PipelineOptimizer® Use Case
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Overview
PipelineOptimizer is a state-of-the-art engineering and operations tool for simulating liquid pipeline hydraulics that will help minimize operating costs. This is done by determining the best pumping schedule and DRA usage to meet the demands of the operating schedule. A great deal of knowledge about the system can be learned through the modeling of pipelines in PipelineOptimizer.

This document walks through a use case for PipelineOptimizer. The inputs for the configuration are described, and then the simulation results are given for the available optimization modes.

Inputs
Schematic

Figure 1. Case Study Schematic
The pipeline described in this use case is configured in PipelineOptimizer as seen in the above screenshot. The configuration includes four supply and four delivery tanks; supply and delivery locations, including the supply boosters and pumps; the three pumping stations with their respective pumps; three heaters; one resistance device; and the pipelines between stations. The two sets of pumps in the supply station have been modeled as two separate stations in order to model the heater in between.

**Elevation Profile**

![Elevation Profile](image)

The elevation profile is entered into the configuration into the Survey table.

**Pipes**

![Pipe Table](image)

Pipe data is entered into the Pipe Types Table, Pipe Profile Table, and the Pipes Table.
Fluids

The three fluids are configured with the corresponding specific gravity, viscosity, specific heat, and vapor pressure for each fluid in the Fluids table.

Stations and Station Set Points

The stations and their corresponding set points are included in the Stations table. Since there are no set points for the “stations” in the Supply Station, the values entered are chosen as to not restrict the flow at those locations.

Supplies/Deliveries

The boundary pressures for the supply and delivery are entered in the Supplies/Deliveries table. The upstream boundary pressure for the supply was chosen to be 190 psi.

Pumps/Pump Curves

Figure 4. Fluids Table

Figure 5. Stations Table

Figure 6. Supplies/Deliveries Table

Figure 7. Pumps Table
The pump information is entered into the Pumps table. This table describes the location, speed, impeller size, and design stages of each pump. Each pump is also paired with its corresponding pump curve. The pump curves are entered through the Pump Curve table, and can be viewed through a pop-up screen by clicking on the corresponding button on the Pumps screen.
Batch Plan

<table>
<thead>
<tr>
<th>Batch ID</th>
<th>Product</th>
<th>Activity</th>
<th>Activity Volume (bbl)</th>
<th>Location</th>
<th>Tank Name</th>
<th>Rate (bbl/hr)</th>
<th>Maximum Volume (bbl)</th>
<th>Synchronized Batch ID</th>
<th>Initial Linfill Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BAT_A_INT</td>
<td>HC1</td>
<td>P</td>
<td>13389.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BAT_A_INT</td>
<td>HC1</td>
<td>FLA</td>
<td>13389.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BAT_B_INT</td>
<td>HC2</td>
<td>P</td>
<td>3803.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>BAT_B_INT</td>
<td>HC2</td>
<td>FLA</td>
<td>3803.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>BAT_C_INT</td>
<td>HC3</td>
<td>P</td>
<td>20915.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BAT_C_INT</td>
<td>HC3</td>
<td>FLA</td>
<td>20915.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>Yes (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>BAT_A</td>
<td>HC1</td>
<td>P</td>
<td>60000.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>BAT_A</td>
<td>HC1</td>
<td>FLA</td>
<td>60000.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>BAT_B</td>
<td>HC2</td>
<td>P</td>
<td>12000.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>BAT_B</td>
<td>HC2</td>
<td>FLA</td>
<td>12000.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>BAT_C</td>
<td>HC3</td>
<td>P</td>
<td>60000.00000</td>
<td>Supply0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>BAT_C</td>
<td>HC3</td>
<td>FLA</td>
<td>60000.00000</td>
<td>Delivery0</td>
<td>0.00000</td>
<td>No (\uparrow)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The batch plan, including the initial linefill, is entered in the Batch Plan table. Under the Activity column, P stands for pumping activity, while FLA stands for full-line all activity.

**DRA Usage**

DRA has been added to the configuration in the following manner:

The DRA degradation factors are entered into the DRA Degradation Table.

The DRA equation types and coefficients are set through the DRA Types Table.

Finally, the DRA injection rules are entered in the DRA Injection Rules Table. For a baseline, DRA will be injected continuously at 20 ppm at Station 1 and Station 2 at a cost of $8/gallon.
Power Contract
The power contracts have been set up in the following manner:

<table>
<thead>
<tr>
<th>Period Name</th>
<th>On-Peak Start (time)</th>
<th>On-Peak Stop (time)</th>
<th>Applies to Day of Week</th>
<th>Override for Date (md)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PeriodA</td>
<td>08:00</td>
<td>16:00</td>
<td>All Days</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13. Peak Periods Table

The peak period has been chosen to be from 08:00 until 16:00, every day of the week.

<table>
<thead>
<tr>
<th>Contract Name</th>
<th>On Peak Demand Price ($MWH)</th>
<th>Off Peak Demand Price ($MWH)</th>
<th>On Peak Energy Price ($/kW-hour)</th>
<th>Off Peak Energy Price ($/kW-hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ContractA</td>
<td>5.750</td>
<td>4.000</td>
<td>0.1200</td>
<td>0.0500</td>
</tr>
</tbody>
</table>

Figure 14. Power Contracts Table

The on- and off-peak demand and energy cost rates are shown in the above table.

Simulations
Capacity Calculation
In capacity mode, PipelineOptimizer computes the maximum possible throughput, running all of the pump units to generate maximum head. This mode will also show the user the current bottlenecks of the system.

One interesting graph to look at is the gradeline plot, which shows the pumps pushing as hard as possible to get maximum flow through the system. The time bar on the left can be dragged to see the gradeline at different points in time.

Figure 15. Gradeline for Capacity Simulation
The Flow plots show how the flow rate changes over time as different fluids enter and leave the system. The short period where the flow rate is zero bbl/hr is a simulated shutdown in the system for 15 minutes.

The bottleneck reporting capability in PLO can provide the user great detail on the location and type of bottlenecks in a given pipeline.

Bottleneck locations are shown by yellow boxes around elements in the pipeline configuration schematic.

The bottleneck report can give more specific detail on the bottlenecks as well. In this instance, there is a pipe pressure limit on Pipe 4 that is active for 20% of the simulation runtime.
Pump Selection
Capacity mode does not necessarily produce an accurate picture of power consumption in the line. Pipelines are typically run near capacity, but without every single pump turned on. To this point, we use Pump Selection mode, which optimizes pump selection while meeting a target throughput at all points in time. To begin, we enter a target throughput in the Model Options.

In this case, we have chosen a target throughput of 2000 bbl/hr.

After running Pump Selection, we can immediately see a difference in the pumps selected in a given time step. At many points in the simulation, pumps in Station 2 and Station 3 are turned off because they are not needed to achieve the target throughput. A booster pump in the Supply station remains off for the entire simulation as it is also unnecessary for meeting the target throughput.
There is also a difference in the gradeline for the Pump Selection simulation. It is easy to see that the pumps do not need to run at full capacity to comply with the given set points of the system. A look at the flow plot for the simulation shows that, while less interesting than the Capacity flow plot, the target throughput has been met for all points in time, the only exception being during the planned shutdown.
Another interesting graph to view is the Pressure Solutions Space (PSS) Chart.

The PSS Chart gives a visual explanation of the different possible solutions the optimizer has traveled to achieve lowest cost. In this example, there were many possibilities for travel between Station SP and Station 1, but very few hydraulic possibilities between Station 1 and Station 2 due to the constraints in the system.

Adding up the off- and on-peak energy cost, demand cost, and DRA cost yields a total cost of $58,946.67 for the given setup for a single batch cycle.

**Power Optimization**

The Power Optimization mode finds the least costly method to run the batch schedule while minimizing power usage. In this mode, the flow rate is allowed to vary in time, while still meeting the target throughput as an average in time.
The gradeline for the Power Optimization is similar to that of Pump Selection; however, there is a significant difference in the power used to reach the same target throughput. We can see in the flow plot the varying flow rates over time, while the target flow rate is still met on average.

Figure 23. Gradeline for Power Optimization

Figure 24. Flow Plot for Power Optimization
DRA Optimization

DRA Optimization mode optimizes the DRA injection rates based on the target flow rate of 2000 bbl/hr.

The gradeline for the DRA optimization is similar to that of Pump Selection and Power Optimization. In this case, the total cost to run one batch plan, which includes off- and on-peak energy costs, demand costs, and DRA cost, was $57,511.55, compared to the Pump Selection cost of $58,946.67, a savings of 2.4%.

The suggested DRA rules are given in the DRA Optimized Injection Rules table. In this case, the suggested DRA rate for Station 1 is 2.23 ppm and 2.02 ppm for Station 2.

Power Optimization with Suggested DRA Injection Rates

Now that we know the suggested DRA injection rates, we can enforce these rates in a Power Optimization simulation to achieve the lowest cost of the pipeline system.
The gradeline is similar again to preview optimization simulations. The flow plot shows a change in the flow pattern for the simulation.

Figure 27. Gradeline for Power Optimization with Suggested DRA Injection Rates

Figure 28. Flow Plot for Power Optimization with Suggested DRA Injection Rates
The gradeline is similar again to preview optimization simulations. The flow plot shows a change in the flow pattern for the simulation.

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Station Cost</th>
<th>DRA Cost</th>
<th>Total Cost</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Selection</td>
<td>$57,733.24</td>
<td>$1,213.43</td>
<td>$58,946.67</td>
<td>-</td>
</tr>
<tr>
<td>Power Optimization</td>
<td>$56,501.18</td>
<td>$1,213.43</td>
<td>$57,714.61</td>
<td>2.1%</td>
</tr>
<tr>
<td>DRA Optimization</td>
<td>$57,382.78</td>
<td>$128.77</td>
<td>$57,511.55</td>
<td>2.4%</td>
</tr>
<tr>
<td>Power Optimization with Suggested DRA Injection Rates</td>
<td>$57,295.94</td>
<td>$128.77</td>
<td>$57,424.71</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

Table 1. Simulation Cost Results