oil assays & then create a blend of the assays.

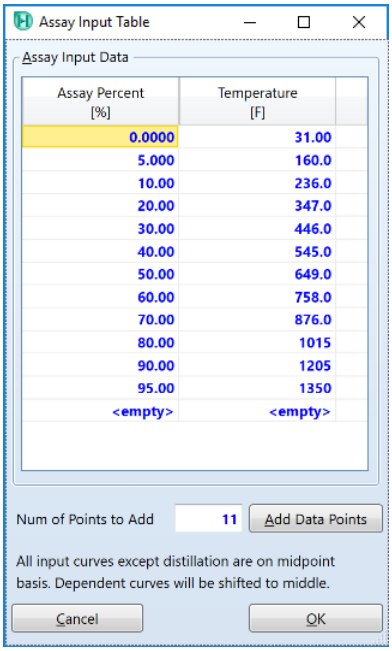


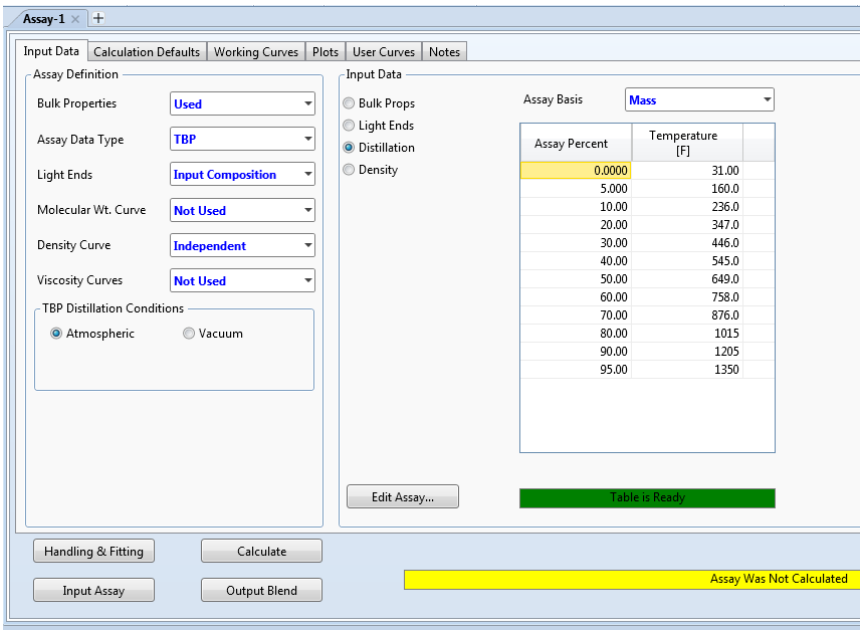
- Click on the *Input Assay* button & then the *Add* button. In the *Assay Definition* section we want to use *Bulk Properties*, specify a TBP *Assay Data Type*, input compositions for the *Light Ends*, and input an independent *Density Curve*. Ensure the *Assay Basis* is Mass. When all of these are specified the Input Data should look like below.



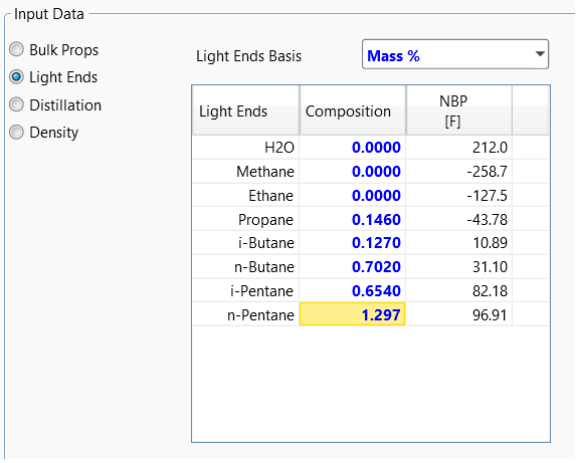
[2] Though the Assay Manager is more powerful it requires a special license which may not be available to you at your location.

- Let's input the TBP curve on a wt% basis for Light Crude. Click on the *Edit Assay…* button. Since we will be entering 12 data points enter 11 for the *Num of Points to Add* & click the *Add Data Points* button (since 1 is already showing). Now the table of Cumulative wt% Yield values (scaled 0 to 100) vs. temperatures (in °F) can be entered. Click *OK*

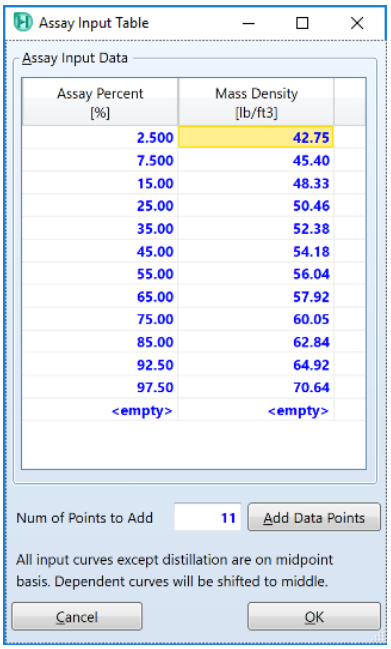


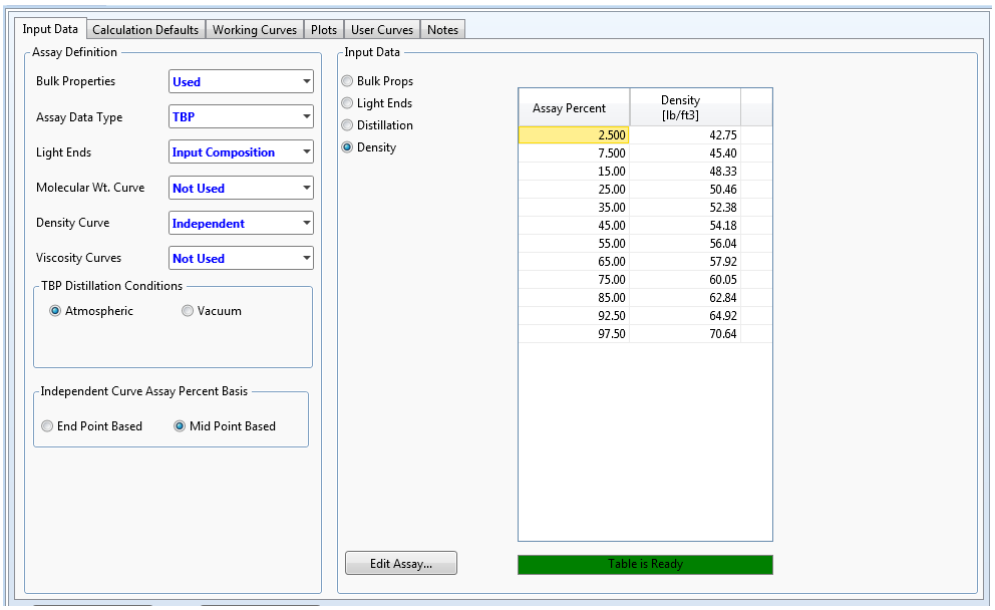


- Now we'll add in the composition of the light ends. Make the *Light Ends* option active & the form will change to allow you to enter the compositions (based on the component list previously specified). Make sure you change the *Light Ends Basis* to Mass%.

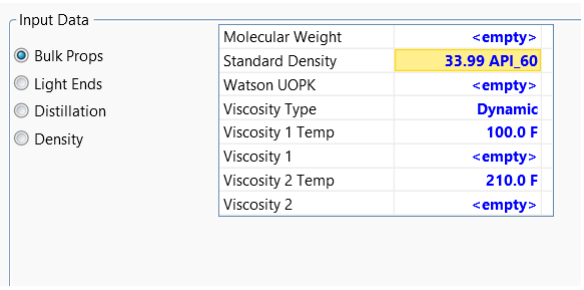


- Now we'll add in the density data. Make the *Density* option active & the form will change to show you the density vs. yield data entered. Click on the *Edit Assay…* button. Since we will be entering 12 data points enter 11 for the *Num of Points to Add* & click the *Add Data Points* button (since 1 is already showing). Now the table of Cumulative wt% Yield values at the middle of the cut (scaled 0 to 100) vs. standard liquid density values (in lb/ft^3) can be entered. Click *OK*. Note that even though the standard liquid density might be in the crude oil assay in other forms (such as specific gravity of API gravity) HYSYS will request the information in a specific form & it cannot be changed on this form.

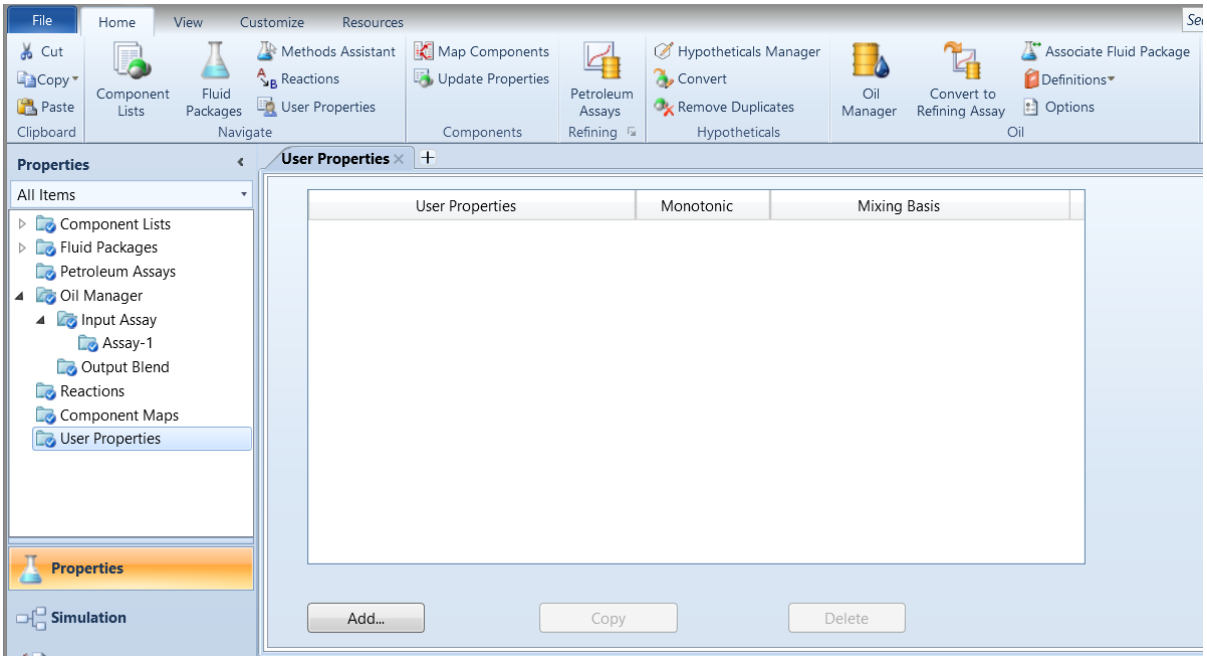




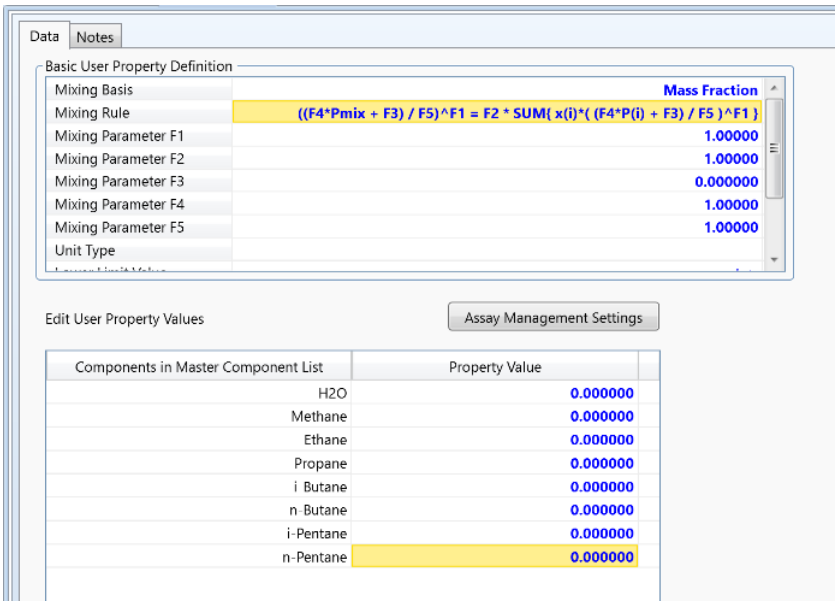
- Let's finish adding in the data needed to characterize the assay and allow HYSYS to create pseudo components. Make the *Bulk Props* option active & the form will change to allow you to enter the data. The only information we have to add is the standard liquid density for the whole crude. Enter this value in the *Standard Density* field. Note that other units can be used on this form. Further note that whatever units are used for the data entry HYSYS will convert the value to the units the form is expecting (in this case API gravity).



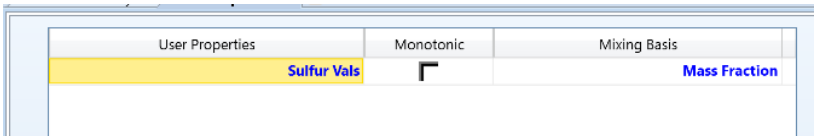
- Even though we can now characterize the pseudo components for the flash calculations we still need to add the sulfur distribution so that this can be tracked. First we'll have to define a User Property that represents the sulfur content. Click on *User Properties* either from the tree structure in the left-hand column or the appropriate button under the *Home* tab. When the User Properties form comes up press the *Add…* button.



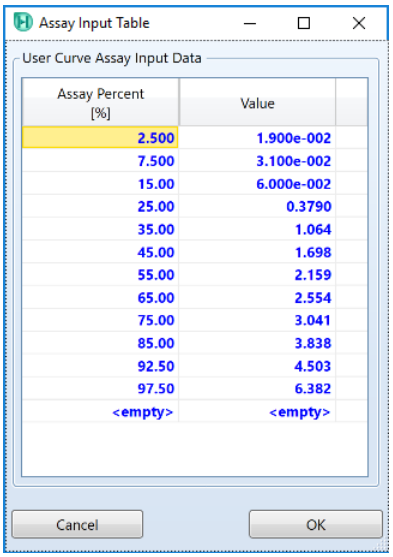
On the *UserProp-1* form choose the *Mass Fraction* option & leave the *F1* through *F5* mixing parameters to the default 1 & 0 values. (These will give an untranslated mas fration mixing of the pure & pseudo component values.) Set the values for the pure components as zeroes.

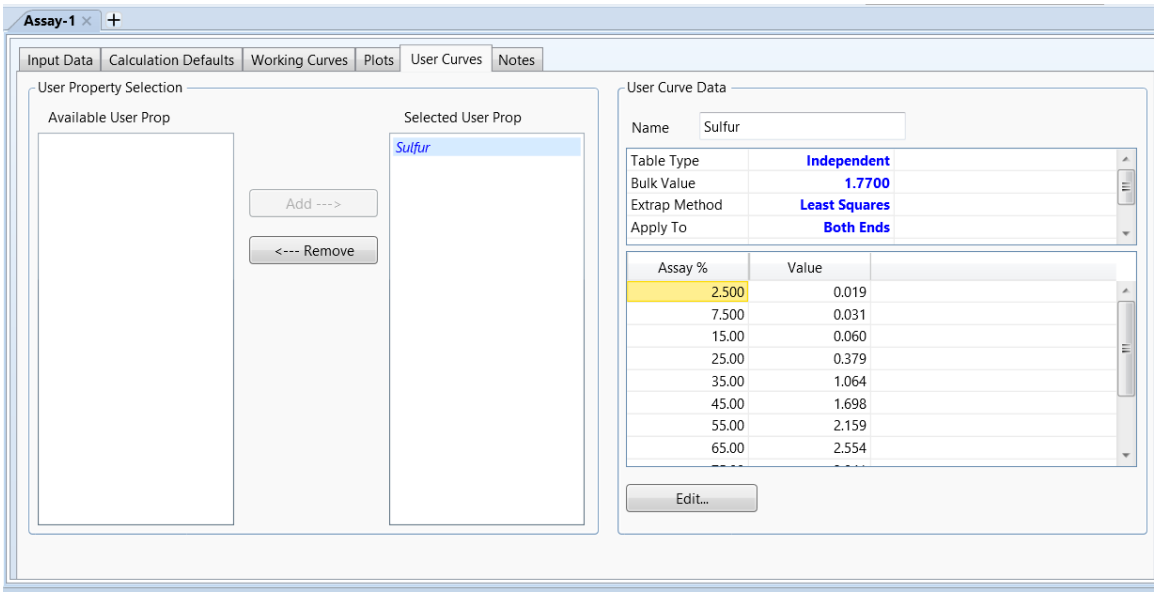


Let's make the label for this property more meaningful. Return to the *User Properties* tab and single click the *UserProp-1* label. Now type in "*Sulfur Vals*".

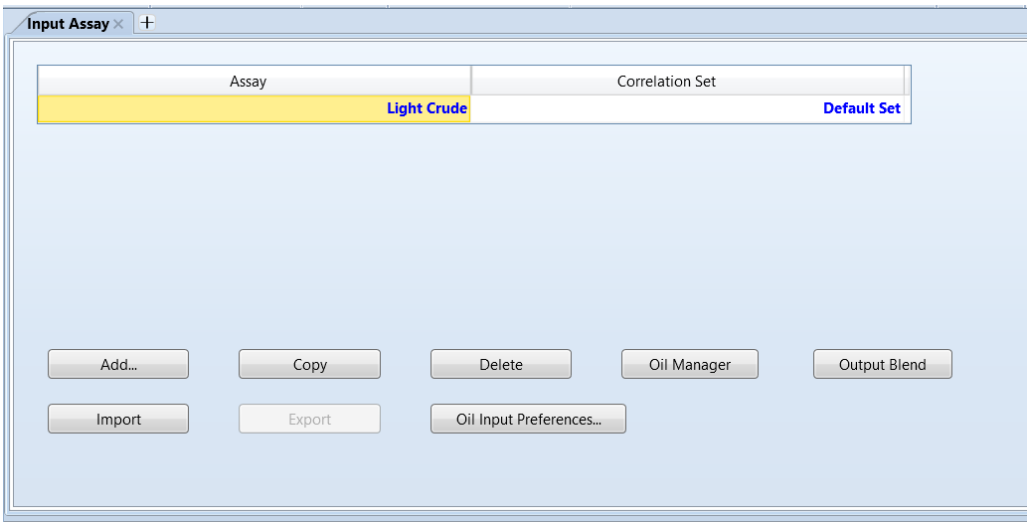


Now we can add the sulfur distribution for the assay. Click on *Assay-1* in the tree structure in the left-hand column & choose the *User Curves* tab. Highlight *Sulfur Vals* in the *Available Properties* column & press *Add--->*. Under the *User Curve Data* area retain the *Independent* setting for the *Table Type*, enter the whole crude value for the *Bulk Value*, and set the lower and upper limits to 0 and 100 (scroll down the list to find these properties). Press the *Edit...* button at the bottom of the form to enter the assay values. Press *OK*.





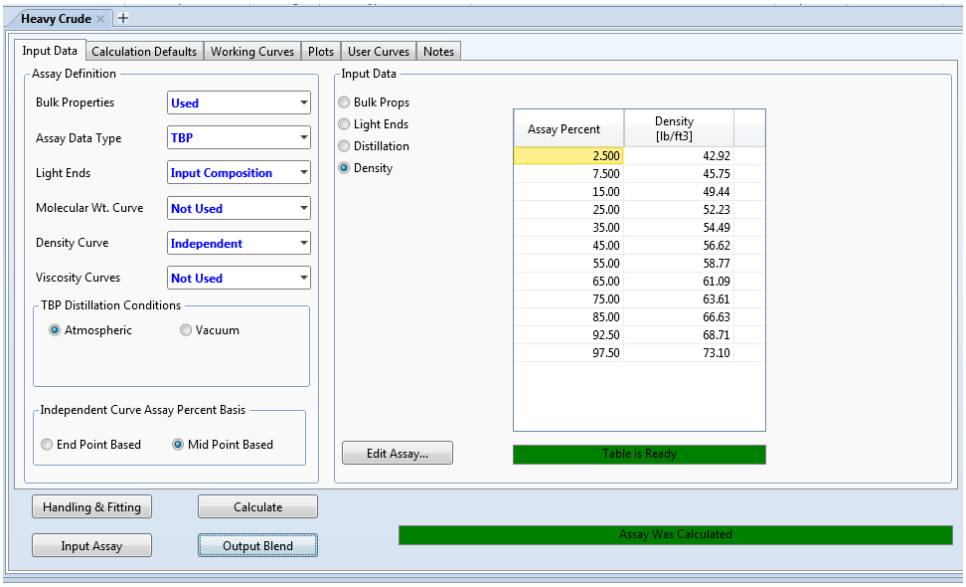
- One more thing to clean up for the assay, changing its name. Click on *Input Assay* in the tree structure of the left-hand column. In the *Input Assay* form single click *Assay-1* & type *Light Crude*.



Repeat the steps for the Medium & Heavy Crudes.

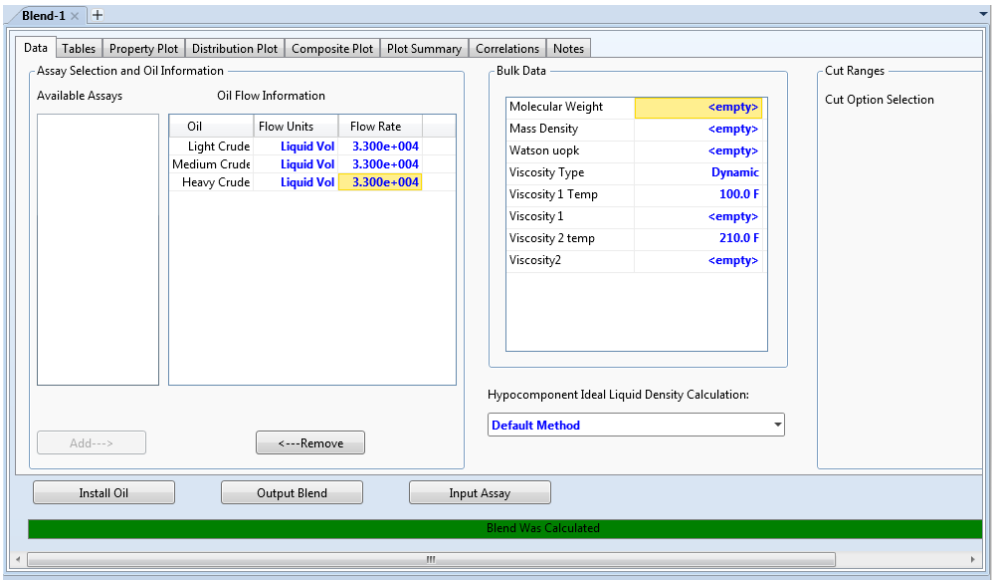
Do characterization calculations, specify crude oil blend, & install into flowsheet

After entering the assay we have to tell HYSYS to perform the characterization calculations. Select each crude oil in the tree structure of the left-hand column & click on the *Calculate* button if there is a warning that the assay has not been calculated. When properly calculated there should be a message in green.

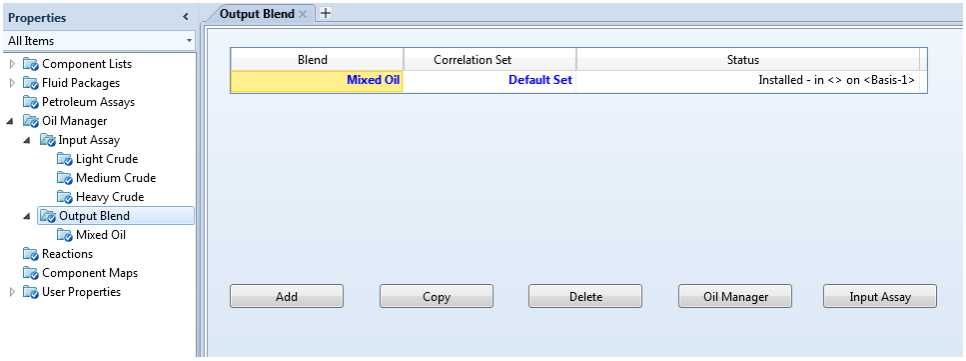


Now we'll create a blend of the three crudes and use that as our feedstock in the simulation. Select *Output Blend* in the tree structure of the left-hand column. On the *Output Blend* tab select the *Add* button. On the *Blend-1* tab select the crudes & press *Add--->*. Accept the *Liquid Vol* option for the *Flow Units*. Enter three equal flow units under *Flow Rate*, such as 33 kbpd (thousands of barrels per day).

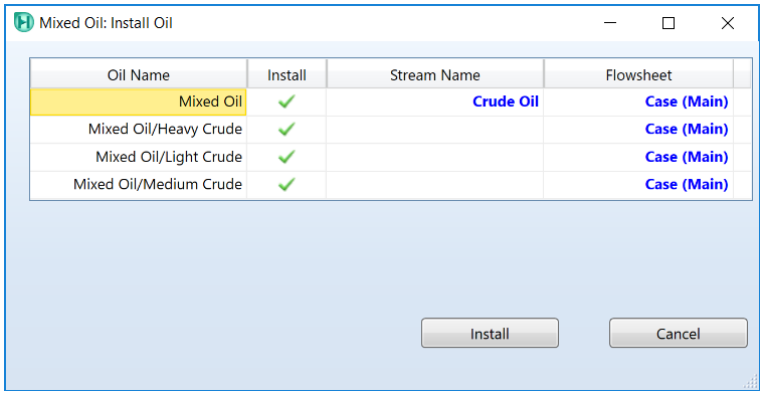
If all of the crude oils have been characterized previous to this then you should receive a *Blend Was Calculated* message in green.



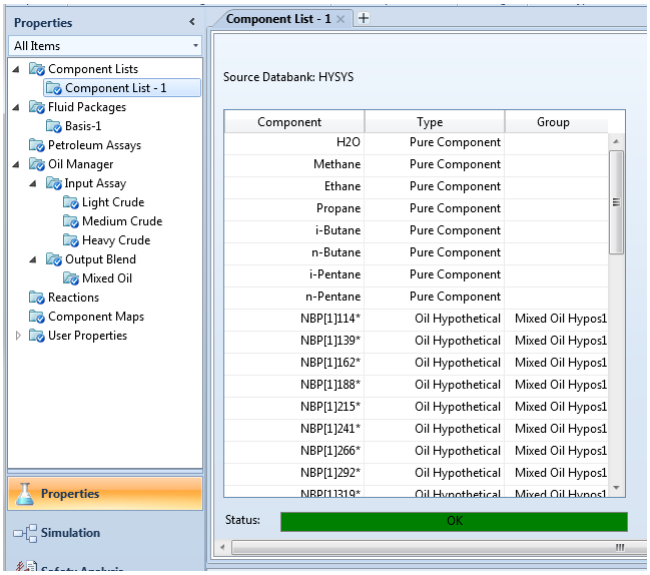
One more cleanup step, changing the name of the blend. Select *Output Blend* in the tree structure of the left-hand column. In the tabbed form select *Blend-1* and change to *Mixed Oil*.



The next step is to install the blend into the flowsheet. From this tabbed form select *Oil Manager* and then select *Install Oil* from the next form. Now we get a form that we can install one or more of the oils. We're only interested in installing the blend, *Mixed Oil*. In the *Stream Name* column enter *Crude Oil* for *Mixed Oil*. Click *Install*.



As a final step let's make sure everything is calculated & the pseudo components are installed into the component list. Select *Oil Manager* in the tree structure in the left-hand column. At the bottom of the form click *Calculate All*. Now when you look at the *Component List* you should see a series of pseudo components after the pure components chosen earlier.

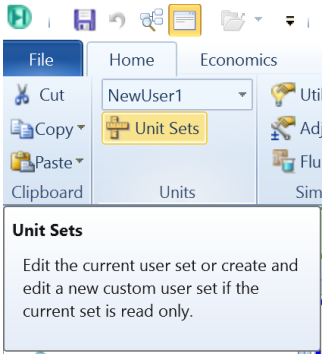


Set up & Solve the Flowsheet

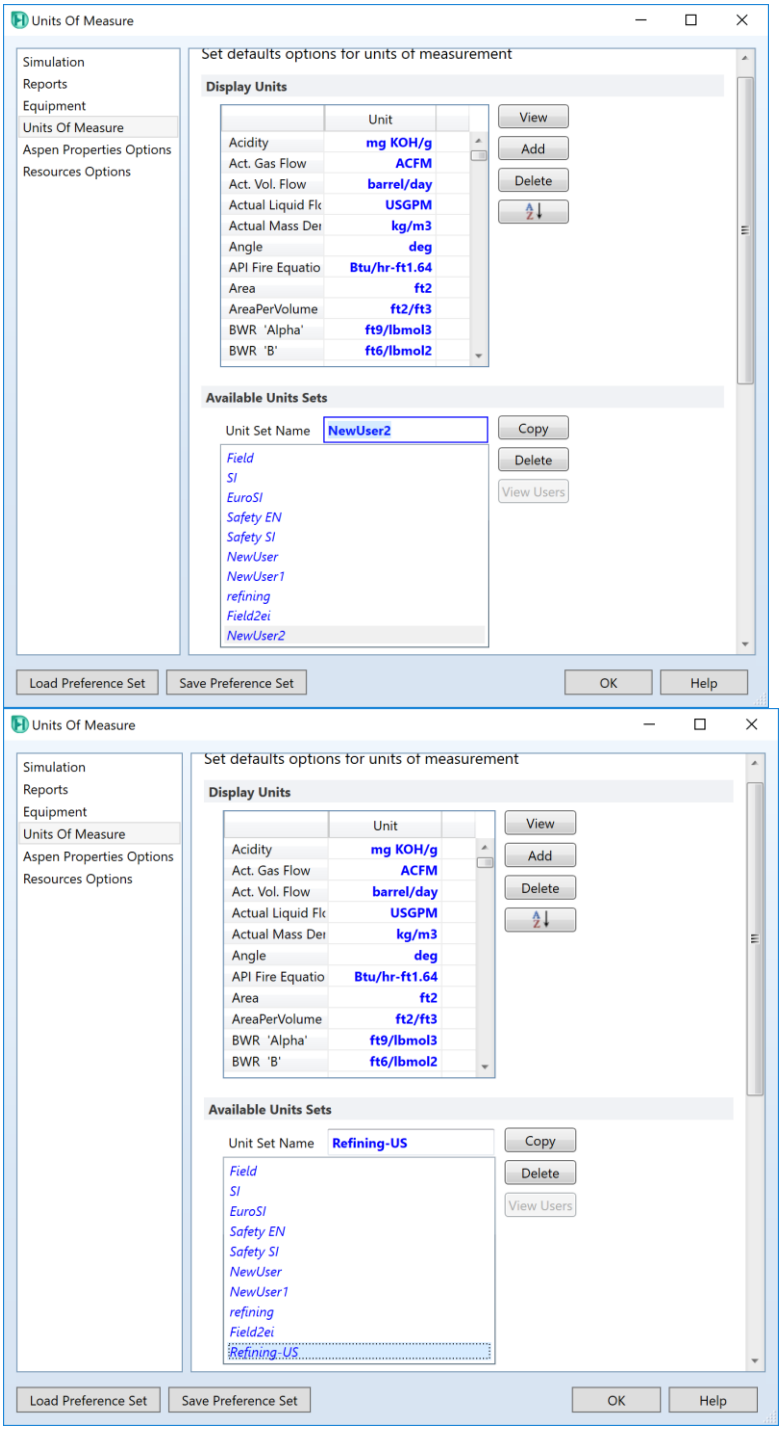
Units Used in Simulation

Before actually setting up the simulation we should determine what set of units are being used. The preference for this example is to use U.S. Customary units (temperature in °F, liquid flow in bbl/day, mass flow in lb/hr, etc.). There is a default unit set, Refining, that is almost everything that we will want.

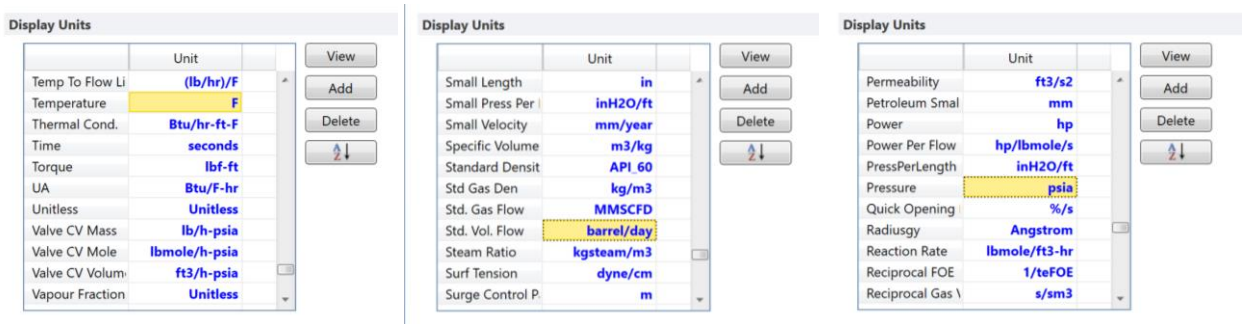
Under the Home tab there is a section for Units that show the current set being used & a button to change options within a unit set. For this problem the default is a set called *NewUser1* (for new files the starting set is dependent on what was previously used on the particular computer being used). To ensure the actual set being used let's create a new one which we will call *Refining-US*. Click on the Unit Sets button to bring up the form to examine the available unit sets & change (if desired).



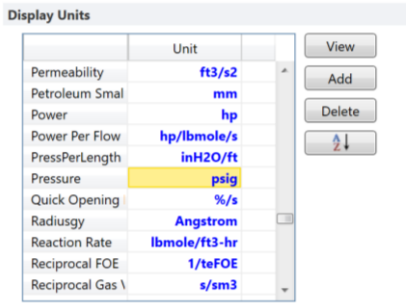
In the lower section let's start with the *refining* unit set. Select refining & press Copy. A new unit set will be created (here called NewUser2). Double click on this name & enter Refining-US.



In the upper section we can set the units used for various properties in the simulation. We can see that most units used are very reasonable. For example, temperature is in °F, standard volumetric flow is in bbl/day, & pressure is in psia.

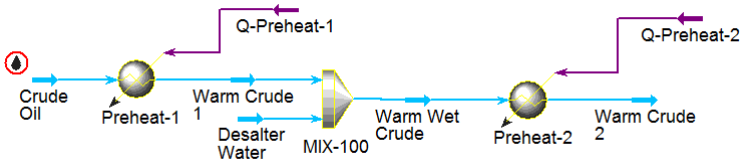


The pressure units would normally be OK, but we'd like to see gauge pressure in this problem instead (especially since all of the operating conditions will be given in this way). We can change the units by clicking on the pressure's dropdown list & choosing psig instead. Click OK when done to close this form.



Crude Oil Feed & Preheat

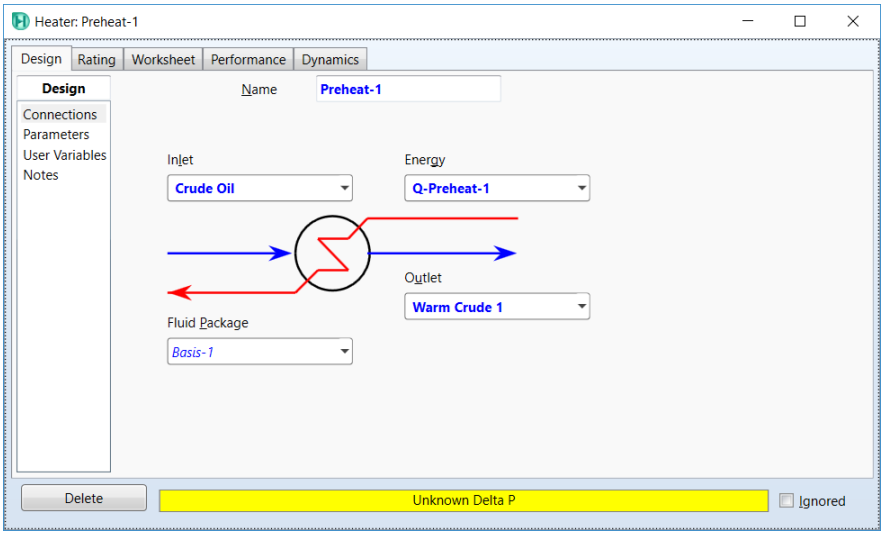
When you activate the Simulation you'll see a single steam called *Crude Oil*. We want to process this stream through two heat exchangers (to model the preheat before & after the Desalter) and a Mixer to set an expected amount of water in the Crude Oil coming from the Desalter.



One way to start the set up is to define the unit & stream attachments before worrying about defining stream compositions & conditions. This can be done by dragging the appropriate units from the Model Palette to the flowsheet (2 *Heaters* & one *Mixer*) and then using the *Design Connection* window to create & attach the streams. For example, after double-clicking on the Heater representing Preheat-1 the *Design Connection* window should look like the following. Note the following:

- The Crude Oil stream was associated with the Inlet by pulling down the list & choosing this existing stream. It exists because it was created in the *Properties* definition step when you clicked the *Install Oil* button.
- The steam names Q-Preheat-1 & Warm Crude 1 can be typed into the Energy & Outlet stream areas. Since these streams do not yet exist they will be created & shown on the PFD.

- The name of the *Heater* can be changed by double-clicking on the *Name* field & replacing with what you want (here *Preheat-1*).

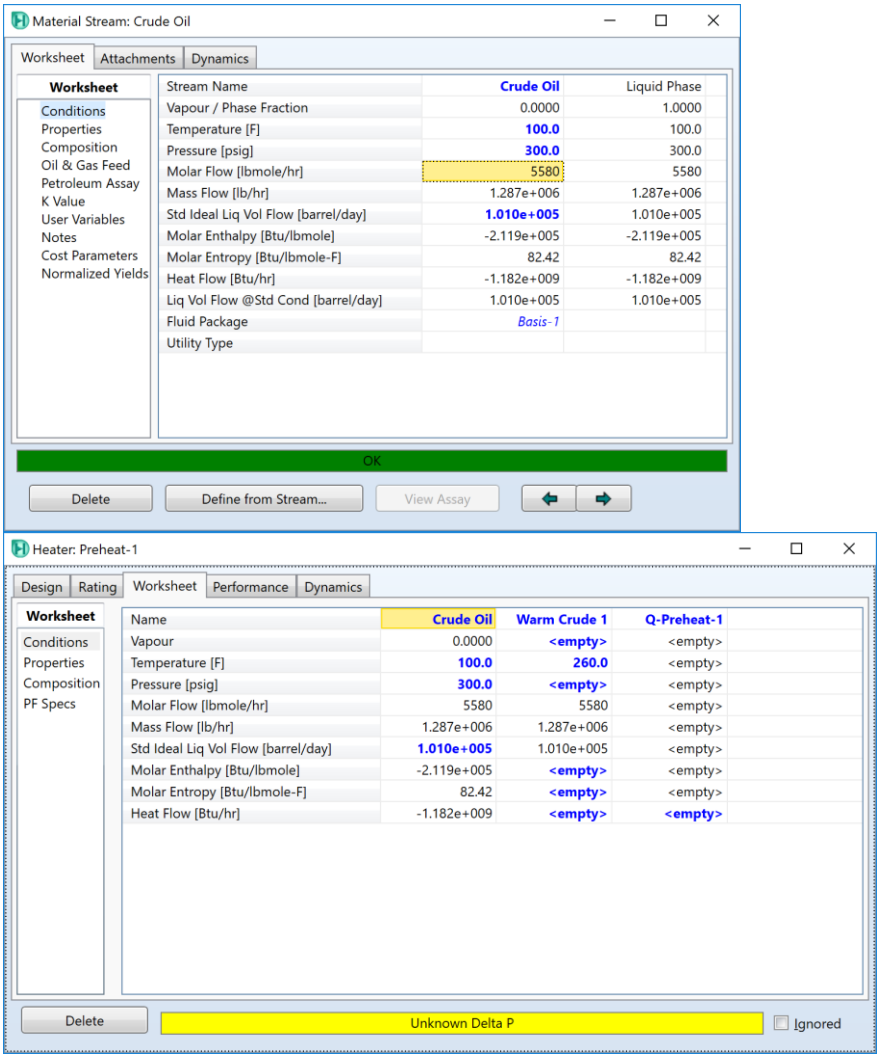


The following are the conditions to be set on the operations.

- Crude Oil Feed: 100°F, 300 psig, 101,000 bpd
- Preheat-1 outlet: 260°F, 294 psig
- Desalter outlet: 260°F, 294 psig, 500 bpd of water
- Preheat-2 outlet: 450°F, 260 psig

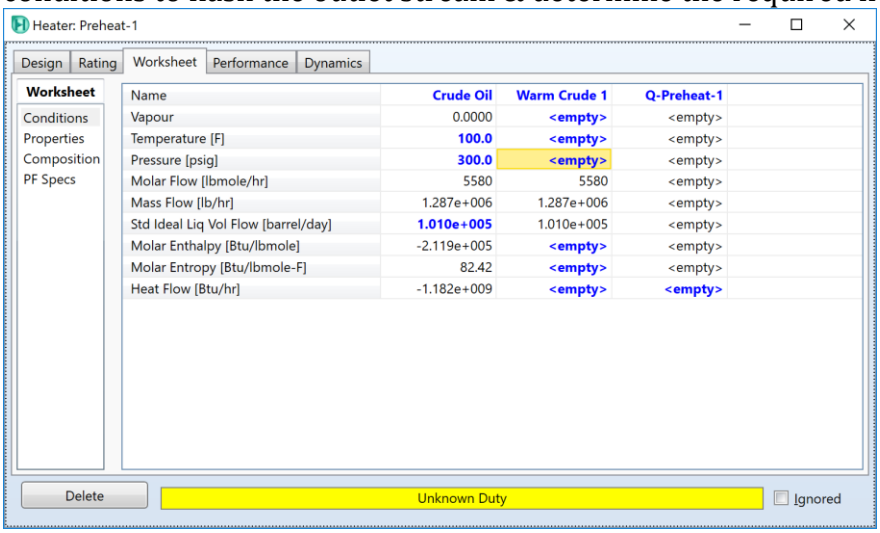
The conditions on the streams can either be set directly on the stream through its forms, indirectly using the unit forms, or a combination of the two. (There are actually other options using *Adjust* operations & spreadsheets but these will be discussed later.)

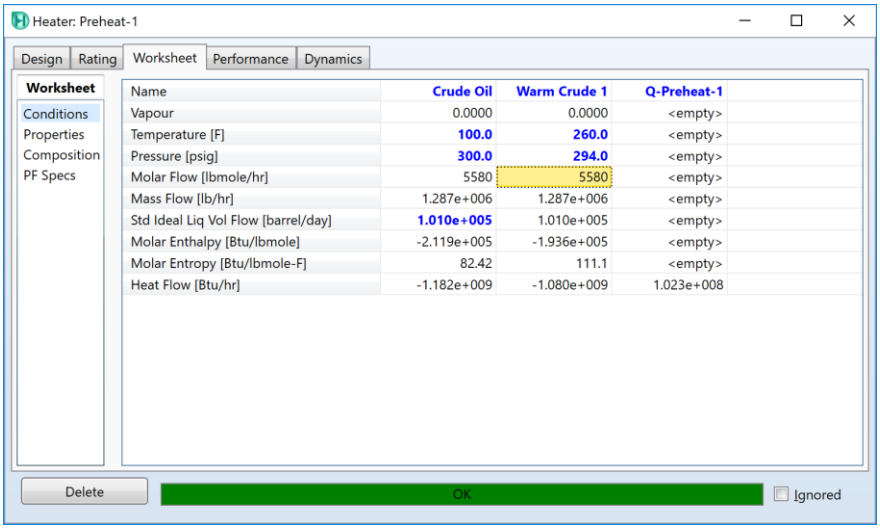
Double-click on the *Crude Oil* stream to open up the entry forms for this stream. Note that the flow rate comes from *Oil Manager*, but we're going to overwrite this. Note that once you enter the pressure & temperature the necessary conditions to define the phase condition for *Crude Oil* are complete & the flash calculations are performed; this is designated by the stream taking on a new color in the flowsheet & the message *OK* is shown at the bottom the stream's form. .



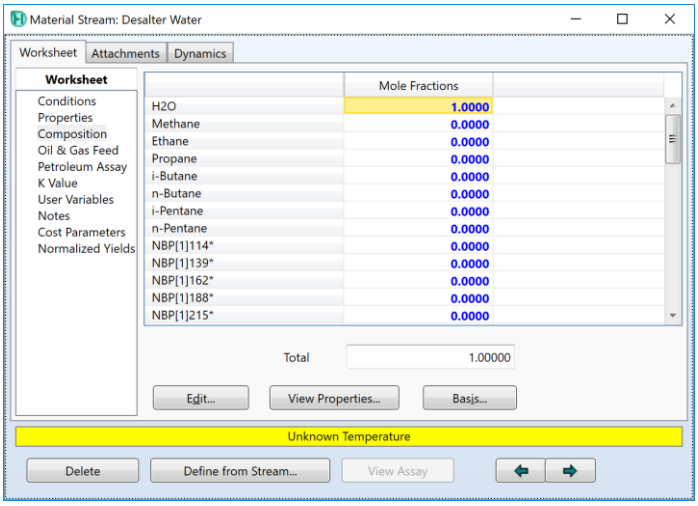
Double-click on the unit for *Preheater-1* & select the *Conditions* option under the *Worksheet* tab. Let's define the pressure & temperature in this window. Note these are sufficient

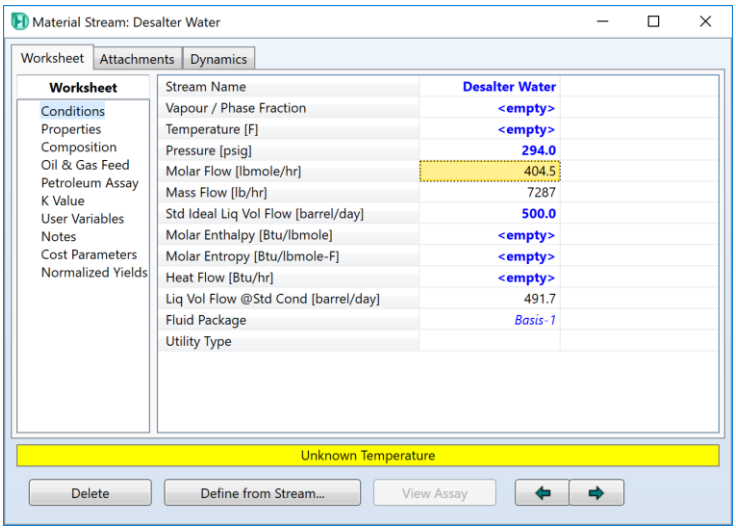
conditions to flash the outlet stream & determine the required heat.





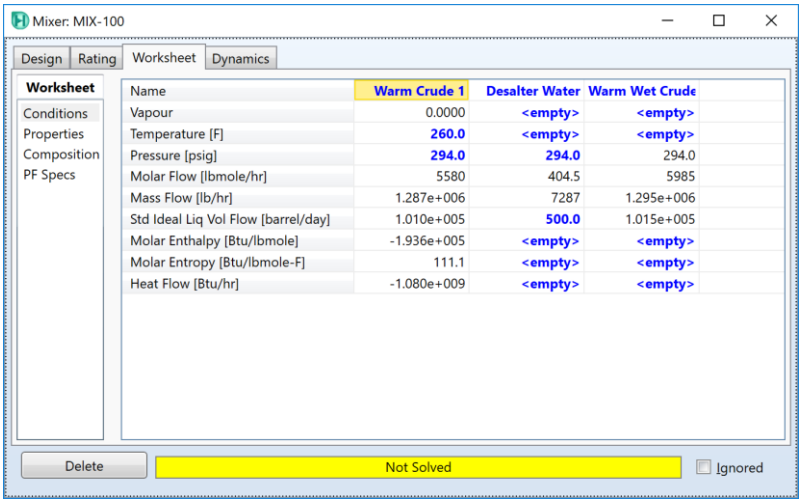
Operating conditions (such as pressure & temperature) & compositions can be set either from the stream forms or the unit forms; there is greater flexibility in set setting compositions of a stream from the stream forms. Here we'll set the entrained water by opening up the input form for *Desalter Water*. On the *Worksheet* tab select *Composition*. Click on the *Edit…* button, enter 1 for the fraction of H2O, click the *Normalize* button, and then *OK*. Next we will set the pressure of the entrained water (same as the outlet from the Desalter) & the flowrate. Note that <u>we will not set the temperature at this time</u>.



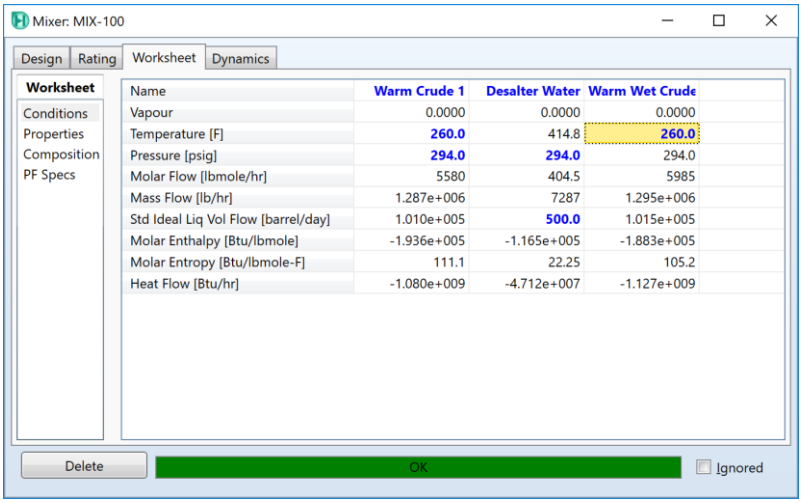


Now let's set the conditions for the outlet of the Desalter. Double click on the *Mixer* and click on the *Worksheet* tab. Note that the pressure of the outlet stream has been determined (set as the lowest pressure of all streams being mixed) & the standard liquid flowrate has been determined (since this is just additive of the two streams into the Mixer). Now, let's specify the temperature of the outlet of the Desalter; note that the temperature of the water stream has been back-calculated to enforce the adiabatic nature of the *Mixer* operation.

Before specifying outlet temperature:



After specifying outlet temperature:

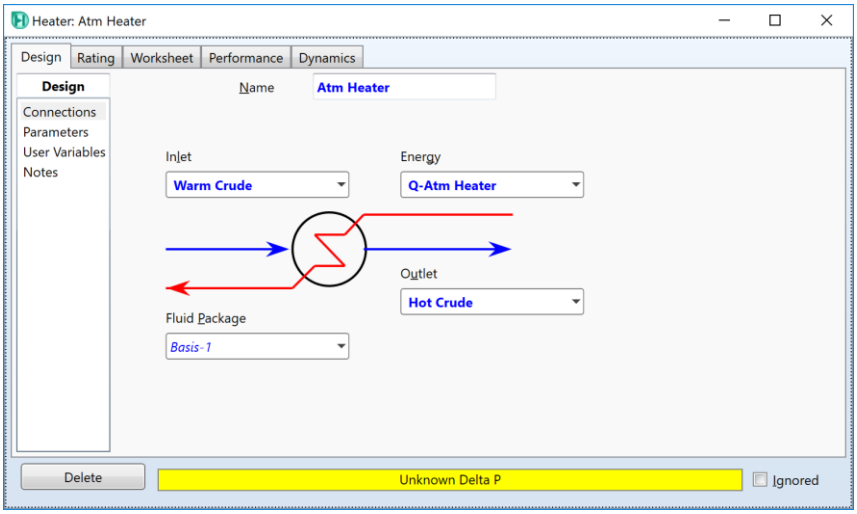


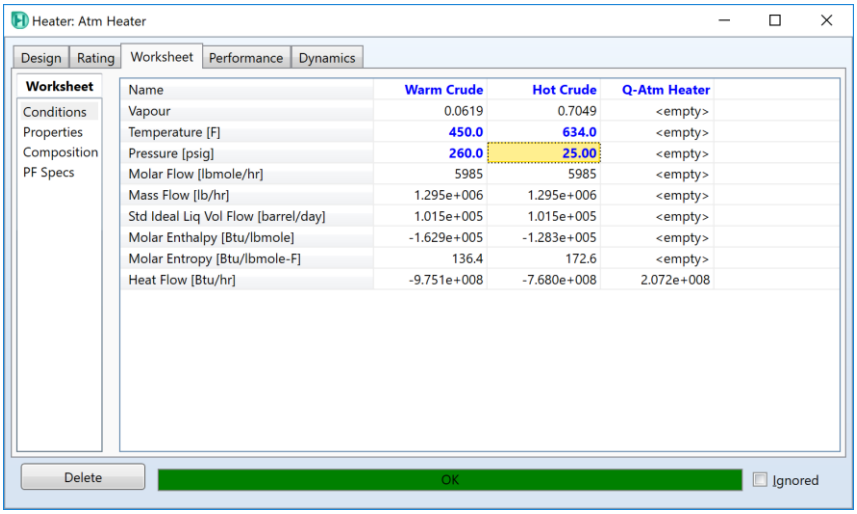
Specifying outlet conditions on the second preheater completes the flowsheet calculations for this part of the simulation.

Atmospheric Distillation Column

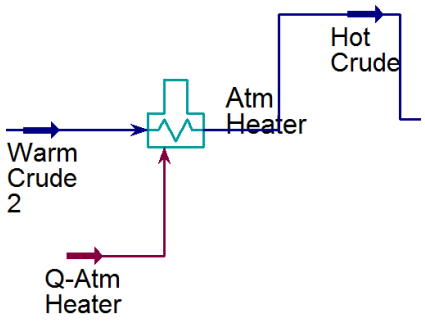
The next step is to set up the Atmospheric Distillation Column. Table 4 contains the conditions & configuration for this column.

The fired heater on the feed is separate from the column environment & will be created first. Create a new Heater on the flowsheet & call it *Atm Heater*. Change the icon to look like a heater instead of a shell & tube heat exchanger. Enter the following connections & set the following outlet conditions to match the approximate atmospheric column conditions in Table 4.





This portion of the PFD should look like the figure on the right.



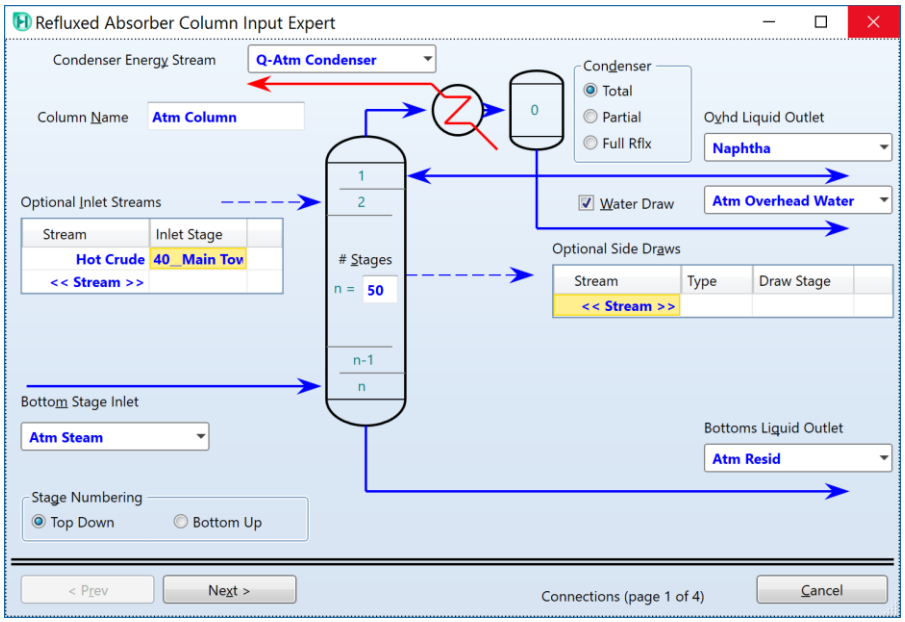
Setting up a distillation column is a multi-step process in HYSYS. First, create a *Refluxed Absorber Column* on the flowsheet then start to fill in the information. (The icon for this unit can be found under the *All* tab of the model palette or specifically under the *Separator* tab.)

Table 4. Definitions for Atmospheric Distillation Column

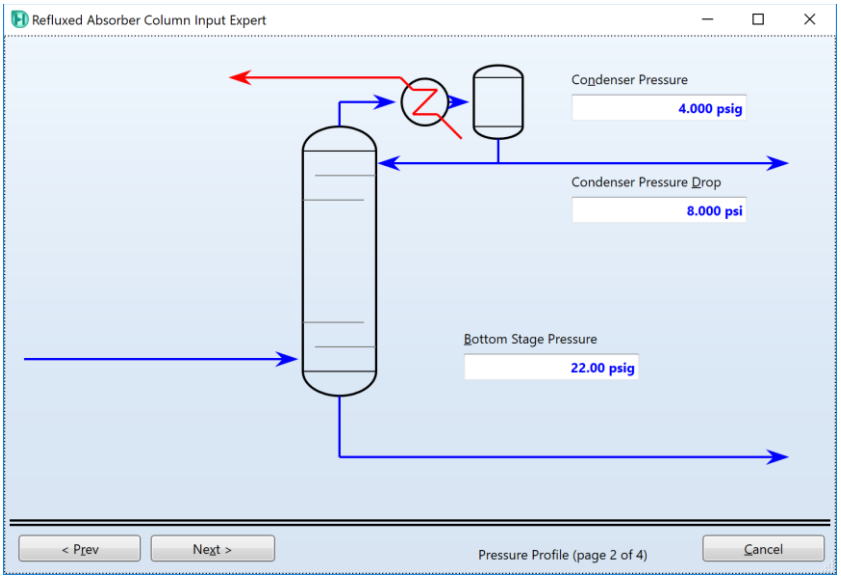
Type	Operating Parameter
Trays & Efficiencies	50 trays. Numbering from top: Trays 1 to 6: 80% Trays 7 to 10: 50% Trays 11 to 16: 70% Trays 17 to 30: 50% Trays 31 to 39: 30% Tray 40: 100% Trays 41 to 50: 30%
Condenser Type	Total Condenser; 130°F (approximate) Distillate product 410°F D86 T95; 30,200 bpd (approximate)
Reboiler Type	None, Direct Fired Heater
Pressures	Condenser: 4 psig Top Tray: 12 psig Bottom Tray: 22 psig
Temperatures	Top Tray #1 250°F (estimate) Bottom Tray #50 650°F (estimate)
Feed Locations	Crude oil to Tray #40 Stripping Steam at bottom (Tray #50) – 20,000 lb/hr @ 500°F, 150 psig
Feed Heater	Outlet @ 25 psig & 635°F Desire is 2,500 bpd overflash (liquid rate from tray above feed, Tray #39)
Side Strippers	Kerosene Stripper 10 trays @ 30% efficiency Kerosene draw from Tray #10, vapor returned to Tray #6 Stripping steam @ bottom (Tray #10) – 2500 lb/hr @ 500°F & 150 psig Kerosene product 525°F D86 T95; 8800 bpd product (approximate)
	Diesel Stripper 10 trays @ 30% efficiency Diesel draw from Tray #20, vapor returned to Tray #16 Stripping steam @ bottom (Tray #10) – 2500 lb/hr @ 500°F & 150 psig Diesel product 645°F D86 T95; 10,240 bpd product (approximate)
	AGO Stripper 10 trays @ 30% efficiency AGO draw from Tray #30, vapor returned to Tray #26 Stripping steam @ bottom (Tray #10) – 2500 lb/hr @ 500°F & 150 psig AGO product 750°F D86 T95; 3835 bpd product (approximate)
Pumparounds	Kerosene Pumparound Draw from Tray #10, returned to Tray #7 25,000 bpd flow, 200°F return temperature
	Diesel Pumparound Draw from Tray #20, returned to Tray #17 15,000 bpd flow, 250°F return temperature
	AGO Pumparound Draw from Tray #30, returned to Tray #27 10,000 bpd flow, 350°F return temperature

When you double click on the column for the first time a wizard starts and will guide you through entering information. If you don't fill it all in, don't worry – you can always specify the information from the forms & column sub-flowsheet.

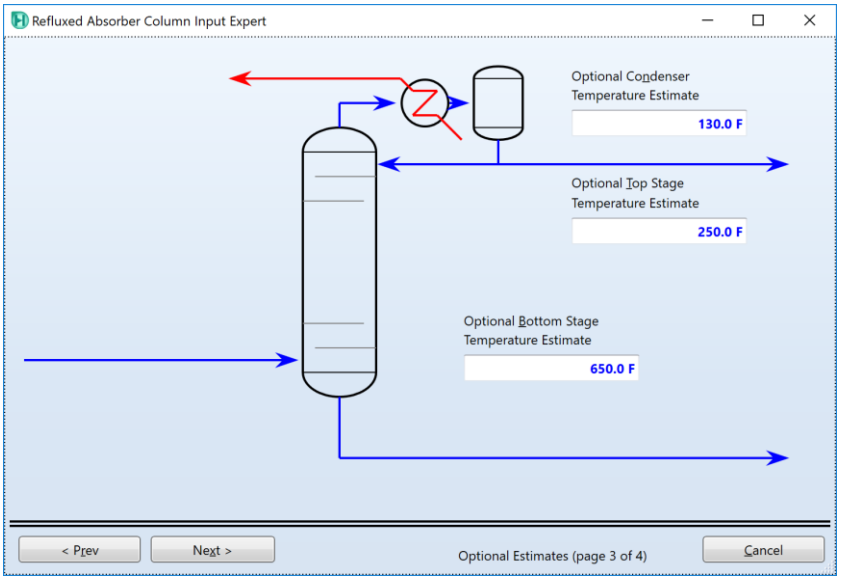
The first step in the wizard is to set up the basic information for the main feeds & products (but not the side products which will be processed through side strippers). Fill in the information as shown below. Make sure you check the box for *Water Draw*. When done press *Next>*.



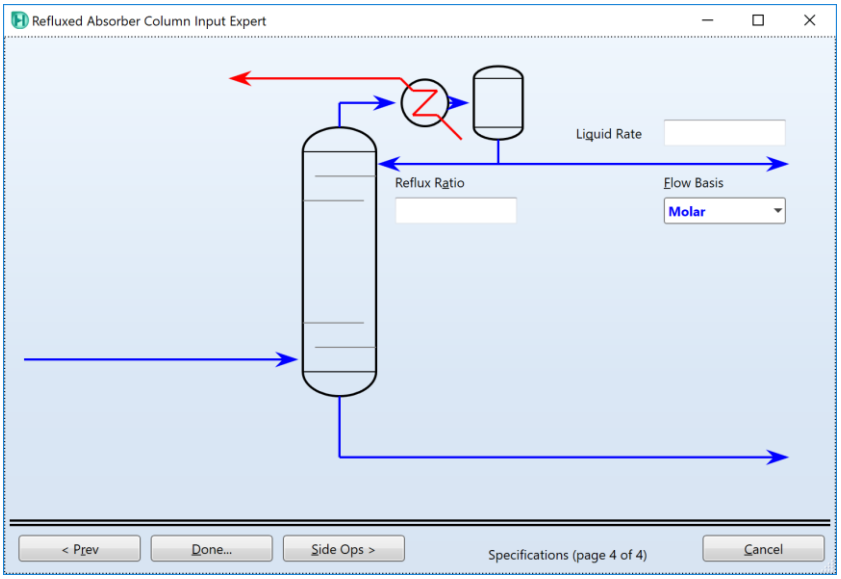
The next step is to set up the basic pressure profile in the column. Fill in values & press *Next>*.



Press *Next>*. On the third screen we will set an estimate for the condenser temperature. Though the other temperatures are not required it's usually good practice to enter values. For an atmospheric crude tower reasonable starting points are 250°F & 650°F for the top & bottom stages, respectively.

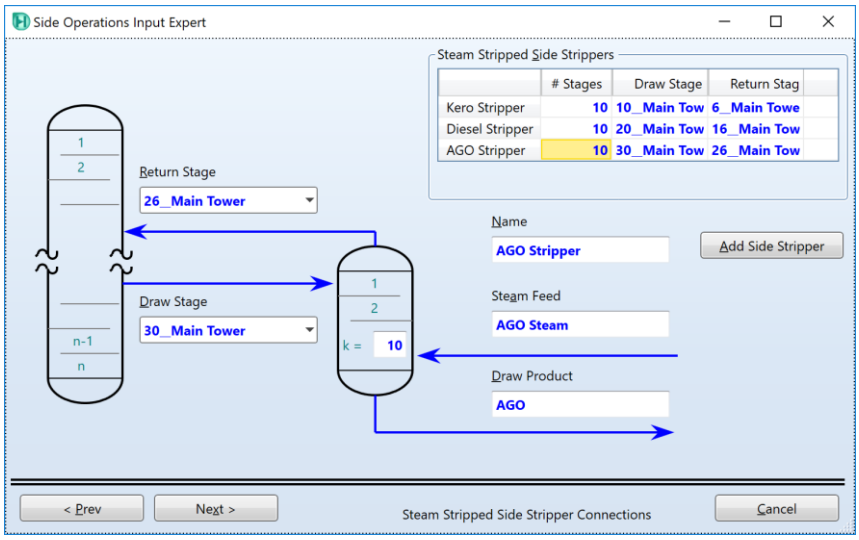


Press *Next>*. On the fourth screen we'll set an estimate for the distillate rate.



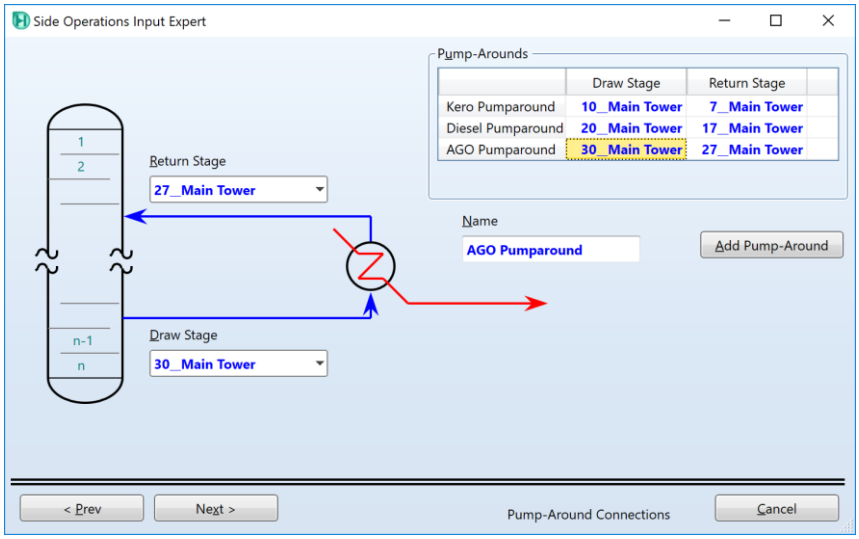
Press the *Side Ops>* button to start setting up the side strippers & pumparounds. We'll skip this first side operation screen since none of the side strippers are reboiled (they use stripping steam instead). Press *Next>*.

Now we can start adding the basic information for the three side strippers. To start entering the configuration information for each side stripper press the *Add Side Stripper* button; when done press the *Install* button. When done with the three side strippers press the *Next>* button.



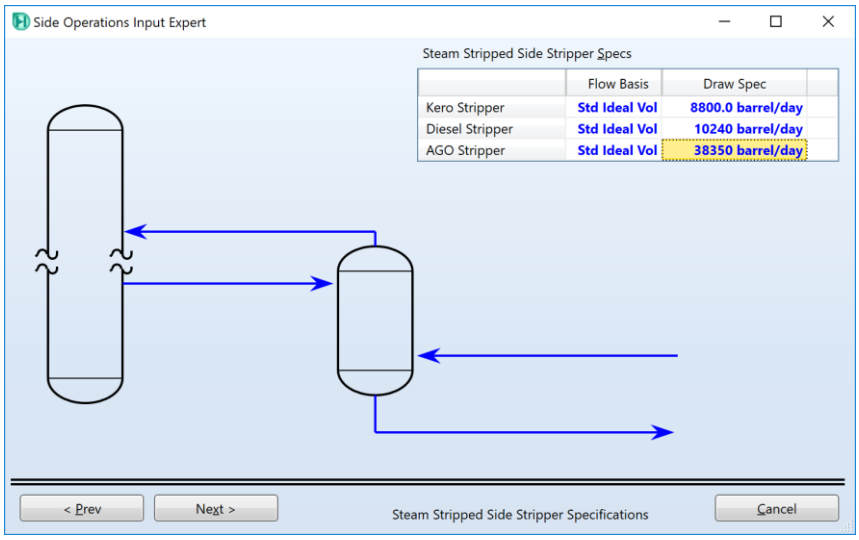
We do not have any side rectifiers. Press the *Next>* button.

Now we can start adding the basic information for the three pumparounds. To start entering the configuration information for each pumparound press the *Add Pump-Around* button; when done press the *Install* button. When done with the three pumparounds press the *Next>* button.

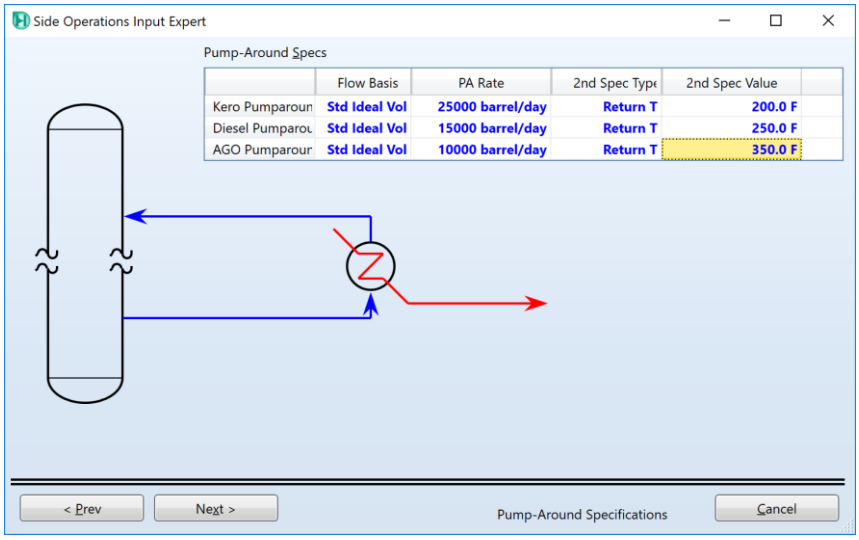


We do not have any vapor bypasses. Press the *Next>* button.

Now we can enter the side product flows through the side strippers. Enter the estimates for the flowrates out the bottom of the strippers & then press *Next*>.



Now we can set the specs on the pumparounds. Enter the flowrate values & the values associated with the heat exchanger duties. Note that all of the duty/temperature specs are *Return T* type. When done press *Next*>.



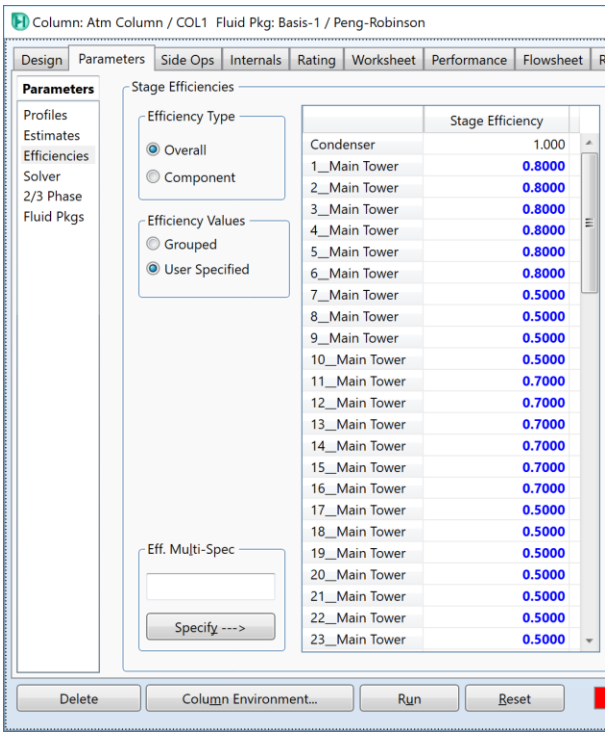
Now we can set the pressures in the side strippers. Use the default values with no changes. Press *Next*>.

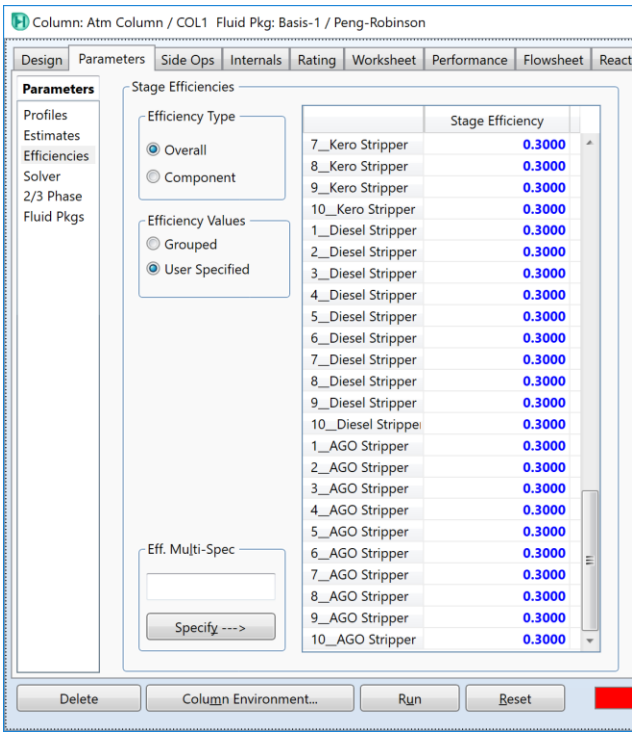
Now we can set the pressure drops across the pumparounds. Use the default values of zero. Press *Done*.

Distillation columns are different from the rest of the HYSYS operations in that they do not automatically run the first time they are created; rather, you must press the *Run* button when everything has been set up properly. However, we still have a couple more changes to make so let's not do this yet.

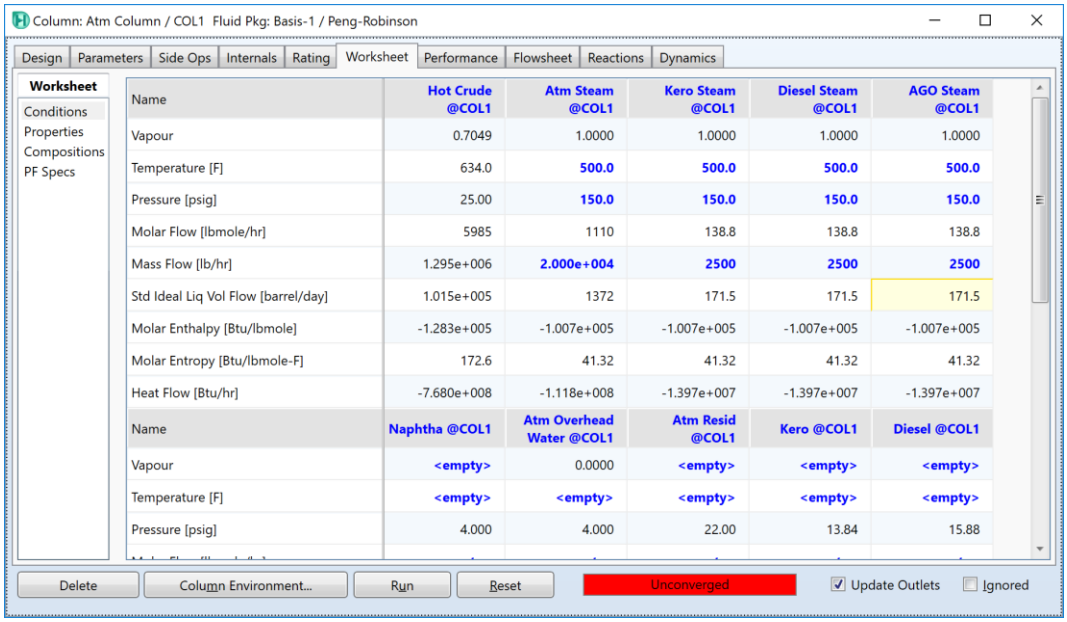
First, let's specify the stage efficiencies to model the stages as real trays. Under the *Parameters* tab select *Efficiencies*. Make sure that *Overall* & *User Specified* items are highlighted. Now let's start applying the efficiencies in Table 4. Note that stages associated

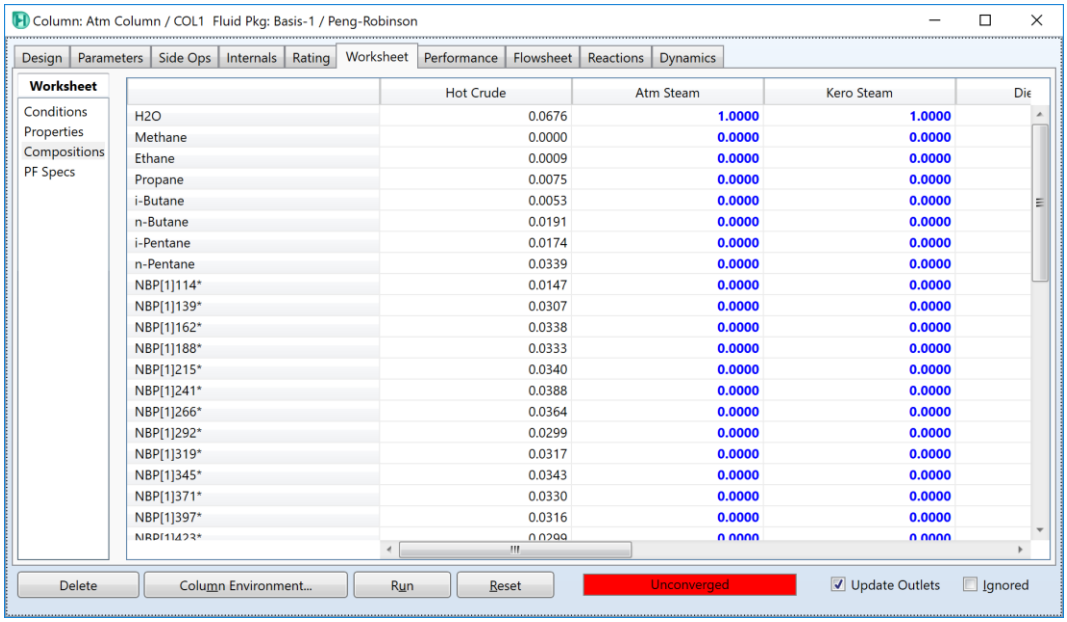
with the side strippers are listed in this table as if part of the main column (in a way they are, but that's a subject for a different discussion).





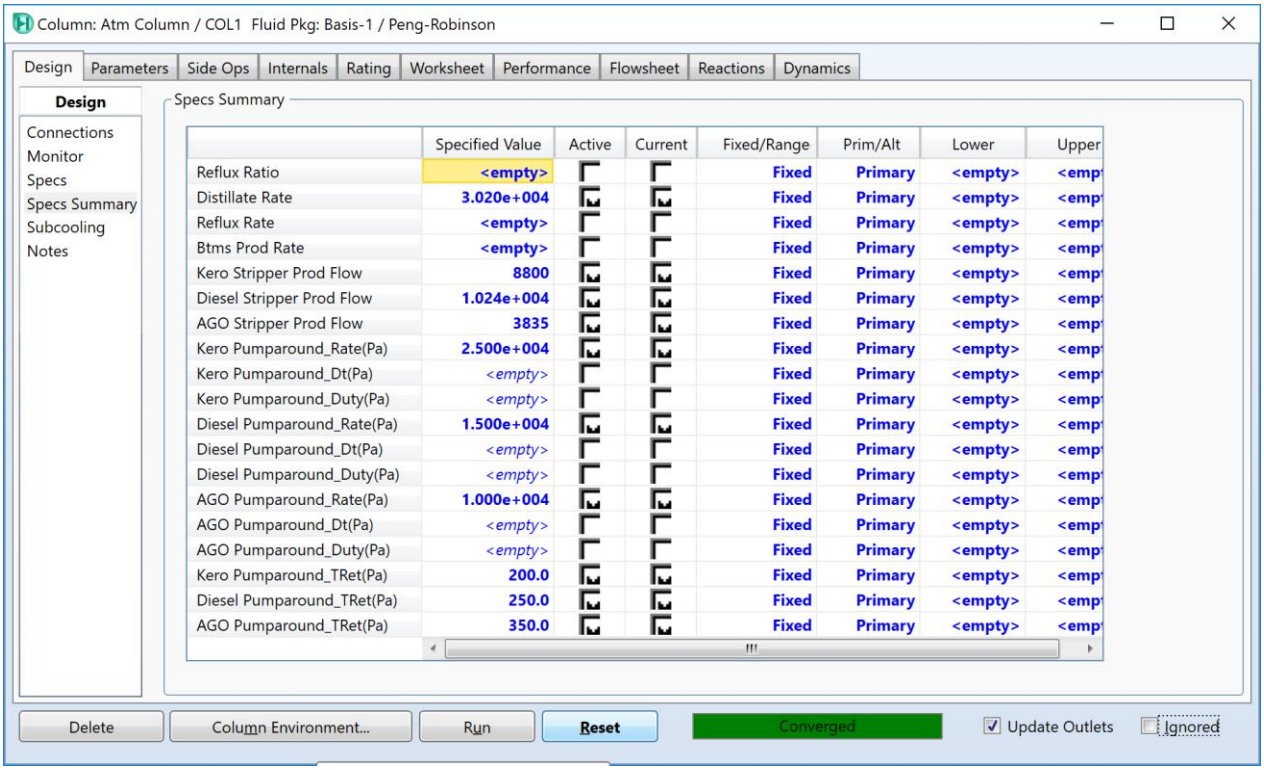
The next requirement is to specify the steam streams. This can be done using the *Worksheet* tab. Select *Conditions* and specify the temperature, pressure, & mass flowrate values. Select *Compositions*; now the compositions can be set as 100% H2O (entering a value of 1 will bring up the *Input Composition* form; press the *Normalize* button & then *OK*). Note that once these values are entered for the steam streams those flash calcuatlions can be completed; the associated calcualtions for the product streams cannot be done until the tower calculations are completed.



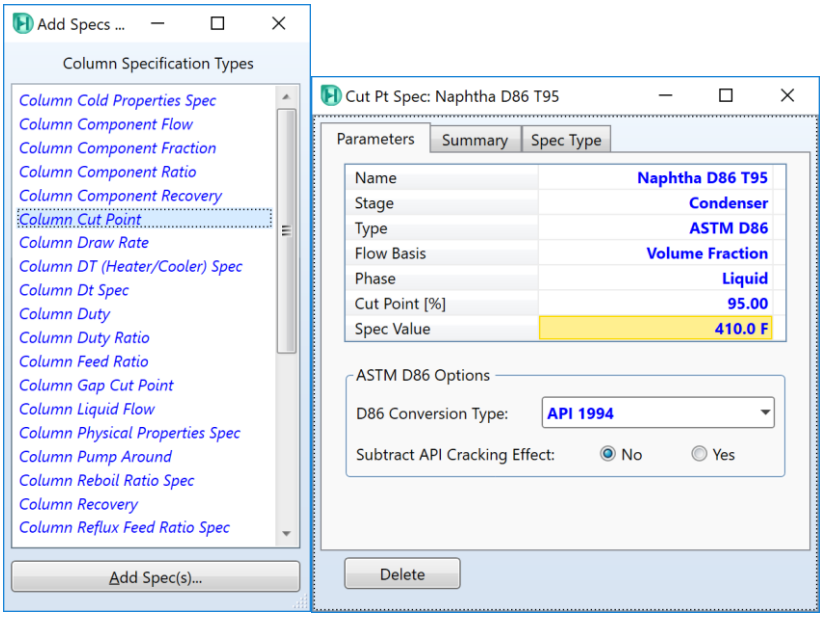


Even though we don't have all of the operating specs added we can do an initial run of the simulation by pressing *Run*. You should get a converged solution within 10 iterations.

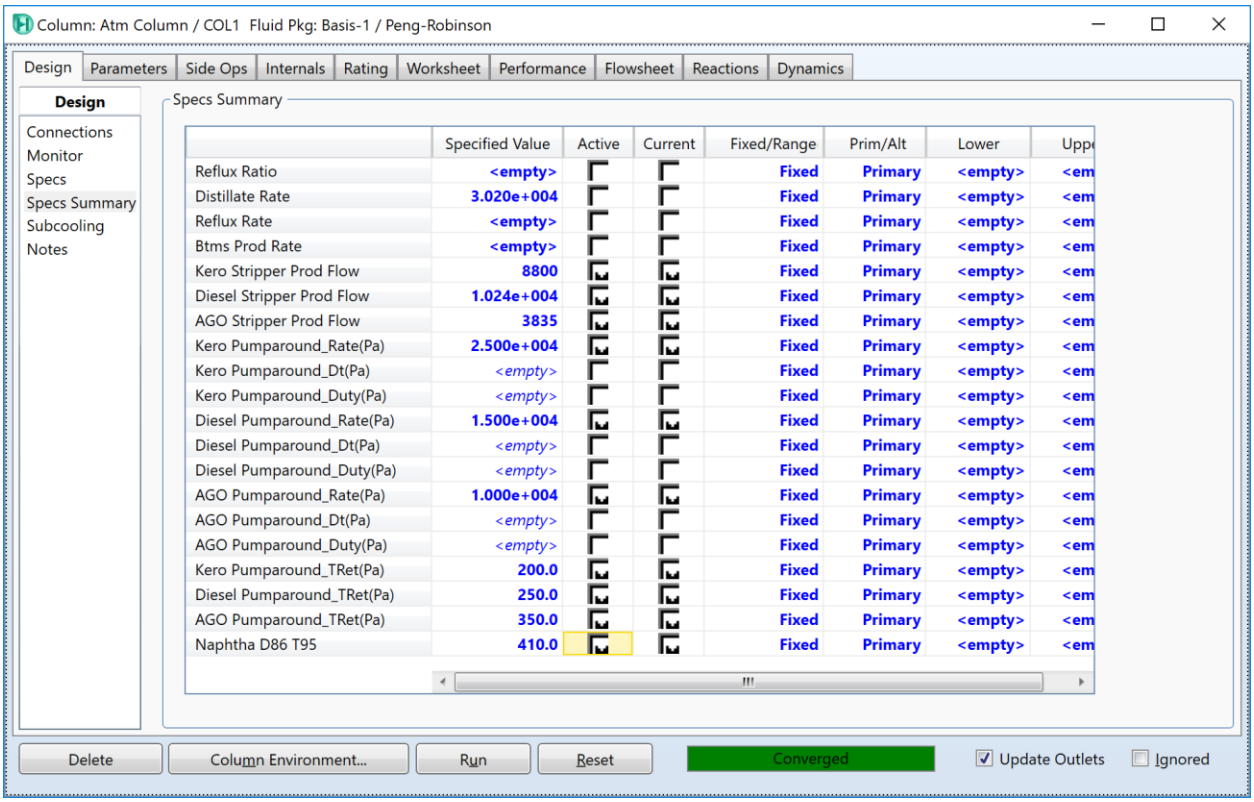
How can the distillation column equations be solved without putting the composition specs? This is because the "estimated" flowrates entered during the setup are used as the actual specifications. We can see this by checking the *Spec Summary* setting under the *Design* tab. Notice that all of these flowrate specs have checks in the *Active* column; this means that these values are the specifications to which the solution is driven.

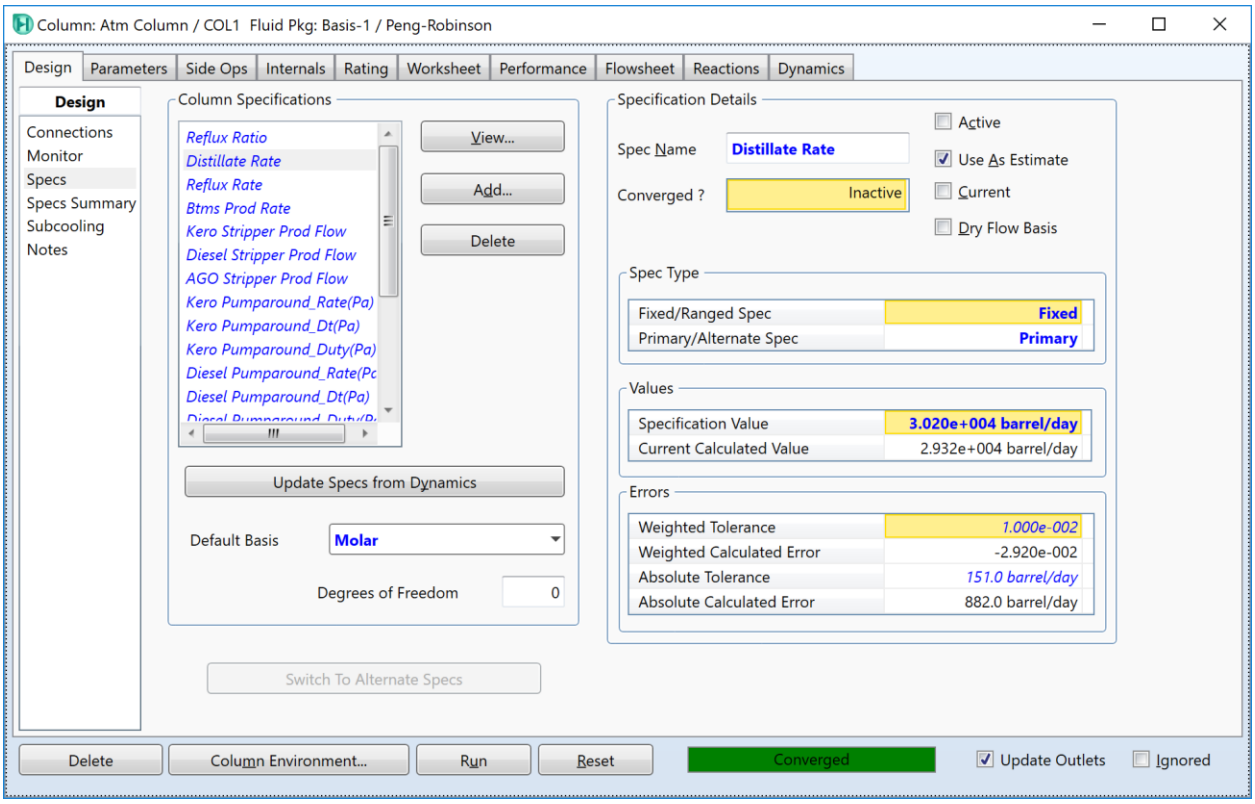


Let's now add the composition specs but not make them active. Select *Specs* under the *Design* tab. In the *Column Specifications* area we can add, remove, or change any of the specs that will show up in the Summary. Let's first add the ASTM D86 95 vol% temperature spec for the Naphtha stream. Click *Add*… In the list that comes up choose Column Cut Point (do not choose *End Point Based Column Cut Pint Spec* near the bottom of the list) & click *Add Spec(s)*… Call the spec Naphtha D86 T95, associate the spec with the liquid phase off of the Condenser, set the % as 95, and set the Spec Value as 410°F. (Keep the default *API 1974* conversion method.) You can now close the form.

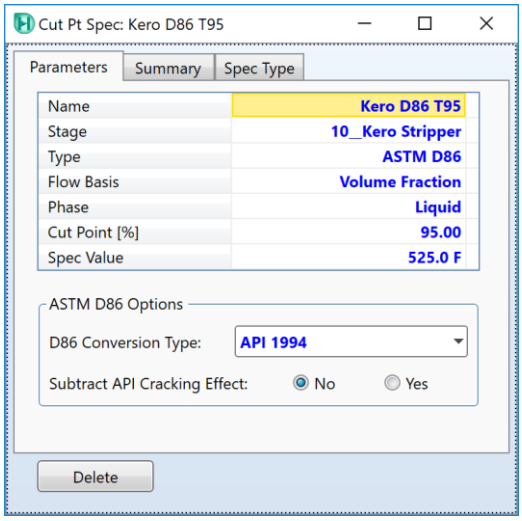


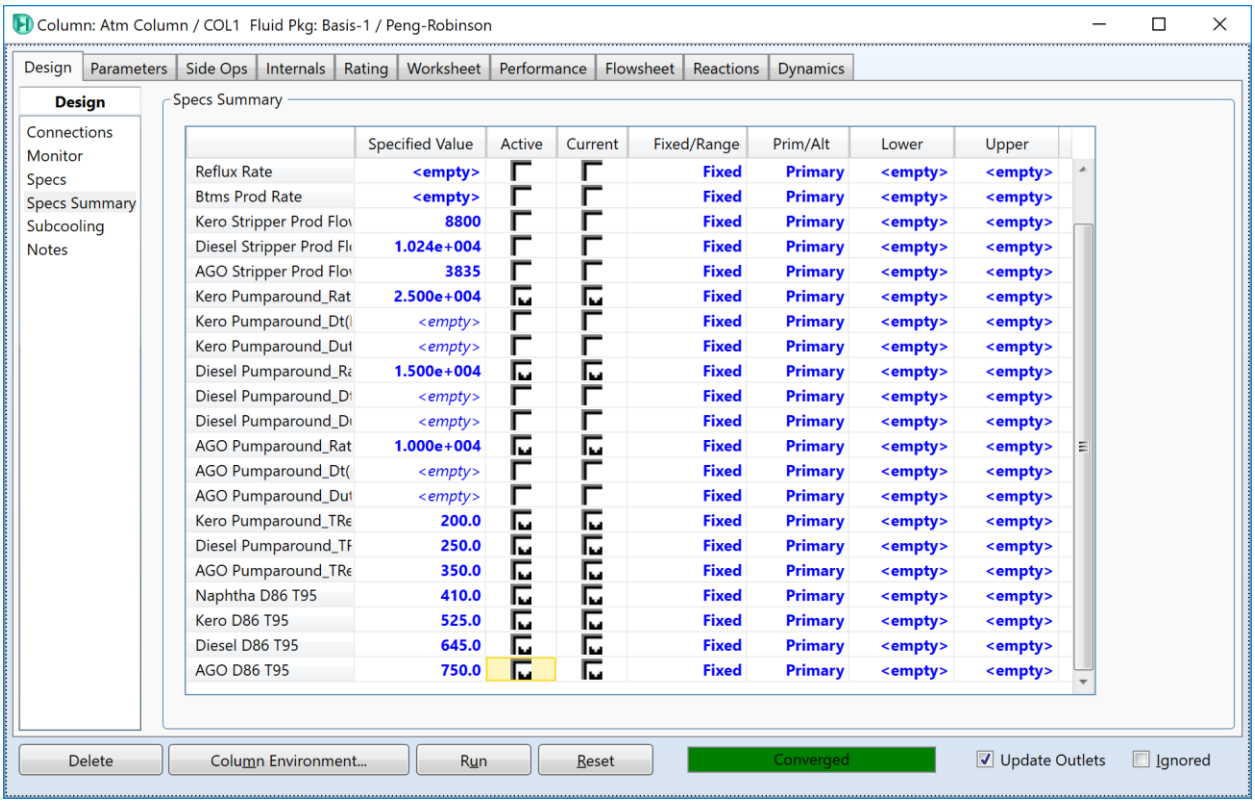
Once we close the input form we can see information about the specification details. The value is supposed to be 410°F but because the spec is not active the value is 419.4°F. Close, but not close enough. In the actual operation of the tower we would adjust the distillate draw rate to make this spec. In HYSYS we make the *Distillate Rate* spec inactive & make the *Naphtha D86 T95* spec active. The easiest way to do this is from the *Specs Summary* form. Changing the check boxes will cause the tower to rerun & quickly converge. Now when we check the individual specs by selecting *Specs* under the *Design* tab we see that the *Distillate Rate* value is 29,320 bpd, not the 30,200 bpd estimate.

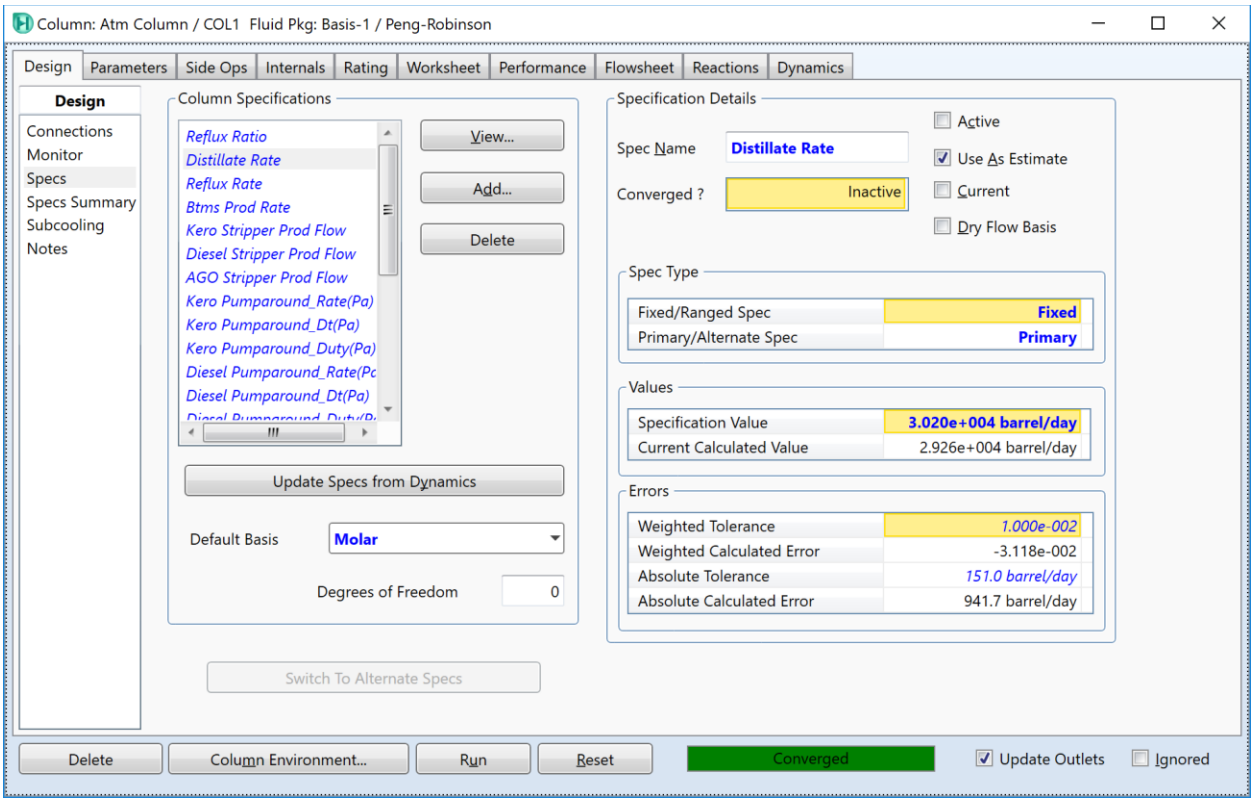

Column: Atm Column / COL1 Fluid Pkg: Basis-1 / Peng-Robinson
Design
Parameters
Side Ops
Internals
Rating
Worksheet
Performance
Flowsheet
Reactions
Dynamics
Design
Connections
Monitor
Specs
Specs Summary
Subcooling
Notes
Specs Summary
Specified Value
Active
Current
Fixed/Range
Prim/Alt
Lower
Upp
Reflux Ratio <empty> Fixed Primary <empty> <em
Distillate Rate 3.020e+004 Fixed Primary <empty> <em
Reflux Rate <empty> Fixed Primary <empty> <em
Btms Prod Rate <empty> Fixed Primary <empty> <em
Kero Stripper Prod Flow 8800 Fixed Primary <empty> <em
Diesel Stripper Prod Flow 1.024e+004 Fixed Primary <empty> <em
AGO Stripper Prod Flow 3835 Fixed Primary <empty> <em
Kero Pumparound_Rate(Pa) 2.500e+004 Fixed Primary <empty> <em
Kero Pumparound_Dt(Pa) <empty> Fixed Primary <empty> <em
Kero Pumparound_Duty(Pa) <empty> Fixed Primary <empty> <em
Diesel Pumparound_Rate(Pa) 1.500e+004 Fixed Primary <empty> <em
Diesel Pumparound_Dt(Pa) <empty> Fixed Primary <empty> <em
Diesel Pumparound_Duty(Pa) <empty> Fixed Primary <empty> <em
AGO Pumparound_Rate(Pa) 1.000e+004 Fixed Primary <empty> <em
AGO Pumparound_Dt(Pa) <empty> Fixed Primary <empty> <em
AGO Pumparound_Duty(Pa) <empty> Fixed Primary <empty> <em
Kero Pumparound_TRet(Pa) 200.0 Fixed Primary <empty> <em
Diesel Pumparound_TRet(Pa) 250.0 Fixed Primary <empty> <em
AGO Pumparound_TRet(Pa) 350.0 Fixed Primary <empty> <em
Naphtha D86 T95 410.0 Fixed Primary <empty> <em
Delete
Column Environment...
Run
Reset
Converged
Update Outlets
Ignored


Column: Atm Column / COL1 Fluid Pkg: Basis-1 / Peng-Robinson
Design
Parameters
Side Ops
Internals
Rating
Worksheet
Performance
Flowsheet
Reactions
Dynamics
Design
Connections
Monitor
Specs
Specs Summary
Subcooling
Notes
Column Specifications
Reflux Ratio
Distillate Rate
Reflux Rate
Btms Prod Rate
Kero Stripper Prod Flow
Diesel Stripper Prod Flow
AGO Stripper Prod Flow
Kero Pumparound_Rate(Pa)
Kero Pumparound_Dt(Pa)
Kero Pumparound_Duty(Pa)
Diesel Pumparound_Rate(Pc
Diesel Pumparound_Dt(Pa)
View...
Add...
Delete
Update Specs from Dynamics
Default Basis
Molar
Degrees of Freedom
0
Switch To Alternate Specs
Specification Details
Spec Name
Distillate Rate
Converged ?
Inactive
Active
Use As Estimate
Current
Dry Flow Basis
Spec Type
Fixed/Ranged Spec
Fixed
Primary/Alternate Spec
Primary
Values
Specification Value
3.020e+004 barrel/day
Current Calculated Value
2.932e+004 barrel/day
Errors
Weighted Tolerance
1.000e-002
Weighted Calculated Error
-2.920e-002
Absolute Tolerance
151.0 barrel/day
Absolute Calculated Error
882.0 barrel/day
Delete
Column Environment...
Run
Reset
Converged
Update Outlets
Ignored

We can create similar design specs for the Kerosene, Diesel, & AGO D86 T95 values. Each time we make the T95 spec active we will make the corresponding production rate inactive. Note that when we make these specifications the stream associated with the spec will be the liquid from the bottom of the appropriate side stripper. Finally, when you compare the actual production rates to the initial estimates you may find that each change in a T95 spec may change other production rates, not just the one assoicatged with that spec. For example, adding all of these T95 specs will change the naphtha rate to 29,260 bpd.







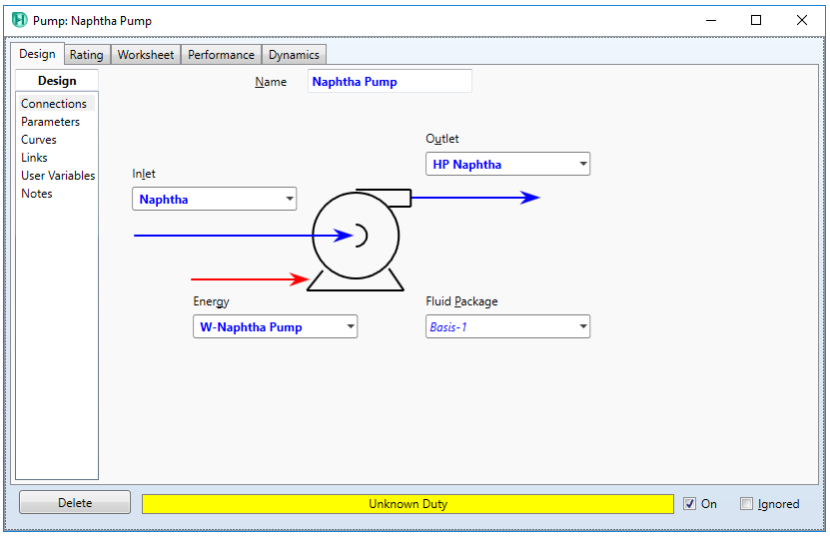
Debutanizer Column

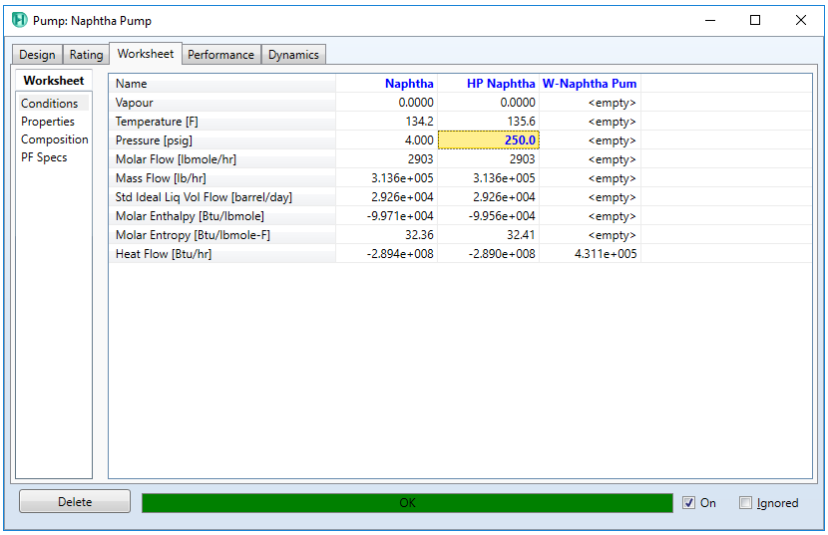
Next, let's do the simpler of the two remaining columns, the Debutanizer Column (i.e., the Naphtha Stabilizer). We will want to operate the Debutanizer at a higher pressure than the Atmospheric Distillation Column, so we will need a pump for the Unstabilized Naptha. We will also preheat the feed entering the column. Table 5 shows the operating conditions for the column & the feed's pump & preheater.

Table 5. Definitions for Debutanizer Column

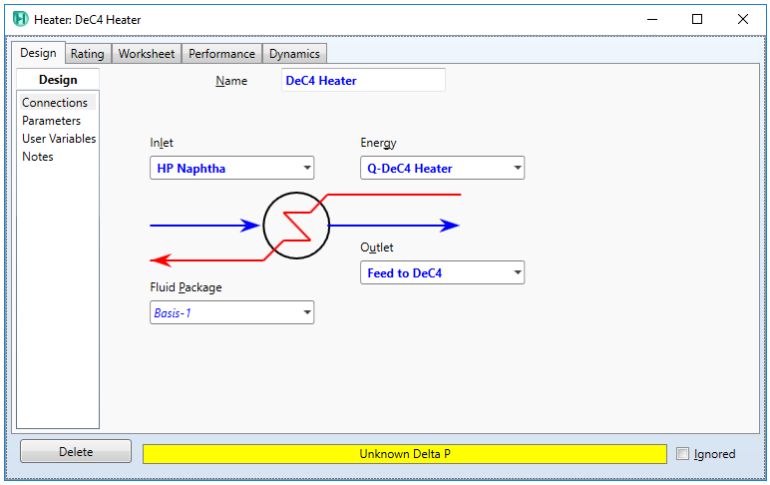
Type	Operating Parameter
Feed Prep	Increase pressure to 250 psig; use default adiabatic efficiency for pump (75%) Preheat to 250°F; assume negligible pressure drop through exchanger
Trays & Efficiencies	45 trays. Number from top. All trays 80% efficiency
Condenser Type	Total condenser 1.5 reflux ratio
Reboiler Type	Kettle reboiler
Pressures	Condenser: 150 psig Top Tray: 150 psig Bottom Tray: 160 psig Reboiler: 160 psig
Temperature	No other estimates needed
Feed Locations	Unstabilized Naphtha to Tray #22
Products	Overhead LPGs, 5,500 bpd Stabilized naphtha from bottom

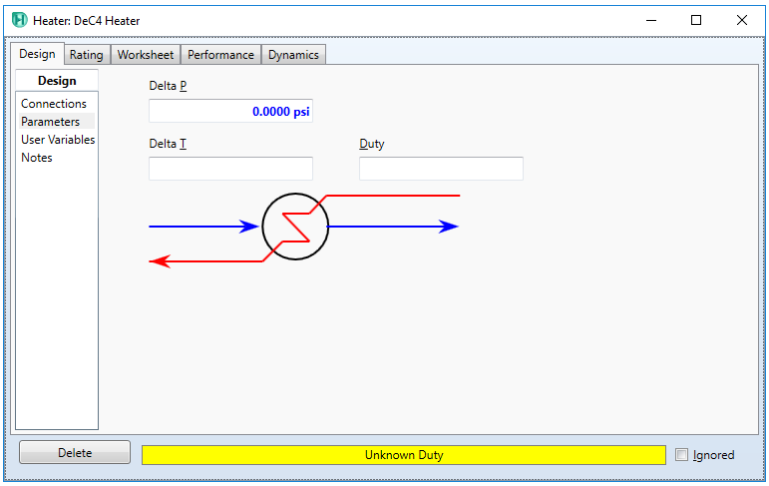
Place a *Pump* on the flowsheet & define the following connections. Retain the default adiabatic efficiency (75%). Set the outlet pressure as 250 psig in the *Worksheet* tab.

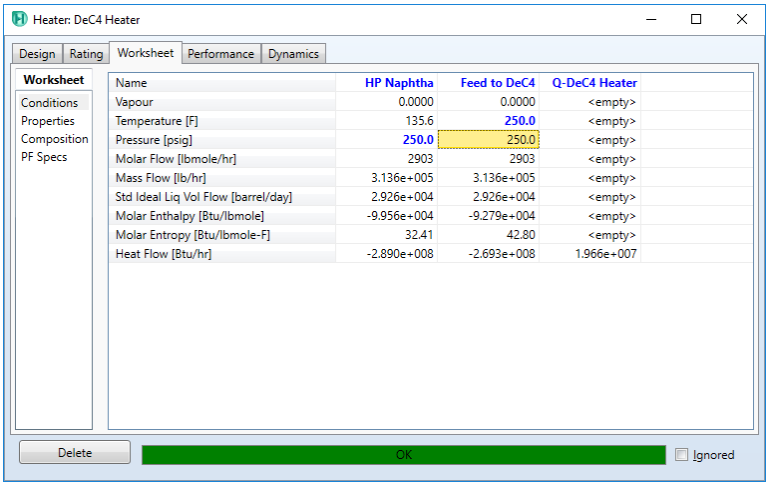




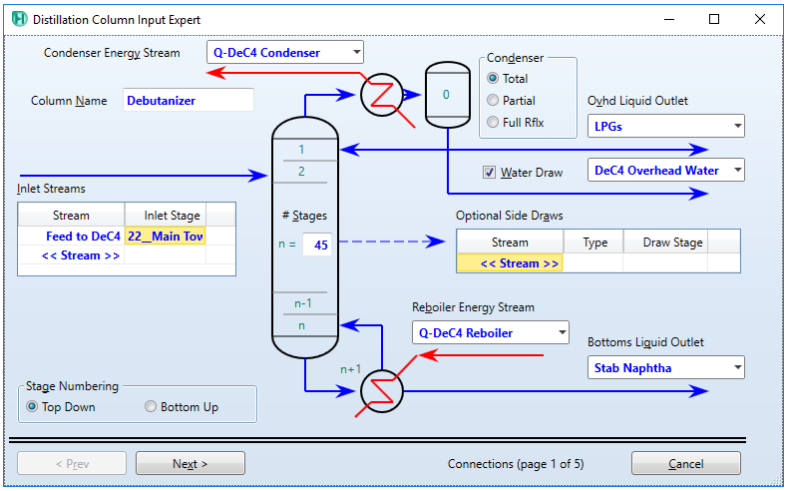
Place a *Heater* on the flowsheet & define the following connections. Set the pressure drop in the *Parameters* section (*Delta P*). Since the outlet pressure is calculated from the pressure drop it does not have to be set on the *Worksheet* tab. However, we still need to set the outlet temperature & this can be done on the *Worksheet* tab.



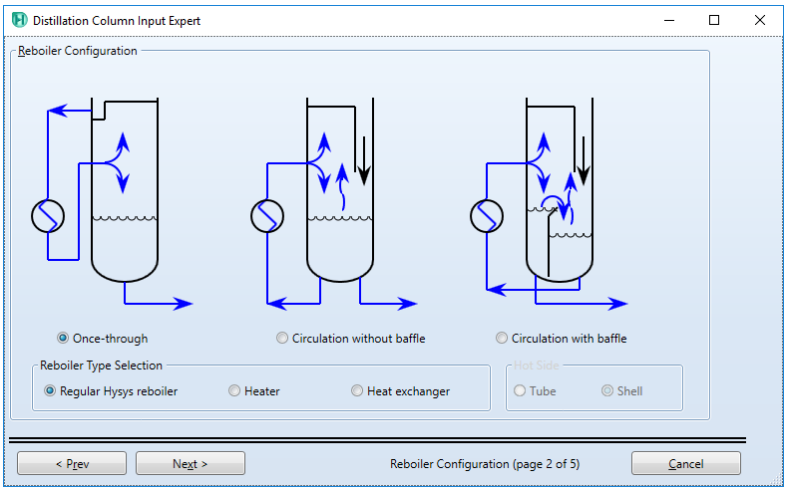




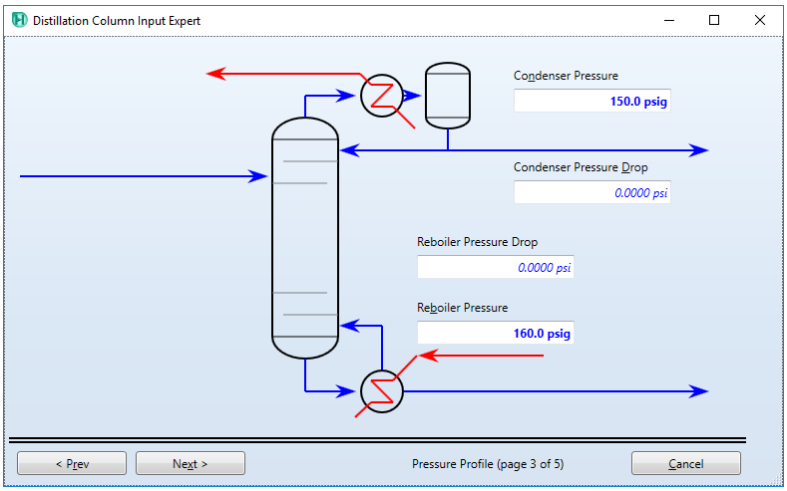
Now we can define the Debutanizer. Just like with the Atmospheric Distillation Column HYSYS will start the process with a multi-step wizard to walk you through the basic configuration. From the *Columns* tab in the model *Palette* chose the *Distillation Column* sub-flowsheet (the one with both a condenser & a reboiler).



The next step is to pick a type of reboiler. The first entitled *Once-through* depicts a kettle reboiler & is the one we want (liquid from the bottom tray is the feed to the reboiler, produced vapors are returned to the bottom tray and the liquid exits as the bottoms product). The other two configurations are for thermosiphon reboilers; though used commercially they will not be chosen for this example. Click *Next>* when done.

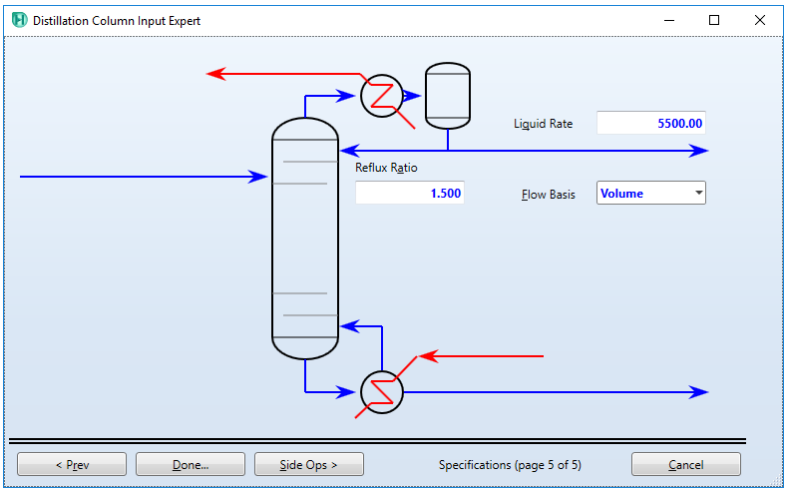


The next form is for entering the basic pressure profile. Enter the values from Table 5. Click *Next>* when done.

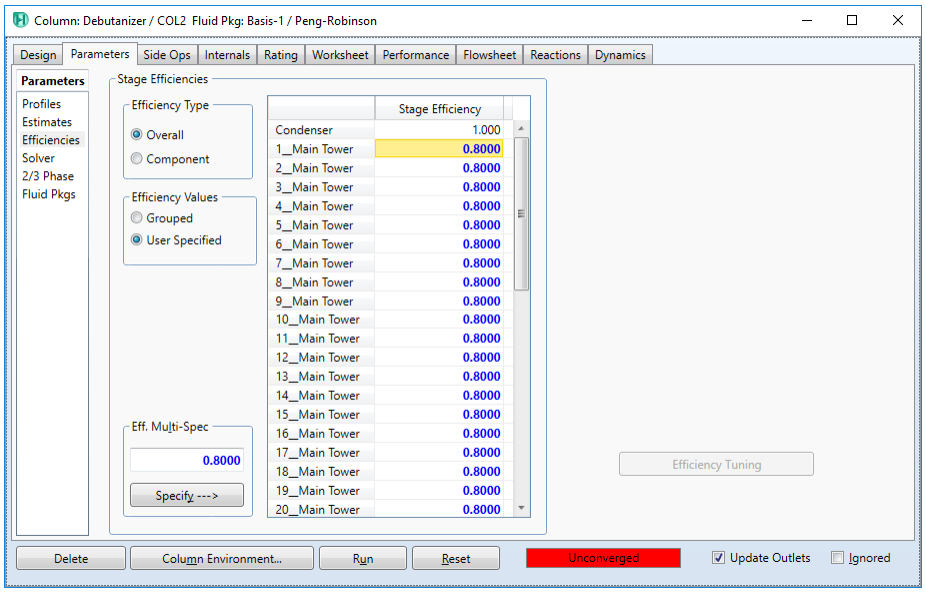


For this tower we will skip entering temperature estimates. Click *Next>*.

On the next form enter the reflux ratio & distillate rate. Click *Done…* when finished.



The final step before trying to run is to specify the stage efficiencies to model the stages as real trays. Under the *Parameters* tab select *Efficiencies*. Make sure that *Overall* & *User Specified* items are highlighted. Apply the same efficiency to all stages representing trays, leaving the efficiencies for the Condenser & Reboiler at 1.0.

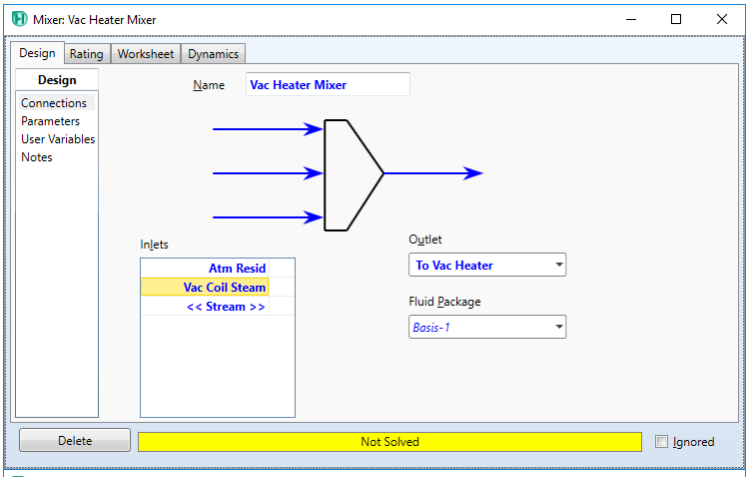


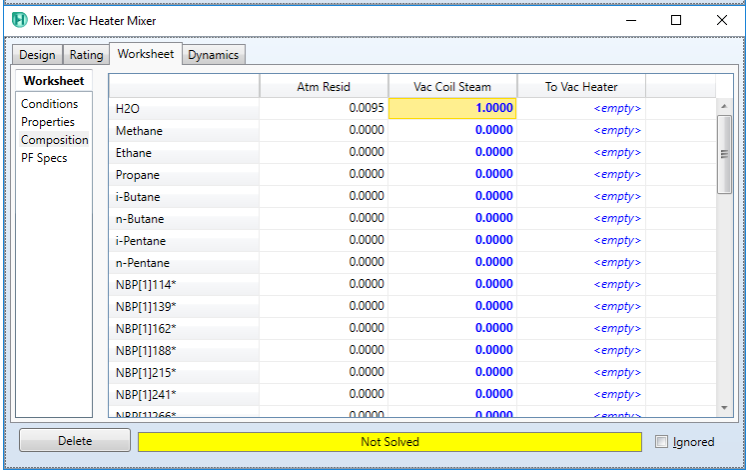
Now we can click on the *Run* button. The convergence should be very rapid.

Vacuum Distillation Column

The final step is to define the feed heater & Vacuum Distillation Column. Additional steam is injected into the Vacuum Feed Heater to increase velocity & minimize coke formation within the heater. Even though the Vacuum Column is packed it will be modeled as "trays," i.e., sections of non-equilibrium stages.

The first step is to mix the *Atm Resid* from the Atmospheric Distillation Column with steam upstream of the Vacuum Heater. Place a *Mixer* on the flowsheet & define the following configuration. You will have to define the steam stream; this can be done via the *Worksheet* tab.





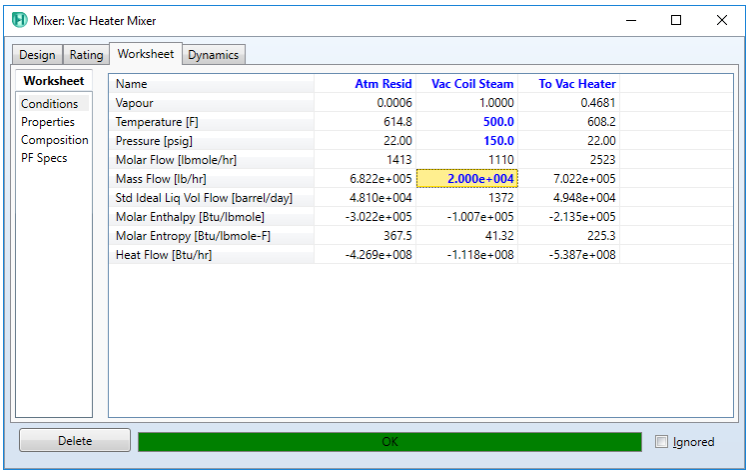
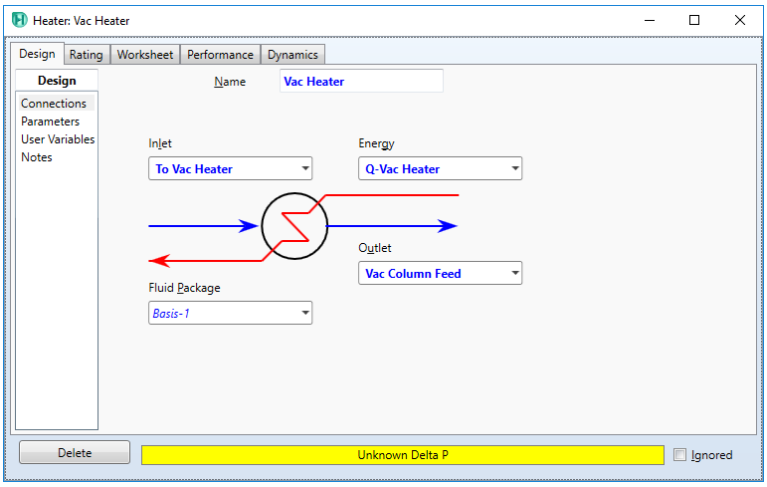
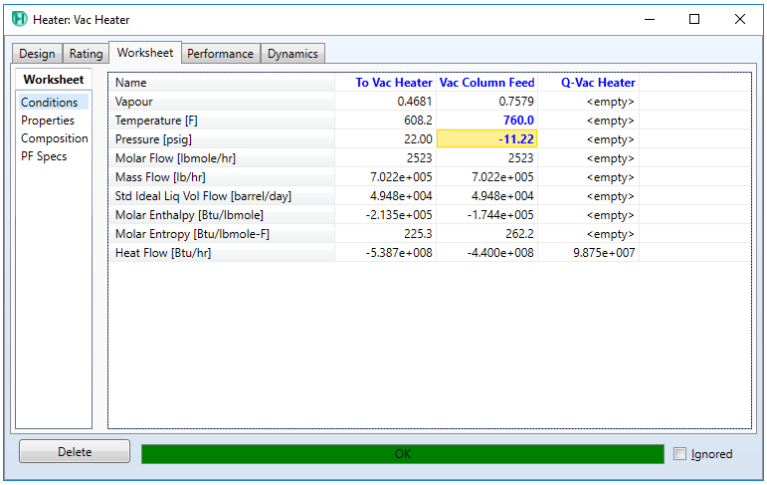


Table 6. Definitions for Vacuum Distillation Column

Type	Operating Parameter
"Trays" & Efficiencies	14 trays. Numbering from top: Tray 1: 100% Trays 2 to 11: 50% Tray 12: 100% Trays 13 to 14: 30%
Condenser Type	No condenser, LVGO pumparound liquid return to top stage
Reboiler Type	None, Direct Fired Heater
Pressures	Top Tray: 50 mmHg Bottom Tray: 62 mmHg
Temperatures	Top 180°F (controlled by top LVGO pumparound)
Feed Locations	Crude oil to Tray #12 Stripping Steam at bottom (Tray #14) – 20,000 lb/hr @ 500°F, 150 psig
Feed Heater	20,000 lb/hr steam injected into heater coils with the Atmospheric Resid feedstock (500°F & 150 psig) Outlet @ 180 mmHg & 760°F (max); would like 3,000 bpd excess wash liquid (liquid rate from tray above feed, #11)
Pumparounds	LVGO Pumparound Draw from Tray #4, returned to Tray #1 22,300 bpd flow, outlet temperature adjusted to control top temperature of tower; approximately 85°F, 42 MMBtu/hr cooling
	HVGO Pumparound Draw from Tray #8, returned to Tray #5 50,000 bpd flow, 150°F cooling
Products	LVGO from Tray #4; 915°F D1160 T95; 5,000 bpd (approximate) HVGO from Tray #8, 1050°F D1160 T95; 21,000 bpd (approximate) Slop Wax from Tray #11, 1,000 bp Vacuum resid from bottom

The fired Vacuum Heater is separate from the column environment & will be created next. Create a new *Heater* on the flowsheet & call it *Vac Heater*. Change the icon to look like a heater instead of a shell & tube heat exchanger. Enter the following connections & set the following outlet conditions to match the vacuum column conditions in Table 6. Note that even though the pressure is specified as *180 mmHg(0C)* the value is immediately converted to the units used in the flowsheet, here *psig*[3].





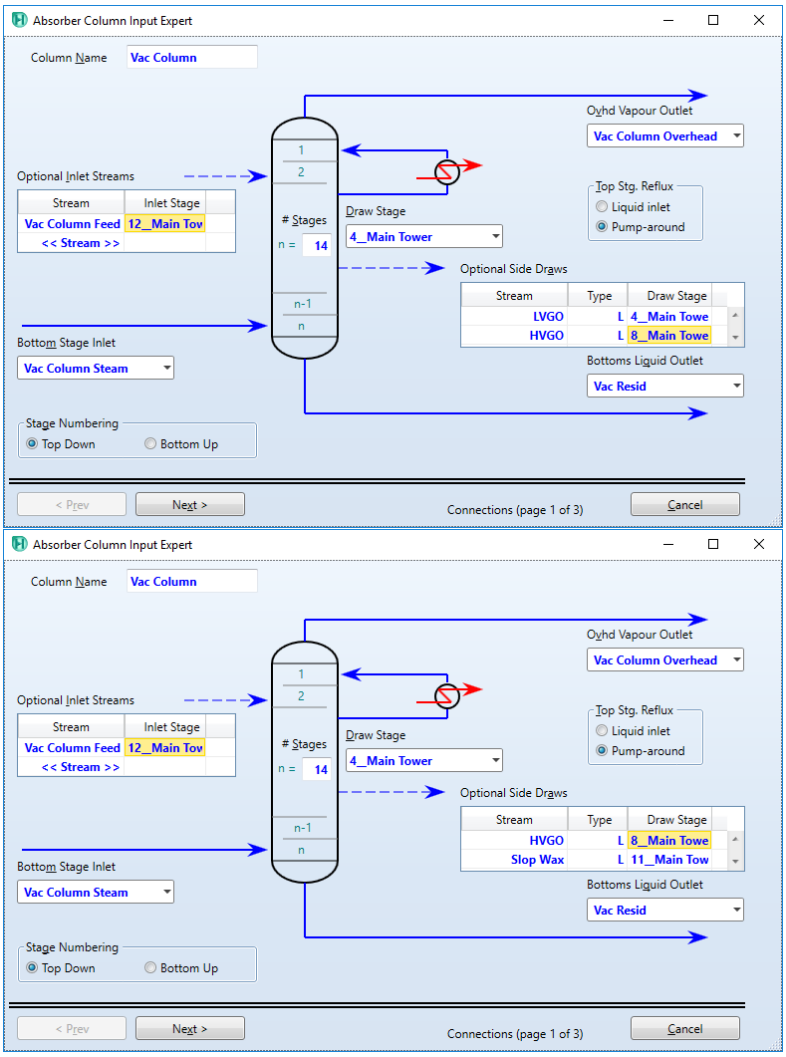
Name	To Vac Heater	Vac Column Feed	Q-Vac Heater
Vapour	0.4681	0.7579	<empty>
Temperature [F]	608.2	760.0	<empty>
Pressure [psig]	22.00	-11.22	<empty>
Molar Flow [lbmole/hr]	2523	2523	<empty>
Mass Flow [lb/hr]	7.022e+005	7.022e+005	<empty>
Std Ideal Liq Vol Flow [barrel/day]	4.948e+004	4.948e+004	<empty>
Molar Enthalpy [Btu/lbmole]	-2.135e+005	-1.744e+005	<empty>
Molar Entropy [Btu/lbmole-F]	225.3	262.2	<empty>
Heat Flow [Btu/hr]	-5.387e+008	-4.400e+008	9.875e+007

Configuring the Vacuum Column for the first time is a multi-step process. First, create an *Absorber Column* on the flowsheet then double-click to fill in the information. Fill in the basic information for the configuration on the first form. Couple things that are different from the previous two columns:

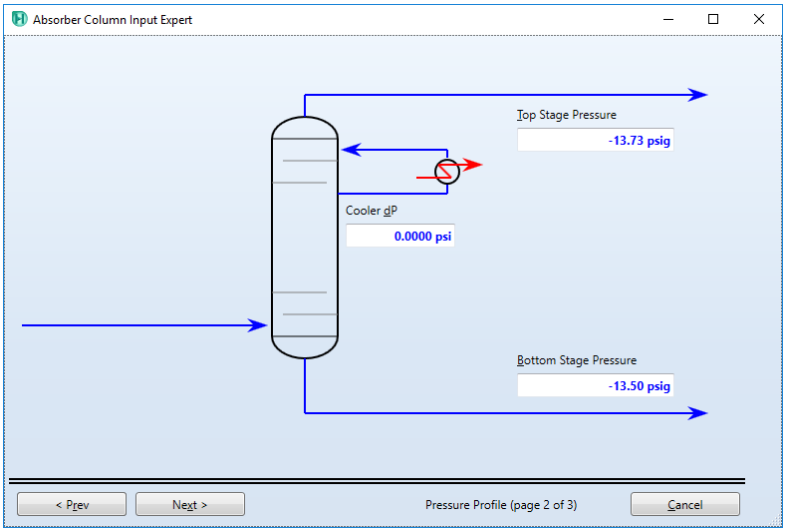
- Specify that the top stage reflux comes from a *Pump-around* (note that HYSYS will define this first pumparound & give it a default name; this can be changed later).
- Specify the *LVGO*, *HVGO*, & *Slop Wax* streams on this form as *Optional Side Draws* (since they are not further processed in side strippers). Note in the image below that

[3] Be very careful which units you choose for the pressure. If you choose *mmHg(0C)_g* by mistake you've specified a gauge pressure & will be much too high since it would be above 1 atm instead of at vacuum conditions.

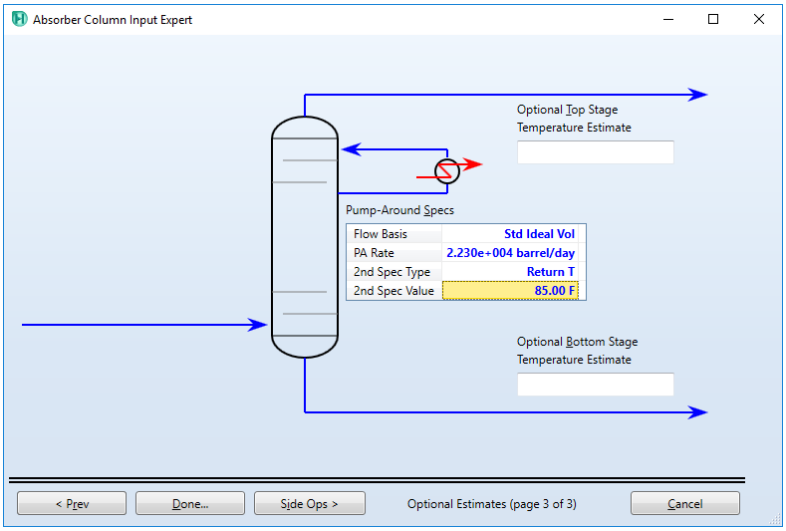
only 2 *Optional Side Draws* are shown; you will have to scroll down to see the connection for the *Slop Wax*.



On the next form we'll initialize the pressure profile. Again, even though the pressures are input in units of *mmHg(0C)* they get converted to *psig*. Click *Next>*.

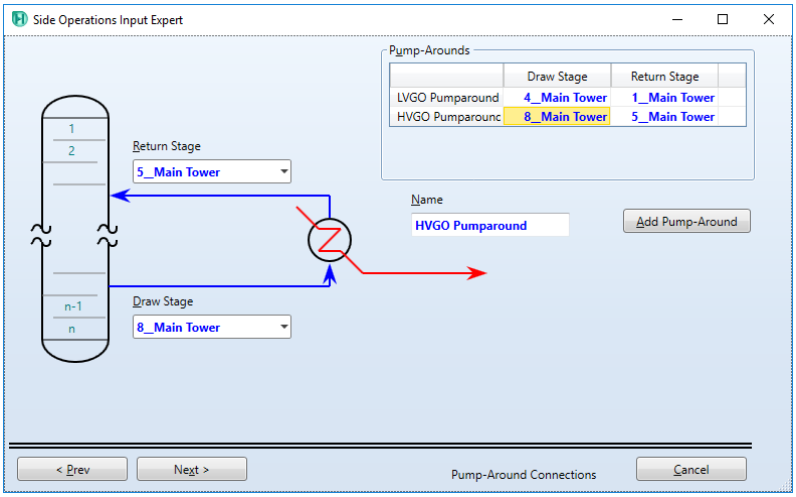


The next form will allow us to add temperature estimates & flow information for the top pumparound. Enter the data for the LVGO Pumparound. We will skip adding temperature estimates on this form & show how they can be added later. Click *Side Ops>*.



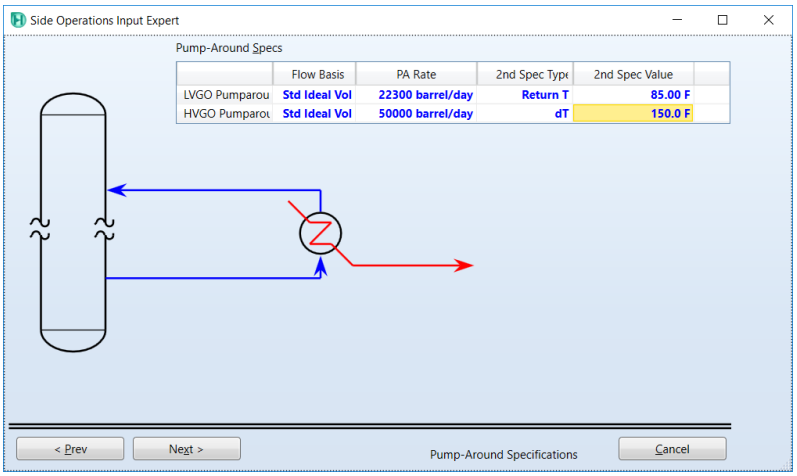
There are no side strippers or rectifiers so skip the next 3 forms for *Reboiled Side Stripper Connections*, *Steam Stripped Side Stripper Connections*, & *Side Rectifier Connections*.

There is already one pumparound defined (since we specified a pumparound return to provide the top stage reflux). Let's changed the Name from the default to *LVGO Pumparound*. Then click *Add Pump-Around* and define the *HVGO Pumparound*. Click Install to add to the list. Click *Next>* when done.

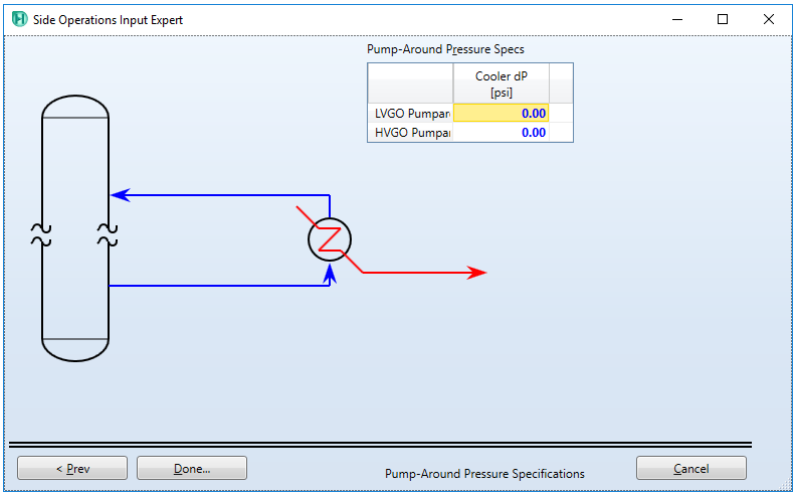


We will skip the next form for *Vapor Bypass Connections*.

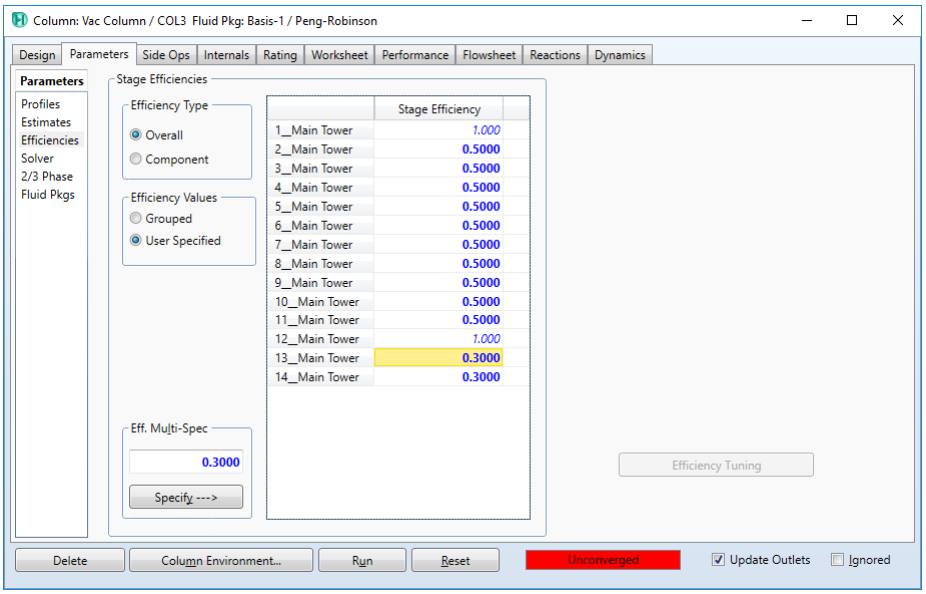
The next form allows us to add the HVGO Pumparound specs. Note that the specs for the LVGO Pumparound were previously entered & are shown here. Click *Next>* when done.



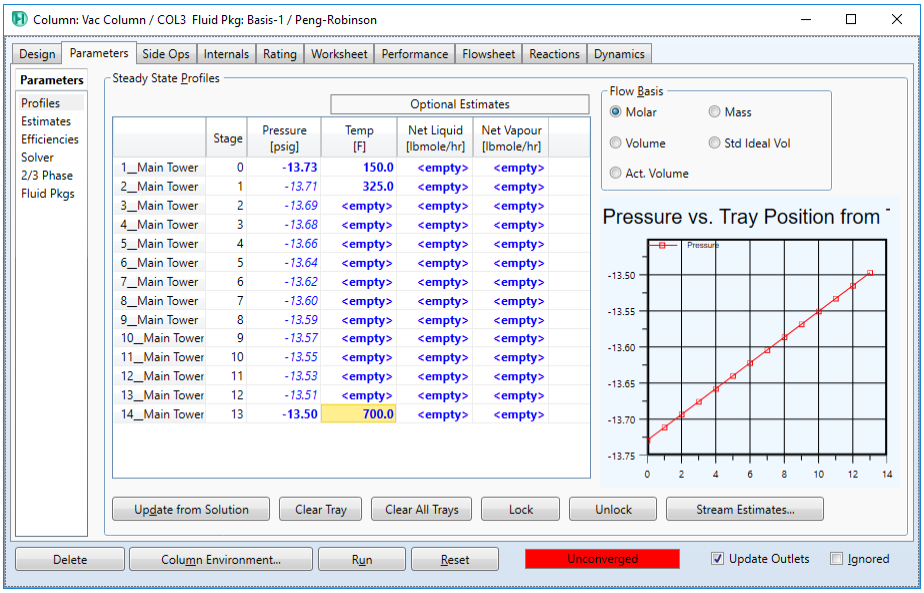
On the last form we will accept zero pressure drops through the pumparounds. Click *Done…*



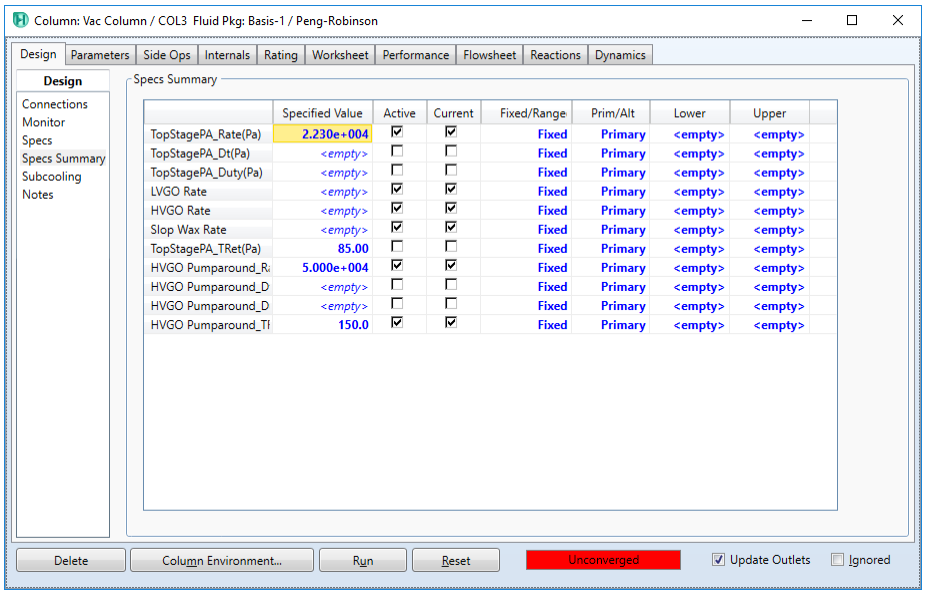
Before we try running the column we need to enter the efficiencies for the stages. Select *Efficiencies* under the *Parameters* tab & enter the values from Table 6.

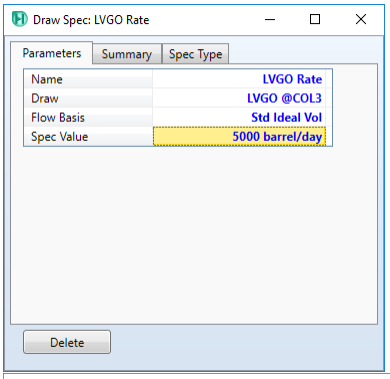


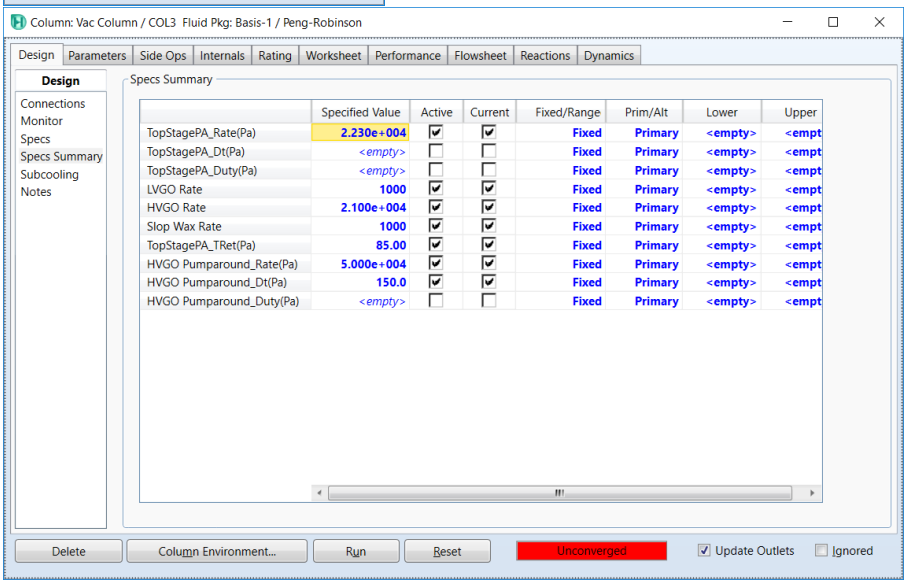
We skipped adding temperature estimates before but we can add them now. Go to the *Profiles* item under the *Parameters* tab. It's pretty typical to have a top temperature of about 150°F (this will actually be changed to be one of our specifications) & a bottom temperature of 700°F. You may also want to specify the 2nd stage temperature of 325°F (since there is a significant cooling between the top & next stage).



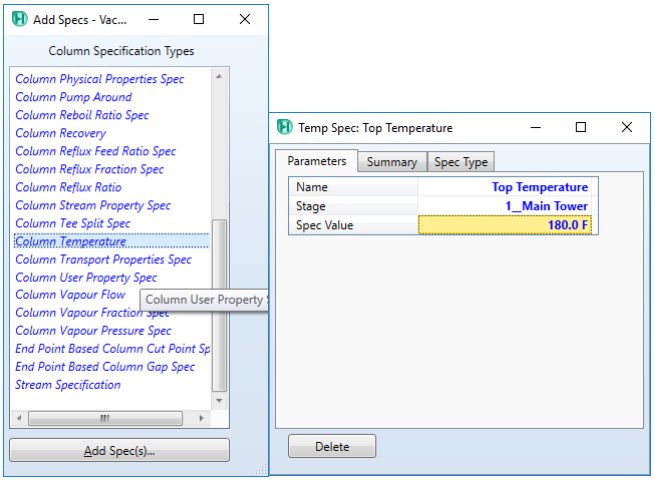
Before we can run the column we have to specify something about the side draws (*LVGO*, *HVGO*, & *Slop Wax*). Let's specify the estimated flowrates and use these as specifications. Click on the *Specs Summary* item under the *Design* tab; note there are items in this list for *LVGO Rate*, *HVGO Rate*, & *Slop Wax Rate*. You could try to specify the values here, but unfortunately the default units are molar rates, not volumetric. So, we'll have to go back to the Specs option & individually select the item for rate, press the View… button, & make the appropriate changes. When done you can go back to the Specs Summary item to see that all values have been added.

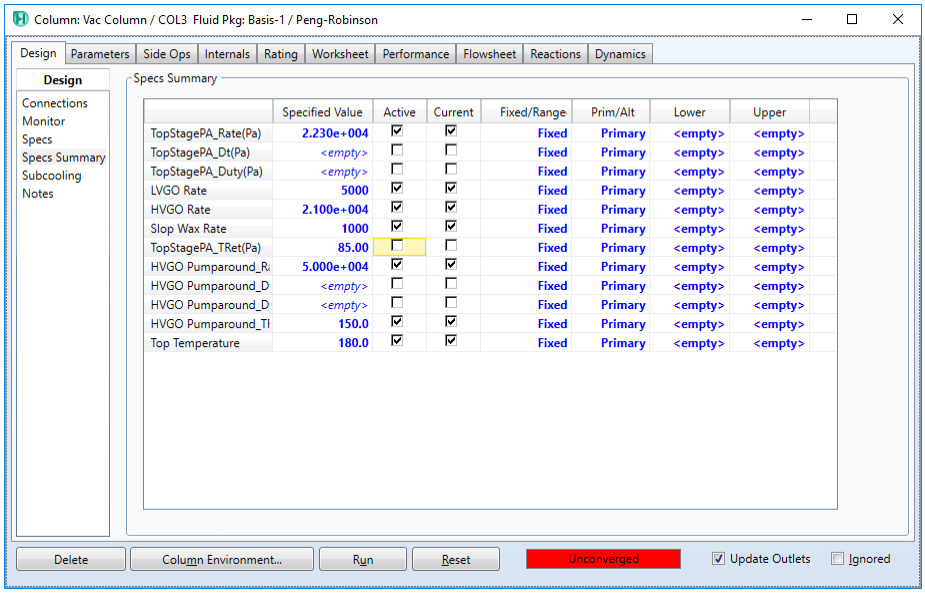




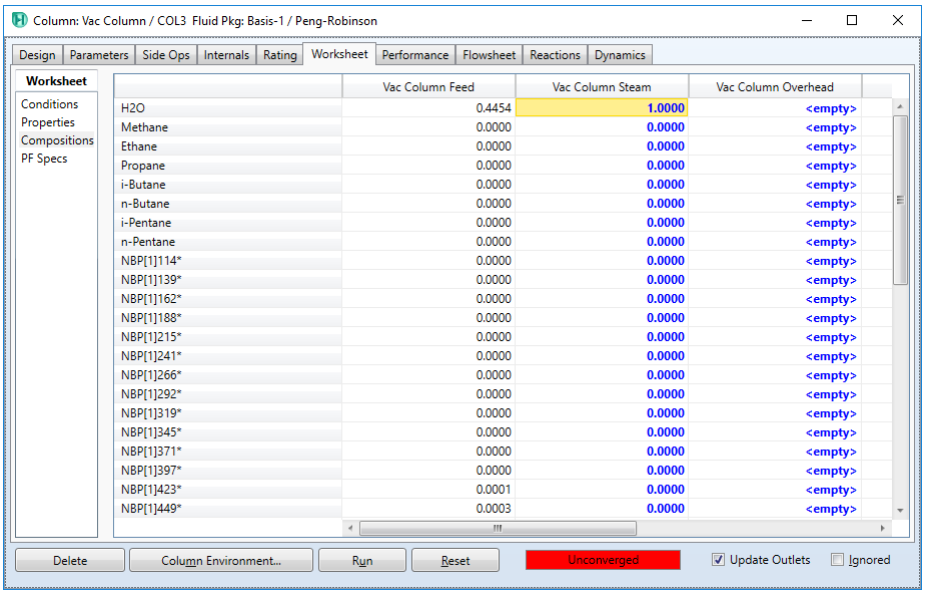


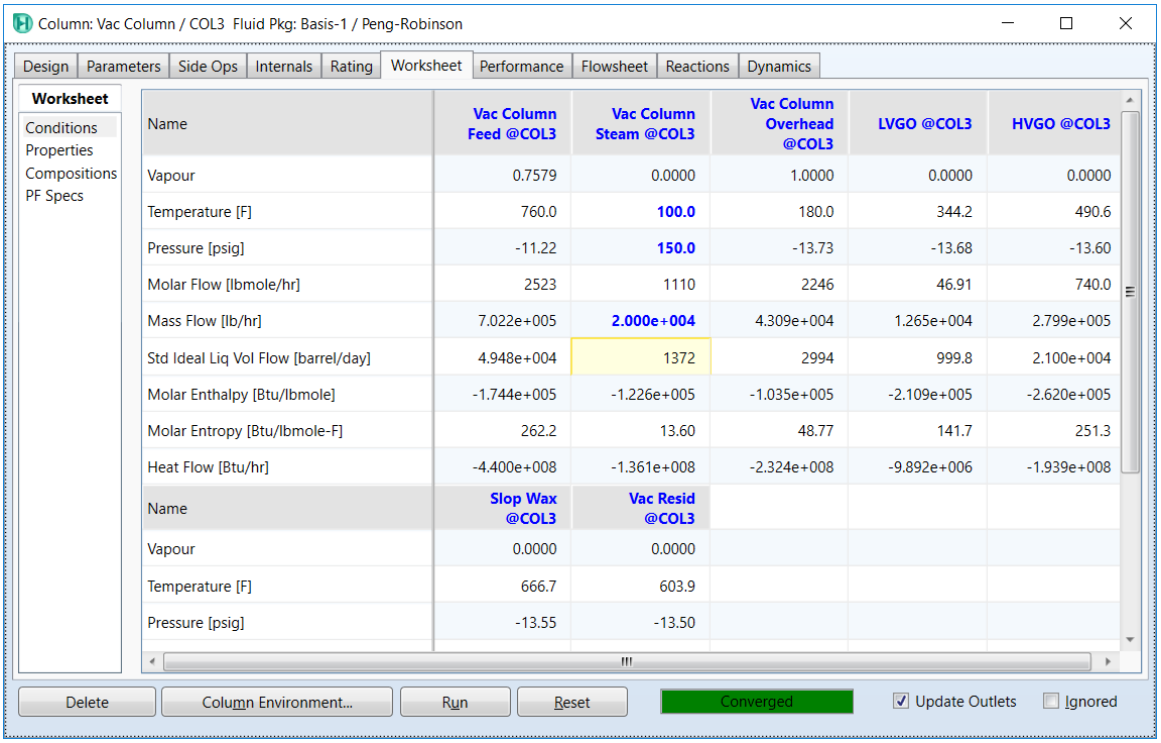
Now let's change the performance of the LVGO Pumparound to adjust the return temperature in that pumparound to meet the temperature spec at the top of the column. Select the *Specs* item under the *Design* tab & click *Add...* Select *Column Temperature* in the list of *Column Specification Types* & click *Add Spec(s)...* add a spec for the top temperature. To make it active go to the *Spec Summary* item, uncheck the *LVGO Pumparound_TRet(Pa)* & check the *Top Temperature* spec.





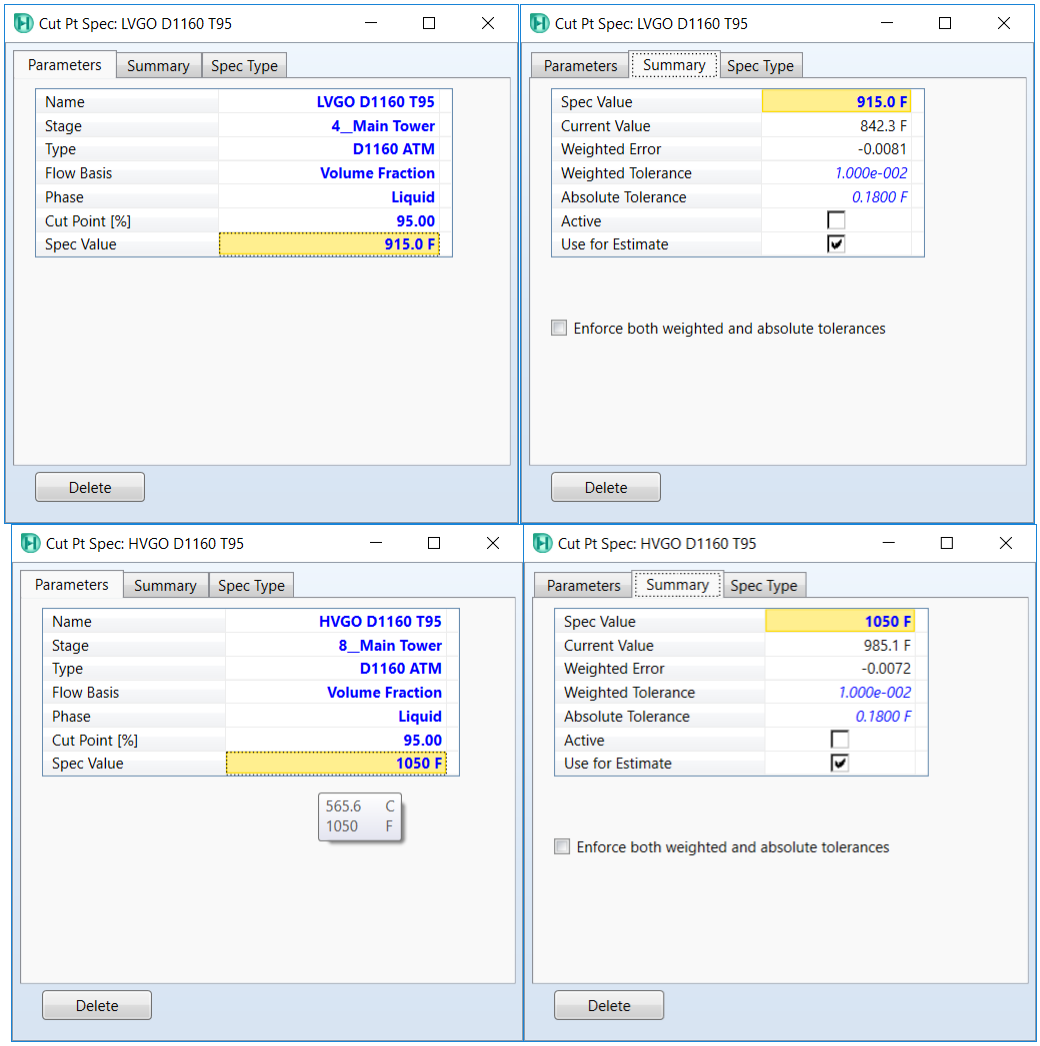
The final step is to define the steam to the bottom of the column. Under the *Worksheet* tab go to the *Compositions* item. Enter a 1 for the H2O value for *Vac Column Steam*. This brings up the screen to add detail to the composition; click *Normalize* & *OK*. Select the Conditions item & specify the *Temperature*, *Pressure*, & *Mass Flow*.



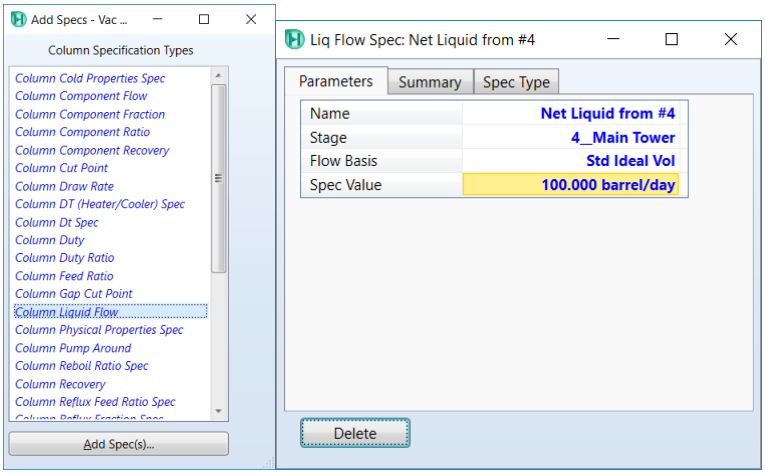


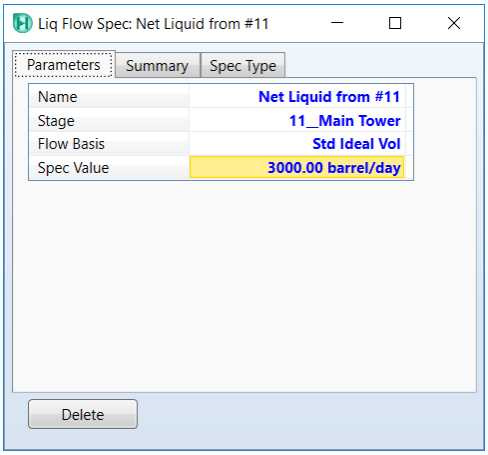
You may not even need to press *Run*. Once you enter the remaining steam information the Vacuum Column should automatically run & converge fairly quickly.

The Vacuum Column has converged but to the flowrates that should be estimates, not the composition specs (as defined by the T95 values). We can add the D1160 specs for the LVGO & HVGO in a similar manner to the Atmospheric Column specs except that these streams are direct liquid draws from the main column & do not go through side strippers. To set the LVGO spec first *Add* a *Column Cut Point* from the *Specs* item on the *Design* tab. However, for right now we do not want to make them active; click on the Summary tab & uncheck the *Active* box. You can also go to the *Specs Summary* item & make sure that these new D1160 specs are not checked in the *Active* column.



It is also useful to add specs for the liquids flowing from the LVGO to the HVGO section (from tray #4) and the overflash back to feed tray (from tray #11). These can be added as a *Column Liquid Flow* spec. Make sure you specify the values as *Std Ideal Vol* for the *Flow Basis* & ensure that the *Active* box is unchecked on the *Summary* tab's form.





Before we apply the D1160 specs for the HVGO & LVGO let's examine some of the internal flowrates. The most important is the liquid runback to the feed tray; this will be the liquid rate from Tray #11. Select the *Specs* item under the *Design* tab & then select the *Net from #11* item in the *Column Specifications*. In the *Specifications Details* area we can see that we'd like to apply a Specification Value of 3,000 bpd & currently have 12,800 bpd. We have some flexibility to pull additional HVGO and/or LVGO without drying up the column.

Let's look at the HVGO D1160 T95 value. We want 1050°F & we actually have 985.1°F. This is reasonably close; we'll increase the HVGO draw rate to increase this value to the spec. Go to the *Spec Summary*, uncheck the *Active* box for *HVGO Rate*, & check the *Active* box for *HVGO D1160 T95*. The simulation should quickly converge. Go back to the *Specs* form to check the actual HVGO D1160 T95 value; it should be 1050°F. (If not, press, *Reset* & *Run*.) Note that the HVGO rate is larger as expected, 25,580 bpd vs. 21,000 bpd. Also note that the *Net from #11* flowrate has decreased to 3,016 bpd.

Now let's look at the LVGO results. For 5,000 bpd LVGO rate the D1160 T95 value is too low, 853.2°F instead of the desired 915°F. Since the T95 value is too low, we can increase the LVGO draw rate to try to meet this spec. Let's apply this D1160 spec instead of the flowrate spec. The column will converge. The LVGO flow rate has increased to 7,661 bpd, the HVGO flow rate has actually decreased to 18,380 bpd, and the Tray #11 liquid runback has increased to 4,193 bpd.

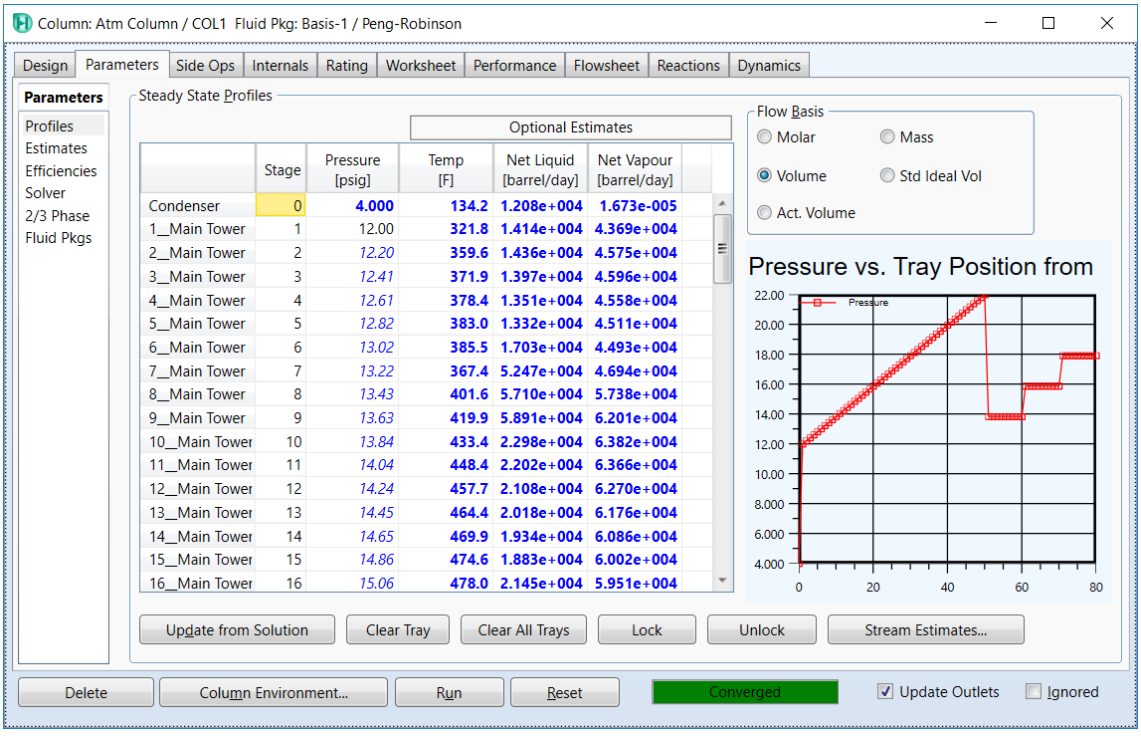
Let's go back to the runback rate. This rate is too large & how could we decrease? We actually have to back up to the Feed Heater & decrease the temperature so that we don't boil up as much gas oils. We can manually adjust to 751.1°F to get 3,008 bpd runback from Tray #11.

Stream & Unit Analyses

Now that the simulation has been run & converged we want to be able to analyze the results. First we'll look at ways of further examining unit & stream results.

First, let's look at the temperature & liquid/vapor traffic in the Atmospheric Column. Let's double click on *Atm Col* & click on the *Parameters* tab. Select the *Profiles* option & you can see the temperatures, pressures, & liquid & vapor flows for all of the trays (including the side stripper trays at the bottom of the list). Notice there are several options for showing the liquid & vapor flows: molar, mass, & 3 types of volume. The molar & mass quantities should be self-evident, but the volume factors are somewhat confusing:

- *Act. Volume* – this is the volumetric flow based on the density at the temperature & pressure conditions (as calculated by the corresponding density method, usually COSTALD). This is the most appropriate value to use when determining the hydrodynamics on the tray & within the column.
- *Volume* – this is the standard liquid volume as calculated from each component's specific gravity value & blended by the mass amount of each component in the mixture assuming ideal mixing (i.e., no shrinkage effects). This is the most normal definition for "standard liquid volume." Note the values in the vapor column are <u>not</u> related to the volumetric flow as a gas (ideal or otherwise); this is the volumetric flowrate if the vapor was condensed to a liquid.
- *Std Ideal Vol* – this is the volumetric flow calculated, not at the actual pressure & temperature for the fluid, but rather at the standard temperature & bubble point pressure (again by the COSTALD method). This will be very similar to the *Volume* value but will include shrinkage effects. This is a value calculated by HYSYS but very few other simulation programs. Note the values in the vapor column are <u>not</u> related to the volumetric flow as a gas (ideal or otherwise); this is the volumetric flowrate if the vapor was condensed to a liquid.



	Stage	Pressure [psig]	Temp [F]	Net Liquid [barrel/day]	Net Vapour [barrel/day]
Condenser	0	4.000	134.2	1.208e+004	1.673e-005
1_Main Tower	1	12.00	321.8	1.414e+004	4.369e+004
2_Main Tower	2	12.20	359.6	1.436e+004	4.575e+004
3_Main Tower	3	12.41	371.9	1.397e+004	4.596e+004
4_Main Tower	4	12.61	378.4	1.351e+004	4.558e+004
5_Main Tower	5	12.82	383.0	1.332e+004	4.511e+004
6_Main Tower	6	13.02	385.5	1.703e+004	4.493e+004
7_Main Tower	7	13.22	367.4	5.247e+004	4.694e+004
8_Main Tower	8	13.43	401.6	5.710e+004	5.738e+004
9_Main Tower	9	13.63	419.9	5.891e+004	6.201e+004
10_Main Tower	10	13.84	433.4	2.298e+004	6.382e+004
11_Main Tower	11	14.04	448.4	2.202e+004	6.366e+004
12_Main Tower	12	14.24	457.7	2.108e+004	6.270e+004
13_Main Tower	13	14.45	464.4	2.018e+004	6.176e+004
14_Main Tower	14	14.65	469.9	1.934e+004	6.086e+004
15_Main Tower	15	14.86	474.6	1.883e+004	6.002e+004
16_Main Tower	16	15.06	478.0	2.145e+004	5.951e+004

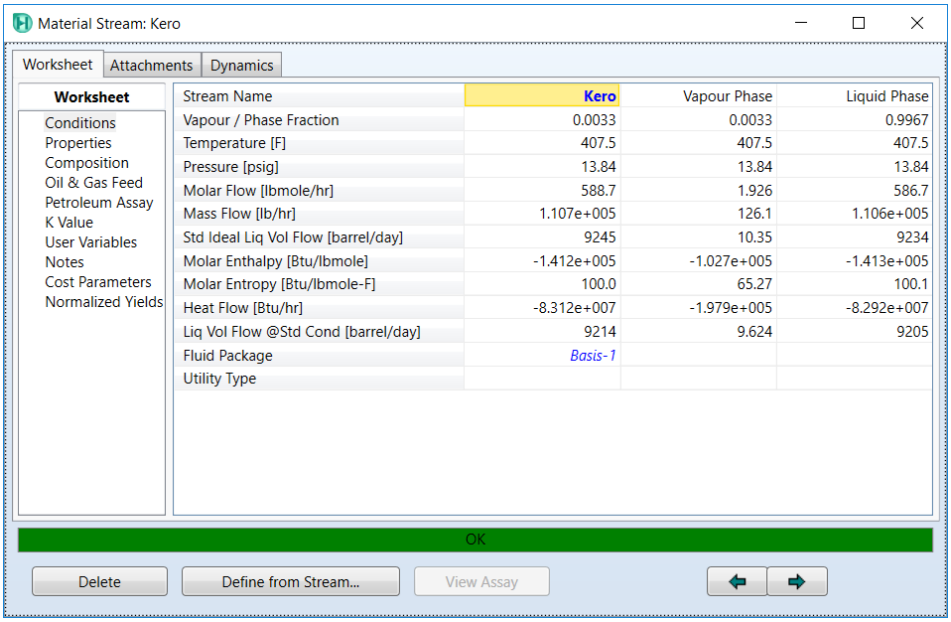
Which of these values should you use? This depends on your purpose:

- If you're trying to track how much of each fraction goes out with each side stream, then use the *Volume* values. As long as there is no chemical reaction these values are conserved (since they are essentially a transformed mass amount).
- If you are doing hydraulic calculations then use the *Act Volume* values.
- If you want to determine the ideal gas flows (such as scf of a produced light gas) then start with *Molar* flow values & convert the units as appropriate.

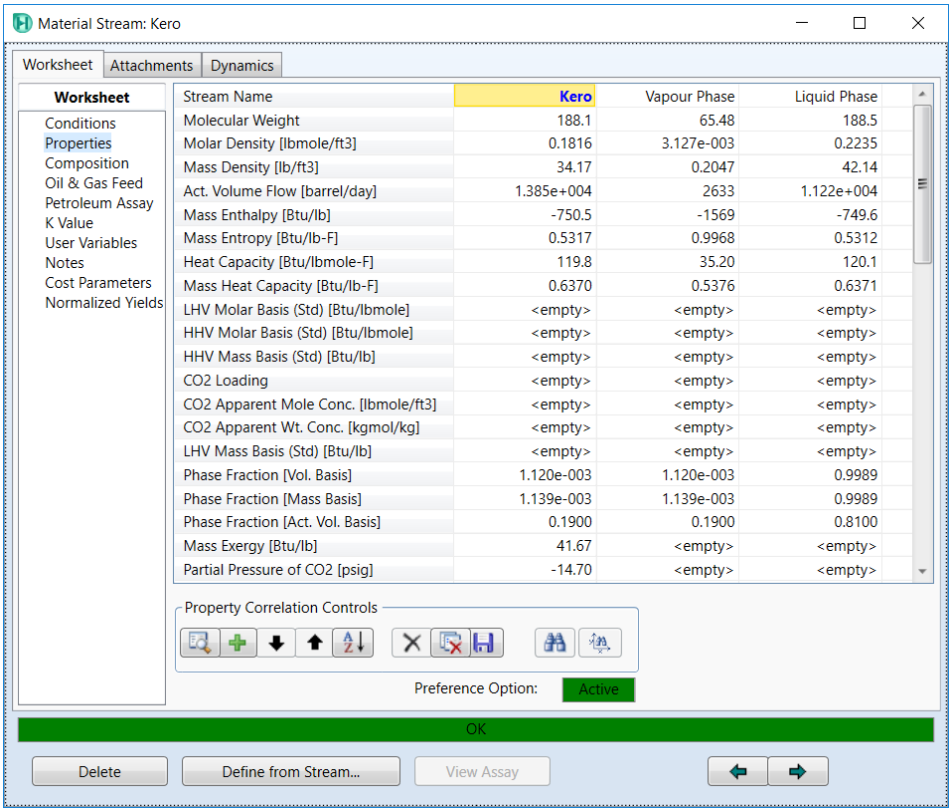
What are some of the properties of interest for streams? In general we will want to know:

- How much?
- What quality?
- At what conditions?

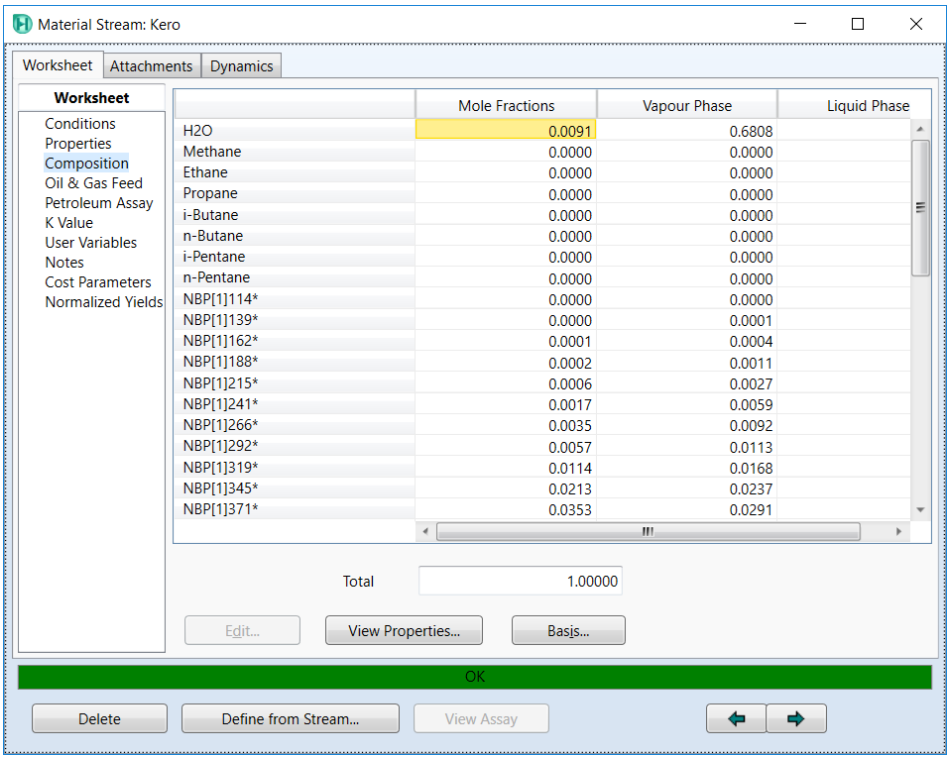
Let's first look at the Kerosene stream. We can double-click on the *Kero* stream in the Flowsheet & look at the *Conditions* item under the *Worksheet* tab. This shows us answers to "how much" & "at what conditions." We can see the pressure & temperature, flowrate in various sets of units (mass, molar, standard liquid volume, & actual volumetric flow at operating conditions).

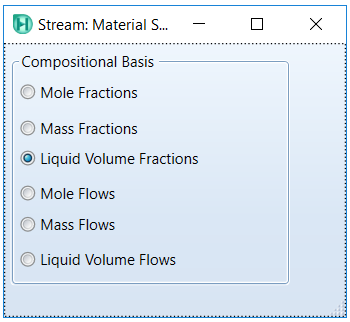


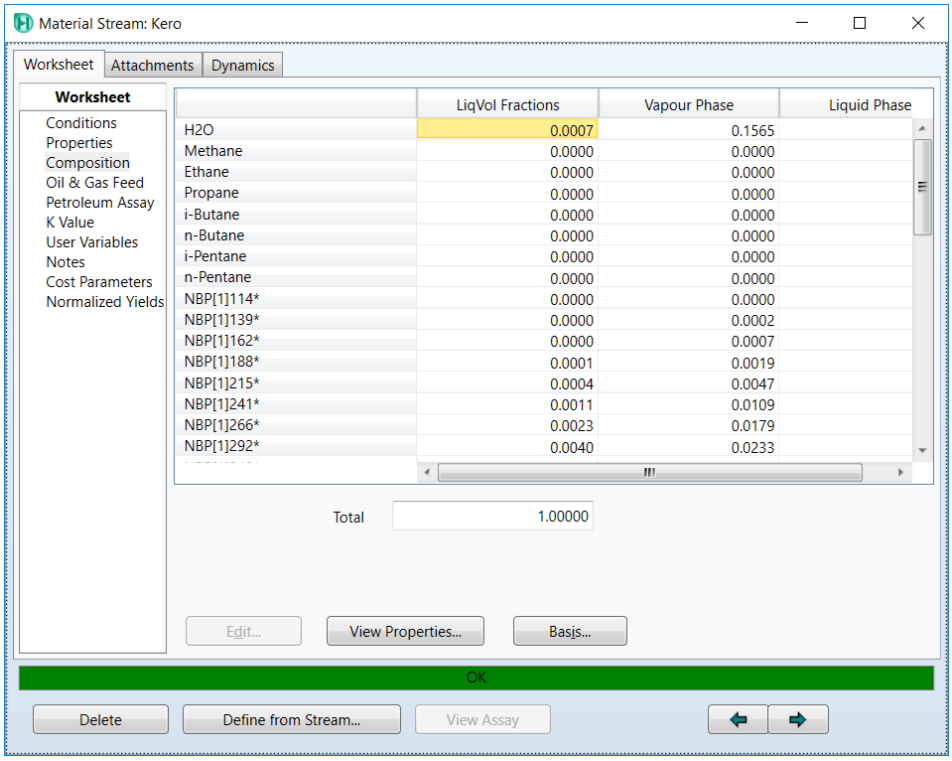
If we want to see other physical properties for this stream we would select the *Properties* item. Now we can see an extensive set of physical & transport properties for this stream. This answers a great deal of the "what quality" questions.

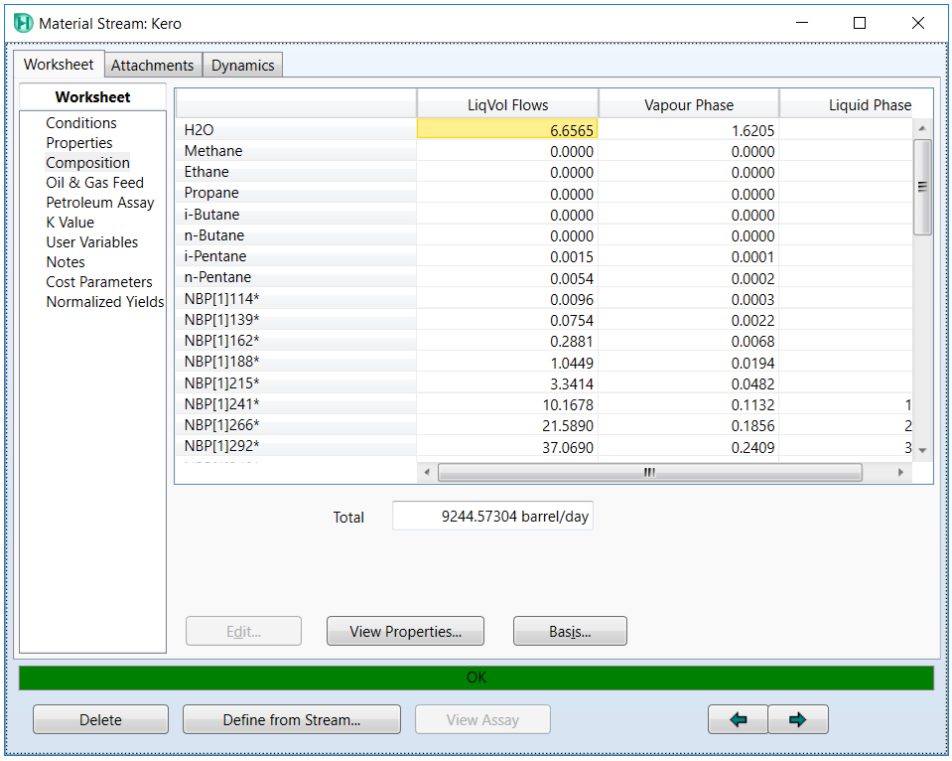


The *Composition* item will show tables of the stream's composition using multiple possible bases: molar, mass, & standard liquid volume. The default will generally be for mole fractions. But pressing the Basis… button will allow you to change to other types on both fractional & flowing values. When working with petroleum fluids the liquid volume fractions or flows are very convenient.



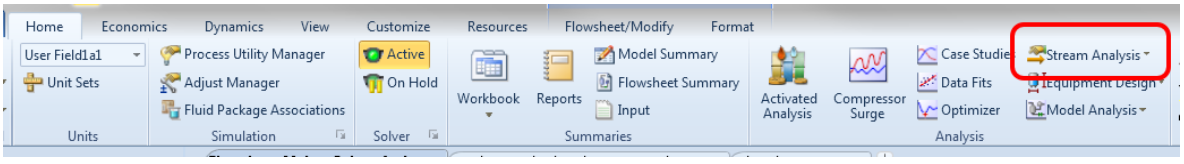

Stream: Material S...
Compositional Basis
Mole Fractions
Mass Fractions
Liquid Volume Fractions
Mole Flows
Mass Flows
Liquid Volume Flows

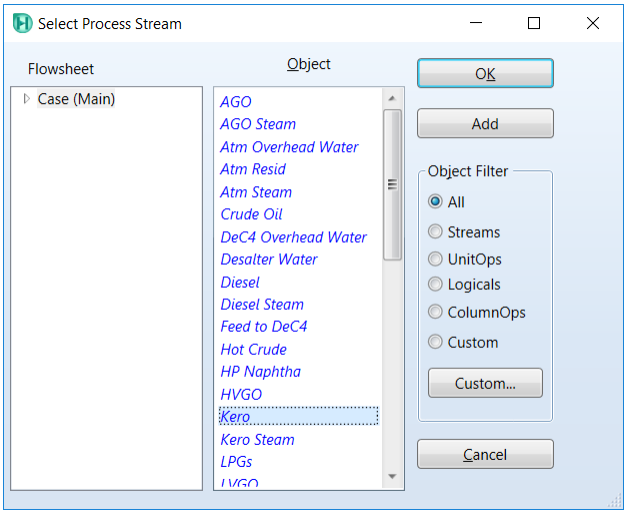

Material Stream: Kero
Worksheet
Attachments
Dynamics
Worksheet
Conditions
Properties
Composition
Oil & Gas Feed
Petroleum Assay
K Value
User Variables
Notes
Cost Parameters
Normalized Yields
LiqVol Fractions
Vapour Phase
Liquid Phase
H2O 0.0007 0.1565
Methane 0.0000 0.0000
Ethane 0.0000 0.0000
Propane 0.0000 0.0000
i-Butane 0.0000 0.0000
n-Butane 0.0000 0.0000
i-Pentane 0.0000 0.0000
n-Pentane 0.0000 0.0000
NBP[1]114* 0.0000 0.0000
NBP[1]139* 0.0000 0.0002
NBP[1]162* 0.0000 0.0007
NBP[1]188* 0.0001 0.0019
NBP[1]215* 0.0004 0.0047
NBP[1]241* 0.0011 0.0109
NBP[1]266* 0.0023 0.0179
NBP[1]292* 0.0040 0.0233
Total 1.00000
Edit...
View Properties...
Basis...
OK
Delete
Define from Stream...
View Assay



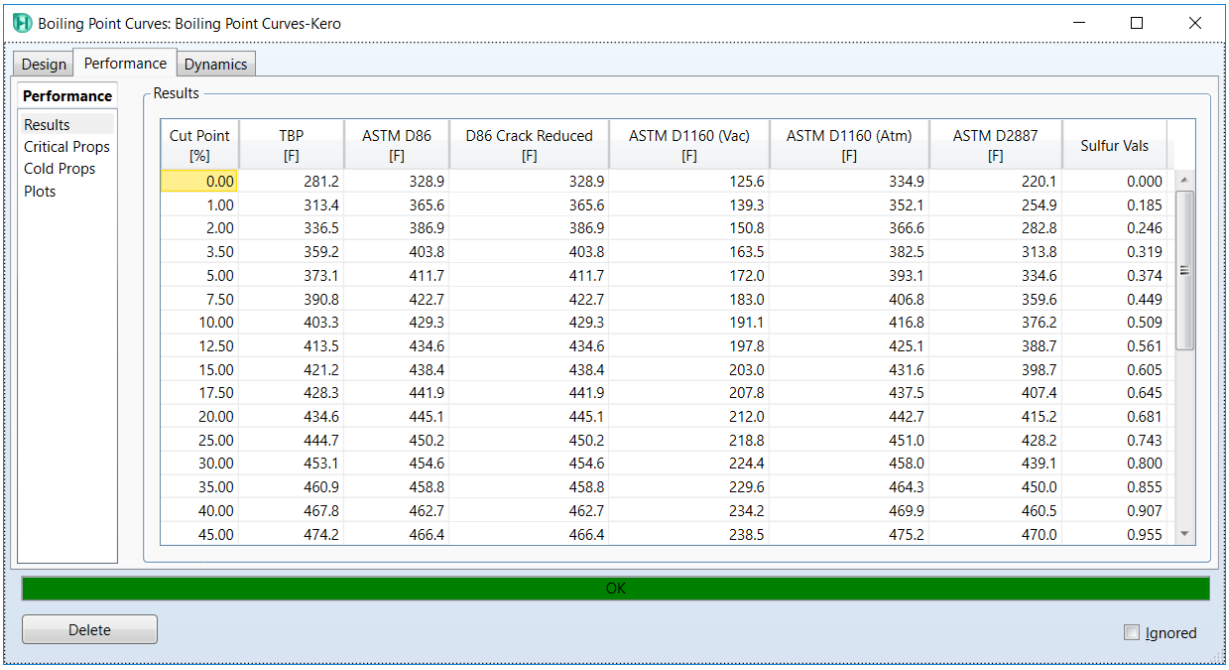
Since we are working with petroleum streams we may also want to determine the distillation curve associated with a stream composition. For this we'll use one of the *Stream Analysis* options. You can create a stream analysis for the first time by right-clicking on a stream & choosing *Create Stream Analysis*> & then *Boiling Point Curves*. A more general way to create a new analysis or review an existing analysis is to choose the *Steam Analysis* drop down list & choosing the *Boiling Point Curves* option in the *Home* tab of the ribbon. Choose the *Kerosene* stream & click *OK*.

> Please note that there is a second similar option, *Petroleum Assay*, but do not choose this. The two options give slightly different results. The *Boiling Point Curves* option is consistent with the correlations used for the tower specs. The *Boiling Point Curves* option is also consistent with what can be calculated using the amounts & boiling points for the pseudo components.

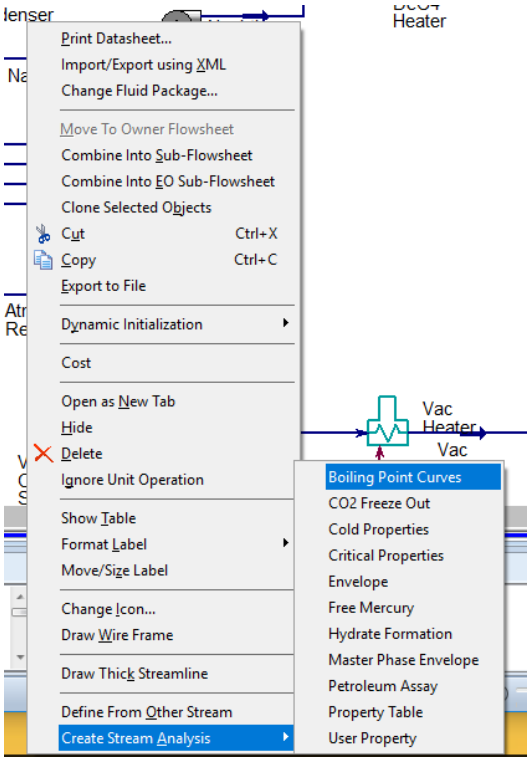




Note that we have various distribution curves based on the cumulative yield for the stream. Two of the curves that will be of most interest are the TBP & ASTM D86 curves. Note that not only can we get the results in tabular form but we can also directly make a plot.



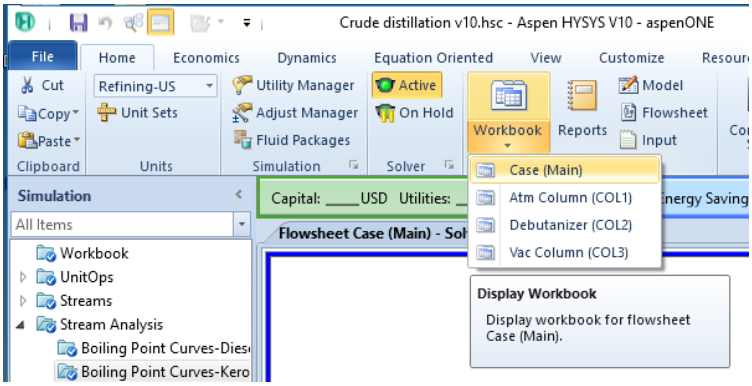
You can also create a Stream Analysis by right-clicking a stream & picking the appropriate option. For example, right-clicking on the Diesel stream can get you to the option shown & will create a set of boiling point curves.



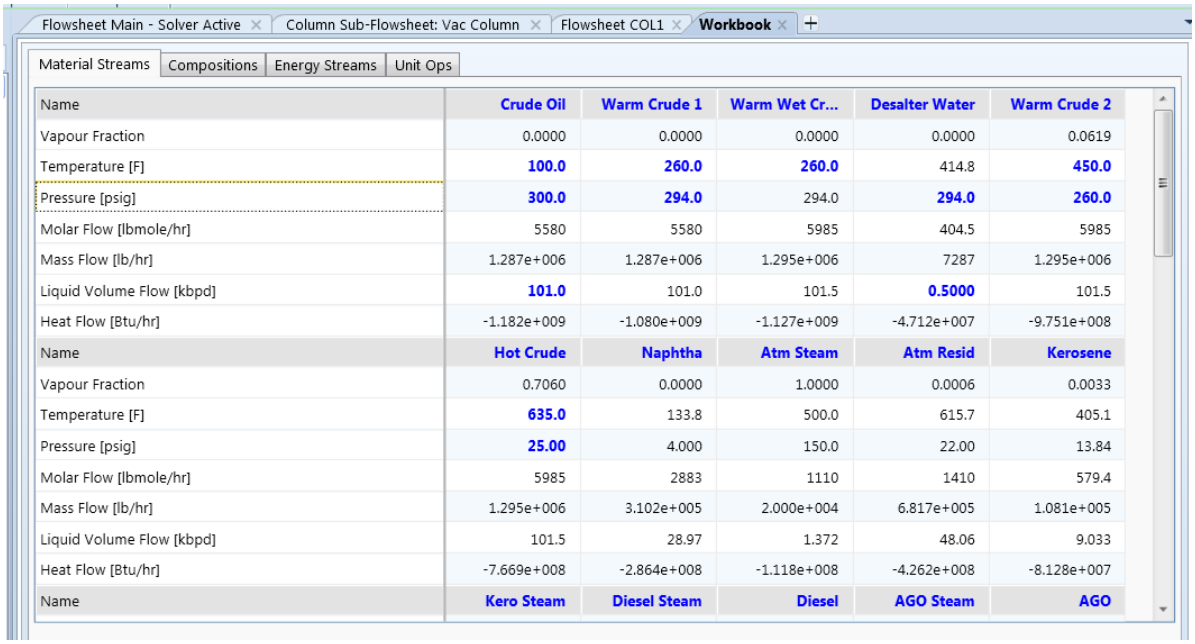
Export results to spreadsheet

There are many times that you'd like to create a general table of stream and/or unit results to a spreadsheet so that you pick & choose various values for *ad hoc* reports. There are a couple options for doing this.

HYSYS has a default workbook that summarizes a great deal of the stream & unit information in a single location. Click on the *Workbook* button under the *Home* tab of the ribbon & choose the default workbook for *Case (Main)*.



You should see a series of tabs that summarize the input & calculated results for the main flowsheet: conditions for the material streams, mole fractions for the pure & pseudo components for the material streams, values for the energy streams, & a summary listing for the unit operations.



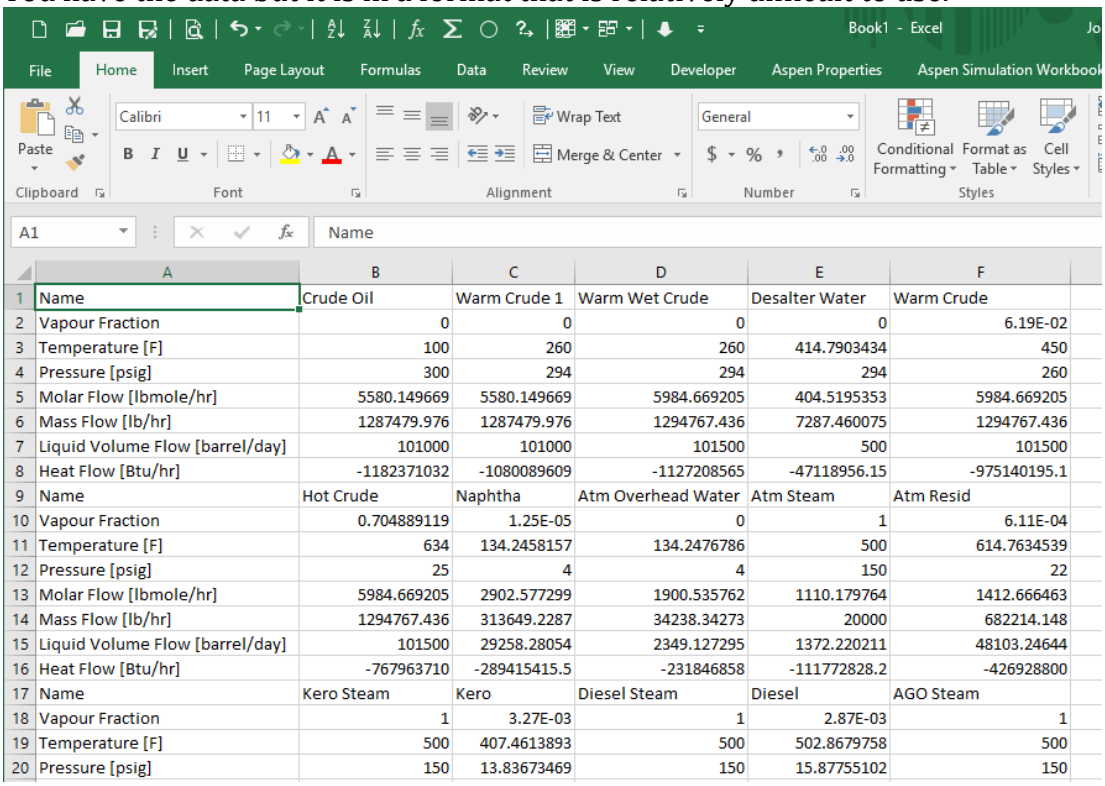
Name	Crude Oil	Warm Crude 1	Warm Wet Cr...	Desalter Water	Warm Crude 2
Vapour Fraction	0.0000	0.0000	0.0000	0.0000	0.0619
Temperature [F]	100.0	260.0	260.0	414.8	450.0
Pressure [psig]	300.0	294.0	294.0	294.0	260.0
Molar Flow [lbmole/hr]	5580	5580	5985	404.5	5985
Mass Flow [lb/hr]	1.287e+006	1.287e+006	1.295e+006	7287	1.295e+006
Liquid Volume Flow [kbpd]	101.0	101.0	101.5	0.5000	101.5
Heat Flow [Btu/hr]	-1.182e+009	-1.080e+009	-1.127e+009	-4.712e+007	-9.751e+008
Name	Hot Crude	Naphtha	Atm Steam	Atm Resid	Kerosene
Vapour Fraction	0.7060	0.0000	1.0000	0.0006	0.0033
Temperature [F]	635.0	133.8	500.0	615.7	405.1
Pressure [psig]	25.00	4.000	150.0	22.00	13.84
Molar Flow [lbmole/hr]	5985	2883	1110	1410	579.4
Mass Flow [lb/hr]	1.295e+006	3.102e+005	2.000e+004	6.817e+005	1.081e+005
Liquid Volume Flow [kbpd]	101.5	28.97	1.372	48.06	9.033
Heat Flow [Btu/hr]	-7.669e+008	-2.864e+008	-1.118e+008	-4.262e+008	-8.128e+007
Name	Kero Steam	Diesel Steam	Diesel	AGO Steam	AGO

Let's look at the table of *Material Streams*. Note that the default format is to have information for each stream in a column & items of information in each row. One might expect that the columns would continue out of view off to the right. Instead, however, only a small set of columns are shown & then the information for the next set of columns is shown below. This is unfortunate in that if you were to copy & paste into a spreadsheet this same format is retained. This can be demonstrated:

- Open up Excel
- Go back to HYSYS & select any cell
- Right-click & choose *Select All*
- Right-click & choose *Copy*
- Go back to Excel & highlight any cell (preferably A1)

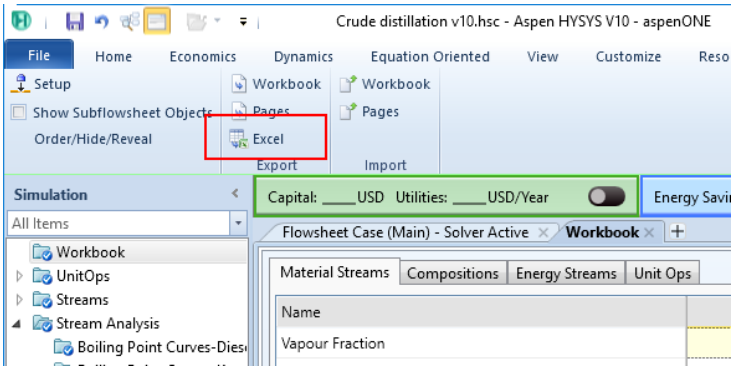
- Paste (either by pressing Ctrl-c or right-click & select the paste text icon). After resizing the columns in Excel you should see table like below.

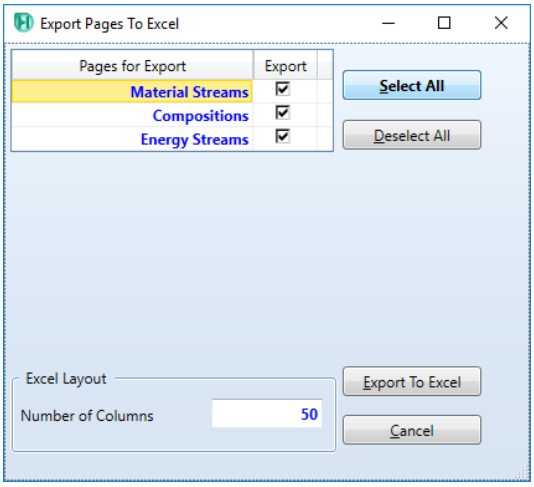
You have the data but it is in a format that is relatively difficult to use.



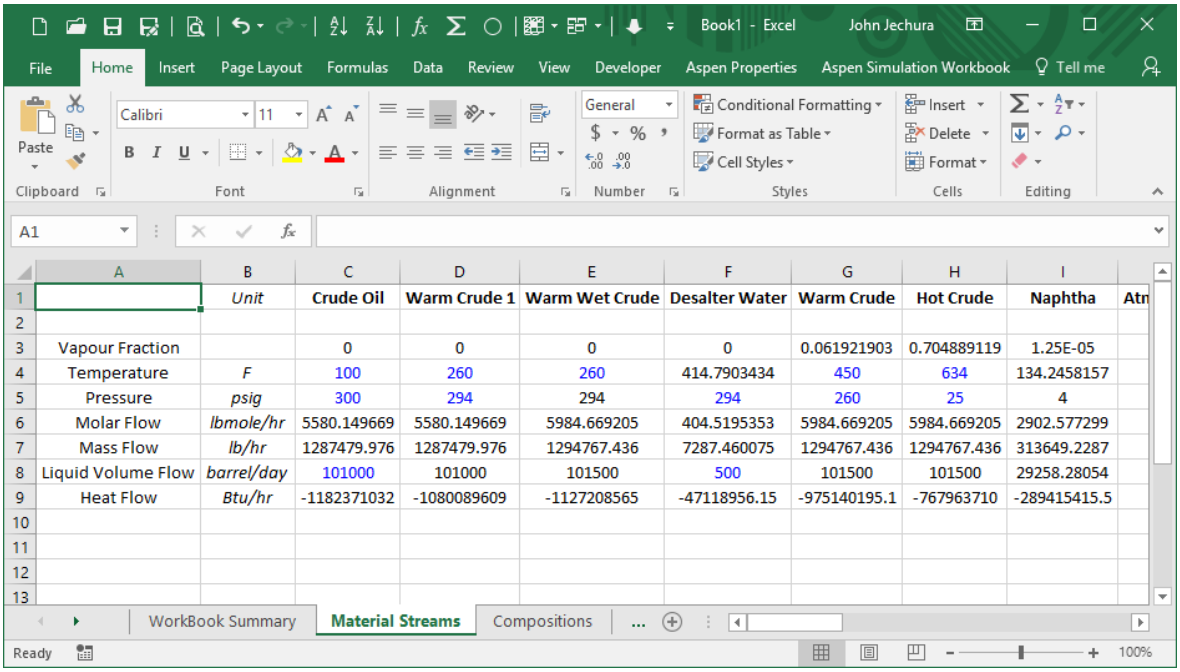
	A	B	C	D	E	F
1	Name	Crude Oil	Warm Crude 1	Warm Wet Crude	Desalter Water	Warm Crude
2	Vapour Fraction	0	0	0	0	6.19E-02
3	Temperature [F]	100	260	260	414.7903434	450
4	Pressure [psig]	300	294	294	294	260
5	Molar Flow [lbmole/hr]	5580.149669	5580.149669	5984.669205	404.5195353	5984.669205
6	Mass Flow [lb/hr]	1287479.976	1287479.976	1294767.436	7287.460075	1294767.436
7	Liquid Volume Flow [barrel/day]	101000	101000	101500	500	101500
8	Heat Flow [Btu/hr]	-1182371032	-1080089609	-1127208565	-47118956.15	-975140195.1
9	Name	Hot Crude	Naphtha	Atm Overhead Water	Atm Steam	Atm Resid
10	Vapour Fraction	0.704889119	1.25E-05	0	1	6.11E-04
11	Temperature [F]	634	134.2458157	134.2476786	500	614.7634539
12	Pressure [psig]	25	4	4	150	22
13	Molar Flow [lbmole/hr]	5984.669205	2902.577299	1900.535762	1110.179764	1412.666463
14	Mass Flow [lb/hr]	1294767.436	313649.2287	34238.34273	20000	682214.148
15	Liquid Volume Flow [barrel/day]	101500	29258.28054	2349.127295	1372.220211	48103.24644
16	Heat Flow [Btu/hr]	-767963710	-289415415.5	-231846858	-111772828.2	-426928800
17	Name	Kero Steam	Kero	Diesel Steam	Diesel	AGO Steam
18	Vapour Fraction	1	3.27E-03	1	2.87E-03	1
19	Temperature [F]	500	407.4613893	500	502.8679758	500
20	Pressure [psig]	150	13.83673469	150	15.87755102	150

There is an option to directly export the workbook information directly to Excel. Press the *Excel* button on the *Workbook* tab in the ribbon. Choose which of the pages you'd like to export (here we'll choose them all) & how many columns to produce before repeating below (50 should be sufficient for this example). Press *Export to Excel*. A set of macros will run that will open a new Excel spreadsheet & values will be copied from the HYSYS simulation to the spreadsheet. Be patient, this may take a while. (It might be a good time to get up & get that cup of coffee you've been wanting.)



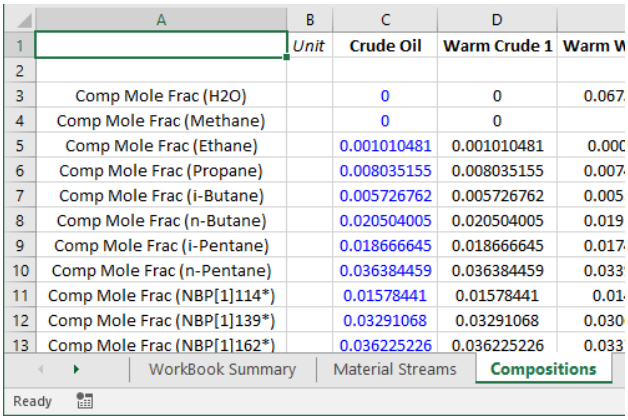


After adjusting column widths the product spreadsheet will look like the following. Note that there will be at least 50 columns before the information is repeated below row 9. Also, the color formatting showing the user input values (in blue) is retained.



	A	B	C	D	E	F	G	H	I
1		*Unit*	**Crude Oil**	**Warm Crude 1**	**Warm Wet Crude**	**Desalter Water**	**Warm Crude**	**Hot Crude**	**Naphtha**
2									
3	Vapour Fraction		0	0	0	0	0.061921903	0.704889119	1.25E-05
4	Temperature	*F*	100	260	260	414.7903434	450	634	134.2458157
5	Pressure	*psig*	300	294	294	294	260	25	4
6	Molar Flow	*lbmole/hr*	5580.149669	5580.149669	5984.669205	404.5195353	5984.669205	5984.669205	2902.577299
7	Mass Flow	*lb/hr*	1287479.976	1287479.976	1294767.436	7287.460075	1294767.436	1294767.436	313649.2287
8	Liquid Volume Flow	*barrel/day*	101000	101000	101500	500	101500	101500	29258.28054
9	Heat Flow	*Btu/hr*	-1182371032	-1080089609	-1127208565	-47118956.15	-975140195.1	-767963710	-289415415.5
10									
11									
12									
13									

There are a couple limitation to this default workbook report. One is the information reported in the *Composition* tab – it is only for the mole fractions. For petroleum streams liquid volume fraction would be more convenient. To get this then you'll have to create a custom workbook sheet and/or report.

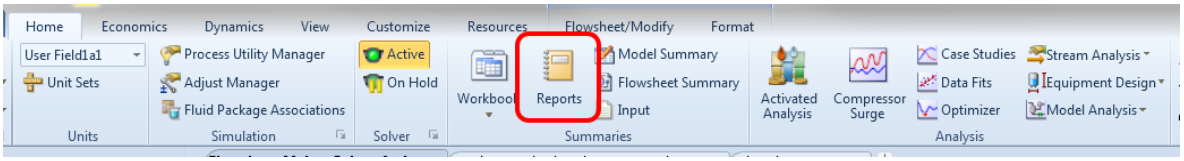


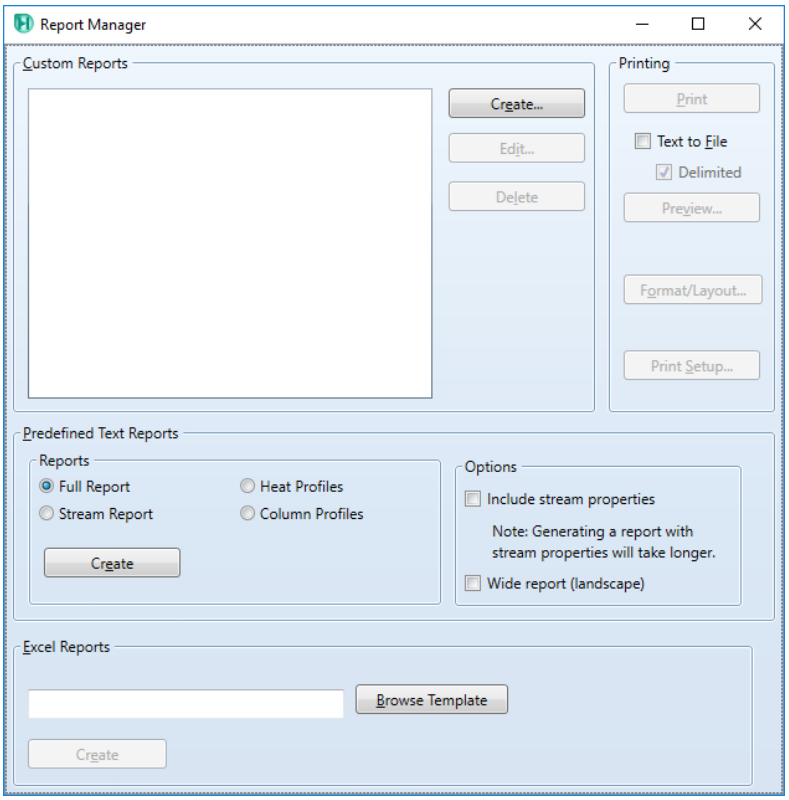
	A	B	C	D	
1		*Unit*	**Crude Oil**	**Warm Crude 1**	**Warm W**
2					
3	Comp Mole Frac (H2O)		0	0	0.067
4	Comp Mole Frac (Methane)		0	0	
5	Comp Mole Frac (Ethane)		0.001010481	0.001010481	0.000
6	Comp Mole Frac (Propane)		0.008035155	0.008035155	0.007
7	Comp Mole Frac (i-Butane)		0.005726762	0.005726762	0.005
8	Comp Mole Frac (n-Butane)		0.020504005	0.020504005	0.019
9	Comp Mole Frac (i-Pentane)		0.018666645	0.018666645	0.017
10	Comp Mole Frac (n-Pentane)		0.036384459	0.036384459	0.033
11	Comp Mole Frac (NBP[1]114*)		0.01578441	0.01578441	0.01
12	Comp Mole Frac (NBP[1]139*)		0.03291068	0.03291068	0.030
13	Comp Mole Frac (NBP[1]162*)		0.036225226	0.036225226	0.033

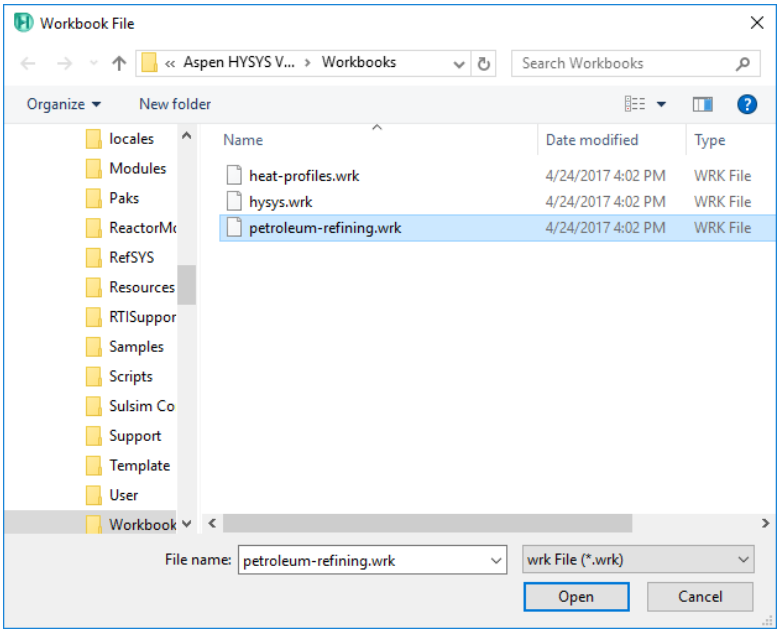
WorkBook Summary | Material Streams | **Compositions**

Ready

Let's look at some report options that come with HYSYS. Click on the *Reports* button in the *Home* tab of the ribbon. At the bottom of the form we'll want to choose one of the existing templates for the *Excel Reports*. Click on the *Browse Template* button. On the next window choose *petroleum-refining.wrk* (make sure you're in the appropriate folder to choose this). Now when you click on the *Create* button a set of macros will run that will open a new Excel spreadsheet & values will be copied from the HYSYS simulation to the spreadsheet. This will also take a while. (It might be a good time to refill that cup of coffee.)




Report Manager
Custom Reports
Create...
Edit...
Delete
Printing
Print
Text to File
Delimited
Preview...
Format/Layout...
Print Setup...
Predefined Text Reports
Reports
Full Report
Heat Profiles
Stream Report
Column Profiles
Create
Options
Include stream properties
Note: Generating a report with stream properties will take longer.
Wide report (landscape)
Excel Reports
Browse Template
Create


Workbook File
Aspen HYSYS V... › Workbooks
Search Workbooks
Organize
New folder
Name
Date modified
Type
heat-profiles.wrk 4/24/2017 4:02 PM WRK File
hysys.wrk 4/24/2017 4:02 PM WRK File
petroleum-refining.wrk 4/24/2017 4:02 PM WRK File
locales
Modules
Paks
RefSYS
Resources
Samples
Scripts
Support
Template
User
File name: petroleum-refining.wrk
wrk File (*.wrk)
Open
Cancel

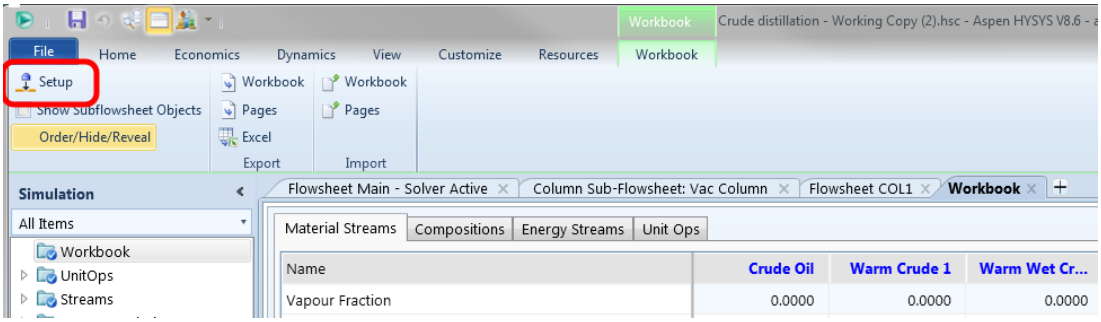
The Excel spreadsheet produced this time has additional information useful for analyzing petroleum streams. If you look at the *Compositions* tab you'll see that this still reports mole fractions (so no difference here). But if you look at the *Material Streams* tab you can see that a lot of the data from the *Conditions* & *Properties* items are in the *Material Streams* tab. This will also contain the TBP & D86 assay information from the *Steam Analysis*. (Unfortunately these are boiling point curves consistent with the *Petroleum Assay* option; we will not want to use these.)

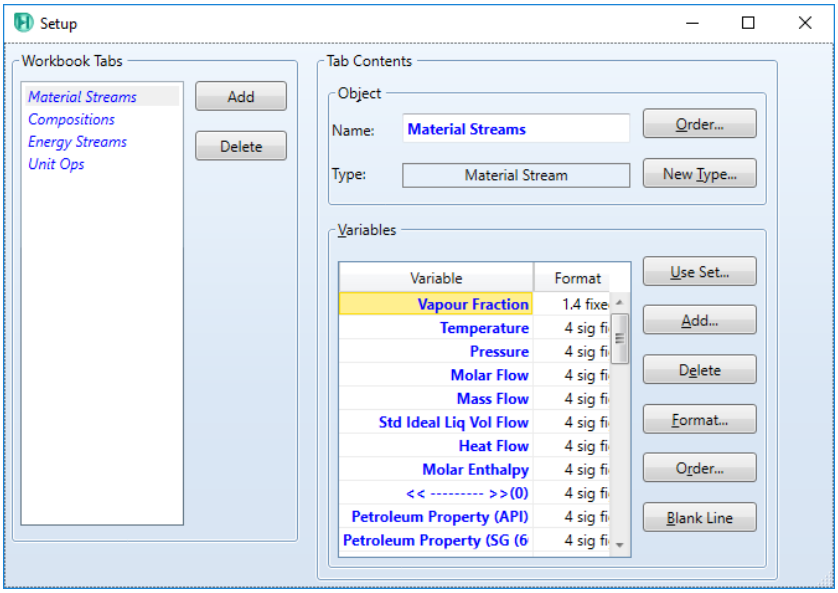
	A	B	C	D
1		*Unit*	**Crude Oil**	**'arm Crude**
2				
3	Vapour Fraction		0	0
4	Temperature	*F*	100	260
5	Pressure	*psig*	300	294
6	Molar Flow	*lbmole/hr*	5580.149669	5580.15
7	Mass Flow	*lb/hr*	1287479.976	1287480
8	Std Ideal Liq Vol Flow	*barrel/day*	101000	101000
9	Heat Flow	*Btu/hr*	-1182371032	-1.1E+09
10	Molar Enthalpy	*Btu/lbmole*	-211886.635	-193557
11				
12	Petroleum Property (API)		30.45122576	30.45123
13	Petroleum Property (SG (60/60))		0.873719846	0.87372
14	Petroleum Property (Std. Liquid Density)		872.8455144	872.8455
15	Petroleum Property (TBP 0%)		-142.361182	-142.361
16	Petroleum Property (TBP 5%)		58.55680548	58.55681
17	Petroleum Property (TBP 10%)		101.0484361	101.0484
18	Petroleum Property (TBP 30%)		225.6626161	225.6626
19	Petroleum Property (TBP 50%)		342.9879653	342.988
20	Petroleum Property (TBP 70%)		480.9265247	480.9265
21	Petroleum Property (TBP 90%)		684.5566077	684.5566
22	Petroleum Property (TBP 95%)		779.2329547	779.233
23	Petroleum Property (TBP 100%)		1030.52328	1030.523
24	Petroleum Property (D86 IBP)		-211.0065915	-211.007
25	Petroleum Property (D86 5%)		79.01897814	79.01898
26	Petroleum Property (D86 10%)		105.8314644	105.8315
27	Petroleum Property (D86 30%)		221.3332341	221.3332
28	Petroleum Property (D86 50%)		332.6289435	332.6289
29	Petroleum Property (D86 70%)		481.9480954	481.9481
30	Petroleum Property (D86 90%)		798.9690918	798.9691
31	Petroleum Property (D86 95%)		843.3786922	843.3787
32	Petroleum Property (D86 FBP)		895.8830114	895.883
33	Petroleum Property (Sulfur Wt Pct)		<empty>	<empty>

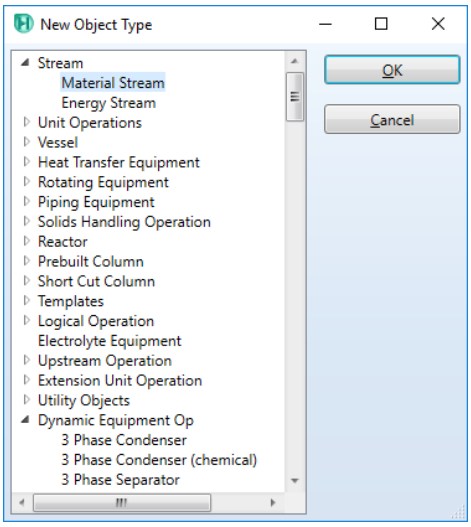
WorkBook Summary | **Material Streams** | Compositions | Energy Streams

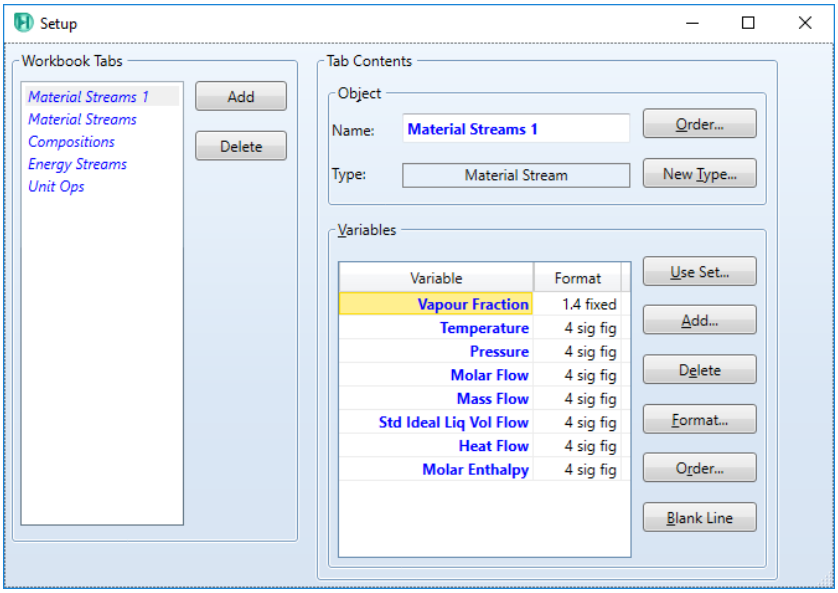
Let's go back to HYSYS & look at the workbook for *Case (Main)*. Notice that the *Materials Streams* tab has now been modified with the extra petroleum-related information that we see in the Excel spreadsheet. This implies that customizing the workbook & subsequently exporting to Excel is possible.

Let's create a new tab in the workbook for the liquid volume flows for each component. Select *Setup* under the *Workbook* tab in the ribbon. Let's *Add* a new *Workbook Tab*. Select the *Material Stream* type. Now there is a new tab called *Material Streams 1* with the basic stream conditions.

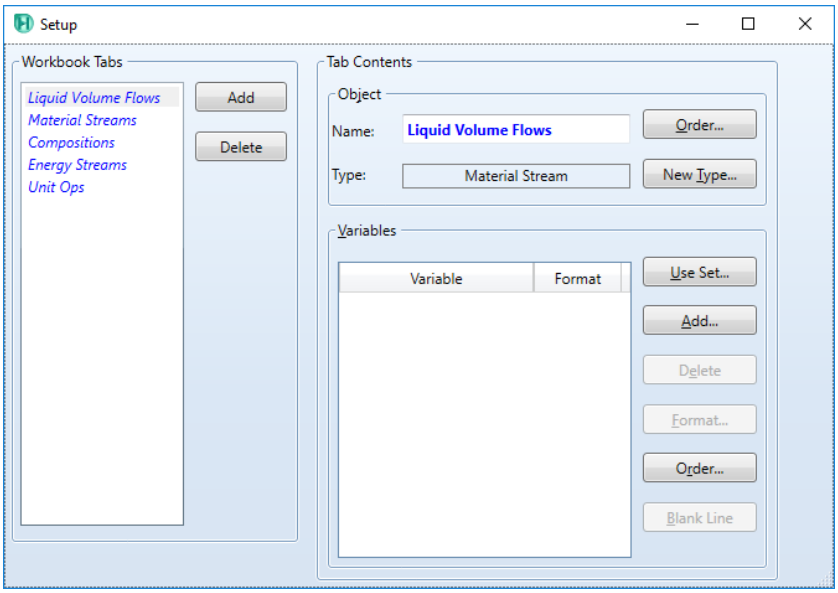



Setup
Workbook Tabs
Material Streams
Compositions
Energy Streams
Unit Ops
Add
Delete
Tab Contents
Object
Name:
Material Streams
Order...
Type:
Material Stream
New Type...
Variables
Variable
Format
Vapour Fraction
Temperature
Pressure
Molar Flow
Mass Flow
Std Ideal Liq Vol Flow
Heat Flow
Molar Enthalpy
<< --------- >> (0)
Petroleum Property (API)
Petroleum Property (SG (6
Use Set...
Add...
Delete
Format...
Order...
Blank Line

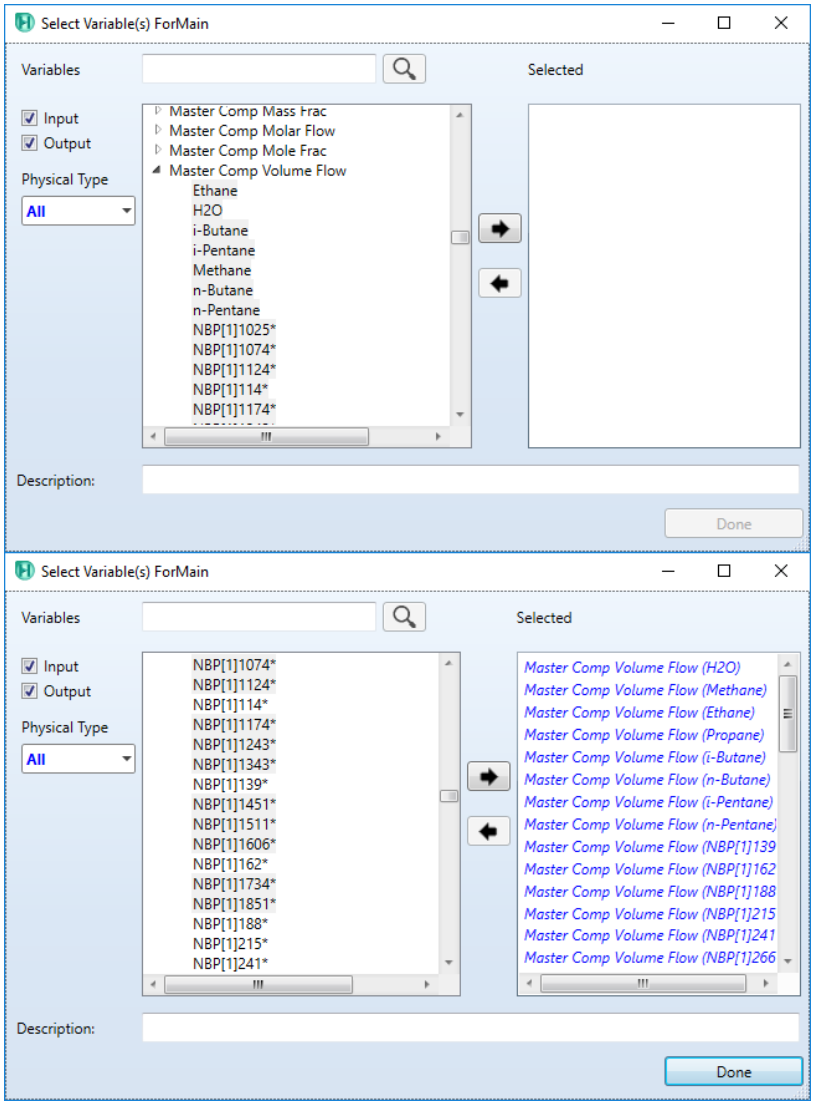

New Object Type
Stream
Material Stream
Energy Stream
Unit Operations
Vessel
Heat Transfer Equipment
Rotating Equipment
Piping Equipment
Solids Handling Operation
Reactor
Prebuilt Column
Short Cut Column
Templates
Logical Operation
Electrolyte Equipment
Upstream Operation
Extension Unit Operation
Utility Objects
Dynamic Equipment Op
3 Phase Condenser
3 Phase Condenser (chemical)
3 Phase Separator
OK
Cancel

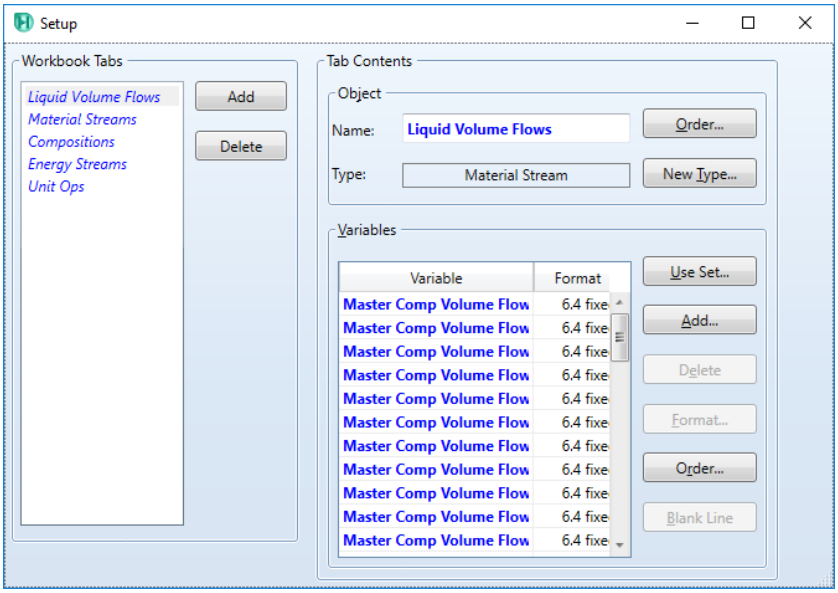


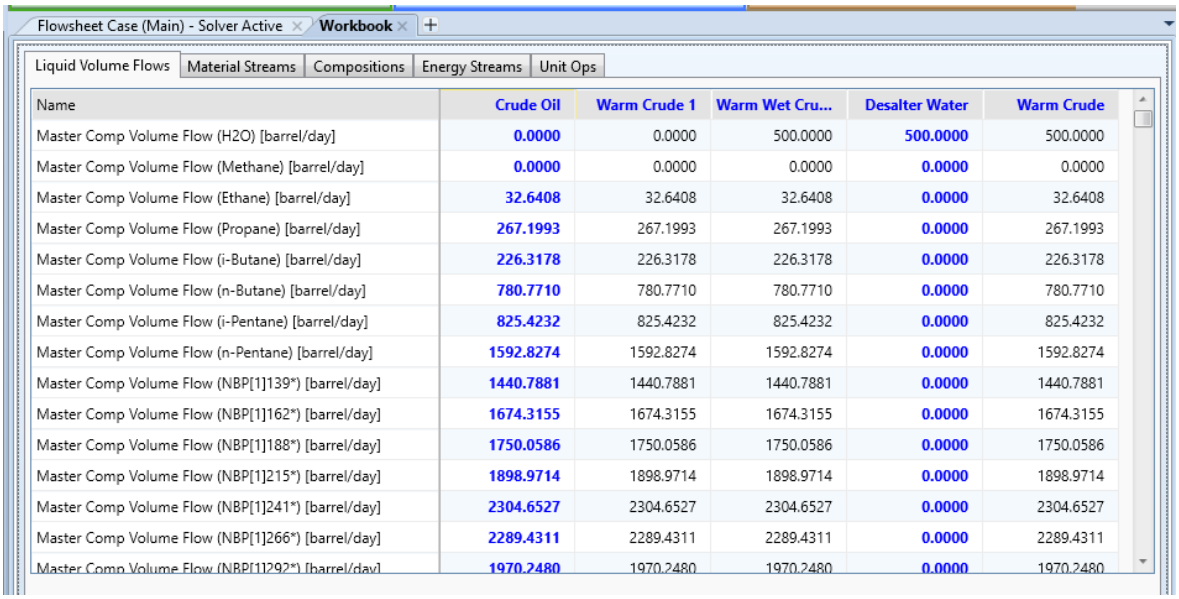
Let's change the *Name* to *Liquid Volume Flows*. Highlight all of the variables in the *Variable* list & press *Delete*. Now we can create a brand-new list of variables.



Press the *Add…* button. From the Variable list expand *Master Comp Volume Flow*; you could highlight all of the components & press the right arrow button. We would get a table with all of the liquid volume flow values for each pure & pseudo component in a weird order (propane at the very bottom, the lighter component not in boiling point order). Instead we can selectively add the light components in the order we which & then, as a group, add the pseudo-components. We can press *OK* when done. Unfortunately, we have to resize the column for the *Variable* name to see the actual order the variables are in. If you do not like the order then you can press the Order… button to change this. Finally, we can close the *Setup* form & see that there is now tab for these component volume flows.

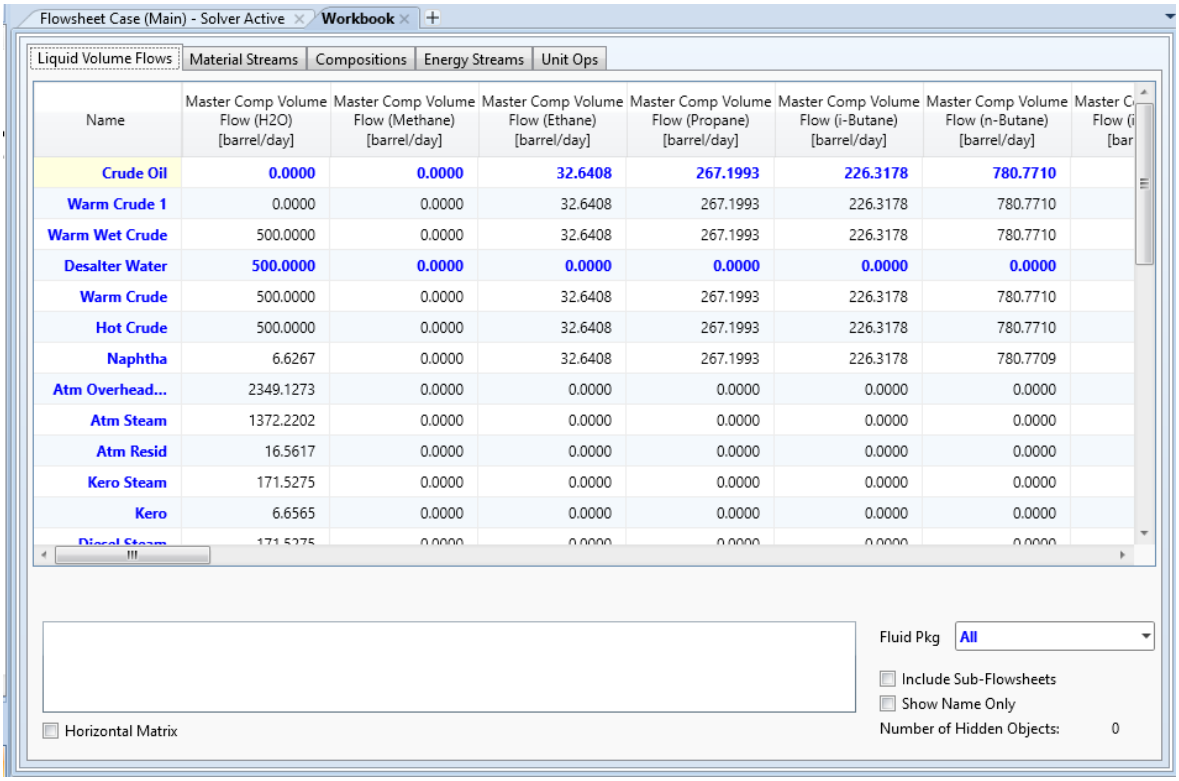




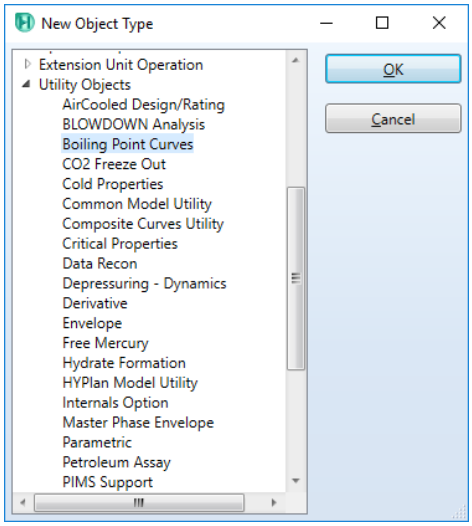


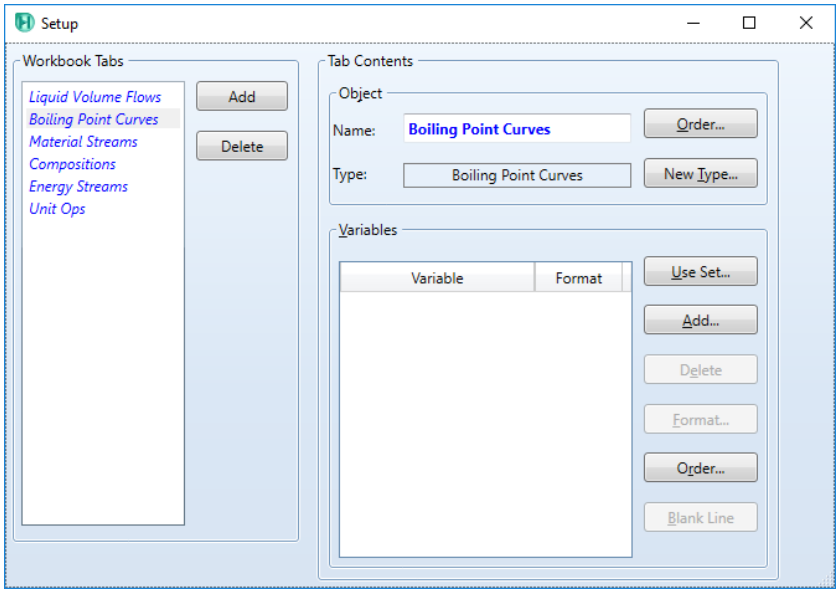
Name	Crude Oil	Warm Crude 1	Warm Wet Cru...	Desalter Water	Warm Crude
Master Comp Volume Flow (H2O) [barrel/day]	0.0000	0.0000	500.0000	500.0000	500.0000
Master Comp Volume Flow (Methane) [barrel/day]	0.0000	0.0000	0.0000	0.0000	0.0000
Master Comp Volume Flow (Ethane) [barrel/day]	32.6408	32.6408	32.6408	0.0000	32.6408
Master Comp Volume Flow (Propane) [barrel/day]	267.1993	267.1993	267.1993	0.0000	267.1993
Master Comp Volume Flow (i-Butane) [barrel/day]	226.3178	226.3178	226.3178	0.0000	226.3178
Master Comp Volume Flow (n-Butane) [barrel/day]	780.7710	780.7710	780.7710	0.0000	780.7710
Master Comp Volume Flow (i-Pentane) [barrel/day]	825.4232	825.4232	825.4232	0.0000	825.4232
Master Comp Volume Flow (n-Pentane) [barrel/day]	1592.8274	1592.8274	1592.8274	0.0000	1592.8274
Master Comp Volume Flow (NBP[1]139*) [barrel/day]	1440.7881	1440.7881	1440.7881	0.0000	1440.7881
Master Comp Volume Flow (NBP[1]162*) [barrel/day]	1674.3155	1674.3155	1674.3155	0.0000	1674.3155
Master Comp Volume Flow (NBP[1]188*) [barrel/day]	1750.0586	1750.0586	1750.0586	0.0000	1750.0586
Master Comp Volume Flow (NBP[1]215*) [barrel/day]	1898.9714	1898.9714	1898.9714	0.0000	1898.9714
Master Comp Volume Flow (NBP[1]241*) [barrel/day]	2304.6527	2304.6527	2304.6527	0.0000	2304.6527
Master Comp Volume Flow (NBP[1]266*) [barrel/day]	2289.4311	2289.4311	2289.4311	0.0000	2289.4311
Master Comp Volume Flow (NBP[1]292*) [barrel/day]	1970.2480	1970.2480	1970.2480	0.0000	1970.2480

We still have an issue that only 5 stream results are shown in the table & then underneath the next set of steam results are shown, & so forth. This is inconvenient when trying to copy the table of results into Excel & use a single table with values that can be easily indexed. A better format would be to unclick the Horizontal Matrix option at the bottom of the form. Now all properties are in the column headings & all streams are in the rows. Now the table can be easily indexed once copied to Excel.

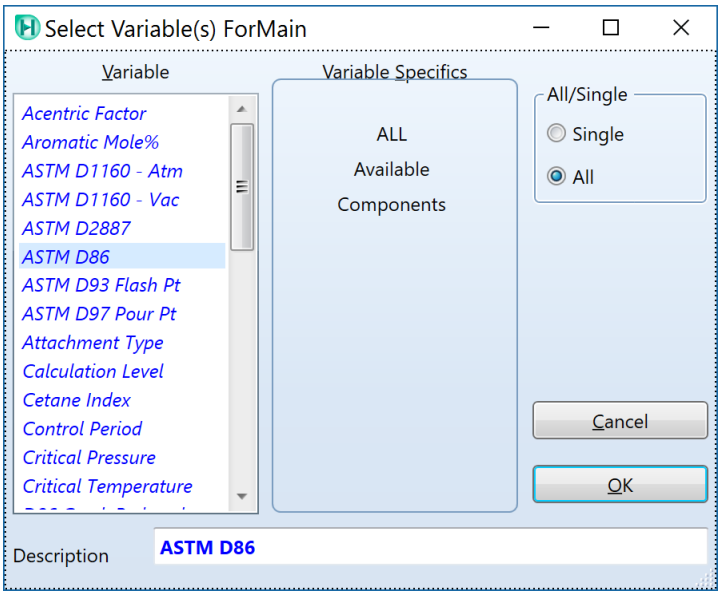


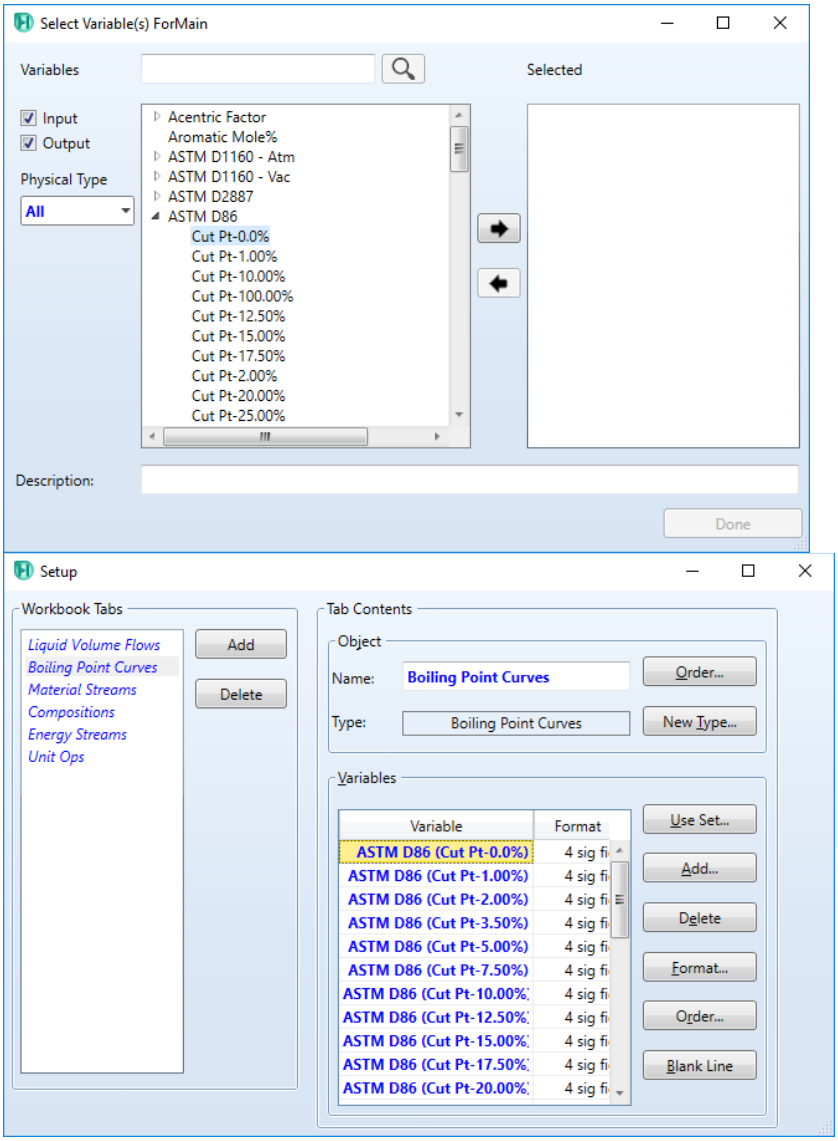
Let's address the issue with the distillation curves that we would really like. Let's create a workbook table that reports the *Boiling Point Curves* for the stream analyses set up in the simulation. Go to the *Workbook* tab & press *Setup*. Similar to what was done before, choose *Add*. But this time expand the *Utility Objects* item & select Boil*ing Point Curves* & press *OK*. The default name should be *Boiling Point Curves* (rename if necessary); there should be no the default items in the list.



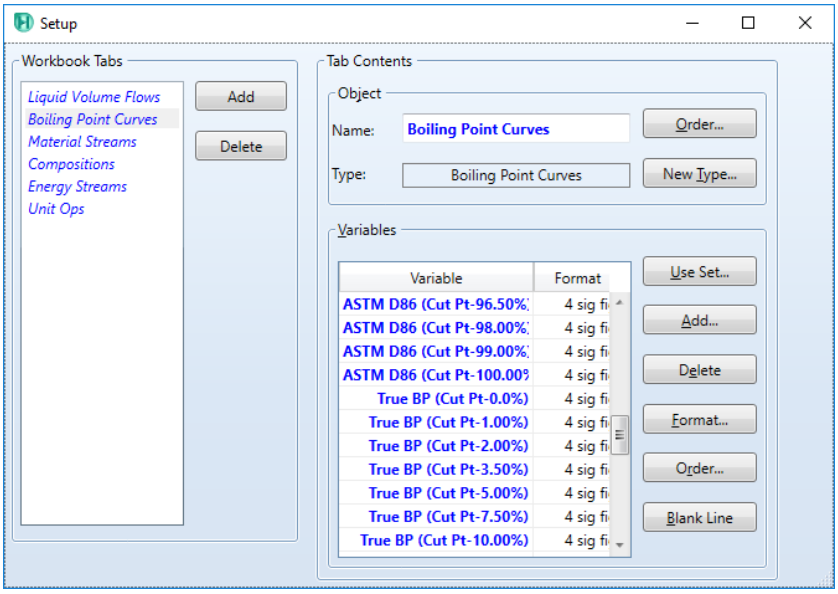


Press the *Add…* button. From the *Variable* list expand *ASTM D86*, selectively highlight the values you want & press the right arrow button. Now we'll get a table with all of the ASTM D86 values as calculated by the routines for the *Boiling Point Curves*. (If you don't like the order you can also redo when you get back to the Setup form.)

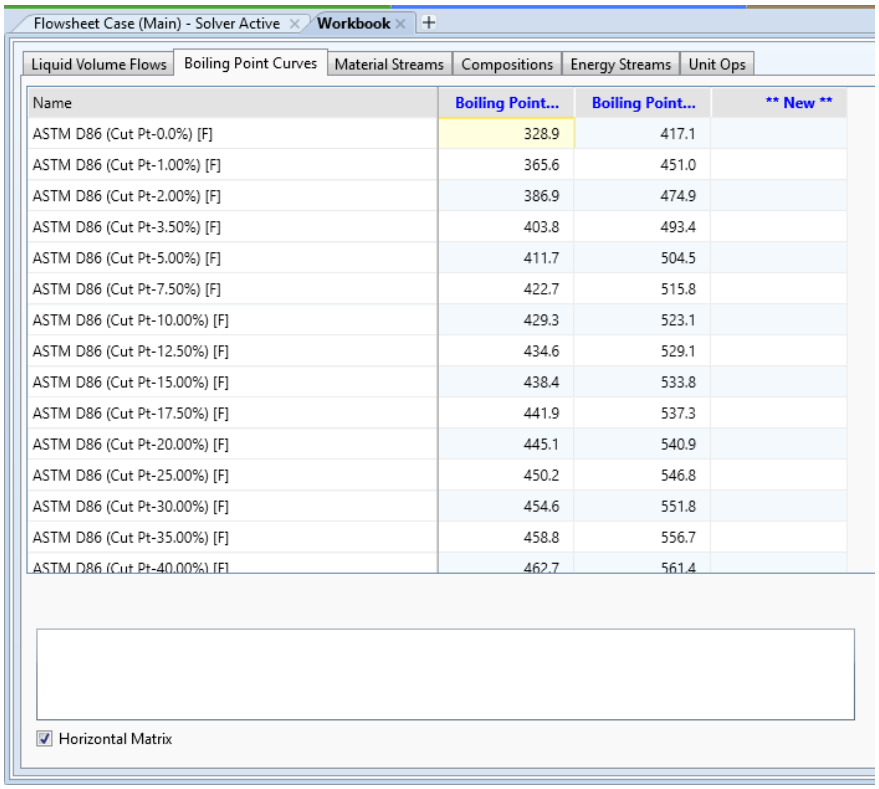


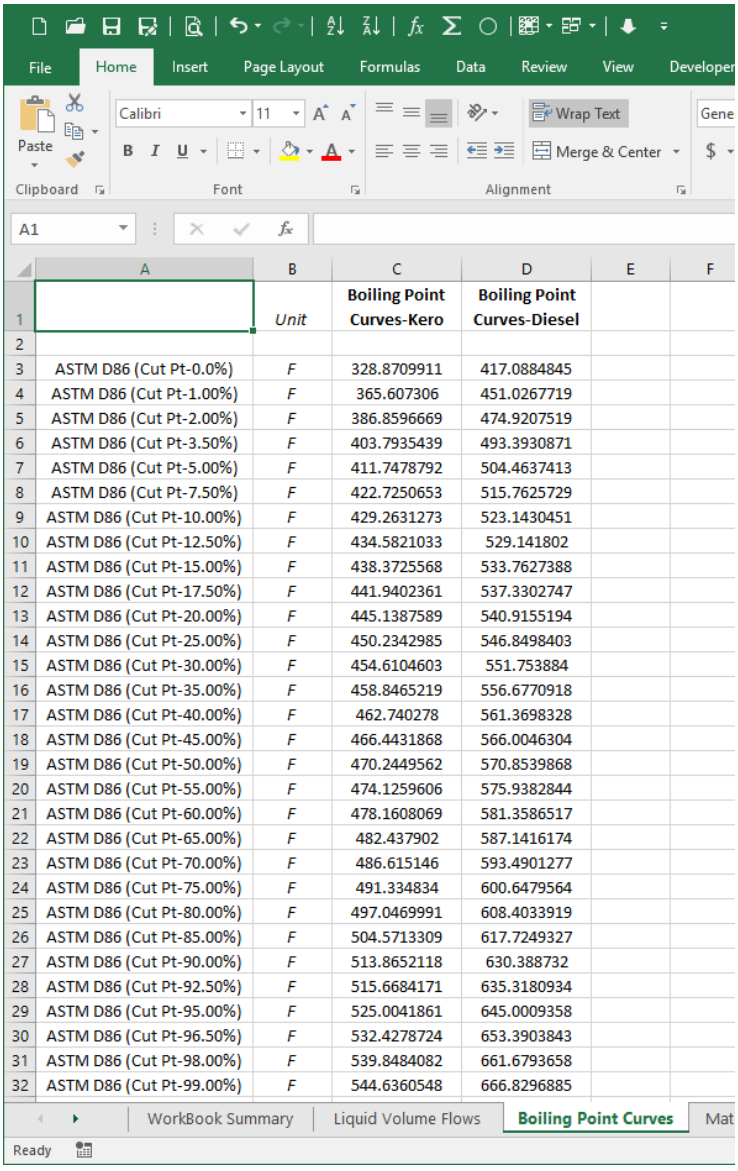

Select Variable(s) ForMain
Variables
Selected
Input
Output
Physical Type
All
Acentric Factor
Aromatic Mole%
ASTM D1160 - Atm
ASTM D1160 - Vac
ASTM D2887
ASTM D86
Cut Pt-0.0%
Cut Pt-1.00%
Cut Pt-10.00%
Cut Pt-100.00%
Cut Pt-12.50%
Cut Pt-15.00%
Cut Pt-17.50%
Cut Pt-2.00%
Cut Pt-20.00%
Cut Pt-25.00%
Description:
Done
Setup
Workbook Tabs
Liquid Volume Flows
Boiling Point Curves
Material Streams
Compositions
Energy Streams
Unit Ops
Add
Delete
Tab Contents
Object
Name:
Boiling Point Curves
Order...
Type:
Boiling Point Curves
New Type...
Variables
Variable
Format
ASTM D86 (Cut Pt-0.0%)
ASTM D86 (Cut Pt-1.00%)
ASTM D86 (Cut Pt-2.00%)
ASTM D86 (Cut Pt-3.50%)
ASTM D86 (Cut Pt-5.00%)
ASTM D86 (Cut Pt-7.50%)
ASTM D86 (Cut Pt-10.00%)
ASTM D86 (Cut Pt-12.50%)
ASTM D86 (Cut Pt-15.00%)
ASTM D86 (Cut Pt-17.50%)
ASTM D86 (Cut Pt-20.00%)
4 sig fi
Use Set...
Add...
Delete
Format...
Order...
Blank Line

Repeat the steps & choose True BP. This will put the TBP values at the bottom the table.



Now the boiling point curves from the Stream Analyses will be part of the workbook. (Note that this will only show the Stream Analyses you have set up; if you did not set up a *Stream Analysis* for a stream it will not be here either.) This spreadsheet can also exported to Excel. (Remember, getting coffee is a good way to kill the time while the values are being exported. But don't blame me if you get a caffeine dependency.)





	A	B	C	D	E	F
1		*Unit*	**Boiling Point Curves-Kero**	**Boiling Point Curves-Diesel**		
2						
3	ASTM D86 (Cut Pt-0.0%)	*F*	328.8709911	417.0884845		
4	ASTM D86 (Cut Pt-1.00%)	*F*	365.607306	451.0267719		
5	ASTM D86 (Cut Pt-2.00%)	*F*	386.8596669	474.9207519		
6	ASTM D86 (Cut Pt-3.50%)	*F*	403.7935439	493.3930871		
7	ASTM D86 (Cut Pt-5.00%)	*F*	411.7478792	504.4637413		
8	ASTM D86 (Cut Pt-7.50%)	*F*	422.7250653	515.7625729		
9	ASTM D86 (Cut Pt-10.00%)	*F*	429.2631273	523.1430451		
10	ASTM D86 (Cut Pt-12.50%)	*F*	434.5821033	529.141802		
11	ASTM D86 (Cut Pt-15.00%)	*F*	438.3725568	533.7627388		
12	ASTM D86 (Cut Pt-17.50%)	*F*	441.9402361	537.3302747		
13	ASTM D86 (Cut Pt-20.00%)	*F*	445.1387589	540.9155194		
14	ASTM D86 (Cut Pt-25.00%)	*F*	450.2342985	546.8498403		
15	ASTM D86 (Cut Pt-30.00%)	*F*	454.6104603	551.753884		
16	ASTM D86 (Cut Pt-35.00%)	*F*	458.8465219	556.6770918		
17	ASTM D86 (Cut Pt-40.00%)	*F*	462.740278	561.3698328		
18	ASTM D86 (Cut Pt-45.00%)	*F*	466.4431868	566.0046304		
19	ASTM D86 (Cut Pt-50.00%)	*F*	470.2449562	570.8539868		
20	ASTM D86 (Cut Pt-55.00%)	*F*	474.1259606	575.9382844		
21	ASTM D86 (Cut Pt-60.00%)	*F*	478.1608069	581.3586517		
22	ASTM D86 (Cut Pt-65.00%)	*F*	482.437902	587.1416174		
23	ASTM D86 (Cut Pt-70.00%)	*F*	486.615146	593.4901277		
24	ASTM D86 (Cut Pt-75.00%)	*F*	491.334834	600.6479564		
25	ASTM D86 (Cut Pt-80.00%)	*F*	497.0469991	608.4033919		
26	ASTM D86 (Cut Pt-85.00%)	*F*	504.5713309	617.7249327		
27	ASTM D86 (Cut Pt-90.00%)	*F*	513.8652118	630.388732		
28	ASTM D86 (Cut Pt-92.50%)	*F*	515.6684171	635.3180934		
29	ASTM D86 (Cut Pt-95.00%)	*F*	525.0041861	645.0009358		
30	ASTM D86 (Cut Pt-96.50%)	*F*	532.4278724	653.3903843		
31	ASTM D86 (Cut Pt-98.00%)	*F*	539.8484082	661.6793658		
32	ASTM D86 (Cut Pt-99.00%)	*F*	544.6360548	666.8296885		