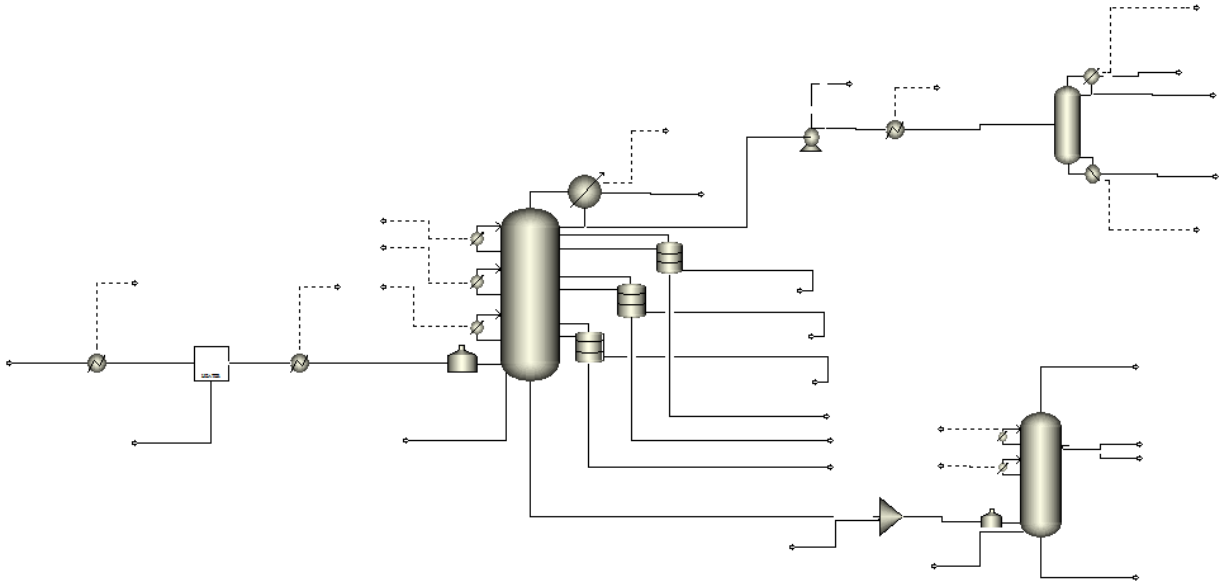
Crude Tower Simulation – Aspen Plus v8.6

Steps to set up a simulation in Aspen Plus v8.6 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

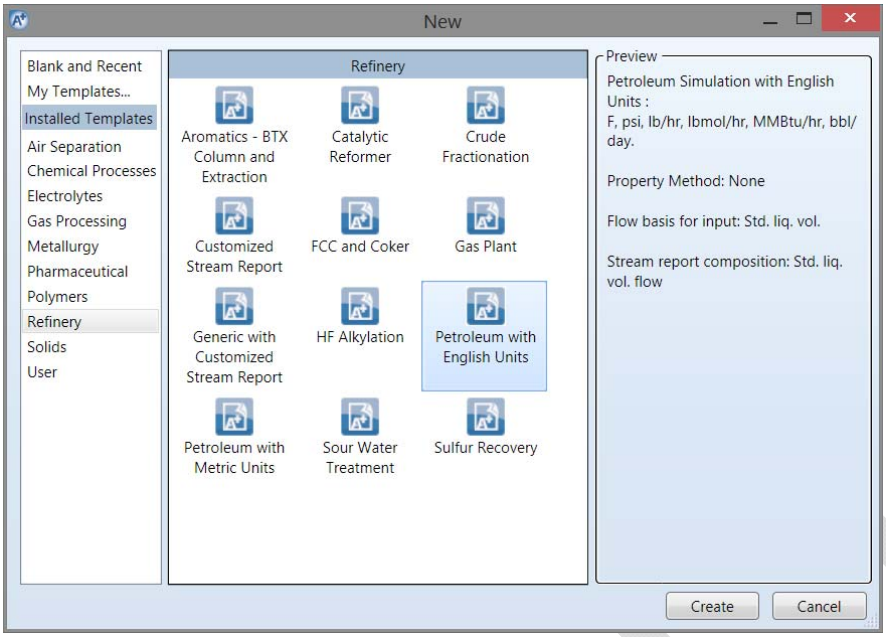
The feedstock to the crude system will be an equal mix of Light, Medium, & Heavy Crude oils.

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



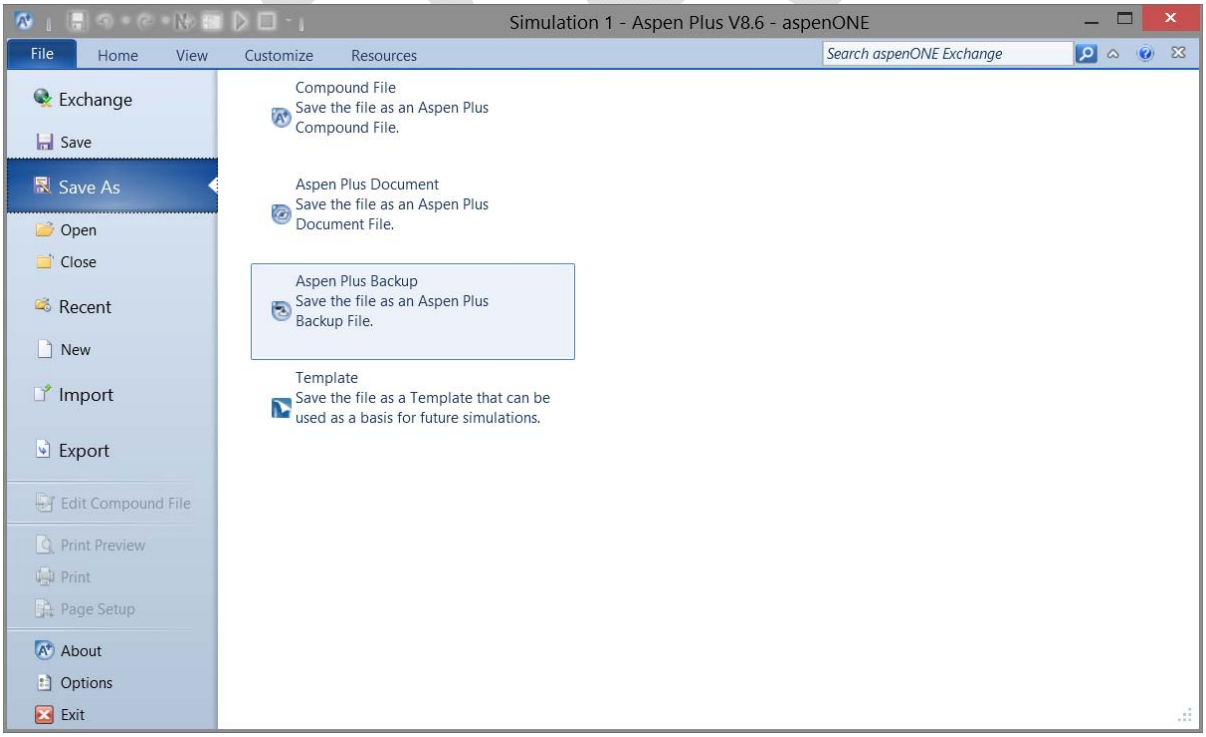
Create new simulation file

Start the program from *Start*, *All Programs*, *Aspen Tech*, *Process Modeling V8.6*, *Aspen Plus*, *Aspen Plus V8.6*. When the program opens choose the *new* button. there are several templates that can be chosen. Select the *Refinery* option in the left-hand column & chose the *Petroleum with English Units* template. Press *Create*.



Save as you go

One of the things you'll want to do is to save your files as you go. The first time you go to the *Save As* option you'll have several formats from which to choose. There are advantages to save as the *Aspen Plus Backup* (BKP) format – the files tend to be smaller & less likely to become corrupted.



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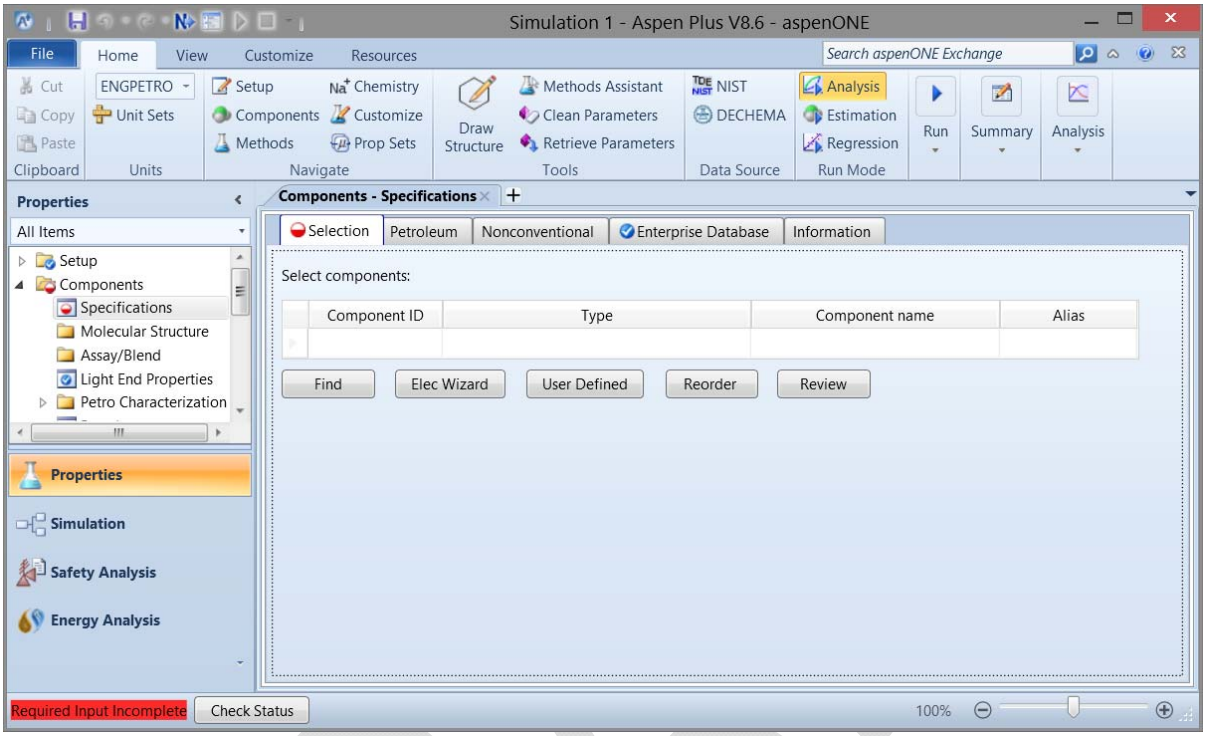
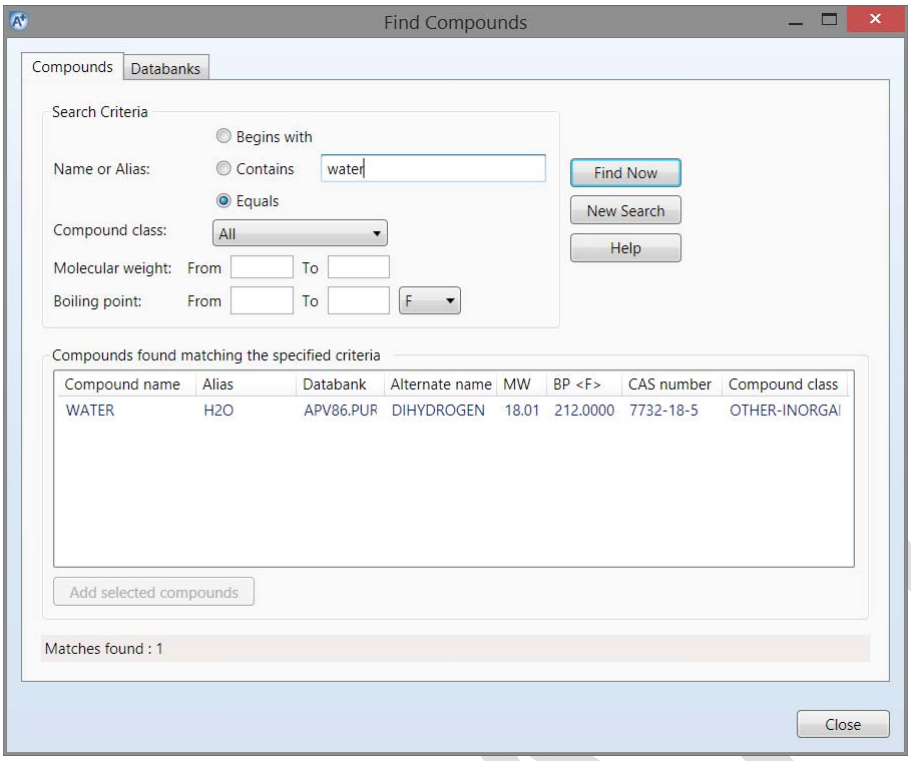
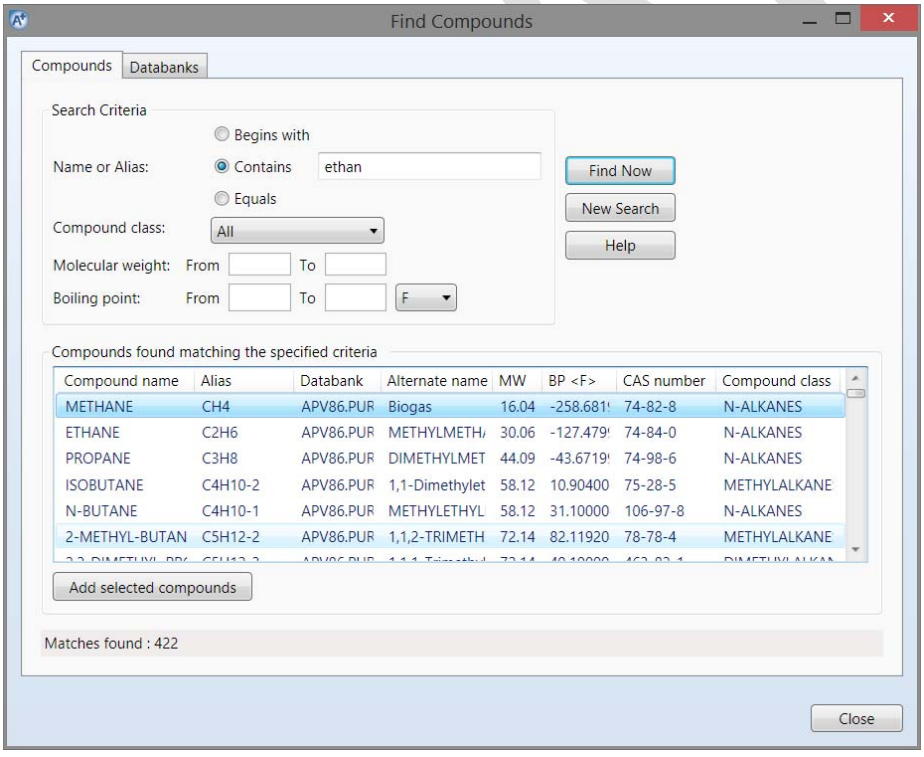
Define the Components & the Property Models

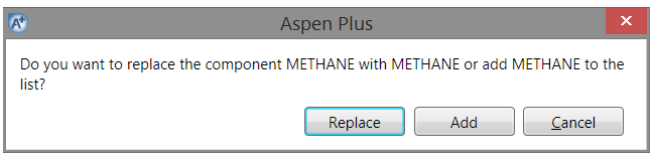
Specify components, fluid property packages, & crude oil assays

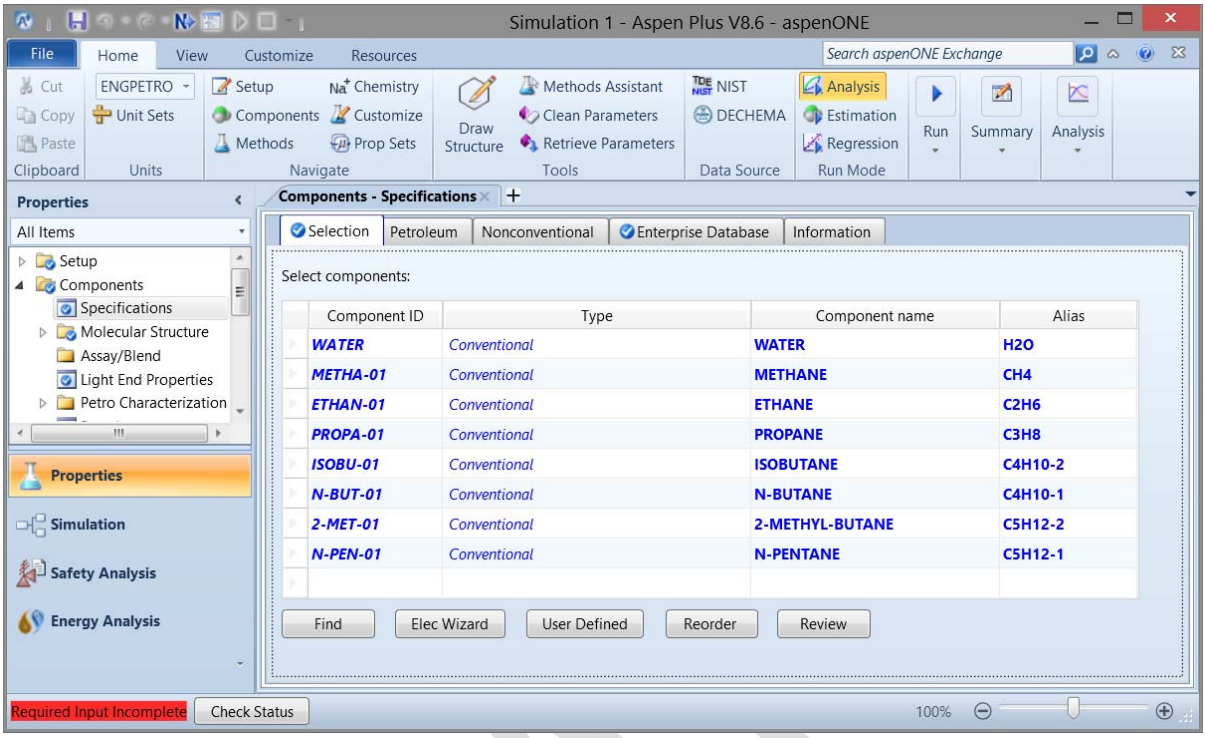


The first step is to add a set of pure chemical species to represent the light components of the crude oils. The *Component - Specifications* form should be the default. (If not, press the *Specifications* item under *Components* in the left-hand column.) W will want to add the following pure components: water, methane, ethane, propane, i-butane, n-butane, i-pentane, & n-pentane. One of the direct ways to do this is to press Find & use the search form to find the desired components. The following form shows a search for H2O; key phrases can be used to with the Equals or Contains options to find all components. For each succeeding compound you will be asked to replace one of the compounds or add to the list; choose add to the list.

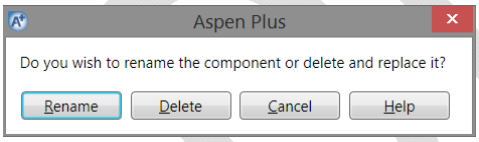

Find Compounds
Compounds
Databanks
Search Criteria
Begins with
Name or Alias:
Contains
water
Equals
Compound class:
All
Molecular weight: From To
Boiling point: From To F
Find Now
New Search
Help
Compounds found matching the specified criteria
Compound name Alias Databank Alternate name MW BP <F> CAS number Compound class
WATER H2O APV86.PUR DIHYDROGEN 18.01 212.0000 7732-18-5 OTER-INORGAI
Add selected compounds
Matches found : 1
Close


Find Compounds
Compounds
Databanks
Search Criteria
Begins with
Name or Alias:
Contains
ethan
Equals
Compound class:
All
Molecular weight: From To
Boiling point: From To F
Find Now
New Search
Help
Compounds found matching the specified criteria
Compound name Alias Databank Alternate name MW BP <F> CAS number Compound class
METHANE CH4 APV86.PUR Biogas 16.04 -258.681 74-82-8 N-ALKANES
ETHANE C2H6 APV86.PUR METHYLMETH 30.06 -127.479 74-84-0 N-ALKANES
PROPANE C3H8 APV86.PUR DIMETHYLMET 44.09 -43.6719 74-98-6 N-ALKANES
ISOBUTANE C4H10-2 APV86.PUR 1,1-Dimethylet 58.12 10.90400 75-28-5 METHYLALKANE
N-BUTANE C4H10-1 APV86.PUR METHYLETHYL 58.12 31.10000 106-97-8 N-ALKANES
2-METHYL-BUTAN C5H12-2 APV86.PUR 1,1,2-TRIMETH 72.14 82.11920 78-78-4 METHYLALKANE
Add selected compounds
Matches found : 422
Close


Aspen Plus
Do you want to replace the component METHANE with METHANE or add METHANE to the list?
Replace
Add
Cancel



Aspen Plus will retrieve information about each component & also create a Component ID for this simulation. You are free to change these IDs to match your personal desires. For example, you change the ID for *METHA-01* to *C1* by doubling clicking on that text item; after changing the text value & pressing enter Aspen Plus will verify that you want to *Rename* the component & not change it to something else. This can be done for all of the components to create (IMHO) more reasonable IDs.



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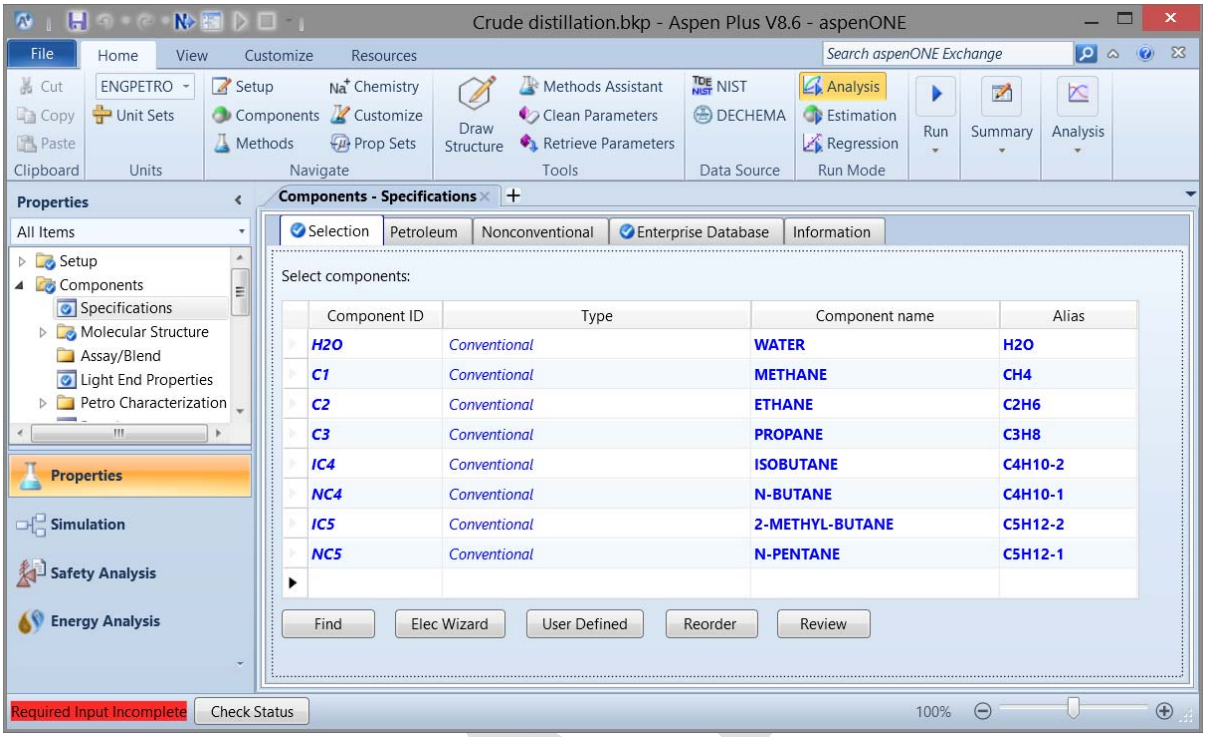
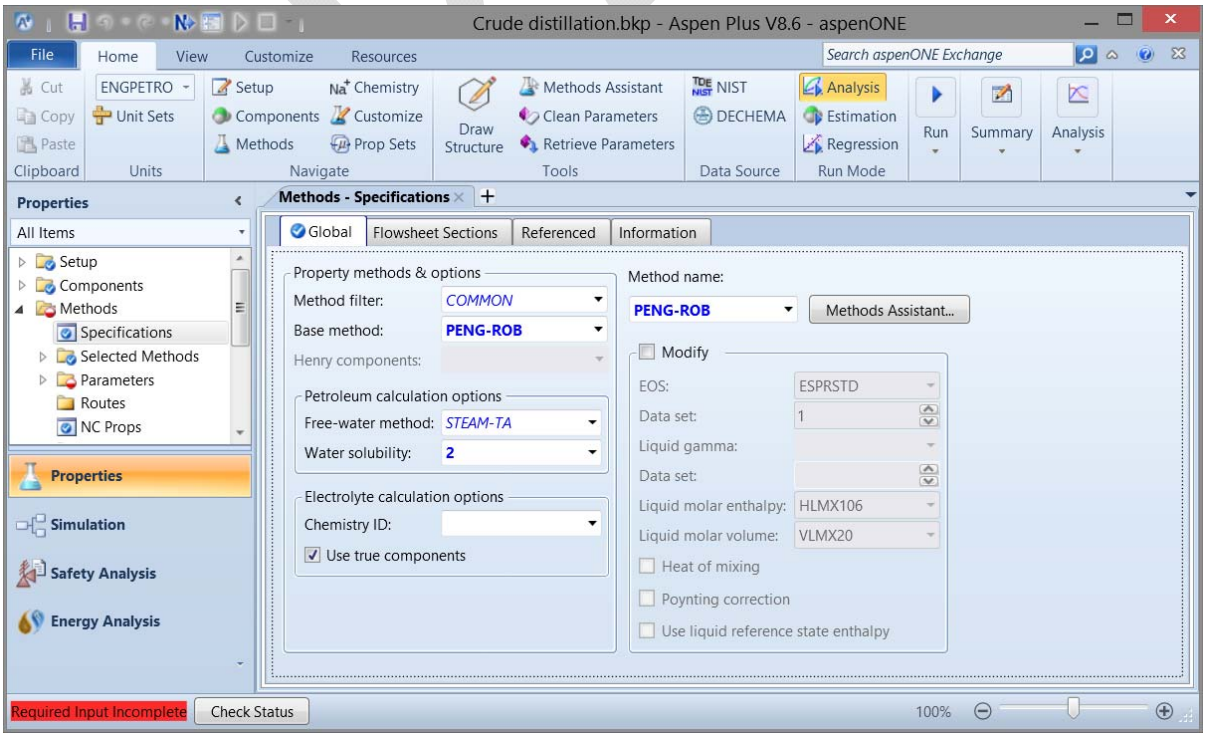
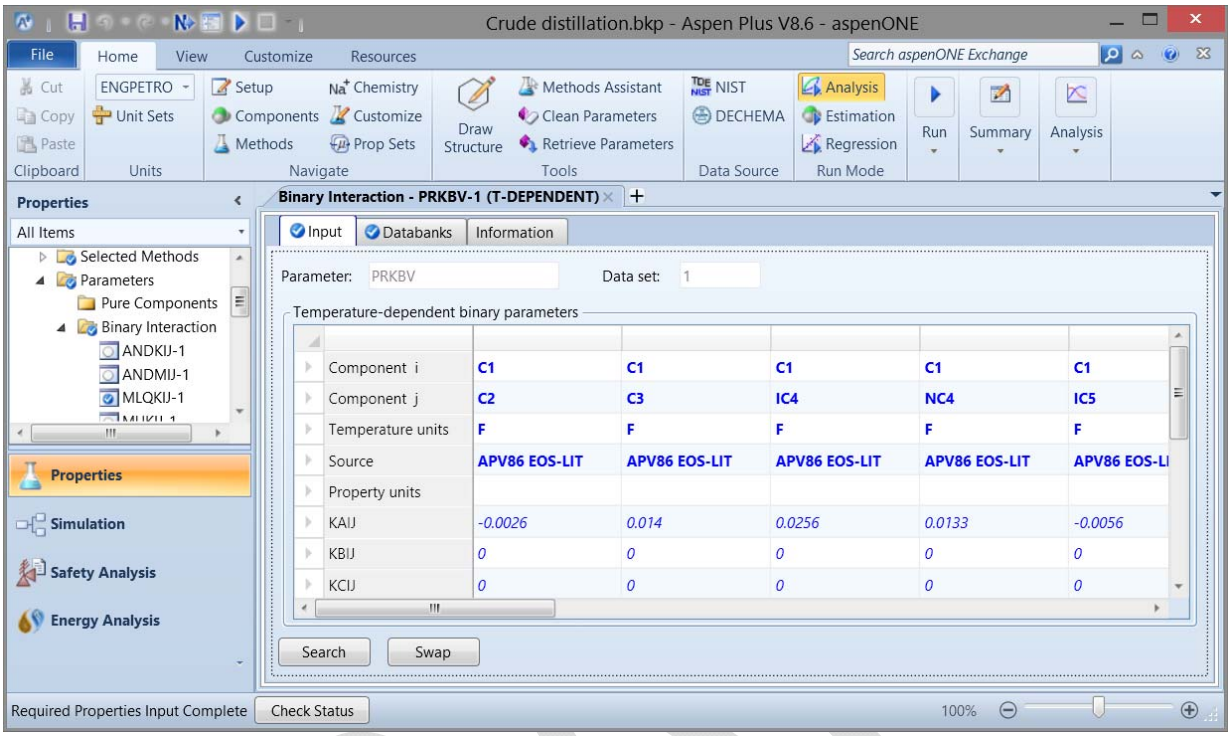


Aspen Plus can guide you through the process of defining your simulation. This is done by pressing the Next button (, either in the ribbon or in the quick access bar). Doing this shows that the next step is to pick a fluid property package on the *Methods – Specifications* form. From the *Base Method* pull-down list choose *PENG-ROB*.



Click the N button. The next form allows us to modify values for the Peng-Robinson binary interaction coefficients. We will not change any of them from the defaults.



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 1 to 3.

Click the N button. But, since we want to add crude assay data & this is not an option on this form. Press *Cancel*.

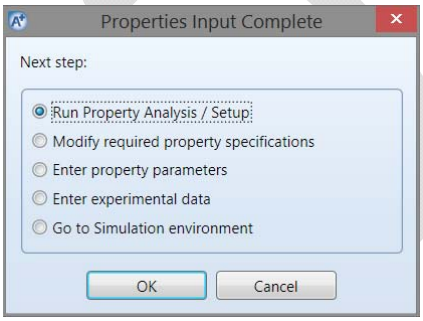


Table 1. Assay Data for Light Crude

Light Crude								
		Cumulative Yield [wt%]		Density	API	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3	Gravity	wt%		[wt%]
Whole Crude				53.27	34.17	1.77	Ethane	0.000
31	160	0	2.5	42.75	74.91	0.019	Propane	0.146
160	236	5	7.5	45.40	62.90	0.031	i-Butane	0.127
236	347	10	15	48.33	51.09	0.060	n-Butane	0.702
347	446	20	25	50.46	43.38	0.379	i-Pentane	0.654
446	545	30	35	52.38	36.97	1.064	n-Pentane	1.297
545	649	40	45	54.18	31.37	1.698		
649	758	50	55	56.04	25.96	2.159		
758	876	60	65	57.92	20.86	2.554		
876	1015	70	75	60.05	15.45	3.041		
1015	1205	80	85	62.84	8.94	3.838		
1205	1350	90	92.5	64.92	4.44	4.503		
1350	FBP	95	97.5	70.64	-6.57	6.382		

Table 2. Assay Data for Medium Crude

Medium Crude								
		Cumulative Yield [wt%]		Density	API	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3	Gravity	wt%		[wt%]
Whole Crude				55.00	28.97	2.83	Ethane	0.000
88	180	0	2.5	43.47	71.51	0.022	Propane	0.030
180	267	5	7.5	47.14	55.69	0.062	i-Butane	0.089
267	395	10	15	49.42	47.08	0.297	n-Butane	0.216
395	504	20	25	51.83	38.78	1.010	i-Pentane	0.403
504	611	30	35	54.08	31.67	2.084	n-Pentane	0.876
611	721	40	45	55.90	26.36	2.777		
721	840	50	55	57.73	21.36	3.284		
840	974	60	65	59.77	16.15	3.857		
974	1131	70	75	62.30	10.15	4.706		
1131	1328	80	85	65.74	2.74	5.967		
1328	1461	90	92.5	68.08	-1.87	6.865		
1461	FBP	95	97.5	73.28	-11.08	8.859		

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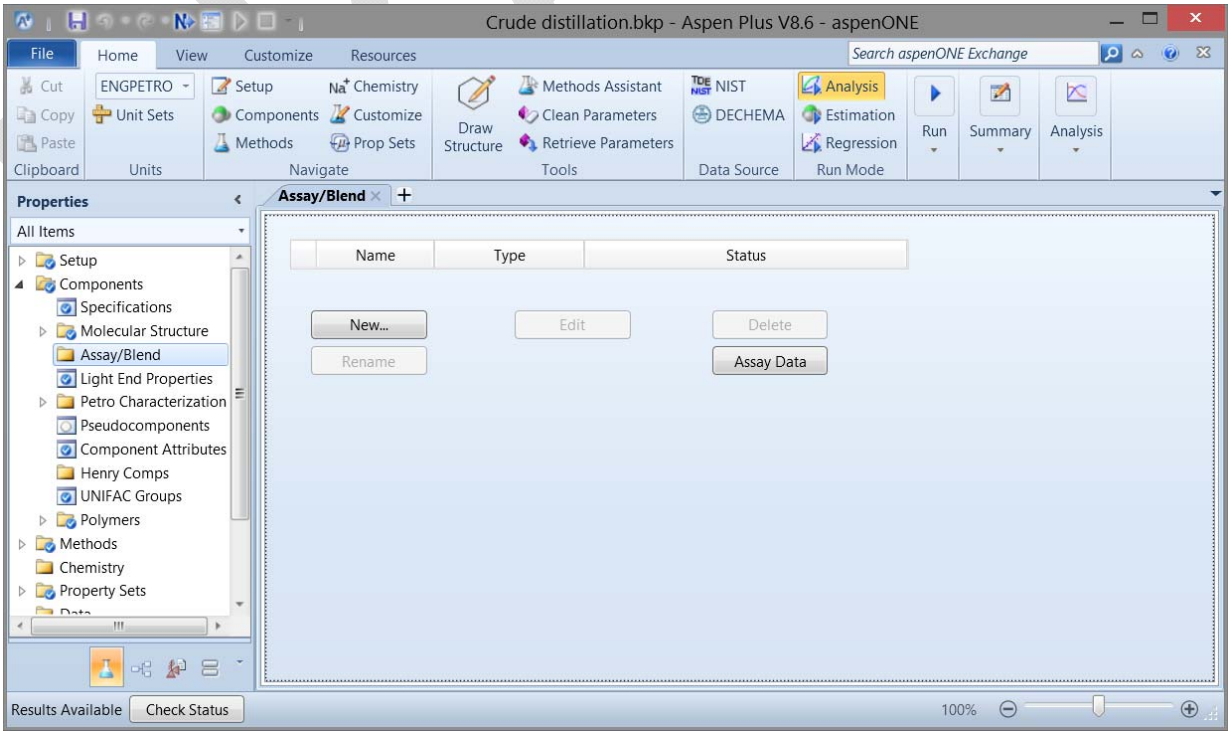
Table 3. Assay Data for Heavy Crude

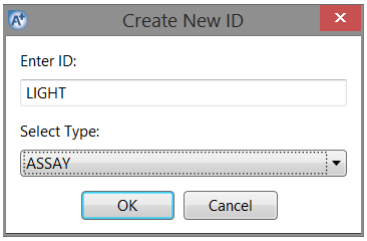
Heavy Crude								
		Cumulative Yield [wt%]		Density	API	Sulfur	Light Ends Analysis	
IBP	EP	@ IBP	@ Mid	lb/ft3	Gravity	wt%		[wt%]
Whole Crude				55.20	28.36	2.8	Ethane	0.039
26.8	153.6	0	2.5	42.92	74.11	0.005	Propane	0.284
153.6	255.1	5	7.5	45.75	61.40	0.041	i-Butane	0.216
255.1	400.5	10	15	49.44	46.98	0.341	n-Butane	0.637
400.5	523.4	20	25	52.23	37.47	1.076	i-Pentane	0.696
523.4	645	30	35	54.49	30.47	1.898	n-Pentane	1.245
645	769.6	40	45	56.62	24.36	2.557		
769.6	901.9	50	55	58.77	18.65	3.185		
901.9	1043.8	60	65	61.09	12.95	3.916		
1043.8	1198.1	70	75	63.61	7.24	4.826		
1198.1	1380.5	80	85	66.63	0.94	5.990		
1380.5	1499.7	90	92.5	68.71	-3.07	6.775		
1499.7	FBP	95	97.5	73.10	-10.78	8.432		

The following steps show how to enter the data for Light Crude. Similar steps should be used for the other crude oils.

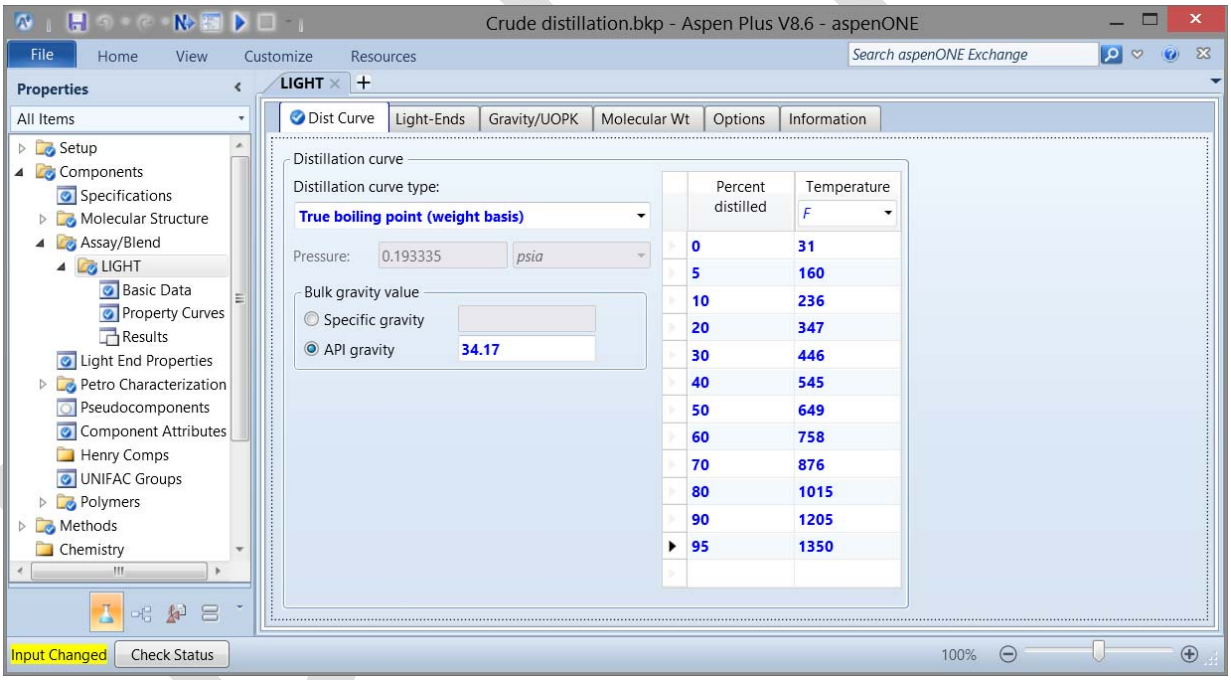
- Select *Assay/Blend* under *Components* in the left-hand column. Click on the *New...* button.



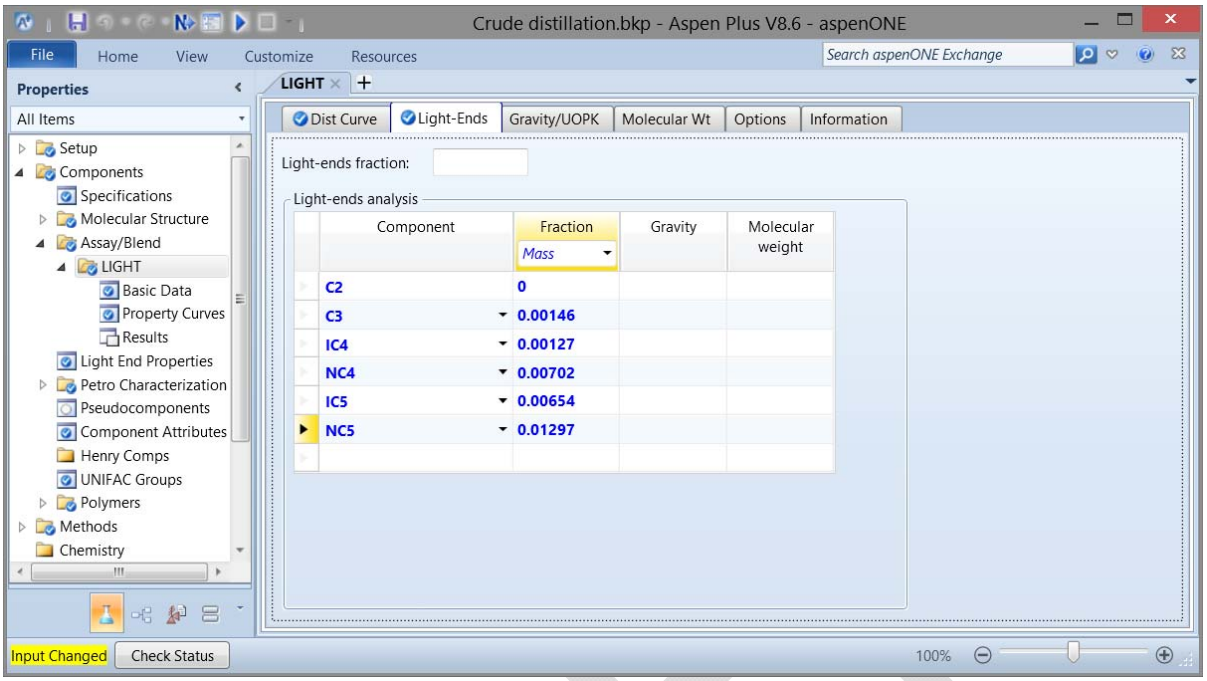
- Call the new crude assay *LIGHT* & choose *Assay* from the *Select Type* drop-down list. Press *OK*.



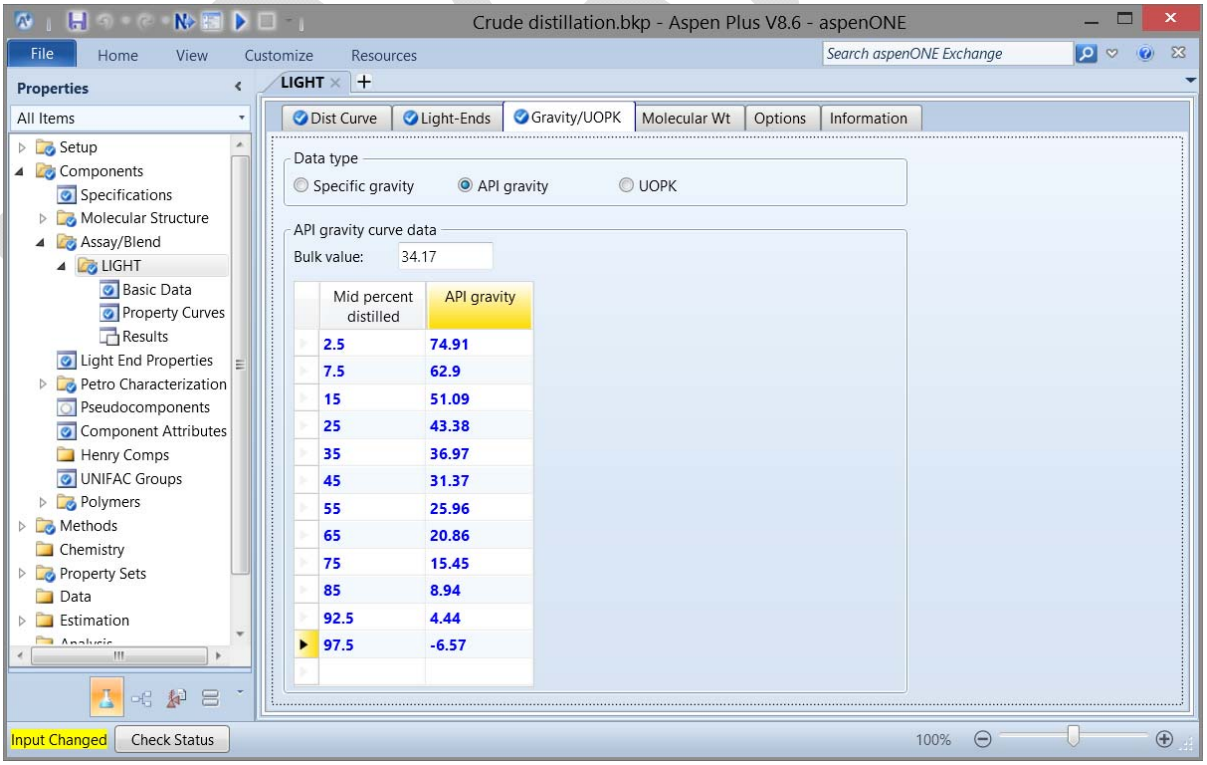
- Make sure the *Dist Curve* tab is active. Make the *API gravity* option active & enter the value from Table 1. In the *Distillation Curve* type drop-down list make the *True boiling point (weight basis)* option active. In the table enter the cumulative yield values vs. associated temperatures. Note that the yield values should be entered as percentages, scaled from 0 to 100.



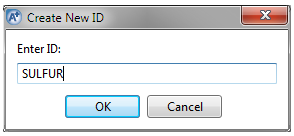
- Now we'll add in the composition of the light ends. Make the *Light-Ends* tab active & the form will change to allow you to enter the compositions. Select the components to be used to define the light ends (based on the component list previously specified). Change the *Fraction* type to *Mass*. Enter the values from Table 1. Note that these are in terms of mass fraction, <u>not</u> percent, and are scaled from 0 to 1.

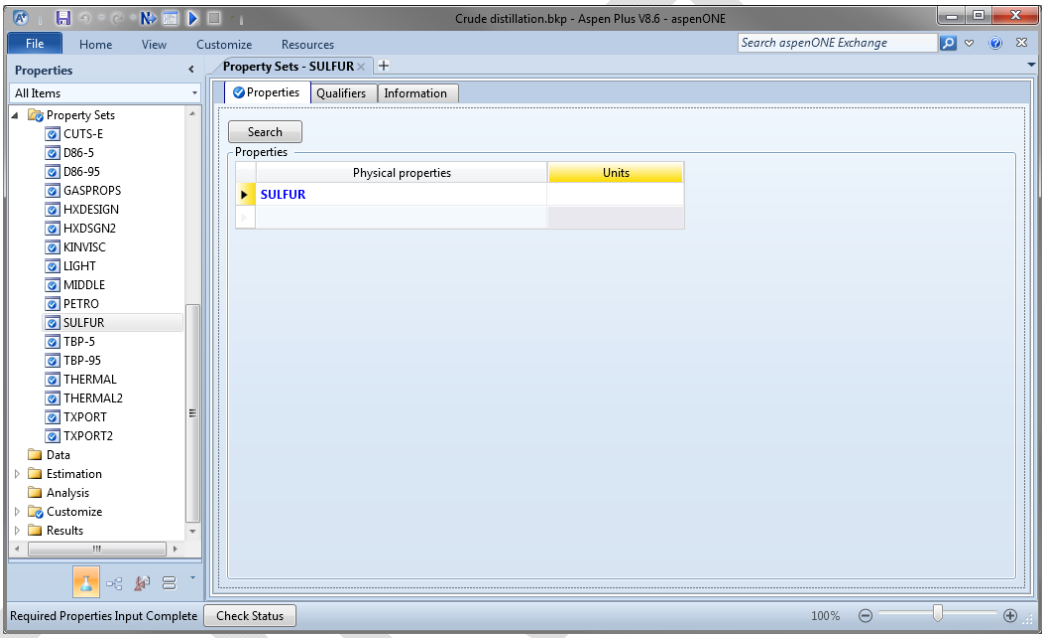


- Now we'll add in the API Gravity data. Make the *Gravity/UOPK* tab active. Make the *API gravity* option active in the *Data type* area. Add the data from Table 1. Note that the yield values should be entered as percentages, scaled from 0 to 100.

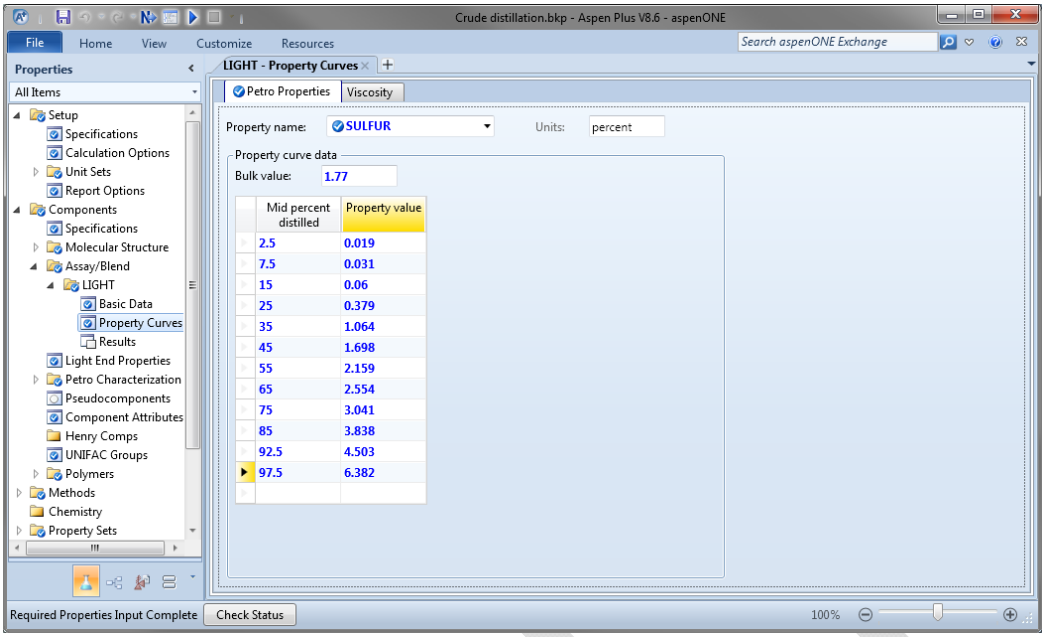


- Even though we can now characterize the pseudo components for the flash calculations we still need to add the sulfur distribution so that the sulfur content can be tracked. First we'll have to need to define sulfur as a property; this will only have to be done once, not for every crude assay. Select *Property Sets* in the left-hand column. Note that there are over a dozen property pre-defined by our selecting the Petroleum template. On the form press *New…* Set the ID as *SULFUR*. On the next form pull down the *Physical Properties* list & select *SULFUR*.

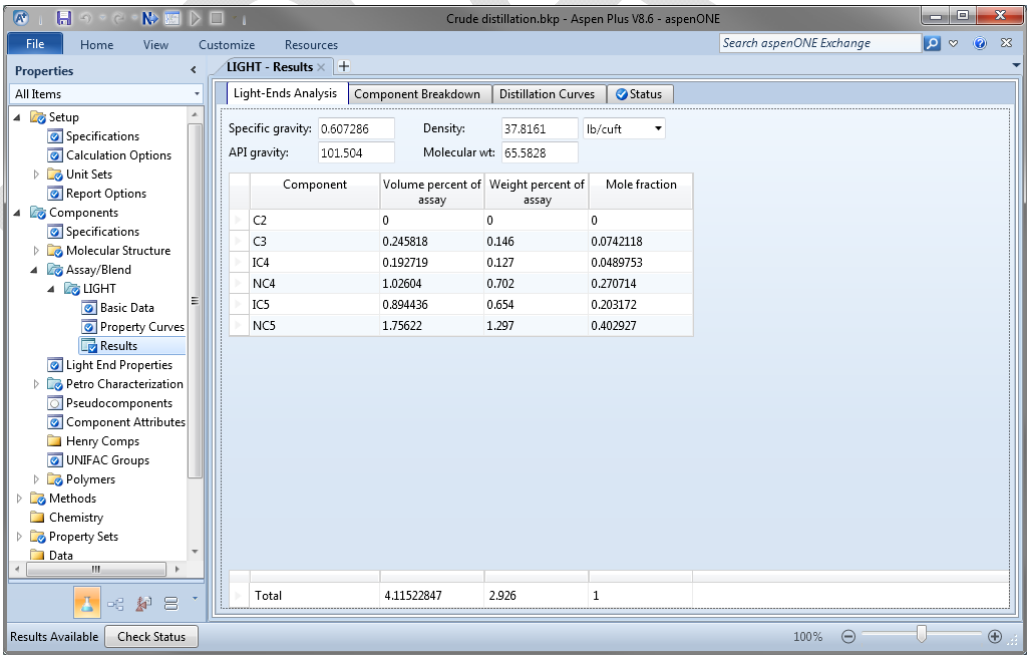


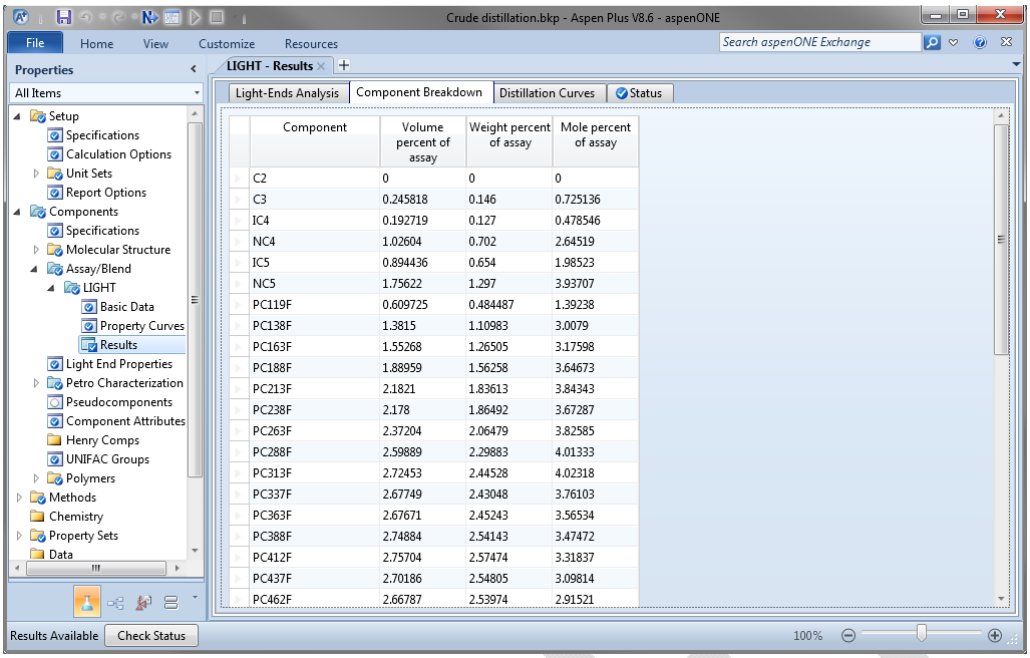


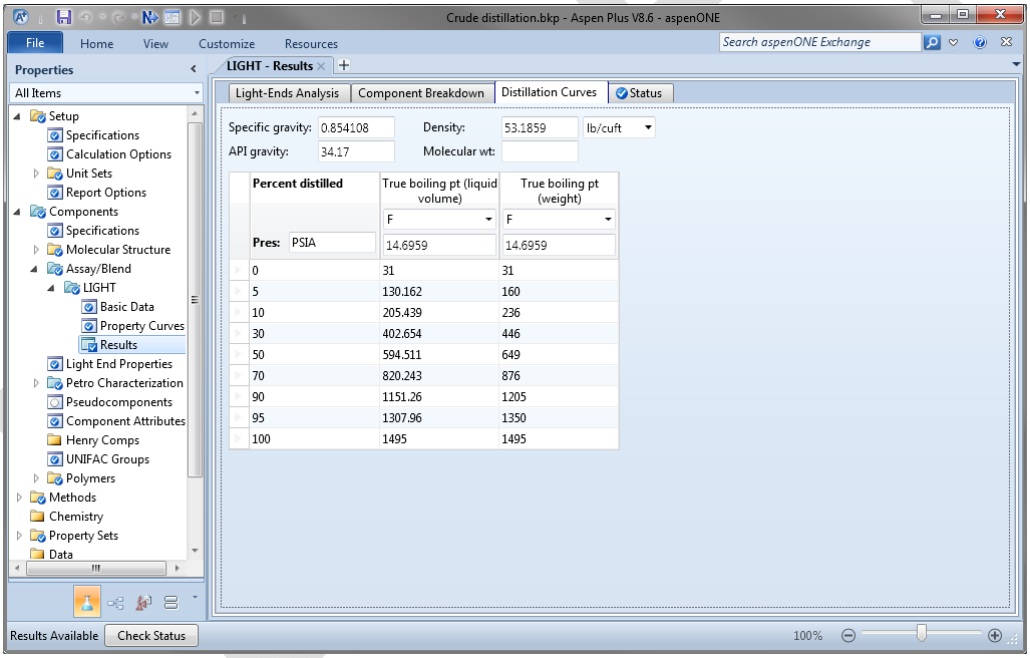
Now we will define the sulfur distribution in the crude oil assay. Check for *LIGHT* in the left-hand column under *Components* & *Assay/Blend*. Notice there is now a subheading for *Property Curves*; select this. On the next form pull down the *Property Name* list and select *SULFUR*. Enter the *Bulk value* (i.e., the sulfur content of the whole crude) and then the distribution.



At this point you could press the Run button (in either the Ribbon or the Quick Access toolbar). Now you can select *Results* and see many of the calculated values form the input data, such as the conversion of the light ends analysis to vol% & mole fraction bases, breakdown of the distillation curve into narrow boiling fraction pseudo components, etc.





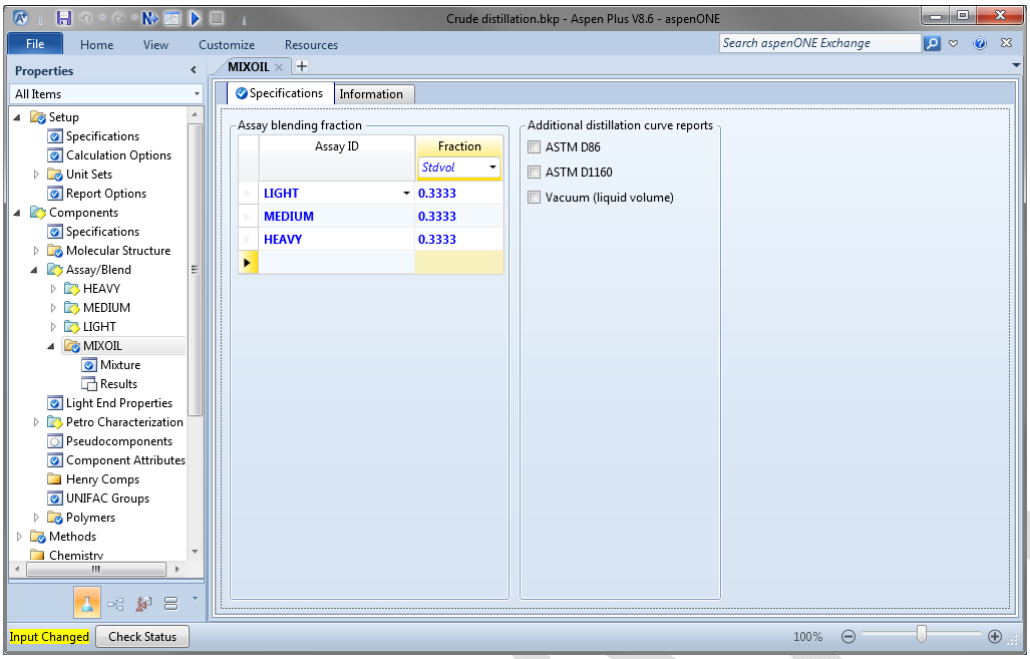


Repeat the steps for the Medium & Heavy Crudes.

Specify crude oil blend, & install into flowsheet

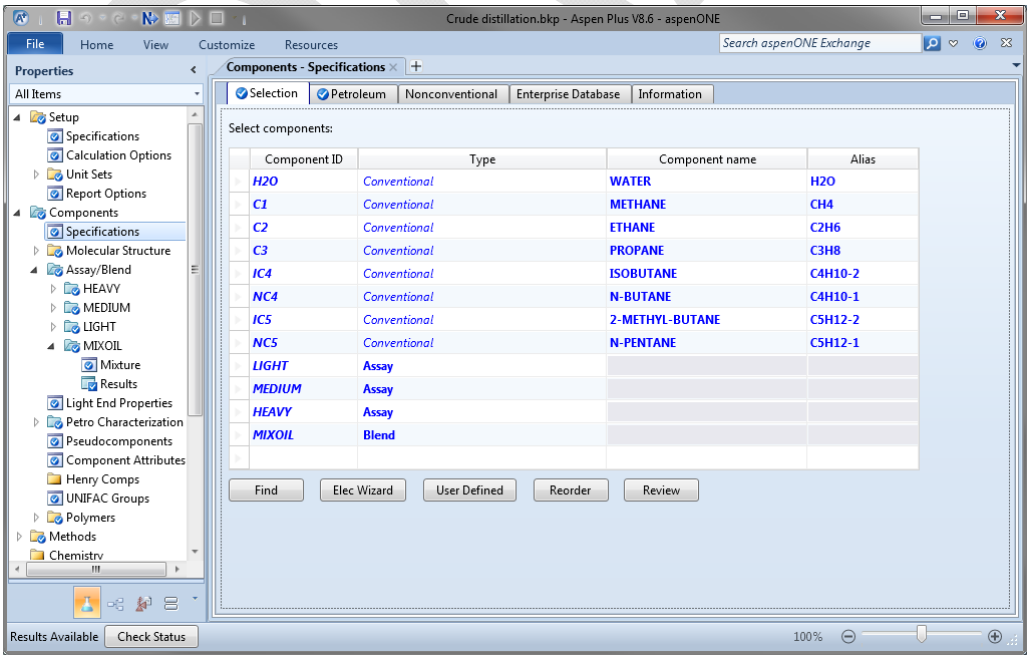
Now we'll create a blend of the three crudes and use that as our feedstock in the simulation. Select *Assay/Blend* under *Components* in the tree structure of the left-hand column. Press the New… button. Call the blend *MIXOIL* & choose *Blend* from the *Select Type* drop-down list. Press *OK*.

On the *Specifications* tab select each crude oil in the pull-down list in the *Assay ID* column. Set the *Stdvol Fraction* value for each to 0.3333.



You can press the Run button & view the *Results*.

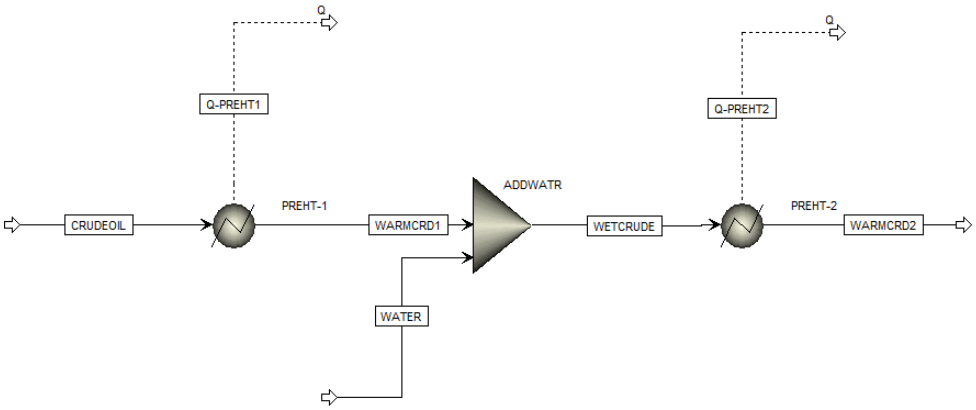
One more thing you may want to check. Select Specifications under Components. Note that the crude oil assays & the blend are listed as single items. The pseudo component representations are not shown in this component list.



Set up & Solve the Flowsheet

Crude Oil Feed & Preheat

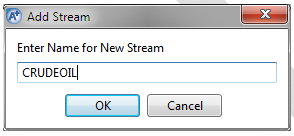
When you activate the *Simulation* you'll see a blank *Main Flowsheet*. We can now start adding streams & units to represent our process.



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

In the Model Palette click on the Material stream. Click & draw a stream on the Main Flowsheet. Click a 2nd time to finish drawing the stream. When prompted name the stream *CRUDEOIL*; click *OK*.



Let's define this feed stream. Either double-click on the stream in the flowsheet or choose *CRUDEOIL* in the left-hand column under *Streams*. Specify the temperature & pressure for the *Flash Type*; specify 500°F, 300 psig, & 101000 bpd in the *State variables* section. We will use the mixed representation of the blended crude by specifying the *Stdvol-Frac* of *MIXOIL* as 1.

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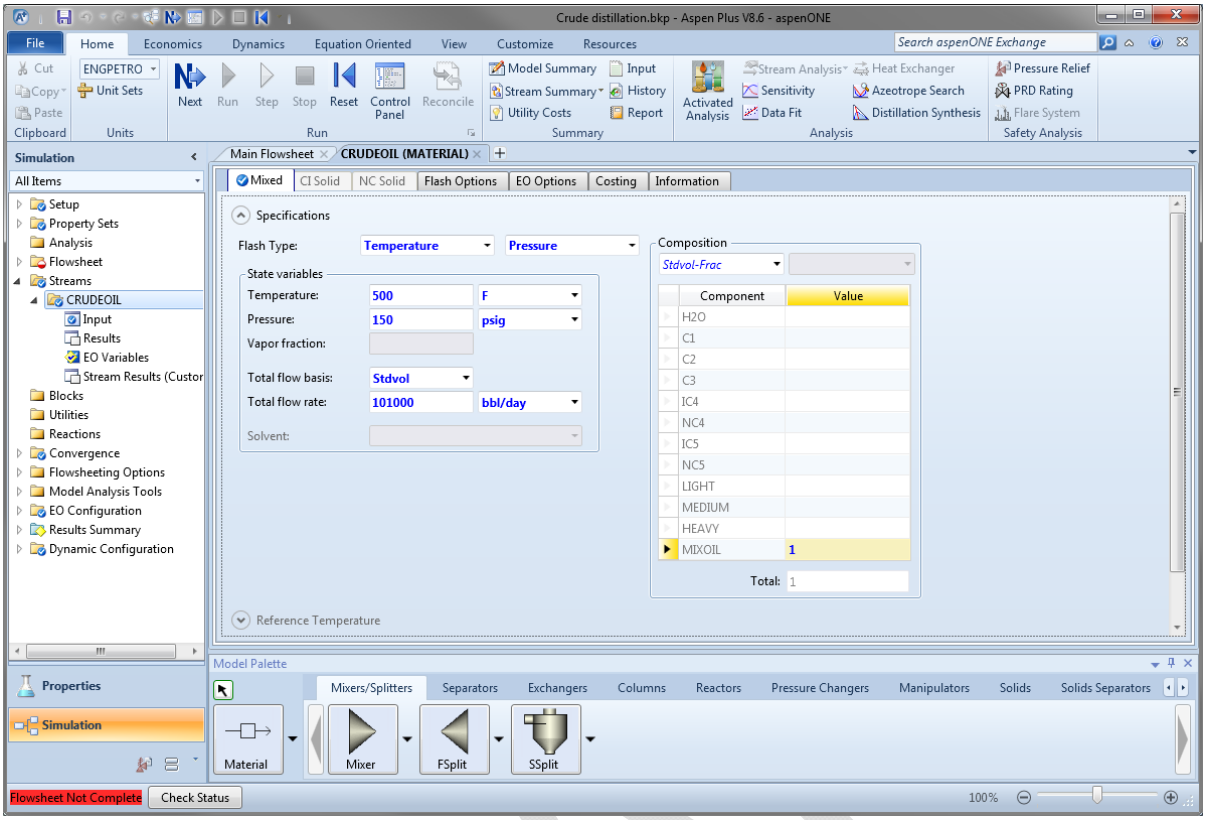
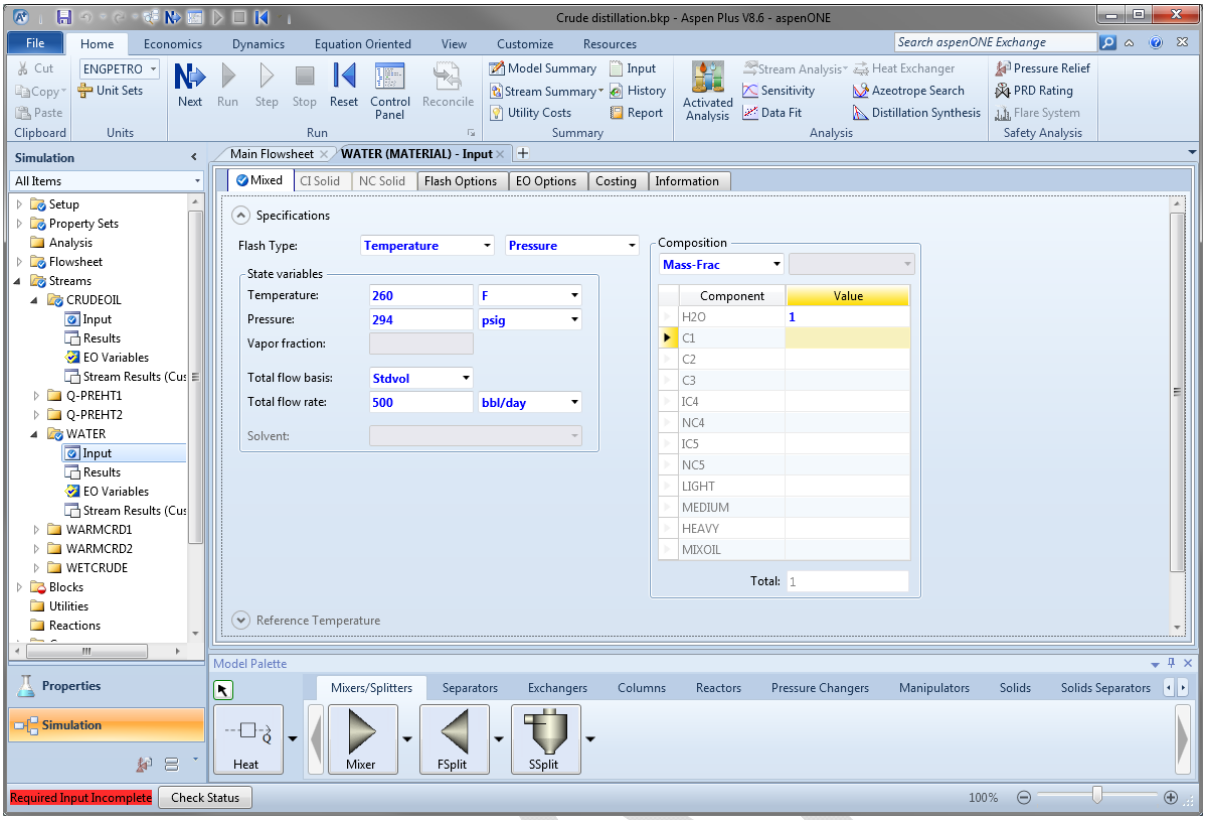


Let's add in the equipment & other streams for the preheat train before we specify rates & operating conditions. Add two *Heaters* and material & heat streams to give a configuration as shown at the beginning of this topic.

We can use the Next button to step us through what needs to be added before we run the simulation. The first thing we should do is define the water carried over from the Desalter. Enter the information as shown. Note that we don't really know an appropriate temperature for the water before it is mixed with the crude, rather, the temperature after the mixing. For now specify the temperature as 260°F.



The next recommendation is to specify the operating conditions for the 1st Preheater. Specify the outlet temperature & pressure.

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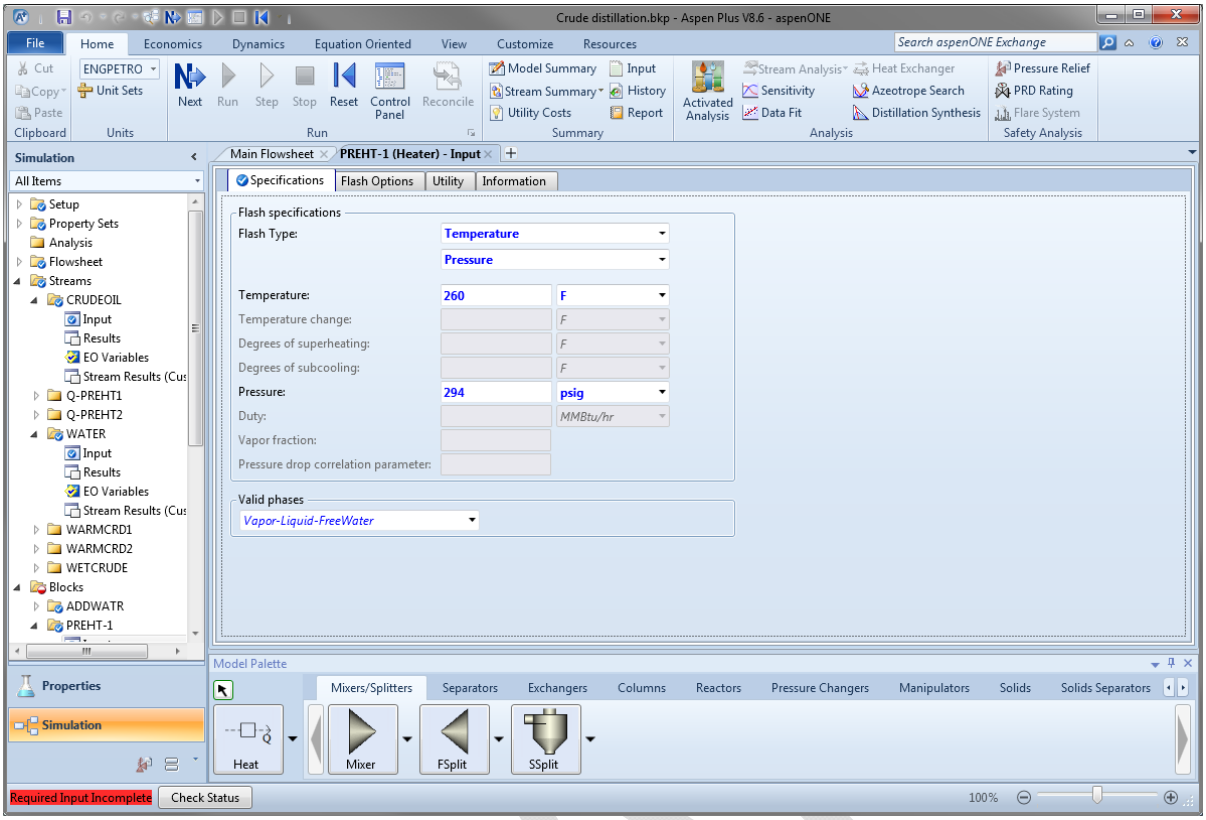

The next recommendation is to specify the operating conditions for the 2nd Preheater. Specify the outlet temperature & pressure.

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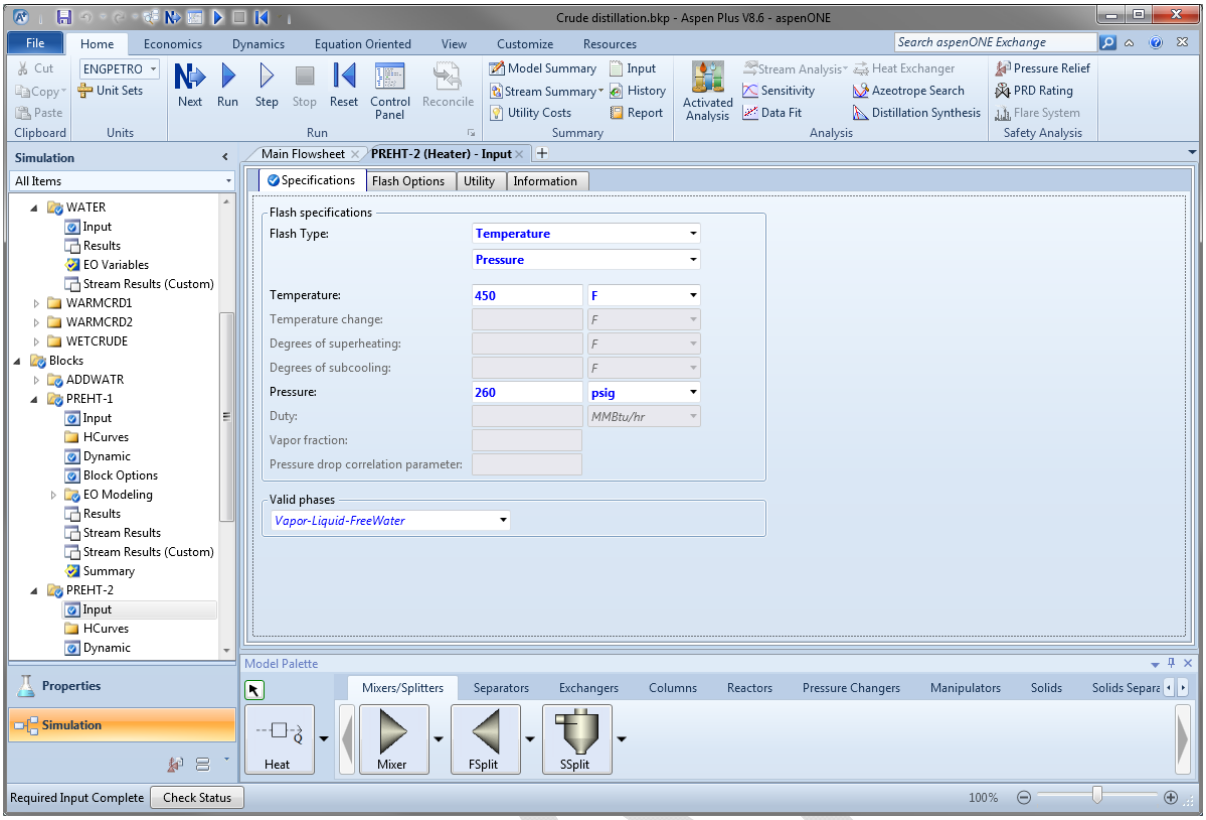
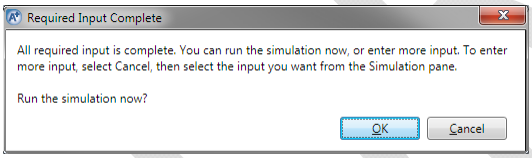
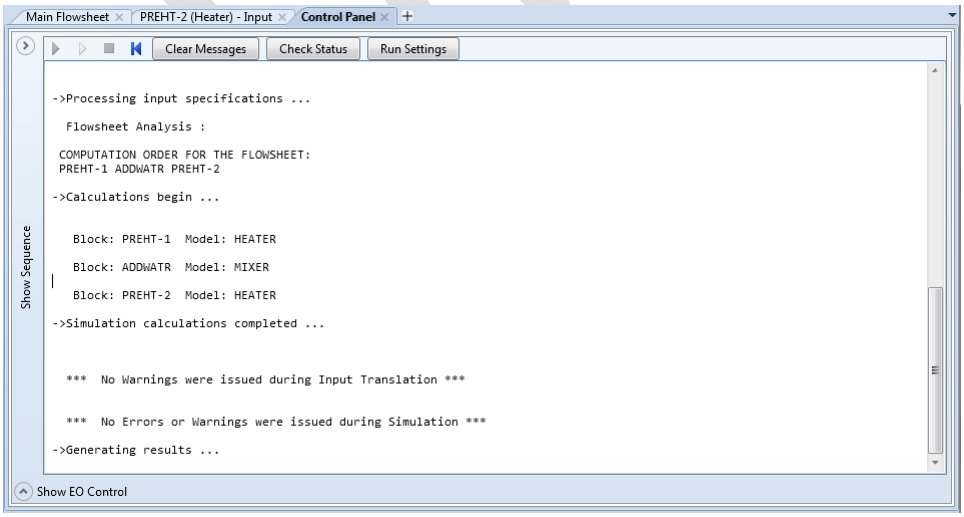
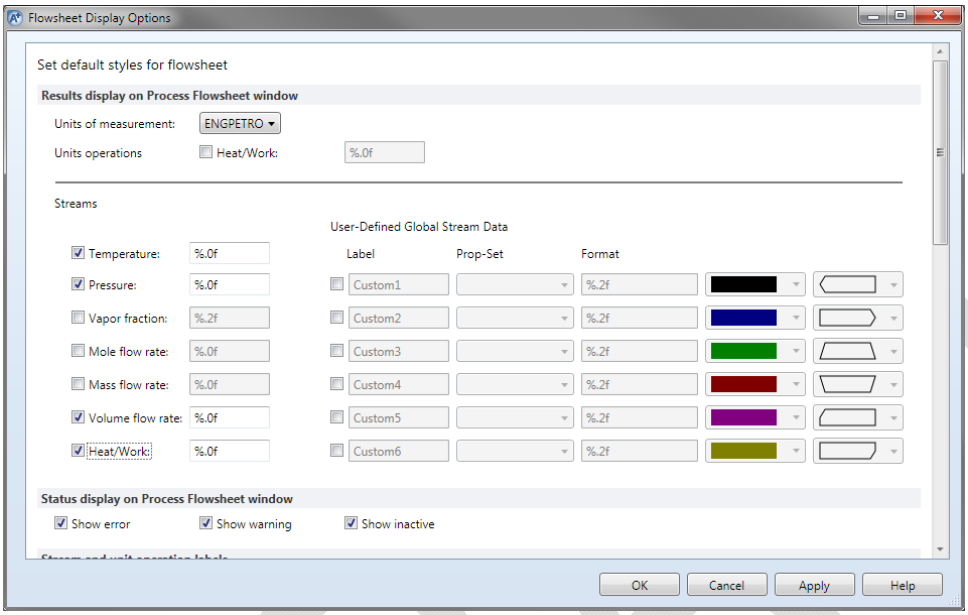


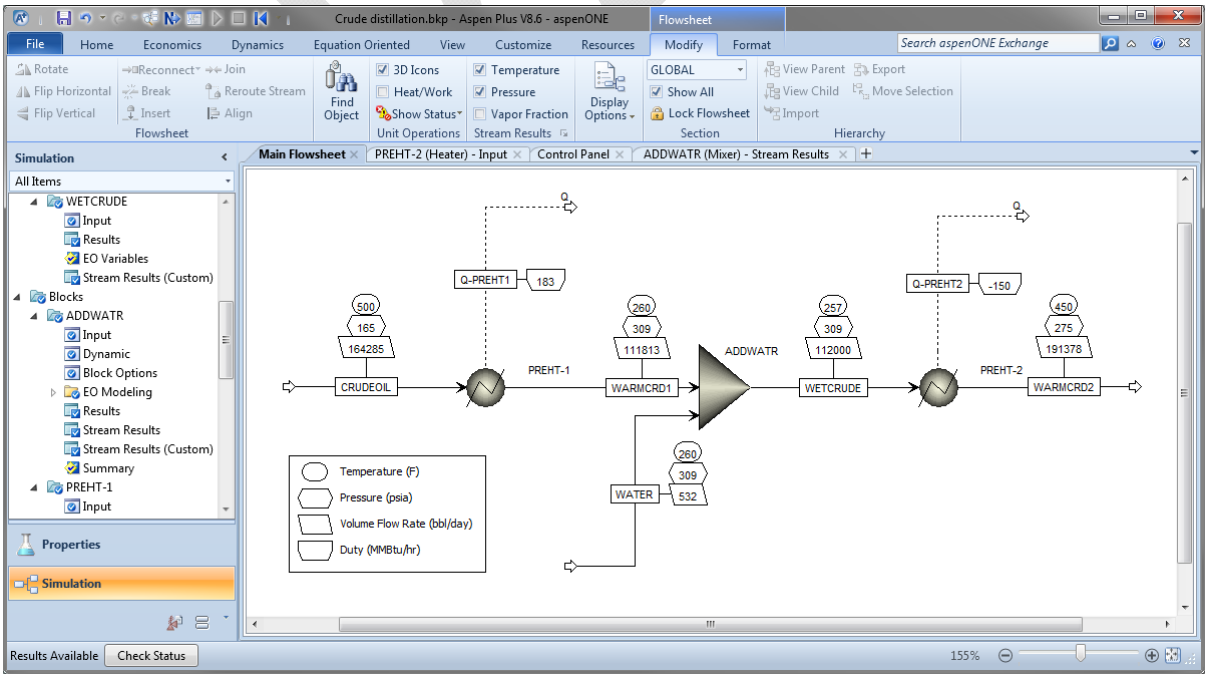
Pressing Next shows that all of the required specifications have been made. Press *OK* to run the simulation. A tab for the *Control Panel* should open up & indicate that the simulation has run successfully.





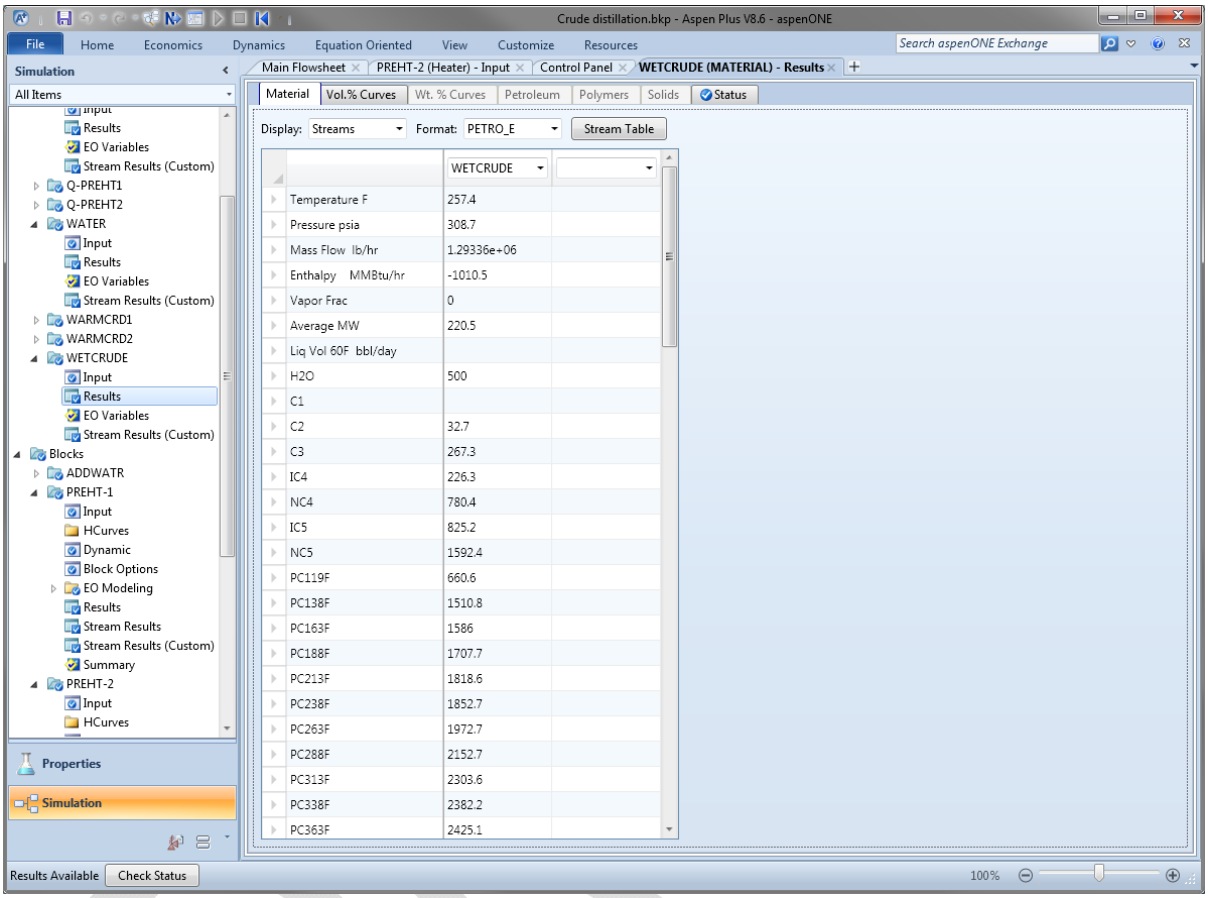
What are some of the results? We can get an overview by posting summary conditions on the flowsheet. Click on Stream Results in the Modify tab of the ribbon. Select *Temperature*, *Pressure*, *Volume flow rate*, & *Heat/Duty*. Press *OK*. Now these numbers are posted on the flowsheet; note that the volumetric flowrate shown in the actual volumetric flowrate (at the flowing temperature & pressure conditions), not the standard volumetric flowrate (that we have been specifying).

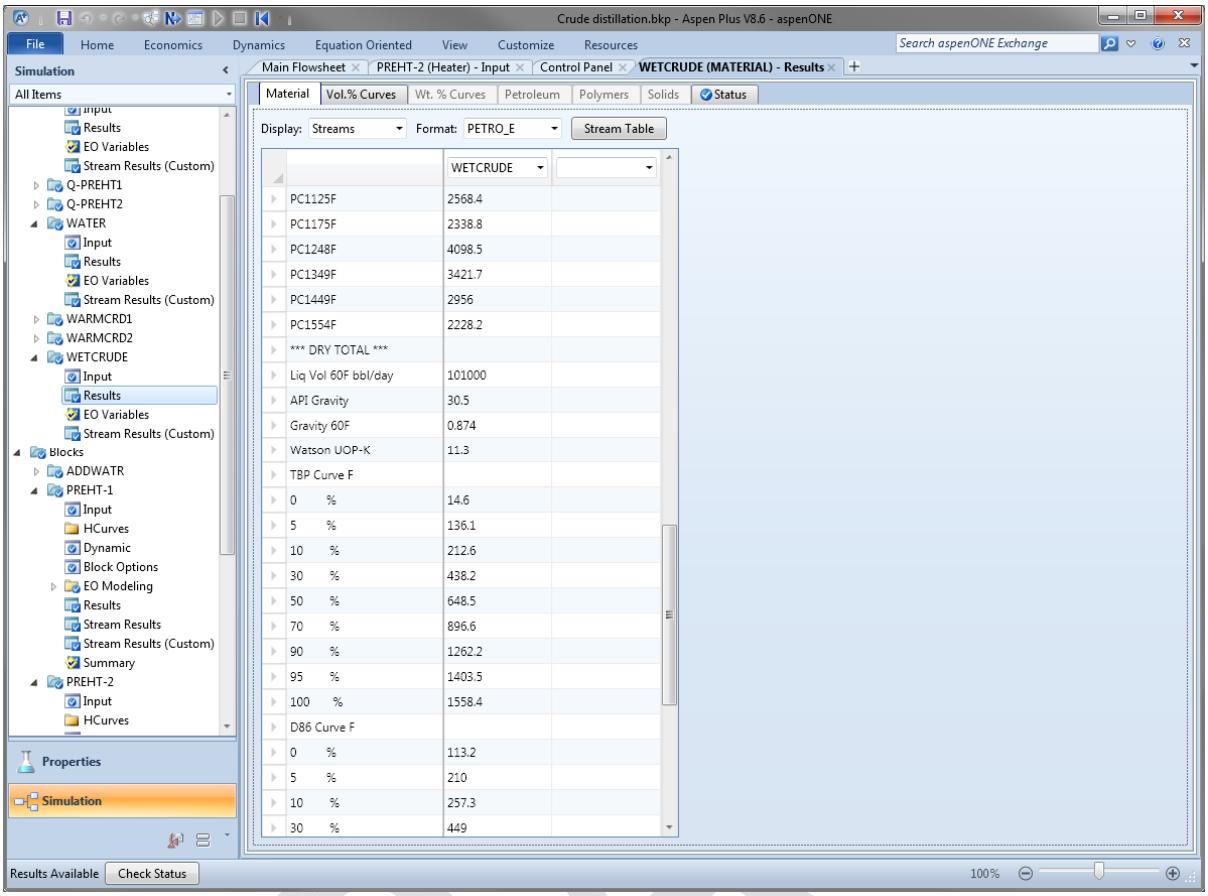


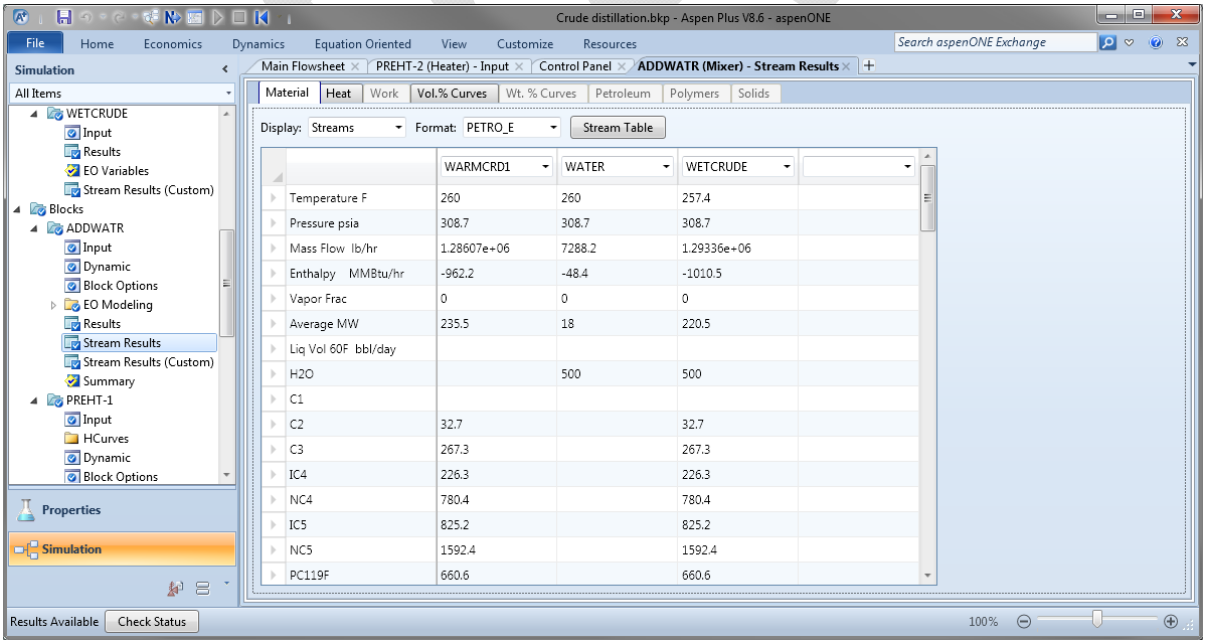


We can see more detailed results by examining the individual streams & units. For example, if we select *Results* for *WETCRUDE* & use the Format *PETRO_E* then we can see the

calculated temperature (257.4°F), the standard liquid volume flowrate of the components (including the pseudo components used). At the bottom of the list you can find the total volumetric flow and distillation curves (on a dry basis). We can see these same results (and more) by selecting the *Stream Results* for *ADDWATER*.





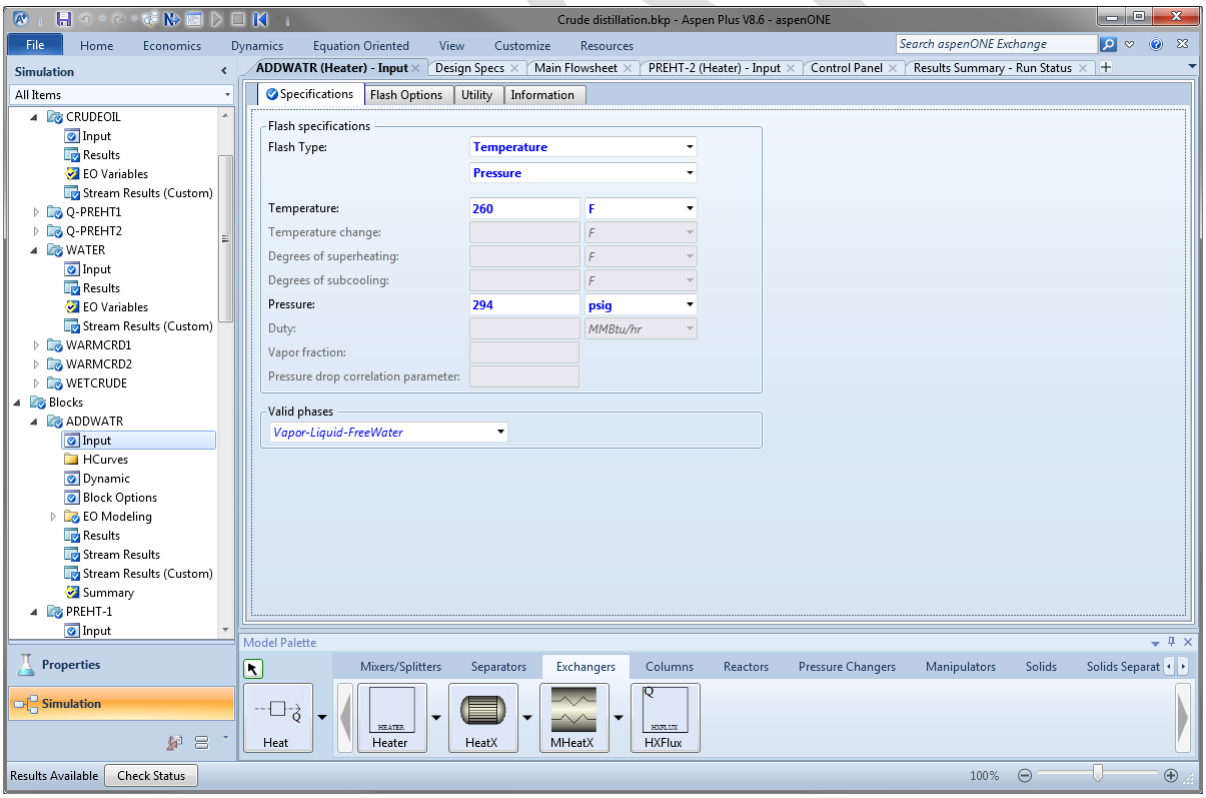


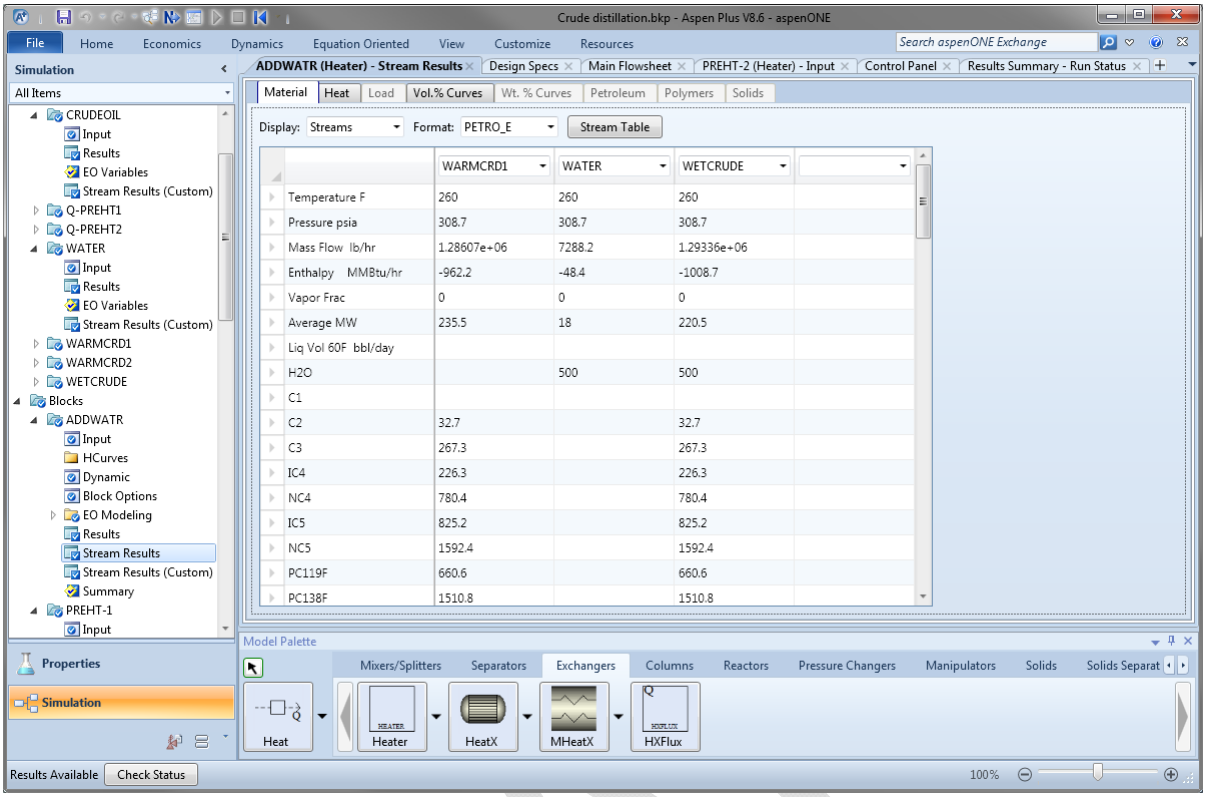
Notice that we would like the temperature of the crude/water mixture to be 260°F, but the result of the mixing operation is a little bit lower, 257°F. Is this a significant deviation from the specifications? Not for anything downstream of the 2nd preheater; this preheater sets

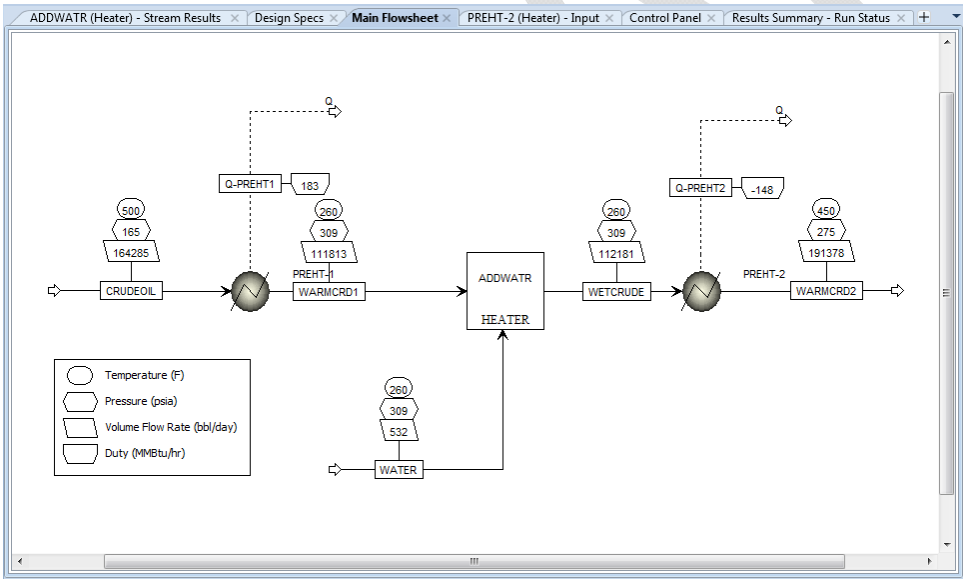
the overall temperature & is not dependent on the inlet conditions. However, it will cause a slight difference in the duty in the 2nd preheater; having a slightly higher inlet temperature will reduce the duty required to bring the outlet temperature up to 450°F. There are two reasonable ways to do this:

- We could change *ADDWATR* to a "dummy" *Heater* & set the temperature of the mixture.
- We could adjust the temperature of the *WATER* stream so that it gives the proper outlet temperature. This adjustment could be done either manually (trial & error) or using a *Design-Spec* block.

If we adjust the conditions of the water stream we find out that the water has to be set as a steam/liquid mixture to get the right properties of WETCRUDE. Since we're not really interested in the conditions of this added water, let's take the dummy heater approach. Highlight the *Mixer ADDWATR* & delete. Let's put a *Heater* in its place; choose a block for its icon; call the block *ADDWATR*. Right-click on *WARMCRD1*, select *Reconnect Destination*, & connect to *ADDWATR*. Do the same for *WATER*. Right-click on *WETCRUDE*, select *Reconnect Source*, & connect to *ADDWATR*. In the left-hand column select *ADWATR* under *Blocks*. Specify the outlet temperature & pressure. Press Run. Now when we look at the Stream Results for ADDWATR we see that the outlet temperature is correct. From the Flowsheet we can see that, indeed, the duty on the 2nd preheater has been reduced slightly, from 150 MMBtu/hr to 148 MMBtu/hr.







Atmospheric Distillation Column

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

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

Aspen Plus has a specific module for efficiently solving crude tower type problems, the *PetroFrac* model (not *RadFrac*). On the *Columns* tab select the list arrow for *PetroFrac*. Now

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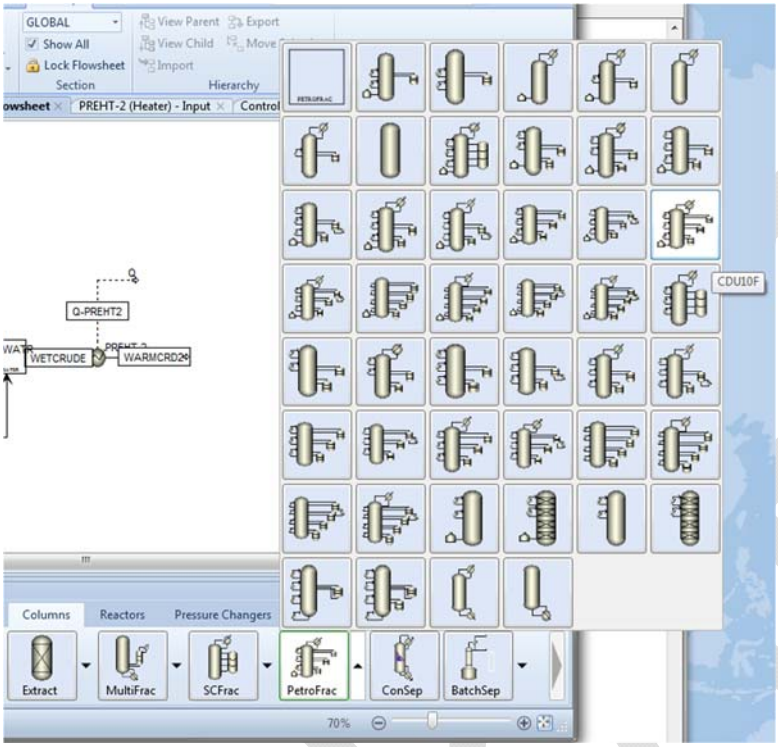
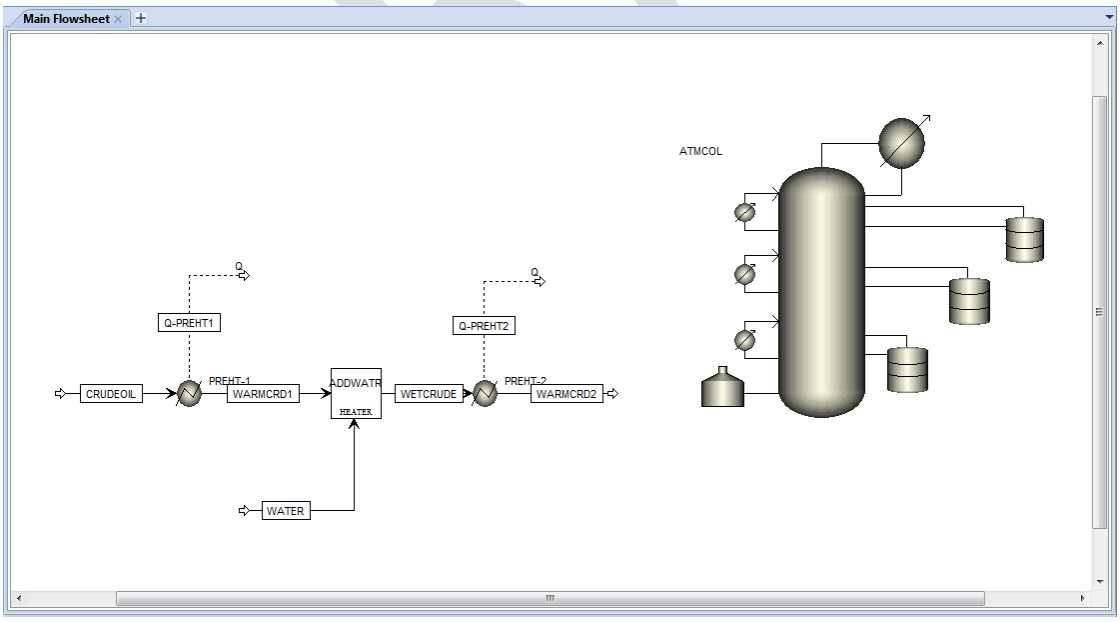
we can choose an icon that will most closely represent out column; choose *CDU10F*, the one with a condenser, fired heater, 3 pumparounds, & 3 side strippers. (This choice only changes the icon, not the ability to specify side operations or the number of each). Place on the flowsheet & name *ATMCOL*. Highlight the icon on the flowsheet & grab a corner to resize (make it much bigger than the icons representing the preheat train).

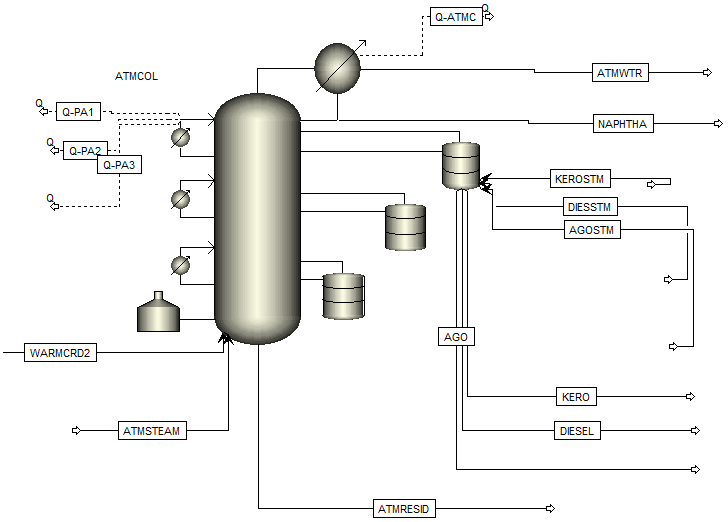


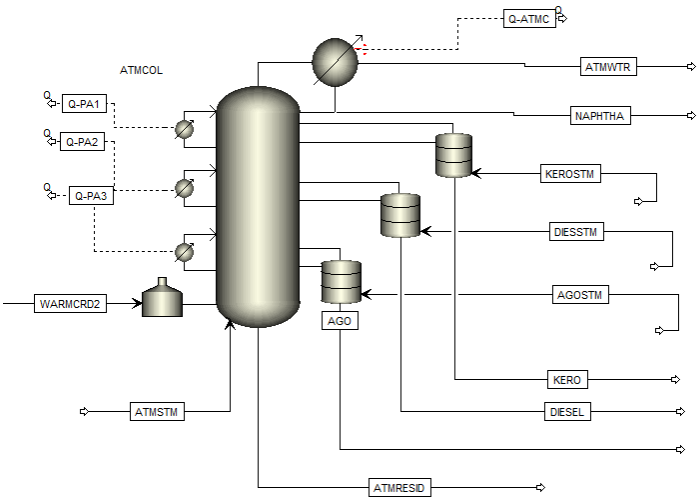


Let's make the stream connections. Right-click WARMCRD2, select Reconnect Destination, & connect to ATMCOL. Create the following additional streams & connect to ATMCOL:

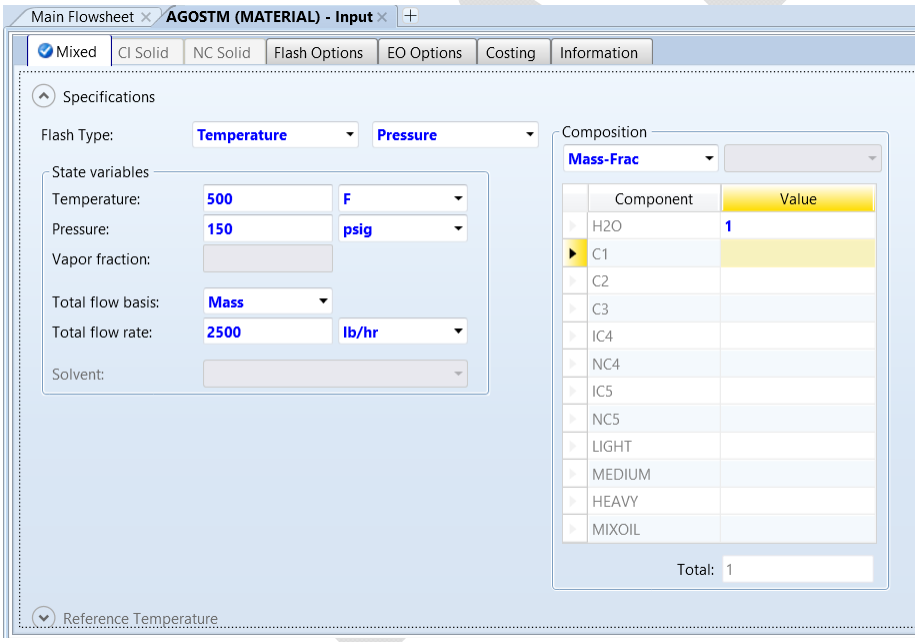
- Material stream ATMSTM to Main Column Feed connections.
- Material streams KEROSTM, DIESSTM, & AGOSTM to Stripper Steam Feed connections.
- Material product streams NAPHTHA from the Distillate Product connection , ATMWTR from the Condenser Water Decant connection, & ATMRESID from the Bottoms Product connection.
- Material product streams KERO, DIESEL, & AGO from the Bottoms Product from Stripper connection.
- Heat streams Q-ATMC from the Condenser Heat Stream connection; Q-PA1, Q-PA2, & Q-PA3 from the Heat Stream from Pumparound connection;

Your flowsheet should have a column that looks something like the image below. You can "clean up" the image by clicking the column icon, "grabbing" the colored inlet or outlet arrows and moving the arrows to make an overall image that looks more reasonable; see the second image below. The new image does not change any connections but rather shows a more logical flow path.

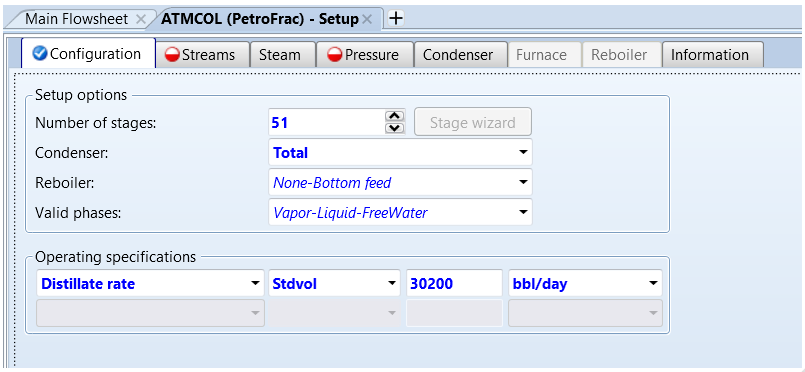




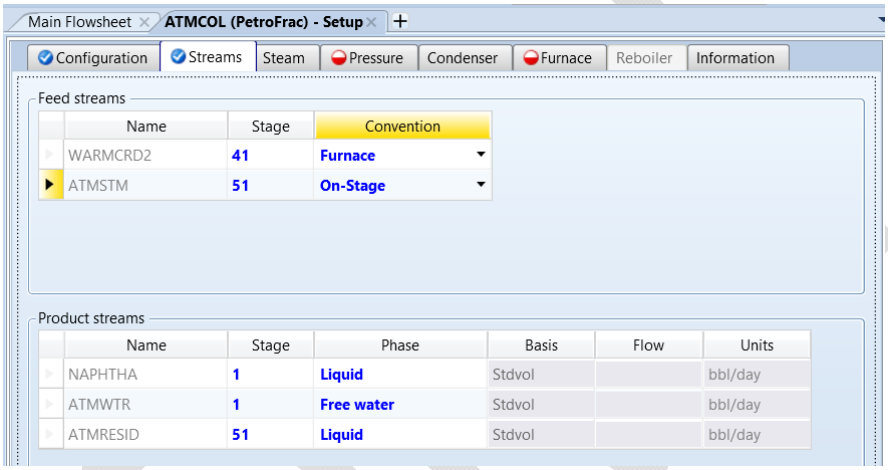
Clicking the Next arrow will step through required steps to set up this distillation column. The first thing required will be the steam streams: ATMSTM, KERSTM, DIESTM, & AGOSTM. All streams will be 500 F & 150 psig; each has to be set up with the proper mass flowrate.



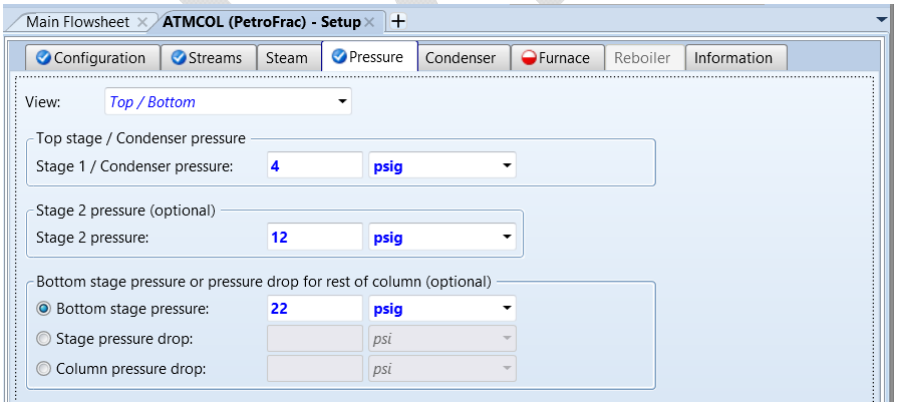
Once past the steam streams the configuration for the column itself comes up. The Configuration tab allows you to set up the most basic information for the column. Note that Aspen Plus counts the condenser as a stage, so the total number is 51 (1 for the condenser & 50 for the trays). On this form enter the estimate for the distillate rate (i.e., the rate for the unstabilized naphtha, NAPHTHA).



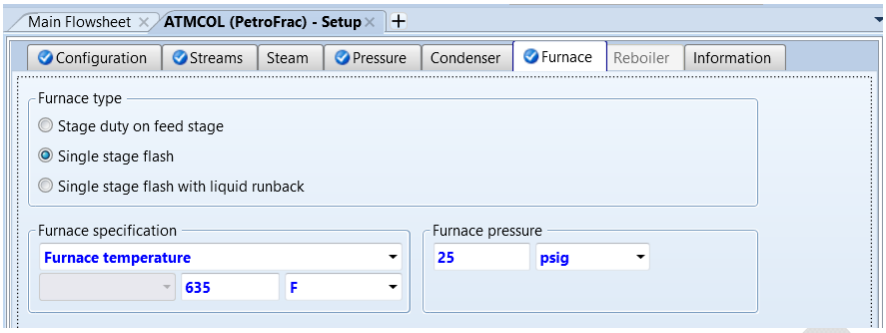
Click Next. Now we'll set up the external feeds to the column. The crude oil will go through the furnace first (the furnace is calculated as part of the column algorithm); remember that the condenser is Stage #1 so we have to add this to the tray numbering for the feed location. The steam if introduced to the bottom stage; remember to mark this as *On-Stage* so that there is vapor traffic to this stage.



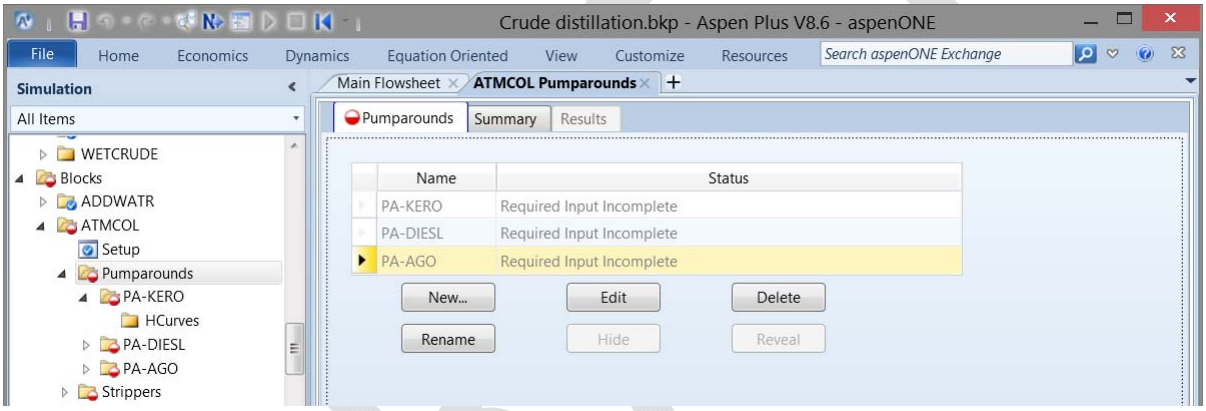
Click Next. Now we will enter the pressures.



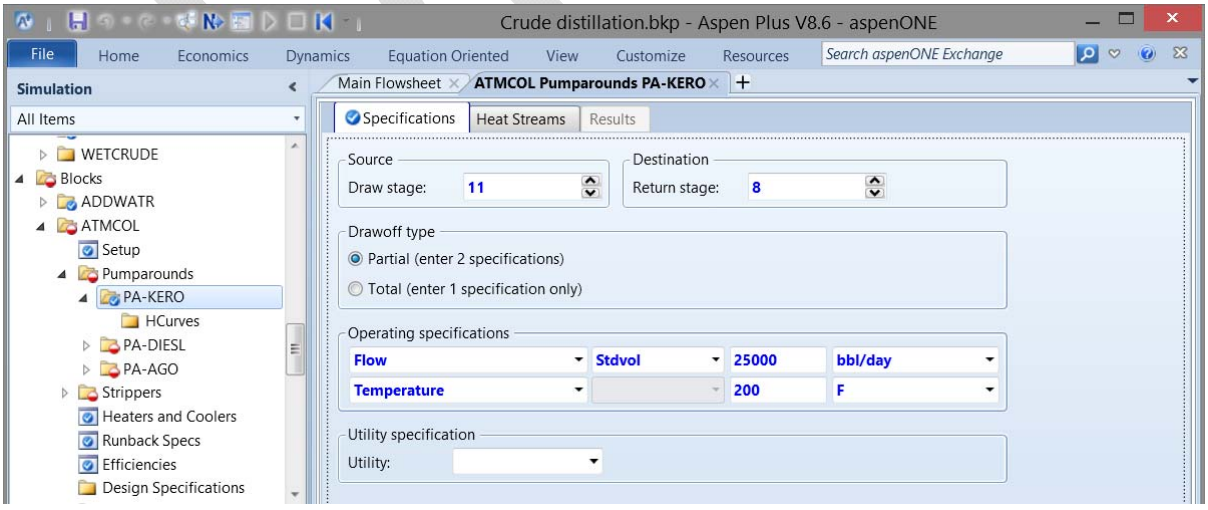
Click Next. Now we will enter the furnace information. Select *Single stage flash* so that Aspen Plus will perform a flash for the outlet temperature of the furnace.



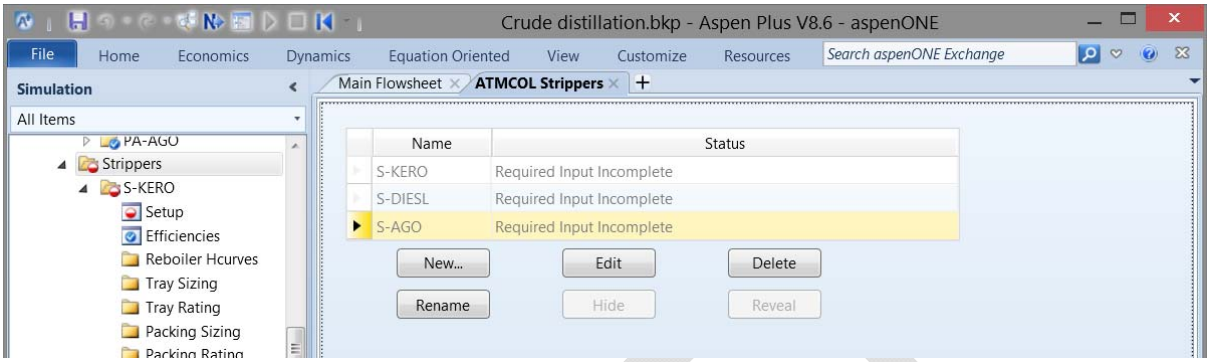
Click Next. Now we are to enter configuration information for the pumparounds. But first let's rename the pumparounds to match the product sections. Select *Pumparounds* under *ATMCOL* in the left-hand column. Select each row & click *Rename*. Change names to *PA-KERO*, *PA-DIESL*, & *PA-AGO*.



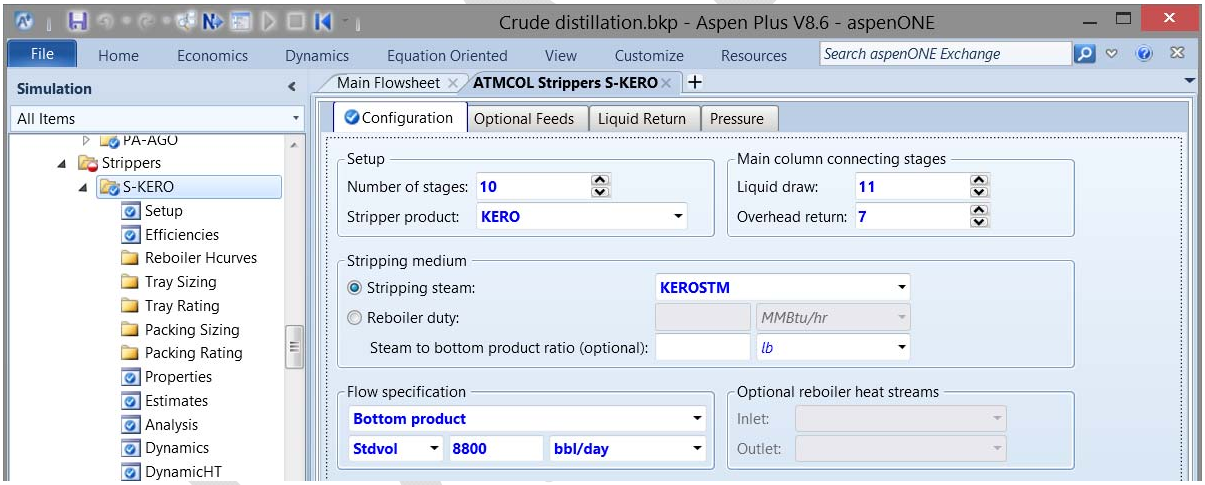
Now let's get back to the Pumparound configuration forms. Select *PA-KERO* in the left-hand column. When specifying the Draw stage & Return stage remember to add 1 to account for the condenser as Stage 1. Do the same for *PA-DIESL* & *PA-AGO*.



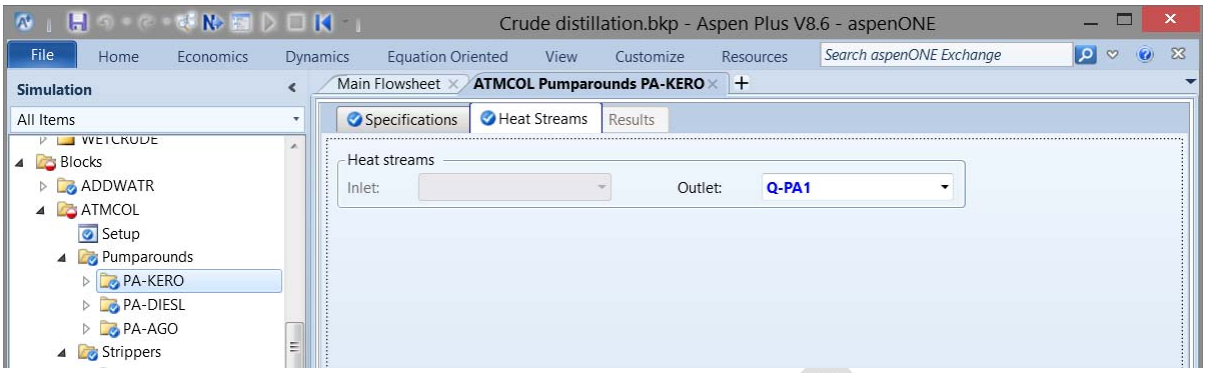
Click Next. Now we are to enter configuration information for the side strippers. But first let's rename the side strippers to match the product sections. Select *Strippers* under *ATMCOL* in the left-hand column. Select each row & click *Rename*. Change names to *S-KERO*, *S-DIESL*, & *S-AGO*.



Now let's get back to the side stripper configuration forms. Select *S-KERO* in the left-hand column. When specifying the Draw stage & Return stage remember to add 1 to account for the condenser as Stage 1. Do the same for *S-DIESL* & *S-AGO*.

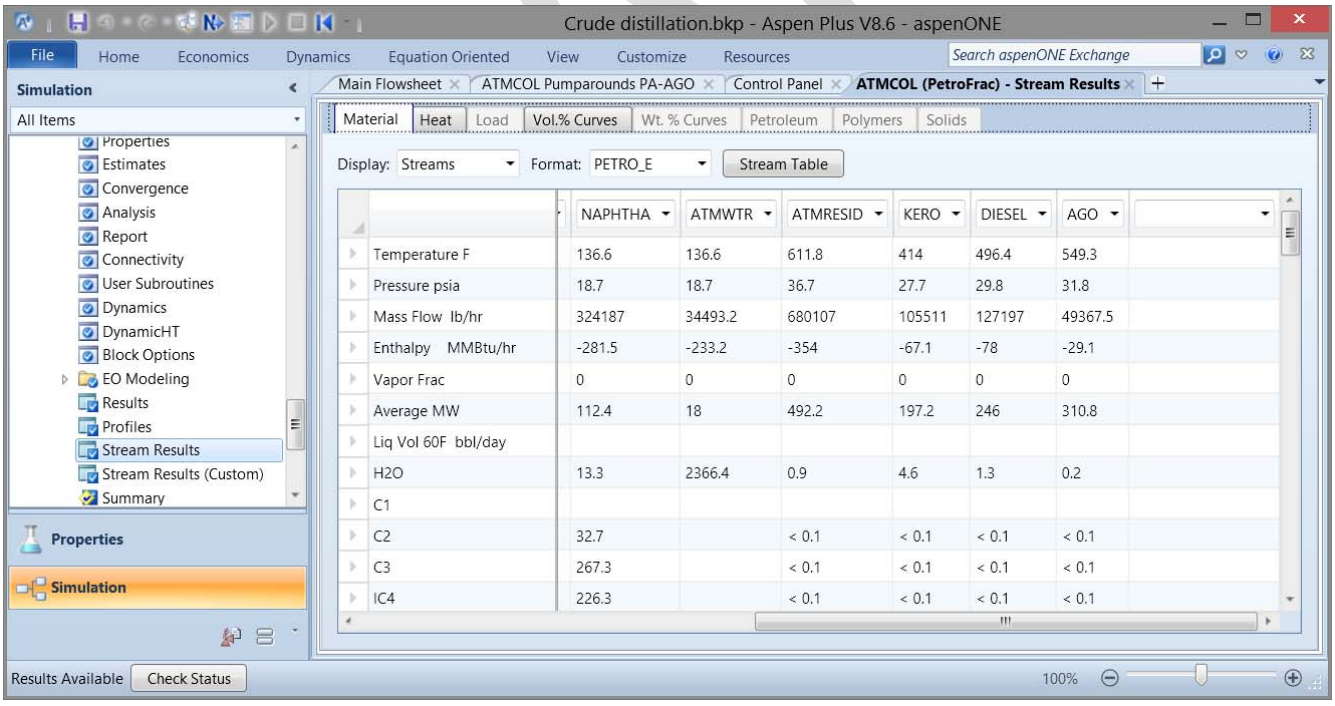


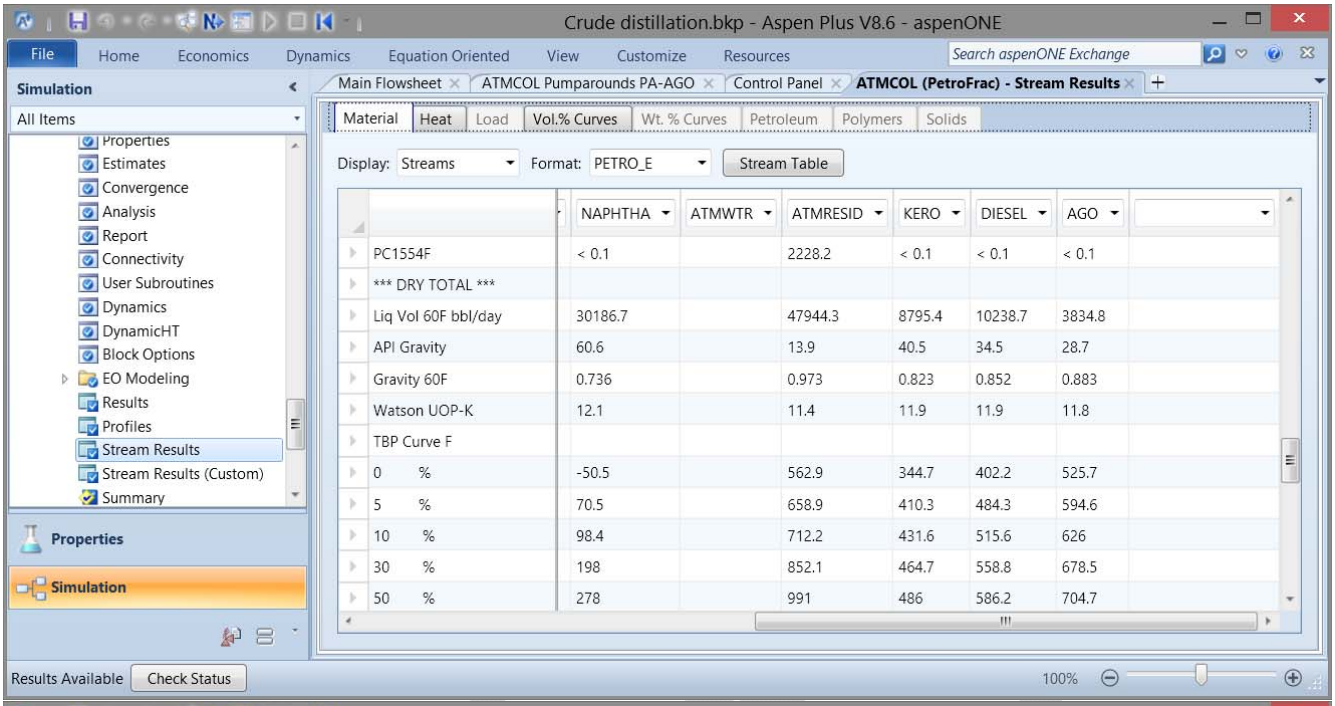
Click Next. Now a form comes up to verify connectivity. We've already connected all of the material streams, now we have to connect the heat streams. The heat stream is connected to the condenser by virtue of how they were originally connect to ATMCOL. But we still have to do the pumparound heat streams. Select *PA-KERO* under *Pumparounds* in the left-hand column. Now select the *Heat Stream* tab; select the pull-down list for Outlet & select one of the Q-PA streams. Do the same for *PA-DIESL* & *PA-AGO*.

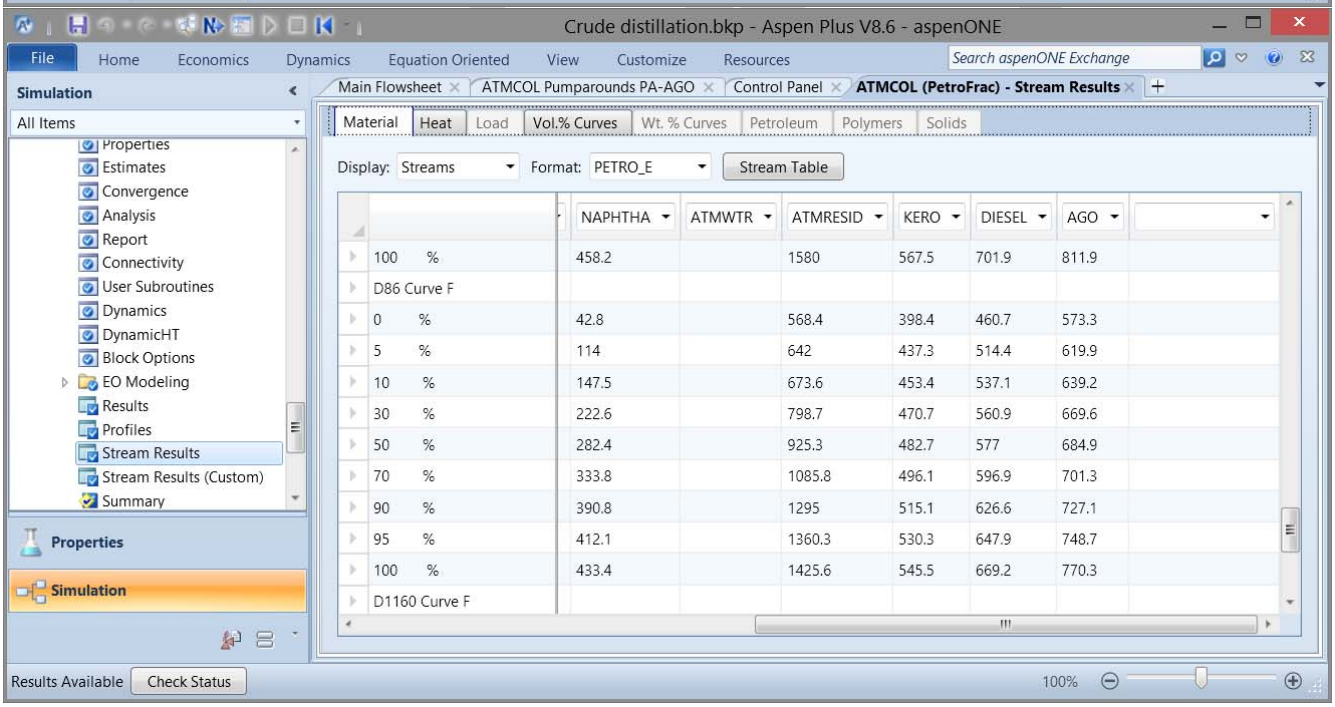


Click Next. We have now entered enough information to run the simulations. However we have not entered the stage efficiencies nor the ASTM D86 specs. Let's press OK and run the simulation anyway. It converges very quickly, in about 4 outer-loop iterations. What do the results look like? We can select the Stream Results tab to look at flowrates & T95 results. Note the following:

- The stream flowrates listed (the 2nd image) are lower than the specifications made on the column; that is because this shows the flowrate on a dry basis (i.e., with the water neglected) & the specification is on a total basis (with the water included).
- The T95 results for the distillation curves are close but not what is desired. We will want to adjust the draw rates to get the desired T95 values.

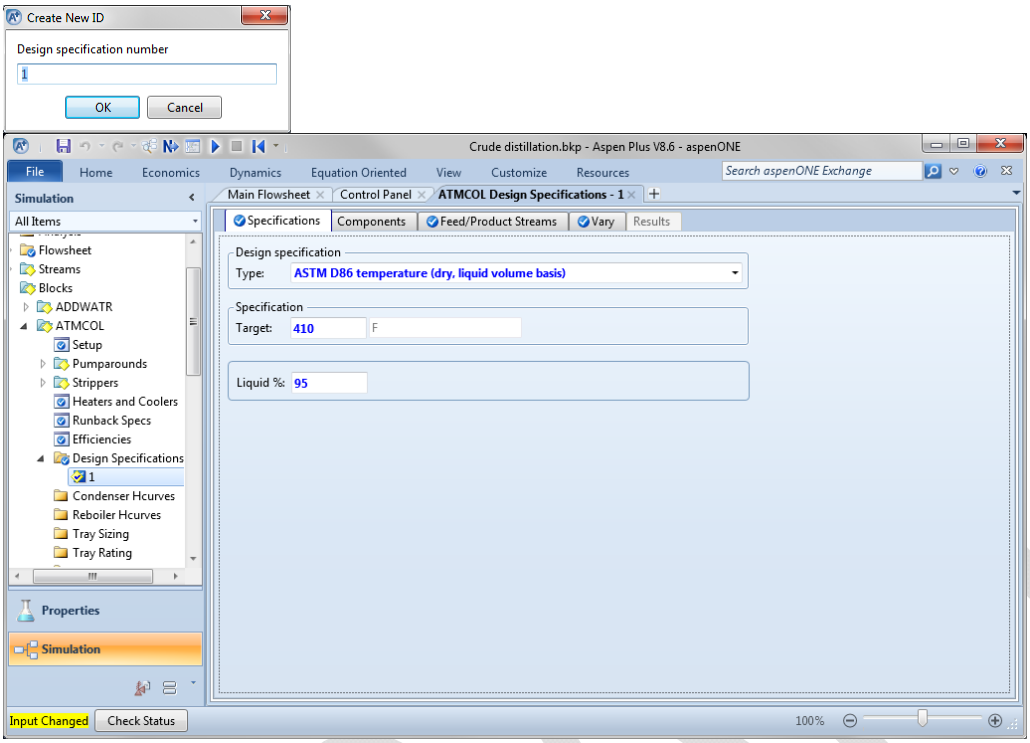


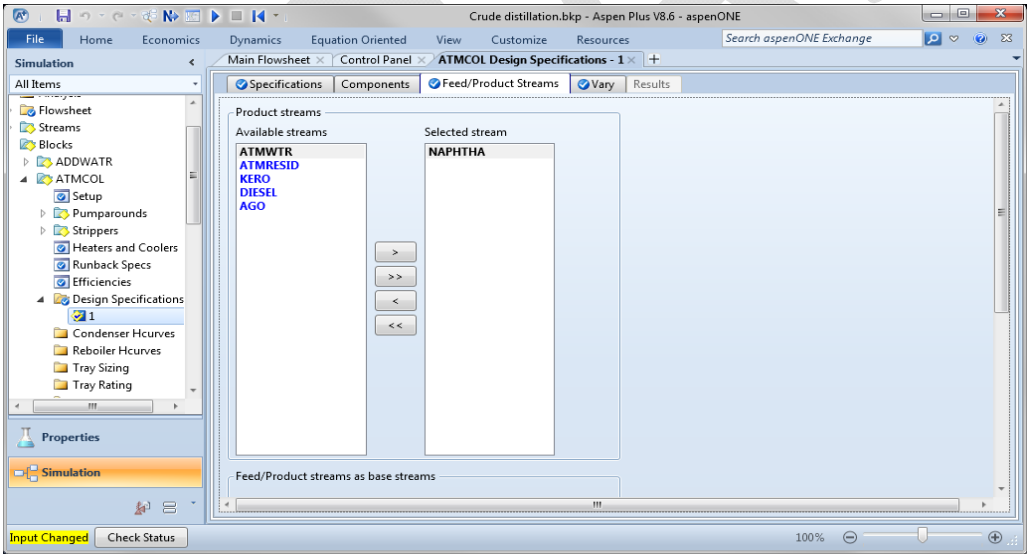


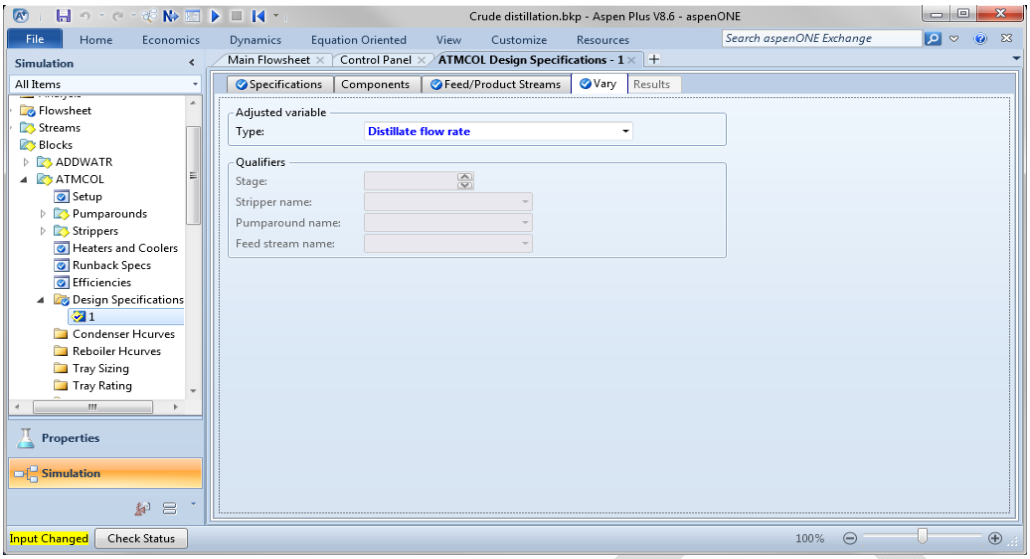


We'll now set the T95 specifications. Select *Design Specifications* under *ATMCOL* in the left-hand column. Press *New…* You cannot name the design specs, only number them; accept the numbers when presented in the *Create New ID* form; press *OK*. Let's first specify the T95 value for the naphtha. Pull down the *Type* list on the *Specifications* tab; select *ASTM D86 temperature (dry, liquid volume basis)*. Set the *Target* value as 410°F & the *Liquid %* as 95. Select the *Feed/Product Streams* tab; highlight the *NAPHTHA* stream & press > to move

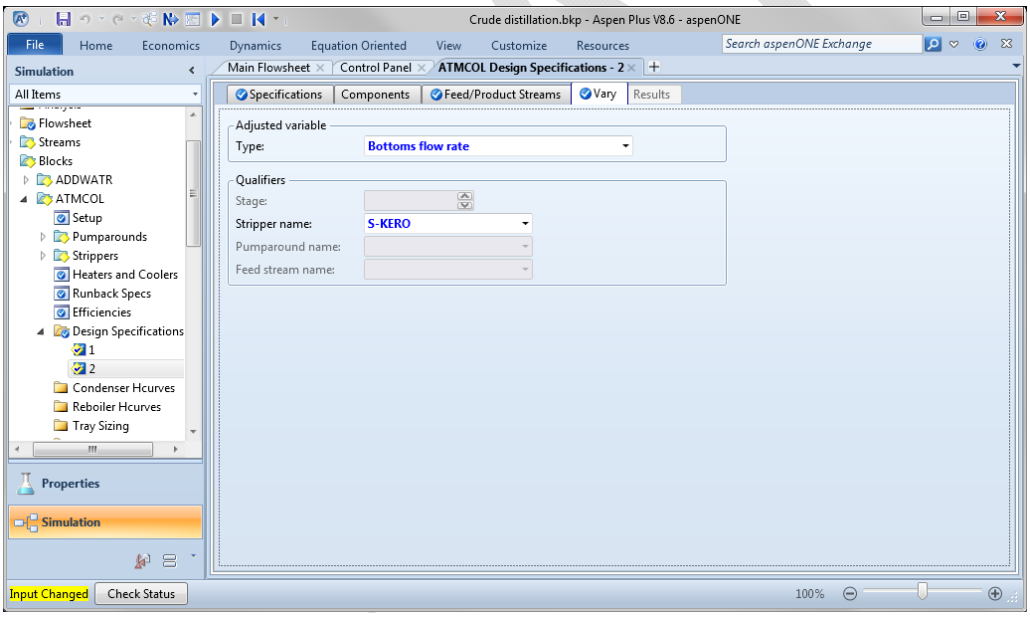
it to the *Selected Stream* column. Select the *Vary* tab; pull down the *Type* list & select *Distillate flow rate.*





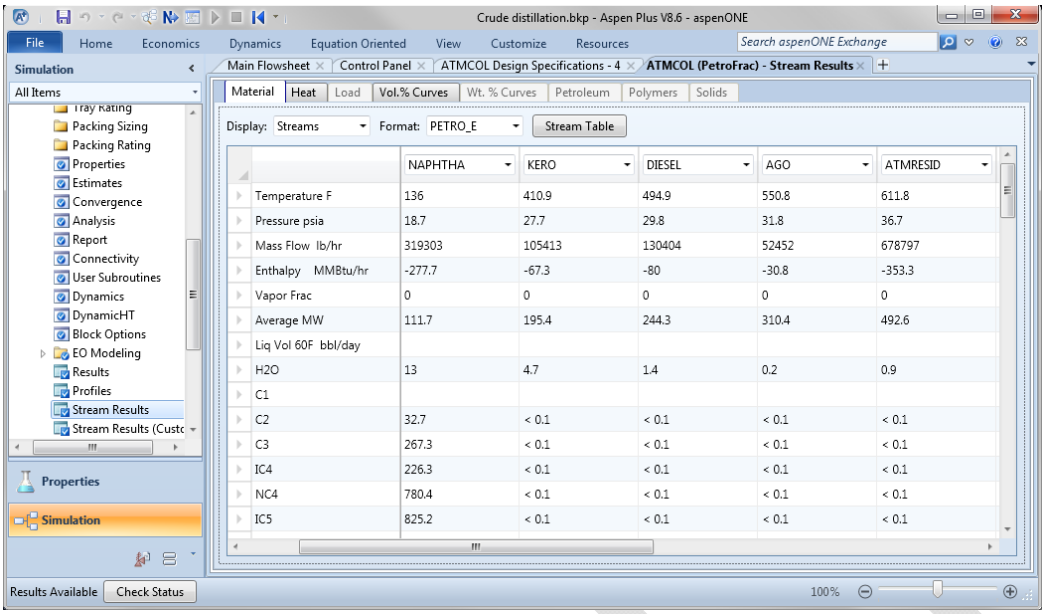


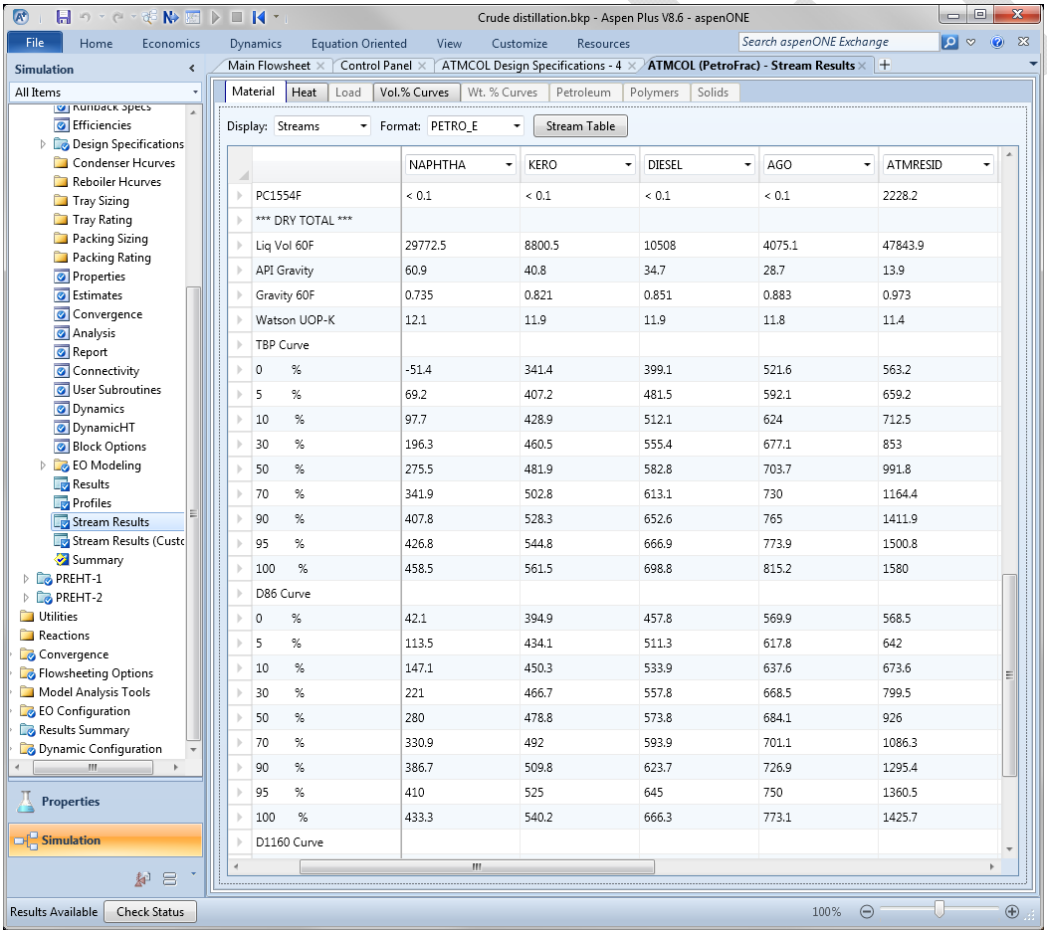
Specifying the T95 values for the kerosene, diesel, & AGO streams is done in a similar manner except when specifying what to vary. For the kerosene stream select the *Vary* tab; pull down the *Type* list & select *Bottoms flow rate* & then select *S-KERO* from the *Stripper name* list. Do similar specifications for the diesel & AGO streams.



We now have replaced the 4 flowrate specifications with the 4 T95 specifications. Select Run. It should again take about 4 outer-loop iterations to solve the column equations.

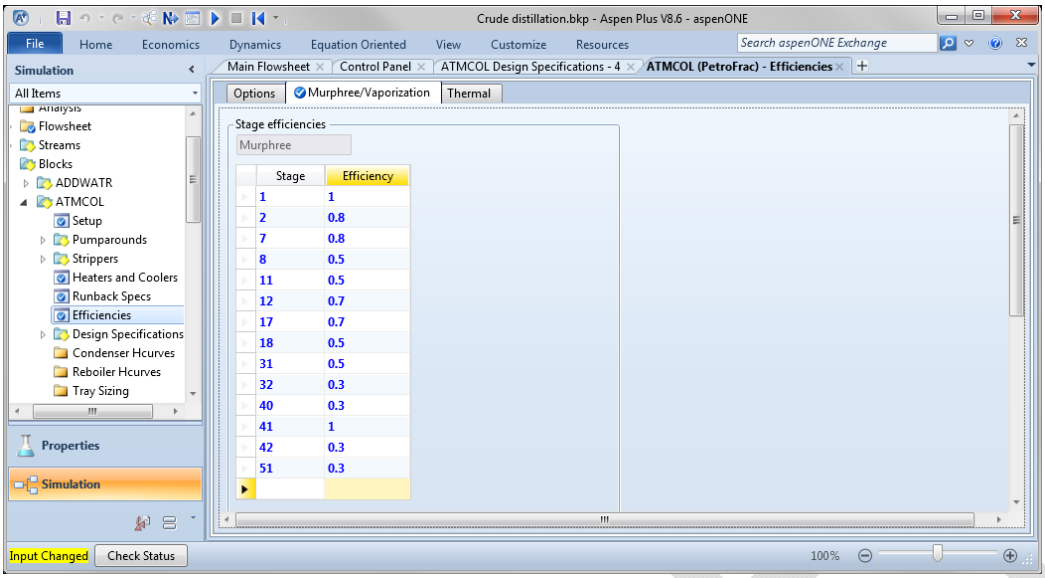
We can again look at the product streams by choosing *Stream Results*.



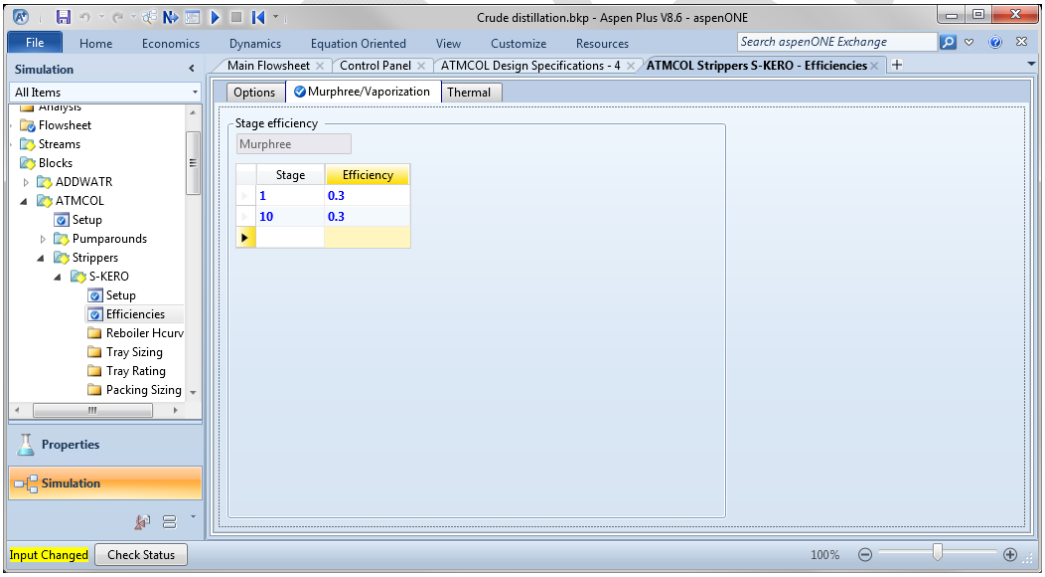


We still haven't added the stage efficiencies to model actual trays. For the main column select *Efficiencies* under *ATMCOL* in the left-hand column. Select the *Murphree/Vaporization* tab. You do not have to specify the efficiencies for each individual stage but rather they can

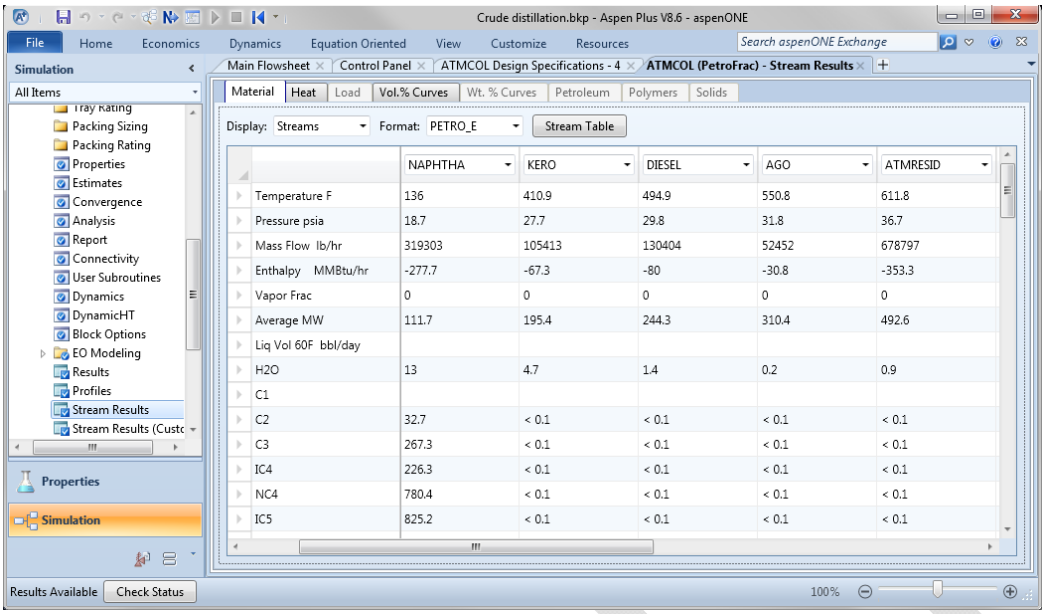
be grouped. Remember to add 1 stage to account for the condenser being Stage #1; the efficiency of the condenser will be 100%.



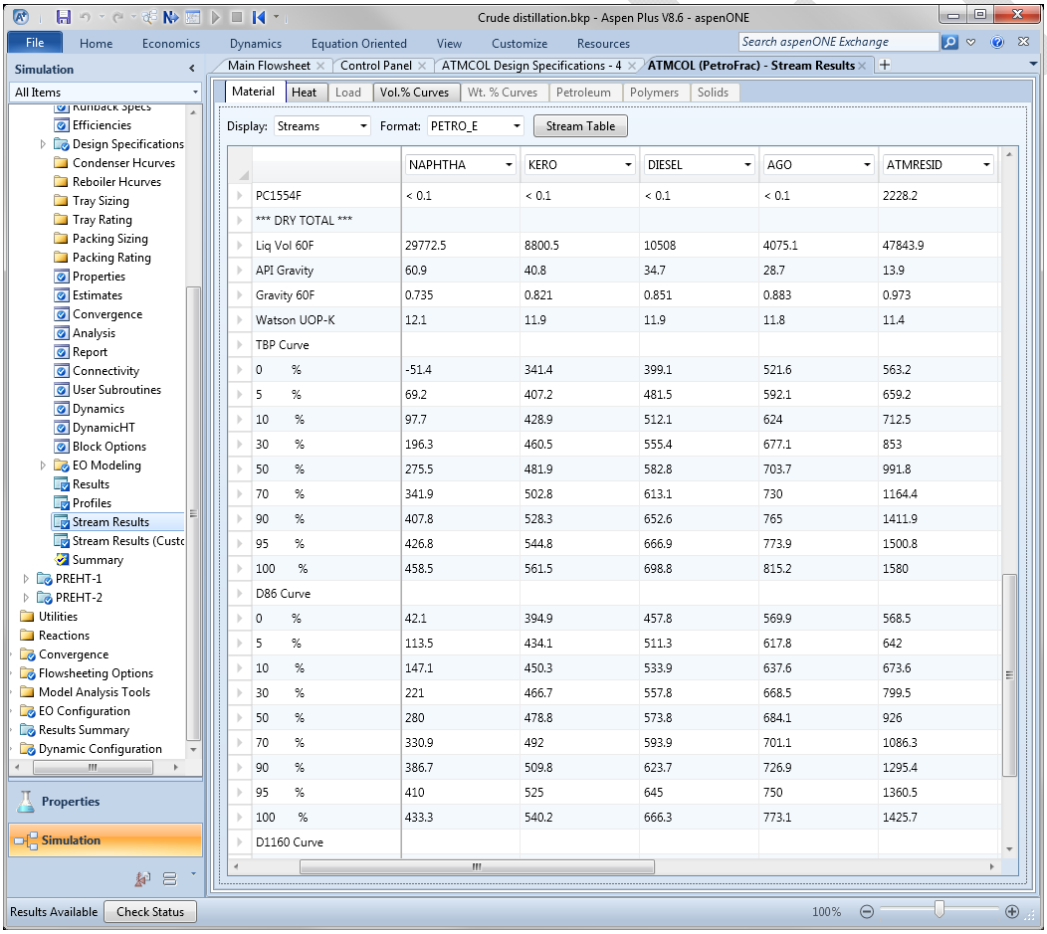
The efficiencies for the side strippers are done in their corresponding section. For the kerosene side stripper select *Efficiencies* under *S-KERO* in the left-hand column. Select the *Murphree/Vaporization* tab. Do similar operations for the diesel & AGO side strippers.



We can now rerun will all specifications. Select Run. It will take more iterations but should still converge in less than 25 outer-loop iterations. We can again look at the product streams by choosing *Stream Results*.



	NAPHTHA	KERO	DIESEL	AGO	ATMRESID
Temperature F	136	410.9	494.9	550.8	611.8
Pressure psia	18.7	27.7	29.8	31.8	36.7
Mass Flow lb/hr	319303	105413	130404	52452	678797
Enthalpy MMBtu/hr	-277.7	-67.3	-80	-30.8	-353.3
Vapor Frac	0	0	0	0	0
Average MW	111.7	195.4	244.3	310.4	492.6
Liq Vol 60F bbl/day					
H2O	13	4.7	1.4	0.2	0.9
C1					
C2	32.7	< 0.1	< 0.1	< 0.1	< 0.1
C3	267.3	< 0.1	< 0.1	< 0.1	< 0.1
IC4	226.3	< 0.1	< 0.1	< 0.1	< 0.1
NC4	780.4	< 0.1	< 0.1	< 0.1	< 0.1
IC5	825.2	< 0.1	< 0.1	< 0.1	< 0.1



	NAPHTHA	KERO	DIESEL	AGO	ATMRESID
PC1554F	< 0.1	< 0.1	< 0.1	< 0.1	2228.2
*** DRY TOTAL ***					
Liq Vol 60F	29772.5	8800.5	10508	4075.1	47843.9
API Gravity	60.9	40.8	34.7	28.7	13.9
Gravity 60F	0.735	0.821	0.851	0.883	0.973
Watson UOP-K	12.1	11.9	11.9	11.8	11.4
TBP Curve					
0 %	-51.4	341.4	399.1	521.6	563.2
5 %	69.2	407.2	481.5	592.1	659.2
10 %	97.7	428.9	512.1	624	712.5
30 %	196.3	460.5	555.4	677.1	853
50 %	275.5	481.9	582.8	703.7	991.8
70 %	341.9	502.8	613.1	730	1164.4
90 %	407.8	528.3	652.6	765	1411.9
95 %	426.8	544.8	666.9	773.9	1500.8
100 %	458.5	561.5	698.8	815.2	1580
D86 Curve					
0 %	42.1	394.9	457.8	569.9	568.5
5 %	113.5	434.1	511.3	617.8	642
10 %	147.1	450.3	533.9	637.6	673.6
30 %	221	466.7	557.8	668.5	799.5
50 %	280	478.8	573.8	684.1	926
70 %	330.9	492	593.9	701.1	1086.3
90 %	386.7	509.8	623.7	726.9	1295.4
95 %	410	525	645	750	1360.5
100 %	433.3	540.2	666.3	773.1	1425.7
D1160 Curve					

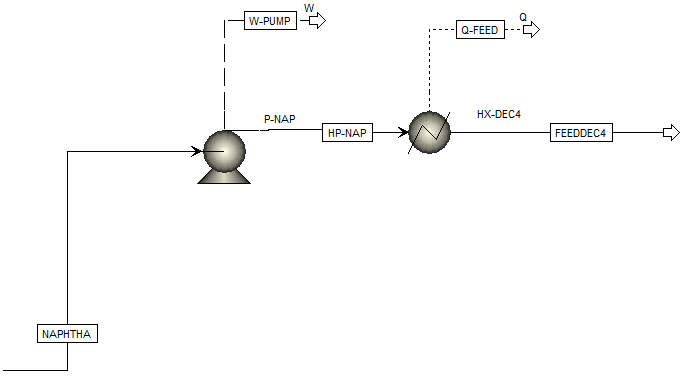
Debutanizer Column

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* & *Heater* on the flowsheet & define the connections as shown on the flowsheet. Click Next & we're to fill in the feed heater information; set the value for *Pressure* to 0 to signify a zero pressure drop. Click Next again & we'll fill in the feed pump information; click for Discharge pressure & set the Pump efficiency to 0.75.



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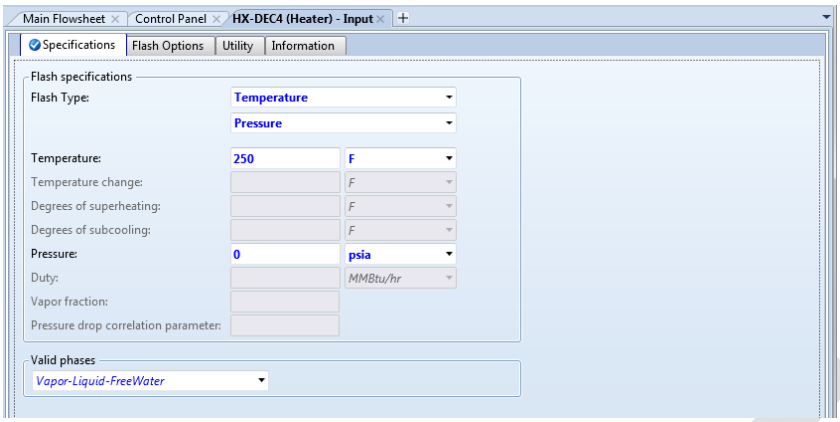
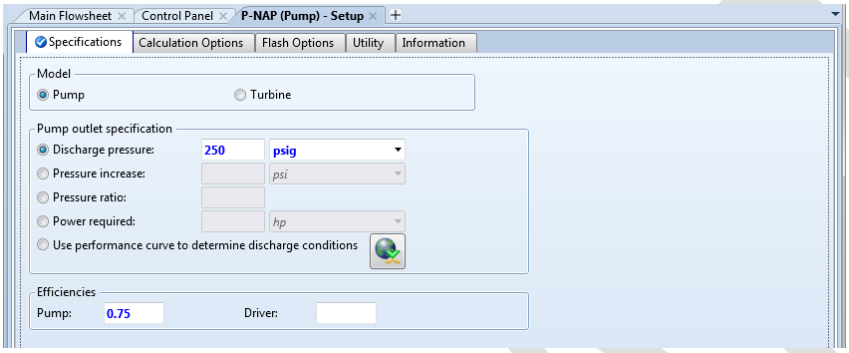
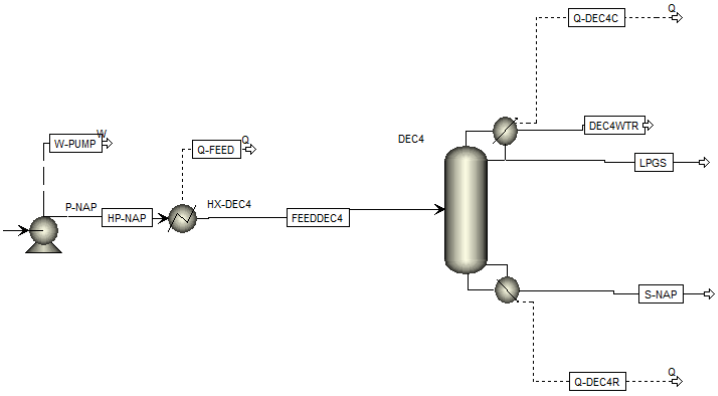


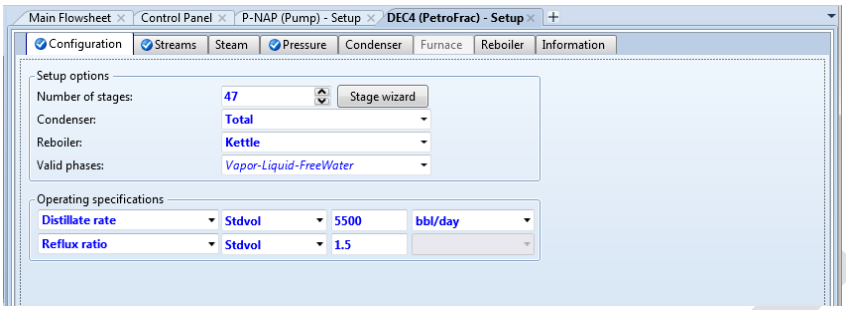


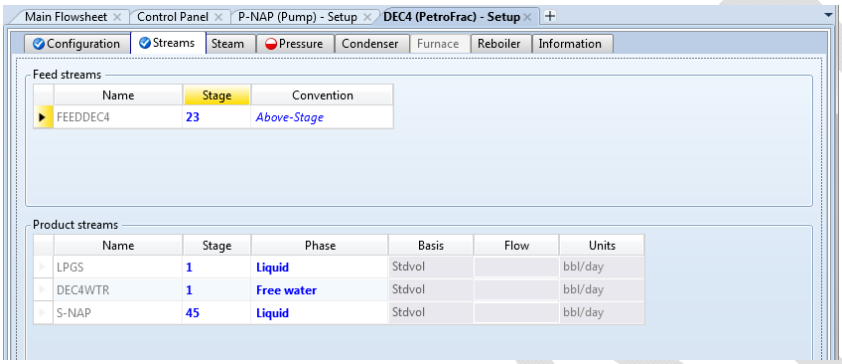
Now we can define the Debutanizer. Just like with the Atmospheric Distillation Column we'll pick an option from *PetroFrac*. Choose the icon on the bottom row with just a reboiler & a condenser (*FRACT*). Connect *FEEDDEC4* as a feed, create products streams *LPGS* & *S-NAP*, overhead water *DEC4WTR*, & heat streams for the condenser & reboiler.

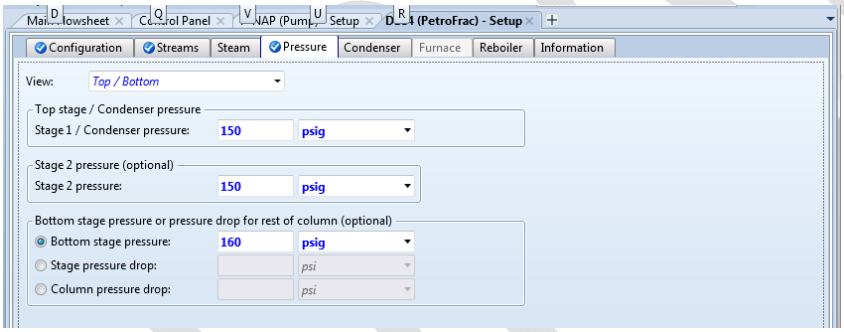


Click Next to start filling in information for this Debutanizer. Remember to add 2 to the *Number of stages* to account for the condenser & the reboiler. Also note that the feed location chosen is *Above-Stage*; this means that liquid from the feed will be introduced to the stage whereas vapor will be put to the stage above (just as if a feed nozzle is put into

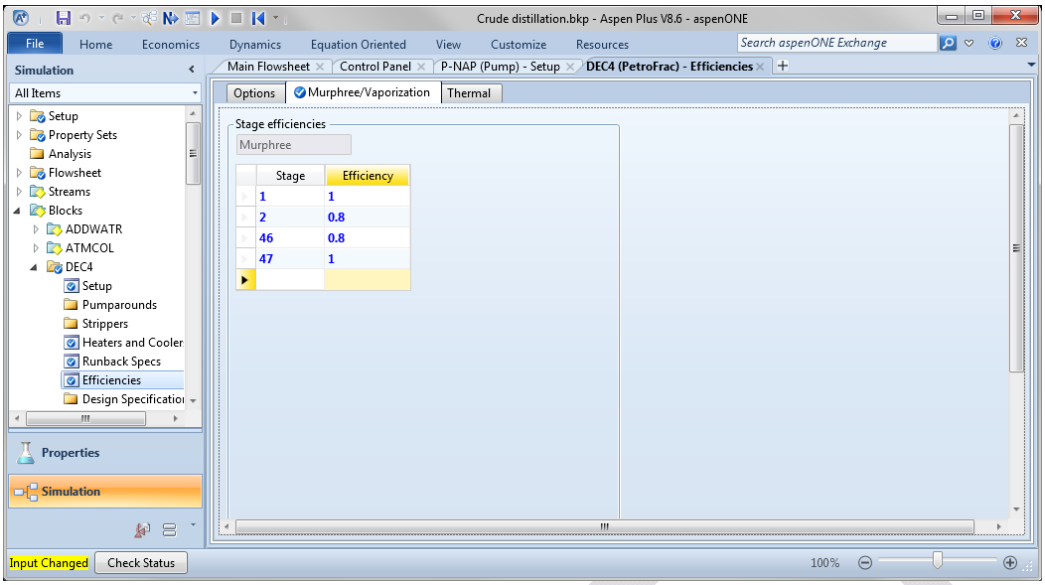
the vapor space above a tray). Remember to add one to the stage location to account for the condenser being Stage #1.







The simulation be run but we need to add the stage efficiencies first. Select *Efficiencies* under *DEC4* in the left-hand column. Select the *Murphree/Vaporization* tab. You do not have to specify the efficiencies for each individual stage but rather they can be grouped. Remember to add 1 stage to account for the condenser being Stage #1 & 1 stage for the reboiler being Stage #47; the efficiencies of the condenser & reboiler will be 100%.



Now we can click Next to run the simulation. It should converge in less than 10 outer-loop iterations.

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.

Place a *Mixer* on the flowsheet downstream from the Atmospheric Column. Next let's place the Vacuum Distillation Column. Just like with the Atmospheric Distillation Column we'll pick an option from *PetroFrac*. Choose the icon with just a fired heater & two pumparounds (*VACUUM1F*). Connect the outlet from the Mixer & a steam stream to the VACCOL as feeds, create products streams *LVGO, HVGO*, & *SLOPWAX* as *Side Products from Main Column*, overhead vapor *VACOVHD*, & heat streams for the two pumparounds.

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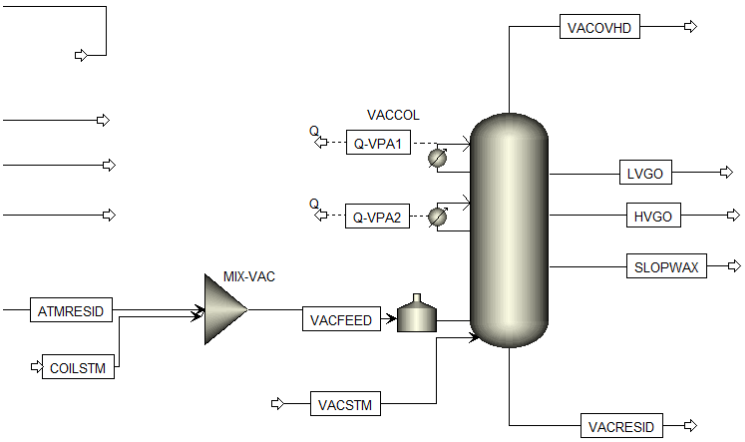

Table 6. Definitions for Vacuum Distillation Column

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; 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, 40 MMBtu/hr cooling
	HVGO Pumparound Draw from Tray #8, returned to Tray #5 50,000 bpd flow, 150°F cooling approximately 400°F, 40 MMBtu/hr 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 bpd Vacuum resid from bottom

First define the steam stream going to the Vacuum Heater Coils. Select COILSTM under STREAMS in the left-hand column. Do the same for the steam stream going to the bottom of the Vacuum Distillation Column, *VACSTM*

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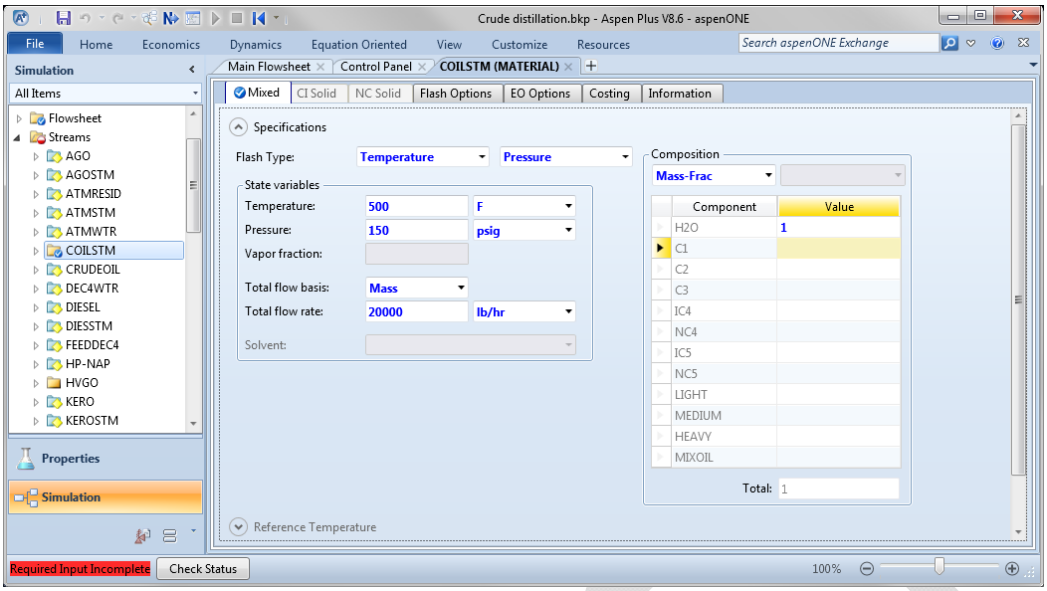
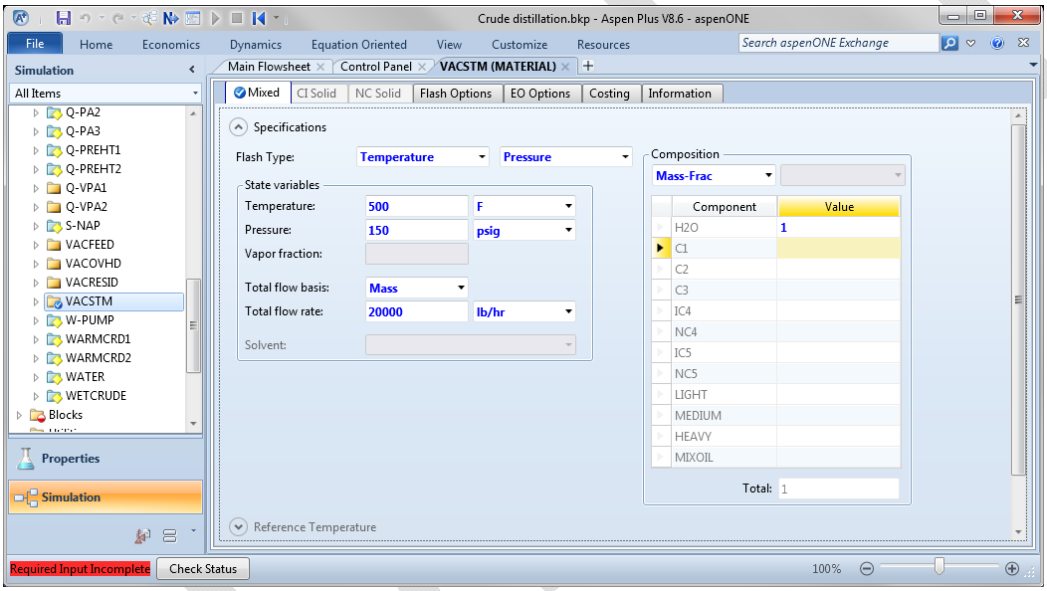
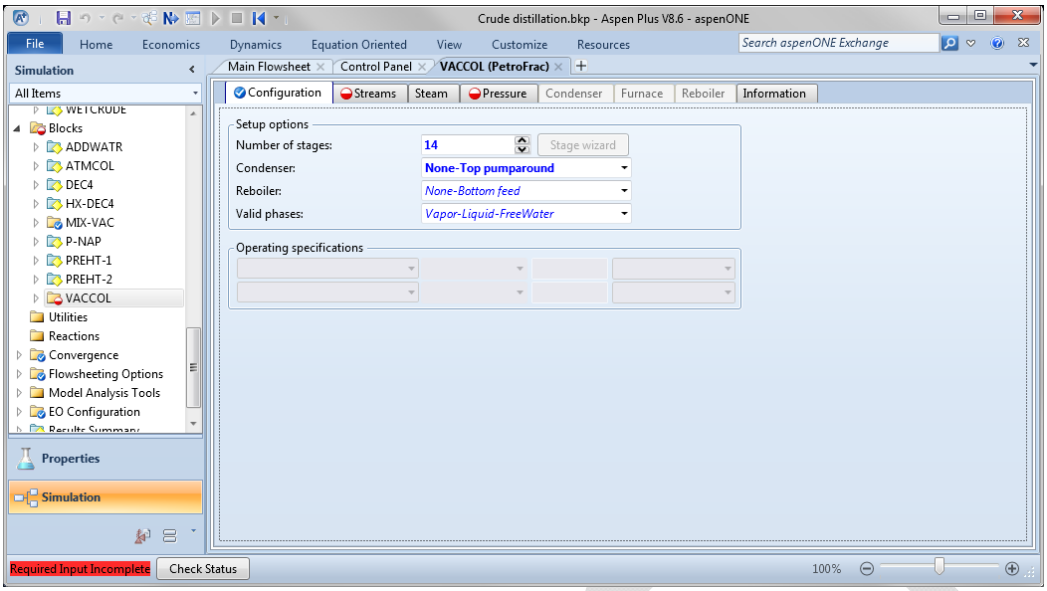




Let's configure the Vacuum Distillation Column itself. Select *VACCOL* under *Blocks* in the left-hand column. Even though the column will be packed we'll model it with a set of non-equilibrium stages. On the Configuration tab pick the *Condenser* option *None-Top pumparound*. On the *Streams* tab denote that *VACFEED* goes through a fired heater before going to Stage #12 & the *VACSTM* goes directly *On-Stage* to #14. Set the top & bottom pressures on the *Pressure* tab. On the *Furnace* tab specify the *Furnace type* as *Single stage flash with liquid runback* & set the outlet temperature & pressure.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MIX-VAC
P-NAP
PREHT-1
PREHT-2
VACCOL
Utilities
Reactions
Convergence
Flowsheeting Options
Model Analysis Tools
EO Configuration
Properties
Simulation
Main Flowsheet
Control Panel
VACCOL (PetroFrac)
Configuration
Streams
Steam
Pressure
Condenser
Furnace
Reboiler
Information
Setup options
Number of stages:
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Stage wizard
Condenser:
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Reboiler:
None-Bottom feed
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Vapor-Liquid-FreeWater
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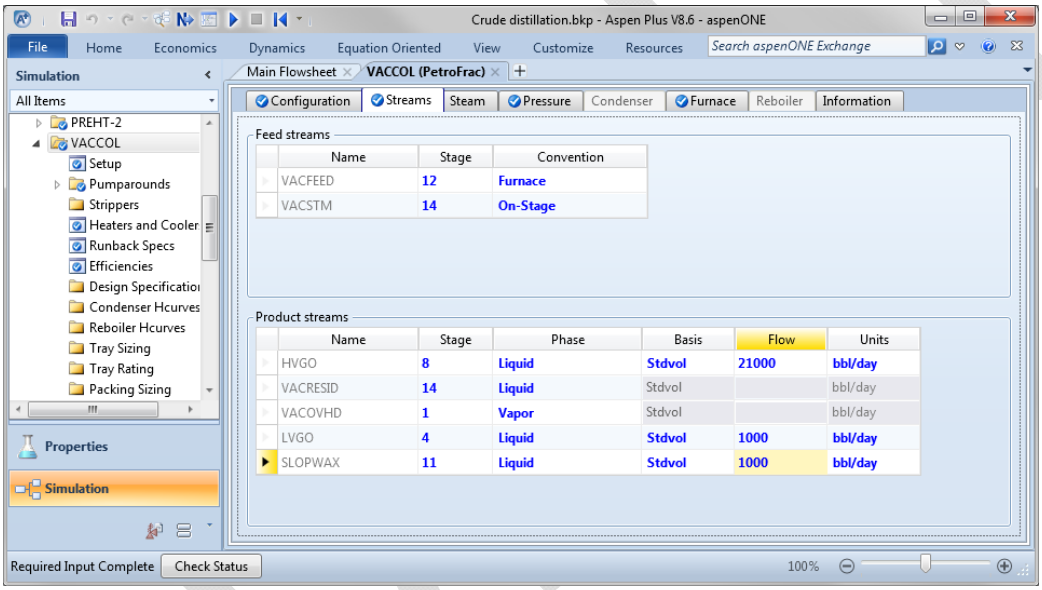
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Strippers
Heaters and Cooler
Runback Specs
Efficiencies
Design Specificatio
Condenser Hcurves
Reboiler Hcurves
Tray Sizing
Tray Rating
Packing Sizing
Properties
Simulation
Main Flowsheet
VACCOL (PetroFrac)
Configuration
Streams
Steam
Pressure
Condenser
Furnace
Reboiler
Information
Feed streams
Name
Stage
Convention
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Furnace
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Basis
Flow
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Vapor
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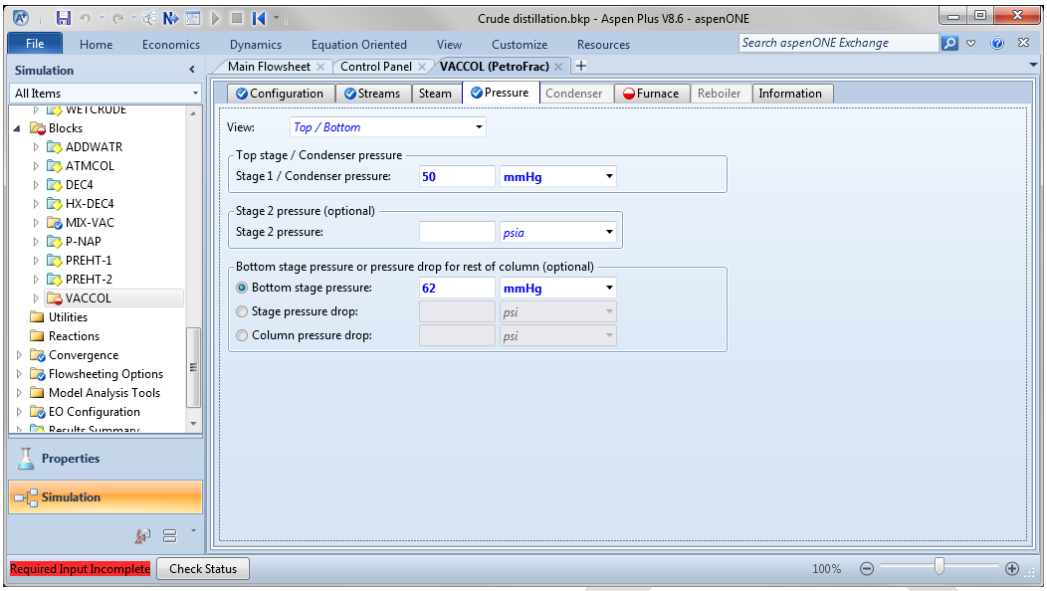
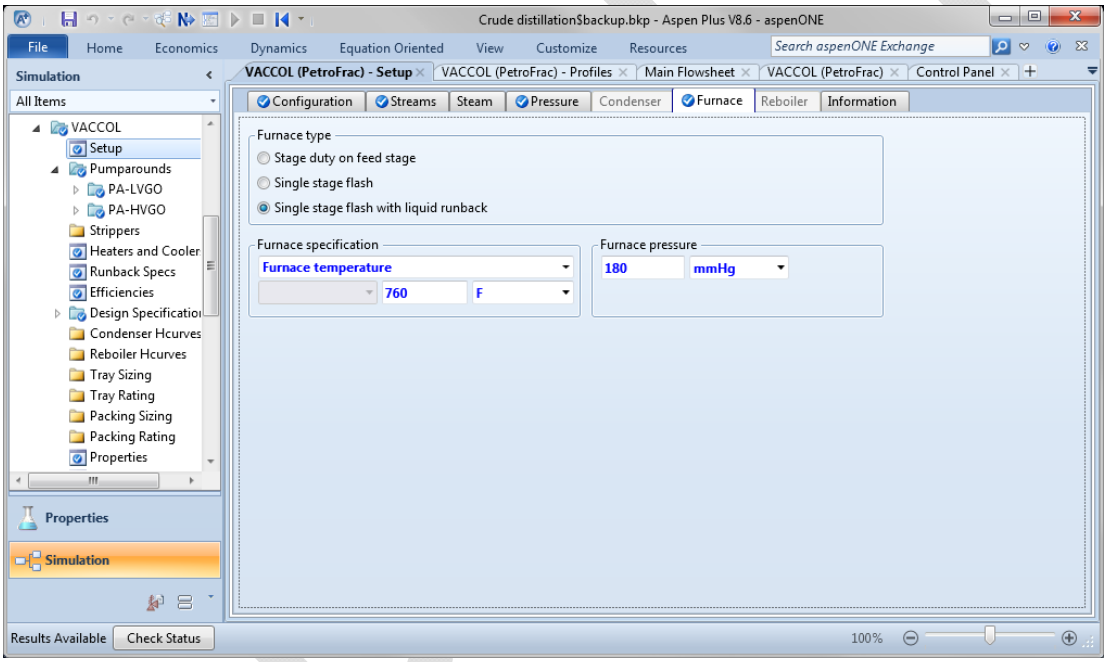
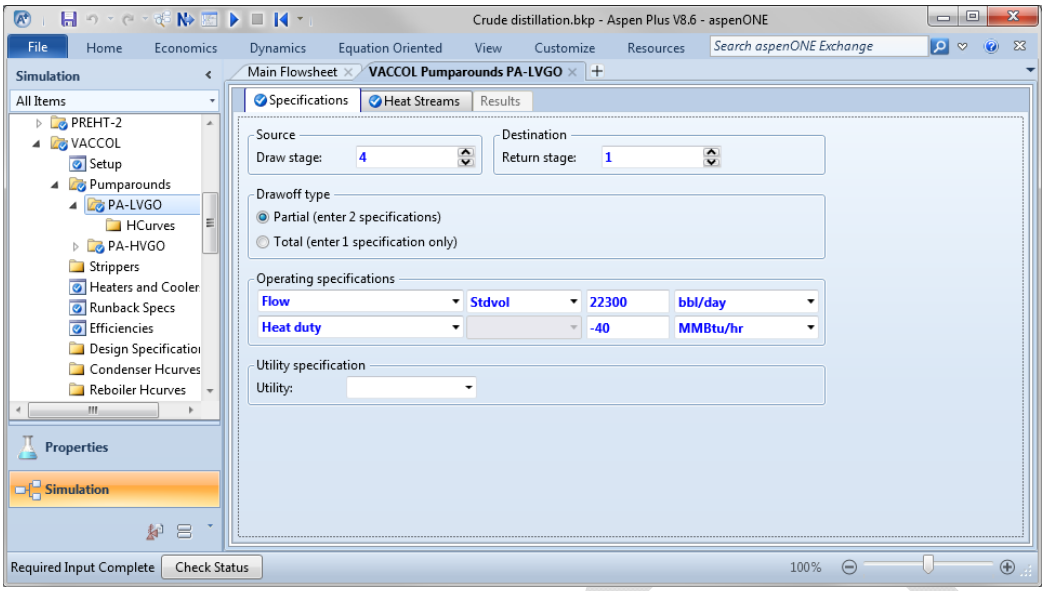
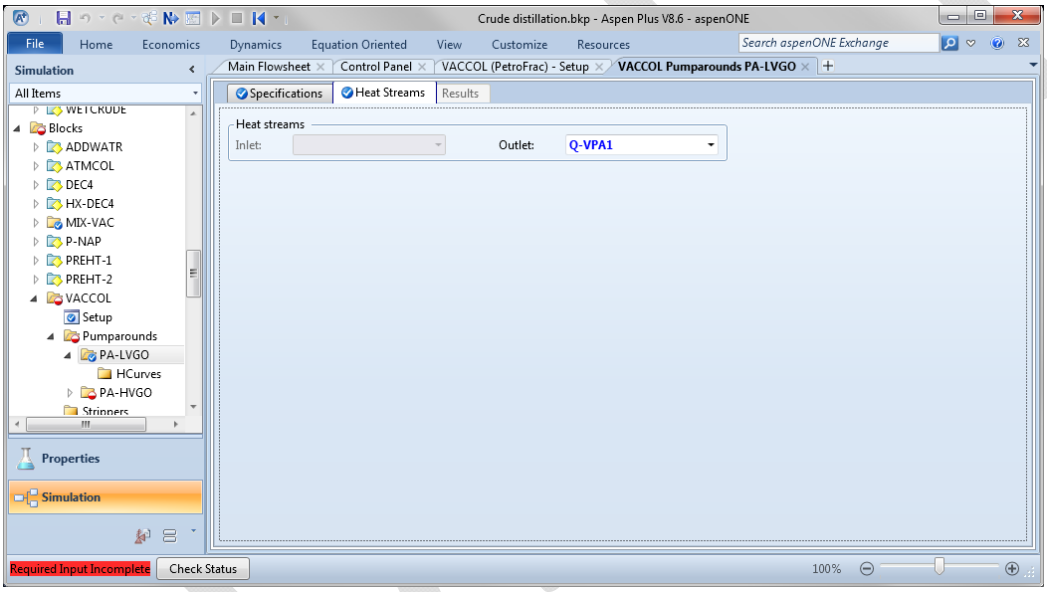


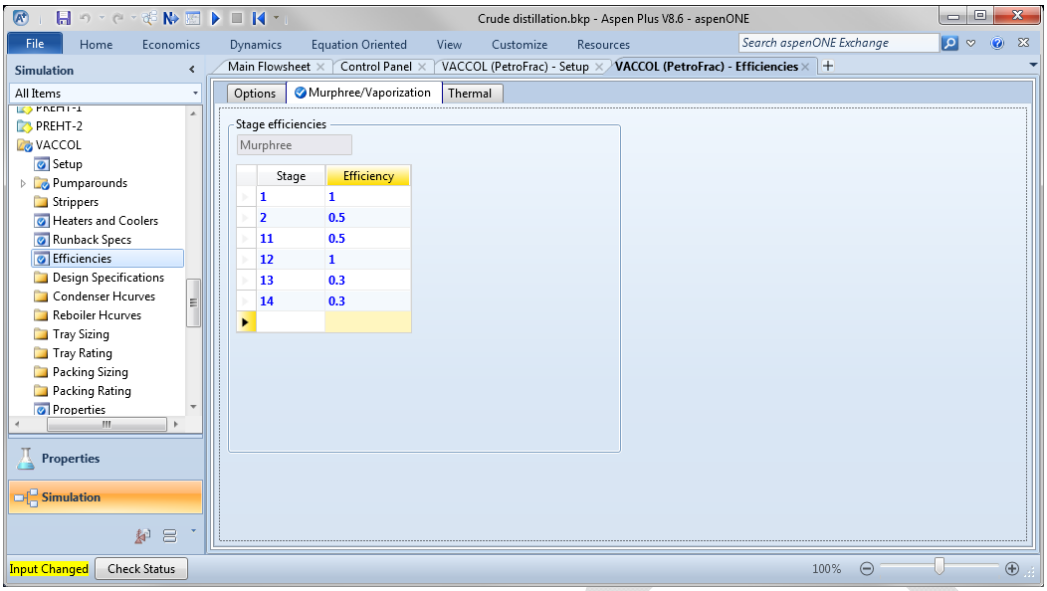


Now let's setup the pumparounds. Change the names to *PA-LVGO* & *PA-HVGO*. Set draw rates & conditions on the *Specifications* tab. Let's apply the approximate specs as Heat duty specs (since these are the most likely to converge). Note that the *Heat duty* values are specified as a negative numbers since they represent cooling (i.e., heat removal). Connect the appropriate heat stream on the *Heat Streams* tab.

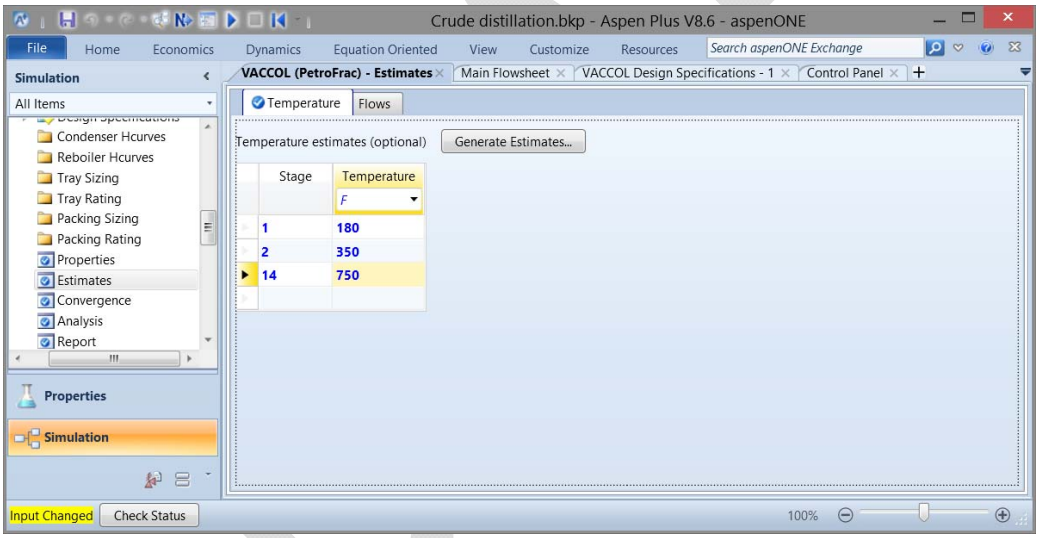




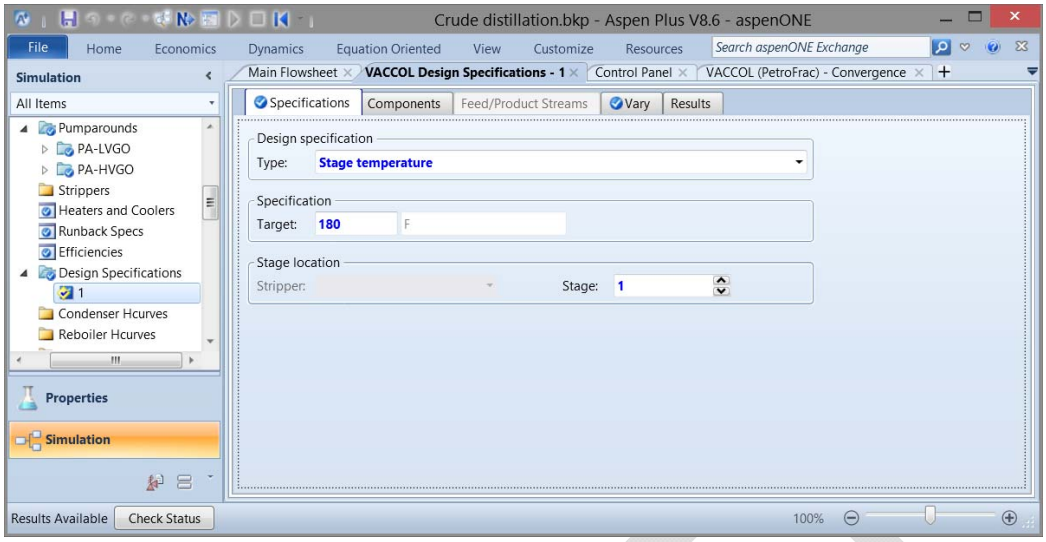
Let's specify the stage efficiencies. Select *Efficiencies* under *VACCOL* in the left-hand column. Select the *Murphree/Vaporization* tab. You do not have to specify the efficiencies for each individual stage but rather they can be grouped.

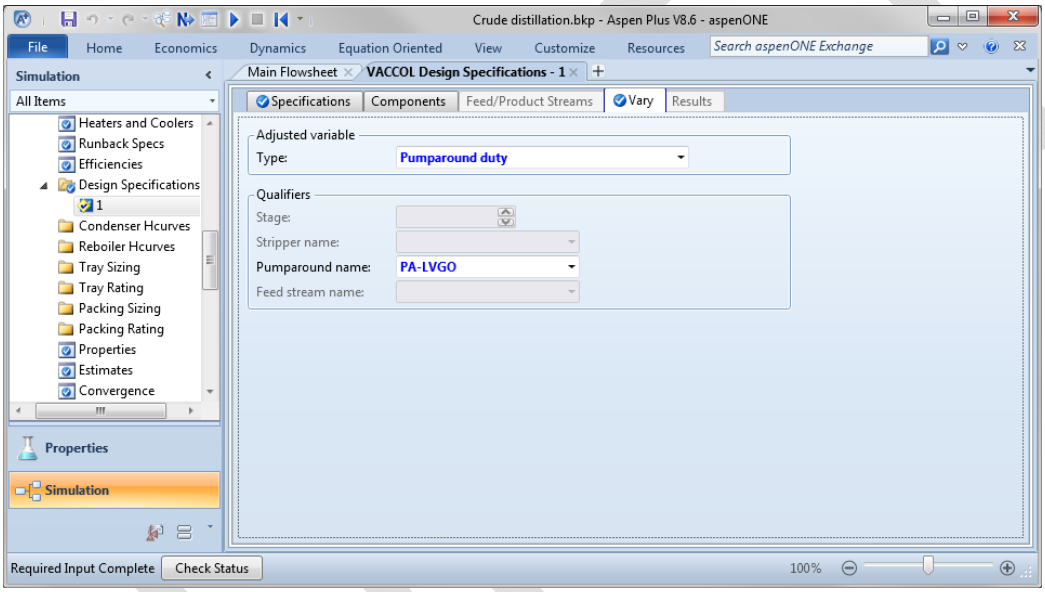


To aid in the convergence of the column let's add a couple temperature estimates. Click on the Estimates item in the left-hand column. Specify values for trays #1, #2, & #14.



Let's apply the first design spec before trying to run the simulation, the one for the top temperature. This is achieved by adjusting the operation of the top pumparound, *PA-LVGO*. Click on *Design Specifications* in the left-hand column, click *New*, and select *OK* for the default name 1. The spec *Type* is *Stage temperature* for *Stage* 1; we'll *Vary* the *Pumparound duty* for *PA-LVGO* (since this is the spec we applied to this pumparound).

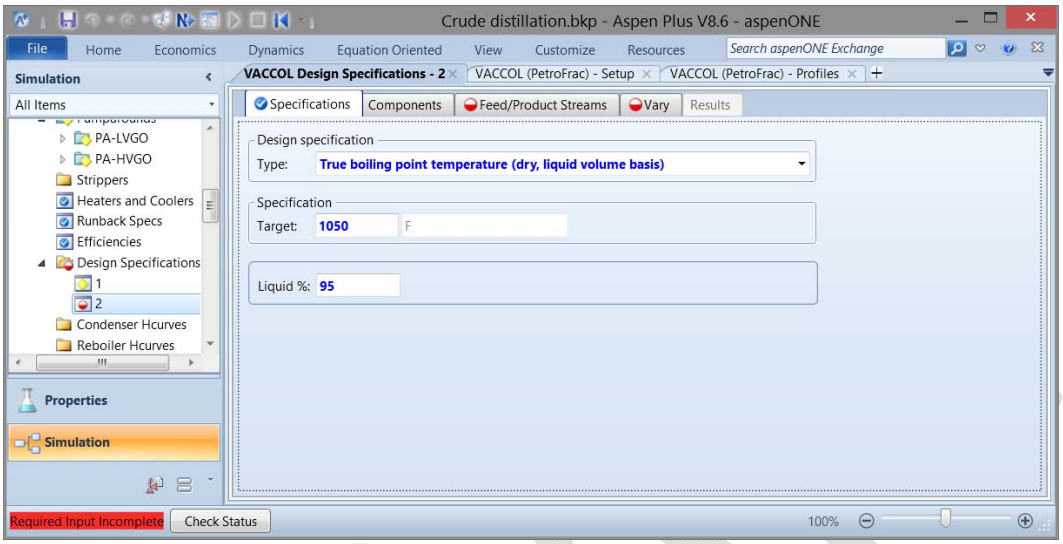


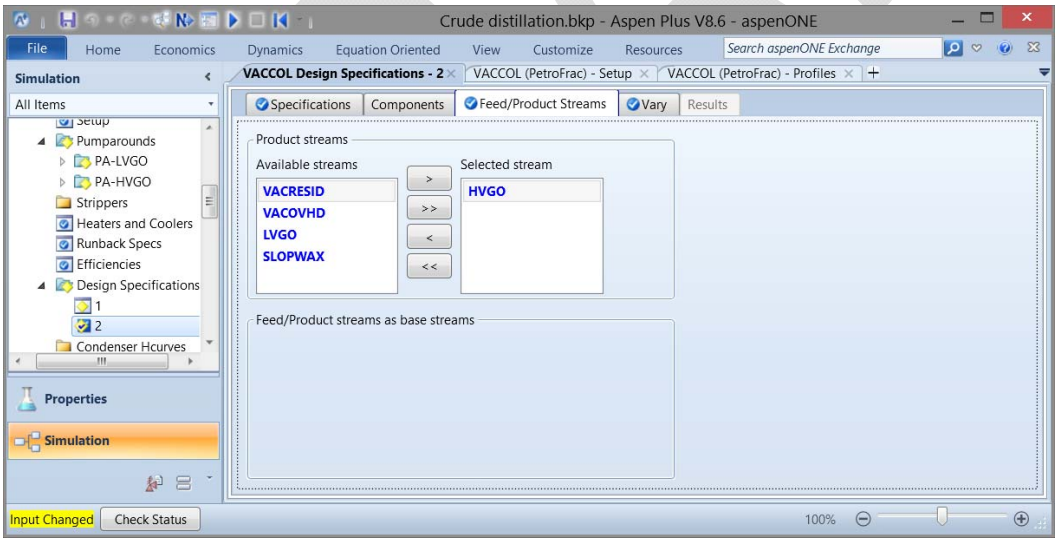


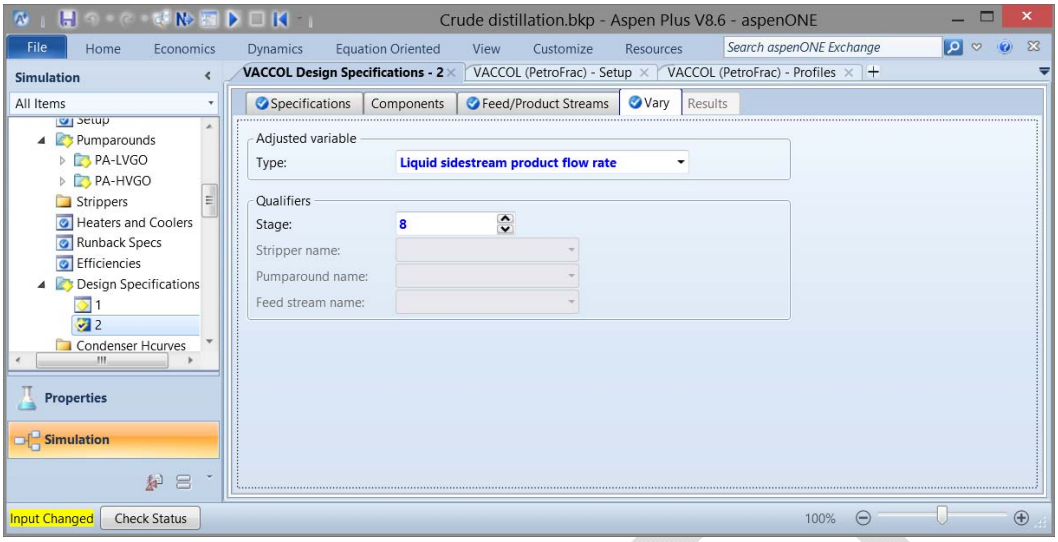
Run the simulation. The Vacuum Column should converge in about 10 iterations.

We have not applied all of the design specs, but let's see how close we come to the desired performance. We are most interested in the D1160 T95 values for the LVGO & HVGO as well as the runback liquid from the section about the feed tray (i.e., the liquid rate from Tray #11). Note that the D1160 values (corrected to 1 atm) above 50% are the TBP values. The T95 values can be found when selected the *Stream Results* in the left-hand column; the TBP values are 768.3°F for the LVGO & 913.9°F for the HVGO. The liquid runback to the feed tray can be calculated from the information in the *Profiles* table. Normally the net flow of liquid from one tray to the one below would be the amount in the *Liquid flow* column minus the amount in the *Liquid product* column. However, for the feed heater chosen, all of the net liquid is fed back to the front of the heater & is considered "liquid product," too. So, the net liquid is really the amount in the *Liquid product* column minus the Slop Wax rate produced; here this is 186,800 bpd.

To increase the T95 value of a side draw we would normally increase the draw rate. We have to be careful, though, not to exceed the values going into each section (and cause that section to dry up). Let's address the HVGO first. Create a new design spec & vary the HVGO draw rate to achieve this. Rerun the simulation; it should converge in less than 20 iterations. Now we have withdrawn 30,676 bpd HVGO to make this T95 spec. The liquid runback has reduced considerably, now down to 3,050 bpd.







Now let's look at the LVGO results. For 5,000 bpd LVGO rate the D1160 T95 value is too low. Since the T95 value is too low, we will have to increase the LVGO draw rate to try to meet this spec. However, there is only 3,518 bpd runback above the feed tray, so we normally think that can't raise the rate above this amount. However, we can actually raise it considerably & not dry up the top of the Vacuum Column. Note that if we raise the LVGO spec to 4,000 bpd we can do this and actually increase the runback. How? Because the HVGO rate decreases by more than 3,000 bpd to keep its T95 spec. So let's apply the LVGO T95 spec; now we've made both T95 specs without drying up the top of the Vacuum Column.

The final spec that we need to achieve is the liquid rate from above the feed tray. The current rate is 6,776 bpd, higher than necessary. We can reduce this rate by reducing the feed heater's outlet temperature (which will reduce the amount of the feed vaporized). We can adjust the feed heater temperature manually to 739.5°F and get a liquid runback rate of 2,990 bpd (just a little bit too low). Can we adjust this automatically to determine the actual temperature? We could add a design spec to modify the furnace temperature make the liquid rate from Tray #11; in past experience this will tend to crash the program. Instead we will use the built-in facility to modify the furnace's outlet conditions by specifying the fractional overflash in the column. Since the total standard flow to the column is 53,632 bpd then 3,000 bpd overflash means a fractional value of 0.05594. Making this specification will give the correct overflash value & results in a furnace outlet temperature of 739.56°F.

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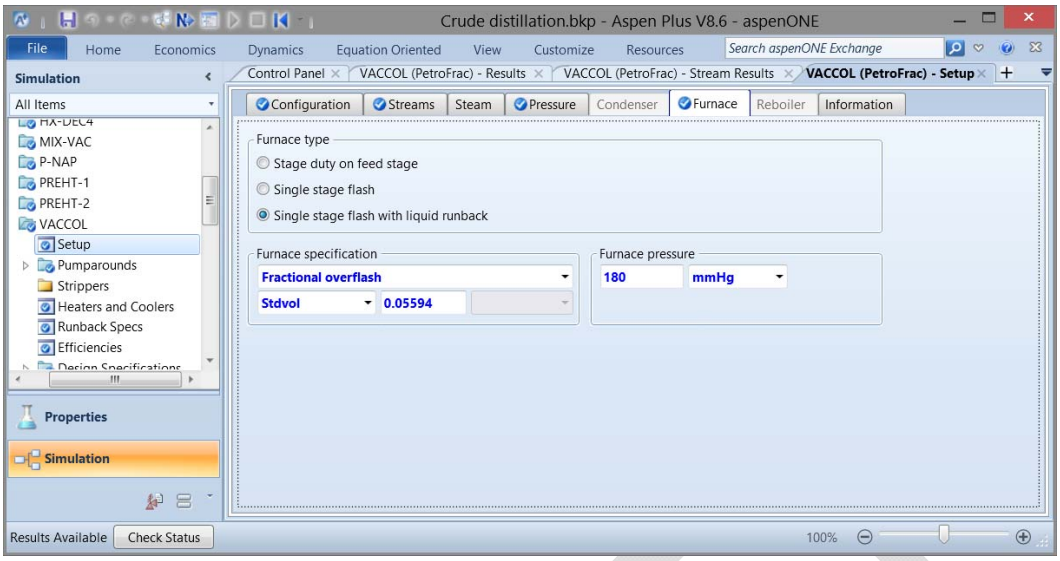

The results of all of these steps are summarized in the following table.

Vacuum Column Results When Applying Different Specs

LVGO Rate [bbl/day]	LVGO D1160 T95 [°F]	HVGO Rate [bbl/day]	HVGO D1160 T95 [°F]	Slop Was Rate [bbl/day]	Runback from Tray #11 [bbl/day]
1,000 ✖	768.4	21,000 ✖	924.4	1,000 ✖	186,810
1,000 ✖	797.1	30,676	1050 ✖	1,000 ✖	3,050
4,000 ✖	825.9	27,220	1050 ✖	1,000 ✖	3,562
16,487	915 ✖	13,855	1050 ✖	1,000 ✖	6,776
16,835	915 ✖	13,185	1050 ✖	1,000 ✖	2,990
16,808	915 ✖	13,212	1050 ✖	1,000 ✖	3,000

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