

# Chromate Free Magnesium Gearbox Protection System

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ASETSDefense  
November 2014

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# Report Documentation Page

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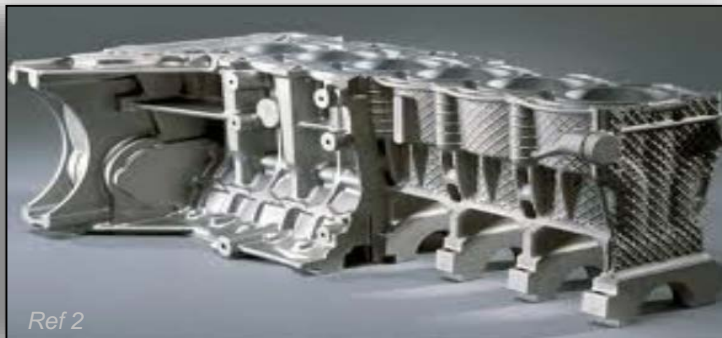
# Outline

- Magnesium: Why mag?
- Application
- Challenging Feature
- Legacy System
- Candidates
- New System
- Functional Requirements, Tests and Results
- Examples of Tests
- Benefits and conclusions



# Why magnesium?

- Lightest of the structural metals
  - 1/4 of steel
  - 1/3 of aluminum
- World production: ~400,000 ann
- No limit:
  - 8<sup>th</sup> most common element
  - 6<sup>th</sup> most abundant metal
  - Sea water contains ~0.15% mag
- Recycling requires only 5% OEM
- The BMW N52 (st6 dohc engine) crankcase shell since 2004. Ref 1
- Since 1936, VW has used cast mag



## *Fast Facts: Magnesium Alloy Engine*

- » Magnesium alloy engine was produced in 300,000 BMW vehicles in 2006
- » Magnesium alloy crankcase is 24 percent lighter than conventional aluminum engine
- » Engine achieves increased power output and higher torque
- » Environmental benefits are reduced fuel consumption and CO<sub>2</sub> emissions
- » R6 is lightest 3.0 liter inline six-cylinder gasoline engine in the world
- » Magnesium alloy engine block and bedplate with aluminum cylinder inserts
- » BMW foundry recycles 40 percent of its magnesium (9,000 tons per year)
- » R6 composite magnesium-aluminum alloy crankcase received the International Magnesium Association's Award of Excellence Ref 2



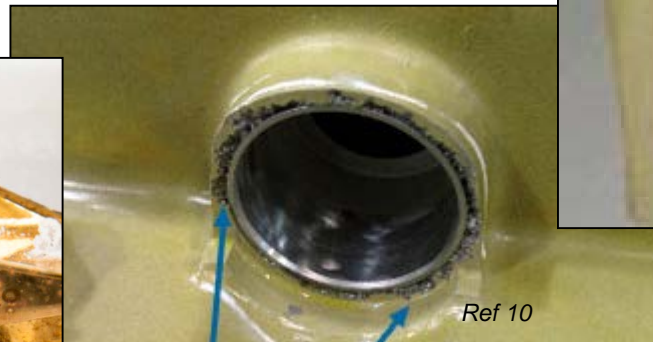
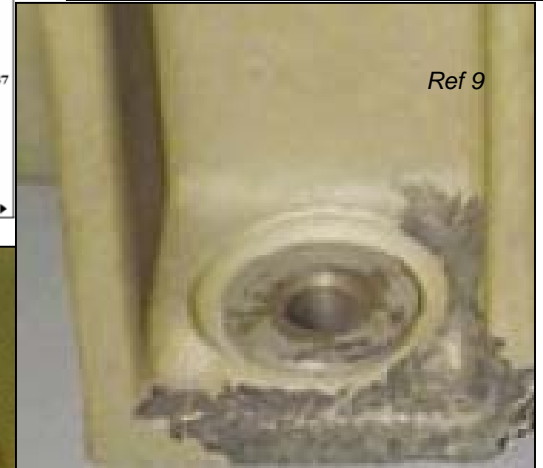
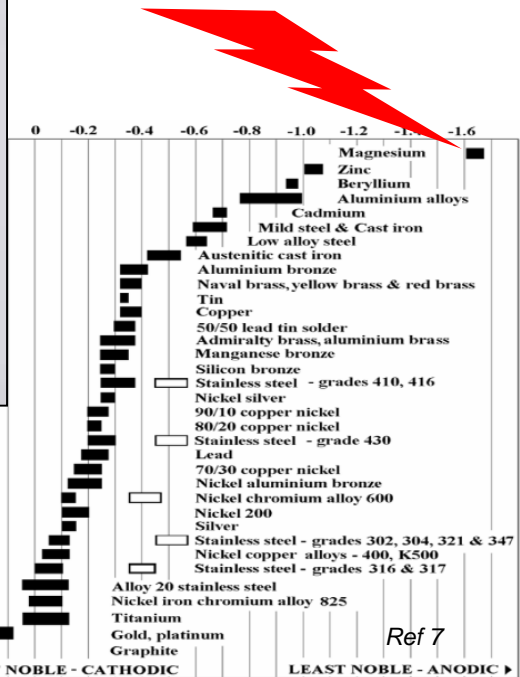
The R6 Composite Magnesium-Aluminum alloy engine is the mainstay of BMW's vehicle fleet.

OEM VW Magnesium Engine Case, 043-101



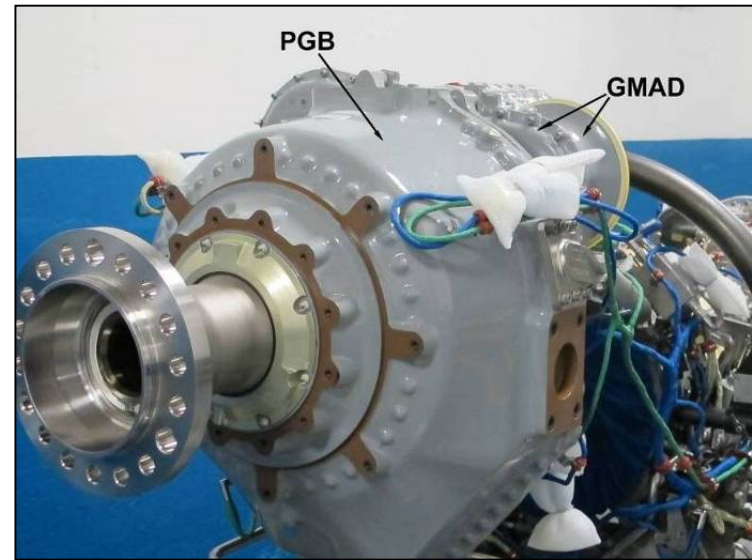
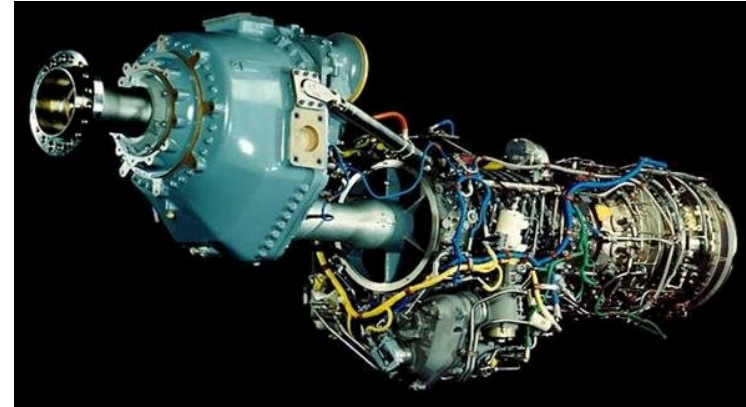
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# Why protect magnesium?



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# The AE2100D3 engine

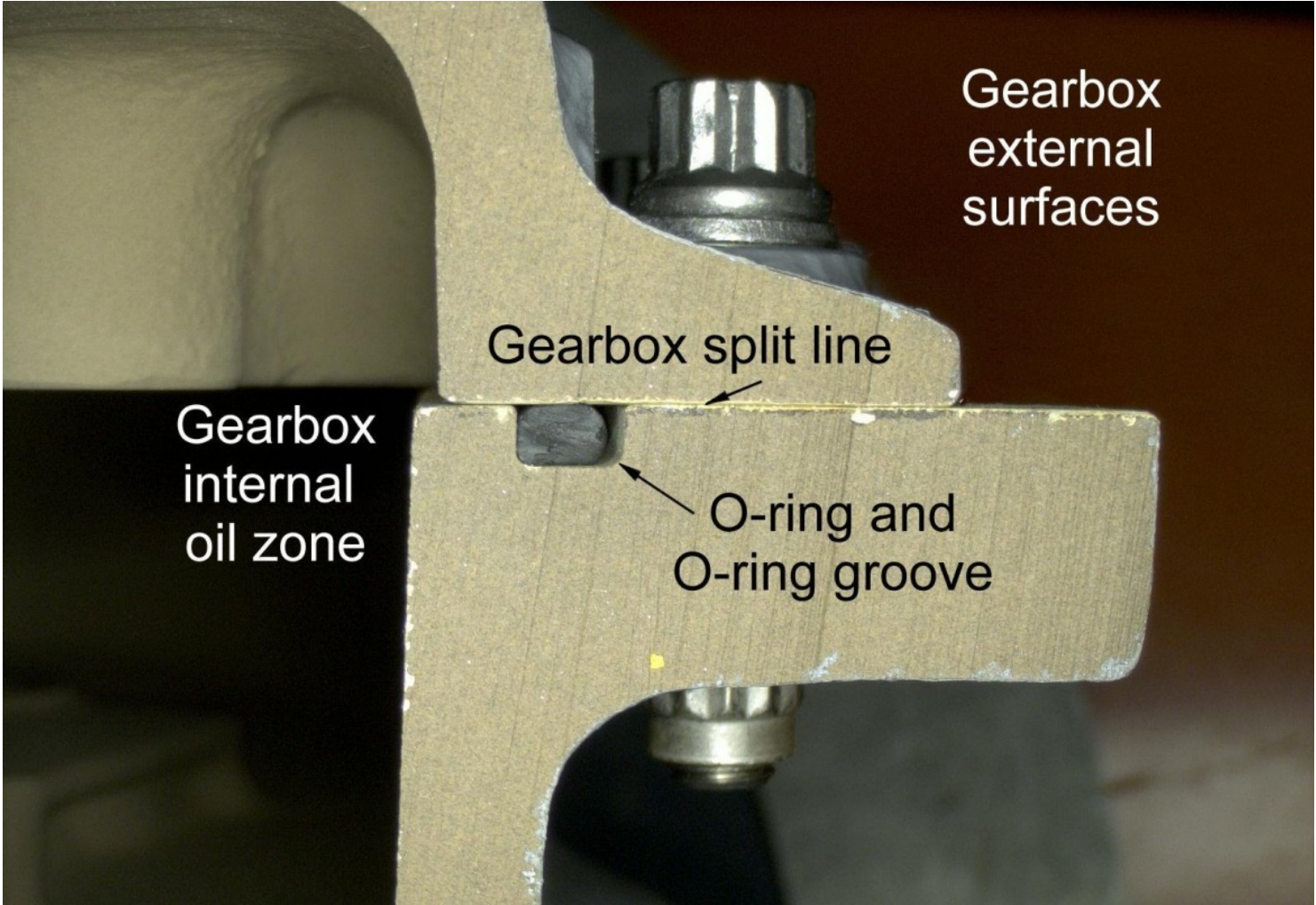


**PGB – Propeller Gear Box**  
**GMAD – Gearbox Mounted Accessory Drive**



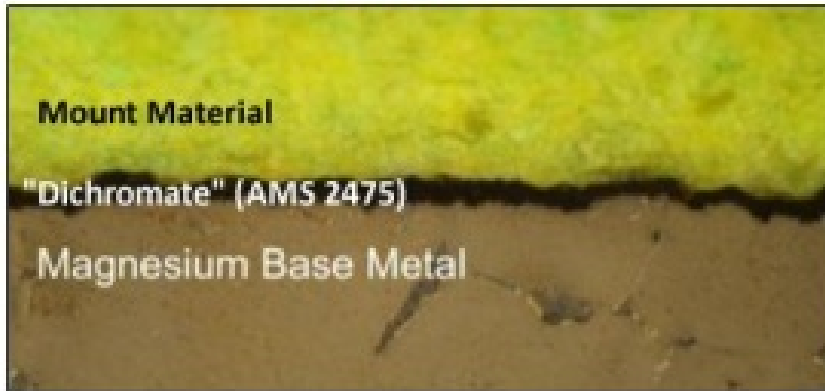
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# Split line illustration

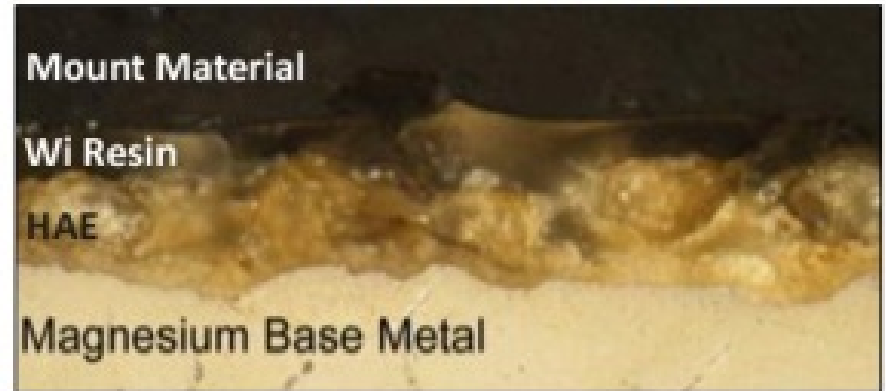


# Legacy coating system

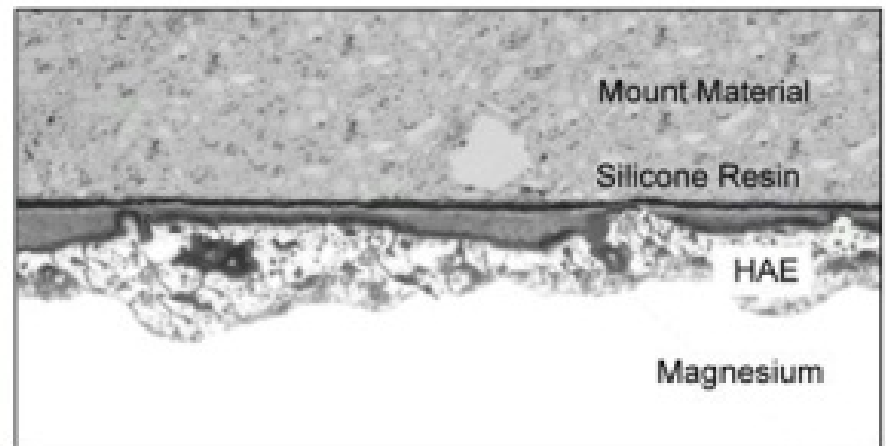
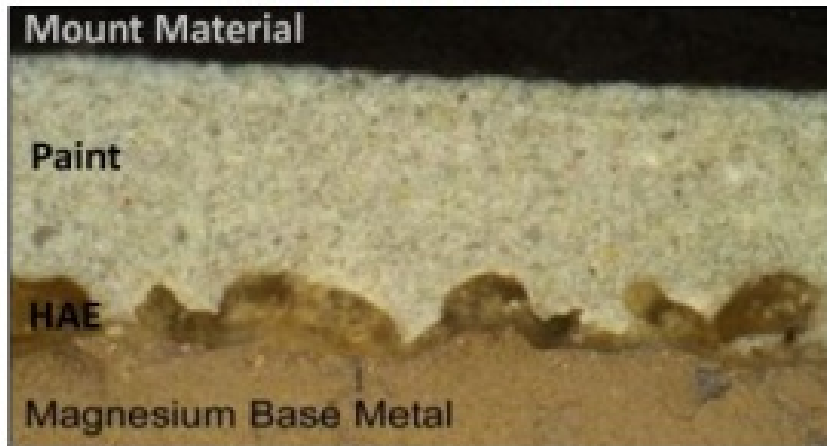
**Oil Wetted Surfaces**  
Dichromate



**Split Lines / Machined Surfaces**  
Silicone Resin over HAE



**External Cast Surfaces**  
Top Coat over HAE



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# Legacy coating system

- HAE
  - Patented in 1952 (by Harry A. Evangelitis)
  - Corrosion resistance
  - Surface finish
- Complex masking scheme for application
- Regulatory pressures
  - Hexavalent Cr – sustainability issue
  - High VOC content in solvents

A comprehensive replacement of the legacy coating was needed

- Improved thickness consistency
- Improved unit cost
- Lessened environmental impact
- Improved corrosion performance and aftermarket cost



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# Proposed coating system

- Anodize
  - Tagnite 8200 Type 1 (AMS 2466)
  
- Paint
  - Indestructible Paint Ltd
    - Chromate free Low VOC 985 series
      - Sealer (green tinted)
      - Primer
      - Top Coat



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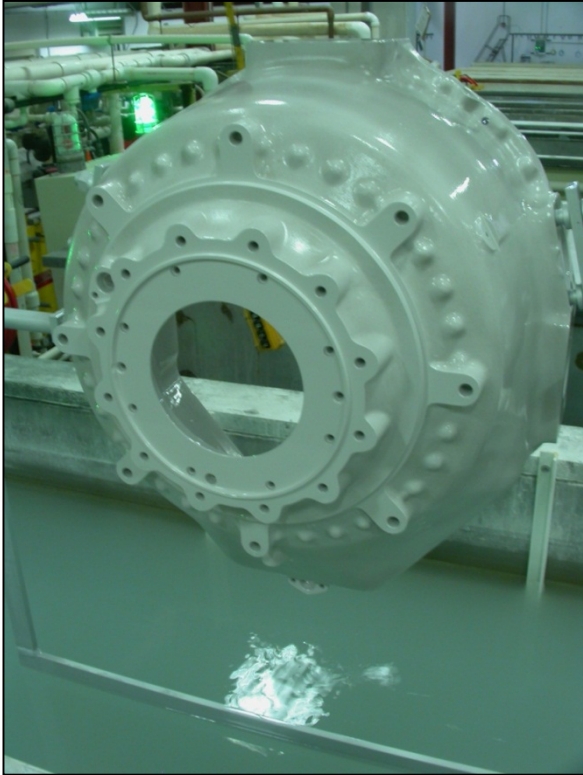
# Tagnite - What is it?

TECHNOLOGY APPLICATIONS GROUP  
EXCELLENCE IN MAGNESIUM SURFACE PROTECTION

## Chemical Composition as a Percentage of Water

Product	Chemical Concentration	Notes
TAGNITE®	5% *	
HAE	25% *	HAE contains heavy metals
Dow 17	56% *	Dow 17 contains heavy metals and chromium

\*Approximations



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# Rockhard - What is it?

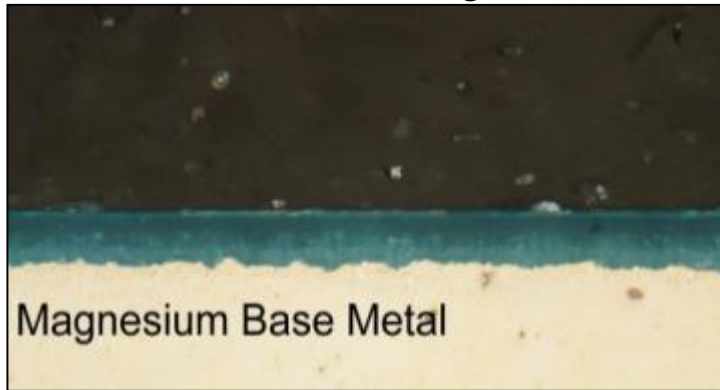


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# Proposed coating system

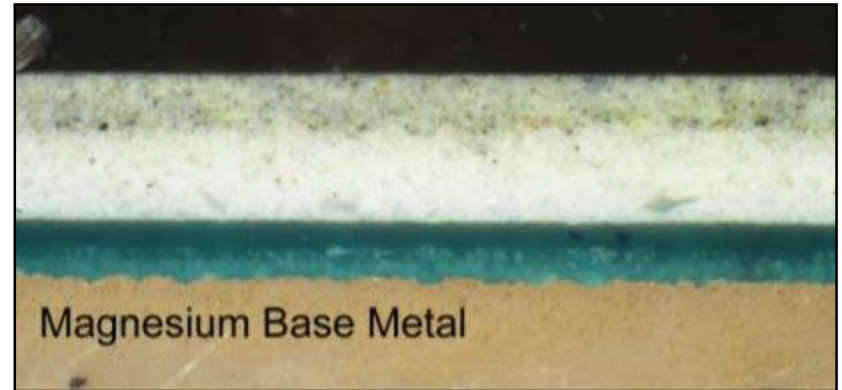
## Internal Oil Wetted Surfaces

Sealer over Tagnite



## Split Line /Machined Surfaces

Top Coat, Primer & Sealer over Tagnite



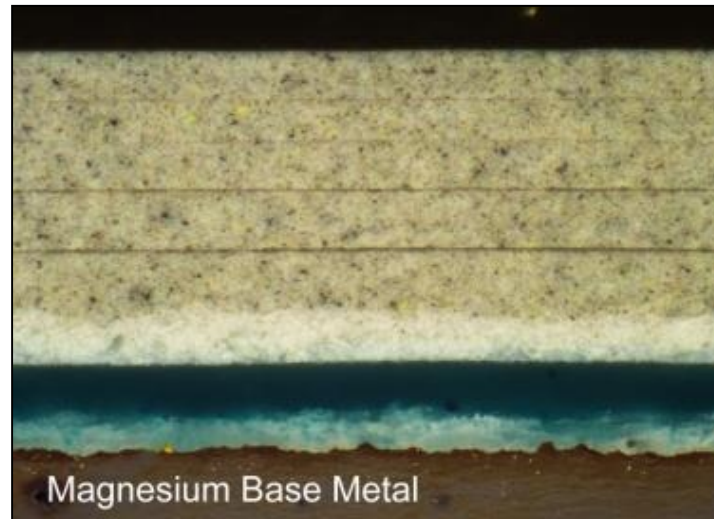
## External Cast Surfaces

Top Coat, Primer & Sealer over Tagnite

*Mount Material*

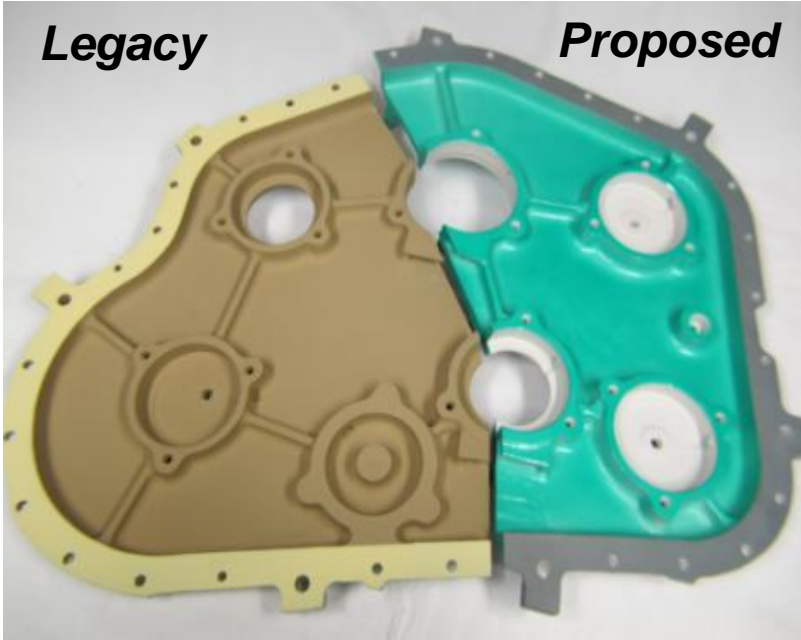
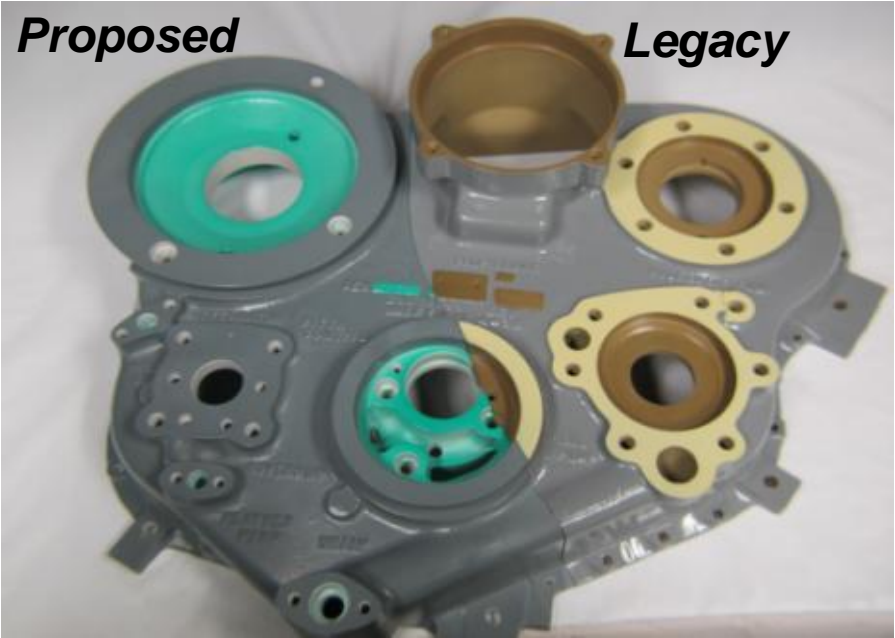
*Rockhard  
Topcoat layers*

*Rockhard Primer  
Rockhard Sealer  
Tagnite*



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# Side by side look at coating schemes



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# Functional Criteria, Tests and Results

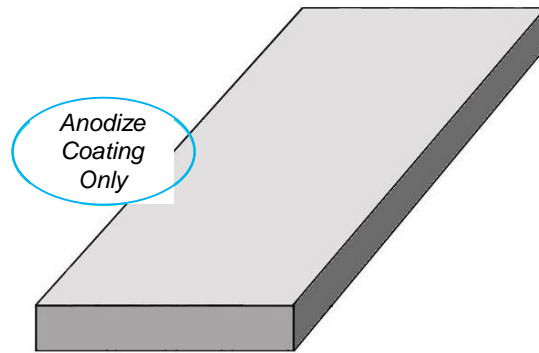
- Coating Adhesion- **PASS**
  - ASTM D3359 Method B
- Corrosion Resistance- **PASS**
  - Neutral Salt Spray: ASTM B117, ASTM D714, ASTM D1654
  - Cyclic Salt Spray:
- Thermal Stability (430°F, 1000 hrs)- **PASS**
  - ASTM D714
- Fluid Resistance (fuel, oil, hydraulic)- **PASS**
  - ISO 2812-1
- Damage Resistance (impact, bend, corner radii)- **PASS**
  - ASTM D2794, ASTM D522, Rolls-Royce Corp Test Method
- Releasability (Ease of Disassembly)- **PASS w/ use of Frekote 700-NC**
  - Rolls-Royce Corp Test Method (per IR 37340)
- Repairability (after damage and touch-up repair)- **PASS w/ Brush Tagnite**
  - Adhesion: ASTM D3359 Method B
  - Neutral Salt Spray: ASTM B117, ASTM D714, ASTM D1654
  - Metallographic
- Fatigue Testing (bar)- **PASS**
- Torque Testing (scrap part)- **PASS**
- Engine Test (assembly/leak check)- **PASS**



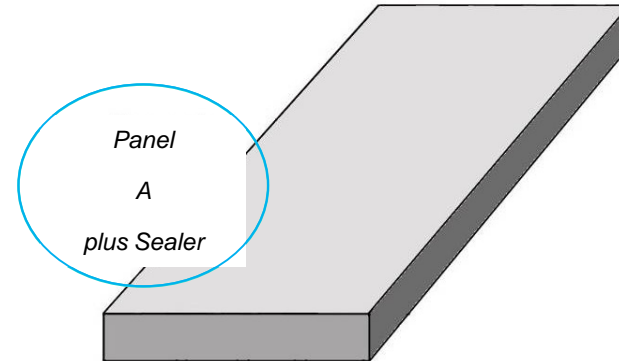
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# Magnesium panels for environmental testing

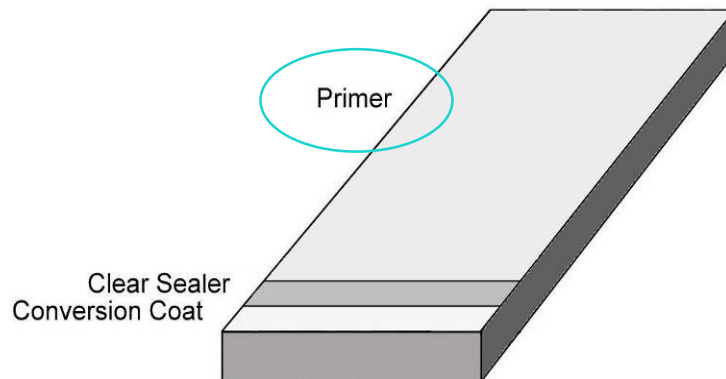
Panel Type  
**A**



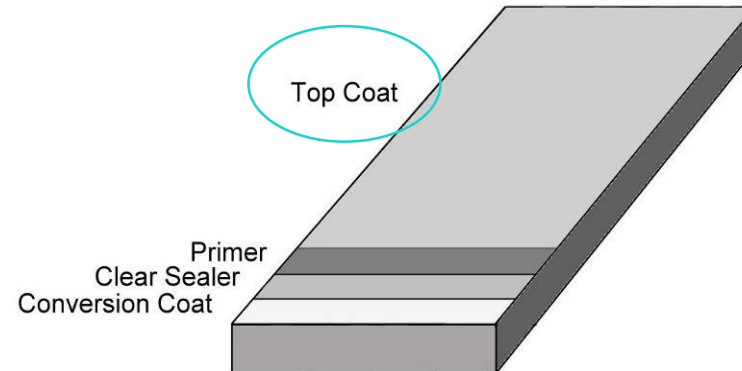
Panel Type  
**B**



Panel Type  
**C**

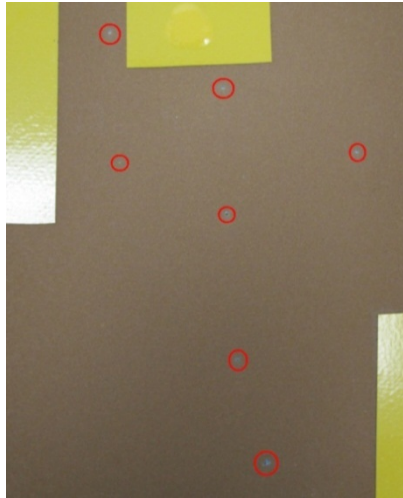


Panel Type  
**D**



# Corrosion testing – anodize coatings

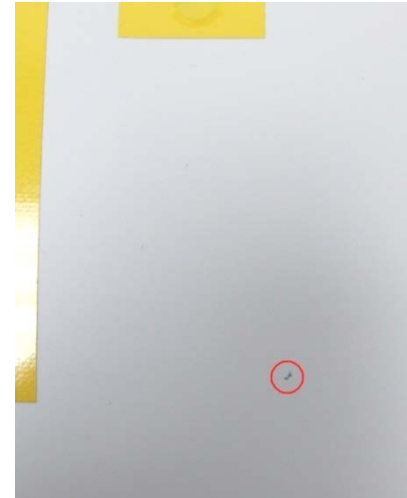
Panel Type A



HAE after 24 hrs.



Tagnite (panel 1) after 24 hrs.



Tagnite (panel 2) after 24 hrs.



HAE after 96 hrs.



Tagnite (panel 1) after 96 hrs.



Tagnite (panel 2) after 96 hrs.

**Criteria:** Coating shall receive a rating of 9 after exposure to 24 hours in neutral salt spray AND the new coating system shall meet or exceed the performance of the old coating configuration.

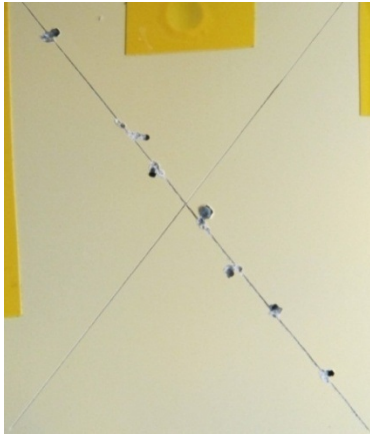
**Result: Pass**



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# Corrosion testing – external surfaces

Panel Type C



Legacy A

Panel Type D



Legacy

Panel Type D



New Coating

**Criteria:** Coating shall receive a rating of 7 after exposure to 250 hours in neutral salt spray AND the new coating system shall meet or exceed the performance of the old coating configuration.

**Result: Pass**



Legacy



Legacy



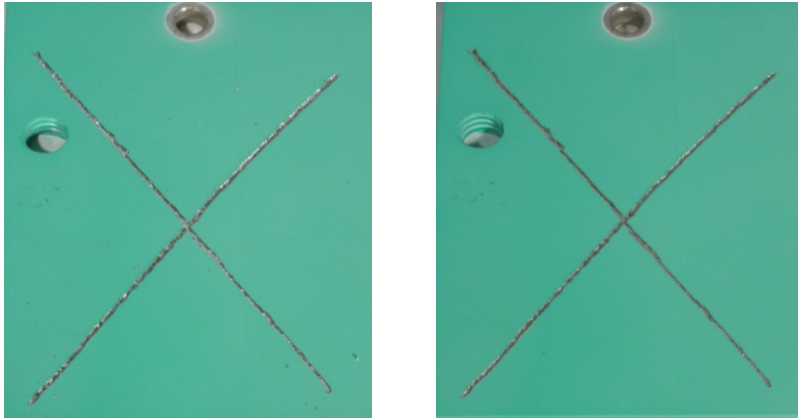
New Coating



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# Fluid Resistance

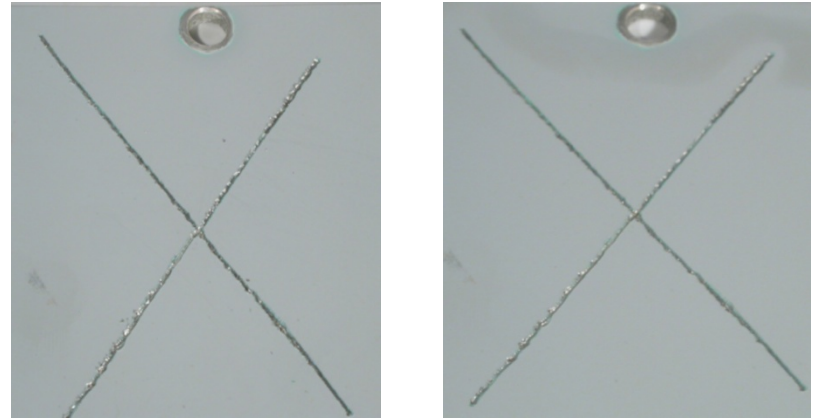
Rockhard Sealer- Panel Type B



Before

After

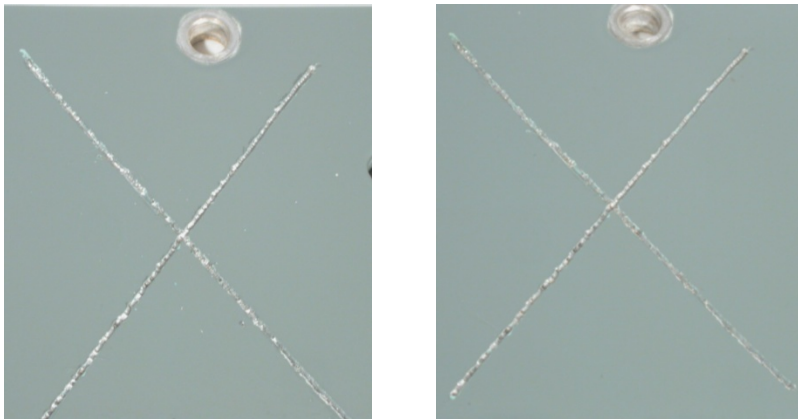
Rockhard Primer- Panel Type C



Before

After

Rockhard Top Coat- Panel Type D



Before

After

**Criteria:** All panels shall show no visual signs of blistering or lifting after exposure to fuel (Jet A) and hydraulic fluid (Royco 782).

**Results: Pass**

Fuel: 70°C, 163 hrs

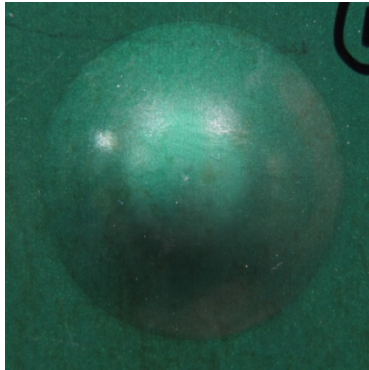
Hydraulic Fluid: 70°C, 189 hrs



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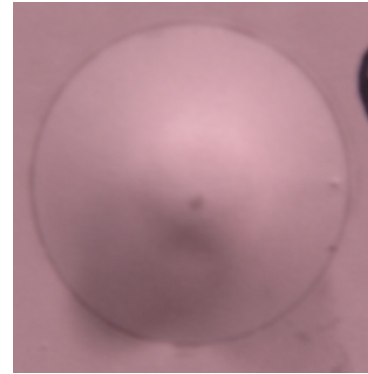
# Impact damage resistance

Panel Type B

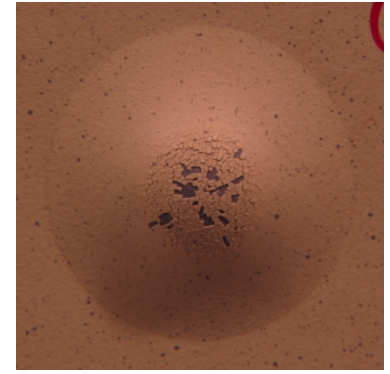


Rockhard

Panel Type C

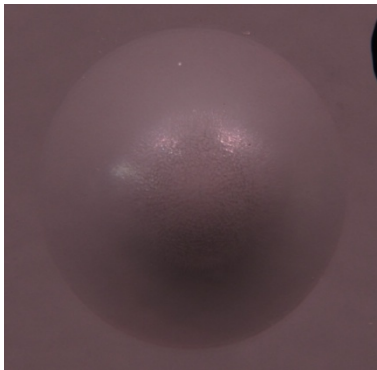


Rockhard

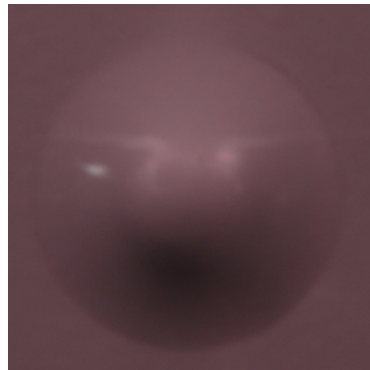


Legacy

Panel Type D



Rockhard



Legacy

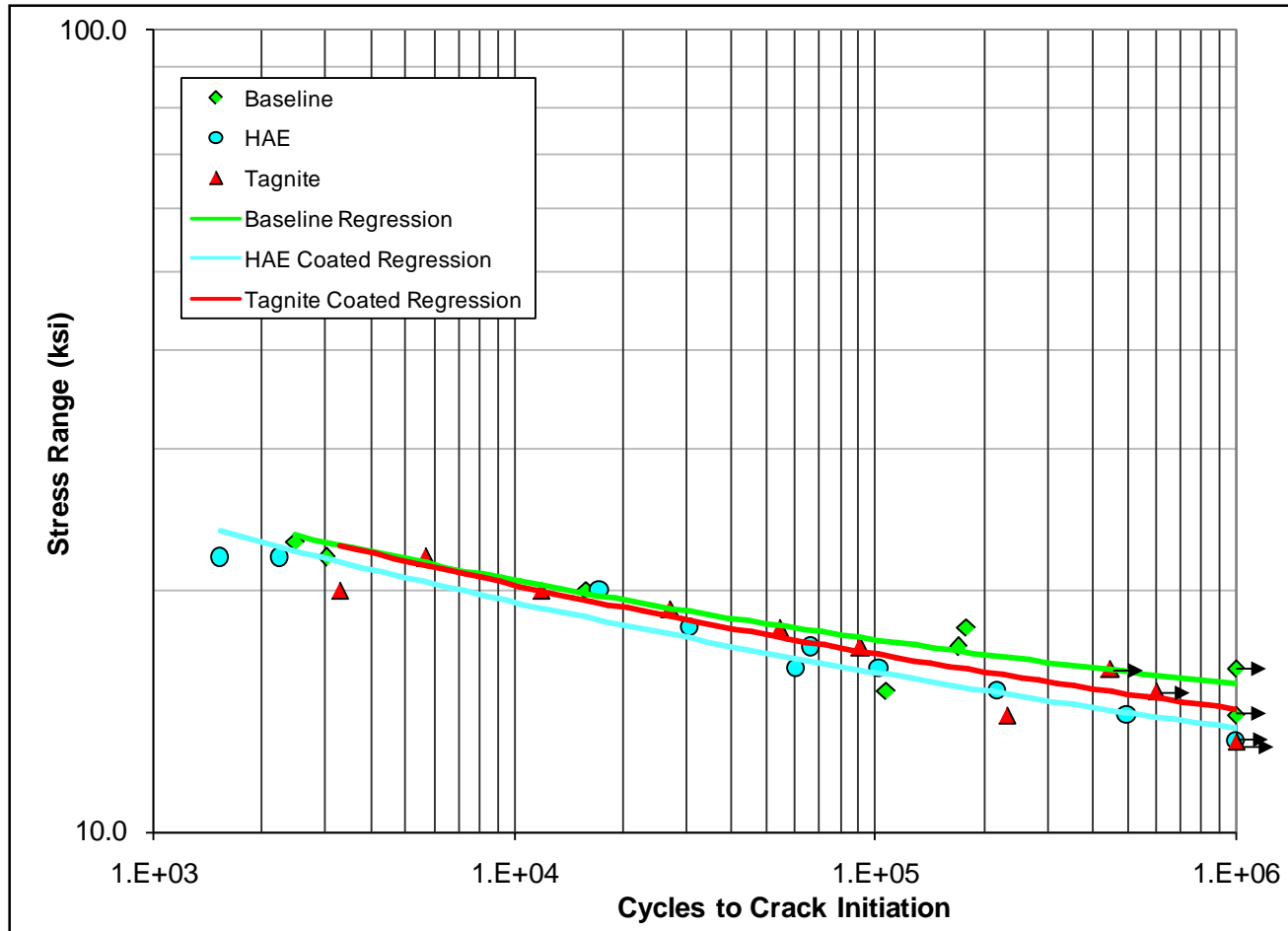
**Criteria:** There shall be no cracking or detachment at an indentation depth of 3.8 mm (.15 inch) using a 1000±1 g punch AND the new coating system shall meet or exceed the performance of the old coating configuration.

**Result: Pass**



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# Fatigue performance



**Criteria:**  
No increase in fatigue debit over legacy or baseline coating.

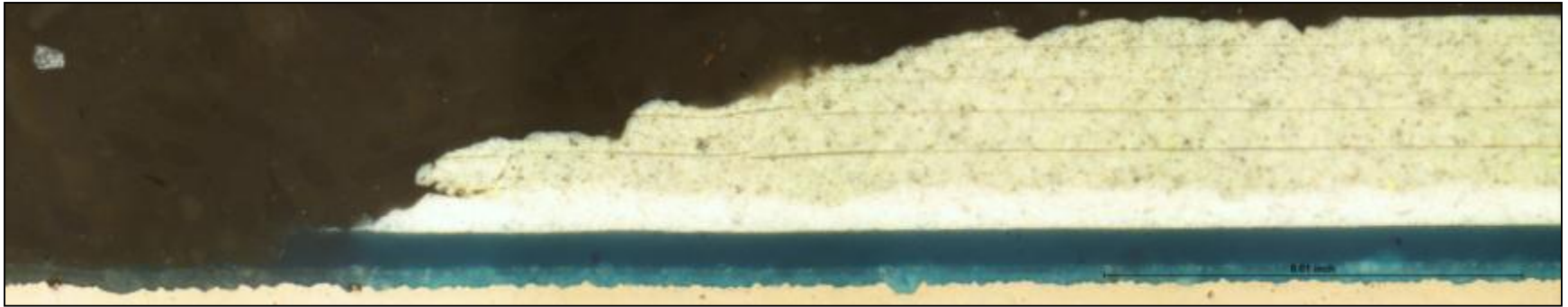
**Result: Pass**



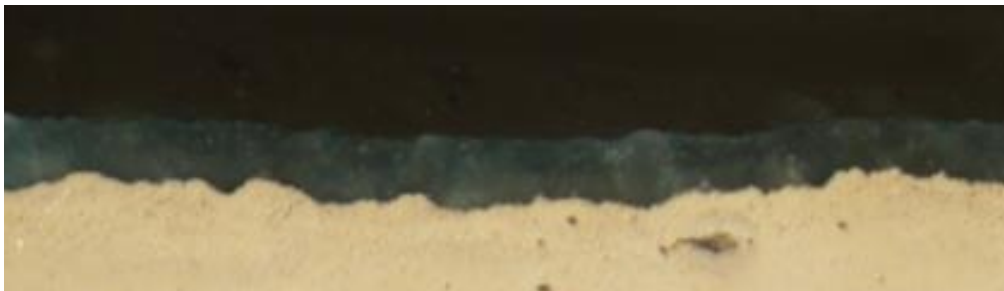
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# Repair and Overhaul

- Plastic Media Blast removal process successful in removing the paint without removing the anodize



*Cross section of a painted panel partially stripped via plastic media blasting*



*Higher magnification view of the remaining conversion coating*

**Criteria:** *The coating shall be strippable and be capable of supporting subsequent re-paint*

**Results: PASSES**



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# Engine Test

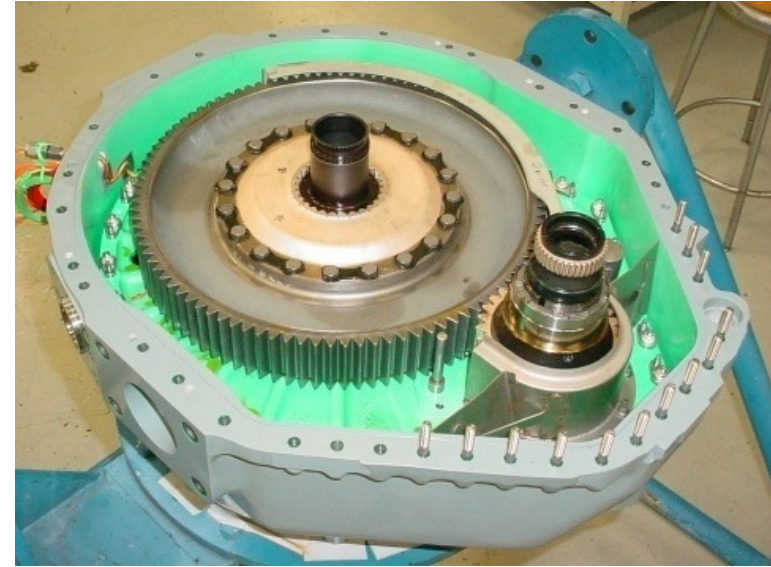
- Purpose
  - Assembly/fit check
  - Leak check
- Testing details
  - Prop Stand test
  - Post-engine test inspection
- Results
  - After 3 tear downs and 150 hours
  - New coating configuration PASSES



# Conclusion:

## It's in production!

- Performance improvement
- Environmental liability eliminated
- Unit Cost neutral
- Improvement in Aftermarket costs



Ref 1: <http://www.magnesium-elektron.com/about-magnesium.asp?ID=1>

Ref 2: [www.intlmag.org/showcase/mg001.pdf](http://www.intlmag.org/showcase/mg001.pdf)

Ref 3: <http://vwparts.aircooled.net/OEM-VW-Magnesium-Engine-Case-043-101-025OE-p/oem-vw-engine-case.htm>

Ref 4: <http://www.fwtec.com/FW/nanosolution.html#>

Ref 5: Rolls-Royce Front Frame example

Ref 6: <http://www.volksworld.com/blog/staff-blogs/jons-blog/stripping-down-a-donor-beetle-engine/>

Ref 7: [http://www.corrosionist.com/galvanic\\_corrosion\\_chart.htm](http://www.corrosionist.com/galvanic_corrosion_chart.htm)

Ref 8: <http://airandspace.si.edu/webimages/highres/5013h.jpg>

Ref 9: Corrosion and Materials, Vol 30 No 6, 2

December 2005 ISSN 1326-193

Ref 10 <http://www.arl.army.mil/www/default.cfm?page=375>



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# Questions?

Ref 1: <http://www.magnesium-elektron.com/about-magnesium.asp?ID=1>  
Ref 2: [www.intlmag.org/showcase/mg001.pdf](http://www.intlmag.org/showcase/mg001.pdf)  
Ref 3: <http://vwparts.aircooled.net/OEM-VW-Magnesium-Engine-Case-043-101-025OE-p/oem-vw-engine-case.htm>  
Ref 4: <http://www.fwtec.com/FW/nanosolution.html#>  
Ref 5: Rolls-Royce Front Frame example  
Ref 6: <http://www.volksworld.com/blog/staff-blogs/jons-blog/stripping-down-a-donor-beetle-engine/>

Ref 7: [http://www.corrosionist.com/galvanic\\_corrosion\\_chart.htm](http://www.corrosionist.com/galvanic_corrosion_chart.htm)  
Ref 8: <http://airandspace.si.edu/webimages/highres/5013h.jpg>  
Ref 9: Corrosion and Materials, Vol 30 No 6, 2  
December 2005 ISSN 1326-193  
Ref 10 <http://www.arl.army.mil/www/default.cfm?page=375>



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