32th JCOV executive board meeting

CORROSION PHENOMENA IN DEMINERALIZED WATER COOLING CIRCUITS

EDMS 718814 v.1

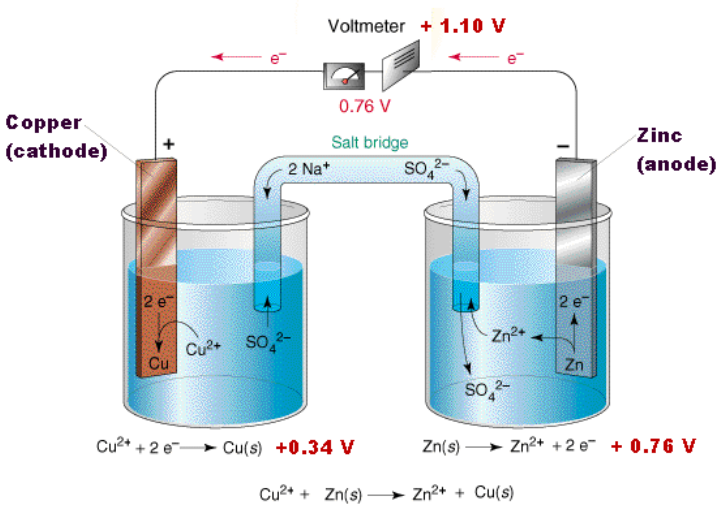
- Main corrosion factors in closed cooling circuits
- Impacts on design choices
- Countermeasures during operation phase

CORROSION FACTORS

Galvanic effect

Thermal efficiency, reduced mass properties or workability exigencies can make the choice of various metals differently advisable according to the application requirements. Result is often the **mixture of metals** inside the same loop.

Galvanic processes can occur between different metals or even different areas of the same metal if in contact with an electrolyte. **Oxidation** will occur at the anode, reduction at the cathode.



Conductivity plays a major role in determining the intensity of galvanic corrosion, as well as the **oxygen content** in the electrolyte and the effective anode-to-cathode **area ratio**.

The smaller the wet surface of **non noble metal** is with relation to the overall, the more dangerous and destructive corrosion phenomena will appear on it.

Ultra pure waters, both demineralised or distilled, in the attempt of compensating their ionic imbalance, are particularly **greedy for gases** as O_2 or CO_2.

A **high electrical potential** between cooled structures and piping can extremely enhance the corrosive effects.

CORROSION FACTORS

Galvanic effect

Resulting **potential differentials** expressed in mV for coupling of metals with different nobility, in presence of aqueous solution at 2% of sodium chloride (NaCl).

Corrosion due to galvanic effect can be neglected for an established potential not exceeding **300 mV**.

Unité : mV
Ne pas dépasser 300 mV.

Métal considéré ↓ / Métal couplé →	Acier inoxydable 304L	Nickel, Ni	Maillechort Cu Zn23 Ni22	Cuivre, Cu	Etain	Alliage Fe-Ni à 25% de Ni	Acier au carbonne XC10	Aluminium 1050A (A5)	Acier au carbonne pour tr. therm.	Alliage AG3	Fer pur, Fe	Chrome, Cr	Zinc, Zn
Acier inoxydable 304L	0												
Nickel	180	0											
Alliage Cu-Zn-Ni	200	20	0										
Cuivre	320	140	120	0									
Etain	550	370	350	230	0								
All. Fe-Ni à 25% de Ni	80	500	480	360	130	0							
Acier au carbonne	750	570	550	430	200	70	0						
Aluminium	840	660	640	520	290	160	90	0					
Acier au carbonne pour tr. therm.	845	685	645	525	295	165	95	5	0				
Alliage AG3	850	670	650	530	300	170	100	10	5	0			
Fer pur	855	675	655	535	305	175	105	15	10	5	0		
Chrome	950	770	750	630	400	270	200	110	105	100	95	0	
Zinc	1150	970	950	830	600	470	400	310	305	300	295	200	0

Source : NFE 25-032

CORROSION FACTORS

Further parameters

1. **Temperature** For solutions with continuous temperature variations over a wide range of values, the electrolytic effect can be stressed, worsening the anodic corrosion. Not expected for TS/CV/DC cooling systems [supply at constant temperature, limited heating up along the sub-detectors circuits].

2. **pH** The farer an aqueous solution is from neutrality conditions, the more corrosion phenomena are relevant. Bacteria, extremely easy to reproduce and accumulate in the dead arms of circuits, makes the pH of a solution alkaline. Absorption of CO_2, which dissolves in water as carbonic acid lowering its pH, causes a diffused corrosion whose gravity progressively rises as pH diminishes. It's in general unadvisable the use of chemicals as anti-tartar, biocide or anti-corrosive into demineralised water circuits for conductivity containment purposes. No significant alteration of the pH is on the contrary expected from the resins normally adopted for the ion exchange mixed bed cartridges.

3. **Oxygen content** Very important factor, setting off the so called corrosion for differential aeration phenomenon if reaching important values in dispersion inside the solution.

4. **Fluid speed** Flow speed going beyond the range 0.5 / 2 m/s is particularly dangerous as easily provoking erosion events. Despite of its high corrosive capacity, demineralised water is advantageous as not fouling at all and presenting very low salinity.

5. **Cleanliness** If metallic particles and machining residuals cause important erosion phenomena, the presence of grease eventually decompounded under radiation can extremely enhance corrosion.

IMPACTS ON THE DESIGN

Metals choice

Due to distinctive chemical aggressiveness of demineralised water and to the galvanic effect anyhow present with low conductivity media, the choice of metals to be used into the different parts of the cooling closed loop shall be compliant with the following non exhaustive list of instructions:

- Metals **compatible** with demineralised water:
  - Stainless steel
  - Copper
  - Aluminium
  - Zinc free bronze

- Metals **non compatible** with demineralised water:
  - Brass
  - Bronze
  - Carbon steel
  - Galvanised steel
  - Chromate steel

- **Allowed metals mixture** in the same circuit
  - Aluminium and stainless steel
  - Copper and stainless steel

- **Mixture of metals** to be avoided in the same circuit
  - Aluminium and copper / copper alloys

IMPACTS ON THE DESIGN

Further items

1. **Instrumentation** Instruments aiming the continuous control of the water chemical properties [conductivity, pH, oxygen content] shall be adopted. It's recommendable to manufacture a portable facility to be easily connected on predisposed circuits diversions, allowing oxygen and pH measurements on isolated portions of fluid.

2. **Resin filters** Mixed bed cartridge filters based on ion exchange are used for both main demineralised water main circuits and dedicated secondary loops with fine temperature tuning. Percentage of mass flow to be circulated inside the filters shall stay in between 20% and 40% of the total according to the application, the demanded conductivity characteristics and circuit conditions.

3. **Air intake restraint** In-depth choice and manufacture of all connections, unions, fittings and weak points of the circuit will allow good tightness of the loop. Most of our stations function according the "leakless principle", with the detectors cooling lines and return tubes in underpressure. Leaks in these parts could impact on water purity and increase its aggressiveness, but an important portion of the incoming air will certainly be pumped outside the circuit.

4. **Flow velocity** Care shall be taken in keeping water speed throughout all circuit sections in the range 0.5 ÷ 2 m/s, in order to prevent erosion phenomena and creation of almost stagnant flow regimes.

5. **Water treatment** The use of chemicals in solution with demineralised water shall be avoided aiming the preservation of the desired conductivity value. Cleaning procedures based on corrosion inhibitors or passivation agents can be envisaged during the yearly periodic maintenance on the systems.

IMPACTS ON MACHINES OPERATION

Filters monitoring, fluid analysis, no dead arms

1. Characteristics set points for our cooling machines will be set between 0.1 and 0.5 µS/cm. This can be achieved by regulating the flow percentage through the filters. The conductivity control instruments, to be correctly chosen in terms of measurement sensibility and adequately positioned inside the loop, shall allow accurate **monitoring of the filters** performances. Consequently, degradation phenomena for both water and resins characteristics can be recognized forestalling consequences on the circuit. Of course a regular replacement of the filters is crucial for this sort of installations.

2. Whenever possible **samples** shall be extracted from the main loop and analyzed to monitor the quantity of metal traces and oxides suspended inside the fluid. Forecasts on the yearly corrosion rate in g/m2 and eventually assessment of adequate countermeasures could follow.

3. As previously mentioned, it's particularly recommendable to **avoid dead arms** where the liquid can be contained almost stagnant for long. This is negative for the water quality as consequently leading to different types of chemical corrosion. It shall be remembered then to empty all parts of the circuit for which long periods of non use are foreseen, drying them up as possible.