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

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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.

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Compounds found m. Compound name WATER	atching the spec Alias H2O	ified criteria Databank APV86.PUR	Alternate name DIHYDROGEN	MW 18.01	BP <f> 212.0000</f>	CAS number 7732-18-5	Compound class OTHER-INORGAI
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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	
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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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Do you wish	to rename the component or delete	and replace it?				
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Light End Properties	E1	Conventional	METHANE	CH4					
Petro Characterization	C2	Conventional	ETHANE	C2H6					
< >	C3	Conventional	PROPANE	СЗН8					
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Ca Properties	NC4	Conventional	N-BUTANE	C4H10-1					
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Aspen Plus can guide you through the process of defining your simulation. This is done by pressing the Next button (N, 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*.

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Click the No 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.

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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 No button. But, since we want to add crude assay data & this is not an option on this form. Press *Cancel*.

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				Light Cru	ıde			
		Cumulative Yield						
		[wt%]		Density API		Sulfur	Light Ends	s Analysis
IBP	EP	@ IBP	@ Mid	lb/ft3	Gravity	wt%		[wt%]
Whole	e 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 1. Assay Data for Light Crude

Table 2. Assay Data for Medium Crude

				Medium C	rude			
		Cumulati	ve 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		

			H	leavy Crude	e			
		Cumulati	ve Yield					
		[wt%]		Density	API	Sulfur	Light Ends	Analysis
IBP	EP	@ IBP	@ Mid	lb/ft3	Gravity	wt%		[wt%]
Whole	e 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		

Table 3. Assay Data for Heavy Crude

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.

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

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• 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.

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• 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.

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• 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.

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Light End Properties	2.5	74.91							
Petro Characterization	7.5	62.9							
Pseudocomponents	15	51.09							
Component Attributes	25	43.38							
🔁 Henry Comps	35	36.97							
UNIFAC Groups	45	31.37							
Polymers	55	25.96							
Methods	65	20.86							
Chemistry Property Sets	75	15.45							
Data	85	8.94							
Estimation	92.5	4.44							
	97.5	-6.57							
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• 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; <u>this will only have to be done once, not for every crude assay</u>. 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*.

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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.

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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.

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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.

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

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Results	Temperature change:		F v		
Z EO Variables	Degrees of superheating:		F v		
📑 Stream Results (Cu:	Degrees of subcooling:		F v		
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Q-PREHT2	Duty:		MMBtu/hr v		
A 🖾 WATER	Vapor fraction:				
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The next recommendation is to specify the operating conditions for the 2^{nd} Preheater. Specify the outlet temperature & pressure.

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WARMCRD2	Temperature change:		F	*	
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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.

Req All ree more Run t	quired Input Complete quired input is complete. You can run the simulation now, or enter more input. To enter input, select Cancel, then select the input you want from the Simulation pane. the simulation now? QK Cancel	•
	Clear Messages Check Status Run Settings	
Show Sequence	->Processing input specifications Flowsheet Analysis : COMPUTATION ORDER FOR THE FLOWSHEET: PREHT-1 ADDWATR PREHT-2 ->Calculations begin Block: PREHT-1 Model: HEATER Block: ADDWATR Model: MIXER Block: PREHT-2 Model: HEATER ->Simulation calculations completed	•
	*** No Warnings were issued during Input Translation *** *** No Errors or Warnings were issued during Simulation *** ->Generating results	E
SI	how EO Control	•

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).

esults display on Process Units of measurement: Units operations	ENGPETRO Heat/Work:	%.0f			E	
Streams		Uses Defined Clabel	Stream Data			
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Mole flow rate:	%.0f	Custom3		▼ %.2f		
Mass flow rate:	%.0f	Custom4		▼ %.2f		
Volume flow rate:	%.0f	Custom5		▼ %.2f	· · ·	
Heat/Work:	%.0f	Custom6		• %.2f	· · ·	
tatus display on Process	Flowsheet window					
Show error	Show warning	Show inactive				
	- -				· · · · · · · · · · · · · · · · · · ·	



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*.

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ZEO Variables	32.7			
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▶ DADDWATR	226.3			
A REHT-1	780.4			
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HCurves	825.2			
Block Options	1592.4			
EO Modeling	F 660.6			
Results PC138F	F 1510.8			
Stream Results PC163F	F 1586			
Distream Results (Custom) PC188F	F 1707.7			
A Impression PC213F	F 1818.6			
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T PC288F	F 2152.7			
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Q-PREHT1			
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A 🖾 WATER	PC1175F 2338.8		
Input Results	PC1248F 4098.5		
Z EO Variables	▶ PC1349F 3421.7		
🕞 Stream Results (Custom)	▶ PC1449F 2956		
WARMCRD1	▶ PC1554F 2228.2		
WARMCRD2	> *** DRY TOTAL ***		
A log WEICRODE	▶ Lig Vol 60E bbl/day 101000		
Results	API Gravity 20.5		
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A Blocks	Watson UOP-K 11.3		
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2			



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.

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🧭 EO Variables		Pressure		-					
🕎 Stream Results (Custom)									
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Q-PREHT2	Temperature change:		F	T					
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🧭 EO Variables	Pressure:	294	psig	•					
🕎 Stream Results (Custom)	Duty:		MMBtu/	hr =					
WARMCRD1	Vapor fraction:								
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🔺 🔯 CRUDEOIL 🔺								
🖉 Input	Display: Streams • Fo	rmat: PETRO_E	Stream Table					
Results						*		
🧭 EO Variables		WARMCRD1 -	WATER -	WEICRUDE -				
🕎 Stream Results (Custom)	Temperature F	260	260	260		=		
Q-PREHT1	Pressure psia	308.7	308.7	308.7				
Q-PREHT2	h Mara Slave Ib for	1 28607 06	7269.2	1 20226 06				
A WATER	P Mass Flow Ib/hr	1.2800/e+06	/200.2	1.29330e+00				
Posultr	Enthalpy MMBtu/hr	-962.2	-48.4	-1008.7				
FO Variables	Vapor Frac	0	0	0				
Stream Results (Custom)	Average MW	235.5	18	220.5				
WARMCRD1	Lig Vol 60E bbl/day							
WARMCRD2			500	500				
VETCRUDE	P H20		500	500				
🔺 📷 Blocks) C1							
ADDWATR	▶ C2	32.7		32.7				
Input	▶ C3	267.3		267.3				
HCurves	IC4	226.3		226.3				
Dynamic	, 104	700.4		22003				
EQ Modeling	INC4	780.4		780.4				
Results	> IC5	825.2		825.2				
Stream Results	NC5	1592.4		1592.4				
Stream Results (Custom)	PC119F	660.6		660.6				
🧭 Summary	PC138E	1510.8		1510.8		-		
🔺 📷 PREHT-1		122200	1	1010.0				
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Simulation		• HeatX	MHeatX					
Results Available Check Status						100%	Θ	 ::. €



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	
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Туре	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
L	

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

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.

Mixed	CI Solid	NC Solid	Flash Options	EO Options	Costing	Info	ormation		
Specifi	cations								
Flash Type	:	Temperat	ure 🔹	Pressure	•	Cor	mposition		
-State var	iables —					M	ass-Frac 🔹		~
Tempera	ature:	500	F	•			Component		Value
Pressure:		150	psi	g –			H2O	1	
Vapor fr	action:					►	C1		
							C2		
lotal flo	w basis:	Mass	•				C3		
Total flo	w rate:	2500	lb/	hr 🔻			IC4		
Solvent:				-			NC4		
							IC5		
							NC5		
							LIGHT		
							MEDIUM		
							HEAVY		
							MIXOIL		
							Total:	1	

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).

Configuration	Streams	Steam	- Pressure	Condense	r Furnace	Reboiler	Information
Setup options —							
Number of stages:		51	\$	Stage wiz	zard		
Condenser:		Total			•		
Reboiler:		None-	Bottom feed		-		
Valid phases:		Vapor-	Liquid-FreeW	ater	-		
Operating specific	ations						
Distillate rate		- Stdvo	· •	30200	bbl/day	-	
		-	~			~	

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.

) (Configuration	🥝 Strear	ns Stea	m 📔 🍚 Pressure	Condenser	Furnace	Reboiler	Information]
ee	d streams —								
	Name	e	Stage	Conven	tion				
	WARMCRD2		41	Furnace	-				
,	ATMSTM		51	On-Stage	•				
0	duct streams —								
0	duct streams — Name	e	Stage	Phase	2	Basis	Flow	Units	
0	duct streams – Name NAPHTHA	e	Stage 1	Phase	e Sto	Basis	Flow	Units bbl/day	
0	duct streams Name NAPHTHA ATMWTR	e	Stage 1 1	Liquid Free water	e Sta	Basis dvol dvol	Flow	Units bbl/day bbl/day	

Click Next. Now we will enter the pressures.

Aain Flowsheet	× ATMCOL (Pet	troFrac) -	Setup × 🕂				
🕜 Configurati	on 🛛 🥑 Streams	Steam	Pressure	Condenser	Furnace	Reboiler	Information
iew: To	o / Rottom		•				
	,						
Top stage / Co	ondenser pressure						
Stage 1 / Con	denser pressure:	4	psig	•			
)	
Stage 2 pressu	ire (optional)						
Stage 2 pressu	ire:	12	psig	-			
D - ++				- (
- Bottom stage	pressure or pressur	e arop to	r rest of colum	n (optional) —			
Bottom sta	ge pressure:	22	psig	•			
Stage press	sure drop:		psi	Ŧ			
🔘 Column pre	essure drop:		psi	Ţ			
L							

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.

urnace type) Stage duty on feed stage) Single stage flash) Single stage flash with liquid runback urnace specification	Configuration	Streams	Steam	🛛 🕜 Pressure	Condenser	Furnace	Reboiler	Information		
Stage duty on feed stage Single stage flash Single stage flash with liquid runback urnace specification	- Furnace type									
Single stage flash Single stage flash with liquid runback Unnace specification	Stage duty on f	eed stage								
Single stage flash with liquid runback	Single stage fla									
urnace specification	Single stage fla	sh with liquid	runback							
and cospective and the spectrum of the spectru		ion			- Furnace pres	sure				
Europee temperature	Eurnace specificati	011		25	nsia	-				
	Furnace specificati	ature			2.5	parg				

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*.

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File Home Economics D	Dynamics Equation	Oriented View	Customize I	Resources	Search aspenONE	Exchange	P	v 🕜	83
Simulation	< Main Flowsheet	ATMCOL Pumpa	rounds PA-KERO \times)+					-
All Items	 Specifications 	Heat Streams	Results						
	Source Draw stage: Drawoff type Partial (enter ^ Operating speci	11 2 2 specifications) I specification only) fications	Destination – Return stage:	8					
PA-DIESL	Flow	-	Stdvol -	25000	bbl/day	-			
Strippers	Temperature	-	~	200	E.	-			
 Heaters and Coolers Runback Specs Efficiencies Design Specifications 	Utility specificat	ion	•						

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*.

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Simulation <	Main Flowsheet × ATMCOL Strippers S-KER	• +
All Items *	Configuration Optional Feeds Liquid I	Return Pressure
P I PA-AGO A Construction of the second s	Setup	Main column connecting stages
4 🔯 S-KERO	Number of stages: 10	Liquid draw: 11
Setup Ffficiencies	Stripper product: KERO	Overhead return: 7
Reboiler Hcurves	Stripping medium	
Tray Sizing	Stripping steam:	KEROSTM
Iray Kating Racking Sizing	🔘 Reboiler duty:	MMBtu/hr 👻
Packing Sizing	Steam to bottom product ratio (optional)	lb -
Properties Fstimates	Flow specification	Optional reboiler heat streams
analysis	Bottom product	▼ Inlet: ▼
Dynamics DynamicHT	Stdvol - 8800 bbl/day	Outlet:

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*.

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Simulation	• _	Main Flowsheet $ imes angle$	ATMCOL Pumpare	ounds PA-	KERO× +			-
All Items	•	Specifications	Heat Streams	Results				
		Heat streams		-	Outlet:	Q-PA1	•	
	;							:

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 <u>dry</u> 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.

File Home Economics	Dynam	nics	Equation Oriented	Vie	w Customiz	e Resourc	es	Se	arch aspenON	IE Exchange	
Simulation	« _	Mai	n Flowsheet × ATMCOL F	Pum	nparounds PA-A	GO × Contro	I Panel × ATM	COL (Petro	Frac) - Stream	m Results × +	
All Items	•	Ma	terial Heat Load Vo	01.%	Curves Wt. %	Curves Petr	oleum Polyme	rs Solids			
Properties Estimates Convergence	-	Disp	olay: Streams 🔻 Fo	rma	at: PETRO_E	• Stream	n Table				
Analysis				-	NAPHTHA -	ATMWTR -	ATMRESID -	KERO -	DIESEL -	AGO 🕶	-
Report Connectivity		2	Temperature F		136.6	136.6	611.8	414	496.4	549.3	1
User Subroutines		Þ	Pressure psia		18.7	18.7	36.7	27.7	29.8	31.8	
Opnamics		>	Mass Flow Ib/hr		324187	34493.2	680107	105511	127197	49367.5	
Options		>	Enthalpy MMBtu/hr		-281.5	-233.2	-354	-67.1	-78	-29.1	
EO Modeling			Vapor Frac		0	0	0	0	0	0	
Results		×.	Average MW		112.4	18	492.2	197.2	246	310.8	
Profiles		5	Liq Vol 60F bbl/day								
Stream Results (Custom)		>	H2O		13.3	2366.4	0.9	4.6	1.3	0.2	
🛃 Summary	*	×	C1								
T Properties		×	C2		32.7		< 0.1	< 0.1	< 0.1	< 0.1	
		5	C3		267.3		< 0.1	< 0.1	< 0.1	< 0.1	
C Simulation		1	IC4		226.3		< 0.1	< 0.1	< 0.1	< 0.1	
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Simulation	<	1	Main	Flowsheet × AT	MCOL Purr	parounds PA-A0	GO × Contro	I Panel × ATM	COL (Petro	Frac) - Strea	m Results × -	ŧ	,
All Items	+	T	Mate	erial Heat Loa	d Vol.%	Curves Wt. %	Curves Petro	oleum Polyme	ers Solids				
Properties													
Stimates			Displ	ay: Streams	 Forma 	t: PETRO_E	• Stream	m Table					
Convergence Analysis		ΙΓ			1				KERO -		AG0 -		
Report			- 21			NAFITTIA	Anywin	ATWICESID	KENO	DIESEE	AUC		
Connectivity				PC1554F		< 0.1		2228.2	< 0.1	< 0.1	< 0.1		
User Subroutines			Þ	*** DRY TOTAL ***									
Opnamics			>	Liq Vol 60F bbl/day	r	30186.7		47944.3	8795.4	10238.7	3834.8		
DynamicH I			>	API Gravity		60.6		13.9	40.5	34.5	28.7		
 EO Modeling 			3	Gravity 60F		0.736		0.973	0.823	0.852	0.883		
Results			5	Watson LIOP-K		12.1		11.4	11.9	11.9	11.8		
Profiles	E		-	TRD Cupie E		12.1		1.1.1	11.5	11.5	11.0		
Stream Results	٣		-	TBP Curve P		50.5		562.0	2447	102.2	5057		=
Stream Results (Custom)	4		P	0 %		-50.5		562.9	344./	402.2	525.7		
Summary	1		2	5 %		70.5		658.9	410.3	484.3	594.6		
A Properties			▶.	10 %		98.4		712.2	431.6	515.6	626		
			÷.	30 %		198		852.1	464.7	558.8	678.5		
			Þ.	50 %		278		991	486	586.2	704.7		-
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All Items	+	T	Mate	erial Heat Loa	d Vol.%	Curves Wt. %	Curves Petr	oleum Polyme	ers Solids				
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Convergence		ΙΓ	1			NUMBER		ATMOSCUP	WEDG	DIFCE			
Analysis Report			- 21		-	NAPHIHA •	AIMWIR -	ATMRESID +	KERO +	DIESEL •	AGO 👻	. * .	
Connectivity			Þ.	100 %		458.2		1580	567.5	701.9	811.9		
Over Subroutines			þ.	D86 Curve F									
Oynamics			Þ.	0 %		42.8		568.4	398.4	460.7	573.3		
DynamicHT			3	5 %		114		642	437.3	514.4	619.9		
EQ Modeling		-	5	10 %		147 5		673.6	453.4	537.1	639.2		
Results	-	-	1	20 %		2226		700 7	470.7	560.0	660.6		
Profiles	Ξ		5	50 %		202.0		025.2	402.7	500.9	604.0		
Stream Results	٣		P	SU %		282.4		925.3	482./	5//	084.9		
Stream Results (Custom)	-		>	70 %		333.8		1085.8	496.1	596.9	701.3		
Summary			Þ.	90 %		390.8		1295	515.1	626.6	727.1		
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and the second			Þ.	100 %		433.4		1425.6	545.5	669.2	770.3		
			» »	100 % D1160 Curve F		433.4		1425.6	545.5	669.2	770.3		-
Simulation	-	-))- 4	100 % D1160 Curve F		433.4		1425.6	545.5	669.2 III	770.3		•
Simulation	•		> > *	100 % D1160 Curve F		433.4		1425.6	545.5	669.2 III	770.3),	

We'll now set the T95 specifications. Select *Design Specifications* under *ATMCOL* in the lefthand 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.*

🐼 Create New ID	×						
Design specification number							
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OK Cancel							
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Pumparounds							
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ADDWATR ADDWATR AMCOL Setun	Qualifiers Stage:	
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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.

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🐼 Setup	Stripper name: S-KERO	•		
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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*.

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All Items -	Material Heat Load V	ol.% Curves Wt. % Cu	rves Petroleum P	olymers Solids		
Packing Sizing	Display: Streams - F	ormat: PETRO_E	Stream Table			
Properties		NAPHTHA -	KERO -	DIESEL	AGO 🔫	ATMRESID -
Convergence	Temperature F	136	410.9	494.9	550.8	611.8
Analysis	Pressure psia	18.7	27.7	29.8	31.8	36.7
🕢 Report	Mass Flow Ib/hr	319303	105413	130404	52452	678797
Connectivity	Enthalpy MMBtu/hr	-277.7	-67.3	-80	-30.8	-353.3
Dynamics E	Vapor Frac	0	0	0	0	0
🕜 DynamicHT	Average MW	111.7	195.4	244.3	310.4	492.6
Block Options EO Modeling	Liq Vol 60F bbl/day					
Results	▶ H2O	13	4.7	1.4	0.2	0.9
Profiles	> C1					
Stream Results	▶ C2	32.7	< 0.1	< 0.1	< 0.1	< 0.1
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T. p it	▶ IC4	226.3	< 0.1	< 0.1	< 0.1	< 0.1
Properties	> NC4	780.4	< 0.1	< 0.1	< 0.1	< 0.1
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Tray Sizing	PC1554F	< 0.1	< 0.1	< 0.1	< 0.1	2228.2
Tray Rating	*** DRY TOTAL ***					
Packing Sizing	Lig Vol 605	20772 5	8800.5	10508	4075.1	47942.0
🚞 Packing Rating		23/72.5	10.0	10500	4073.1	47043.5
Properties	API Gravity	60.9	40.8	34./	28./	13.9
Estimates	Gravity 60F	0.735	0.821	0.851	0.883	0.973
Convergence	Watson UOP-K	12.1	11.9	11.9	11.8	11.4
Analysis Analysis	TBP Curve					
	> 0 %	-51.4	341.4	399.1	521.6	563.2
Vser Subroutines		60.2	407.2	491 5	502.1	650.2
Opposition Dynamics	V J 70	09.2	407.2	401.5	J92.1	039.2
Ø DynamicHT	10 %	97.7	428.9	512.1	624	712.5
Block Options	▶ 30 %	196.3	460.5	555.4	677.1	853
🕨 📴 EO Modeling	50 %	275.5	481.9	582.8	703.7	991.8
Results	> 70 %	341.9	502.8	613.1	730	1164.4
Profiles	90 %	407.8	528.3	652.6	765	1411 9
Stream Results (Custo	05 00	426.0	520.5	652.0	772.0	1500.0
Summary	P 93 76	420.8	544.8	000.9	//3.9	1500.8
PREHT-1	100 %	458.5	561.5	698.8	815.2	1580
PREHT-2	D86 Curve					
Utilities	▶ 0 %	42.1	394.9	457.8	569.9	568.5
Reactions	▶ 5 %	113.5	434.1	511.3	617.8	642
Convergence	10 %	147.1	450.3	533.9	637.6	673.6
Flowsneeting Options	20 %	221	466.7	557.0	669 E	700 F
FO Configuration	7 50 %	221	400.7	557.6	000.3	/99.5
Results Summary	> 50 %	280	478.8	573.8	684.1	926
Dynamic Configuration 👻	70 %	330.9	492	593.9	701.1	1086.3
III +	▶ 90 %	386.7	509.8	623.7	726.9	1295.4
D	> 95 %	410	525	645	750	1360.5
Properties	100 %	433.3	540.2	666.3	773.1	1425.7
Simulation	D1160 Cuere					
Sinuation	P DI160 Curve					
10 - ·	·					

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%.

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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.

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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*.

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🕢 DynamicHT	Average MW	111.7	195.4	244.3	310.4	492.6
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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.

Туре	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

Table 5. Definitions for Debutanizer Column

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.

onfiguration	Streams 🏈	Steam	Pressure	Condenser	Furnace	Reboiler	Information			
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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%.

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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.



Table 6. Definitions for Vacuum Distillation Column

Туре	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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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.

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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.

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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.

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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).

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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.



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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 <u>fractional</u> overflash in the column. Since the <u>total standard</u> 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.

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

Vacuum Column Results When Applying Different Specs