Corrosion Issues & Test Methods

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Global Industrial Fluids

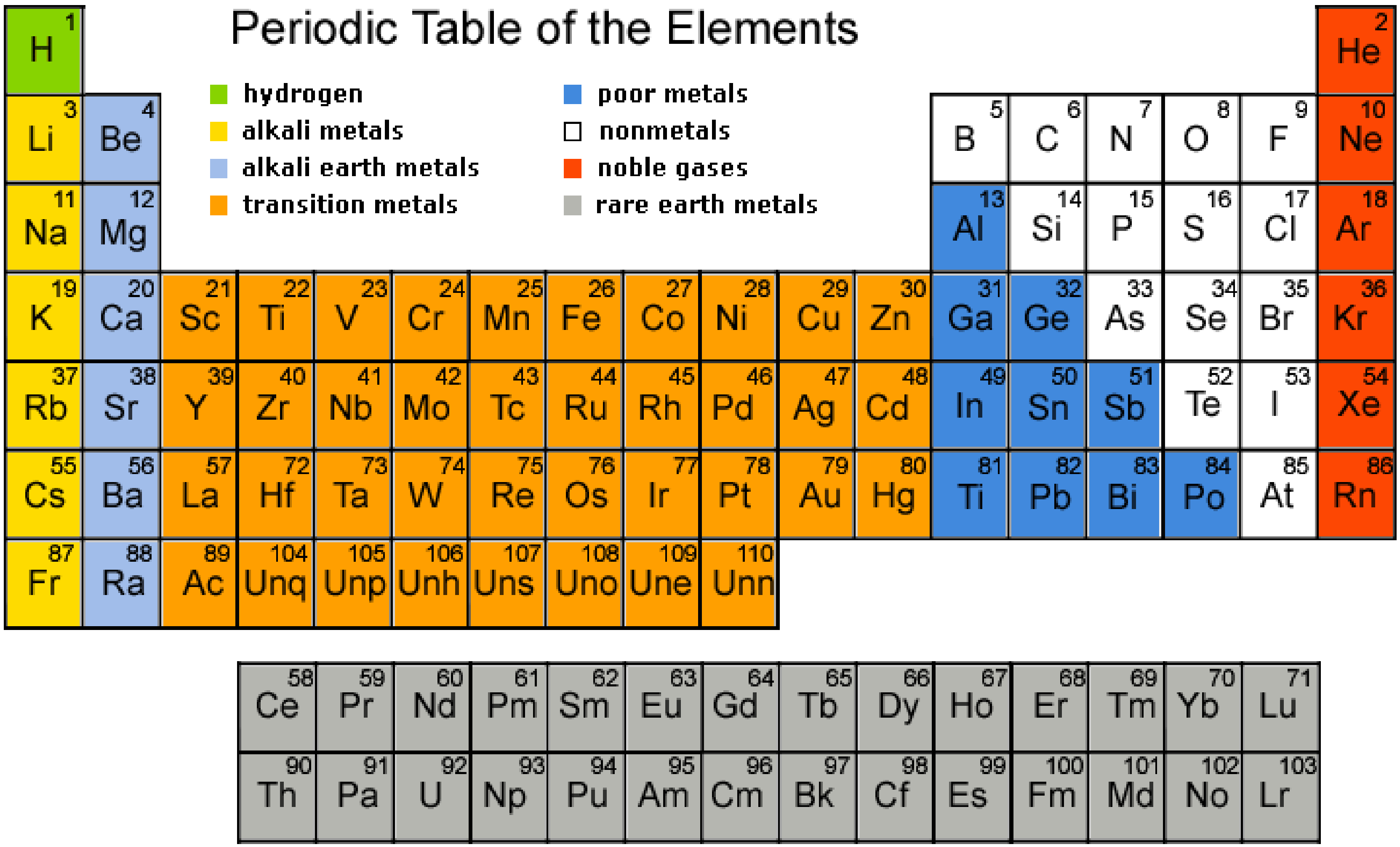
Cost of Corrosion to US Industries

- **Corrosion** is the deterioration of a material (often a metal) due to interaction with its environment.
- A study in 1998 estimated the direct cost of corrosion to be **$275.7 Billion**
- Represents **3.1%** of the US Gross Domestic Product
- Indirect costs (lost productivity due to outages, delays, failures, and litigation) considered to be at least equal to the direct costs.

Factors that Affect Corrosion Rate

- Moisture (Humidity)
- Temperature
- Air Pollution/Contamination
- Water Quality (see photo)
- Lean MWF dilutions
- Acids/Bases/Salts
- Concentration differences across metal surface
- Crevices
- Contact between dissimilar metals

There are just over 100 known chemical elements. About 80 are metals.



Corrosion Issues – Metals Considered

- Iron
- Aluminum
- Copper
- Magnesium
- Titanium

Cast Iron & Steel

IRON (Fe)

- 90% of all mining for metallic ores is for extraction of iron
- Its low cost and high strength make it indispensable in engineering applications such as the construction of machinery, machine tools, automobiles, hulls of ships, and structural components for buildings.
- Addition of tiny quantities of carbon to iron greatly increases its strength
- Steel has lower carbon content that cast iron
- The main disadvantage of most iron alloys is rust!

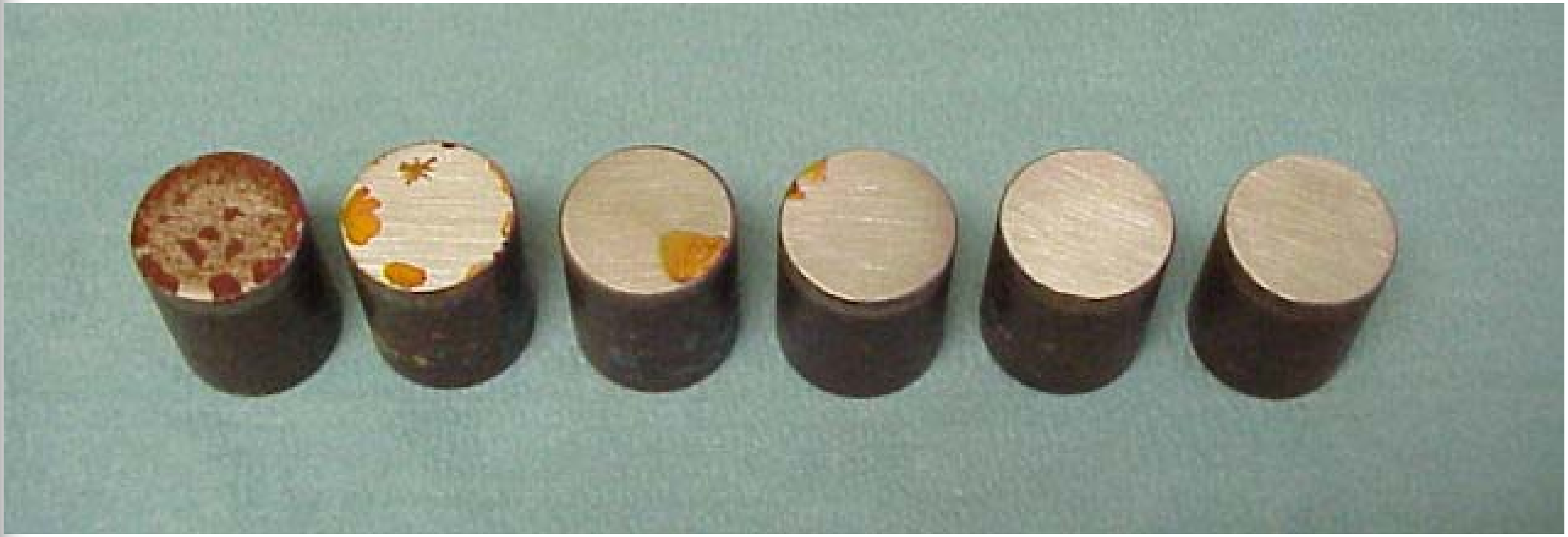
Rust Happens!

Rusted, Pitted Camshaft

Caused by high chlorides & high humidity

Open Face Cast Iron Cylinders

held overnight at 100% RH & Room Temp



Breakpoint: Weakest concentration that will control rust

STACKED STEEL CORROSION TEST

Stacking reduces fluid volume & excludes oxygen

Cast Iron Chip Test

Comparison of Cast Iron Chip Methods

<u>ASTM D4627</u>

- 4 g chips
- Filter paper: glass fiber
- Water hardness: 100 ppm
- 5 ml fluid
- 20-24 hr fluid contact

<u>DIN 51360-2</u>

- 2 g chips
- Filter paper: standard
- Water hardness: 340 ppm hardness
- 2 ml fluid
- 2 hr fluid contact

Cast Iron Test Breakpoints

PRODUCT	ASTM D4627	DIN 51360-2	Cylinders
Syn A	4%	2%	1%
Syn B	2%	2%	2%
Syn C	5%	7%	1%
Semi D	5%	>10%	>10%
Semi E	2.5%	7%	3.5%
Semi F	2.5%	4%	2.5%
Sol Oil G	5%	5%	5%
Sol Oil H	2.5%	3%	1.5%

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The problem with metal chips

Metal chips have a very large surface area that extracts corrosion inhibitors from solution.

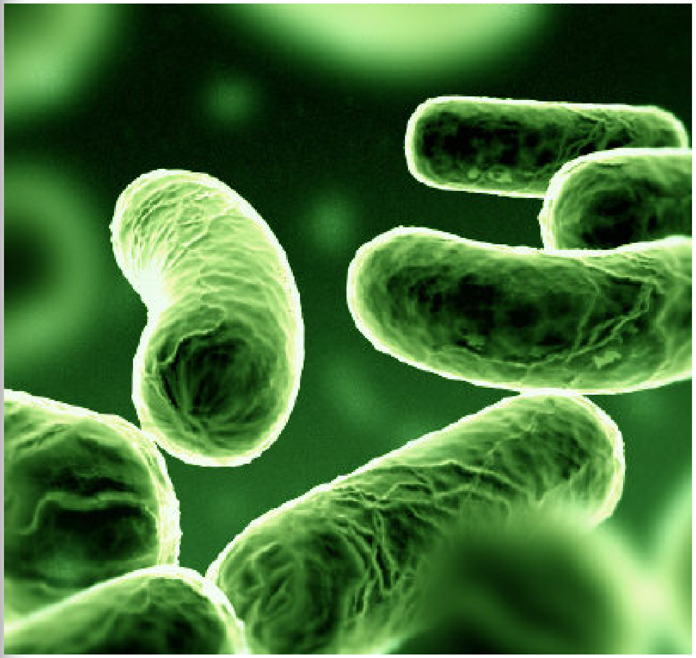
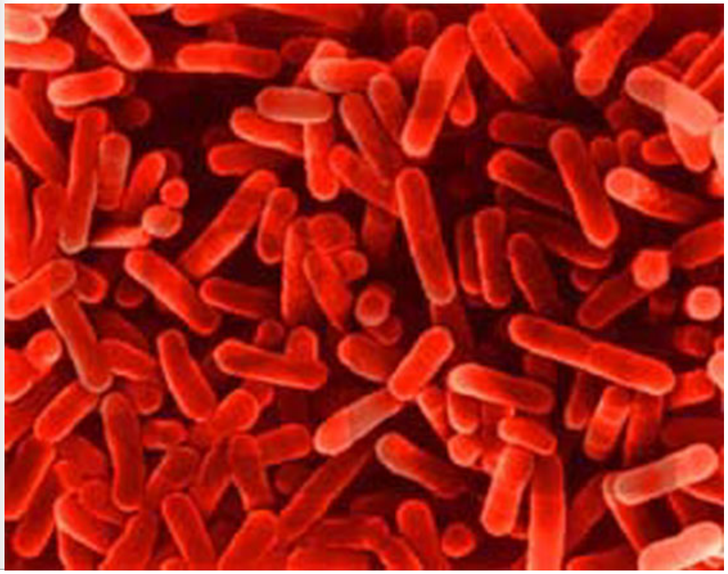
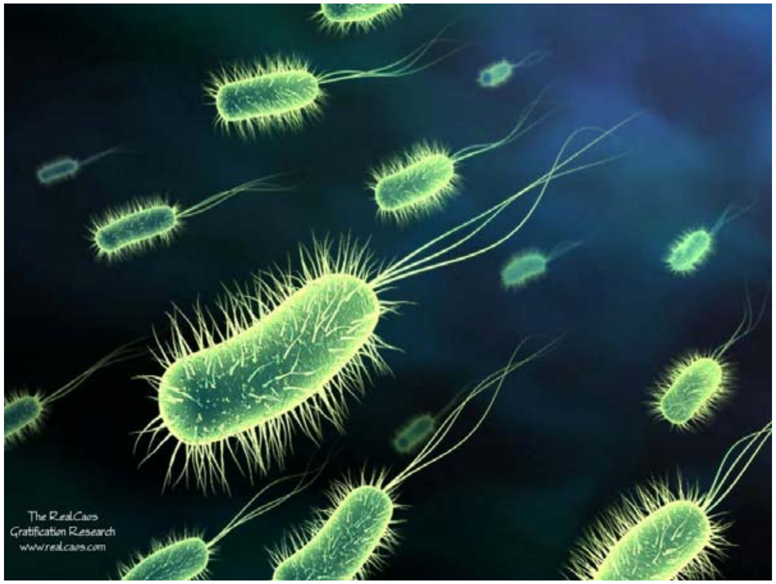


illustration: Don Smith

Microbially Induced Corrosion





Bacteria & Mold Can Cause Corrosion Problems

- Bacteria and mold are everywhere: water, air, operator’s hands, incoming parts, walls of the sump and pipes, etc.
- It is only natural that they wind up in the cutting fluid mix.
- Low levels cause no problem
- At higher levels the organisms begin to digest critical fluid components (such as rust inhibitors) and leave acidic by-products in their place. The combined effects cause corrosion problems.

Microbes & Rust

ASTM D4627 Cast Iron Chip Test

(Shown with chips removed)

ALUMINUM
(Al)

ALUMINUM

- Soft, durable, lightweight metal
- About 1/3 the density and stiffness of steel
- Vital for aerospace, and useful in other areas of transportation to help reduce fuel consumption.
- Good thermal and electrical conductor
- Remarkable for its ability to resist corrosion
- Corrosion resistance is reduced by
  - Aqueous salts
  - Combinations with other metals

Fluid Developed for Ferrous Metals, But is Bad on Aluminum

Corrosion of Aluminum

- **High alkalinity or salts**

  Darkening: gray to black

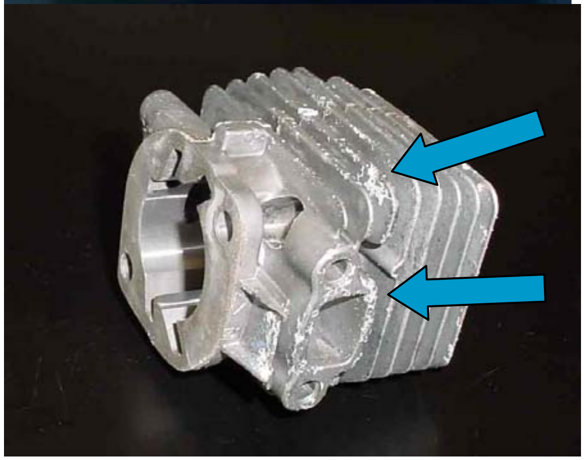
- **Galvanic or Bimetallic**

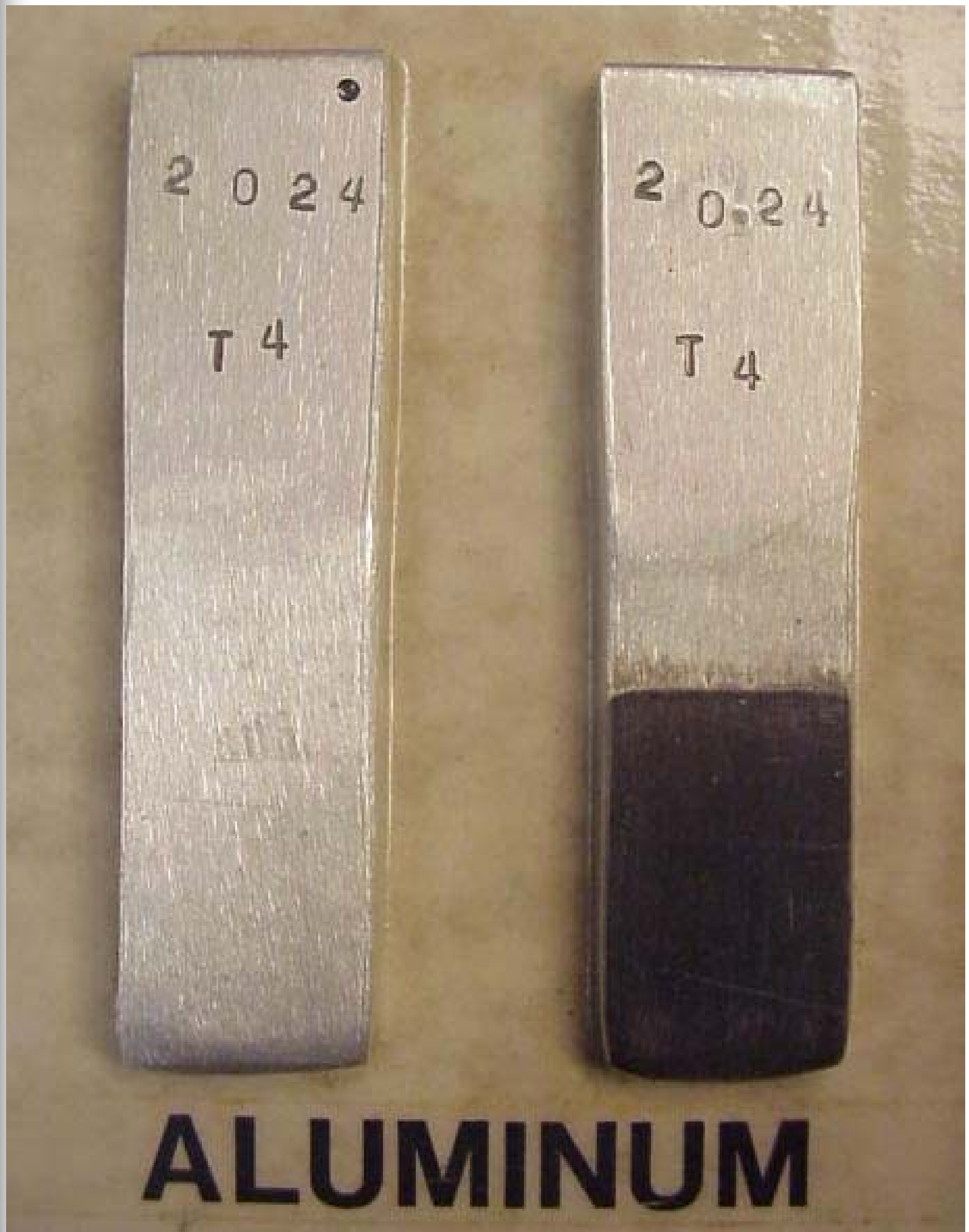
  Electrical phenomenon

  Look for outline of contact area

- **White corrosion**

  Alloys with high Mg or Zn content – caused by plain water





Simple Aluminum Corrosion test:

Immerse freshly ground metal strip in fluid at desired dilution for 20-24 hours.

Observe metal surface and rate.

Boeing Spec. BAC 5008 - 12.3 Aluminum "Sandwich" Test

- Prepare "sandwich" with two metal coupons and a piece of filter paper soaked with MWF.
- Test is run with both MWF concentrate and diluted mix.
- Conditions: 100º F for 8 hr and 100º F + 100% humidity for 16 hr – 7 day duration.
- Coupons: 7075 T-6 clad aluminum and 7075 T-6 anodized, (2 in. x 4 in.)
- Sizes: Coupons 2 in. x 4 in., Paper 1 in. x 3 in.
- Compare to distilled water as control fluid.

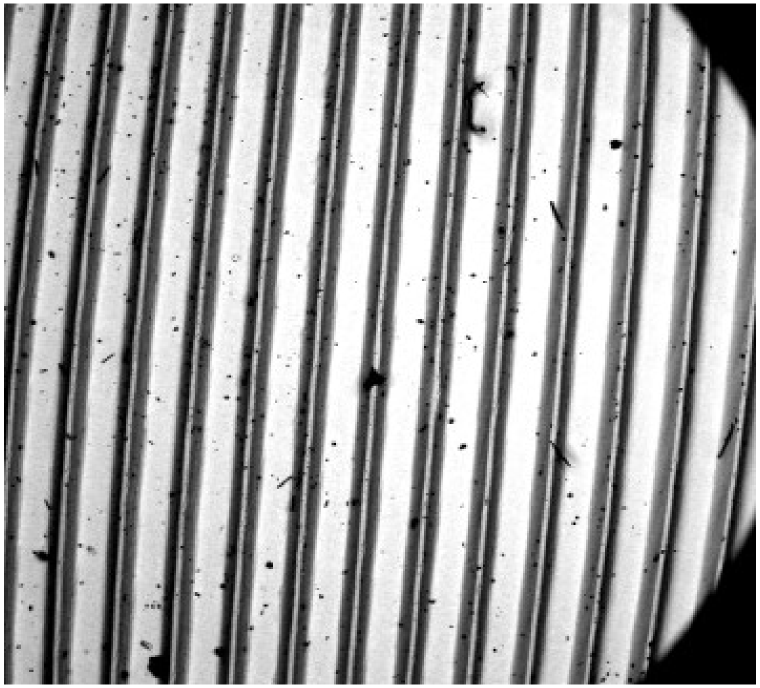

A6
A7
A8
CLAD 7075 T-6 ALUMINUM
B6
B7
B8

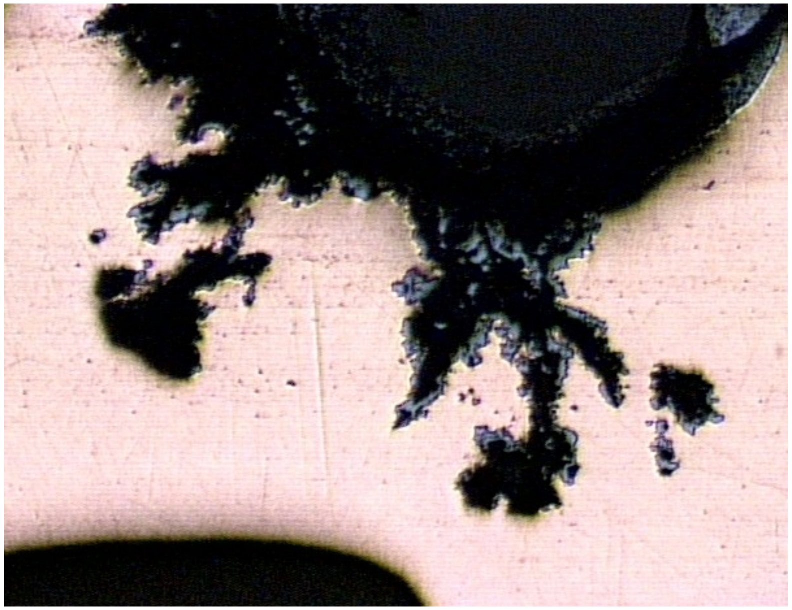
Comparison of Results, 7075 Aluminum

PRODUCT	24 Hr Strip Immersion, 5% mix	Boeing 12.3 Sandwich Test
Synthetic	Clean	•Mix Passed •Conc. Passed
Soluble Oil A	Clean	•Mix Failed •Conc. Passed
Soluble Oil B	Clean	•Mix Passed •Conc. Failed
Soluble Oil C	Clean	•Mix Failed •Conc. Failed

COPPER (Cu)

Formicary Corrosion





- Note pits on interior surface of copper tube (top photo).
- Formicary corrosion pattern looks like tunnels in an ant farm (bottom photo).
- Bottom photo shows branched tunnels associated with Formicary Corrosion in the evaporator tube.

Formicary Corrosion

- Some experts say Formicary Corrosion is caused by hydrolytic breakdown of drawing lubricants to form low levels of Formic Acid and Acetic Acid.
- Test Method: 90 g lube + 10 g water + 1 g alumina, reflux 48 hours. Extract with 90 g more water. **Passing result is <20 ppm** formate/acetate.
- Alternate procedure is ASTM D2619.
- **However**, even copper tubing "as supplied" shows significant interior & exterior pitting

Formicary Corrosion - Hydrolysis Test Results

for copper tube bending & forming lubes

PRODUCT	Formate + Acetate
Lube A	78 ppm (fail)
Lube A, reformulated	2 – 4 ppm (pass)
Lube B	100 ppm (fail)
Lube B, reformulated	10 ppm (pass)

MAGNESIUM (Mg)

MAGNESIUM

- **Light-weight metal, 2/3 the density of aluminium**
- **Highly reactive**
- **Metal burns with a bright flame**
- **<u>Chips react with water to release Hydrogen gas</u>**
- **Magnesium is the third most commonly used structural metal, following steel and aluminium.**
- **Principal use is as an alloying additive to aluminium**
- **Strong and light weight, it is used for many consumer goods: “mag” wheels, engine blocks, laptop shells, mobile phones, cameras, etc.**

Magnesium Reacts in Water to Generate Hydrogen

$Mg\ (s) + 2H_2O(\ell) \rightarrow Mg(OH)_2(aq) + H_2(g)$

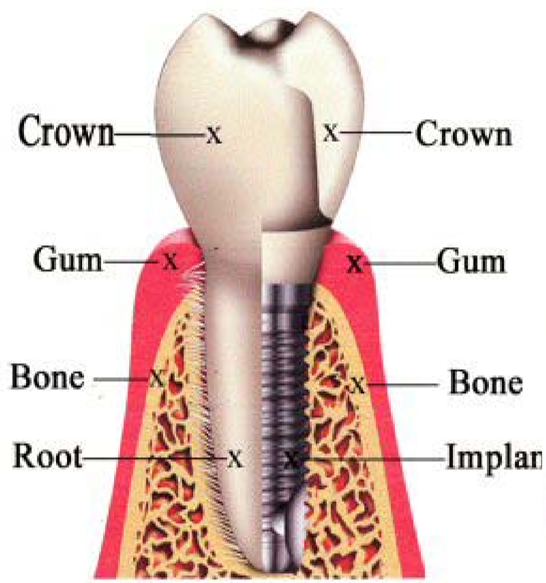
- Note hydrogen generation in test tube on the left.
- Products can be ranked by the volume of hydrogen produced, as well as by degree of stain on Mg surface.

Magnesium Stain vs H_2 Generation

	Magnesium Stain	Hydrogen Volume, 24hr
Syn A (lt. duty)	Heavy	>1000 ml
Syn B (med duty)	None	60 ml
Semi C	Heavy	3.5 ml
Semi D	None	42 ml
Sol Oil H	None	0 ml
Sol Oil R	Trace	11 ml

TITANIUM

TOOTH



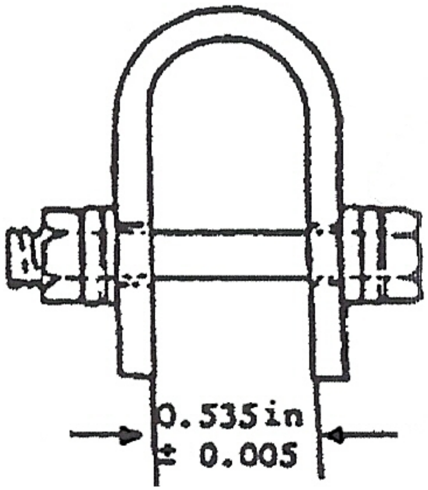
TITANIUM (Ti)

- Corrosion resistant
- Highest strength to weight ratio of any metal
- Can be alloyed with many metals
- Light weight strong alloys for aerospace, military, industry, medical, dental, sports
- Susceptible to stress corrosion cracking at elevated temperatures.

TITANIUM

- **ASTM F945** tests for stress-corrosion cracking of pre-stressed titanium specimens (3 in. x 0.75in. x 0.05 in.)
- AMS 4911 & AMS 4916 Titanium Alloys
- Method A = 500^{o}F (168 hrs.)
- Method B = 900^{o}F (8 hrs.)
- Comparison is made to salt (NaCl) solution.
- Sometimes small changes in a formulation can make big changes in the test result.

TITANIUM



No Crack

Cracking Observed

SUMMARY & CONCLUSIONS

- Many different metals are being machined in industry.
- Each has a unique corrosion concern associated with it.
- In this talk we described some of the test methods that may be used for each metal.
- We also showed that different test methods can give different results for the same metal alloy.
- Some of these methods may be useful for monitoring the condition of used MWF, but others are too time consuming for routine use.

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