Internal Linings for Vessels and Tanks
What are the vessel deteriorating factors that need to be overcome:

- Corrosion
- Galvanic
- Pitting
- Crevice
- SCC
- Bacterial
What are the options?

**Materials of Construction**
- Carbon Steel
- Corrosion Resistant Alloys
- Overlaid Carbon Steel
- Non Metallic Materials

**Internal Linings**
- Epoxy Paint
- Glass Flake Coatings
- “Ceramic Coatings“
- Hybrid Epoxy Novolac Linings
What are the considerations

- **Metal Cladding / Weld Overlay**
  Weight, Cost, Availability, Chemical Resistance

- **Corrosion Allowance**
  Weight, Design Life, Root Cause

- **Cathodic / Anodic Protection**
  Cost, Effectiveness, Reliability

- **Internal Lining**
  Reliability, Application Quality, Resilience
Internal lining – cost effective solution

Cost Benefit Study carried out by major Engineering Contractor for a Middle East Oil and Gas new construction project

<table>
<thead>
<tr>
<th>Component</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CapEx</td>
<td>USD 57.1 million</td>
<td>USD 211.6 million</td>
</tr>
<tr>
<td>OpEx (External inspection)</td>
<td>USD 2.0 million</td>
<td>USD 2.0 million</td>
</tr>
<tr>
<td>OpEx (Clean out)</td>
<td>USD 3.0 million</td>
<td>USD 3.0 million</td>
</tr>
<tr>
<td>OpEx (Maintenance)</td>
<td>USD 0.75 million</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>USD 62.9 million</strong></td>
<td><strong>USD 216.6 million</strong></td>
</tr>
</tbody>
</table>

Hybrid Epoxy Novolac Lining Option

CRA Option
Selecting a suitable internal lining

Determine the following:

- Design and operating temperature
- Design and Operating pressure
- Operating Fluids
- Levels of corrosive gases (\(\text{H}_2\text{S} / \text{CO}_2\))
- Levels of solids entrainment (e.g., Sand)
- Chemical Additives (e.g., Well stimulation)
- Decompression Cycling
- Microbiological Activity
- Chemical Cleaning
- Steam Cleaning
- Vessel Configuration (for “coatability”)
- Nozzle Sizes
- Flange Face Configuration
Performance Testing – Immersion Temperature Resistance

- NACE TM0174: Atlas Cell Immersion

- Glass cells up to 95ºC / 203ºF
- Steel pressure cells up to 180ºC / 356ºF
- Minimum 6 months test
Performance Testing – Steam out resistance

- Resistance To Steam-Out
  - Autoclave
  - 96 hours
  - Up to 210°C / 410°F
Performance Testing – Depressurisation Resistance

- NACE TM0185 Rapid Decompression

Typical Test Program:
100 bar (1450 psi)
Reduced to 50 bar (725 psi) in 5 minutes
Then reduced to atmospheric in a further 10 minutes

Recommended 5 bar/min
Performance Testing – Cathodic Disbondment Resistance

- ASTM G8, G42 or G95
  - 28 day test
  - Elevated temperature ASTM G42 / G95 tests run at temperatures up to 90°C
- Radii as low as 2.5 mm at 80°C / 176°F
Performance Testing – Erosion Resistance

- **ASTM D4060: Taber Abrader**
  - Sliding abrasion
  - 1 kg load, 1000 cycles
  - Wet or dry test
Performance Testing – Erosion Resistance

- Leeds University Slurry Jet
  - Impact abrasion
  - Silica sand in water
  - 100 hours at 20 m/s flow rate
  - 90° impact angle
  - Up to 70°C
Performance Testing – Chemical Resistance

- ISO 2812-1
  - Coated steel rods
  - Ambient and elevated temperatures
  - Reagents including ethanolamines and other process additives (e.g. Nalco)
  - 12 months immersion
Hybrid Epoxy Novolac - Lining Performance Parameters

- Suitable for Immersion Temperatures up to 180°C
- Tested up to 120bar decompression resistance
- Steam out resistance over 210°C
- Resistant to H2s and CO2 in saturated solution
- Excellent resistance to entrained solids
- Resistant to SRB / MIC
Hybrid Epoxy Novolac lining – System Properties

- Brush Applied Products with immersion temperature resistance up to 180°C
- Spray applied products with immersion temperature resistance up to 150°C
- Repair grade products with immersion temperature resistance up to 150°C
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>204</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>206</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>207</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>208</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>Kuwait Oil Company</td>
<td>Kuwait Oil Company</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>211</td>
<td>Rabigh Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>Rabigh Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>SWCC Khobar</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Oil and Gas Separator</td>
<td></td>
</tr>
<tr>
<td>214</td>
<td>Bas Tanura Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Multi-Effect Condenser Unit</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>Ras Tanura Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Multi-Effect Condenser Unit</td>
<td></td>
</tr>
<tr>
<td>218</td>
<td>Rabigh Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Deaerator</td>
<td></td>
</tr>
<tr>
<td>219</td>
<td>Rabigh Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Deaerator</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>Rabigh Refinery</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>Deaerator</td>
<td></td>
</tr>
<tr>
<td>221</td>
<td>Barri Gas Plant</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>DGA Amino Concrete Sump Pit</td>
<td></td>
</tr>
<tr>
<td>222</td>
<td>Berri Gas Plant</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>58% Sulfuric Acid Containment Area</td>
<td></td>
</tr>
<tr>
<td>223</td>
<td>National Methanol, Jubail</td>
<td>Saudi Aramco</td>
<td>1391</td>
<td>98% Sulfuric Acid Containment Area</td>
<td></td>
</tr>
</tbody>
</table>

**PROJECT DATABASE 1994 TO 2014**

**BELZONA**

Repair • Protect • Improve
The original glass flake coating had failed in service leading to substrate pitting and corrosion.
Flash Drum Lining - Argentina

June, 2007

Inspection in 2010

Flash drum to be exposed to diglycolamine, wet H₂S and CO₂ at 80°C.
Amine Still Column - Turkey

August, 2012

Completed application

Vessel needed protection from hydrogen sulphide and carbon dioxide at operating temperatures of 93°C (200°F)
High H$_2$S presence in the gas field called for high performance corrosion protection to 32 new build carbon steel vessels.
SBM And Petrobras, Brazil

September, 2009

4 pressure vessels - in-service temperatures of up to 180°C. Adjacent flange faces and nozzles also required corrosion protection. Inspected in 2013, all in perfect condition.
Protection of weld areas subject to stress corrosion cracking at elevated temperatures due to the presence of H2S. Weld areas only protected using high temperature Hybrid Epoxy Novolac lining system with operating temperature in excess of 150°C.
Flange Face Repair and Protection

Flange Face Repair Kit
Flange faces formed using Belzona materials to prevent corrosion and leaks

Suitable for: ANSI 150, 300, 600 and 900 Flanges.
Small Bore Nozzle Protection
Small Bore Nozzle Protection

Belzona nozzle inserts bonded into small bore nozzles, protect against corrosion and erosion
Small Bore Nozzle Protection
SBM and Petrobras

Brazil, 2009

1. Preparing flange

2. Face formed

3. Bonding nozzle insert

4. Completed application

Flange face forming and small bore nozzle protection, applied in 2009, inspected in 2013.
The acid washing process at elevated temperature led to severe pitting within the tower and significant loss of wall thickness adjacent to tray support rings. High Temperature repair compound used to restore wall thickness then acid resistant lining applied to resist operating conditions at 95C - Inspected in Year 2011 and in good condition.
Chemical Tank Protection

**Equipment**
Chemical Process Tank

**Problem**
Severe corrosion due to chemical attack to tank resulted in costly replacement

**Solution**
High Temperature Epoxy Novolac internal lining selected for its excellent chemical resistance
Repair and Protection of Effluent Treatment Tank

**Equipment**
Large Steel tank used for the treatment of effluent

**Problem**
Corrosion pitting and loss of wall thickness due to previous coating failures

**Solution**
Repair compound used to repair pitting and bond plates to damaged areas then coating system applied
Repair and Protection of Storage Tank

**Equipment**
Hydrocarbon Storage Tank

**Problem**
Corrosion pitting and loss of thickness in the base of the tank due to previous coating failures

**Solution**
Repair compound used to fill pitting and bond plates to damages area of the tank then internal coating system Applied.
Repair and Protection of Produced Water Tank – Occidental Oman Year 2011 Ongoing

**Equipment**
Produced Water Storage Tank operating up to 115°C

**Problem**
Corrosion pitting and loss of thickness in the base due to previous coating failures

**Solution**
Repair system used to fill pitting / and then High Temperature Coating System applied.
Internal Linings for Vessels and Tanks

**BELZONA HYBRID EPOXY NOVOLAC SOLUTIONS**

- Proven to provide solutions for pressure vessels operating at elevated temperatures and pressures
- Novel solutions for flanges and small bore nozzles
- Cold bonding Solutions for Internal Furniture
- Proven to outperform traditional conventional paints and coatings
- Accepted and specified by many major Oil and Gas companies
- Proven to provide a cost effective through life alternative to traditional materials of construction

**ONGOING INVESTMENT IN RESEARCH AND DEVELOPMENT**

**NEW!** Belzona 1500 Series High Temperature Coating Systems
Internal Corrosion Management of Pressure Vessels

ANY QUESTIONS?

Presented By: Mr Ron Campbell
Belzona Polymerics Ltd
Internal Linings for Vessels and Tanks