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Oil Refinery Optimization

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Optimization of an Oil Refinery

Problem Statement

Objective
A major daily operating goal at an oil refinery is to maximize profit within operating unit constraints. Crude oil that enters the refinery is separated into many different products. In this problem, you will maximize the refinery's profit in a single day by finding the optimal set of flows for all streams off an initial crude distillation unit. Also, calculate the profit margin (profit/revenue) at this optimal point.

Background
From a broad point of view, oil refining is a simple process. Crude oil is fed to a distillation unit where it is boiled. The boiling separates the oil into distinct streams due to different boiling points of the constituents in crude oil. These streams are further processed into separate products such as diesel, gasoline, and asphalt.

The molecules that exit the column through the overhead stream are too small to become gasoline. They are "reformed" in the reformer into larger molecules which can be used in gasoline. The molecules in the bottom two streams are too heavy to be used in diesel fuel, so they must be cracked or coked into smaller molecules suitable for use as diesel. The cracker is able to handle materials of medium to heavy density, while the coker handles the heaviest and largest molecules. The coker produces molecules that can be blended into the diesel stream and a residual product "coke" (which is similar to coal and is used in steel making and other processes).

Lubricant oil is another product made from the cracker stream. This stream is processed at a lubes plant to become lubricating oil. Excess heavy material that cannot be used in the coker can be sold as asphalt base.

Before the diesel fuel and gasoline can be used commercially, they both must have much of the sulfur removed. This is done in the hydrodesulfurization (HDS) units. Because the properties of gas and diesel differ, refineries have separate HDS units for each product

Figure 1 shows the simplified flow diagram of a refinery for the optimization model.

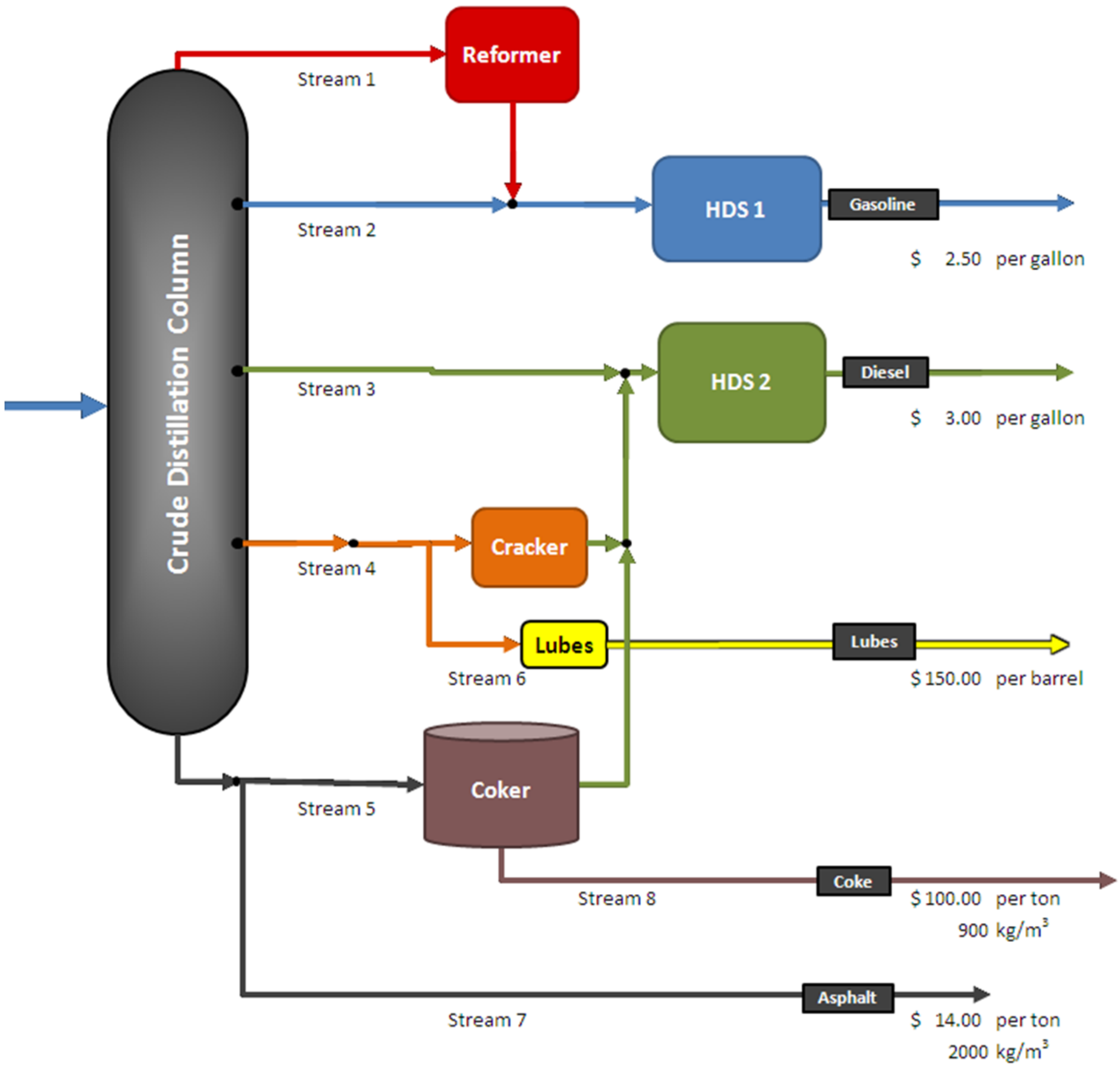

Figure 1 - Process Flow Diagram of the Refinery

Details

Table 1 shows the capacities of each of the processing units in thousands of barrels per day (kbd).

Table 1 - Unit Capacities

Unit Capacities (kbd)	
Crude Distillation	600
Reformer	60
HDS 1	200
HDS 2	250
Cracker	100
Lubes Plant	30
Coker	150

Table 2 shows the fractional amounts of crude allowable in each stream after distillation. These limits are functions of the crude properties and of the crude distillation unit operation. Assume these limits are constant for this model.

Table 2 - Stream Max and Min Limits

Crude Properties	
Stream 1	>5%
Stream 2	10-25%
Stream 3	10-20%
Stream 4	<20%
Stream 5	<40%

Streams 6, 7, and 8 do not come directly off the distillation tower. Stream 6 can have up to 10% of stream 4. Assume the coker will convert 40% of stream 5 into coke (stream 8). Stream 7 is the asphalt stream and has no upper bound.

The variable operating costs to run each unit have been empirically determined from refinery data. They are functions of flow rate and are of the form $ax + bx^2 + cx^3$, where x is the flow rate into the unit in kbd. The coefficients a, b and c for each unit are shown in Table 3.

Table 3 - Fitting Parameters for Variable Unit Cost

	a	b	c
Reformer	3.4	-0.037	0.00019
HDS A	4.4	-0.012	0.000014
HDS B	5.8	-0.014	0.000014
Cracker	9.1	-0.057	0.00021
Lubes	13.8	-0.19	0.0002
Coker	6.5	-0.024	0.00004

Other Assumptions

Assume crude properties are constant; therefore, all product properties remain constant.
One barrel of crude into the refinery results in one barrel of total product.
There are 42 US gallons/barrel of oil.
The plant has a fixed cost of $2.7M/day due to wages, capital expenses, maintenance, overhead, etc.
The cost of crude oil is $98/barrel
Assume that all other costs (including running the crude distillation) are included in the fixed costs.
Product prices and densities of some products are shown in Figure 1