Atmospheric Crude Tower with Aspen HYSYS® V8.0

1. Lesson Objectives
   - Assign petroleum assay to stream
   - Configure column pre-heater
   - Configure crude tower

2. Prerequisites
   - Aspen HYSYS V8.0
   - Introduction to distillation

3. Background
   Oil refineries take crude oil and separate it into more useful/valuable products such as naphtha, diesel, kerosene, and gas oil. An atmospheric distillation column is one of the many unit operations that can be found in an oil refinery. Crude oil is fed into the atmospheric distillation column and several fractions are produced which are then fed to other process units such as hydrotreaters, hydrocrackers, reformers, and vacuum distillation columns. In this lesson we will be focusing solely on the atmospheric crude unit.

   The examples presented are solely intended to illustrate specific concepts and principles. They may not reflect an industrial application or real situation.

4. Problem Statement and Aspen HYSYS Solution

Problem Statement

In this simulation we wish to simulate an atmospheric crude fractionator. 100,000 barrel/day of Arabian Light crude is fed to a furnace that will vaporize a portion of the crude. This crude stream is then fed to an atmospheric crude column. The column will operate with three coupled side strippers and three pump around circuits.

Aspen HYSYS Solution

4.01. Create a new simulation in Aspen HYSYS V8.0.

4.02. Create a component list. In the Component List folder, select Add. Add Water, Methane, Ethane, Propane, i-Butane, and n-Butane to the component list.
4.03. Add hypotheticals to the component list. In the Component List – 1 form, change the Select option to Hypothetical. Enter an Initial Boiling Point of 30°C, a Final Boiling Point of 900°C, and an Interval of 10°C. Click Generate Hypos to generate a hypothetical group.
4.04. After generating the hypothetical group, click **Add All** to add all generated hypotheticals to the component list.

4.05. Define property package. In the **Fluid Packages** folder select **Add**. Select **Peng-Robinson** as the property package.
4.06. We will now characterize our crude oil. Go to the Petroleum Assays folder. Click Add. Enter Arabian Light for Name, select Specified for Assay Source, and select Basis-1 for Fluid Package.

4.07. In the Arabian Light form, select Import From. A window will appear, select Assay Library.

4.08. The Assay Library window will appear. Since we wish to model the Arabian Light crude, we will select Middle East for Region Name, and Saudi Arabia for Country Name. We can then select Arabian Light and click Import Selected Assay.
4.09. After a few moments the distillation cut data for the Arabian Light crude will populate the Assay Property form.
4.10. Go to the Light Ends form to enter data for the light components to be included in the crude. Enter the following Volume % for each component. Check the box for Input and enter a Total Percentage of 1.4. This means that the specified light ends will comprise 1.4 percent of the total crude.

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>6.500e-003</td>
</tr>
<tr>
<td>Ethane</td>
<td>2.250e-002</td>
</tr>
<tr>
<td>Propane</td>
<td>0.3200</td>
</tr>
<tr>
<td>i-Butane</td>
<td>0.2400</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.8200</td>
</tr>
<tr>
<td>H2O</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

4.11. Move back to the Assay Property form and click Calculate Assay. After a few moments the status bar should turn green and say OK. You can go to the Results tab to view a true boiling point (TBP) curve, composition data, and bulk properties of the crude, among other results.
4.12. We are now ready to move to the simulation environment to begin creating our flowsheet. Click the Simulation button in the bottom left of the screen.

4.13. In the Home ribbon, change the units to Field units.

4.14. Add a material stream to the flowsheet. This will be our crude feed which will be heated by a furnace and then fed to the distillation column.
4.15. Double click the material stream and rename it **Raw Crude**. Enter a **Temperature** of 77°F, a **Pressure** of 58.02 psia (4 bar), and a **Std Ideal Liq Vol Flow** of 100,000 barrels/day.

4.16. We must now attach the petroleum assay to this stream. Go to the Petroleum Assay form and select **Petroleum Assay From Library**. Next, select **Arabian Light**. You will notice that the stream compositions will populate and the stream will solve.
4.17. If you go to the **Composition** form you will see that the composition for all hypothetical components and light ends are complete.
4.18. We will now add a **Heater** block to the flowsheet. This will serve to pre-heat the crude stream and prepare it to enter the distillation column.
4.19. Double click the heater block (E-100). Select **Raw Crude** as the *Inlet* stream, create an *Outlet* stream called **ColumnFeed**, and create an *Energy* stream called **Q-Heat**.
4.20. In the **Parameters** form, enter a **Delta P** of **7.252 psi** (0.5 bar).

4.21. In the **Worksheet** tab enter an outlet **Temperature** of **626°F**. The heater should solve.
4.22. Before adding the column to the flowsheet, we must first define the steam and energy streams that will be used by the column. Add 3 Material Streams to the flowsheet. Name them Main Steam, Diesel Steam, and AGO Steam.
4.23. Double click on each steam stream and enter the following information. Enter a **Mole Fraction** of 1 for **Water** for each stream as well.

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Vapor Fraction</th>
<th>Pressure (psia)</th>
<th>Mass Flow (lb/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam</td>
<td>1</td>
<td>145</td>
<td>6614</td>
</tr>
<tr>
<td>Ago Steam</td>
<td>1</td>
<td>145</td>
<td>2205</td>
</tr>
<tr>
<td>Diesel Steam</td>
<td>1</td>
<td>145</td>
<td>2205</td>
</tr>
</tbody>
</table>

4.24. **Add an Energy stream called Q-Trim.** This stream does not require any specifications; it will be calculated by the column.
4.25. Add a Blank Column Sub-Flowsheet from the Model Palette.

4.26. A window will appear, select Read an Existing Column Template.

4.27. Select template 3sscrude.col and click Open.
4.28. The column property window will appear. On the **Design | Connections** form, you can view all the internal streams within the column sub-flowsheet. The first thing we must do is connect the **Internal** and **External Streams** as shown below. Also enter a top stage pressure of **14.5 psia** and a bottom pressure of **20.31 psia**.
4.29. We must now modify the stage locations for the side strippers and pump arounds. Go to the Side Ops tab. In the Side Strippers form select the following Liq Draw and Vap Return Stages.

![Side Strippers Form](image)

4.30. In the Pump Arounds form select the following Draw and Return Stages.

![Pump Arounds Form](image)

4.31. We must now define the column operating specifications. Go to the Specs form under the Design tab. You will notice that in order to run this column you must define 13 specifications. The table below summarizes the design specifications chosen for this column.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Spec Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflux Ratio</td>
<td>1</td>
</tr>
<tr>
<td>Condenser Temp</td>
<td>110°F</td>
</tr>
<tr>
<td>Kerosene D86 95% Temperature</td>
<td>520°F</td>
</tr>
<tr>
<td>Diesel D86 95% Temperature</td>
<td>665°F</td>
</tr>
<tr>
<td>AGO TBP 95% Temperature</td>
<td>885°F</td>
</tr>
<tr>
<td>Pump Around 1 Return Temp</td>
<td>175°F</td>
</tr>
<tr>
<td>Pump Around 2 Return Temp</td>
<td>310°F</td>
</tr>
<tr>
<td>Pump Around 3 Return Temp</td>
<td>450°F</td>
</tr>
<tr>
<td>Vapour Flow off condenser</td>
<td>0 kgmole/h</td>
</tr>
<tr>
<td>Kerosene SS Duty</td>
<td>3.966 MMBtu/hr</td>
</tr>
<tr>
<td>Pump Around 1 Draw Rate</td>
<td>15,100 barrel/day</td>
</tr>
<tr>
<td>Pump Around 2 Draw Rate</td>
<td>15,100 barrel/day</td>
</tr>
<tr>
<td>Pump Around 3 Draw Rate</td>
<td>15,100 barrel/day</td>
</tr>
</tbody>
</table>

4.32. In the Specs form it may be easiest to initially delete all of the default specifications for the column.
4.33. Click **Add** to add each design specification one by one. The following pages will include a screenshot of each individual specification window.

**Reflux Ratio**

**Condenser Temperature**
Kerosene D86 95% Temperature

The D86 95% stream property is found under the Petroleum branch after clicking Select Property.
Diesel D86 95% Temperature

AGO TBP 95% Temperature

The TBP 95% stream property is found under the Petroleum branch after clicking Select Property.
**Pump Around 1 Return Temperature**

![Image of Pump Around Spec: PA_1_TRet(Pa)]

**Pump Around 2 Return Temperature**

![Image of Pump Around Spec: PA_2_TRet(Pa)]
**Pump Around 3 Return Temperature**

![Image of Pump Around Spec: PA_3_TRet(Pa) window]

**Vapour Flow off condenser**

![Image of Vap Flow Spec: Vapour Flow window]
Kerosene SS Duty

Pump Around 1 Draw Rate
4.34. Once all 13 specifications are entered you should notice that the Degrees of Freedom is now 0. This means that the column is ready to begin calculations.
4.35. Before we run the column, we will enter top and bottom stage temperature estimates to help the column to converge. Go to the Profiles form under the Parameters tab. Enter a Condenser temperature of 110°F and a Stage 29 temperature of 630°F. The bottom stage temperature estimate was chosen because we know the column feed stream is being fed into stage 29, therefore the stage 29 temperature should be around the same temperature.
4.36. Click the Run button and the column will begin calculations. After a few moments the column should converge.
4.37. Check results. Go to the **Summary** form under the **Performance** tab. Here you can view the flowrates and compositions for each product stream. Note that Arabian Light is a light crude, therefore there is a large flowrate for the light products in the naptha stream, and lower flowrates for kerosene, diesel, and gas oil.
5. Conclusions
In this lesson we learned how to model a petroleum assay and assign a stream to an assay. We also learned how to insert and configure an atmospheric crude tower to produce petroleum products. A light crude, such as Arabian Light, will produce a high quantity of light products such as gasoline and naptha, while a heavier crude will produce a higher quantity of heavier products such as kerosene, diesel, and fuel oil.

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