Accelerated Corrosion Testing for Automotive Applications

Q-Lab Corporation
Topics

• Automotive Corrosion overview

• Recent developments in Cyclic Corrosion Testing
  – Relative humidity control
  – Electrolyte (salt) solutions

• Modern cyclic corrosion test methods and laboratory equipment
Corrosion of Automotive Components
What Causes Automotive Corrosion?

- Exposure to a corrosive climate
  - Wet and dry cycles
- Accelerated if chemicals present
  - Salt, Acid Rain
- Metal becomes exposed
  - Scratch, impact, chip
- Paint or coating may not protect after the initial damage
Mechanics of Corrosion

Anti-corrosion coating: real-life scenario

1. Atmosphere, mechanical damage
   - Barrier coating insulates substrate from the corrosive atmosphere

2. Coat integrity broken: moisture and corrosive species pass through
   - Corrosion and barrier coating undercutting
Corrosion Types

Cosmetic corrosion
- Paint Protection
- High Moisture
- Road Splash Effect

Structural Corrosion
- No UV
- Parts are coated?
Corrosive failure modes

- Mixed material construction
  - Galvanic corrosion
  - Crevice corrosion
  - Filiform corrosion
- Critical to correlate laboratory test methods to real world conditions

5xxx series Aluminium joined to Carbon Fiber

Steel rivets into sheet aluminium
Corrosive Failure modes

Filiform corrosion on 6xxx series painted sheet aluminium.

Filiform corrosion on (lacquered) diamond cut road wheel surface, Al-Si-Mg

Painted sheet aluminium

- Cosmetic ‘Filiform’ corrosion
- Accelerated by galvanic & crevice conditions, cut edges, reworked surfaces
Automotive Corrosion Testing
Component level

Test Method Types

• Neutral Salt Spray
• CCT
• CASS
• Filiform

Test Specimen Types

• Flat panels/coupons: open, crevice, cosmetic
• Full components: e.g. fasteners, exhaust trim, badges, wheels
Automotive Corrosion Testing
Whole Vehicle

- Humidity & temperature
- Salt spray
- Drive cycles (dust tracks, off road, durability roads)
- Teardown & evaluations
Automotive Corrosion Testing Objectives

• **Objective 1**: Determine performance *before* and *after* damage

• **Objective 2**: Select and use realistic test methods

• **Objective 3**: Accelerate test and generate correlative results

*Recent advances in cyclic corrosion testing help us reach these objectives*
Laboratory Accelerated Corrosion Testing

Cyclic testing and Relative Humidity Control
What is changing about cyclic corrosion testing, and why?

- Cyclic tests like PV1210 and JASO M609 more realistic than simple tests like ASTM B117 but not good enough for all applications
- **Modern Corrosion tests** control and maintain RH between 50-90%
Key Aspects of Modern Corrosion Tests

• Specific relative humidity settings (not just ambient, wet, or dry)

• Controlled temp/RH and transitions to improve reproducibility

• Custom electrolyte (salt) solutions

• Salt “Fog” sometimes replaced by direct spray ("Shower")
## Summary of Environmental Conditions in Modern Automotive Corrosion Standards

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Solution</th>
<th>Spray Type</th>
<th>RH &lt; 50%</th>
<th>50%≤RH&lt;76%</th>
<th>RH≥76%</th>
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<tbody>
<tr>
<td>Ford L-467/Volvo (ACT2)</td>
<td>NaCl 0.5% pH uncontrolled</td>
<td>Shower</td>
<td>0%</td>
<td>66%</td>
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<td>GMW 14872</td>
<td>NaCl 0.9%</td>
<td>Shower</td>
<td>46% (22% below RH30%)</td>
<td>16%</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>CaCl₂ 0.1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NaHCO₃ 0.075% pH uncontrolled</td>
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<tr>
<td>Renault D17 2028 (ECC1)</td>
<td>NaCl 1.0% pH =4.0 (H₂SO₄)</td>
<td>Fog</td>
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<td>62%</td>
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<td>VDA 233-102</td>
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<td>Fog</td>
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**Variety of electrolyte solutions and acidities**
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**Shower and Fog still both used widely**
Fog

- Atomizing nozzle
- Separate compressed air and liquid solution lines
- Controlled by pump speed and air pressure

Shower

- Non-compressed air nozzles installed over existing atomizing fog nozzle
- Controlled by adjustable pump pressure and spray on/off cycling
Advantages of Shower (Spray)

- High volume spray wets specimens faster than traditional fog (~100× more volume)
- Spray volume can be controlled to adjust corrosion rates
- Fixed position with uniform coverage of chamber; no need for constant user adjustment
- Flow rate detection alerts user if a nozzle is plugged
- Self-cleaning with DI water
Q-FOG CRH Shower Uniformity – 40 positions (Ford L-467, Volvo ACT2)

Local Collection Position

Far Left | Center | Far Right

Spray Volume (L/m²)

Q-FOG CRH Local Collections

Minimum Local Collection

Maximum Local Collection

Maximum Average Collection

Minimum Average Collection

Q-FOG CRH Average Collection

Max/Min: 1.9
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All standards require control at intermediate values of Relative Humidity
• All regions spend considerable time at intermediate RH (around 76%)
• Modern test standards recognize this and control RH at these levels!
Relative Humidity
“controlling the middle”

- RH control between 50% and 90% is critical

- Wet and Dry Cycling cannot do this
  - Can only do wet, dry, ambient
  - No control of RH transition times
  - Variable specimen dry-off rates
Corrosion Chamber with Metal Panels
Environmental Chamber
Test Chamber Types

**Corrosion/Salt Spray**
- More rectangular than square
- Single layer specimen mounting
- Stainless steels won’t last in the environment
- Static air necessary during salt spray
- Liquid solutions & precipitated salts create microclimates
- Precise control is more difficult
- Dew point reduction is not common

**Environmental (Temp & RH)**
- Cubic/cuboid in shape
- Multi-layer specimen mounting
- Interiors are usually stainless steel
- Constant air flow (low or high flow types)
- Rarely spray water
- Precise temperature & RH capabilities
- Dew point reduction is common
Q-FOG CRH

- Two types of salt spray delivery (Fog, Shower)
- Controlled linear transitions of temperature & RH
- Dehumidification via air preconditioner
- HSCR model features Rapid Ramp Heater for fast transitions
Q-FOG CRH Air Pre-Conditioner

- Delivers consistently dry air to system
- Hot or cold
- Expands range of achievable conditions
- Allows precise control of temp and RH transitions
Performance Improvement with Air Preconditioner

No Air Preconditioner

With Air Preconditioner

Temperature (°C), RH (%)

Time (hours)
Q-FOG CRH: Meets Test Conditions in All Major Automotive Standards

- Without Air Preconditioner
- With Air Preconditioner

Ambient RH = 60%

Dots represent set points of common test methods.
# Q-FOG CRH Standards Met

<table>
<thead>
<tr>
<th>Test Standard</th>
<th>Standard Model</th>
<th>Rapid Ramp Heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>JASO M609</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CCT-C</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CCT-I</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>CCT-IV</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Renault D17-2028 (ECC1)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Volvo VCS 1027, 149 (ACT I)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Volvo VCS 1027, 1449 (ACT II)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GMW 14872</td>
<td>✓</td>
<td>✓</td>
</tr>
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</table>
JASO M609 (ISO 14993, 11997-1)

- Chamber Volume – 1100 L
- Chamber Load – 250 x 3” x 6” Steel Panels
- FOG Solution – 5% NaCl Solution
- Laboratory Room Temperature – 28-30 °C

<table>
<thead>
<tr>
<th>Step</th>
<th>Function</th>
<th>Chamber Air Temp (°C)</th>
<th>RH (%)</th>
<th>Step Time (hh:mm)</th>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FOG</td>
<td>35 °C</td>
<td></td>
<td>2:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>2</td>
<td>RH</td>
<td>60 °C</td>
<td>25 %</td>
<td>4:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>3</td>
<td>RH</td>
<td>50 °C</td>
<td>100 %</td>
<td>2:00</td>
<td>&lt; 0:15</td>
</tr>
</tbody>
</table>
## JASO M609

Transition times for JASO M609 in full Q-FOG CRH 1100 HSCR Chamber.

<table>
<thead>
<tr>
<th>Function</th>
<th>Transition</th>
<th>Transition Time Requirement</th>
<th>Actual Temperature Transition Time</th>
<th>Actual RH Transition Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fog to Dry</td>
<td>35 °C → 60 ± 1 °C</td>
<td>&lt; 0:30</td>
<td>0:13</td>
<td>0:14</td>
</tr>
<tr>
<td></td>
<td>FOG → &lt; 30% RH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry to Wet</td>
<td>60 ± 1 °C → 50 ± 1 °C</td>
<td>&lt; 0:15</td>
<td>0:04</td>
<td>0:15</td>
</tr>
<tr>
<td></td>
<td>&lt; 30% RH → &gt; 95% RH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet to Fog</td>
<td>50 ± 1 °C → 35 °C</td>
<td>&lt; 0:30</td>
<td>0:06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 95% RH → FOG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CCT-C

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<tr>
<th>Step</th>
<th>Function</th>
<th>Chamber Air Temp (°C)</th>
<th>RH (%)</th>
<th>Step Time (hh:mm)</th>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FOG</td>
<td>50 °C</td>
<td></td>
<td>4:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>2</td>
<td>RH</td>
<td>70 °C</td>
<td>25 %</td>
<td>5:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>3</td>
<td>RH</td>
<td>50 °C</td>
<td>87 %</td>
<td>12:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>4</td>
<td>RH</td>
<td>70 °C</td>
<td>25 %</td>
<td>2:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>5</td>
<td>RH</td>
<td>23 °C*</td>
<td>60 %*</td>
<td>1:00</td>
<td></td>
</tr>
</tbody>
</table>

- Chamber Volume – 1100 l
- Chamber Load – 250 x 3” x 6” Steel Panels
- FOG Solution – 5% NaCl Solution
- Laboratory Room Temperature – 30-35 °C
### CCT-I

- **Chamber Volume** – 1100 l
- **Chamber Load** – 210x Aluminum & Steel Panels
- **FOG Solution** – 5% NaCl
- **Laboratory Room Temperature** – 26-28°C

#### Step Function

<table>
<thead>
<tr>
<th>Step</th>
<th>Function</th>
<th>Chamber Air Temp (°C)</th>
<th>RH (%)</th>
<th>Step Time (hh:mm)</th>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FOG</td>
<td>35 °C</td>
<td></td>
<td>4:00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>RH</td>
<td>60 °C</td>
<td>25 %</td>
<td>2:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>3</td>
<td>RH</td>
<td>50 °C</td>
<td>95 %</td>
<td>2:00</td>
<td>&lt; 0:30</td>
</tr>
<tr>
<td>4</td>
<td>Final Step – Go To Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**CCT-IV**

- Chamber Volume – 1100 L
- Chamber Load – Empty
- FOG Solution – DI Water
- Laboratory Room Temperature – 22-25°C

### Step Function Table

<table>
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<td>0:15</td>
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</tr>
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<td>2</td>
<td>RH</td>
<td>60 °C</td>
<td>25 %</td>
<td>2:30</td>
<td>&lt; 0:30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>RH</td>
<td>60 °C</td>
<td>95 %</td>
<td>1:15</td>
<td>&lt; 0:30</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Subcycle*</td>
<td>Repeat steps 5-6 5x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>RH</td>
<td>60 °C</td>
<td>25 %</td>
<td>2:40</td>
<td>&lt; 0:30</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>RH</td>
<td>60 °C</td>
<td>95 %</td>
<td>1:20</td>
<td>&lt; 0:30</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Final Step</td>
<td>Go To Step 1</td>
<td></td>
<td></td>
<td></td>
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</tr>
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Closing remarks

• Corrosion is a major problem that paint, galvanization, and anodization methods try to prevent

• Modern corrosion test methods are used to evaluate these techniques
  – Combine salt spray and environmental tests
  – Use linear temperature/RH transitions & accurate RH control

• A variety of tests are available, including both salt fog and shower

• Q-FOG CRH delivers stable test conditions, controlled transitions, and the –HSCR model can meet even demanding automotive tests like JASO M609
Thank you for your attention!

Questions?
info@q-lab.com