Overcoming situational seawater fouling for sustaining energy efficiency with innovative solutions

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Introduction – PCS

- Upstream company of Singapore Petrochemical Complex on Jurong Island
  - supply high quality ethylene, propylene, acetylene, butadiene, 1-butene, MTBE and benzene to companies within Island

- 1977 – incorporation

- 1984 – first ethylene plant (cracker) in Southeast Asia on stream

- 1997 – second cracker unit on stream

- Present shareholders
  - Japan-Singapore Petrochemicals Co., Ltd (50%) (JSPC led by Sumitomo Chemical)
  - QPI* and Shell Petrochemicals (Singapore) Pte Ltd (50%) (*QPI: Qatar Petroleum International)
Introduction to PCS – Integration with Jurong Island

Jurong Island

Singapore
Introduction to PCS – Integration with Singapore Petrochemical Complex (SPC)
Factors Affecting Energy Efficiency

Process Design, Equipment Selection

Equipment Replacement and Rejuvenation

Process Safety + Energy Efficiency

Operation Performance Monitoring

Process Operating Conditions

Equipment Selection
- Most efficient design

Process Monitoring
- On-line specific energy

Operation Monitoring
- Plant reliability cells

Equipment Maintenance
- Root cause analysis

Equipment Reinstatement
- Holistic approach

Deterioration of Heat Transfer performance in heat exchangers results in less energy efficient operations
Seawater Application & Experience in PCS

• Large quantity of seawater (WS) is used as cooling medium
  ✓ To dissipate residual heat after comprehensive heat integration
  ✓ Heat exchange between the hot process streams and WS takes place in WS heat exchangers

• Small suspended particulates in WS are deposited over time in the WS heat exchangers (fouling)
  ✓ Deterioration of the heat exchange (duty) efficiency in the WS heat exchangers
Seawater Application & Experience in PCS

- **Bar Screen/ Travelling Screen:** Screen off large debris present in WS

- **Sodium Hypochlorite (NaOCl injection):** Controlled injection for biological fouling control
World is drowning in plastic, study says

A study that tracked the global manufacture and distribution of plastics since they became widespread after World War II has found that only 1.8 billion tonnes of that plastic are still in use.

Of the total, 6.3 billion tonnes are stuck on earth as garbage in landfills, recycled trash or pollution in the environment, including oceans, where it has been found in whales and the bellies of dead seabirds that mistook it for food. A small amount is eliminated in incinerators.

Source: www.straitstimes.com
Seawater Application & Experience in PCS

Worldwide reliance on disposable plastic packaging is overwhelming our planet. By 2050, the oceans will contain more plastic than fish by weight.

Source: www.plasticpollutioncoalition.org
Seawater Application & Experience in PCS

WS to heat exchangers
PCS-II seawater intake is sub-surface: Less problems encountered associated with surface debris

Source of debris fouling: Mainly mud, sand, broken sea shells
Seawater Application & Experience in PCS

- The effects of fouling are:

  **Reduction in WS flow:**
  - The accumulated deposits restrict WS flow, and reduce in rate of heat exchange

  **Increased thermal resistance:**
  - The deposits impede thermal conductivity and reducing rate of heat exchange

  **Process Upset:**
  - Poor heat exchange leads to higher process outlet temperatures that may exceed process/equipment design

  **Energy inefficiency:**
  - Process operates away from optimum points to compensate for higher process temperatures caused by reduced cooling
Seawater Application & Experience in PCS

Reduction in WS flow

\[ Q = m \times C_p \times \Delta T \]

- For the same duty \( Q \), \( m \downarrow \) results in \( \Delta T \uparrow \)
- Reverse solubility of salts and minerals in WS e.g. \( \text{CaCO}_3 \) – leading to Precipitation, scaling

Source: A. Weidell, Solubilities of Inorganic and Organic Compounds
Seawater Application & Experience in PCS

Increased Thermal Resistance

\[ Q = U_o \times A \times LMTD \]

where \( U_o \) = Overall heat transfer coefficient

Fouling layers create resistance to heat transfer and lower the overall heat transfer coefficient.
Seawater Application & Experience in PCS

• Reduction in WS flow
• Higher WS temperature also leads to increased biological fouling potential

Source: S Pugh et al. Fouling During the Use of Seawater as Coolant – The Development of a ‘User Guide’
Biologically induced corrosion

Anaerobic conditions
Sulphate Reducing Bacteria produce hydrogen sulphide from sulphates
Copper sulphide is mechanically unstable and falls
Fresh metal is exposed to attack

Source: B Little et al. Microbiologically Influenced Corrosion in Copper and Nickel Seawater Piping Systems
Seawater Application & Experience in PCS

• Commercial Solutions to Fouling
  ✓ Circulating compressible balls slightly larger than the heat exchanger tube diameters
  ✓ Balls effect a cleaning motion on the heat exchanger tubes inner walls as they are pushed through the tubes

Source: www.taprogge.com
Seawater Application & Experience in PCS

• Commercial Solutions to Fouling
  ✓ Not suited for the observed type of fouling where tubes are clogged – no flow path for the balls to pass through
  ✓ Ideally more suited for indirect seawater cooling

✓ PCS mainly uses **direct seawater cooling system**, and would require the full set-up (ball circulating pump, ball strainer, ball injection) for each of its >100 seawater heat exchangers

✓ Space constraints
Discovery Process of Energy Efficiency Opportunities

- **Best Practice Technology (BPT)**
  - Chemical processes

- **Operations and maintenance – existing facilities**
  - High efficiency compressors
  - Rejuvenate aged equipment

- **Energy Saving and CO₂ Emission Reductions**
  - Process optimization

- **Retrofitting plant facilities**
  - Supply and demand

- **Process Optimization and Control**
  - Modification for heat recovery
Discovery Process of Energy Efficiency Opportunities

- Energy audits / pinch analyses
- Industry best practices
- Root cause analysis
- Employee participation (suggestion) scheme

<table>
<thead>
<tr>
<th>Idea Originate From:</th>
<th>Cyborg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department:</td>
<td>Olefin II</td>
</tr>
<tr>
<td>Group Name:</td>
<td>Cyborg</td>
</tr>
<tr>
<td>Group Members (Indicate Idea Generator):</td>
<td>[Redacted]</td>
</tr>
<tr>
<td>Suggestion Title:</td>
<td>To &quot;Hot-Tap&quot; 2E-443</td>
</tr>
<tr>
<td>Category:</td>
<td>GSS</td>
</tr>
<tr>
<td>Present Status/Experience/Event:</td>
<td>Since 26/01/2014, 2E-443 outlet temperature has gradually risen from 35.5 to 42 degree Celsius. 2E-442 was recently back-flushed with minimum improvement.</td>
</tr>
<tr>
<td>Proposal:</td>
<td>To &quot;Hot-Tap&quot; 2E-443 so that we can install valve nozzles to carry out back-flushing operations on the WS line.</td>
</tr>
<tr>
<td>Expected Improvement (Indicate Implementor &amp; expected completion date, if any):</td>
<td>To improve efficiency to 2T-440 &amp; 2CM-450 system.</td>
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</table>
Using valves to switch the flow direction of WS to flush out accumulated debris in the heat exchanger
Challenges/ Innovation

• Space constraint to install additional valves and piping
  ✓ Multiple site checks to check feasibility for each equipment
  ✓ Solutions to fit individual equipment specific space constraints

• Operation of multiple valves to switch flow direction
  ✓ Potential risk of misoperation
  ✓ Loss of WS flow leading to severe process upset
  ✓ Careful analysis and determining optimal sequence of valve operation

• Momentary loss of duty during flow direction switch
  ✓ Transient loss of duty – mitigated by reduced load
  ✓ Potential temperature spike in the process stream
  ✓ Close monitoring and communication during operation
Challenges/ Innovation

• Calculations to verify the adequacy of heat duties under reverse flow condition
Justification for Investment

Reduced energy efficiency directly impacts cost of production

- Operate equipment at design point (high energy efficiency)
- Improve Specific Energy (Energy used per unit product)
- Power consumption of compressors
- Increased product recovery
- Reduce In-process material loss
Justification for Investment

• Reduced energy efficiency directly impacts cost of production
  ✓ Power consumption of compressors
  ✓ In-process material loss
  ✓ Operating at design point (high energy efficiency)
  ✓ Increased product recovery

• Prioritise and schedule equipment modification in phases
  ✓ Identify critical heat exchangers
  ✓ Phased implementation depending on priority
Energy Efficiency Benefits – Increase Product Recovery
Energy Efficiency Benefits – Increase Product Recovery

Improvement in Energy Efficiency with Back-flushing of Seawater Exchanger

- Do bottlenecking Project
- Shut-down, Exchanger cleaning
- Shut-down, Installation of back-flushing nozzles

- Specific energy improvement
- Back-flushing carried out

Specific Energy of Product

Column Reflux Rate

Time

- Specific Energy of Product
- Column Reflux Rate
Other Benefits

- **Improved Plant Reliability**

  ✓ Reduced occurrence of corrosion in heat exchangers
    ▪ Prolonged operation of WS heat exchangers with low WS flow results in increased corrosion potential
    ▪ Presence of deposits leading to Corrosion Under Deposit
    ▪ Biologically induced corrosion

  ✓ Reduce frequency of shut-down of plant for repair / rectification
Other Benefits

• **Reduced Maintenance Time & Costs**

  ✓ Fouling and low WS flow increases the potential for formation of hardened scale by minerals present in WS

  ✓ Hardened scale is difficult to remove, even with use of ultra-high pressure water jets

  ✓ Cleaning is time-consuming and the use of high pressure poses risk of damage to the heat exchanger tubes
Conclusion

• Adopting a Practical Approach on Energy Efficiency in Process Plants to continuously identify and assess Energy Efficiency Opportunities

• Energy efficiency improvements can be implemented with little or no significant capital investment

• Improving energy efficiency goes beyond energy savings
  ✓ Safe, stable and reliable operations
  ✓ Promote employees participation for continual improvement
THANK YOU