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Assignment

Effects of an elysator on the chemical composition of water in a closed cooling system.

The elysator was installed in a realistic use environment. The chosen use environment was the cooling system for ventilation. Molybdenum-containing inhibitor was added to the system earlier and it was not rinsed out. The elysator was installed by the orderer and all measurements and monitoring of the condition of the elysator was conducted by the orderer. VTT conducted the water sampling and the analysing of the samples.

Samples

Water and precipitate samples from the ventilation cooling system

Before sampling, all the valves in the cooling system were opened manually so that the whole system circulated for at least 12 hours before sampling.

A separate branch pipe was made in the flow direction of the piping before the elysator by-pass flow connection. The samples were taken with a silicone hose connected to the sampling branch pipe. The precipitates in the elysator were monitored with the aid of the solids collected in the exhaust valve during each inspection period.

The sampling times were

0 months	8.4.2011	Water samples before the installation of the elysator
1 month	5.5.2011	Water samples and precipitates from the elysator
3 months	6.7.2011	Water samples and precipitates from the elysator
6 months	11.10.2011	Water samples and precipitates from the elysator

Execution and results

Oxygen content, pH, conductivity and redox

The oxygen content was measured during sampling with a portable analyzer. Conductivity, pH and redox were measured in the laboratory with electrodes. The results are given in Table 1 on page 5.

Alkalinity and bicarbonate

Alkalinity was analysed in accordance with method SFS-EN ISO 9963-1 and bicarbonate in accordance with ISO R 741 mod. The results are presented in Table 1 on page 5.

Anaerobic and aerobic bacteria

Microbe cultures were conducted by filtering (100 ml and 10 ml) and by spreading from a dilution series to a plate count agar (PCA). The samples were treated with inactivation solution for 5 minutes. The samples were incubated for three days in a +30 °C temperature cabinet both aerobically and anaerobically, after which the colony-forming units (CFU) were counted per millilitre. The results are given in Table 1 on page 5.

Chloride and sulphate

The chloride- (Cl) and sulphate contents (SO_4^{2-}) of the water samples were analysed ion chromatographically (IC). The results are given in Table 1 on page 5.

Elementary analysis

The iron, copper, calcium, magnesium, silicon and molybdenum contents were analysed with the ICP-AES technique and the potassium content was analysed using a flame atomic absorption spectroscopy. The results are given in Table 2 on page 5.

The semi quantitative x-ray-fluorescence analysis of the exiting residues

The precipitation water samples were decanted and the elemental compositions of the samples were determined by means of a Philips PW2404 X-ray spectrometer using the semi-quantitative SemiQ program. The samples were checked for fluorine (F) and for elements heavier than fluorine; checks were made for a total of 79 elements. The limit of determination in the method is about 0.01% The analysis results are given in Table 3 on page 6. The concentrations of elements not listed in the table were below the detection limit.

Summary of the results

Oxygen content, pH, conductivity and redox

Each measured quantity improved during the test from the point of view of corrosion protection. The oxygen content decreased from starting value 0.6 mg/l to 0.3 mg/l. At 3 months, foaming, caused possibly by the inhibitor, interfered with the measuring of the oxygen content. On the whole, the oxygen content remained on a good level. pH increased from 8.8 to 10.1. Redox, describing the total oxidizing, decreased from 290 to 50.

Alkalinity and bicarbonate

No clear change was detected in alkalinity and bicarbonate.

Anaerobic and aerobic bacteria

No significant change can be detected in bacteria quantities.

Chloride and sulphate

The chloride and sulphate contents did not change.

Dissolved iron, copper, calcium, magnesium, silicon and molybdenum contents

Iron and calcium contents decreased during the tests. A slight decrease was also found in the silicon content. The increase in magnesium content is caused by the dissolution of the magnesium anode in the elysator. No significant changes were found in the contents of other elements determined, although dissolved copper was never found in the water.

Exiting residues

The exiting solids were mainly calcium and iron precipitates. In addition to this, aluminium, zinc and sulphur sediments were found to exit in smaller amounts that increased as the test progressed. The magnesium dissolving from the elysator anode was not found to increase in the precipitate. The molybdenum content increased slightly during the test. Corresponding decrease in dissolved molybdenum was not observed, so it is likely that the exiting molybdenum has been in the piping as a precipitate.

Conclusions

All in all, the changes in the system were positive. Especially the increase in pH, decrease in redox and decrease in oxygen content reduce the oxidizing corrosion in the piping. In addition to this, from the point of view of the functionality of the cooling system, it is positive that the general calcium and iron precipitations exited the system. The exiting of more precious particle metals, such as copper, reduces the pit corrosion risk of the iron pipes on its part. As hoped, the magnesium anode, which is central to the operation of the elysator, had dissolved in the water, which showed as increase in solute magnesium. The magnesium content in the exiting precipitate did not increase during the test.

It has been agreed with the orderer that the test arrangement is to be continued with a longer term follow-up, so that the analyses are to be conducted again 18 months after the beginning of the test.

Espoo, 16 December 2011

Tapio Klasila
Team Leader

Markku Honkala
Team Leader

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Table 1. Water property table

Sample	**Dissolved oxygen, mg/l**	**pH**	Conductivity, mS/m(µS/cm)	**Redox (E_H), mV**	Alkalinity, mmol/l	Bicarbonate, g/l	Aerobic bacteria pmy/ml	Anaerobic bacteria pmy/ml	Chloride, Cl^-, mg/l	Sulphate SO_4^{2-}, mg/l
0 months 08.04.2011, beginning	**0,61**	**8,8**	59,8 (598)	**292**	4,9	0,15	1900	n.d. (< 0,01)	6,4	25
1 months 05.05.2011	**0,45**	**9,0**	60,1 (601)	**140**	4,9	0,13	6300	0,15	6,1	26
3 months 06.07.2011	**0,83 (foaming)**	**9,7**	59,8 (598)	**101**	5,0	0,45	1190	0,39	6,5	26
6 months 11.10.2011	**0,29**	**10,1**	58,7 (587)	**47**	5,0	n.d.	9880	0,04	6,1	26

Table 2. Element contents of the water sample

Element	0 months, beginning	1 months 05.05.2011	3 months 06.07.2011	6 months 11.10.2011
Iron (Fe), mg/l	**1,4**	**1,1**	**0,53**	**0,29**
Copper (Cu), mg/l	< 0,3	< 0,3	< 0,3	< 0,3
Potassium, (K), mg/l	2,2	2,2	2,1	2,0
Calcium (Ca), mg/l	**24**	**21**	**14**	**8,7**
Magnesium (Mg), mg/l	**1,6**	**4,9**	**11**	**16**
Silicon (Si), mg/l	**1,4**	**1,4**	**1,2**	**1,0**
Molybdenum (Mo), mg/l	160	160	150	160

Table 3. Results of the semi-quantitative X-ray fluorescence analysis of the precipitate exiting from under the elysator (%).

Element	1 month 05.05.2011 precipitate	3 month 06.07.2011 precipitate	6 month 11.10.2011 precipitate
Fluorine, F	-	2,2	-
Sodium, Na	0,20	0,37	0,15
Magnesium, Mg	**1,4**	**0,83**	**1,4**
Aluminium, Al	**0,28**	**0,63**	**1,0**
Silicon, Si	**1,6**	**7,9**	**4,9**
Phosphorus, P	0,03	0,04	0,09
Sulphur, S	**0,06**	**0,13**	**1,9**
Chlorine, Cl	0,03	0,02	0,04
Potassium, K	0,03	0,22	0,16
Calcium, Ca	**22**	**33**	**9,7**
Titanium, Ti	1,0	3,8	1,2
Chromium, Cr	0,19	0,11	0,08
Manganese, Mn	0,36	1,8	0,55
Iron, Fe	**24**	**14**	**36**
Nickel, Ni	-	0,03	0,06
Copper, Cu	**0,81**	**0,77**	**7,3**
Zinc, Zn	**0,01**	**0,11**	**0,47**
Strontium, Sr	0,01	0,02	-
Zirconium, Zr	-	0,03	-
Molybdenum, Mo	**0,48**	**0,68**	**0,72**
Lead, Pb	0,43	-	-
Barium, Ba	-	-	0,05

"-" Concentration is below the limit of determination.