Use of Vapor Phase Corrosion Inhibitors for Galvanized Steel Protection

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- Introduction
- Evaluation of Corrosion Protection Provided by VpCl Additive to Galvanized Steel
  - Protection Ability Tasted With Tidal Pool
  - Linear Polarisation Resistance (LPR) Study
  - Immersion Corrosion Test
  - Testing In Pilot Cooling Tower
- Toxicity Testing
- Conclusions
- References
Introduction

- Cost of corrosion (~$276 billion)
  - food processing industry at 2.1 billion
  - pulp & paper industry at 6 billion
  - chemical, pharmaceutical at 1.7 billion
- Galvanizing: The coating of zinc onto steel
- Vapor Phase Corrosion Inhibitors (VpCI)
  - biodegradable, low-toxic products which can be incorporated into conventional water-treatment programs to provide effective corrosion protection in different media.
  - The applied VpCI additive is a synergistic blend of salts of carboxylic acids and alkalinity builders.

Evaluation of Corrosion Protection Provided by VpCI Additive to Galvanized Steel

- Protection Ability Tested With Tafel Plots
- Linear Polarization Resistance (LPR) Study
- Immersion Corrosion Test
- Testing in Pilot Cooling Tower

Protection Ability Tested With Tafel Plots

Test Equipment:
- Potentiostat/Galvanostat "Versamet" with corrosion software model 352/352
- Cathode: Zirconium electrode
- Graphite counter electrode
- SCE reference electrode

Test Parameters
- Tap water: pH 7 TDS = ppm, Conductivity = µS
- CaCO₃ in Tap water: pH 7 TDS = ppm, Conductivity = µS
- Polariation was applied 20 minutes after the working electrode was immersed in electrolyte.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Corrosion Rate in Tap Water, µpy</th>
<th>Protection Ability, %</th>
<th>Corrosion Rate in 300ppm CaCO₃ Solution, µpy</th>
<th>Protection Ability, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>100ppm VpCI</td>
<td>1.06</td>
<td>86.5</td>
<td>0.24</td>
<td>87.2</td>
</tr>
<tr>
<td>Addition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>7.8</td>
<td>-</td>
<td>1.8</td>
<td>-</td>
</tr>
</tbody>
</table>
Linear Polarization Resistance (LPR) Study

Test Parameters
5000ppm VpCl was added into two different types of water

<table>
<thead>
<tr>
<th>Sample</th>
<th>Corrosion Rate, mpy</th>
<th>Protection Ability, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water with VpCl</td>
<td>0.2242</td>
<td>89</td>
</tr>
<tr>
<td>Control Water</td>
<td>2.061</td>
<td>-</td>
</tr>
<tr>
<td>Tap water, pH 6.0</td>
<td>0.3934</td>
<td>98</td>
</tr>
<tr>
<td>Conductivity 350μS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Immersion Corrosion Test

Test Parameters
Immersion at 40°C for 10 days

Test Solutions
VpCl was added at 250ppm in two different water treatment program formulas (TF1 and TF2) both containing a blend of antisalts (phosphates, molybdenum, phosphonates, acrylics, and amines). These mixtures were then added to tap water at 2000ppm

<table>
<thead>
<tr>
<th>Material</th>
<th>Protection Ability, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF1 + VpCl additive</td>
<td>94.3</td>
</tr>
<tr>
<td>TF2 + VpCl additive</td>
<td>94</td>
</tr>
<tr>
<td>TF1</td>
<td>74</td>
</tr>
<tr>
<td>TF2</td>
<td>31</td>
</tr>
<tr>
<td>Control (tap water)</td>
<td>-</td>
</tr>
</tbody>
</table>

Testing In Pilot Cooling Tower

Test Equipment
RSD Towers, Model 005 Cooling Tower
50 GPM recirculation rate, 3.6 inch inlet and outlet diameter

Test Parameters
45-55°C tap water with 1.5-2.5 cycles of concentration
pH = 8.3±0.2, TDS = 1250-2000ppm, Conductivity = 5000-8000μS
Continuous flow treatment of 200ppm for 1 week, 500ppm for 1 week and then 50ppm during the following 4 weeks

<table>
<thead>
<tr>
<th>Solution Tested</th>
<th>Corrosion Rate, mpy</th>
<th>Protection Ability, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF1 + VpCl additive</td>
<td>0.59</td>
<td>89</td>
</tr>
<tr>
<td>TF1</td>
<td>4.49</td>
<td>-</td>
</tr>
</tbody>
</table>
Toxicity Testing

Aquatic Toxicity Tests: VpCl was also tested for aquatic toxicity with several species.

<table>
<thead>
<tr>
<th>Species</th>
<th>NOEC</th>
<th>LOEC</th>
<th>LC$_{20}$</th>
<th>LC$_{50}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. Beryllina</td>
<td>1000ppm</td>
<td>2500ppm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M. Bahia</td>
<td>600ppm</td>
<td>1000ppm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fathead minnow</td>
<td>-</td>
<td>-</td>
<td>1700ppm</td>
<td>140ppm</td>
</tr>
<tr>
<td>C. dubia</td>
<td>-</td>
<td>-</td>
<td>1100ppm</td>
<td>90ppm</td>
</tr>
</tbody>
</table>

Toxicity Testing

- **Primary Skin Irritation Test:** VpCl additive was applied at 4000ppm to skin of rabbits. The final Primary Irritation Index (PII) was 0, the best score possible in this test.

- **Theoretical LD-50 (rat):** >4000ppm

**CONCLUSION**

- VpCl additive is safe for handling and use in cooling water treatment programs. At concentration of use it remains safe for many species allowing discharge according to local authorities.

Conclusion

The advantage of using a VpCl additive in cooling water was tested with various methods including immersion tests, pilot cooling tower tests and electrochemical analysis.

These tests all show the effectiveness of a vapor phase corrosion inhibitor based additive (VpCl additive) to protect galvanized steel against corrosion.

VpCls which are safe and environmentally acceptable for use can be added to traditional water treatment programs to significantly improve corrosion protection of galvanized steel.
References


- ASTM G 3-97, Standard Reference Test Method for Making Potentiodynamic and Polarization Anode Polarization Measurements

- ASTM G 3-97, Standard Practice for Laboratory Immersion Corrosion Testing of Metals

- ASTM G 3-90, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

- Lab project # 9693, VitoMED Biosafety Laboratories

- Environmental Enterprises, USA, and Environmental Consulting & Testing