DEVELOPMENTS IN SPRAY APPLIED COATINGS FOR THE PROTECTION OF PROCESS VESSELS

Presented By:

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Protective Coatings

• Performance of Hand Applied Protective Coatings is well documented

• Used for the internal lining of process vessels. Subject to erosion and corrosion from aggressive fluids.

**HOWEVER** -

• Internal linings are limited by their immersion temperature resistance
Alternative to Protective Coatings

Materials of Construction

• Stainless Steel
• Exotic Alloys
• Overlaid Carbon Steel
• Fusion Bonded alloys

Limitations

• Must be applied at Construction phase
• Can be expensive for marginal projects
• Difficult to maintain / repair on-site
• Can suffer galvanic effects
Protective Coating Selection Considerations

Equipment Operating Conditions

• Operating and design temperatures
• Operating and design pressures
• Process Fluids
• Solids entrainment

Shutdown / Maintenance Conditions

• Steam out conditions
• Chemical Cleaning
• Mechanical cleaning
• Hot work restrictions
• Turn-around times
Protective Coating Selection Considerations

Ensure Coating is Suitable for Operating Conditions

• Analyze equipment operating modes
• Select coating based on most aggressive operating condition:
  - Dry Heat (Gas Phase)
  - Wet Heat (Vapor Phase)
✓ - Immersion (Immersion Phase)

• Check Coating Manufacturers Data to ensure correct coating selection
Protective Coating Selection Considerations

Consider Other operating Factors

• Operating and Design Pressure
  - Pressure vessels can be subject to sudden depressurization resulting in coating failure.

• Decontamination procedures
  - Steam out at elevated temperature
  - Chemical cleaning
Protective Coating Selection Considerations

Consider Other operating Factors

• Erosion from Entrained Solids
  - Process vessels can have entrained solids present either by design or changes to original operating parameters.

• Attack from Chemicals
  - Process vessels may in many situations require or produce chemical reactions that can cause deterioration in protective coatings e.g. :
    - Corrosion Inhibitors
    - Amine Solutions (MEA / MDEA ...)
    - High levels of CO2 / H2S
Protective Coating Selection Considerations

Consider all factors before making your coating selection OR discounting the use of a Coating Solution

- Operating and Design Temperatures
- Operating and Design Pressures
- Vessel Operating Phases
- Shutdown conditions
- Erosion from entrained solids
- Chemical attack
- Application characteristics
- “Repairability”
- Cost effectiveness
Hand Applied Protective Coatings

**Phase 1** - Completed in 1994 utilizing modified Phenol Epoxy Novolac technology to design a product to withstand immersion temperatures in aqueous / hydrocarbon fluids up to 120 C.

**Coating Properties:**

- **Type**: Two Component binary reacting Modified Epoxy Novolac System containing abrasive fillers to enhance abrasion and erosion resistance.
- **Immersion Temperature Resistance**: 120 C
- **Steam-Out Temperature Resistance**: 210C
- **Explosive Decompression Resistance**: 100 bar (limit of testing to date)
Hand Applied Protective Coatings

Phase 2 - Further developments using enhanced resins and chemically bonded fillers to increase immersion temperature resistance up to 180 C. In-house and Independent testing was completed to confirm performance.

Coating Properties:

Type (1591) : Two Component binary reacting silicone Modified Epoxy Novalac System containing abrasive fillers to enhance abrasion and erosion resistance.

Immersion Temperature Resistance : 180 C
Steam-Out Temperature Resistance : 210C +
Explosive Decompression Resistance : 80 bar (limit of testing to date)
## Hand Applied Coatings – Application Histories

<table>
<thead>
<tr>
<th>Equipment</th>
<th>- Existing Oil and Gas Test Separators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material of Construction</td>
<td>- Carbon Steel</td>
</tr>
<tr>
<td>Location</td>
<td>- Global Locations</td>
</tr>
<tr>
<td>Service Conditions</td>
<td>- Variable depending on well conditions between 80 and 155 C and pressures up to 100 bar.</td>
</tr>
<tr>
<td>Coating System</td>
<td>- 1591</td>
</tr>
<tr>
<td>Application Date</td>
<td>- 1997 to date</td>
</tr>
<tr>
<td>Specification</td>
<td>- Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 800 microns</td>
</tr>
</tbody>
</table>
# Hand Applied Coatings – Application Histories

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Process vessels for new Major Offshore Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Singapore</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>Service Conditions</td>
<td>Variable depending on well conditions between 60 and 110°C and pressures up to 75 bar.</td>
</tr>
<tr>
<td>Coating System</td>
<td>1391</td>
</tr>
<tr>
<td>Application Date</td>
<td>2004</td>
</tr>
<tr>
<td>Specification</td>
<td>Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 1000 microns</td>
</tr>
<tr>
<td><strong>Hand Applied Coatings – Application Histories</strong></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td>Mercury Extraction vessels for New Major Offshore installation</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Malaysia</td>
</tr>
<tr>
<td><strong>Material of Construction</strong></td>
<td>Carbon Steel</td>
</tr>
<tr>
<td><strong>Service Conditions</strong></td>
<td>Variable depending on well conditions between 60 and 105 C and pressures up to 40 bar.</td>
</tr>
<tr>
<td><strong>Coating System</strong></td>
<td>1391</td>
</tr>
<tr>
<td><strong>Application Date</strong></td>
<td>2006</td>
</tr>
<tr>
<td><strong>Specification</strong></td>
<td>Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 1000microns</td>
</tr>
</tbody>
</table>
Hand Applied Coatings – Application Histories

Equipment - Distilled water production unit in Refinery

Location - Thailand

Material of Construction - Stainless Steel

Service Conditions - Operating condition of 97°C

Coating System - 1391

Application Date - 1999

Specification - Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 1000 microns
Hand Applied Coatings – Application Histories

Equipment - Sour Water Stripper in Refinery

Location - Australia

Material of Construction - Carbon steel

Service Conditions - Operating condition of 70 – 105°C

Coating System - 1391

Application Date - 2004

Specification - Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 1000 microns
Hand Applied Coatings – Summary

- Temperature range up to 180°C immersion resistance
- Pressure let-down resistance up to 100 Bar
- Excellent erosion resistance
- Good application characteristics
- Solvent free
- Excellent resistance to hydrocarbons, amines and aqueous solutions
- Short cure times / fast return to service
- Repairable on-site
- Proven track record
- Available globally
Spray Applied Coatings Development

Sprayable Coating Design Considerations

• To be based on proven hand applied coating resin and filler technology

• Use minimum level of resin modifier to achieve spray viscosity

• Optimize the filler blend and filler level to minimize effect on viscosity

• Remove coarse silicon carbide filler which would cause severe wear on the spray equipment

• Target immersion temperature resistance at minimum 120°C (248°F)
Spray Applied Coatings Development

Functionality and Cross Linked Density

Cross link density is the number of reactive chemical sites within a given volume of Polymer material and the higher the cross linked density, the higher the polymer becomes to permeation.

Higher Cross linked density results in:

- Increased glass transition/heat distortion temperature
- Higher resistance to water & gas permeation
- Higher resistance to explosive decompression
The development therefore of the sprayable high temperature resistant coating systems has revolved around increasing the number of reactive sites within the matrix using known polymer technology based on the hand applied systems BUT reducing the viscosity of the resins systems to enable them to be sprayed.
Spray Applied Coatings Development

Sprayable Coating Testing Program

Sprayability:

The products were designed to be applied using either SINGLE component heated airless spray OR DUAL component heated airless spray.

Immersion Temperature Resistance:

The products were designed to perform in immersion temperatures up to 150C in pressurized service – Hydrocarbon and Water mixtures.
Spray Applied Coatings Development

Sprayable Coating Testing Program

Adhesion:

High levels of adhesion are required to resist the effects of osmosis as well as the forces exerted on the coating during decompression cycling.

Chemical Resistance at Elevated Temperatures:

The ability of the coatings to resist attack from the service liquids is important to ensure long-term performance.
Spray Applied Coatings Development

Summary

• Range of Coating systems available
• Sprayable using single or dual component heated airless spray
• Solvent free systems
• Immersion temperature resistance up to 150C and down to -40C
• Resistant to explosive decompression
• Resistant to process fluids and well chemicals
• Suitable for sour gas service (H2S / CO2)
Independent Testing to Support Coating Performance

<table>
<thead>
<tr>
<th>Coating Manufacturer</th>
<th>Duration</th>
<th>Temperature</th>
<th>Pressure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent-free Ceramic filled Epoxy Phenol Novolac</td>
<td>1 month</td>
<td>85°C</td>
<td>1160psi</td>
<td>Stabilised crude/produced water/methane/1% carbon dioxide</td>
</tr>
<tr>
<td>Statoil</td>
<td>1200 hours</td>
<td>80°C</td>
<td>435psi</td>
<td>Water and Gas Mixture</td>
</tr>
<tr>
<td>Charter Coatings</td>
<td>1 month</td>
<td>98°C</td>
<td>1305psi</td>
<td>Gas condensate/methane/4% carbon dioxide/3% hydrogen sulphide</td>
</tr>
<tr>
<td>Advantica</td>
<td>300 hours</td>
<td>85°C</td>
<td>435psi</td>
<td>Stabilised crude/water/carbon dioxide</td>
</tr>
</tbody>
</table>
Independent Testing to Support Coating Performance

**Intermolecularly bonded Epoxy Phenol Novolac Composite Coatings**

<table>
<thead>
<tr>
<th>Coating</th>
<th>Duration</th>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNC</td>
<td>6 months</td>
<td>130°C</td>
<td>435 psi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Stabilised crude/produced water/methane/2% carbon dioxide 50ppm Hydrogen Sulphide)</td>
<td></td>
</tr>
<tr>
<td>SACMET</td>
<td>600 hours</td>
<td>160°C</td>
<td>145 psi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Water/steam cycling)</td>
<td></td>
</tr>
<tr>
<td>Advantica</td>
<td>300 hours</td>
<td>85°C</td>
<td>435 psi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Stabilised crude/water/carbon dioxide)</td>
<td></td>
</tr>
</tbody>
</table>
Spraying Capabilities and Specification

Typical Spray Set - Up

- Minimum 56:1 ratio pump
- Heated circulating water for spray lines at 60 - 70°C
- Spray tip size 423-527
- Tip pressure 4300 psi
- Tip temperature approx 50°C
Spray Applied Coatings – Application Histories

Equipment - New Construction Offshore Process Vessels

Location - Middle East

Material of Construction - Carbon Steel

Service Conditions - 80 to 110 C and pressures up to 60 bar.

Coating System - 1521

Application Date - 2007

Specification - Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 850 microns.
Spray Applied Coatings – Application Histories

Equipment: New Construction Offshore Process Vessels

Location: Middle East

Material of Construction: Carbon Steel

Service Conditions: 95 to 115 C and pressures up to 55 bar.

Coating System: 5891/1391S

Application Date: 2008

Specification: Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 850 microns in 2 coats.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>New Construction Offshore Process Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Indonesia</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>Service Conditions</td>
<td>60 to 95°C and pressures up to 25 bar.</td>
</tr>
<tr>
<td>Coating System</td>
<td>1521</td>
</tr>
<tr>
<td>Application Date</td>
<td>2008</td>
</tr>
<tr>
<td>Specification</td>
<td>Grit blasting to SA 2.5 with a surface profile of 75 microns followed by the application of the coating at a thickness of 750 microns.</td>
</tr>
</tbody>
</table>
Spray Applied Coatings – Application Histories

Equipment - Portable Methanol Storage Tanks

Location - Australia

Material of Construction - Carbon Steel

Service Conditions - Ambient Temperature (50°C+)

Coating System - 5891

Application Date - 2004

Specification - Grit blasting to SA 2.5 with a 75 micron profile after which coating was applied at a thickness of 600 microns
### Spray Applied Coatings – Application Histories

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Effluent Treatment Tank / Dearator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>China</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Carbon Steel / Concrete</td>
</tr>
<tr>
<td>Service Conditions</td>
<td>Ambient Temperature 15 – 50°C</td>
</tr>
<tr>
<td>Coating System</td>
<td>5811</td>
</tr>
<tr>
<td>Application Date</td>
<td>2005</td>
</tr>
<tr>
<td>Specification</td>
<td>Grit blasting after which coating was applied at a thickness of 600 microns</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td>Chemical Treatment Tank</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Thailand</td>
</tr>
<tr>
<td><strong>Material of</strong></td>
<td>Carbon Steel</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td></td>
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<tr>
<td><strong>Service Conditions</strong></td>
<td>Ambient Temperature 55 – 80C</td>
</tr>
<tr>
<td><strong>Coating System</strong></td>
<td>5891</td>
</tr>
<tr>
<td><strong>Application Date</strong></td>
<td>2006</td>
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<tr>
<td><strong>Specification</strong></td>
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</tbody>
</table>
Developments in Spray Applied Coatings

Summary

Development of these high temperature spray applied coating systems suitable for immersed service conditions at elevated temperatures has now been completed although there are still future opportunities to improve application characteristics as well as performance.

The range of products currently available is summarized as follows:

- Coating for immersion service conditions up to 50°C (5811)
- Coating for immersion service conditions up to 95°C (5891)
- Coating for immersion service conditions up to 120°C (1391S)
- Coating for immersion service conditions up to 150°C (1521)
Developments in Spray Applied Coatings

Coating Characteristics

Sprayability

Suitable for application using single component of dual component heated airless spray systems.

Temperature Resistance

Immersion temperature resistance up to 150°C in aqueous and hydrocarbon service and resistant to steam out conditions at temperatures up to 210°C

Chemical Resistance

Good resistance to hydrocarbons / aqueous solutions as well as amines (MEA / MDEA etc) used for the removal of acidic gases at elevated temperatures.
Developments in Spray Applied Coatings

Limitations

• Not suitable for dry heat conditions where no moisture is present in the process
• Application thickness needs to be strictly controlled to avoid over-stressing the coating.

NOTE:

ANY COATING IS ONLY AS GOOD AS THE APPLICATORS APPLYING THE PRODUCTS AND THE INSPECTOR / SUPERVISOR CONTROLLING THE JOB
Developments in Spray Applied Coatings

Application Controls and Training

- Fully documented procedures available

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**METHOD STATEMENT FOR VESSEL COATING**

WITH BELZONA 1111/1301 FOR ...... TAG NO. ASEDA V 4255

<table>
<thead>
<tr>
<th>REVISION NO.</th>
<th>Rev.2 - 19/08/08</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPROVED Belzona Polymers Ltd (MANUFACTURER)</td>
<td>Simon Latty</td>
</tr>
<tr>
<td>APPROVED Belzona Service Nord APPLICATOR</td>
<td></td>
</tr>
<tr>
<td>APPROVED FABRICATOR</td>
<td></td>
</tr>
<tr>
<td>APPROVED DESIGNER</td>
<td></td>
</tr>
<tr>
<td>REVIEWED (COMPANY)</td>
<td></td>
</tr>
</tbody>
</table>
Developments in Spray Applied Coatings

Application Controls and Training

• Factory Training available for Coating Supervisors
Developments in Spray Applied Coatings

Application Controls and Training

• On-Site Project Supervision and Inspection Services available from NACE level 1 to NACE Level 3 manufacturers personnel
• On-Site training available
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THANK YOU FOR YOUR ATTENTION