Corrosion Problems and Solutions in Antifreeze Cooling Systems – case study

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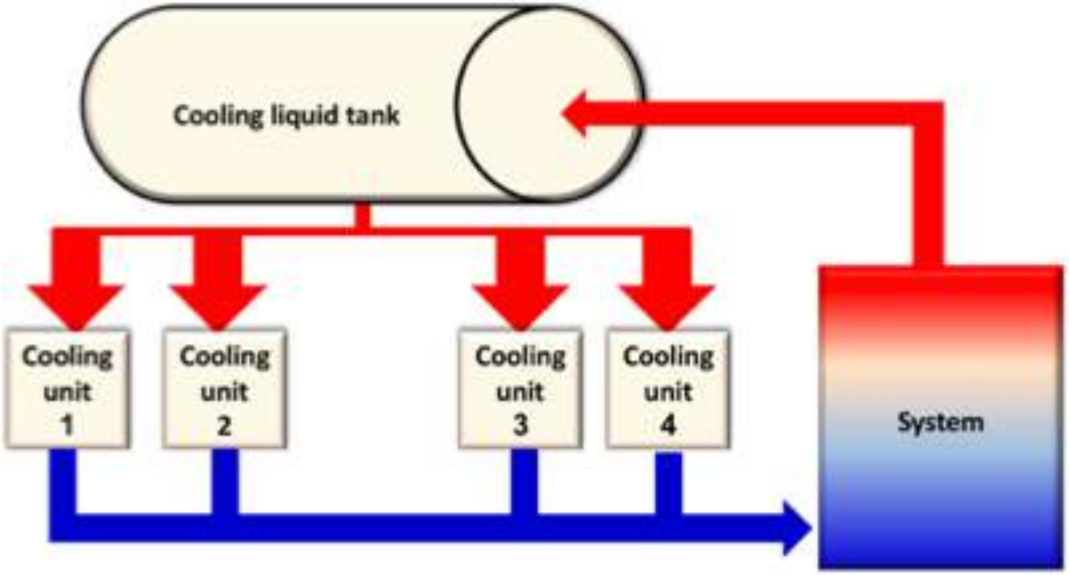
8th of November 2018

Outline

- Case study: conditions
- First signs of corrosion
- Cooling system failure
- Causes
- Case study conclusions
- Predictive and proactive maintenance
- ON-LINE Analysis
- Non destructive analysis
- Conclusions

The Cooling System



- The system was designed for closed cooling of electronic equipment.
- The coolant was an aqueous solution of EG (40%) with corrosion inhibitors.
- The system consisted of heat exchangers (plates and fins) made of aluminum, brass pipes and stainless steel parts.

First signs of corrosion

Failure of cooling system

- Leaking from the cooling plates
- Clogged filter with blue “gel”
- Overheating electronic components
- Short circuits
- Shutdown of all the system

Causes

- Using wrong cooling liquid without corrosion inhibitors leads to system failure.
- General corrosion of brass surface and galvanic corrosion of aluminum components because of accumulation of copper ions on aluminum until full destruction of aluminum parts.

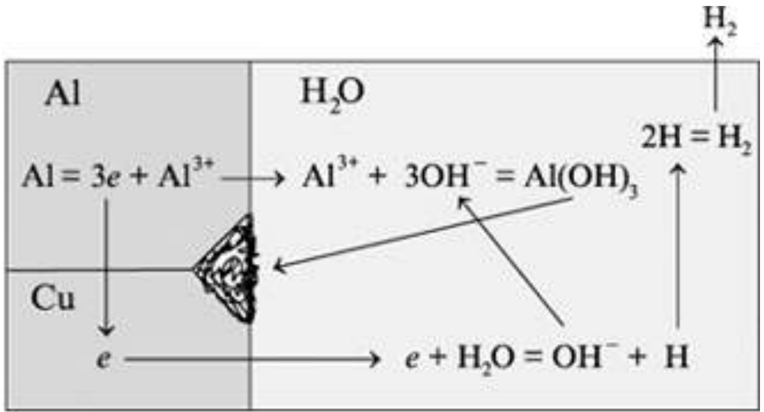
Galvanic corrosion process in the system

All copper corrosion products were directly transferred to the aluminum elements by the coolant.

$$\begin{cases} Cu^{2+}+2e^- \rightleftarrows Cu_{(s)} \; +0.337\,V \\ Al^{3+}+3e^- \rightleftarrows Al_{(s)} \; -1.67\,V \end{cases}$$

$$3Cu^{2+}+2Al_{(s)} \rightleftarrows 3Cu_{(s)}+2Al^{3+}$$

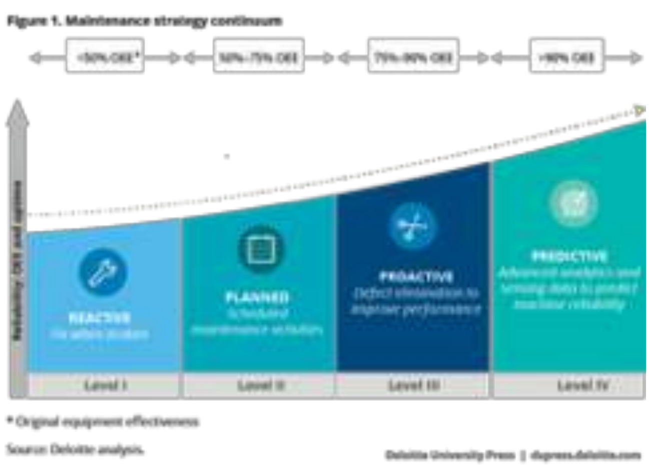
$$E=+0.337-(-1.67)=\mathbf{2\ V}$$



Conclusions and recommendations from the case study

- Proper material compatibility
- Use proper cooling liquid with corrosion inhibitors
  - Technical requirements for coolant
  - Quality control of coolant
- Maintenance strategy

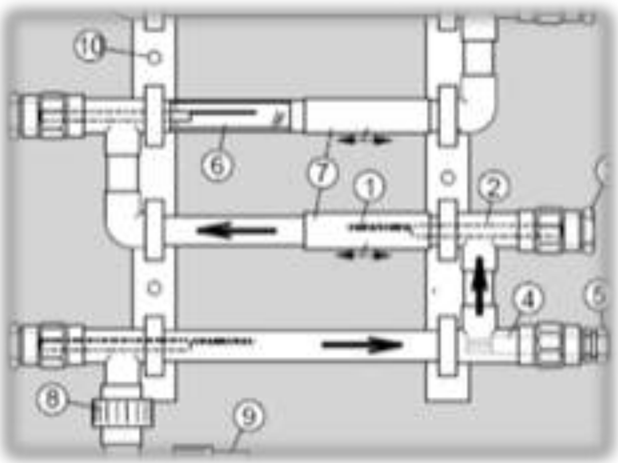
Maintenance strategy



Proactive and Predictive maintenance

- ON-Line monitoring
- Physicochemical analytical analysis
- Non Destructive Analysis
- Ability to “solve” critical problems in the cooling system

ON-Line monitoring

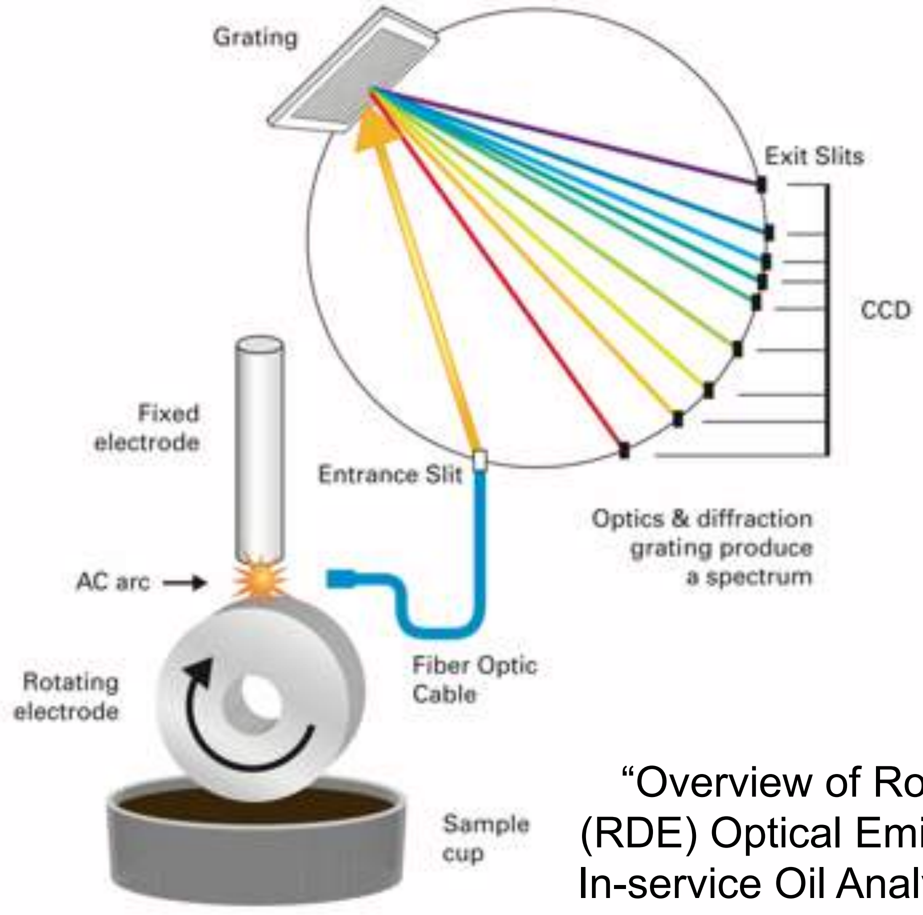


- Weight Loss (coupons)
- LPR (Linear Polarization Resistance) – electrochemical method
- Flow, pressure and temperature control
- On-line warning control

Physicochemical and microbiological control

- Acidity analysis.
- pH
- Additive analysis
- Contamination analysis
- Concentration of EG analysis
- Corrosion test
- Physical analysis
- Electrochemical analysis
- Microbiological Control

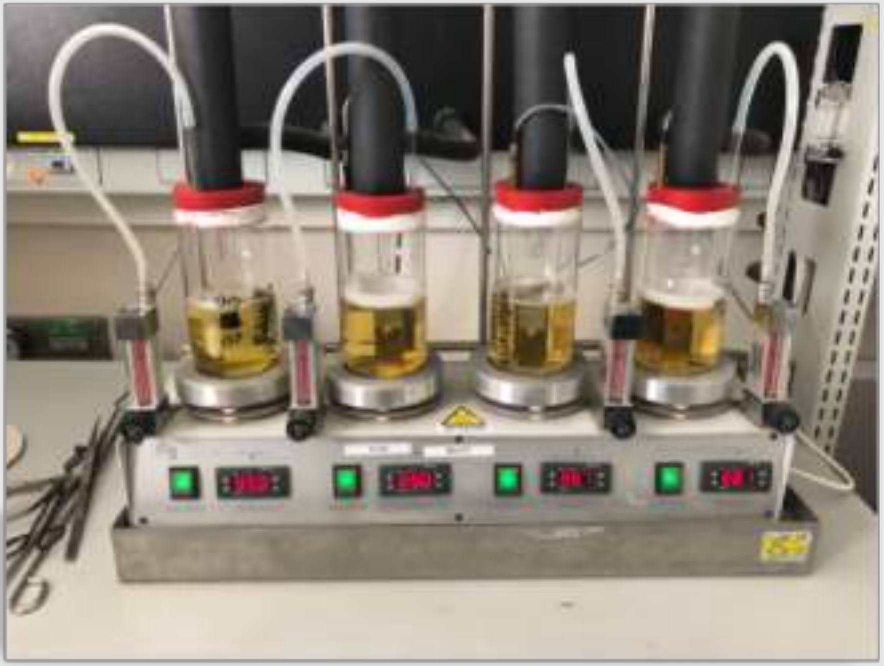
Elemental Analysis of Coolant Using a RDE Emission Spectrometer



"Overview of Rotating Disc Electrode (RDE) Optical Emission Spectroscopy for In-service Oil Analysis", Spectro Scientific

Corrosivity test (ASTM D1384)

- <u>Not complete test</u>
- Long duration: 2 weeks
- Statistic test: 3 cells required for 1 experiment
- Does not reveal problems in long timescale
- Costly test: disposable coupons



Non-destructive testing

- Micro focus X-ray analysis
- Flow and pressure analysis
- Thermo analysis

Technical requirements of the coolant

4.5. General Requirements

4.5.1. The cooling liquid consists of Ethylene Glycol and deionized water that includes additives for corrosion prevention/mitigation of aluminum and copper alloys, austenitic stainless steels, and solder.

4.5.2. The concentration of Ethylene Glycol should be 40 wt% (±1%) in cooling liquid.

4.5.3. The concentration of the raw (original) Ethylene Glycol is at least 99 wt% which is used for the cooling liquid preparation. It is required to present the Ethylene Glycol quality specification.

4.5.4. Deionized water should be used for the cooling liquid preparation. The electrical conductivity of deionized water should be < 0.05 μS/cm (R > 18 MΩ · cm) at 25°C. It is required to present the water's specification when using it to prepare the solution.

4.5.5. The cooling liquid shall not contain any color additives.

4.5.6. The cooling liquid shall not contain chromate and borate compounds.

4.5.7. The cooling liquid should be compatible with following materials:

- EPDM rubber (ASTM D2000-18).
- Copper - CDA 110 (UNS C11000).
- Solder.
- Brass - CDA 260 (UNS C26000).
- Stainless steel 316L (UNS S31603).
- Cast Aluminum – Al 319 (UNS A13190).
- Aluminum alloy – Al 6061T6 (UNS A96061).

4.5.8. The package of the final product (cooling liquid) should be hermetically closed with a seal in an opaque, non-metallic, plastic container with capacity of 20 to 25 liters.

4.5.9. The container shall be equipped with handles.

4.5.10. The testing of existing batches of cooling liquid is less intensive and time consuming than authorizing a new supplier.

4.5.11. The cooling liquid shall be supplied with SDS (former MSDS).

4.5.12. Storage shelf life: minimum 3 years.

4.5.13. The list of examinations and criteria of the constituents/additives of the cooling liquid for the two stages. At the first stage, main additives in the cooling liquid should be analytically examined and defined. At the second stage, a final solution (cooling liquid) should be analytically examined.

4.5.14. The solution should contain three main additives (corrosion inhibitors):

Sodium benzoate: ≥ 1.5 wt%.

Conclusions

- A cooling system is no less important than other systems
- A coolant and its specification must suit each component of the system
- Critical components in the system must be defined
- Maintenance strategy should be defined and kept up

References

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Questions?

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