"The Key to Residue Upgrading"

Advanced EUREKA Process
Introduction

The Eureka process is a commercially proven thermal cracking process to produce valuable cracked oil and aromatic petroleum pitch from heavy residual materials. The etymological meaning of “EUREKA” is “I’ve found it” - Archimedes’ exclamation when he discovered the principle of buoyancy. The first commercial plant was constructed in Fuji Oil Refinery Complex in Japan and commenced operation in 1976.

The unit has been operated successfully for more than 30 years since then. Accumulated successful operational experiences and continuous engineering developments have resulted in further significant improvements to the process. Two years of continuous operation by controlling coking have been achieved and more sophisticated and robust design improvements have been implemented using up-to-date technologies such as computational fluid dynamics (CFD) and finite element analysis (FEA). In addition, an energy saving device has been introduced.

Outstanding Environmentally Friendly Process

- Continuous operation in a closed system
- Environmentally clean and healthy plant yard
- Accomplishment of stringent legislative requirements

Unique Pitch Utilization

- Binder for metallurgical coke
- Boiler fuel as solid
- Feedstock to gasification as liquid

Advances in Technology

- Two years of continuous operation
- Saving energy and resources
- Ground-breaking reliable design

Engineering Tools for Robust Design

By CFD

By FEA

Pitch Combustion System

Syncrude Production Scheme in Combination with Gasification

Chemical and Refinery Integration in Combination with Gasification
The Eureka plant, using heavy vacuum residue, employs process technology for thermal cracking, cracked oil fractionation, and pitch cooling and flaking. Figure 1 is a simplified Eureka process flow diagram. The feedstock from storage tank is first preheated at the feed preheater, led to the cracking heater via the bottom section of the fractionator and heated to about 490°C. The effluent from the cracking heater flows into one of the two reactors through an automatically operated switch valve. Thus the reaction in the reactor is carried out semi-batch-wise under operating conditions of 50 – 80kPa(g) and 400°C – 430°C. In the reactor the thermally cracked low-molecular-weight hydrocarbons are stripped by steam and sent to the fractionator.

A simultaneous radical condensation reaction causes the remnant to finally form a petroleum pitch. At the end of the reaction, the pitch remaining in the reactor is quenched then allowed to flow down to the pitch stabilizer. The molten pitch is continuously pumped out from the pitch stabilizer and sent to the pitch flaker where it is cooled and solidified into flakes.

The cracked vapor is fractionated in the fractionator into heavy cracked oil and light cracked oil. A large amount of heat from the reactor is recovered in the form of steam. Cracked gas is compressed and then routed to a sour gas treater. Steam condensate is sent to the foul water treatment facilities.

Figure 1. EUREKA PROCESS FLOW
**Products**

1. **Large Yield of Cracked Oils**

Products yields from this feedstock are shown in Table 2. The yield of cracked oils is greater than those from other residual thermal cracking processes.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Vacuum residue of Middle East crude mixture</th>
<th>240/540ºC Cracked heavy oil</th>
<th>420/540ºC Cracked heavy oil</th>
<th>80ºC-180ºC Coker oil</th>
<th>240/550ºC Coker gas oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>54%</td>
<td>24%</td>
<td>4%</td>
<td>17%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1.33%</td>
<td>1.26%</td>
<td>2.70%</td>
<td>2.08%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1980 ppm</td>
<td>2600 ppm</td>
<td>1860 ppm</td>
<td>1780 ppm</td>
<td>300 ppm</td>
</tr>
<tr>
<td>ASTM 188</td>
<td>43ºC</td>
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2. **Production of Valuable Petroleum Pitch**

The most characteristic feature of the Eureka Process is that the thermally cracked remnant is a pitch of an aromatic nature in a molten state during the process and is stable as a solid. Typical pitch properties are shown in Table 3. In the various scenarios described below, there are numerous possibilities for utilization of the pitch.

**3. Product Oil is Easy to Upgrade**

The product cracked oil contains only very small amounts of metals, carbon residues and asphaltenes. So it is possible to produce a large amount of low sulfur fuel oil or light distillates from the petroleum residue feedstock by providing downstream hydrodesulfurization, catalytic cracking or hydrcracking. Typical product oil properties are shown in Table 5.

**4. Advantages in Technology**

- **Improving Operability and Maintainability (Two Years of Continuous Operation)**

Through more than 30 years operation in Fuji Oil Refinery, many challenging improvements to operability and maintainability have been performed. During two years of continuous operation a high availability of around 97% (including planned shutdowns) has been achieved.

- **Saving Energy and Resources**

1. **Ammonia–Water Power Generation System**

For the purpose of energy saving in the process, the refined Rankin Cycle using ammonia-water was applied in 2005 in Fuji Oil Refinery. The lower level heat of Eureka fractionator overhead stream (around 110ºC), which was originally wasted by cooling with air fin cooler, is now recovered as electric power, by introduction of the system where the design capacity of power generator is 4,000 KW, thus electric power consumption in the Eureka process is almost balanced.

2. **Waste Water Recycling System**

From the viewpoint of saving resources and global application of the Eureka process, the reduction of waste water is regarded as one of the key issues and therefore a Waste Water Recycling System is being developed. This system consists of the combination of stripping and distillation columns and the steam recovered from the distillation column can be recycled to the reactor through the steam superheater.

- **Enhancing Reliable Design**

1. Analysis of bubbling type reactor

   The coking issue in the reactor upper section and overhead line is caused by the entrained coke precursor in the reactor vapor. For resolving this issue, the liquid droplet behavior in the reactor was analyzed using Computational Fluid Dynamics (CFD).

   As the result of this investigation, the amount of steam injected and the layout of steam injection nozzles were optimized so that the control of coking can be limited by suppressing the amount of entrainment.

   The new reactors applied with this design concept were installed in 2007 in Fuji Oil Refinery and the performance is under observation.

2. Analysis of thermal stress on reactor support type

   The reactor was exposed to conditions of thermal stress because the temperature of the reactor increased from 350ºC to 430ºC every 3 hrs.

   In spite of these circumstances, the Eureka reactors have, up to now, coped extremely well except only for some limited repairs required around the saddles, which originally supported the reactors on the structure. Finite element analysis has now been performed to determine a more robust design for the supports.

   Reactors with new type of support were installed in 2007.

3. Analysis of cracking heater

   The cracking heater is one of the critical equipment in the Eureka process. From an operability and maintainability point of view a sufficient run length between decoking has to be achieved. To estimate the fouling rate in the tubes, a tubular fouling model was established.

   Currently, by using CFD, heat distribution in the cracking heater can be analyzed. By changing burner distributions and firing states, equalization of heat flux and surface temperature of heating tube can be achieved.

   In combination with the coking simulator and firing analysis by CFD the local formation of coke can be prevented.

**Table 1** Typical Feedstock Properties

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**Table 2** Typical Product Yield

<table>
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<tr>
<th>Feedstock</th>
<th>H2S gas</th>
<th>Co-Cracked gas</th>
<th>CUMR8ºC Cracked light oil</th>
<th>240/54ºC Cracked heavy oil</th>
<th>Petroleum pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>0.7 wt%</td>
<td>3.6 wt%</td>
<td>19.2 wt%</td>
<td>42.5 wt%</td>
<td>34.0 wt%</td>
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**Table 3** Typical Properties of Product Pitch

<table>
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<th>Property</th>
<th>Eureka</th>
<th>Delayed Coking</th>
<th>Fluid Coking</th>
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<tr>
<td>Volatile matter, wt%</td>
<td>40 - 50</td>
<td>6 - 14</td>
<td>4 - 10</td>
</tr>
<tr>
<td>Heating value, Kcal/kg</td>
<td>7,800 - 9,200</td>
<td>7,800 - 8,600</td>
<td>7,700 - 8,000</td>
</tr>
<tr>
<td>Hardgroove index</td>
<td>150 - 170</td>
<td>50 - 100</td>
<td>15 - 20</td>
</tr>
<tr>
<td>Fuel Ratio *</td>
<td>&lt; 2</td>
<td>5 - 10</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Particle fineness, %</td>
<td>Base</td>
<td>More</td>
<td>More</td>
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</tbody>
</table>

*1 When being applied Ammonia-Water Power Generation System.
*2 When being utilized C4 Cracked Gas generated.
*3 When being applied Waste Water Recycling System.