Ethylene Glycol Production from Syngas

A New Route

Jon Penney
Eastman Chemical Company
Monoethylene glycol (MEG)

- The most common industrial diol with a consumption of ~25 million tpa
- Colourless, odourless, sweet tasting liquid
- Primarily used as an intermediate in the manufacture of polyester fibre and fabrics and polyethylene terephthalate (PET) resin used in bottling
- Coolant and heat transfer agent
- Antifreeze
- Hydrate inhibitor in gas pipelines
- First modern industrial process via ethylene oxide started in 1937
Typical Polyester Products

Specialty Co-polyesters
MEG Demand by Application

% World Demand

- Polyester Fibre: 54%
- PET Bottle: 26%
- PET Film/Others: 9%
- Antifreeze: 6%
- Industrial: 5%

Total MEG production ~25 million tpa in 2014
Global MEG Demand and Capacity Utilisation

- Capacity (million tonnes)
- Production (million tonnes)
- Utilisation Rate (%)
How did we get here?

A global specialty chemical company headquartered in Kingsport, Tennessee

Approximately 14,000 employees and 50 manufacturing sites around the globe

2016 revenue of $9 billion
Beaumont Gasification Project

- Mid 2000’s Eastman was Developing a 7,500 Ton/Day Gasification complex to be built in Beaumont Texas
- Syngas derivatives “park”
- Eastman began developing derivative technologies
- One of those was a route to ethylene glycol from syngas
A Change In Plans

- 2008/2009 recession and a spike in construction costs
- In order to be viable, project dependent on uncertain CO$_2$ regulation and subsidies
- Derivative Technologies not quite ready and hard to get long term off takes
- Off take agreements were for methanol and hydrogen (commodities)
- Eastman strategy change to a Specialty Chemical Company
A Partnership is Formed

Johnson Matthey sector structure

Change to a Licensing Strategy for New Technologies
JM Davy Has a Strong Record in Commercialising New Technologies

• JM Davy focus on development rather than fundamental research.
• Works with the chemistry to select optimum reactor and flowsheet.
• Capability to successfully translate from miniplant to commercial scale.
  – Miniplants
  – VLE
  – Hydraulic rigs
  – Simulations and modelling
• Close interactions between chemists, process engineers and other engineering disciplines is critical.
Oxo Alcohols – since 1970’s
Butanediol – since 1980’s
Tetrahydrofuran – since 1990’s
Ethyl Acetate – 2000
Detergent Alcohols – 2002
2PH – 2007

………..and now our efforts are focused on

MEG
Successful experience with very high scale factors.

Computer models confirm many separate design aspects.
- Reaction kinetics
- Heat transfer
- Vapour/liquid equilibria
- Mechanical arrangement
- CFD modelling including reactions

Methanol converter weighing 600 tonnes was installed without pilot plant trials.
Eastman and JM Davy Collaboration on MEG

- Eastman and JM Davy collaborated on a successful R&D to commercial development project in the early 1990s
- Collaboration on MEG started in 2006
- Eastman and JM Davy have combined their complementary strengths in R&D, technology development, project execution and manufacturing to deliver MEG
- Eastman and JM Davy have assigned experienced teams of chemists, engineers and commercial persons to work alongside each other in a dedicated team focussed on MEG
Syngas to Chemicals JM Technologies

- FT: gasoline/diesel
- SNG: methane
- NH₃: ammonia
- Methanol: methanol
- DME: formaldehyde
- MTO: poly olefins
- MEG: MEG
- Oxo: 2EH/butanol, 2PH
- C3= formaldehyde
- C4= methanol

Processes:
- Syngas to FT
- Syngas to SNG
- Syngas to NH₃
- Syngas to methanol
- Syngas to DME
- Syngas to MEG
- Syngas to MTO
MEG Production Technologies
Routes to MEG from coal or naphtha

- Conventional Route (Naphtha-based)
  - naphtha → ethylene → ethylene oxide → MEG

- Coal Routes (Syngas-based)
  1. Oxalate Process
  - syngas → DMO → MEG

  2. MTO Process
  - syngas → methanol → olefins → separation → ethylene → ethylene oxide → MEG

  3. Eastman /JM Davy’s MEG Process
  - syngas → methanol → intermediate → MEG
Advantages of Eastman/JM Davy MEG Process

Breakthrough Technology, reducing consumption of energy resources at competitive costs

- MEG product suitable for fibre applications and meets both ASTM and Chinese specifications
- Process using well proven unit operations – competitive investment cost
- Based on new, proprietary catalyst
- Basic raw materials are synthesis gas and methanol, readily available
Advantages of Eastman/JM Davy MEG Process

Favourable Environmental Footprint

- Efficient use of raw materials (high conversion and selectivity)
- Low waste water emissions
- No hazardous by products
- Co-product is diethylene glycol (DEG) which has value in market
Competitive Economics Compared to Other Commercial Processes

- Expect economies of scale with capacities > 200 kta
- Single train up to capacities of 500 kt/a
- Capex is expected to be competitive with other coal based routes
- Net production costs favourable compared to all other routes
- ROI > 20% expected with competitively priced feedstocks
Eastman / JM Davy’s MEG Process

syngas → methanol → intermediate → MEG

methanol, air → CO → H₂ → MEG (product)

formaldehyde → hydrocarboxylation → hydrogenation → refining

DEG (co-product)
The MEG product purity meets fibre application requirements and the specification of ASTM E2470-09

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono Ethylene Glycol</td>
<td>wt%</td>
<td>99.9 min</td>
</tr>
<tr>
<td>Diethylene Glycol</td>
<td>wt%</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Acidity (as acetic acid)</td>
<td>wt ppm</td>
<td>20 max</td>
</tr>
<tr>
<td>Water</td>
<td>wt%</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Colour (Pt-Co)</td>
<td></td>
<td>5 max</td>
</tr>
<tr>
<td>Iron</td>
<td>wt ppm</td>
<td>0.1 max</td>
</tr>
<tr>
<td>Ash Content</td>
<td>wt ppm</td>
<td>40 max</td>
</tr>
<tr>
<td>Chlorides (as Cl)</td>
<td>wt ppm</td>
<td>0.2 max</td>
</tr>
<tr>
<td>Ultraviolet transmittance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>220 nm</td>
<td>%</td>
<td>≥70</td>
</tr>
<tr>
<td>250 nm</td>
<td>%</td>
<td>≥90</td>
</tr>
<tr>
<td>275 nm</td>
<td>%</td>
<td>≥94</td>
</tr>
<tr>
<td>350 nm</td>
<td>%</td>
<td>≥98</td>
</tr>
</tbody>
</table>
The DEG product purity meets the specification of ASTM D2694-05 (2011).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diethylene Glycol</td>
<td>wt%</td>
<td>99.8 min</td>
</tr>
<tr>
<td>Mono Ethylene Glycol</td>
<td>wt%</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Triethylene Glycol</td>
<td>wt%</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Acidity</td>
<td>wt ppm</td>
<td>50 max</td>
</tr>
<tr>
<td>Water</td>
<td>wt%</td>
<td>0.05 max</td>
</tr>
<tr>
<td>Colour (Pt-Co)</td>
<td></td>
<td>10 max</td>
</tr>
<tr>
<td>Ash Content</td>
<td>wt ppm</td>
<td>50 max</td>
</tr>
</tbody>
</table>
Block Flow Diagram – Syngas to Methanol and MEG

- **Natural gas** to **Syngas Plant**
- **Oxygen** to **Syngas Plant**
- **CO** and **H₂** from **Syngas Plant** to **Methanol Plant**
- **Methanol Plant** produces **Methanol Product**
- **Syngas Plant** produces **MEG Product** and **DEG Co-product**
**Performance Data - Syngas to 1,800 kta Methanol and 500 kta MEG**

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas to syngas plant</td>
<td>255,600 Nm³/h</td>
</tr>
<tr>
<td>Oxygen to syngas plant</td>
<td>93,700 Nm³/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Products</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>225 t/h</td>
</tr>
<tr>
<td>MEG</td>
<td>62.5 t/h</td>
</tr>
<tr>
<td>DEG</td>
<td>1.5 t/h</td>
</tr>
</tbody>
</table>

Utility consumptions are combined syngas, methanol & MEG Units

<table>
<thead>
<tr>
<th>Utility</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam (all levels)</td>
<td>335 t/h (5.3 t/t MEG)</td>
</tr>
<tr>
<td>Cooling Water</td>
<td>62,646 m³/h (1000 m³/t MEG)</td>
</tr>
<tr>
<td>Electric Power</td>
<td>25.1 MWh (402 kWh/t MEG)</td>
</tr>
</tbody>
</table>
Summary

• Eastman/JM Davy have a strong track record of bringing new technologies to commercialisation

• Eastman/JM Davy technology introduces a new syngas to MEG process which has:
  – Competitive investment and operating cost
  – Economies of scale – single train up to 500 kt/a
  – Demonstrated MEG product quality meeting fibre grade application requirements

• JM Davy is now actively licensing this exciting new technology. If you would like further details please contact Atul Shah at atulshah@matthey.com

Thank You