PCT MAO’s Enhanced Performance by Specially Designed Sealers for Superior Service & Environments
# PCT MAO's Enhanced Performance by Specially Designed Sealers for Superior Service & Environments

**Performing Organization:**
PCT Protective Coating Technology, 103 Halutzei Hatasia St., Haifa Bay, 26110 Israel.

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32
PCT - Protective Coating Technologies develops and applies unique corrosion-resistant protection solutions where other coating methods have failed.

Current Technologies deployed by PCT are:

- **Micro-arc oxidation (lower energy)**
- **Organo-ceramic sealing**
- **Organic Sealing in Vacuum**
- **Aluminized Steel**
The PCT Layer

Dense Oxide Functional Layer

Intermediate Bonding Layer

Substrate
Aluminized Steel Facts
• Aluminized steel became commercially available in the 1950's. Similar to the galvanizing process, aluminum is metallurgically bonded to the steel surface, providing excellent heat reflectivity and corrosion protection.
• Traditional Aluminized Steel (ASTM-A463) is hot-dip coated on both sides with an aluminum/silicon alloy coating.
• PCT’s Process is with low silicon content.
• Aluminized Steel + PCT MAO can be a cost effective alternative to Stainless Steel, Super Duplex and Titanium.
PCT Solutions for Steel

Optimal protection of steel from erosion and corrosion:

**Step-1: Aluminization of steel**
- Coating the surface by Aluminum.

**Step-2: MAO Micro-arc Oxidation**
- Converting the surface to hard protective ceramic layer.

**Step-3: PCT sealer (if necessary)**
- Fills and planarize the pores in the ceramic layer to increase chemical resistance.
Step-1: Aluminization of Steel

Hot deep process conditions were optimized in order to receive:

- Diffusion of Al to the steel.
- An intermetallic layer to increase adhesion.
- Surface Al layer to allow the MAO process.

Representative GDA Spectrum
Step-2: MAO of Aluminized Steel

MAO process conditions were optimized in order to receive:

- Conversion of the Al to hard ceramic layer.
- Best adhesion of the complex layer stack.
Step-2: MAO of Aluminized Steel

Adhesion test results:

• **Layer ranking: category number 1 (less than 5% of the coating was peeled off).**
• **The coating has excellent adhesion to the substrate.**
Special Top Coatings (Sealers):

- Organo-Ceramic
- Organic
- Conductive
<table>
<thead>
<tr>
<th>TYPE OF TECHNOLOGY/ PROPERTIES</th>
<th>PCT 2000</th>
<th>PCT – P seal</th>
<th>PCT - S seal</th>
<th>PCT Classic 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Layer thickness:</strong> 80-100 micron*</td>
<td>✔️ if the S Seal is applied</td>
<td>✔️ if the P Seal is applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Layer thickness:</strong> 40-80 micron*</td>
<td>✔️ if the S Seal is applied</td>
<td>✔️ if the P Seal is applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Layer thickness:</strong> 10-40 micron*</td>
<td>✔️ if the S Seal is applied</td>
<td>✔️ if the P Seal is applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Layer thickness:</strong> 10-20 micron*</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PCT 2000**
- High corrosive resistance > 4,000 hours by Salt Spray (SST) method.
- Up to thermal treatment temp.
- Resists in chemical environments PH 1-11 in maintenance conditions
  - Dielectric strength of up to 3 KV for a 40 micron layer.
  - Up to 200° C

**PCT – P seal**
- Typical Layer thickness: 40-80 micron*
- Organic sealer
- Hydrophobic surface, reduces sedimentation
- Resists in chemical environments PH 0 to 14, in operating conditions.
  - Dielectric strength of up to 6KV for a 75 micron layer.
  - Up to 120° C
  - Hardness up to 1,500HV
  - Wear resistance as mil std 8625
  - Up to thermal treatment temp.

**PCT - S seal**
- Typical Layer thickness: 10-40 micron*
- Organo-ceramic sealer
- Hydrophobic surface, reduces sedimentation.

**PCT Classic 1000**
- Typical Layer thickness: 10-20 micron*
- Hydrophilic surface
- Perfect preparation for paints, adhesives.
PCT Sealer – S Seal

- **S-Seal** – unique Organo-Ceramic Sol-Gel formula.
- Applied by spraying, brushing, wiping, dipping.

**SURFACE**
- Hydrophobic surface with antifouling and anti-scaling properties and reduces sedimentation.
- Adjustable friction coefficient
- Very low permeability to gases and water vapor

**HARDNESS**
- Based on the primary surface parameter.

**CORROSION**
- 4,000 hours by Salt Spray (SST) method*

**TEMPERATURE**
- Stable up to 220°C

**ELECTRICAL RESISTANCE**
- Dielectric strength of up to 1KV for a 40 micron layer*

**ENVIRONMENTS**
- Resists in environment pH 1-8.6 in maintenance conditions*

* above PCT 1000/PCT 2000 coating
The following chemical resistance tests were done on our MAO + S-SEAL coating:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Time to failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfamic Acid, 10%, 40°C</td>
<td>&gt;14 days</td>
</tr>
<tr>
<td>Sulfamic Acid, 10%, 60°C</td>
<td>&gt;7 days*</td>
</tr>
<tr>
<td>7.5%wt HCl, 1.5%wt HF at 66°C</td>
<td>&gt;48 hours*</td>
</tr>
<tr>
<td>EDTA PH=11 at 55 °C</td>
<td>&gt;24 Days *</td>
</tr>
<tr>
<td>30% CaCl2 at 70°C</td>
<td>&gt;60 Days*</td>
</tr>
<tr>
<td>2%wt KCl + 9%wt NaCl l at 100°C</td>
<td>&gt;60 Days*</td>
</tr>
<tr>
<td>Pilot at heat exchanger, 3% salinity at 48°C</td>
<td>90 Days*</td>
</tr>
</tbody>
</table>

* = the test was stopped without failure
**PCT Sealer – P Seal**


- **HARDNESS**: Based on the primary surface parameter

- **CORROSION**: 4,000 hours by Salt Spray (SST) method*

- **TEMPERATURE**: Up to 120°C

- **ELECTRICAL RESISTANCE**: Dielectric strength of up to 5KV for a 60 micron layer*

- **ENVIRONMENTS**: Resists in environment pH 0-14 in operation conditions, good barrier properties for inorganic and organic media, strong acids, caustic solutions, gases and water vapor*

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*above PCT 1000/ PCT 2000 coating
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**P-seal – Organic Polymer.**
- **Applied by vacuum deposition.**
The following chemical resistance tests were done on our MAO + P-SEAL coating:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Time to failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfamic Acid, 10%, 40°C</td>
<td>&gt;14 days</td>
</tr>
<tr>
<td>Sulfamic Acid, 10%, 60°C</td>
<td>&gt;48 hours</td>
</tr>
<tr>
<td>7.5%wt HCl, 1.5%wt HF at 66°C</td>
<td>&gt;140 hours*</td>
</tr>
<tr>
<td>15%wt HCl, at 100°C</td>
<td>&gt;24 hours *</td>
</tr>
<tr>
<td>25% CaCl2 at 93°C</td>
<td>&gt;60 Days*</td>
</tr>
<tr>
<td>2%wt KCl + 9%wt NaCl I at 100°C</td>
<td>&gt;60 Days*</td>
</tr>
<tr>
<td>Pilot for IWT, pH = 11-12.5, 100°C-110°C</td>
<td>30 days*</td>
</tr>
</tbody>
</table>

* = the test was stopped without failure

Samples after 7.5% HCl + 1.5% HF test
The following chemical resistance tests were done on our MAO + P-SEAL coating:

- Fastener in 500 ppm NaCl acidified to pH 3 with HCL; Carbon steel = 0.83% weight loss; PCT treated bolt = NO WEIGHT LOSS

- PCT vs. Carbon steel bolt in 1% HCL; Carbon steel = 47.8% weight loss; PCT treated bolt = 0.39% weight loss NO CORROSION
The PCT C1 conductive coating is a secondary electro less process which greatly improves the substrates resistance to galling and leaves a predictable, uniform nickel with low phosphorous range (1-4%) coating for high-precision parts. It can be applied on the PCT 1000, PCT 2000 conversion coating or any both ferrous and non-ferrous surfaces of any geometry or intricate shape.

PCT C1 layer is of a uniform thickness, absent of pours and cracks for protection against corrosion where low electrical resistance is required. Meet MIL DTL 5541F Standard.

### Conductive Sealer C1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Characteristics</td>
<td>A uniform deposit thickness, dense and amorphous layer.</td>
</tr>
<tr>
<td>Hardness</td>
<td>600 HV depending on the alloy and the thickness of coating</td>
</tr>
<tr>
<td>Corrosion</td>
<td>&gt; 720 hours by Salt Spray (SST) method</td>
</tr>
<tr>
<td>Temperature</td>
<td>Up to thermal treatment temperature of the alloy</td>
</tr>
<tr>
<td>Electrical Resistance</td>
<td>&lt; 5,000 micro Ohms per square inch</td>
</tr>
<tr>
<td>Environments</td>
<td>Resists in alkaline environments</td>
</tr>
</tbody>
</table>

PCT Secondary Conductive Sealer
The PCT C2 conductive coating is a secondary electro less process which greatly improves the substrates resistance to galling and leaves a predictable, uniform nickel with high phosphorous range (10-14%) coating for high-precision parts. It can be applied on the PCT 1000, PCT 2000 conversion coating or any both ferrous and non-ferrous surfaces of any geometry or intricate shape.

PCT C2 layer is of a uniform thickness, absent of pours and cracks for protection against corrosion where low electrical resistance is required. Meet MIL DTL 5541F Standard.

### Conductive Sealer C2

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Characteristics</td>
<td>A uniform deposit thickness, dense and amorphous layer.</td>
</tr>
<tr>
<td>Hardness</td>
<td>700 HV depending on the alloy and the thickness of coating</td>
</tr>
<tr>
<td>Corrosion</td>
<td>&gt; 720 hours by Salt Spray (SST) method</td>
</tr>
<tr>
<td>Temperature</td>
<td>Up to thermal treatment temperature of the alloy</td>
</tr>
<tr>
<td>Electrical Resistance</td>
<td>&lt; 5,000 micro Ohms per square inch</td>
</tr>
<tr>
<td>Environments</td>
<td>Resists in acidic environments</td>
</tr>
</tbody>
</table>
PCT treated aluminum parts (sealed and scratched) in highly corrosive environments

Traditionally coated MAO aluminum will fail after a few hours in a corrosive media

PCT Resists Corrosion
Salt Spray Test
PCT2000 - Ultra Hard Coating for Aluminium

**Surface:** Hydrophilic surface with high adhesive strength.

**Hardness:** 1,500 HV depending on the alloy and the thickness of coating

**Wear Resistance:** Tested and passed MIL. STANDARD 8625

**Corrosion:**
- 4,000 hours by Salt Spray (SST) method

**Temperature:** Up to thermal treatment temperature of the alloy.

As grown layer

After 30,000 cycles Taber wear test

Al Substrate  Ultra Hard MAO layer
PCT2000 - Ultra Hard Coating for Al Taber Wear Resistance Test

- **TABER® Rotary Platform Abrasion Tester - Model 5135 or 5155**
- **Abrasive Media: CS-17 stones**
- **The test was conducted acc. to MIL –A-8625**

![Graph No.1- Abrasion resistance- Taber test](image-url)
• **Seawater Sedimentation** – reduced by 75%

• **Electrical resistance (1000V)** – 5MΩ @ 5µ; 600MΩ @ 30µ;

• **Thermal Shock** – Scribed X, 1) +38°C for 3 hours, 2) -30°C for 3 hours, 3) immersion into ethyl alcohol -74°C for 5 minutes, 4) water steam 100°C 30 seconds – PASSED
• Passed 100,000 cycles 0-4 bars without micro cracks
• Passed 7 bars continuous pressure test

PCT in Heat Exchangers
PCT Prevents Galvanic Corrosion

Insulating, High Dielectric Strength
Additional PCT Features

- Minimum dimensional change
- No surface preparation required
- Protects against short, high-temperature flashes
- Complex geometries & internal surfaces
MAGNESIUM

... is 35% lighter than Aluminum
... has a high strength-to-weight ratio

PCT Protects Magnesium from oxidation
providing greater opportunities for weight reduction
# PCT layer – Magnesium

<table>
<thead>
<tr>
<th>SURFACE</th>
<th>Typical layer thickness: 20 micron Hydrophilic surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>HARDNESS</td>
<td>700 HV</td>
</tr>
<tr>
<td>CORROSION</td>
<td>➢ 1,000 -2,000 hours by Salt Spray (SST) method* (sealed)</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td>Up to the thermal treatment temperature</td>
</tr>
</tbody>
</table>

* above PCT 1000/PCT 2000 coating
• **Salt Spray Test** – PCT 20µ, per ASTM B117, IAI, grade 9 (0.01-0.03) surface after 336 hours

• **Corrosion after Paint (aerospace test)** – PCT 20µ + epoxy-based color per IAI standard 24.3900 class 1 – passed 2,000 hours salt spray per Mil-PRF-23377
• Sports
• Aerospace
• Military

PCT in Magnesium
PCT Applications

Marine

Automotive

Medical
• Reduction of Drag force in Military High Speed boats
Thank you.

For more information:

www.pcoatings-tech.com
info@pcoatings-tech.com

PCT is featured in the June 2013 edition of NACE MP Materials Performance Magazine.