Overall Plant Energy-saving by Mathematical Optimization through HERO Service & Energy-saving Distillation System SUPERHIDIC®


November 7th

TOYO ENGINEERING CORPORATION
Energy-saving Distillation System

SUPERHIDIC®

November 2019

TOYO ENGINEERING CORPORATION
Heat Integrated Distillation Column
- Fundamental -

Ideal

- Distillate
- Infinite stages
- Heat removal @all stages with infinitesimal duty
- Infinite stages
- Heat input @all stages with infinitesimal duty

Reversible Distillation

Reality

- Distillate
- Comp’or
- Increased pressure, subsequent increased temp. @rectifying section

HIDiC

Heat transfer

Feed

Reboiler

Condenser
Findings through intensive thermodynamics study:

- Ideal heat duty is dependent on the composition (stage).
- Some composition may require heat while some others may not. Thus, discrete side H/Ex allocation.
- Seldom to have ideal heat duties at the same elevation.
- Stage having similar heat duty demand should be combined.

Inappropriate side H/Ex manner = Increase in column loading in vain = Increase in compressor

Discrete & a few side H/Ex
Different heat duty at each side H/Ex
Appropriate stage to be exchanged not at same level
【Features】

- **Side exchangers**
  - Normal stabbed-in type H/Ex (Normal S/T H/Ex can be used)
  - Installed at the desired composition
  - Freedom in pairing of stages
  - Heat transfer area is variable
  - Limited number (around 4) only

- **Column**
  - Strip. sect. elevated above rect. sect.
  - No pump is required for circulation
  - Normal tray or packing

Maintenance possible
- Applicable to any process scheme, e.g. side-cut product draw-off, multi-feed
- Optimal side heat duty allocation close to reversible distillation achievable
Actual Performance in Commercial Plant

Awarded for world-1st HIDiC commercial application with SUPERHIDiC® in 2014 3Q

Contract Summary
- Client: Maruzen Petrochemical
- Site: Chiba, Japan
- Process Unit: MEK
- Scope: License & EPC TKLS
- Replacement of conventional distillation column

Results
- Energy Conservation: 57% reduction to conventional distillation
- Stable Operation w/ 0 kW Reboiler Duty
- More than 3 years commercial operation
Bypass line w/ block valve

Reboiler Duty “0” kW in stale operation!! (6135 kW@conv. dist)
## Actual Performance in Commercial Plant

<table>
<thead>
<tr>
<th></th>
<th>SUPERHIDIC</th>
<th>Conv. Distillation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feed rate</strong></td>
<td>[S kL/h]</td>
<td>19.5</td>
</tr>
<tr>
<td><strong>Operating pressure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low pressure column @OVHD</td>
<td>[kPa]</td>
<td>109</td>
</tr>
<tr>
<td>High pressure column @OVHD</td>
<td>[kPa]</td>
<td>229</td>
</tr>
<tr>
<td><strong>Separation specifications</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEK @distillate</td>
<td>[wt%]</td>
<td>99.94</td>
</tr>
<tr>
<td>MEK @bottoms</td>
<td>[wtppm]</td>
<td>200</td>
</tr>
<tr>
<td><strong>Energy consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reboiler duty</td>
<td>[kW]</td>
<td>0</td>
</tr>
<tr>
<td>Compressor power</td>
<td>[kW]</td>
<td>915</td>
</tr>
<tr>
<td>Reflux/dist. Pump</td>
<td>[kW]</td>
<td>25</td>
</tr>
<tr>
<td>Bottoms pump</td>
<td>[kW]</td>
<td>27</td>
</tr>
<tr>
<td>Recycle pump</td>
<td>[kW]</td>
<td>34</td>
</tr>
<tr>
<td><strong>Reboiler duty</strong></td>
<td></td>
<td>6135</td>
</tr>
</tbody>
</table>

**Energy Saving [%] = \left(1 - \frac{Q_{r-SH} + \frac{W_{SH}}{0.366}}{Q_{r-conv} + \frac{W_{conv}}{0.366}}\right) \times 100**

- \(Q_{r-SH}\): Reboiler duty in SUPERHIDIC [MW]
- \(Q_{r-conv}\): Reboiler duty in conv. Distillation [MW]
- \(W_{SH}\): Compressor & pumps power in SUPERHIDIC [MW]
- \(W_{conv}\): Compressor & pumps power in conv. distillation [MW]

Energy Saving 56.7% to Conv. Distillation
Awards

- 2014 Nikkei Green Innovation Prize
- 2017 ENAA Engineering Excellence Award
- 2018 Energy Conservation Grand Award (METI Prize)
- 2018 SCEJ Award for Outstanding Technical Development
- 2018 JPI Award for Technological Progress
- 2019 SSEJ Award for Outstanding Technical Development
Next

How to apply such nice technology to your plant

How to achieve energy-saving and reduction of GHGs emission even without such super-technology
Energy Conservation & Reduction of GHGs Emission for Overall Process/Utility Plant by Mathematical Optimization — Hybrid Energy system Re-Optimization — November 2019

TOYO ENGINEERING CORPORATION
Simultaneous Optimization on both Process and Utility Systems

Comprehensive model optimizes both systems simultaneously for direct minimization of external utility resource usage.

**Objective**

- Minimization of external utility usage
- Fuel
- Sell/Buy Electricity

**Comprehensive mathematical optimization model**

- Requested heat duty
- Pressure flowrate of consumed STM
- Requested Power
- Power supply / pressure flowrate of consumed STM
Superior Process System Optimization

Objective

Fuel
Sell/Buy
Electricity

Comprehensive mathematical optimization model

- Implementation of new HEXs
- Multi-effect dist. intensification
- Implementation of heat-pump distillation etc...

Process Sys.

Requested heat duty
Power

Utility Sys.

Pressure Flowrate
of consumed STM

- Requested Power
- Power Supply / Pressure Flowrate of consumed STM
Optimization on Heat Exchanges

All options which might be effective are covered.

- Cooling: Condenser, heat recoveries at outlets
- Heating: Reboiler, feed preheaters

From the all combinations, effective configuration is selected.
Optimization on Operating Pressure

Operating pressures of distillation columns are also optimized

Linearized models for several ranges of operation pressure are embedded.
As for each distillation column, implementation of heat-pump distillation—especially SUPERHIDIC®, is also examined.
Superior Utility System Optimization

Comprehensive mathematical optimization model

Objective

- Fuel
- Sell/Buy Electricity

- Turbine refit
- Header press. change
- Letdown adjustment etc...

Requested heat duty
Power Supply / Pressure Flowrate of consumed STM

Request Power
Pressure Flowrate of consumed STM

Process Sys

Utility Sys.
Alternation of turbine-inlet steam is examined.

Header press. is optimized.

Power to process system.

Implementation of additional header level is examined.

Steam usage/generation @ process sys.

Header press. is optimized.

Header press. is optimized.
Scale of Optimization

In the case of x 6 columns & 4 levels of STM headers

- # of ope. press. ranges: 4
- # of feed state ranges: 4
- SUPERHIDIC® option: included
- # of candidate press. of each STM header: 3

Heat-exchange comb. Dist. col. STM header
ox ope. range ope press.

\[2(2\times6)\times(3\times6)\times(4^2 \times 2)^6 \times 3^4 \approx 10^{75}\text{ conditions}\]

Corresponds to: \(2^{(# \text{ of possible comb.})}\)

**Even this alone** results in \(10^{63}\) conditions

Solve 1 case w/ 1 sec \(\Rightarrow 10^{57}\) years

HERO’s efficient search using Mixed Integer Linear Prog. can find out the solution within moderate calc. time.
## Achievements (through a National Project)

### Case 1

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Proposal</th>
<th>Energy Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Steam</td>
<td>31.3</td>
<td>18.9</td>
<td>12.4 (39.7% Saving)</td>
</tr>
</tbody>
</table>

### Case 2

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Proposal</th>
<th>Energy Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Steam</td>
<td>9.24</td>
<td>9.24</td>
<td>0</td>
</tr>
<tr>
<td>MP Steam</td>
<td>-2.7</td>
<td>-15.48</td>
<td>12.78 (473% for Sell)</td>
</tr>
</tbody>
</table>

### Case 3

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Prop. 1</th>
<th>Prop. 2</th>
<th>Energy Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Oil</td>
<td>12.32</td>
<td>9.85 MW</td>
<td>9.51 MW</td>
<td>Prop. 1: 2.47 (20% Saving) Prop. 2: 2.81 (23% Saving)</td>
</tr>
</tbody>
</table>
Business Scheme

Development of **tailor-made** model for specific process & utility configuration ➞ Proposal of “Overall” Optimum

- Configuration: Process & utility systems
- Operation/Design Data
- Operation Philosophy

- Optimal operation target
- Modification plan

Min. initial charge

Energy saving score

Proposal A
Proposal B
Proposal C

Investment (or Equip. modification degree)

Performance-based reward
- Concept Purchase
- ΔOPEX-based charge
Thank you for your kind attention!

For more details...

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