CHLOR-ALKALI TECHNOLOGY

A Partnership for Life

INEOS Technologies
Philip See (Business Development Manager)

- Chartered Mechanical Engineer
- 26 Years in Chlor-Alkali with ICI/INEOS
- Engineering Manager for
  - 40 kte KOH Plant (ICI FM21 membrane electrolysers)
  - 600 kte Chlorine Plant (ICI amalgam electrolysers)
- Plant Design and Commissioning
  - 430 kte Chlorine Plant (BICHLOR™ Electrolysers)
  - Technology benchmarking and operability studies
INEOS Overview

**Turnover**
$47 Billion

**Employees**
15,000

**Production**
60 Million Tonnes

**Heritage**
AMOCO, BASF, BAYER, BOREALIS, BP, DEGUSSA, DOW, ENICHEM, ERDOLCHEMIE, HOECHST, ICI, INNOVENE, LANXESS, MONSANTO, NORSK HYDRO, SOLVAY

**Sites**
51 Manufacturing Plants in 11 Countries

**Growth**
- 15 Petrochemical/Chemical Businesses
- Growth by acquisition since 1998
- World’s 4th largest independent chemical company

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INEOS Technologies Portfolio and Heritage

- Chlorine
- EDC
- VCM
- PVC

- Polypropylene
- Maleic Anhydride

- LL/HD swing Polyethylene
- Acrylonitrile
- Maleic Anhydride
- Expanded Polystyrene

- HD bi-modal slurry Polyethylene
R&D/ Technical/ Manufacturing Centres
~400 people World-wide.
Extensive Intellectual Property and 6000 patents

Commercial Centres - Rolle (Switzerland), Lyndhurst and Runcorn (UK), Lisle (USA), and Shanghai (China)
117 chlor-alkali projects over 30 years

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### Americas – Strong and Growing Presence

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF Chlor-Alkali</td>
<td>USA</td>
<td>2014</td>
</tr>
<tr>
<td>Skymine</td>
<td>USA</td>
<td>2013</td>
</tr>
<tr>
<td>Fluoders</td>
<td>Paraguay</td>
<td>2013</td>
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<tr>
<td>Kuehne</td>
<td>USA</td>
<td>2001 / 2011</td>
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<tr>
<td>Olin</td>
<td>USA</td>
<td>2011 / 2014</td>
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<td>FSTI/CSP</td>
<td>USA</td>
<td>2008</td>
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<tr>
<td>Allied</td>
<td>USA</td>
<td>2009</td>
</tr>
<tr>
<td>Lapsolite</td>
<td>Mexico</td>
<td>2006</td>
</tr>
<tr>
<td>Proquimsa</td>
<td>Ecuador</td>
<td>2005 / 2009</td>
</tr>
</tbody>
</table>
Successful Plant Lifespan – Vital to INEOS ChlorVinyls

- A designer and operator of chlorine plants for over 110 years
- 7 cell-rooms across Europe, total capacity 1,600,000 MTPA Cl2
- A major European Chlor-Vinyls Manufacturer
Successful Plant Lifespan – Key Factors

Successful Lifespan

- Safe Operation
- Reliability
- Efficiency
INEOS Runcorn – Driving Continuous Improvement

- 430kte/yr chlorine
- 20 BiChlor electrolysers
- Designed to Lifecycle Principles
- INEOS Know-How applied
- World Class Performance

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Techniques – A Structured Way of Working

1. Process Description/Purpose
2. Potential Failure Mode
3. Potential effect of failure
4. Severity
5. Potential cause of failure
6. Occurrence
7. Current Controls
8. Detection
9. RPN
10. Recommended actions
11. Responsibility/Start date
12. Action Results

Performance of O Ring carriers
Wrong material used in manufacture
Splits/cracks
Dissolves/Wear away
Chemical Degrades
Thermal Expansion effect on seal
Porous
Sticks to tup tube
Cause reaction with other materials/products

Supplier changes RM without informing ICL
Supplier changes RM informs ICL
Change of supplier
Raw materials to supplier changes without their knowledge
Lack of detailed agreed specification
Shelf Life: - Components

None
Change of BOM
Process – Agreed BOM integrating into ETB systems
Specification – QA systems & registration
Specification – maybe not detailed enough QA systems & registrations
Operator inspection & operational experience

None
- shelf life not known
- no stock rotation

10 3 3 9 9 10
200 30 60 450 900 100

Generate approved supplier list
Review specification & produce audit trial
Specifications agreed with supplier.
Establish if there is Shelf life
Develop Stock rotation process

Performance of O Ring carriers
Dimensionally wrong
Too Narrow – Can’t Assemble
Too Wide – Leaks in service

Supplier delivers outside of spec
Supplier delivers outside of spec

8 8

Drawings
Operator
Drawings
Operator
Cell room

measurements

3 9
48 720

Develop robust spec
Carry out QC Check on tolerances
Sample test

Lifecycle Value Analysis
Loss Elimination - FMECA
Critical Items Analysis
Risk Based Inspection
Safe Operation

Successful Lifespan

Safe Operation

Reliability

Efficiency
Safe Operation – Built In

• **Modular Technology Avoids…..**
  – Interaction with live electrolysers
  – Leaks – modules are bolted, sealed & pressure tested

• **Fully Wetted Membrane**
  – Gas/Liquor interface above the membrane
  – Avoids damage and pin-holing of membrane
  – Prevents mixing of Cl₂ / H₂ to avoid explosions

• **Safety in Plant Design**
  – Inherently safe design features
  – HAZOP

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[Image of Modular Technology and Membrane System]

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[Image of Safety in Plant Design]

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[Logo: INEOS Technologies]
Reliability – INEOS has the Knowledge

Rapid Module Change

Dynamic Modelling

Materials of Construction

Robust electrode coatings

Layout analysis

Accessible Headers

High Integrity Design

Stray Currents

Optioneering

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Reliability – Avoiding Damaging Pressure Excursions

- Dynamic model of the gas section downstream of electrolyser
- Simulate transient events – cellroom trip, electrolyser trip, load changes

- Model validated by comparing DP predicted by model with plant data
- Large negative DP excursion – improvement required

- Model used to develop control scheme to avoid reverse DP
- Excellent system response
Efficiency

Successful Lifespan

Safe Operation

Reliability

Efficiency
Power Efficiency – At the Heart of BiChlor

- Module low voltage dimple design
  - Max use of nickel post in cathode pan
  - Min use of titanium post in anode pan
- Explosion bonded Ti/Ni discs for excellent inter-module connection
- Zero gap electrodes
- Self aligning modules
Efficiency – 30 Years of Coatings Development

• Anode Coating
  – Lower power consumption
  – Greater resistance to Alkaline wear

• Cathode Coating
  – Highly resistant to upset conditions
  – 16 year warranty

• Modern coating plant and extensive refurbishment centre

INEOS Technologies
Efficiency – Accessing our Operations Expertise

- **Designated Technical Service Manager**
  - Experienced chlor-alkali specialist
  - Usually member of original commissioning team
  - Regular visits and contact

- **Getting the most from your plant**
  - Performance evaluation
  - Operating and Technical support
  - Electrolyser maintenance planning

- **Customer forum every 2 years**
  - Technical and Social content
  - Highly valued by clients
Efficiency – Evolution not Revolution

BICHLOOR™ Start-up Power Consumption vs Current Density

Power Consumption (KWh/te NaOH) vs current density (KA/sq.m.)

Incremental improvement
INEOS – A Partnership for Life

- Unrivalled knowledge of chlor-alkali technology and operations
- Technology built to perform over the long term
- A partnership for the long-term