Vapor Corrosion Inhibitors (VCIs) for Storage Tanks
Corrosion Controlled Cost Controlled

Presented by Kelly Baker, Zerust Oil & Gas
Efim Lyublinski, Monique Posner, Terry Natale,
Yefim Vaks, Ronnie Singh
Northern Technologies International Corporation, USA

Marcelo Schultz
Petrobras, Brazil
Topics For Discussion

1. VCI Background
2. Problem definition
3. Corrosion protection of storage tanks soil side bottom (SSB)
4. Corrosion protection of oil storage tank roofs
5. Conclusions
Definition - VCI

Vapor Corrosion Inhibitors

Also referred to as Volatile Corrosion Inhibitors

• A class of corrosion inhibiting compounds which have vapor pressures higher than that of air.

• This results in the release of vapor molecules of inhibitor into the air.

• These molecules will adsorb to the surface of steel and block other molecules from coming in contact with the steel.
Many forms of VCI

What’s the difference?

1. **Self-fogging Flash Corrosion Inhibitor (FCI™) technology**
   - High vapor pressure, low vapor density
   - Fast acting flash corrosion inhibitor
   - Fills vapor spaces immediately
   - Highest volume of protection per weight of active ingredient
   - Navigates complex systems

2. **Long-term Vapor Corrosion Inhibitor (VCI) protection**
   - Slower evolving, long-term vapor corrosion inhibitor

3. **Long-term Soluble Corrosion Inhibitor (SCI) protection**
   - Contact corrosion inhibitors activated when water present
   - Chloride “neutralizer”
Automotive industry – 30+ years

Not “NEW” Technology

- Thousands of machined parts must remain pristine during transport and storage.
- Clean, environmentally friendly, requires no cleaning prior to assembly.
VCIs have been sold through major retailers for years

Several ‘consumer market’ products you can try

- Lowes
- Cabellas
- Flambeau
- Kobalt
- ...others
Some consumers are more demanding than others ...

The Navy SEALS

- VCI capsules in the engine housing

The Marines in Iraq

- VCI gun sleeves
Long Term Corrosion Protection

Shipping, Storage, Mothballing
Corrosion cannot be eliminated, it’s mechanism can only be retarded
Applications!

How can VCI be used in AST’s?
Problem Definition

Corrosion Is One Of The Biggest Problems In The Oil And Gas Industry Worldwide

**Risks**

- Critical risks from corrosion of storage tanks are:
  - Loss of product
  - Contamination of environment
  - Critical component down time
  - Risk of fire and explosion

**Costs**

- Estimated corrosion costs: ~ $0.40 per barrel of oil produced
- Maintenance Costs: ~ 60% of all are related to corrosion
- Loss of oil production: ~ 10%
- Production Industries: ~ $12.8B annually in 2002
Existing Solutions

Existing Corrosion Protection Methods (CPM)

Some CPM may not be appropriate or are not efficient when used alone:

- Cathodic Protection Systems (CPS)
- Coatings / Linings
- Volatile or Vapor Corrosion Inhibitors (VCI)

Discussion focus:

- Crude oil storage tanks soil side bottoms (SSB)
- Tank roofs
- Case Studies of these VCI solutions
Tank Bottom Geometries

Aggregate Ring Wall

Concrete Ring Wall

Concrete or Asphalt Base with Reinforced Polymer Barrier

Double Bottom

Dike Floor

Cone Up - Flat - Cone Down
Examples of Problems

Penetrations due to tank bottom corrosion
What are VCIs?

- A class of corrosion inhibiting compounds which have vapor pressures higher than that of air.
- This results in the release of vapor molecules of inhibitor into the air.
- These molecules will adsorb to the surface of steel and block other molecules from coming in contact with the steel.

- Can protect immersed surfaces
- Not a ‘coating’
- Does not change metallurgy
- Not permanent

- Can be painted/welded
- Non-toxic
- Can be designed for specific service exposure
How Do VCIs Work Under Tanks?

Tank Shell

Gap

Tank Floor & Void

VCI Adsorb

Sand Base

VCI Molecules
Case Study – Double Bottom

Soil Side Bottom (SSB) Protection

Test

Control

VCI in Sand

Test Coupons

No VCI
Coupon Tests

Coupons were removed in 2007 and 2011 for corrosion rate evaluation according to ASTM G1-03

1018 Carbon Steel

Test

Control
# Surface Area Results

## Surface Area Affected by Corrosion - 2007 Specimens

<table>
<thead>
<tr>
<th>Specimen Type</th>
<th>Specimen ID</th>
<th>% Corroded Surface Area</th>
<th>Predominant Type of Corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Tank</td>
<td>B</td>
<td>86</td>
<td>Uniform / General</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Control Tank</td>
<td>Control</td>
<td>22</td>
<td>Pitting</td>
</tr>
</tbody>
</table>
## Corrosion Rate Results

<table>
<thead>
<tr>
<th>Specimen Type</th>
<th>Specimen ID</th>
<th>Corrosion Rate (mm/year)</th>
<th>2007 Specimens</th>
<th>2011 Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test Tank</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>--</td>
<td>0.0014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.0041</td>
<td>0.0013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.023</td>
<td>0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.042</td>
<td>0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.0075</td>
<td>0.0017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.0085</td>
<td>0.0041</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.0050</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ALL (Avg)</strong></td>
<td></td>
<td>0.015</td>
<td>0.0075</td>
<td></td>
</tr>
<tr>
<td><strong>Control Tank</strong></td>
<td>Control</td>
<td>0.059</td>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Control P*</td>
<td>0.19</td>
<td>--</td>
<td></td>
<td>--</td>
</tr>
</tbody>
</table>

*Control P is the measured maximum pitting depth*
Control P is the measured max pitting depth (9 months)
1. VCIs can work in conjunction with other forms of corrosion protection or stand-alone.

2. Can be installed under almost any tank pad design.

3. Tank pad design determines whether the original VCI installation can be accomplished while the tank is in service, or if it needs to be out-of-service.

4. VCI can be replenished as needed over time without taking the tank out-of-service, in any of the scenarios mentioned above.

5. Testing indicates that VCIs have a significant impact on reducing pitting corrosion.

6. Reduction in corrosion rates extend the life of the asset and the maintenance interval.
Difficulty in Protection

Tank roof and support beam

Coatings do not effectively cover all surfaces
Steel roof plates

Top-side welds

Flexing of roof plates allows for crevice corrosion
Basic Composition Tank Top Vapor Space Atmospheres

Typical vapor space environment for a crude oil storage tank considered in developing the corrosion protection solution

<table>
<thead>
<tr>
<th>Components</th>
<th>O₂</th>
<th>SO₂</th>
<th>H₂S</th>
<th>Cl⁻</th>
<th>N₂</th>
<th>CO₂</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents, %</td>
<td>4.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>70.0</td>
<td>12.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Relative humidity (RH): Close to 100%  
Temperature: Ranges up to +80°C

Corrosion environments are unpredictable.  
Corrosion occurs in the acidic condensed water layer (pH as low as 2-5) on the inner surface of the tank roofs

<table>
<thead>
<tr>
<th>Type of Corrosion:</th>
<th>General</th>
<th>Galvanic</th>
<th>Pitting</th>
<th>Crevice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Rate, mm/year, up to:</td>
<td>0.5</td>
<td>3.0</td>
<td>5.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>
• Molecular vapor pressure disperses the inhibitor from canisters installed during a tank shutdown.

• Inhibitor levels can be monitored and replenished while the tank is “In-Service”.
VCI in Vapor Space
Works on Vapor Pressure – No Moving Parts

1. Liquid VCI volatizes into a vapor.
2. Vapor pressure forces the VCI molecules down through the opening into the tank vapor space.
Field Trial and Results

Location: Petrobras refinery in Brazil
Setup: Two crude oil storage tanks - with and without VCI protection

Environment Conditions Of Tanks

<table>
<thead>
<tr>
<th>Basic Parameters</th>
<th>Monitoring Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tank 1 (Control)</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>20 – 55</td>
</tr>
<tr>
<td>RH %</td>
<td>40 - 100</td>
</tr>
<tr>
<td>Concentration</td>
<td></td>
</tr>
<tr>
<td>O₂ (%)</td>
<td>18-18.9</td>
</tr>
<tr>
<td>SO₂ (ppm)</td>
<td>1.0-7.0</td>
</tr>
<tr>
<td>H₂S (ppm)</td>
<td>3.0-6.0</td>
</tr>
</tbody>
</table>

Test tank (with inhibitor) environment was more aggressive than that of the control tank
## Trial Results

### Average Roof Thickness Loss

<table>
<thead>
<tr>
<th>Exposure Time (days)</th>
<th>Average Total Roof Thickness Loss (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tank 1 (Control)</td>
<td>Tank 2 (With Inhibitor)</td>
</tr>
<tr>
<td>90</td>
<td>0.17</td>
<td>0.03</td>
</tr>
<tr>
<td>185</td>
<td>0.25</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Even with the more aggressive environment, a 4-fold reduction in thickness loss was achieved with applied VCI protection.
1. 4-fold reduction in thickness loss in trial with VCI application.

2. Reduction in thickness losses translates into increased tank service life.

3. Corrosion Protection System applicable to new and existing AST roofs.

4. Corrosion Protection System Advantages:
   - Reduces tank down time (for replacement of tops or coatings)
   - Eliminates need of more expensive construction materials (stainless steel, aluminum and plastic) instead of carbon steel
   - Reduces risks of environmental contamination, fire and explosion
Thank you for your attention!

Questions?

Kelly Baker
kbaker@ntic.com
832-465-5668