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Finnish Recovery Boiler Committee

SOTU II PROJECT

Corrosion Chemistry on the Flue Gas Side of Recovery Boilers at High Steam Values: 1. Corrosion Tests of Superheater Materials

Report on laboratory work performed at Åbo Akademi University 2004-2005

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Preface

This report is part of the Finnish Recovery Boiler Committee's project The Recovery Boiler in the Future II (SOTU II), partly financed by the Finnish Funding Agency for Technology and Innovation (Tekes). The objective of the SOTU II Project, with a planned duration of three years, 2004-2006, is to study the possibilities of achieving a significant increase in recovery boiler steam values compared with the present level, thus reaching a higher power-to-heat ratio in electricity generation.

The report presents the results of the extensive laboratory work aimed at studying the chemistry of superheater corrosion, as part of Åbo Akademi University's subproject Corrosion Chemistry on the Flue Gas Side of Recovery Boilers at High Steam Values. The laboratory tests were made in isothermal laboratory ovens, where it was possible to follow the progress of corrosion with brief tests under controlled conditions and thus clarify the degree to which the corrosion of selected superheater materials depends on the composition of the salt deposit on the superheater surface.

The research at Åbo Akademi University was led by Docent Bengt-Johan Skrifvars and Professor Mikko Hupa. Docent Rainer Backman provided expert advice throughout the project. M.Sc. Linus Silvander was responsible for carrying out the laboratory tests in practice.

A steering group presided by Keijo Salmenoja, Metsä-Botnia Oy, and coordinated by Esa Vakkilainen, Jaakko Pöyry Oy, supervised the project on behalf of the Finnish Recovery Boiler Committee.

The authors wish to thank all those participating in the project for the inspiring cooperation and hope that the interesting results achieved meet the expectations placed on the project.

1. Background

This work carried out at Åbo Akademi University is part of the Finnish Recovery Boiler Committee's project The Recovery Boiler in the Future II (SOTU II). The objective of the project is to study, by various methods, the possibilities of increasing the power-to-heat-ratio in the generation of electricity in recovery boilers through a significant increase in steam values from the present level.

The plan for the Åbo Akademi University subproject was based on the university's preliminary report presented to the Finnish Recovery Boiler Committee (Hupa, M., Backman, R., Risks of Corrosion in Recovery Boilers at High Steam Values – A Preliminary Report on Corrosion Mechanisms and Research Needs, 15 October 2002).

The general conclusions drawn in the preliminary report of Åbo Akademi University were the following:

"In this study, a brief review was made of the present situation of research in corrosion on the flue gas side of recovery boilers. The objective was to clarify which corrosion types are critical and in which direction research should be channelled to raise the values of boiler steam-water circulation significantly from the present level.

According to the report, the most essential research needs relate to superheater corrosion. The report points out that research should be especially focused on further analyses of the role of chlorine and on identifying the corrosive effects of deposits with a low chlorine content.

Also, bottom tube corrosion needs to be further researched by clarifying more in detail the formation of a concentrated bottom deposit and its melting behaviour.

Åbo Akademi University is prepared to participate in the Finnish Recovery Boiler Committee's project and to make a proposal for a more detailed research plan concerning the open questions on corrosion chemistry presented above. We are also prepared to check the follow-up of North American research and know-how within the framework of the project."

Based on the preliminary report, Åbo Akademi University made more detailed plans for its subproject Corrosion Chemistry on the Flue Gas Side of Recovery Boilers at High Steam Values, which the Finnish Recovery Boiler Committee commissioned in February 2004.

This report presents the results of the laboratory tests made in the Åbo Akademi University project. The tests started in the spring of 2004 and finished in late spring 2005. During the tests a measuring method was developed making it possible to map the corrosive effect of different salt deposits on selected superheater steel grades based on an exposure time of approximately one week.

The objectives of the tests were to:

- clarify the effect of potassium and chlorine contained in the alkali salt deposit on the superheater surface on superheater material corrosion
- study the differences between selected steel grades in corrosion induced by alkali salts

- gain more insight into the mechanisms of alkali salt corrosion, especially the connection between salt mixture melting and corrosion

In the project, a total of 264 exposure tests for six different steel grades and six different salt mixtures were made under different conditions.

2. Experimental design

2.1. Testing equipment and preparation of samples

The experimental design developed during an earlier Tekes project ("Tulikorr") based on tube furnaces was used in the tests. In the tests, steel samples with a deposit of selected salt on top were placed in a special-purpose sample holder and introduced into the tube furnace at a controlled standard temperature. In the course of the project, the method was further developed and the number of parallel tests could be increased from the earlier five to ten (at the end of the subproject even to fifteen), without any significant lengthening of the test time. Also, the improved corrosion measuring methods made it possible to study corrosion marks not only on the selected spots on the sample disk but also along the entire sample cross section (panoramic imaging).

The tests were performed on square 20 x 20 x 5 mm, preoxidised steel specimens. After preoxidation in furnace air for 24 h at 200°C, the specimen surface was covered with a selected salt deposit made from pure chemicals by mixing. In order to achieve the most homogenous result possible, the mixture of Na₂SO₄, K₂SO₄ and NaCl source materials was premelted, refrigerated and crushed into powder. Particles with a size of 125-150 μ m were sifted out of this powder for the test.



Figure 1. Different phases of corrosion tests on steel samples; Figure to the left: Preoxidised sample with a synthetic deposit Figure in the middle: Sample after exposure to corrosion Figure to the right: Sample cast in epoxy, sawn and polished for SEM analysis

The steel samples were exposed to corrosion in a tube furnace at different temperatures; 450, 500, 525, 550, 575 and 600° C. The gas atmosphere was air, the general exposure time being one week (168 hours). However, certain tests were carried out with exposure times of 72 and 840 hours.

After the corrosion tests the samples with their deposits were cast in epoxy resin, sawn with precision saw and their cross-section surface was polished. Finally the cross-section surface was analysed with a scanning electron microscope with energy dispersive X-Ray analyser (SEM/EDXA).

2.2. Corrosion measurement

Corrosion measurement consisted of measurement of steel corrosion, i.e. measurement of the oxide layer thickness after exposure to corrosion. Of the entire cross-section surface, typically seven SEM-BSE (back-scatter electron) microscope images were taken. These images were combined with an image processing program into a panoramic image. Figure 2 presents an example of a typical panoramic image and of a coloured panoramic image produced by an image processing program.



Figure 2. Figure above: Seven different SEM-BSE cross-section images of a steel sample after corrosion test combined into a panoramic image.

Figure below: Cross-section image produced by an image analyser, where red represents steel, light green the oxide layer and blue the epoxy resin used in casting.

The portion of steel exposed to corrosion (oxide layer) was identified in the images and its thickness was measured with an image analyser. As a result, the thickness of the oxide layer under different conditions was obtained across the whole cross-section surface of the sample. Figure 3 shows the oxide layer thickness of the above sample across the entire cross-section surface.



Figure 3. Oxide layer thickness measured based on the above SEM-BSE panoramic image across the entire.

Finally the reported oxide layer thickness was calculated as a mean value of the thickness of the oxide layer under the salt deposit. In addition, the median value and distribution were calculated. The maximum oxide layer thickness and the measured thickness of the sample before and after corrosion tests were also documented. All numerical values are shown in Table 1.1, Annex 1.

The result images (Figures 7-16) in the report include two types of zero oxide layer thickness, i.e. 1) measured values and ii) assumed values. The thickness of the oxide layer was assumed to be zero (alternative ii) if

- a zero oxide layer thickness was measured at the following higher exposure temperature,
- there was one or more test points between two zero oxide layer thickness measurements (on the temperature and/or salt axis)

These assumed zero oxide layer thicknesses are compiled in Table 1.2, Annex 1.

X-ray microanalysis was performed on one microscope image area in each sample (generally the central image area), which gave the position of the key chemical elements in the analysed point on the cross-section surface. These results are shown in Annex 2.

Figure 4 shows all 264 oxide layer measurements arranged in order of ascending mean value. The corresponding median value, the most frequent value measured in one sample and the maximum value have also been plotted into the figure. The figure indicates that the mean values (black diamonds in Figure 4) and the median values (white squares) are almost superimposed, i.e. both illustrate the progress of corrosion in the same way. There are, however, some isolated deviations. The most frequent value (ticks in Figure 4) deviates somewhat from the mean and median values and is always lower. The maximum value (triangles) clearly deviates from the rest of the values, a fact which has not been used to describe corrosion in this report.

In the following, all given values of the oxide layer thickness are mean values. All numeric values are also presented in Table 1.1, Annex 1.



Figure 4. Mean oxide layer thickness, median, maximum and most frequent values of all samples in order of ascending mean value.

In addition, 34 repeatability tests were made in the test series. Figure 5 shows these repeatability tests in order of ascending mean value. Most generally repeatability tests were made once, but in some separate cases twice (Figure 5, 2, 14, 15, 16, 28, 30 and 32) or three times (Figure 5, 7 and 19).



Figure 5. Repeatability tests of oxide layer thickness measurements in the samples in order of ascending mean value.

The mean value describes satisfactorily the individual measurement values, although there are some deviations.

2.3. Steel grades

The six steel grades described below were selected for the corrosion tests. Table 1 and Figure 6 present the composition of the steels in order of descending iron content. The first two steel grades are ferritic steels with a relatively low chrome content. The third, fourth and fifth grades are austenitic steels. In the fourth and fifth steel grades the combined share of chrome and nickel is already over half. The sixth grade is a nickel-based almost iron-free steel. The selected steel grades represent well the most important materials with different high temperature corrosion.

Table 1. Composition of the steel grades used in the corrosion tests /Science Direct/.

Ste	eel	10CrMo 9-10	T91	Esshete 1250 paino-%	Sanicro 28	HR11N	Sanicro 63
Fe		95-97	87-90	61-70	31-41	24-34	0-5
	Cr	2-2.5	8-9.5	14-16	26-28	27-30	20-23
	Мо	0.9-1.1	0.85-1.05	0.8-1.25	3-4	0.5-1.5	8-10
	Mn	00.6	0.3-0.6	5.5-7	0-2.5	0-2	0-0.5
	Si	0-0.5	0.2-0.5	0.2-1.2	0-1	0-0.6	0-0.5
	Ni		0-0.4	9-11	29.5-32.5	38-42	58-69
	V		0.18-0.25	0.15-0.4			
	С	0-0.15	0.08-0.12	0.06-0.15	0-0.03		0-0.1
	Nb		0.06-0.1	0.75-12.5).75-12.5		3.15-4.15
	Ν		0.03-0.07			0.1-0.2	
	AI		0-0.04				0-0.4
	Ρ	0-0.03	0-0.02	0-0.04	0-0.03		0-0.015
	S	0-0.03	0-0.01	0-0.03	0-0.03		0-0.015
	в		(0.003-0.00	9		
	Ti						0-0.4
	Со						0-1
							•
Weight-%	100 - 80 - 60 - 40 - 20 -						■ Res ■ Nb ■ Mn ■ Mo ■ Ni ■ Cr ■ Fe
	,o ^c	INO ²¹⁰	101 455 Mate	2250 sail	2 ² 2 ²	rt saticio	ό ²

Figure 6. Composition of the steel grades selected for the corrosion tests in order of descending iron content.

2.4. Salt mixtures

All together six salt mixtures were used in the tests. In addition, reference tests were made with all steel grades at all temperatures in pure air completely without the effect of the deposit.

The salt mixtures were labelled "Ash 5 - Ash 10". The base of the salt mixtures was pure sodium sulphate (Na_2SO_4), mixed with potassium and chlorine. The mixtures were selected in a way that clearly illustrates the effect of chlorine and potassium both alone and combined. The composition of the ashes is qualitatively described below.

5: pure sodium sulphate
6: (5) + potassium sulphate
7: (5) + some chlorine (no potassium)
8: (5) + potassium sulphate + some chlorine
9: (5) + more chlorine
10: (5) + potassium sulphate + more chlorine

Because of their different composition, the melting behaviour of the salt mixtures is very dissimilar. The melting behaviour of the mixtures was determined with Åbo Akademi University's theoretical melting model and was, in addition, confirmed with differential thermal analysis measurements (DTA).

Table 2. Composition of the synthetic deposits (salt mixtures) used in the corrosion tests and first melting points measured by DTA.

Salt	5	6	7	8	9	10
			weigh	nt-%		
Na⁺	32.37	24.77	32.40	24.79	32.52	24.88
K+	0.00	10.53	0.00	10.54	0.00	10.58
SO42-	67.63	64.69	67.35	64.42	66.20	63.31
Cl	0.00	0.00	0.29	0.25	1.29	1.25
T_{0. DTA}	884°C	834°C	625°C	526°C	621ºC	522°C

Table 2 details the composition of the salts and shows the measured first melting points. Figure 7 illustrates the theoretically calculated melting curves of the salts as a function of temperature. The mixtures clearly have different melting zones. The chlorine-free mixtures (Ashes 5 and 6) do not start to melt until at a temperature of over 830° C. Adding of chlorine lowers the start of sodium sulphate melting - the first melting point T₀ - by some two hundred degrees to approximately 620° C (Ashes 7 and 9). When both chlorine and potassium are added to sodium sulphate, first melting occurs already at 530° C, approximately (Ashes 8 and 10). The amount of melt at the first melting point is all the smaller the lower the content of chlorine in the mixture. In Mixture 8, melt is formed already at an approximate temperature of 530° C, but the percentage of the formed melt at that temperature is under one per cent. In Mixture 10 a higher percentage of melt is formed at the first melting point. (See Figure 7).

Earlier superheater corrosion studies have revealed that molten phase formation in immediate contact with superheater steel seems to induce especially strong corrosion. However, it has remained unexplained to what degree corrosion occurs also when there is no direct molten phase in the deposit and steel interface.

Thus, in addition to giving information about the effect of the presence of potassium and chlorine on corrosion, the selected six salt mixtures also provide an interesting comparison of the effect of the molten phase on corrosion speed.



Figure 7. Calculated melting curves of the salt mixtures used in the tests.

3. Results

In the following, the results of the corrosion tests are shown as bar diagrams. The vertical axis gives the thickness of the formed corrosion product deposit given as a mean value of the entire cross section. The results are presented separately for each one of the six steel grades, so that the first horizontal axis indicates the exposure temperature and the second the salt mixture deposited on the steel surface. In all tests, the reference test is exposure in pure air without any salt deposit. All the tests presented in Figures 8-13 have an exposure time of one week (168 hours).

More detailed results of all tests are given in Annex 1. Annex 2 presents, in addition, examples of microscope images of the corrosion layer between each steel type and salt deposit.

3.1. Steel 10CrMo9-10

The oxide layer thicknesses of steel 10CrMo9-10 under different conditions are presented in Figure 8. The figure gives rise to the following observations:

- This steel grade oxides significantly even without any salt deposit in pure air at a temperature above 500°C (closest bar line).
- A deposit consisting only of sodium sulphate somehow seems to protect the steel from oxidising (second bar line) and oxidation seems to shift to higher temperatures. It is, however, unclear if this result has any meaning in practice at longer exposure times with a real deposit.

- The presence of potassium in the deposit seems to increase oxidation somewhat (third bar line). The oxide layer clearly starts to grow at a temperature above 500°C.
- The presence of chlorine clearly decreases oxidation starting temperature. As low a wt% as 0.2 of salt in the mixture (Salt 7) lowers this temperature to below 500°C (fourth bar line).
- The simultaneous presence of chlorine and potassium deteriorates the situation further and a clear increase in the oxide layer can be observed at as low a temperature as 450°C.
- The first melting point of mixtures containing chlorine does not seem to have any direct interconnection with oxidation starting temperature, but oxidation is strong already below first melting temperatures also in mixtures containing potassium (compare pair Ash 7 Ash 8, or pair Ash 9 Ash 10).



Figure 8. Mean oxide layer thickness of Steel 10CrMo9-10 as a function of temperature and salt mixture.

3.2. Steel T91

Figure 9 exposes the oxide layer thicknesses of Steel T91 under different conditions. Based on the figure, the following observations can be made:

- This steel endures oxidation at very high temperatures. High temperature oxidation does not proceed without a salt deposit in the measured temperature range of 450° C 600° C (closest bar line). The oxide layer is thin (1 3 µm) and seems to protect the steel effectively from further oxidation.
- A deposit of only sodium sulphate does not increase oxidation within the measured temperature range of 450°C 600°C (second bar line).

- The presence of potassium in the deposit does not either seem to increase oxidation in the measured temperature range (third bar line).
- Even a small amount of chloride (Ashes 7 and 9) changes the situation and causes increased growth of the oxide layer; however, not until the top end of the measured temperature range (575 600°C).
- The simultaneous presence of chorine and potassium in the deposit strengthens oxidation dramatically. Oxidation starts at a temperature of only 500°C, or even below (Ashes 8 and 10).

Figure 9. Mean oxide layer thickness of Steel T91 as a function of temperature and salt mixture.

3.3. Steel Esshete 1250

Figure 10 presents the oxide layer thicknesses of Steel Esshete 1250 under different conditions. The following can be observed in the figure:

- The thin $(1 3 \mu m)$ oxide layer also of this stainless steel effectively combats high temperature oxidation in pure air, beneath the sodium sulphate and sodium-potassium sulphate deposits within the whole measured temperature range 450 600°C (three closest lines).
- A small amount of chlorine (Ash 7, 0.2 wt% Cl) causes the oxide layer to grow at 525°C (fourth bar line).
- The simultaneous presence of chorine and potassium in the deposit clearly increases oxidation. An accelerated growth of the measured oxide layer occurs as at low a temperature as 500°C.

Figure 10. Mean oxide layer thickness of Steel Esshete 1250 as a function of temperature and salt mixture.

3.4. Steel Sanicro 28

Figure 11 illustrates the oxide layer thicknesses of Steel Sanicro 28 under different conditions. The following can be observed in the figure:

- In the same way as the earlier steels T91 and Esshete 1250, also Sanicro 28 forms a thin and dense oxide layer $(1 3 \mu m)$, which effectively combats high temperature oxidation in pure air, under the sodium sulphate and sodium-potassium sulphate deposits within the whole measured temperature range 450 600°C (three closest bar lines).
- In this steel grade even a low chloride content (0.2 wt% Cl) in the deposit did not lead to accelerated oxidation (Ash7).
- A higher chlorine content (1.2 wt%) led to a slight acceleration of oxide layer growth at higher temperatures, 575-600°C (Ash 9).
- The simultaneous presence of chorine and potassium in the deposit led to a higher oxidation also of this steel at temperatures of 525°C and above.

Figure 11. Mean oxide layer thickness of Steel Sanicro 28 as a function of temperature and salt mixture.

3.5. Steel HR11N

Figure 12 shows the oxide layer thicknesses of steel HR11N under different conditions. The following can be observed in the figure:

• This steel grade also showed a very high resistance to high temperature oxidation. It did not oxide or corrode under any measured conditions besides by a salt deposit simultaneously containing both potassium and a significant amount of chlorine (Ash 10). Then the growth of the oxide layer started accelerating at as low a temperature as 525°C.

Figure 12. Mean oxide layer thickness of Steel HR11N as a function of temperature and salt mixture.

3.6. Steel Sanicro 63

Figure 13 displays the oxide layer thicknesses of Steel Sanicro 63 under different conditions. The following can be observed in the figure:

- As in the case of the above steel grade HR11N, this grade does not either oxidise at high temperatures under any measured conditions, except under the effect of Ash 10.
- Of all the measured steels, the oxidation of this grade is the slowest.

Figure 13. Oxide layer thicknesses of Steel Sanicro 63 as a function of temperature and salt mixture.

3.7. Effect of exposure time

All the tests with the above results had an exposure time of one week (168 h). A few reference tests were made in the project, both with longer and shorter exposure times. The oxide layer thicknesses of five steel grades, as a function of time, at a temperature of 525° C and with Ash 8 are shown in Figure 14.

The figure indicates that the oxide layer thickness doubles on Steels T91 and Esshete 1250 when the exposure time is lengthened from one week (168h) to four weeks (840h). The oxide layer thickness of Steel Sanicro 28 does not grow after a week, and the oxide layers of Steels HR11N and Sanicro 63 hardly grow at all under these conditions (525°C, Salt 8, atmosphere).

The figure also shows that the measured oxidation vulnerability of the steel grades remains the same at all three exposure times.

Figure 14. Mean oxide layer thickness of Steels T91, Esshete 1250, Sanicro 28, HR11N and Sanicro 63 as a function of time at a temperature of 525°C, with Ash 8.

4. Summary

The results of the laboratory tests have been presented graphically in different ways in Figures 15-17 to facilitate the comparison between the different steel grades.

Figure 15 shows the effect of the two most harmful salt mixtures (Ashes 8 and 10, where potassium and chloride are simultaneously present) on the oxidation of all six steel grades under measurement conditions (exposure of one week).

Figure 15. Effect of salts containing both potassium and chlorine on the oxidation of all steel grades. Ash 8 to the left, Ash 10 to the right.(450-600oC, 168 h, with air as gas atmosphere).

All steels showed certain accelerated oxidation in the measured temperature range, if the salt deposit on their surface contained simultaneously potassium and a significant amount of chlorine (Ash 10).

The resistance of the steels correlates well with their extent of mixing. Steels T91 and Esshete 1250 starts oxidising already at conditions corresponding to 525°C and 10CrMo9-10 clearly already at 450°C. Steels HR11N and Sanicro63 seem to resist as high a temperature as 600°C if the salt deposit contains only very small amounts of chlorine in combination with potassium (0.2 wt% of the salt).

The other steels oxide although the salt contains only 0.2 wt% of chlorine, 10CrMo9-10 at 450°C, T91 and Esshete at 1250 525°C and Sanicro 28 at 550°C.

In Figure 16 there is a corresponding comparison of the effect of mixtures containing only chlorine but no potassium (Ashes 7 and 9) on the corrosion of all steel grades. The figure shows that the resistance of Sanicro 28, HR11N and Sanicro 63 under such a salt deposit is good within the entire measured temperature range. Esshete 1250, on the other hand, starts to oxide already at 500 - 525°C, T91 at 550°C and 10CrMo9-10 even at a temperature below 450°C.

Figure 16. Effect of salts containing chlorine but no potassium on the oxidation of all steel grades. Ash 7 to the left, Ash 9 to the right. (450–600oC, 168 h, with air as gas atmosphere).

Figure 17 shows the same comparison of the effect of Salts 5 and 6 on the oxidation of all steel grades. The figure indicates that if there is no chlorine and at the most approximately 10 wt% of potassium in the salts, all the tested steels except 10CrMo9-10 resist the conditions up to a temperature of 600°C.

Figure 17. Effect of chlorine-free sulphate salts on the corrosion of all steel grades. Ash 5 to the left, Ash 6 to the right. $(450 - 600^{\circ}C, 168 \text{ h}, with air as gas atmosphere).$

5. Conclusions

At this stage of the work some general conclusions can be drawn concerning the testing methods in themselves and the results obtained, on the one hand, and, on the other, the importance of the results for the objectives of the SOTU II Project.

The research method developed during the work worked well and gave accurate and repeatable results. The measuring method continues to be somewhat laborious, and in possible further studies efforts should be made to speed up work by reducing the analytical and microscope procedures. The entire panoramic imaging may not be necessary to obtain an oxide layer thickness measurement representative of all samples.

The method is based on oxide layer thickness measurement, i.e. oxidising of steel, and oxidation is interpreted directly as corrosion. In this connection it is necessary to point out that the disappearance of the oxide layer, e.g. for mechanical reasons, leads to an underestimation of corrosion. At laboratory scale this risk is clearly smaller than in corrosion tests in full-scale institutions.

Abundantly additional information was obtained on the corrosive effect of alkali salts. Pure sodium sulphate as such does not seem to cause corrosion even in the least alloyed steels.

The dramatic and different effect of potassium and chlorine was clearly exposed. Potassium by itself added to sodium sulphate did not seem to accelerate corrosion. On the other hand, very small amounts of chorine seemed sufficient to cause strong corrosion of almost all steels tested.

New information was also obtained on the importance of the first melting point (T_0) on corrosion starting temperature. Based on the results, it is evident that the presence of a significant molten phase in the deposit and steel interface produces strong corrosion even of high alloy steels: Ash 10 caused accelerated corrosion of all steels already at a temperature of 525°C.

Furthermore, the results clearly indicated that corrosion may occur under chlorous deposits even at temperatures below the first melting point. Regarding this corrosion occurring below the first melting point of the deposit, the high alloy steels Sanicro 28, HR11N and Sanicro 63 were clearly more corrosion resistant than the lower alloy steels used in the tests.

The microscope analyses of corrosion layer cross-sections carried out in the work provide good opportunities to clarify the mechanisms of corrosion progression further.

In view of the objectives of the SOTU II Project, this laboratory work provides clear indications of methods by which superheater temperature can be raised in the future. Using suitable materials and/or by adjusting deposit chemistry, superheater material temperatures could be substantially increased.

An important continuation of this work are the probe measurements of recovery boilers now under way, in which the same materials are tested over a longer period of time under real boiler conditions. These types of measurements are crucial to calibrating and verifying the laboratory measurements performed. ANNEX 1. Numeric values of oxide layer thicknesses

Test nr	Гетрегаture [°C]	Time [h]	Steel	Salt	Mean value [µm]	e Med value	ian [µm]	Max value [µm]	Most frequent value [µm]
1	600	72	Alloy 625	1	n.m.				
2	600	72	Alloy 625	1	n.m.				
3	600	72	Alloy 625	1	n.m.				
4	600	72	Alloy 625	2	n.m.	-			-
5	600	72	Alloy 625	3	n.m.		Prel	iminary	
6	500	72	Alloy 625	1	n.m.		tests	S	
7	500	72	Alloy 625	1	n.m.			-	
8	500	72	Alloy 625	1	n.m.				
9	-	-	10CrMo9-10	-	n.m.				
10	-	-	10CrMo9-10	-	n.m.				
11	600	72	T91	5	0.0	0.0)	0.0	0.0
12	600	72	T91	5	0.0	0.0)	0.0	0.0
13	600	72	T91	-	0.0	0.0)	0.0	0.0
14	600	72	T91	6	0.0	0.0)	0.0	0.0
15	600	72	T91	6	0.0	0.0)	0.0	0.0
16	600	168	T91	5	0.0	0.0)	0.0	0.0
17	600	168	10CrMo9-10	5	22.0	21.	5	45.7	21.1
18	600	168	10CrMo9-10	-	28.7	28.	5	43.7	28.1
19	600	168	T91	6	0.0	0.0)	0.0	0.0
20	600	168	10CrMo9-10	6	39.5	39.	8	56.3	37.5
21	600	168	T91	7	0.0	0.0)	0.0	0.0
22	600	168	10CrMo9-10	7	35.6	35.	2	81.6	35.2
23	600	168	10CrMo9-10	9	85.1	84.	0	134.4	81.6
24	600	168	T91	9	68.2	67.	6	139.4	72.7
25	600	168	10CrMo9-10	9	64.3	64.	4	94.9	60.9
26	500	168	10CrMo9-10	8	29.8	28.	1	79.7	25.8
27	500	168	T91	8	19.7	17.	2	55.9	14.5
28	500	168	10CrMo9-10	8	n.m.				
29	500	168	T91	10	10.2	9.0)	55.1	8.2
30	500	168	10CrMo9-10	10	78.3	74.	6	168.0	63.7
31	550	168	10CrMo9-10	7	23.8	22.	7	56.6	22.3
32	550	168	T91	7	0.0	0.0)	0.0	0.0
33	550	168	T91	9	0.0	0.0)	0.0	0.0
34	550	168	10CrMo9-10	9	28.5	28.	5	55.1	28.5
35	550	168	10CrMo9-10	9	36.0	36.	3	57.0	37.5
36	550	72	10CrMo9-10	8	31.6	30.	9	82.4	30.9
37	550	72	T91	8	35.8	33.	2	72.3	28.1
38	550	72	10CrMo9-10	8	49.0	46.	5	155.8	46.1
39	550	72	T91	10	67.6	60.	2	159.0	37.9
40	550	72	10CrMo9-10	10	50.2	42.	2	215.6	39.1
41	600	72	T91	7	0.0	0.0)	0.0	0.0
42	600	72	T91	7	0.0	0.0)	0.0	0.0
43	600	72	10CrMo9-10	7	29.1	28.	9	55.9	28.9

Table 1.1. Oxide layer thicknesses measured in the samples, calculated as mean, median, most frequent and maximum values

Test	Femperature	Time	Steel	Salt	Mean value	e Median	Max value	Most frequent
nr	$\begin{bmatrix} \mathbf{C} \end{bmatrix}$	[11]			ιμπι	value [µIII]	[µm]	[um]
44	600	72	T 91	9	573	55 9	98.8	53.9
45	600	72	10CrMo9-10	9	76 4	76.6	123.4	75.8
46	500	168	10CrMo9-10	-	70.4 5.8	59	11.3	59
47	500	168	10CrMo9-10	_	0.7	0.4	63	0.4
48	500	168	10CrMo9-10	_	0.7	0.4	0.0	0.0
49	500	168	T91	_	0.0	0.0	0.0	0.0
50	500	168	T91	_	0.0	0.0	0.0	0.0
51	600	168	T91	-	0.0	0.0	0.0	0.0
52	600	168	T91	_	0.0	0.0	0.0	0.0
53	600	168	T91	-	0.0	0.0	0.0	0.0
54	600	168	10CrMo9-10	-	49.0	49.2	64.4	49.2
55	600	168	10CrMo9-10	_	49.5	49.6	64.1	50.0
56	525	168	10CrMo9-10	8	42.2	43.0	77 3	44 5
57	525	168	10CrMo9-10	8	54.0	52.3	1137	43.4
58	525	168	T91	8	36.3	34.0	114.1	31.6
59	525	168	10CrMo9-10	10	99.6	71.1	351.9	63.7
60	525	168	T91	10	87.6	77.3	234.8	57.4
61	575	168	T91	7	9.6	98	18.4	94
62	575	168	10CrMo9-10	7	36.6	36.7	61.3	36.7
63	575	168	T91	9	26.7	23.0	80.1	22.3
64	575	168	10CrMo9-10	9	39.1	37.5	103.1	37.9
65	575	168	T91	9	0.0	0.0	0.0	0.0
66	450	168	10CrMo9-10	-	0.0	0.0	0.0	0.0
67	450	168	10CrMo9-10	8	9.6	7.8	52.7	7.0
68	450	168	HR11N	8	0.0	0.0	0.0	0.0
69	450	168	10CrMo9-10	10	24.3	18.4	95.7	13.3
70	450	168	HR11N	10	0.0	0.0	0.0	0.0
71	525	168	HR11N	7	0.0	0.0	0.0	0.0
72	525	168	10CrMo9-10	7	12.9	12.9	23.0	12.9
73	525	168	HR11N	9	0.0	0.0	0.0	0.0
74	525	168	HR11N	9	0.0	0.0	0.0	0.0
75	525	168	10CrMo9-10	9	28.5	46.1	98.0	18.4
76	550	168	T91	8	52.1	46.1	147.3	38.3
77	550	168	HR11N	8	0.0	0.0	0.0	0.0
78	550	168	T91	8	67.3	66.0	166.8	71.5
79	550	168	HR11N	10	34.9	29.3	180.1	20.7
80	550	168	T91	10	61.9	56.2	237.1	53.5
81	575	168	HR11N	8	0.0	0.0	0.0	0.0
82	575	168	T91	8	68.5	58.2	203.5	54.7
83	575	168	HR11N	10	16.3	13.3	76.6	8.6
84	575	168	T91	10	78.3	66.8	214.4	61.7
85	575	168	HR11N	10	14.7	13.7	53.5	12.9
86	600	168	HR11N	5	0.0	0.0	0.0	0.0
87	600	168	10CrMo9-10	5	41.0	41.4	57.8	47.0
88	600	168	HR11N	6	0.0	0.0	0.0	0.0
89	600	168	10CrMo9-10	6	42.7	43.4	71.9	46.1

Test	Γemperature [°C]	Time [h]	Steel	Salt	Mean value [µm]	Median value [µm]	Max value	Most frequent
nr		1.00	100 10 0 10				[µm]	value [µm]
90 01	600	168	10CrMo9-10	-	13.4	8.6	32.8	7.8
91	600	168	HRIIN	/	0.0	0.0	0.0	0.0
92	600	168	10CrMo9-10	7	42.1	41.8	68.4	41.8
93	600	168	HRIIN	9	0.0	0.0	0.0	0.0
94	600	168	10CrMo9-10	9	96.2	95.7	159.4	98.0
95	600	168	HR11N	9	0.0	0.0	0.0	0.0
96	600	168	HR11N	8	0.0	0.0	0.0	0.0
97	600	168	T91	8	72.4	68.4	127.7	56.6
98	600	168	HR11N	10	52.1	49.6	133.6	38.7
99	600	168	191	10	72.8	74.2	134.8	81.6
100	600	168	HR11N	10	52.7	49.2	178.5	35.5
101	525	72	10CrMo9-10	8	33.1	28.9	91.4	27.0
102	525	72	T91	8	33.9	32.0	122.3	31.6
103	525	72	10CrMo9-10	10	91.8	57.8	378.5	36.3
104	525	72	T91	10	74.2	58.6	230.1	48.0
105	525	72	10CrMo9-10	-	3.5	3.5	9.8	3.5
106	575	168	10CrMo9-10	5	0.0	0.0	0.0	0.0
107	575	168	10CrMo9-10	6	15.3	15.2	35.5	15.2
108	450	168	T91	8	0.0	0.0	0.0	0.0
109	450	168	T91	10	8.1	7.8	20.3	7.8
110	500	168	10CrMo9-10	7	18.7	16.8	67.6	16.0
111	500	168	10CrMo9-10	9	22.4	17.6	90.6	16.4
112	550	168	10CrMo9-10	8	109.0	103.9	235.5	98.0
113	550	168	HR11N	10	38.4	34.8	173.8	14.1
114	550	168	T91	10	119.5	107.0	308.6	102.7
115	550	168	10CrMo9-10	10	87.7	55.5	262.9	46.1
116	575	168	10CrMo9-10	7	34.8	34.4	79.3	35.2
117	575	168	T91	7	29.2	29.3	62.1	28.9
118	575	168	T91	9	54.9	53.1	110.5	47.3
119	575	168	HR11N	9	0.0	0.0	0.0	0.0
120	575	168	10CrMo9-10	9	62.8	59.8	135.9	53.5
121	550	168	10CrMo9-10	8	76.8	76.2	140.6	69.9
122	550	168	T91	8	68.4	65.2	169.5	63.3
123	550	168	HR11N	10	15.9	14.1	57.0	11.3
124	550	168	10CrMo9-10	10	98.5	70.3	353.1	53.1
125	550	168	T91	10	93.0	81.2	271.9	78.1
126	525	168	10CrMo9-10	-	9.9	9.8	22.7	9.4
127	525	168	HR11N	-	0.0	0.0	0.0	0.0
128	525	168	HR11N	10	51.1	47.3	159.4	43.4
129	525	168	T91	10	67.0	55.5	266.8	48.8
130	600	168	10CrMo9-10	8	51.7	51.2	117.6	55.9
131	600	168	10CrMo9-10	10	126.4	122.3	258.6	112.9
132	600	168	HR11N	-	0.0	0.0	0.0	0.0
133	575	168	10CrMo9-10	8	45.2	45.3	109.0	48.8
134	575	168	10CrMo9-10	10	128.1	112.5	294.1	107.8
135	450	168	10CrMo9-10	7	3.6	3.5	32.0	3.5
136	450	168	10CrMo9-10	9	4.2	3.9	9.8	3.9

Test	Гетрегаture [°C]	Time [h]	Steel	Salt	Mean value [µm]	Median value [µm]	Max value	Most frequent
nr	550	1.0	100 10 10	-	-, -	0.6	[µm]	value [µm]
13/	550	108	10CrMo9-10	0	8.9 10.5	8.0 10.5	25.0	/.8
138	550	108	IUCIM09-10	-	10.5	10.5	18.4	10.0
139	600	108	Sanicro 28	5	0.0	0.0	0.0	0.0
140	600	168	Sanicro 28	6	0.0	0.0	0.0	0.0
141	600	168	Sanicro 28	-	0.0	0.0	0.0	0.0
142	600	168	Sanicro 28	/	0.0	0.0	0.0	0.0
143	600	168	Sanicro 28	9	3.0	2.7	16.0	2.0
144	575	168	Sanicro 28	-	0.0	0.0	0.0	0.0
145	600	168	Esshete 1250	5	0.0	0.0	0.0	0.0
146	600	168	Esshete 1250	6	0.0	0.0	0.0	0.0
14/	600	168	Esshete 1250	/	6./	/.0	24.6	0.4
148	600	108	Essnete 1250	-	0.0	0.0	0.0	0.0
149	600	168	Essnete 1250	9	30.0	30.9	/8.1	31.6
150	600	168	Esshete 1250	8	15.3	13.7	52.7	9.4
151	600	168	Sanicro 28	8	0.0	0.0	0.0	0.0
152	600	168	Esshete 1250	10	65./	62.9	196.5	58.6
153	600 500	108	Sanicro 28	10	/1.5	/0./	182.8	/1.5
154	500	168	HKIIN	10	0.0	0.0	0.0	0.0
155	575	168	Sanicro 28	8	11.8	10.5	37.9	9.4
156	575	168	Sanicro 28	10	58.5	50.4	198.8	53.9
157	575	168	Esshete 1250	10	91.4	90.2	157.8	87.9
158	575	168	Esshete 1250	/	8.8	8.2	43.4	0.4
159	575	168	Sanicro 28	/	0.0	0.0	0.0	0.0
160	575	168	191	7	13.4	13.3	56.2	12.5
161	575	168	Sanicro 28	9	1.6	1.6	7.8	1.6
162	575	168	Esshete 1250	9	9.1	8.6	38.3	8.2
163	575	168	Esshete 1250	8	16.0	10.9	/8.1	0.4
164	575	168	Sanicro 28	8	5.9	4./	34.4	2.0
165	575	168	Esshete 1250	10	79.0	71.9	245.3	55.5
166	575	168	Sanicro 28	10	38.1	37.1	110.1	41.4
16/	575	168	10CrMo9-10	-	23.1	3.5	13.3	3.1
168	550	168	Esshete 1250	10	67.5	67.2	150.0	69.1
109	550	108	Sanicro 28	10	02.5	57.8	180.5	54.4 22.1
170	600 525	108	191		25.2	25.8	38.3	23.1
1/1	525	168	10CrMo9-10	0 10	/.4	/.0	16.0	6.6
172	525	108	Essnete 1250	10	62.3 26.6	59.0 20.7	151.9	49.6
174	525	108	Sanicro 28	10	30.0 10.9	29.7 19.7	125.0	14.5
174	550	168	Essnete 1250	8	19.8	18.7	64.4 20.1	18.4
175	550	168	Esshete 1250	9	5./	5.1	39.1	4.7
170	600	108	Sanicro 63	2	0.0	0.0	0.0	0.0
1//	600	108	Sanicro 63	07	0.0	0.0	0.0	0.0
1/8	000	108	Sanicro 63	/	0.0	0.0	0.0	0.0
1/9	000	108	Sanicro 63	9	0.0	0.0	0.0	0.0
180	600	108	Sanicro 63	8 10	0.0	0.0	0.0	0.0
181	000 575	108	Sanicro 63	10	10.0	ð.2	83.9 0.0	4.5
182	5/5	108	Sanicro 63	ð 10	0.0	0.0	0.0	0.0
183	5/5	108	Sanicro 63	10	/.0	5.9	04.1	3.9

Test nr	Femperature [°C]	Time [h]	Steel	Salt	Mean value [µm]	Median value [µm]	Max value [um]	Most frequent value [um]
184	575	168	Sanicro 63	5	0.0	0.0	0.0	0.0
185	575	168	Sanicro 28	5	0.0	0.0	0.0	0.0
186	575	168	HR11N	6	0.0	0.0	0.0	0.0
187	575	168	Sanicro 63	6	0.0	0.0	0.0	0.0
188	575	168	Sanicro 28	6	0.0	0.0	0.0	0.0
189	575	168	Esshete 1250	5	0.0	0.0	0.0	0.0
190	575	168	T91	5	0.0	0.0	0.0	0.0
191	575	168	HR11N	5	0.0	0.0	0.0	0.0
192	575	168	Esshete 1250	6	0.0	0.0	0.0	0.0
193	575	168	T91	6	0.0	0.0	0.0	0.0
194	575	168	Sanicro 63	7	0.0	0.0	0.0	0.0
195	575	168	HR11N	7	0.0	0.0	0.0	0.0
196	575	168	Sanicro 63	9	0.0	0.0	0.0	0.0
197	500	168	Esshete 1250	10	17.0	15.6	80.9	14.5
198	500	168	HR11N	10	0.0	0.0	0.0	0.0
199	500	168	Sanicro 28	10	0.0	0.0	0.0	0.0
200	525	168	Esshete 1250	8	14.1	12.1	62.5	9.4
201	525	168	Sanicro 28	8	14.6	9.8	119.5	2.7
202	525	168	HR11N	10	31.5	26.2	161.7	14.5
203	550	168	Esshete 1250	7	11.4	10.2	10.2	9.8
204	550	168	Sanicro 28	7	0.0	0.0	0.0	0.0
205	550	168	Sanicro 63	7	0.0	0.0	0.0	0.0
206	550	168	Sanicro 28	9	0.0	0.0	0.0	0.0
207	550	168	Sanicro 63	9	0.0	0.0	0.0	0.0
208	550	168	Sanicro 28	8	12.2	10.5	73.8	1.2
209	550	168	Sanicro 63	8	0.0	0.0	0.0	0.0
210	550	168	Sanicro 63	10	18.4	11.7	105.5	0.0
211	525	168	Esshete 1250	9	7.9	6.6	47.7	0.0
212	525	168	Esshete 1250	9	7.3	6.2	31.6	4.7
213	525	168	Sanicro 63	8	0.0	0.0	0.0	0.0
214	525	168	Sanicro 63	10	0.0	0.0	0.0	0.0
215	550	168	Sanicro 63	5	0.0	0.0	0.0	0.0
216	550	168	10CrMo9-10	5	6.7	8.2	31.6	0.0
217	550	168	10CrMo9-10	6	0.5	0.4	10.2	0.4
218	550	168	Sanicro 63	6	0.0	0.0	0.0	0.0
219	500	168	10CrMo9-10	6	1.1	0.8	7.0	0.0
220	500	168	Sanicro 28	6	0.0	0.0	0.0	0.0
221	500	168	Sanicro 28	5	0.0	0.0	0.0	0.0
222	500	168	Sanicro 28	7	0.0	0.0	0.0	0.0
223	500	168	Sanicro 28	9	0.0	0.0	0.0	0.0
224	500	168	Esshete 1250	8	9.9	6.3	84.8	0.0
225	500	168	Sanicro 28	8	0.0	0.0	0.0	0.0
226	500	72	Sanicro 28	10	0.0	0.0	0.0	0.0
227	500	72	Esshete 1250	10	11.4	9.4	55.9	5.5
228	500	72	Esshete 1250	8	9.2	7.4	50.8	0.0
229	550	72	Esshete 1250	8	29.3	20.7	130.9	12.5
230	550	72	Sanicro 28	8	11.6	9.8	53.1	6.6

Test	[°C]	Time [h]	Steel	Salt	Mean valu	e Median value [µm]	Max value	Most frequent	
nr							[µm]	value [µm]	
231	550	72	HR11N	10	24.4	16.8	157.4	10.6	
232	550	72	Esshete 1250	10	40.4	38.7	118.7	39.5	
233	550	72	Sanicro 28	10	55.1	50.0	146.5	32.0	
234	575	72	10CrMo9-10	7	19.9	19.9	42.6	20.7	
235	575	72	T91	7	15.0	14.8	31.3	14.1	
236	575	72	Esshete 1250	7	6.5	6.6	30.5	0.0	
237	575	72	10CrMo9-10	9	29.2	29.3	52.7	30.1	
238	575	72	T91	9	0.0	0.0	0.0	0.0	
239	525	72	Esshete 1250	8	25.3	23.1	76.6	17.6	
240	525	72	Sanicro 28	8	6.8	4.7	58.6	2.0	
241	525	72	HR11N	10	52.2	43.8	175.4	27.0	
242	525	72	Esshete 1250	10	16.9	14.1	63.7	7.8	
243	525	72	Sanicro 28	10	17.2	11.0	102.3	5.1	
244	525	72	Sanicro 63	10	2.7	0.8	49.2	0.8	
245	550	72	Sanicro 63	10	2.4	1.2	43.8	0.0	
246	600	72	10CrMo9-10	-	13.6	13.7	22.7	13.7	
247	600	168	Sanicro 63	-	0.0	0.0	0.0	0.0	
248	450	168	10CrMo9-10	6	0.0	0.0	0.0	0.0	
249	450	168	Sanicro 28	10	0.0	0.0	0.0	0.0	
250	525	168	T91	7	0.0	0.0	0.0	0.0	
251	525	168	T91	9	0.0	0.0	0.0	0.0	
252	500	72	Sanicro 28	8	0.0	0.0	0.0	0.0	
253	500	72	HR11N	10	0.0	0.0	0.0	0.0	
254	500	72	Sanicro 63	10	0.0	0.0	0.0	0.0	
255	550	72	10CrMo9-10	7	17.9	18.0	36.3	18.4	
256	550	72	Esshete 1250	7	5.4	4.7	29.7	3.5	
257	550	72	10CrMo9-10	9	14.2	14.1	25.0	13.7	
258	550	72	Esshete 1250	9	7.6	7.4	40.2	3.9	
259	575	72	Esshete 1250	9	9.1	9.0	27.3	7.8	
260	525	840	T91	8	87.8	85.5	164.8	81.2	
261	525	840	HR11N	8	0.8	0.4	7.8	0.0	
262	525	840	Sanicro 28	8	8.6	7.4	51.2	2.0	
263	525	840	Esshete1250	8	52.8	48.8	153.1	49.2	
264	525	840	Sanicro 63	8	1.6	1.6	14.1	0.0	

n.m. = no measurement

Temperature	Time			Default	Femperature	Time			Default
[°C]	[h]	Steel	Salt	value		[h]	Steel	Salt	value
450	169	100-14-0.0	5	[µm]	500	1.0	Carriana 29		[µm]
450	108	10CrMo9-9	5	0	500	108	Sanicro 28	-	0
500	100	10CrMo9-9	5	0	525	100	Sanicro 28	5	0
525	108	TUCTM09-9	5	0	525	108	Sanicro 28	07	0
450	168	Essnete 1250	5	0	525	168	Sanicro 28	/	0
450	168	Essnete 1250	6	0	525	168	Sanicro 28	9	0
450	168	Esshete 1250	/	0	525	168	Sanicro 28	-	0
450	169	Esshete 1250	8	0	550	168	Sanicro 28	5	0
450	168	Esshete 1250	9	0	550	168	Sanicro 28	6	0
450	169	Esshete 1250	10	0	550	168	Sanicro 28	-	0
450	168	Esshete 1250	-	0	450	168	Sanicro 63	5	0
500	168	Esshete 1250	5	0	450	168	Sanicro 63	6	0
500	168	Esshete 1250	6	0	450	168	Sanicro 63	7	0
500	168	Esshete 1250	7	0	450	168	Sanicro 63	8	0
500	168	Esshete 1250	9	0	450	168	Sanicro 63	9	0
500	168	Esshete 1250	-	0	450	168	Sanicro 63	10	0
525	168	Esshete 1250	5	0	450	168	Sanicro 63	-	0
525	168	Esshete 1250	6	0	500	168	Sanicro 63	5	0
525	168	Esshete 1250	7	0	500	168	Sanicro 63	6	0
525	168	Esshete 1250	-	0	500	168	Sanicro 63	7	0
550	168	Esshete 1250	5	0	500	168	Sanicro 63	8	0
550	168	Esshete 1250	6	0	500	168	Sanicro 63	9	0
550	168	Esshete 1250	-	0	500	168	Sanicro 63	10	0
575	168	Esshete 1250	-	0	500	168	Sanicro 63	-	0
450	168	HR11N	5	0	525	168	Sanicro 63	5	0
450	168	HR11N	6	0	525	168	Sanicro 63	6	0
450	168	HR11N	7	0	525	168	Sanicro 63	7	0
450	168	HR11N	9	0	525	168	Sanicro 63	9	0
450	168	HR11N	-	0	525	168	Sanicro 63	-	0
500	168	HR11N	5	0	550	168	Sanicro 63	-	0
500	168	HR11N	6	0	575	168	Sanicro 63	-	0
500	168	HR11N	7	0	450	168	T91	5	0
500	168	HR11N	8	0	450	168	T91	6	0
500	168	HR11N	9	0	450	168	T91	7	0
500	168	HR11N	-	0	450	168	T91	9	0
525	168	HR11N	5	0	450	168	T91	-	0
525	168	HR11N	6	0	500	168	T91	5	0
525	168	HR11N	8	0	500	168	T91	6	0
550	168	HR11N	5	0	500	168	T91	7	0
550	168	HR11N	6	0	500	168	T91	9	0
550	168	HR11N	7	0	525	168	T91	5	0
550	168	HR11N	9	0	525	168	T91	6	0
550	168	HR11N	-	0	525	168	T91	_	0
575	168	HR11N	_	Õ	550	168	T91	5	Ő
450	168	Sanicro 28	5	Ő	550	168	T91	6	Õ
450	168	Sanicro 28	6	Ő	550	168	T91	-	0
450	168	Sanicro 28	7	0	575	168	T91	_	0
450	168	Sanicro 28	, 8	Ő	575	100	. / 1		v
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Table 1.2. Test samples with an oxide layer thickness default value of zero