STUDY OF CORROSION CAUSE ON EVAPORATOR TUBES IN THE COMBUSTION CHAMBER OF THE STEAM BOILER

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Abstract

The paper solves the cause and character of the damages of tubes, or evaporator tubes made of refractory carbon steel L290NB, used for the evaporators of combustion chambers of steam boilers used for production of steam, and necessary for subsequent production of electricity. Based on the evaluation of steel samples defected by perforation with incrustation deposit, the mechanism degrading the material of evaporator boiler tubes was discovered. The higher temperature in the combustion chamber, higher content of alkalizing solution of P_2O_5 and presence of copper ions are the cause of such degradation.

Keywords: Surface, corrosion, tube, analysis, steam

1. INTRODUCTION

Corrosive degradation of the boiler evaporator tube material is a serious problem which has an ultimate impact on reduction of total steam production, and subsequently electricity production. A fault of evaporator tubes leads to unstable performance, which also results in the expenditure of considerable costs for repairs.

Corrosive attack of the evaporator tubes always occurs on the inner surface of the tubes which are made of structural carbon steel L290NB and are part of the combustion chamber of the steam boiler with 10MP operating pressure, in which demineralized chemically treated boiler water circulates along with the alkalizing solution of Na_3PO_4. The outer surface of the evaporator tubes is heated by the flue gas with temperature up to 1200°C, leading to the formation of saturated steam, which is changed to output superheated steam in the boiler superheater. Further, the steam is used to heat water in a three-stage brass heater. Subsequently, the steam flows through the copper condensers into steel pressure vessels, where it is, together with demineralized water, dosed into the boiler with the addition of alkalizing solution of Na_3PO_4.

Corrosive attack and formation of corrosive incrustation always occurs on the inner walls of tubes in areas of uneven and non-homogeneous surfaces, which are the areas of welded joints. Tube leakage is always accompanied by leakage of control fluid into the area of the boiler combustion chamber. Violation of the tube integrity leads to the forced shutdown of facilities producing superheated steam and electricity. Based on the above facts, the experimental tests of mass and spectral analysis of corrosive incrustation were carried along with the study on how chemical treatment of demineralized boiler water affects the corrosion damage. Furthermore, the effect of temperature on corrosion damage of tubes has also been evaluated.

2. RESULTS OF EXPERIMENTAL TESTS

2.1. Spectral and mass analysis of corrosion incrustation

Spectral and mass analysis showed the rate of corrosion damage to the wall of the tube walls in form of mesh cracks with significant deposits of copper at the site of damage. Damage is always detected in the area of the tube wall surface inhomogeneity, i.e. in the place of welded joint with localization in the direction of media flow, behind the welded root.

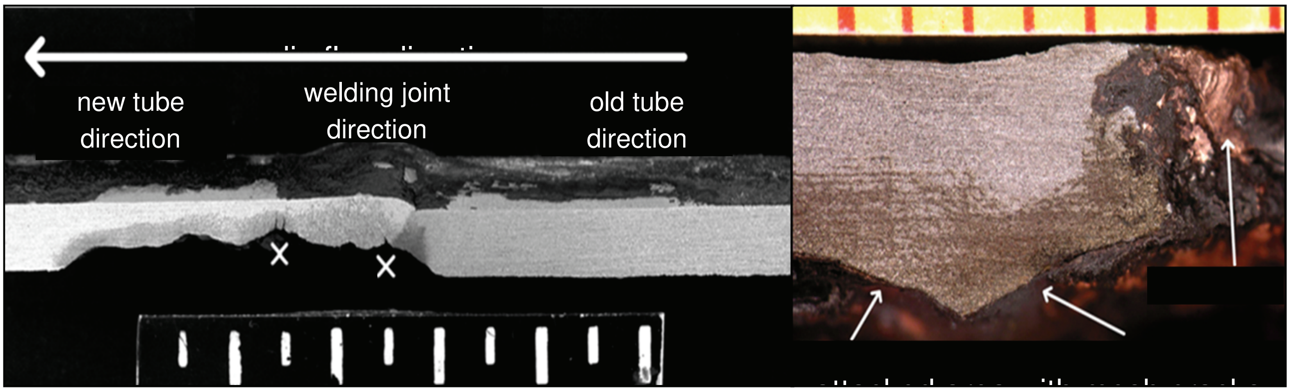

Figure 1 Photos of damaged tubes, enlarged 4x/8x [3]

Microanalysis of samples of the inner walls of the tubes is shown in **Table 1** below. The results confirm increased content of oxygen, copper, sodium, phosphorus and calcium. This is an inner state of the tube wall, in which demineralized boiler water treated by phosphate mode flows, and which is contaminated with the elements involved in speeding the overall degrading corrosion process and the formation of incrustations.

Table 1 Microanalysis of tube inner walls incrustations [4]

Microanalysis of tube inner walls incrustations										
chem. element	**Ca**	**Mg**	**P**	**O**	**Si**	**S**	**Fe**	**Cu**	**Mn**	**Na**
[hm%]	1.72	1.49	1.49	29.61	0.48	0.53	70.03	27.8	1.84	15.48

From the incrustation microanalysis shown in **Figures 3, 4, 5 and 6** results that in addition to high parameters of the common oxide phases of magnetite and hematite, the phases associated with aqueous phosphate mode or phase of Ca, Mg, Cl have also been found. Element highly present during collection at all positions, was copper, both in the metal and oxides forms.

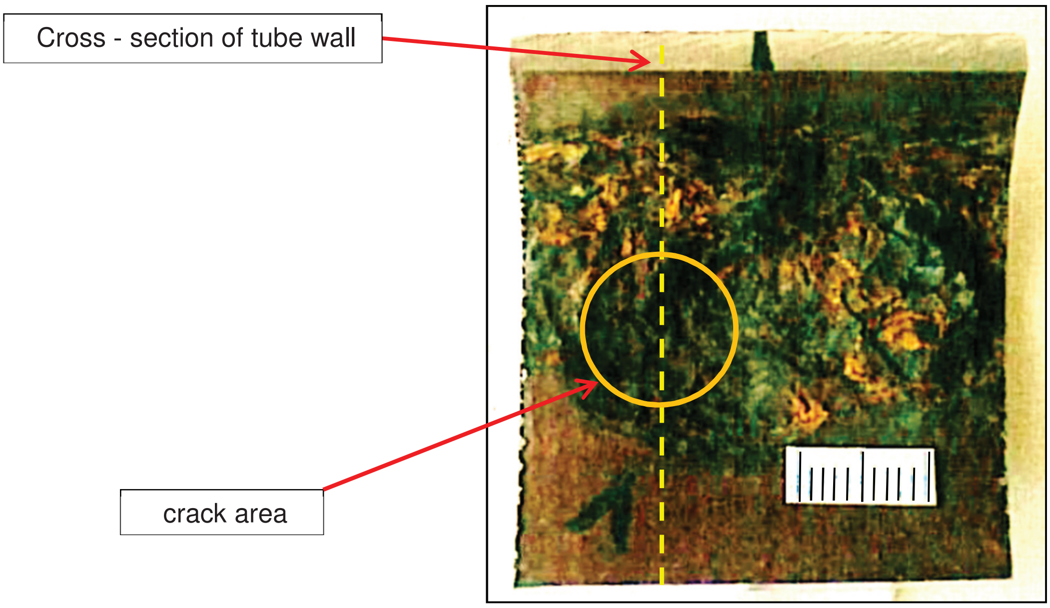

Figure 2 Photo of corrosion of tube inner wall **incrustation**, enlarged 4x [4]

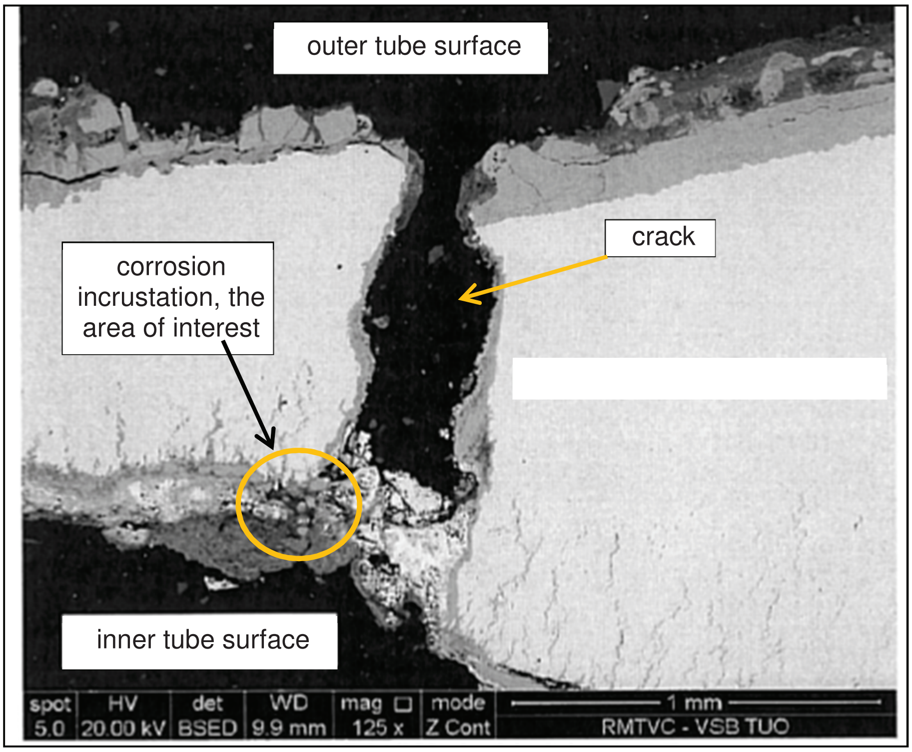

Figure 3 Crack - microanalysis of tube surface, enlarged 125x [4]

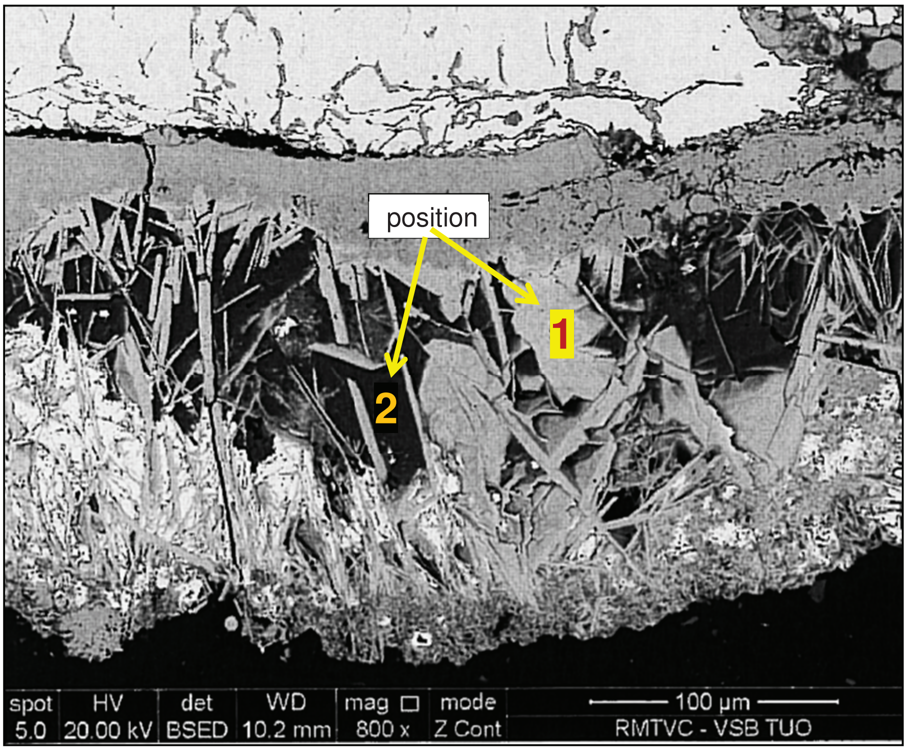

Figure 4 Spectral microanalysis of tube surface - position 1 and 2, enlarged 800x [4]

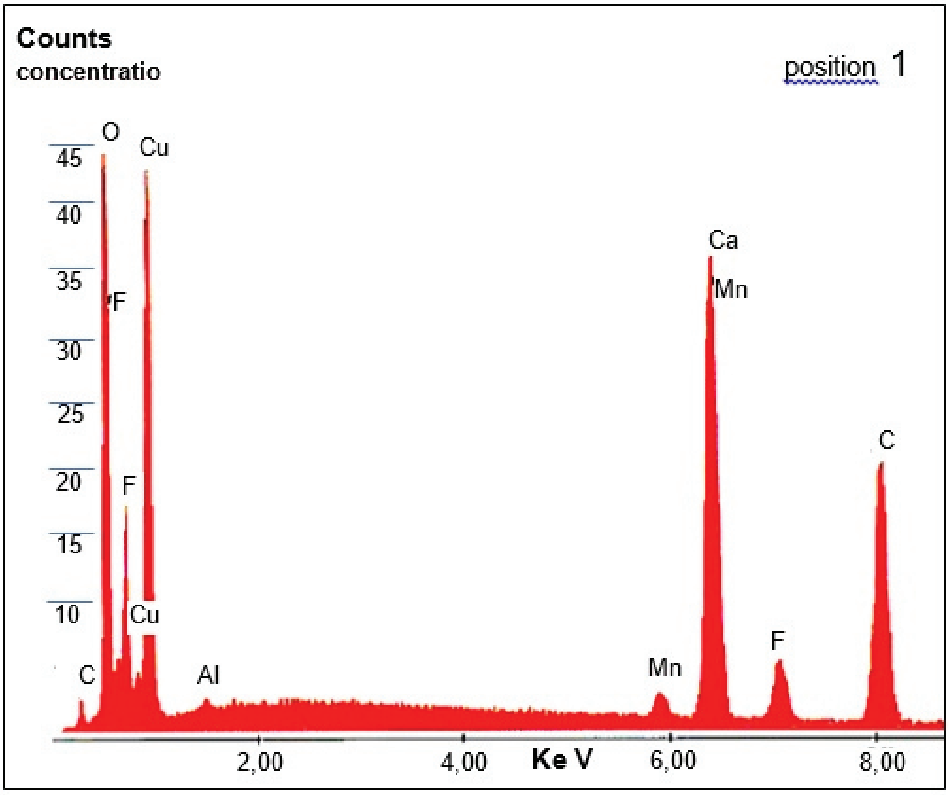

Figure 5 Spectrum of position 1 [4]

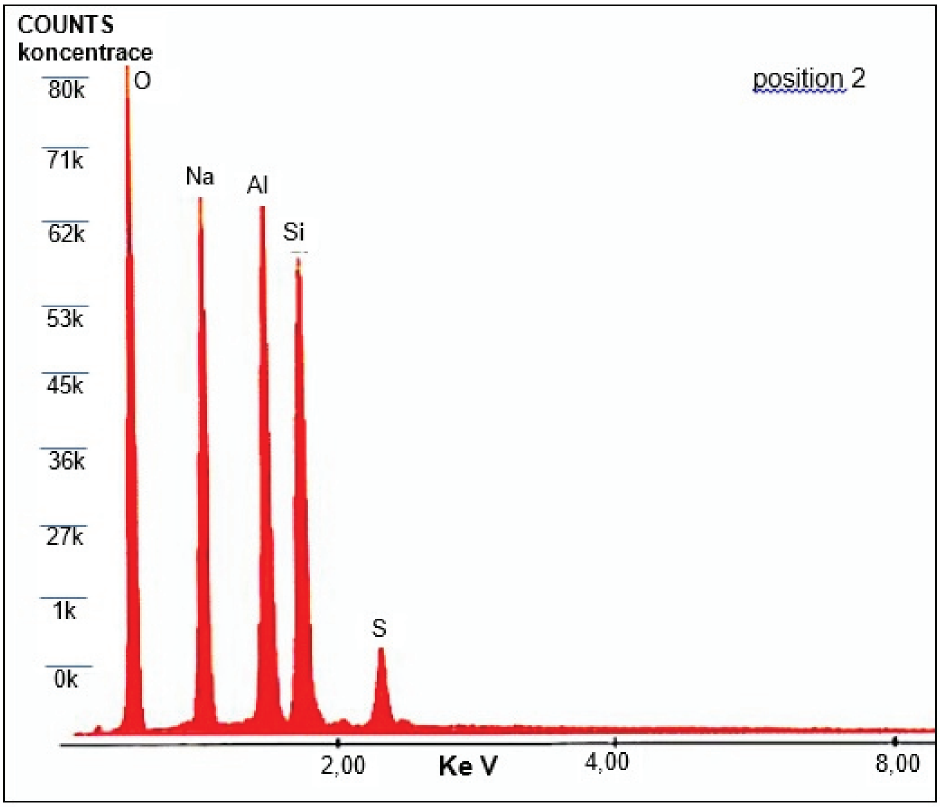

Figure 6 Spectrum of position 2 [4]

Mass analysis of corrosive incrustations from **Figure 7** is stated in **Table 2**.

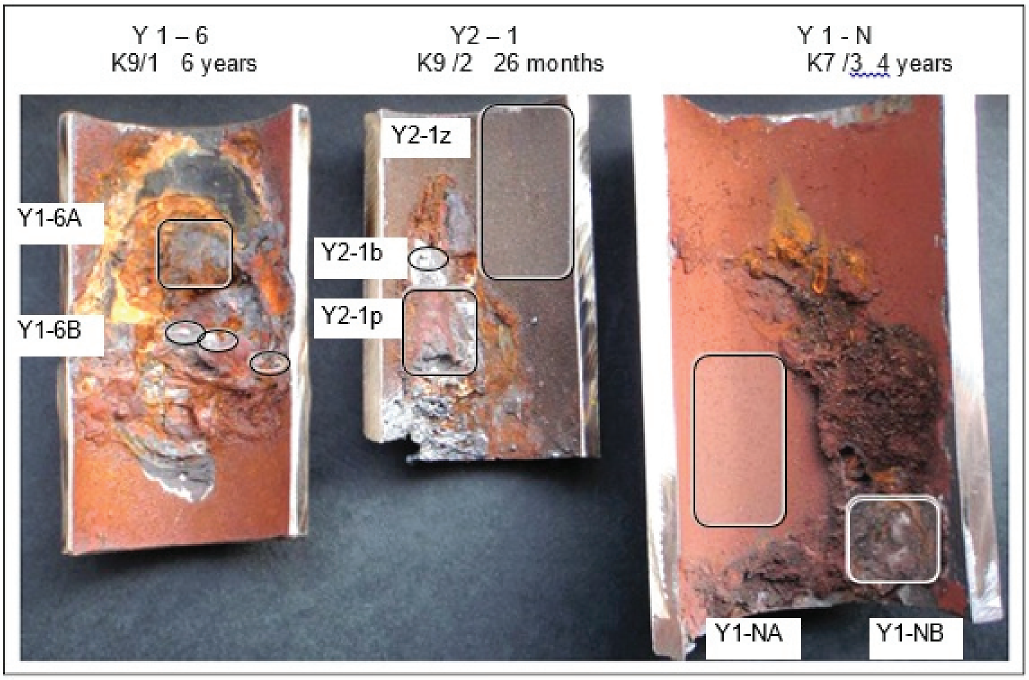

Figure 7 Corrosive incrustation of tube surface [2]

Table 2 Results of mass analysis of corrosive incrustations [2]

Tube origin/oper. time	**K 9-2 / 26 months**			**K 9-1 / 6 years**		**K 7 - 3 / 4years**	
cons.:	**free surf.**	**blister**	**white spot**	**scales**	**white spot**	**free surf.**	**crust**
Content, % wght. Sym.:	y2-1z	y2-1p	y2-1b	y1-6a	y1-6b	y1-na	y1-nb
Na	0.76	4.1	16	0.53	18	0.53	
Mg	0.32	0.15		0.14	0.3	0.46	0.63
Al	0.54	2.8	11	0.33	9.3	1.4	0.32
Si	0.52	2	11	0.83	7.7	0.54	0.99
P	0.43	0.25	0.08	0.48	6	5	0.84
Si	0.19	0.1	0.17	0.13	0.35	0.086	0.089
Cl	0.09	0.55	4.2	0.03		0.14	0.024
Ca	0.35	0.14	0.037	0.16	0.6	7.5	0.74
Fe	27	75	37	77	38	48	47
Cu	4.3	7.2	5.8	9.4	18	31	48
Zn	0.24	0.075	0.2	0.092	0.315	0.51	0.19

2.2. Chemical treatment effect of boiler water

Demineralized water containing phosphate composition, wherein the standard pH water value is between 9.2 < pHLIM < 9.7, has a significant effect on creation of corrosion [6, 9].

During evaluation of boiler water alkalinity has been found that there is unevenness in the content of alkalizing solution of P_2O_5 in the boiler water, which resulted in a deflection of pH values between 4 and 11.4 leading to a rapid deterioration of tube surface. Degrading process was faster at values of pH 4 and long term at pH 11.4.

2.3. Measurement of temperature fields in the boiler combustion chamber

The flue gases that heat the boiler water in the evaporator tubes in the combustion chamber may have a maximum temperature of 1200 °C according to the boiler structure. Use of different types of fossil fuels has resulted in a different flue gas temperature. The measurements of the temperature at individual elevations of boiler combustion chamber have shown the temperature of flue gas up to 1644 °C. Due to this the perforative damage of evaporator tubes with corrosive degradation of the tube inner walls has occurred.

2.4. Mechanical properties of the material of damaged tubes

To check the changes of the mechanical properties of the tube material, the samples from various positions were taken for bend impact testing. The experiments carried out during dynamic load showed that the test pieces taken from the refraction area show significantly lower impact values (2^{-12} J) compared to intact areas of the tube material (12.5 - 13 J). The evaluation of fracture surfaces, see **Figure 8** confirmed the fracture surface material of the tube damaged area is fine-grained, without significant macroscopic deformation with high frequency of very small cracks. The fracture surface of the test piece from the undamaged section of the tube showed signs of persistent damage with moderate shear edges, see **Figure 8**.

Because the damaged inner walls of the tubes were in contact with steam, the diffusion of hydrogen into the tube material was easier and accelerated the degrading process. By means of thermo evolutionary method (LECO analyzer) it was found that in the undamaged part of the tube the content of hydrogen was H2 = 1 $mg.kg^{-1}$, compared to the damaged part where much higher values of H2 = 10 to 60 $mg.\ kg^{-1}$ were found.

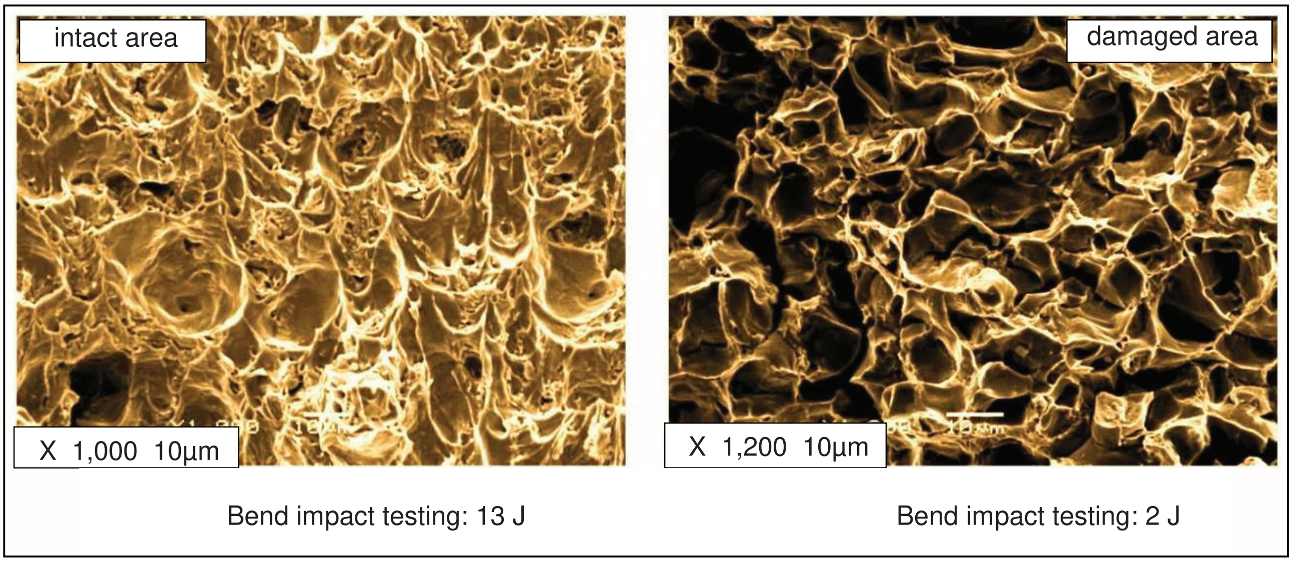

Figure 8 Photos of fracture surface of samples from damaged and intact area. [2]

3. CONCLUSION

Based on the results of experimental tests it was found that due to uneven dosing of alkalizing solution the content of the monitored amounts of P_2O_5 increases during the production of saturated steam. It remains in the boiler water together with ions of copper released from brass and copper tubes of the boiler supporting device. Due to the presence of copper ions the corrosion mechanism of the tube inner walls is influenced and accelerated. From the results of empirical measurements it was shown that at the same time the process of corrosive attack is supported by the heat load of the tube material exposed to flue gas temperature to 1600° C, and by corrosive effect of increased hydrogen content. Reduction of P_2O_5 content and Cu ions together with the heat load results in reduction of corrosive attack [2, 5, 7].

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