Finnish Recovery Boiler Committee

SKYREC STEERING COMMITTEE MEETING IV

TIME	September 8th, 2009 10.00 – 16.00	
PLACE	Metso Power Oy, Tampere	
PARTICIPANTS		
	Steering group:	
	Lasse Koivisto	Andritz Oy, Varkaus
	Matti Tikka	UPM-Kymmene Oyj, Kymi, chairman
	Keijo Salmenoja	Suomen Soodakattilayhdistys ry, Rauma
	Johanna Tuiremo	Metso Power Oy, Tampere
	Timo-Pekka Veijonen	Stora Enso Oyj, Pulp Competence Center Imatra
	Timo Peltola	Sandvik, Helsinki
	Mika Paju	Oy Metsä-Botnia Ab, Joutseno
	Hiroshi Matsuo	Suomitomo Metals, London
	Group members without a right to vote:	
	Reijo Hukkanen	Stora Enso, Oulu
	Esa Vakkilainen	LUT (Lappeenranta University of Technology), Project coordinator, Lappeenranta
	Outi Pisto	Finnish Recovery Boiler Committee, secretary
During item 5	Nikolai DeMartini	Åbo Akademi University, Turku

APPENDIXES

I	Project budget
II	Boildec Oy: Field testing of compound materials, test no 1
III	Nikolai DeMartini, Åbo Akademi: Co-firing black liquor and bio-mass-laboratory tests
IV	LUT: Once-through and reheater recovery boiler concepts, report on progress 24.8.2009
V	Åbo Akademi: Corrosion behaviour of four steels under reducing conditions, an intermediate report
VI	Tanja Pentinsaari: Transient phenomena in recovery boiler char bed
VII	Teollisuuden Vesi Oy, offer for an extra work: TOC-removal methods and applicability for recovery boiler make-up water treatment (in Finnish)
VIII	University of Oulu, offer: Ceramics in furnace (in Finnish)

DISTRIBUTION

Steering committee and their substitutes
Durability Sub Committee
Board of the FRBC
OMP, MNN, EPT/Files

1 ABSENCES

Martti Korkiakoski, Olli Talaslahti and Kalle Salmi were not able to attend the meeting. Johanna Tuiremo was present as a substitute of Kalle Salmi.

2 MEMO OF THE PREVIOUS MEETING

The memo of the previous meeting was accepted.

3 BUDGET

Project budget is presented in Appendix I. Budget and schedule overview needs to be done. Especially how well we are fulfilling the proposal and what was stated there. Esa Vakkilainen to do it by September 30th.

4 SCHEDULE

Mr. Vakkilainen to prepare a list of the status of the SKYREC subprojects including a time schedule for the subprojects ought yet to be done by September 30th.

The original schedule of the project is January 1, 2008 – June 30, 2010. Starting of the project was delayed because the decision of the project funding was received from Tekes in late April 2008.

Setbacks in the furnace and superheater material tests may cause problems in the time schedule.

It is possible to apply a one year extension to the project. Secretariat of the committee to prepare an extension application to Tekes during autumn 2009.

5 ONGOING PROJECTS

Separate groups needs to be formed for preparing a furnace and superheater material recommendation and a water quality recommendation. Durability subcommittee to make a suggestion for persons to be included in each group. Each group's work to be reported to the steering committee.

5.1 WP3: Increase of steam pressure

TP3: Field tests of candidate furnace materials for high temperatures

The first experiment was failed second time, this time because the test specimen was destroyed due to a power lost of the air fan cooling the probe. Timo Karjunen's (Boildec Oy) intermediate report on the subproject is presented in Appendix II.

As Karjunen has promised that only successful experiments will be charged, the first invoice will be paid after first actual results are obtained.

New test will be started as the new test specimens has been prepared by VTT.

Comments:

Temperature measurement data is needed instead of calculatory temperature data.

5.2 WP1: New recovery boiler concepts in electricity production

S1: Broadening RB fuel flexibility

Nikolai DeMartini reported laboratory combustion tests for co-firing black liquor and biomass, see Appendix III.

Project final report was accepted.

Åbo Akademi will send a proposal for the continuation of the project to the secretary to be delivered to the steering committee.

Mr. DeMartini has wrote an abstract to be presented in the ICRC2010. The paper was accepted. Mr. DeMartini will send the abstract to the secretary to be distributed to the steering group.

S3: Recovery boiler as a once-through boiler – concept study

Esa Vakkilainen presented the status of the project, see Appendix IV.

Mr. Vakkilainen will deliver the results of the calculations for comments. An intermediate meeting will be arranged, if needed.

The project report will be ready for comments in November.

5.3 WP2: Increase of steam temperature

TM2: Corrosion chemistry with high steam values

1. Laboratory tests of superheater materials

Åbo Akademi's intermediate report on the subproject is presented in Appendix V.

The project shall be ready in December 2009.

Comments:

One test could be also done without a char. It was noted that the results under reducing conditions seem not to be so severe compared to the results of the SoTu II where the same experiments were done under oxidising conditions.

TM3: Mill tests of superheater materials

Corrosion field tests of superheater tube materials has been ordered from VTT.

Following materials are chosen to be tested:

AISI 347	**San 67**	**Alloy 28 (HR21, San 28)**	**TP310**	**HR11N**	**Super 625***

* 50 Ni – 21.5 Cr – 17.5 Fe – 9 Mo

Sumitomo has started to manufacture sample tubes of HR11N and SUPER625 (50.8 mm OD). Materials will be ready by the end of November.

Markku Orjala to contact Timo Peltola, Sandvik and Hiroshi Matsuo, Sumitomo for the testing materials. Secretary will provide contact information for Mr. Orjala.

Mr. Orjala is asked to present the safety system of the probe water cooling system to Mika Paju.

Reijo Hukkanen to contact Mr. Orjala for the project schedule and to get required safety information.

5.4 WP3: Increase of steam pressure

TP2: Effect of the furnace heat load on the recovery boiler designing

Tanja Pentinsaari has finished her M.Sc. thesis “Transient Phenomena in Recovery Boiler Char Bed“ (thesis in Finnish) and the work has been graded. Comments on the thesis can be sent to Mr. Vakkilainen by 20th September.

Esa Vakkilainen gave presentation on the study, see Appendix VI.

5.5 WP4: Development of water treatment

V02: Layer formation in autoclave tests

The work has been order from VTT and the first invoice 19.500 € + VAT has been paid. Laboratory tests will be started during September.

Amines to be tested have not been chosen. VTT is asked to suggest amines for the tests. Acceptance for suggested amines by e-mail.

The work will be finished by the end of April 2010.

V03: Development of water treatment and quality control

The work, “Ion exchange and organic load” and “TOC removal methods”, has been order from Teollisuuden Vesi Oy and the first invoice 18.000 € + VAT has been paid.

The work will be carried out during autumn 2009.

Durability subcommittee has ordered a study “Reduction of TOC from recovery boiler make-up water” from University of Oulu. The study will be carried out as a graduate thesis and it will be ready by the end of May 2010.

6 PROPOSALS

6.1 WP4: Development of water treatment

V03: Development of water treatment and quality control

Teollisuuden Vesi Oy has offered an extra work on TOC research, Appendix VII.

It was decided not to order the work, because the study concerns one mill only, and therefore it will not benefit the other members of the committee.

6.2 WP3: Increase of steam pressure

TP1: Ceramic structural materials

University of Oulu (OY) has sent a new proposal on mill tests of the ceramic structural materials, Appendix VIII.

Mr. Hukkanen to ask OY to add an option for the offer of studying micro structure of the materials. If some test material appears to be stable, the micro structure will be studied. Durability subcommittee can order the work if the measurement system is found satisfactory.

Comments:

Most probably the specimens cannot be pulled off from the furnace for inspection and put back in the boiler without that the specimens get broken. It was suggested that the specimens will be held in the furnace for certain predetermined period and inspected after that.

Reference material could be the same as usually used in the furnaces, for example Hassle D39 or D1700A.

7 OTHER ISSUES

The secretary of the FRBC will leave on maternity leave in the middle of October. FRBC's secretary Markus Nieminen (010 33 22525, markus.nieminen@poyry.com,) will continue as a secretary of the steering group starting 19th October.

8 NEXT MEETINGS

The next meeting will be held at Pöyry Industry Oy, Vantaa, on December 16th at 10.00 a.m.

APPENDIX I

Project budget

SKYREC

		Ordered	Offers	2008	2009	2010
WP1	**New recovery boiler concepts in electricity production**					
S1	Broadening RB fuel flexibility					
	- ÅA: Broadening RB fuel flexibility part 1	7 500,00 €			7 500,00 €	
	- ÅA: Broadening RB fuel flexibility		25 000,00 €		10 000,00 €	15 000,00 €
S2	Increase of recovery boiler electricity production					
S3	Recovery boiler as a once-through boiler - concept studies					
	- LTY: Recovery boiler as a once-through boiler – concept study	33 800,00 €				33 800,00 €
	~~- TKK: Recovery boiler as a once-through boiler – concept study~~		~~100 000,00 €~~			
		41 300,00 €	**25 000,00 €**			
WP2	**Increase of steam temperature**					
TM1	Analysis and utilisation of the existing information					
TM2	New superheater materials, material selection					
TM3	Corrosion chemistry with high steam values					
	- ÅA: Laboratory tests of superheater materials	37 000,00 €			37 000,00 €	
	- ÅA: Mill tests of superheater materials - probe development		~~15 000,00 €~~			
	- ÅA: Mill tests of superheater materials		~~83 000,00 €~~			
	- VTT: Mill tests of superheater materials	104 000,00 €			62 400,00 €	41 600,00 €
	~~- Savcor: Mill tests of superheater materials~~		~~20 000,00 €~~			
TM4	Suitability of superheater materials with high steam values					
		141 000,00 €	**- €**			
WP3	**Increase of steam pressure**					
TP0	Analysis and utilisation of the existing information					
	- FRBC's material recommendation (KTR)		25 000,00 €			
TP1	Ceramic structural materials					
	- OY: Ceramic structural materials		15 200,00 €			
	~~- OY: Ceramic structural materials, laboratory tests~~		~~16 877,00 €~~			
TP2	Effect of the furnace heat load on the recovery boiler designing					
	- LTY: Heat transfer properties of the recovery boiler char bed	14 800,00 €			14 800,00 €	
TP3	Field tests of candidate furnace materials for high temperatures					
	- Boildec: Field tests of furnace materials	98 000,00 €		19 600,00 €	19 600,00 €	58 800,00 €

	- Boildec: Field tests of furnace materials (reservation)		50 000,00 €			
	- VTT: Analysis of the test materials	29 000,00 €			19 000,00 €	10 000,00 €
		141 800,00 €	**90 200,00 €**			
WP4	**Quality of boiler water and steam**					
V0	Analysis and utilisation of the existing information					
	- VTT: Literature survey on degradation of organic compounds	17 700,00 €		5 310,00 €	12 390,00 €	
V1	Development of the testing method of chemicals					
	- VTT (reservation)		40 000,00 €			
V3	Testing of oxygen scavengers					
V2	Layer formation in autoclave tests					
	- VTT: Effect of water quality and different chemicals on magnetite layer properties	65 000,00 €			19 500,00 €	45 500,00 €
V3	Development of water treatment and quality control					
	- Teollisuuden vesi Oy: Effect of the water quality and boiler chemicals on the corrosion problems of the recovery boiler air preheaters		~~94 350,00 €~~			
			~~59 200,00 €~~			
	- Teollisuuden vesi Oy: Effect of the water quality and boiler chemicals on the corrosion problems of the recovery boiler air preheaters	24 600,00 €			24 600,00 €	
	- Teollisuuden vesi Oy: TOC research	45 000,00 €			45 000,00 €	
	- University of Oulu: TOC research	10 000,00 €				10 000,00 €
	- Boildec Oy: Recommendation on water quality control in recovery boilers		11 200,00 €			11 200,00 €
		162 300,00 €	**51 200,00 €**			
WP5	**Coordination and other**					
K1	Coordinator	4 000,00 €				4 000,00 €
K2	Secretary services					
K3	Meetings and communication	15 690,00 €		2 690,00 €	8 000,00 €	5 000,00 €
K4	Translations		10 000,00 €			10 000,00 €
In total		**506 090,00 €**	**176 400,00 €**	**27 600,00 €**	**279 790,00 €**	**244 900,00 €**
		682 490,00 €				

	Reservation
	Proposal
	~~Not ordered~~

APPENDIX II

Boildec Oy:
Field testing of compound materials, test no 1

24.8.2009

FIELD TESTING OF COMPOUND MATERIALS, TEST NRO 1

The purpose of the test was to expose different compound tube materials to conditions in recovery boiler furnace for 1000 h so that the surface temperature is about 440°C.

Test was initiated by installing an oil-cooled test probe into unused liquor gun opening in Metsä Botnia Joutseno mill recovery boiler.

It was soon discovered that the surface-mounted thermocouples, which had been planned to be used for input for cooling fan control, did not produce meaningful results. Therefore it was decided to replace the thermocouple reading in the fan control by pressure reading, as it was concluded from previous experiments and design calculations that stable pressure would yield variations in surface temperature that were still tolerable. In fact, this way of controlling the surface temperatures resembles the way real boilers are operated more closely.

The alterations in the control system were completed on 8.7.2009 and the system pressure tuned to right level on 9.7.2009, as operation scheme of liquor guns had to be changed so that wet liquor did no longer spray on the test probe, as continuous spraying of wet black liquor on test probe makes pressure and temperature control impossible.

The pressure set point was estimated on the basis of the previous experiment that took place in September 2006. In the previous test the right surface temperature was achieved when the system pressure was about 4,5 bar (overpressure). This time the materials are different, as real compound material is used in stead of pure stainless steel specimens. The tube material has considerable better conductivity and therefore the temperature difference between hot surface facing furnace and the cold, oil-cooled surface is in this case smaller. This difference has to be compensated by increasing the probe pressure. Design calculations implied that the correct surface temperatures would be reached with the probe pressure of 5,3 bar (overpressure). At this pressure, the cooling oil saturation temperature is about 362ºC.

At the beginning of the experiment the set point for probe pressure was increased to 6,3 bar (overpressure), since boiler was operating at that time at lower load than normally. As boiler load was increased on 10.7.2009, the set point was reduced to final value of 5,3 bar (overpressure).

Experimental setup functioned well for four weeks, until on 9.8.2009 at 20:30 the air fan responsible for the cooling of the whole setup lost power for some unknown reason. As a result, the test probe pressure rose uncontrollably until safety valve opened and cooling oil was lost. Soon after natural cooling of the test specimens was lost and the test specimens were destroyed. The test had to be terminated after 750 hours of operation.

As long as power was available, the experimental setup was working well and in a controllable manner. For example, the probe pressure was relatively stable, see figure 1.

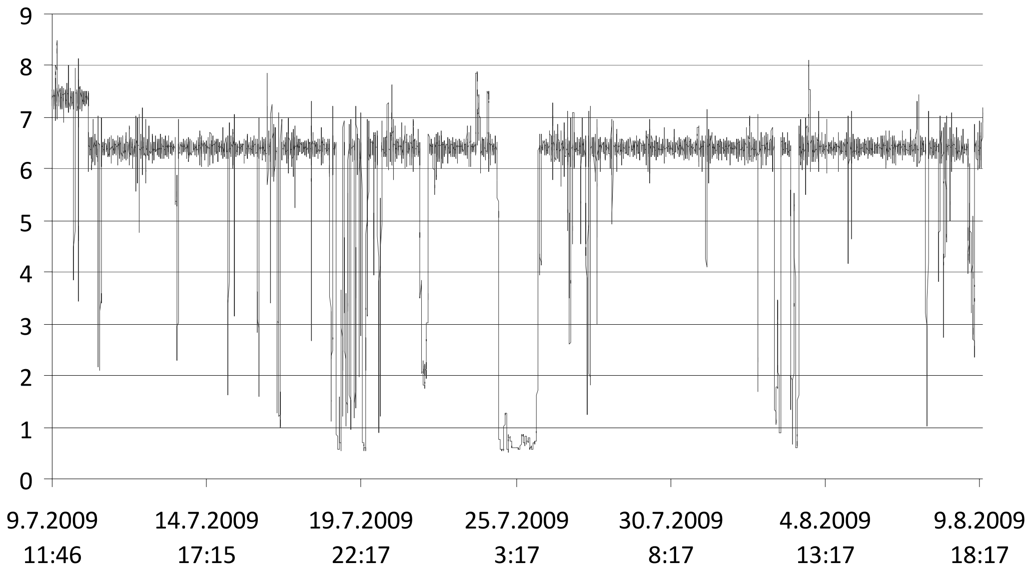


Figure 1. System pressure during the test nro 1 (absolute pressure)

The longest period when the pressure control was not working well was a 36 hours period between 12.00 24.7. – 23.30 25.7., when apparently wet black liquor was spraying on the probe cooling it uncontrollably. There were also some instances when the pressure was momentarily lowered. However, pressure control was able to keep the pressure close (in the range of 4,3 – 6,3 bar) to set point more than 85 % of the total time and the maximum pressure below 7,3 bar, i.e. control the saturation temperature of the oil below 378ºC, not more than 16ºC above the temperature corresponding to the set point pressure.

The surface temperatures calculated using the average heat flux (as measured in the previous experiment in 2006) and the measured system pressure (and using known material dimensions and properties for test materials) are shown in figure 2.

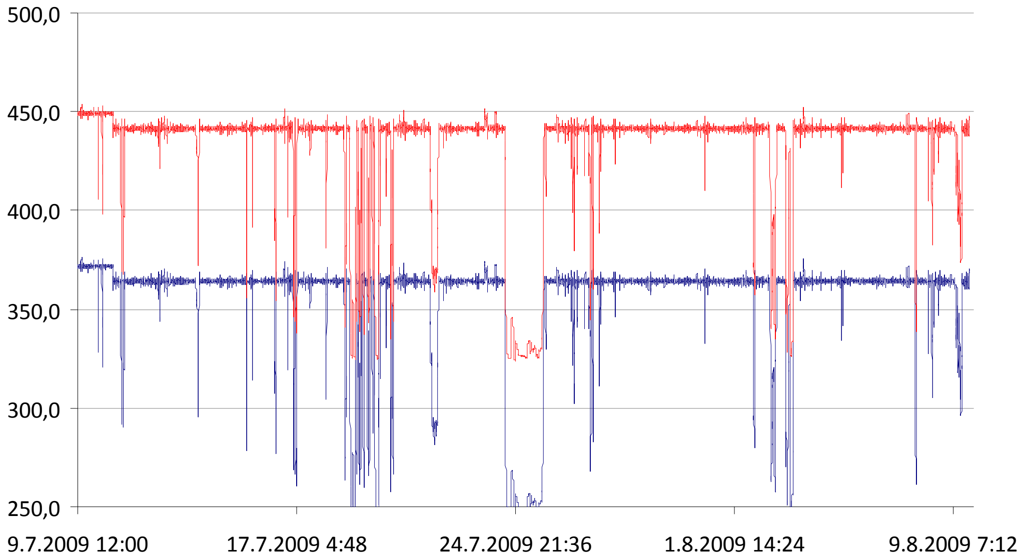


Figure 2. Oil temperature and test material temperatures (both calculated) in test nro 1 (red line – material, blue line – oil)

As can be seen from the figure 2, the material temperatures were relatively stable and close to the 440ºC target level, apart from short periods during which wet black liquor was spraying on the probe.

The test will be repeated as soon as the probe is repaired.

The temperature measurements will be modified so that in stead of surface mounting, two thermocouples will be installed in holes drilled into test specimens form above (the uppermost specimen) or below (the lowermost specimen). The test materials form one wall in the probe.

The reason for the loss of power is currently unknown. After the loss of power, the cable proding power to the fan was removed from the wall socket and plugged into another socket. All equipment started to function well. The wall socket operation was tested with another extension cable and found to be out of power. However, the inquiries for the cause of the loss of power have produced no results so far.

24.8.2009, in Vantaa

Timo Karjunen

APPENDIX III

Nikolai DeMartini, Åbo Akademi:
Co-firing black liquor and biomass-laboratory tests

Co-firing black liquor and biomass- laboratory tests

Nikolai DeMartini
Esperanza Monedero*

*Instituto de Investigación en Energías Renovables, Albacete, Spain.

Objective

- Provide initial laboratory data on the impact of four fuels (bark, wood, peat, biosludge) on the combustion properties of BL when mixed in at two addition levels.
- Properties studied:
  - Swelling
  - Duration of burning stages
  - Carbon release
  - NO formation

Outline

- Experimental
- Swelling Results
- Videos – BL, +13,3% Peat; +25,5% Peat; +0,8% BS; +1.8% BS.
- Duration of Combustion Stages
- Carbon Resease
- NO formation
- Topics for Phase 2

Experiments

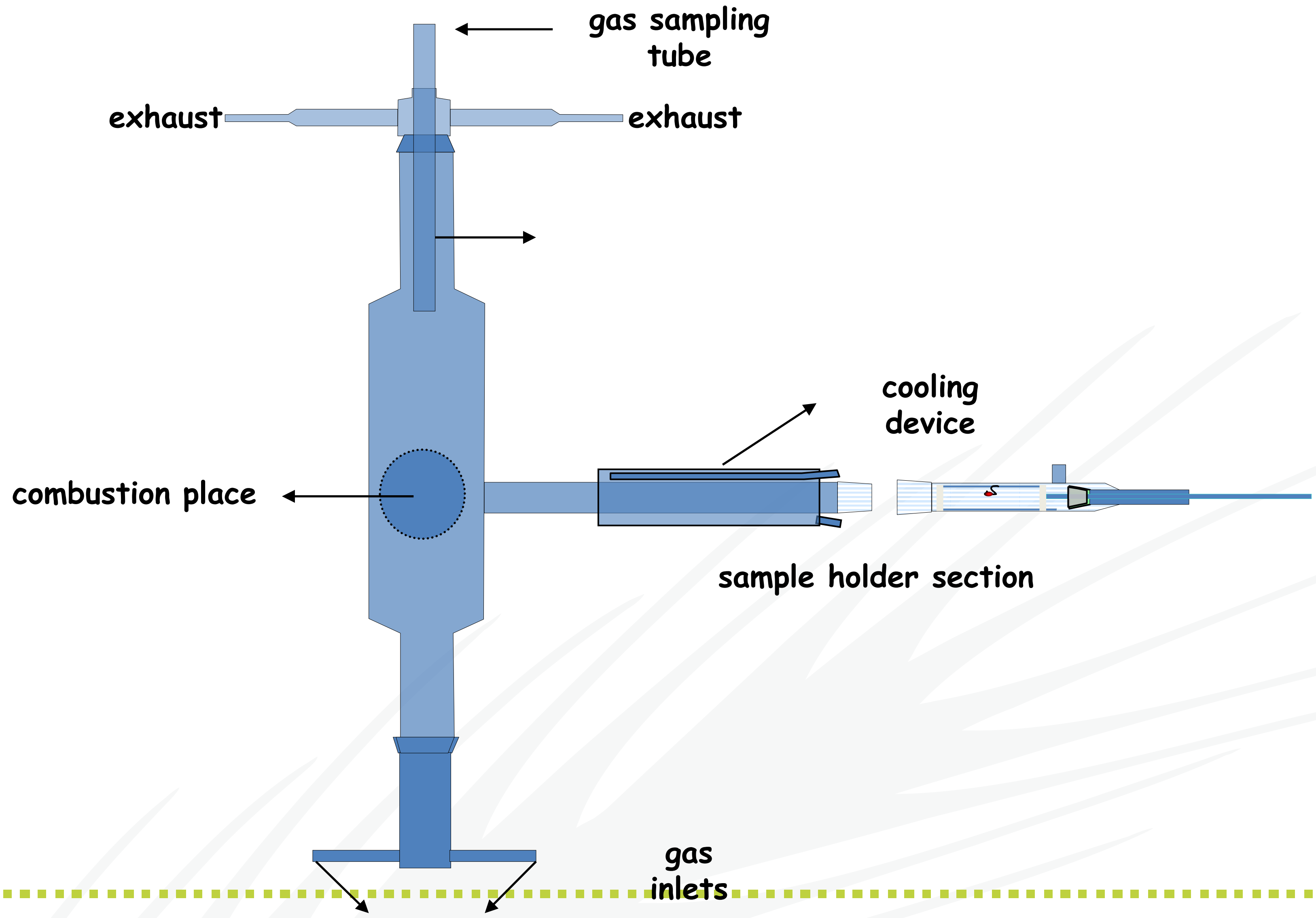
Conditions:

- $3\%\ O_2$
- 1100ºC
- 6 repetitions for each run

Raw Fuels:

- BL: Finnish, softwood
- Bark: particle size <1mm
- Wood Chips: particle size =4 mm
- Peat: particle size =powder
- Bio-Sludge: predried sample

Droplet Furnace



Tests performed

Sample	Dry Solids (wt %)	Mass Fraction Biomass (wt % d.s.)	Mixture (wt % d.s.)
Black Liquor	80,4		80,4
Bark	95,0	13,2 / 25,6	82,1 / 83,7
Wood Chips	95,9	13,3 / 26,9	82,2 / 84,1
Peat	94,2	13,3 / 25,5	82,0 / 83,5
Bio-sludge	21,9	0,82 / 1,84	78,7 / 76,6

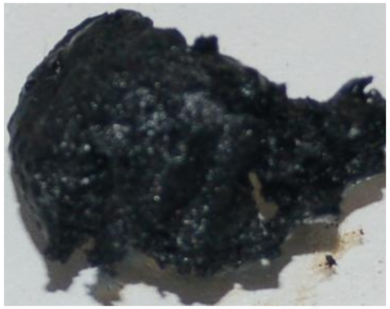
BL 468

BL + 13,2 %
Bark

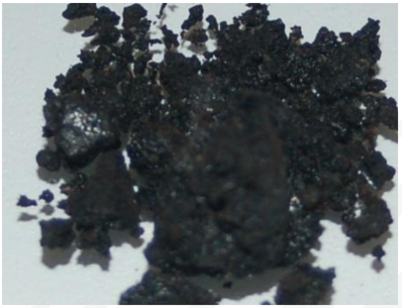
BL + 25,6 %
Bark

BL + 13,3 %
Wood Chips

BL + 26,9 %
Wood Chips



BL + 13,3 %
Peat



BL + 25,5 %
Peat

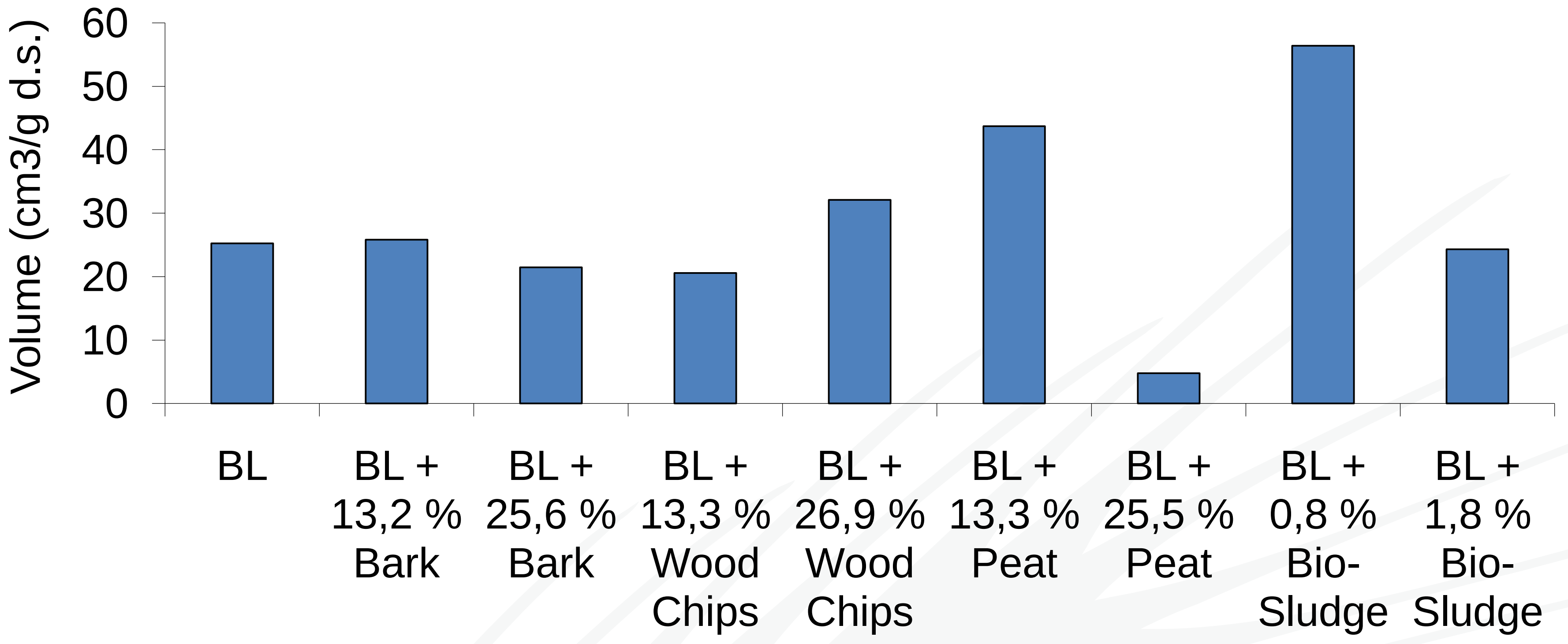
BL + 0,82 %
Bio-sludge

BL + 1,84 %
Bio-sludge

Maximum Swelling

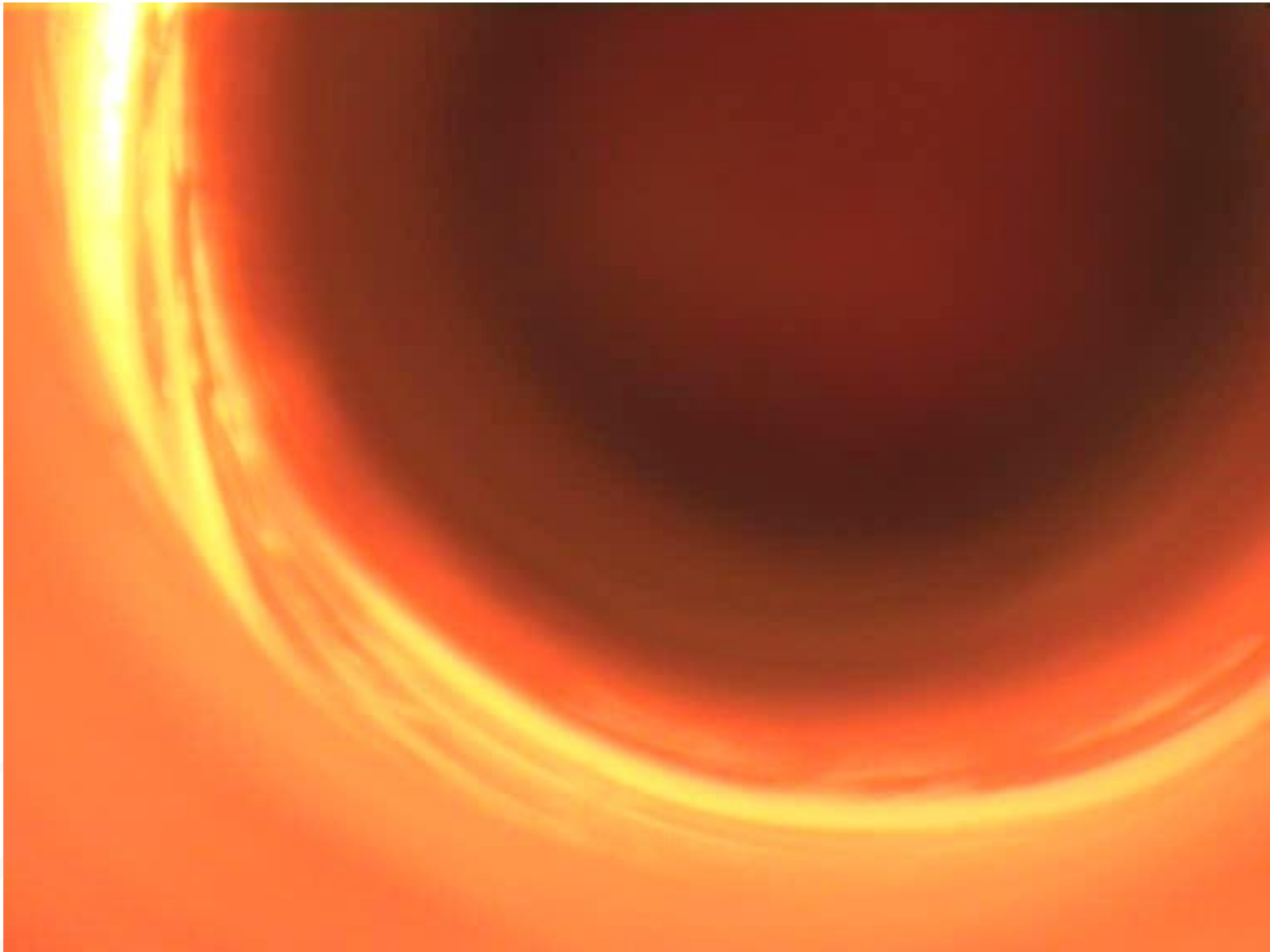
- Measured from 2-D digital image of droplet at maximum swelling
- 2-D surface fit to elipse or circle
- Volume and surface determined for best fit of an elipse or circle

Average Maximum Swelling



Videos

1. BL
2. 13,3P
3. 25,5P
4. 0,8BS
5. 1,8BS

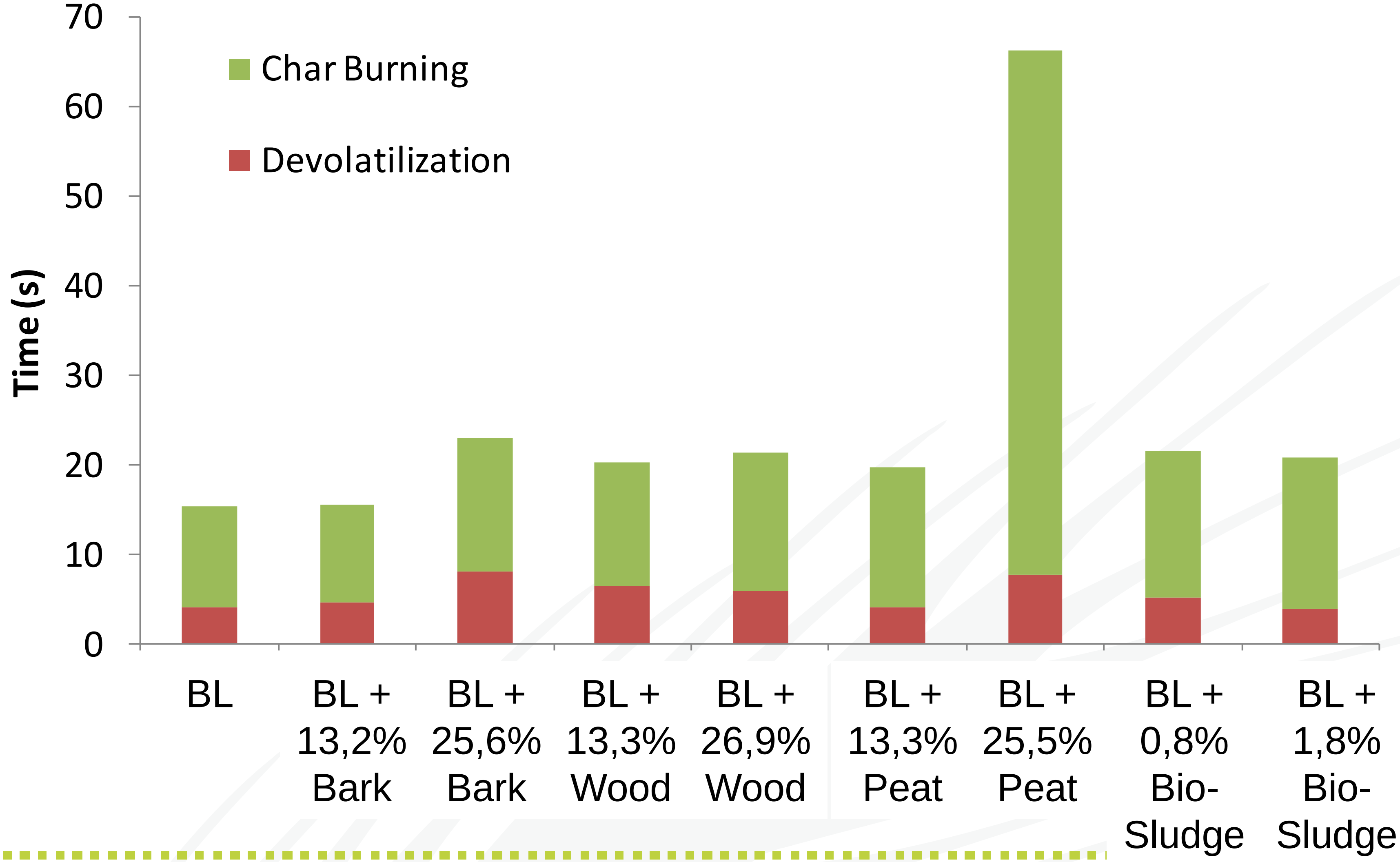


Duration of Combustion Stages

- Determined from droplet combustion videos
- Drying* – time between insertion and flame
- Devolatilization – time from beginning to end of flame
- Char burning – time from end of flame to char collapse

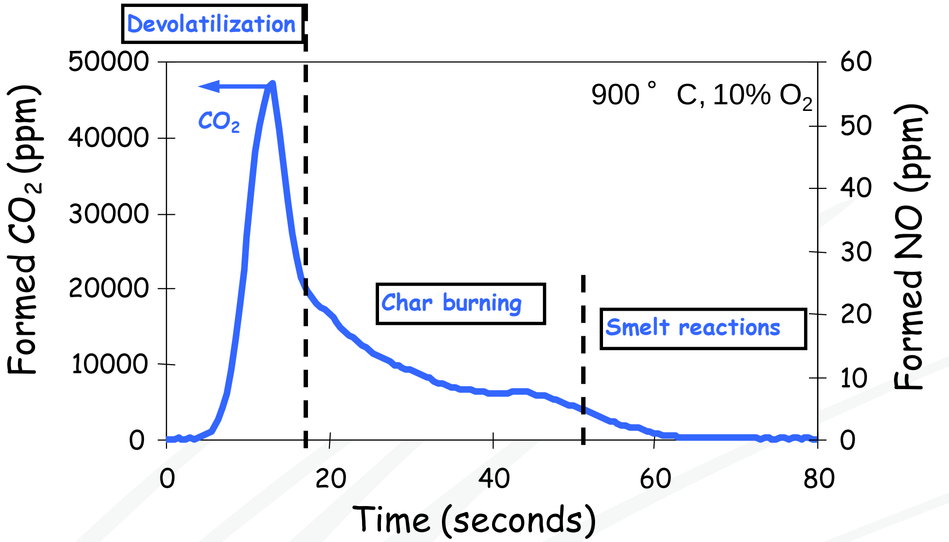
*Drying not reported as some drying occured already before insertion due to high reactor temperature

Duration of Combustion Stages



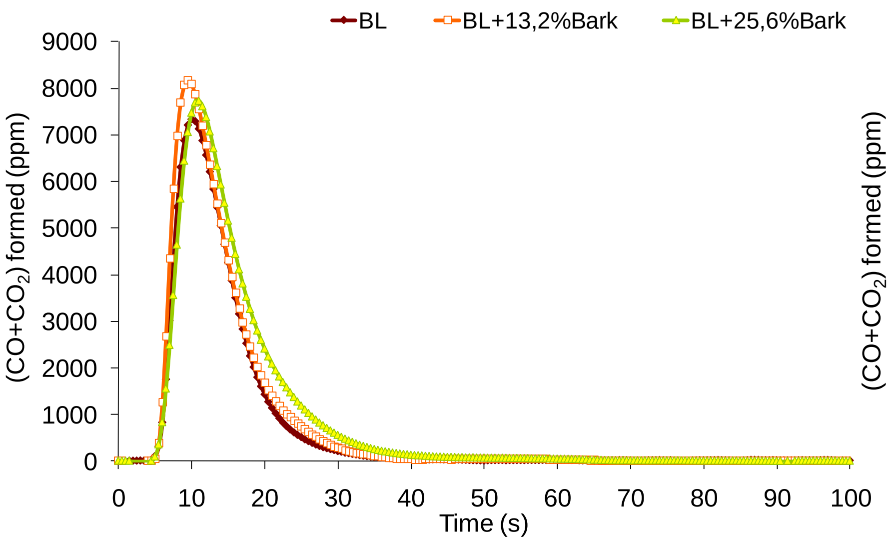
Carbon Release

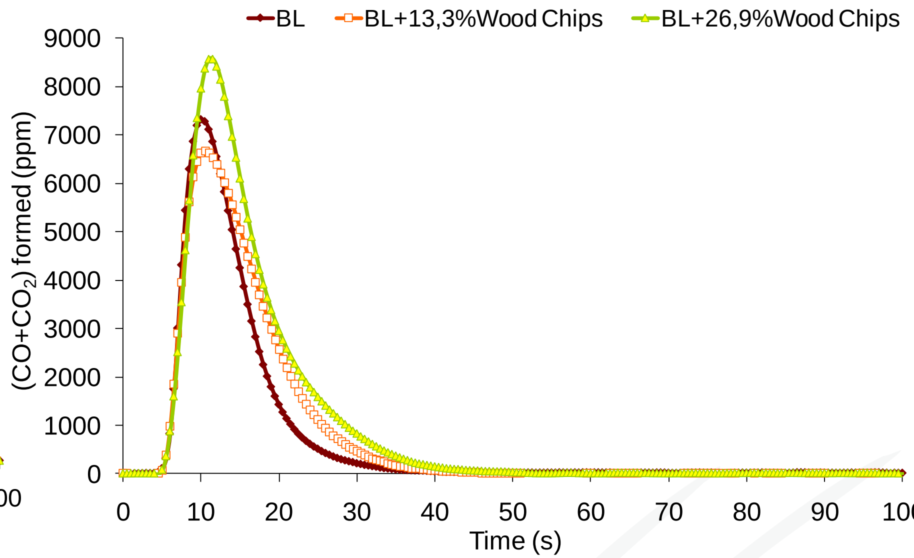
- CO and CO_2 measured with on-line infrared analyzers
- CO and CO_2 release can be divided into devolatilization and char burning stages

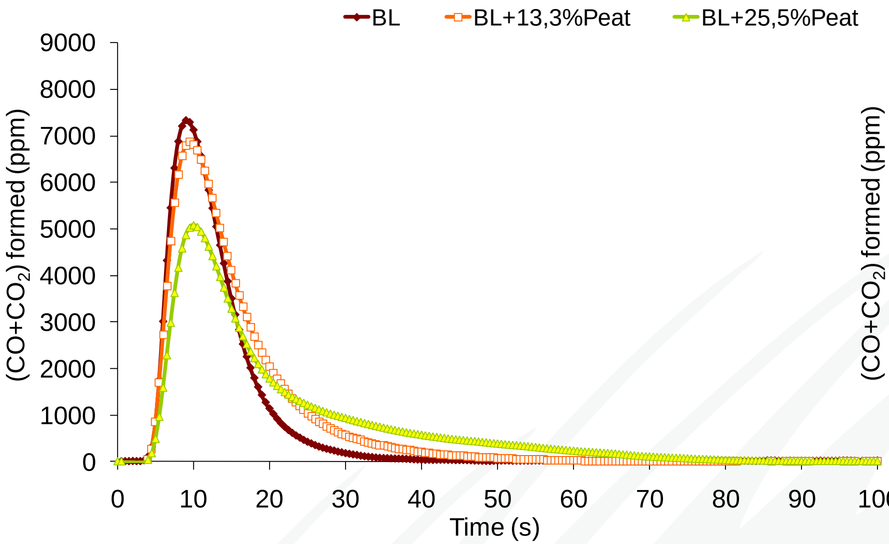


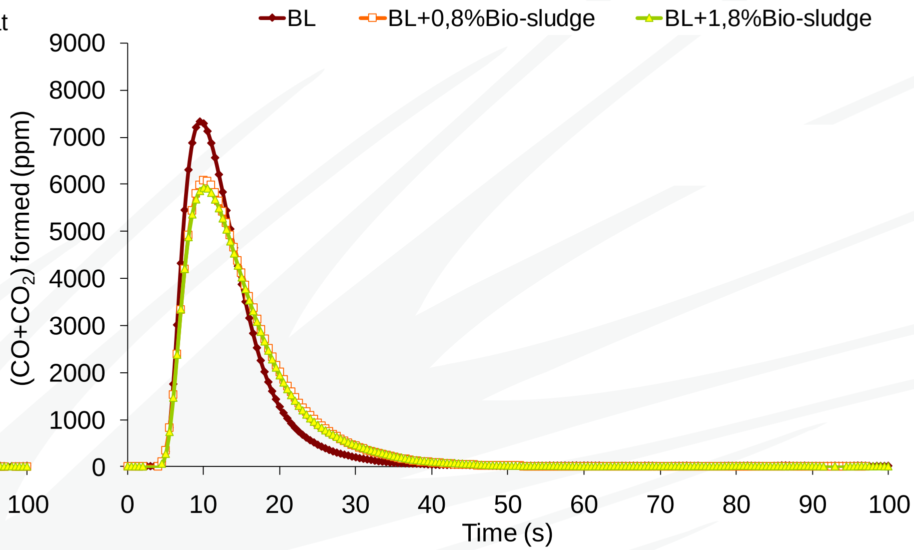
Forssén et al. 2001

Carbon Release Curves ($CO+CO_2$)



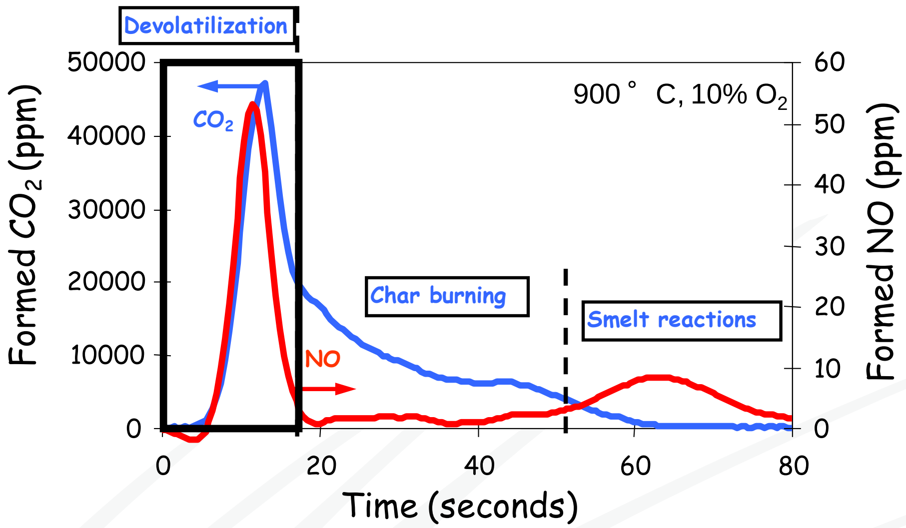






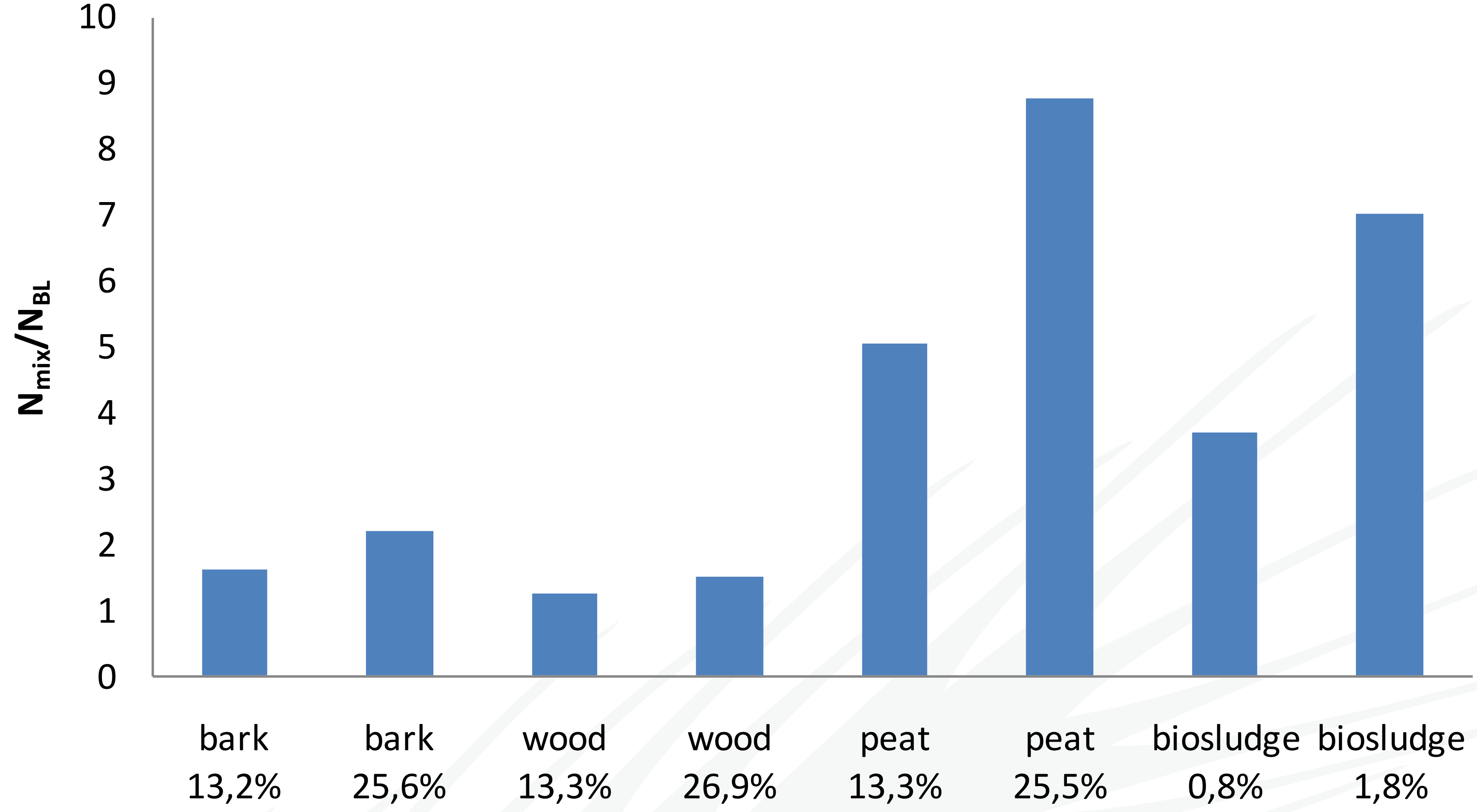
NO formation

- NO measured by an online chemiluminescence analyzer
- Below 900 °C, expect separate NO peaks for devolatilization and char burning stages
- Above 900 °C, there is overlap and only one peak in droplet tests



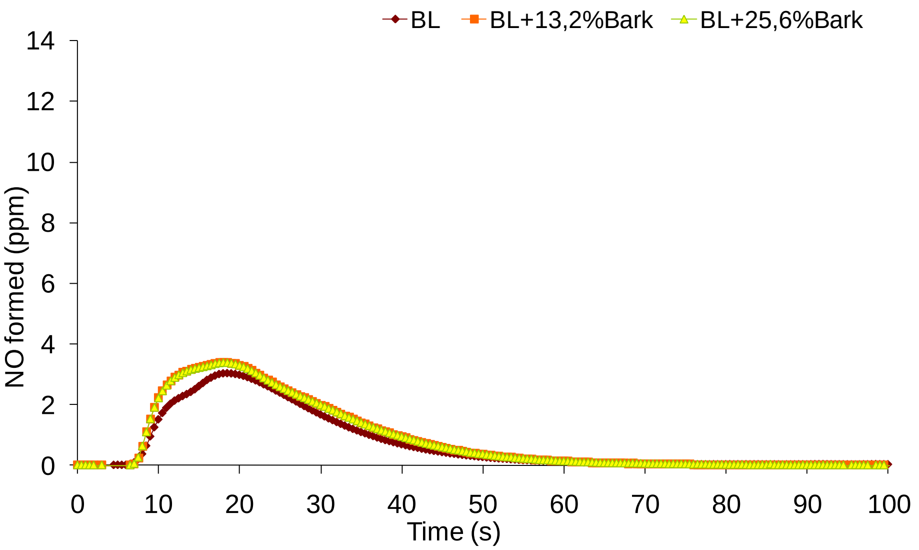
Forssén et al. 2001

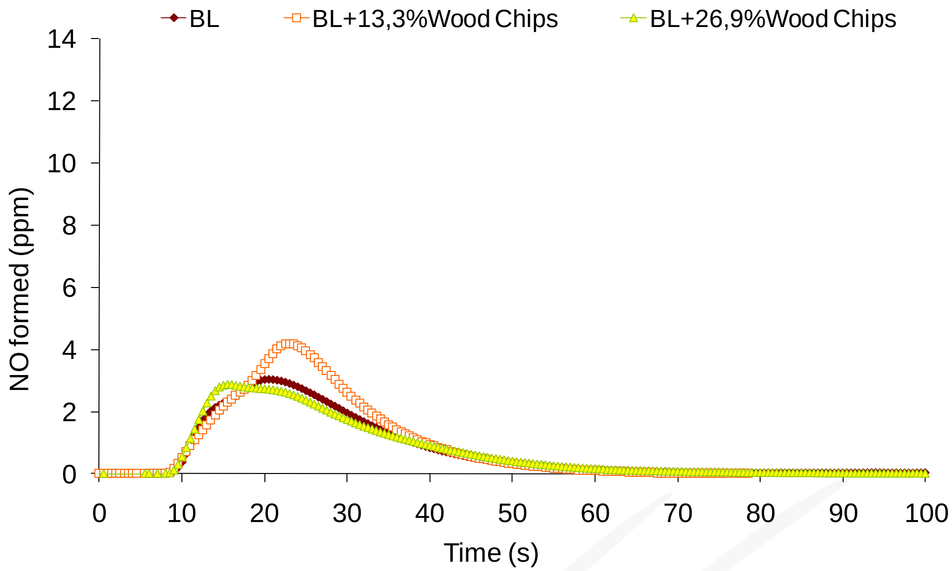
Estimated* N_{mix}/N_{BL}

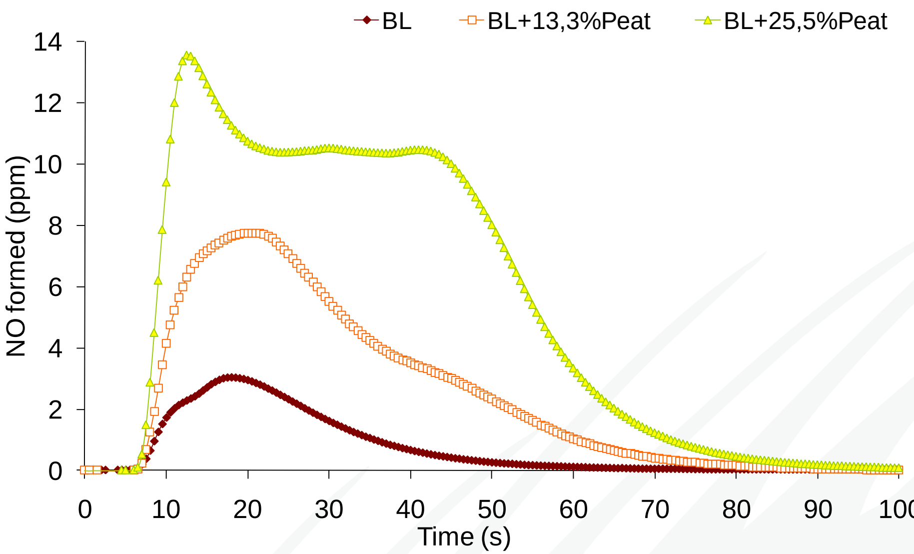


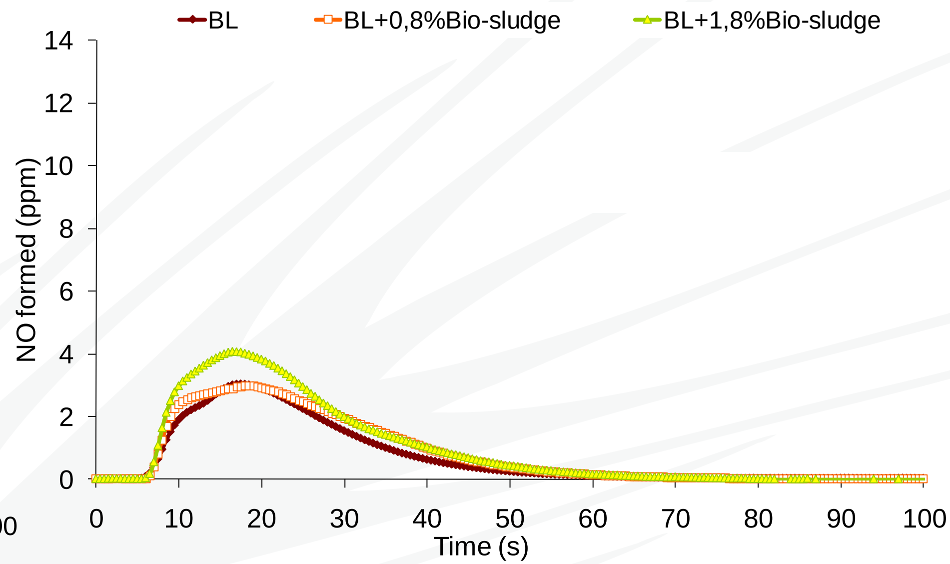
*Have analysis for peat, but not other fuels so estimated based on literature.

NO formed (ppm)

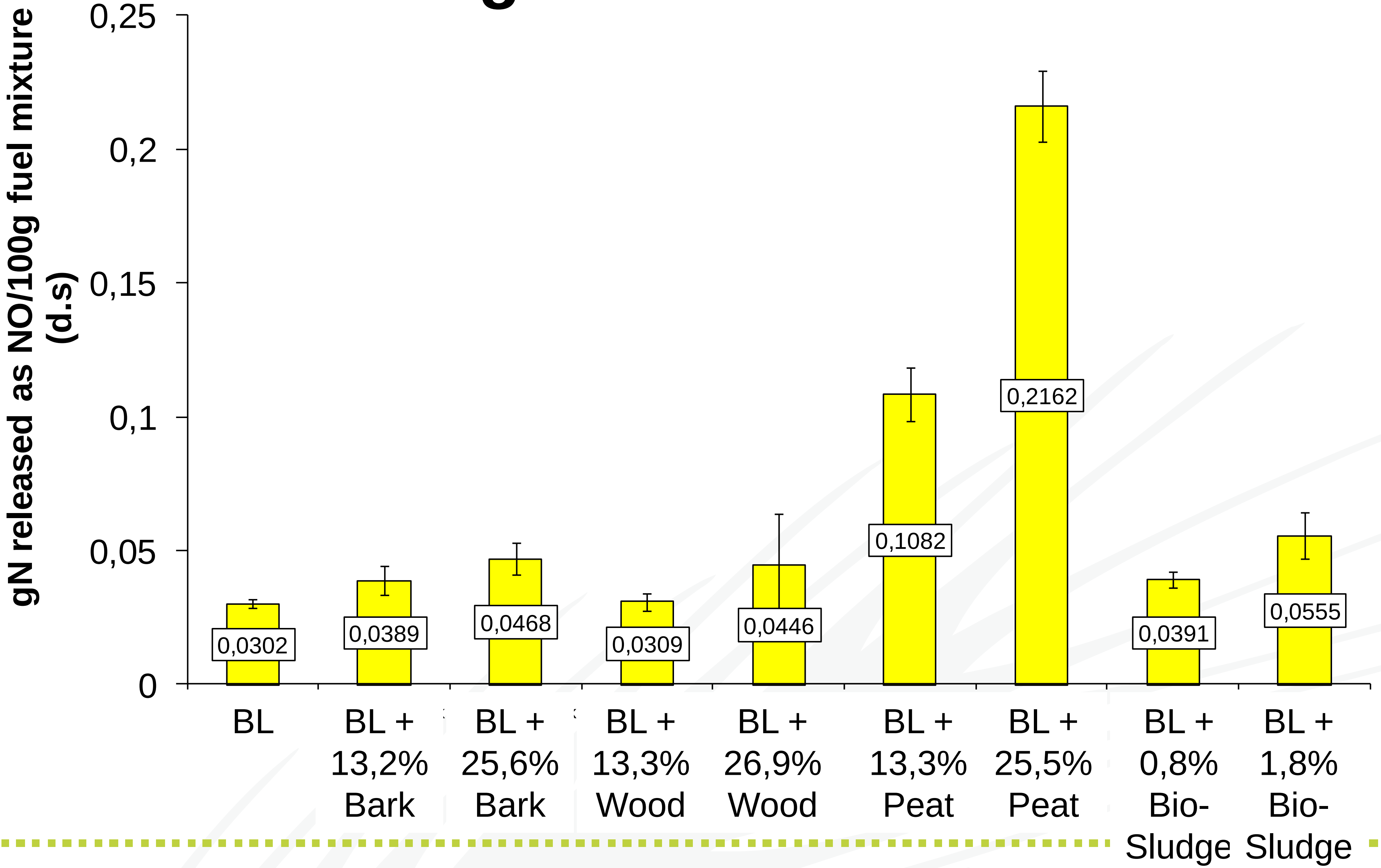








Nitrogen released as NO



Summary

- Droplet homogeneity difficult to ensure
- Peat had the largest overall impact
- Changes in swelling difficult to explain
- Char burning marginally increased by all fuels except 13,3% bark (no change) and 25,5% peat (large change)
- Large increase in NO from peat can likely be controled to some extent in boiler by proper air staging

Conclusions

- Results show promise for co-combustion
- Upper limit for bark, wood?
- Fate of added elements (eg. K) need to be considered
- Does some of the bark N go to the smelt (does the amount of cyanate increase?)
- Modified BL's (ex. lignin removed) + bark or wood?
- Feeding?

Phase 2. Interesting Questions

1. What is the upper limit for bark and wood addition?
2. What is the impact of bark moisture and combustion temperature?
3. What are the burning characteristics of reduced lignin black liquor with the addition of bark?
4. What is the fate of nitrogen in bark - does the char have more cyanate?

APPENDIX IV

LUT:
Once-through and reheater recovery boiler concepts, report on progress
24.8.2009

LAPPEENRANTA
UNIVERSITY OF TECHNOLOGY

Once-through and reheater recovery boiler concepts

Report on progress 24.8.2009

Esa K. Vakkilainen

Progress report

- Studied concepts redefined 26.6.2009
- Requirement to do mill balances for No Power boiler concepts
- Mill balances for all concepts finished
- Reheater concept

Concepts studied (redifined, 26.6.2009)

A. Natural circulation 82 %, 490 °C, 9.0 MPa (Joutseno)

B. Natural circulation 85 %, 505 °C, 10.2 MPa (Kymi)

C. Natural circulation 85 %, 515 °C, 12.0 MPa (Yonago)

Future boiler concept

D. Assisted circulation 85 %, 540 °C, 16.0 MPa (SoTu)

Reheat boilers

E. Natural circulation 85 %, 515/515 °C, 12.0/3.0 MPa (SkyRec)

F. Once-through 85 %, 540/540 °C, 26.0/5.4 MPa (Skyrec+)

Case		A	B	C	D	E	F
Capacity	tds/d	5500	5500	5500	5500	5500	5500
capacity (virgin)	tds/d	5005	5005	5005	5005	5005	5005
Dry solids	%	82.0	85.0	85.0	85.0	85.0	85.0
ds (virgin)	%	80.6	83.8	83.8	83.8	83.8	83.8
recycle ash	%	9.0	9.0	9.0	9.0	9.0	9.0
HHV	MJ/kgds	13.00	13.00	13.00	13.00	13.00	13.00
LHV	MJ/kgds	12.28	12.28	12.28	12.28	12.28	12.28
O2 in dry flue gas	%	2.8	2.8	2.8	2.8	2.8	2.8
Primary air percentage	%	23.0	22.0	22.0	22.0	22.0	22.0
Primary air temperature	°C	150.0	190.0	190.0	190.0	190.0	190.0
Secondary air percentage	%	50.0	54.0	54.0	54.0	54.0	54.0
Secondary air temperature	°C	120.0	190.0	190.0	190.0	190.0	190.0
Tertiary air percentage	%	27.0	12.0	12.0	12.0	12.0	12.0
Tertiary air temperature	°C	30.0	190.0	190.0	190.0	190.0	190.0
Quartenary air percentage	%	0.0	12.0	12.0	12.0	12.0	12.0
Quartenary air temperature	°C	30.0	190.0	190.0	190.0	190.0	190.0
Total air temperature	°C	102.6	190.0	190.0	190.0	190.0	190.0
Reduction	%	95.00	96.00	96.00	96.00	96.00	96.00
Main steam pressure RB	bar(a)	91.0	102.0	120.0	160.0	105.0	260.0
Main steam temperature RB	°C	490.0	505.0	515.0	540.0	505.0	540.0
Main steam pressure PB	bar(a)	91.0	102.0	102.0	102.0	102.0	102.0
Main steam temperature PB	°C	490.0	505.0	505.0	505.0	505.0	505.0
Feedwater pressure	bar(a)	110.0	121.0	146.0	182.0	290.0	290.0
Feedwater temperature	°C	120.0	148.0	148.0	148.0	148.0	148.0
		511.3	630.9	632.5	634.8	641.8	641.8
Reheater inlet pressure	bar(a)					36	56
Reheater inlet temperature	°C					348	337
Reheater outlet pressure	bar(a)					34	54
Reheater outlet temperature	°C					400	460
HP FWpreheater inlet temperature	°C	200	200	200	200	200	200
HP FWpreheater outlet temperatu	°C	200	200	220	220	220	220
Flue gas temperature (eco out)	°C	155	197	197	197	197	197
Flue gas temperature (to stack)	°C		155	155	155	155	155
Sootblowing	kg/s	6.0	6.0	6.0	6.0	8.0	8.0

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Electricity generation

Mill with power boiler		A	B	C	D	E	F
Pulping usage total	MW	87.6	88.1	88.9	90.2	88.2	93.2
Mill total usage	MW	95.5	96.1	96.9	98.3	96.2	101.2
Electricity production	MW	233.8	238.4	245.6	261.1	245.1	263.4
Surplus electricity production	MW	138.3	142.2	148.7	162.8	148.9	162.2
Change in electricity production	MW	0.0	3.9	10.4	24.6	10.6	23.9
	%	0.0	2.9	7.5	17.8	7.7	17.3
Mill without power boiler							
Pulping usage total	MW	87.6	88.1	88.9	90.2	88.1	93.2
Mill total usage	MW	91.1	91.7	92.4	93.8	91.7	96.8
Electricity production	MW	149.0	152.9	160.9	174.8	159.3	177.9
Surplus electricity production	MW	57.8	61.2	68.4	81.0	67.6	81.1
Change in electricity production	MW	0.0	3.4	10.6	23.2	9.8	23.3
	%	0.0	5.8	18.3	40.2	16.9	40.3

Recovery boiler electricity consumption

Case		A	B	C	D	E	F
Air fan power	kW	2275	2296	2296	2296	2296	2296
Flue gas fan power	kW	2570	2534	2534	2534	2534	2534
Feedwater pumping pc	kW	2958	3488	4208	5581	3551	8478
Other power	kW	1500	1500	1500	1500	1500	1500
Total power	kW	9304	9818	10538	11911	9881	14809

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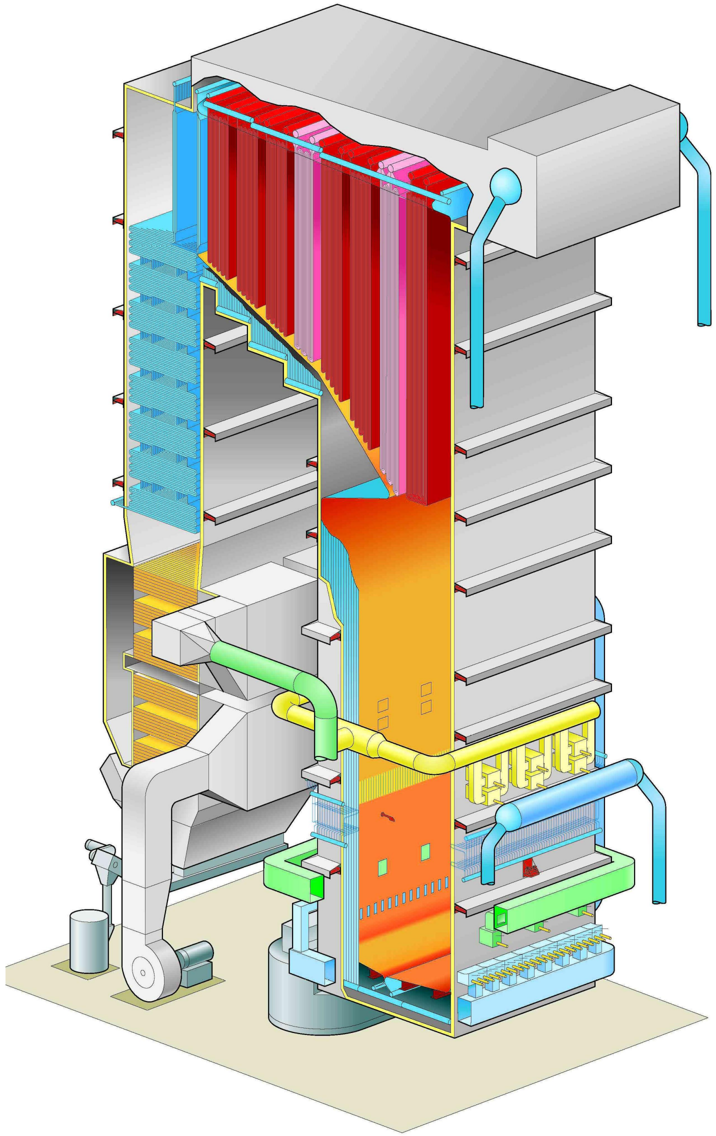
Reheater recovery boiler concept



Reheater recovery boiler concept Vendor Babcock & Wilcox, Capacity 4500 t ds/24h, Black liquor ds 85 %

Main steam 130 kg/s 179 bar(a) 510 °C

Reheated steam 62 bar(a) 443 °C.

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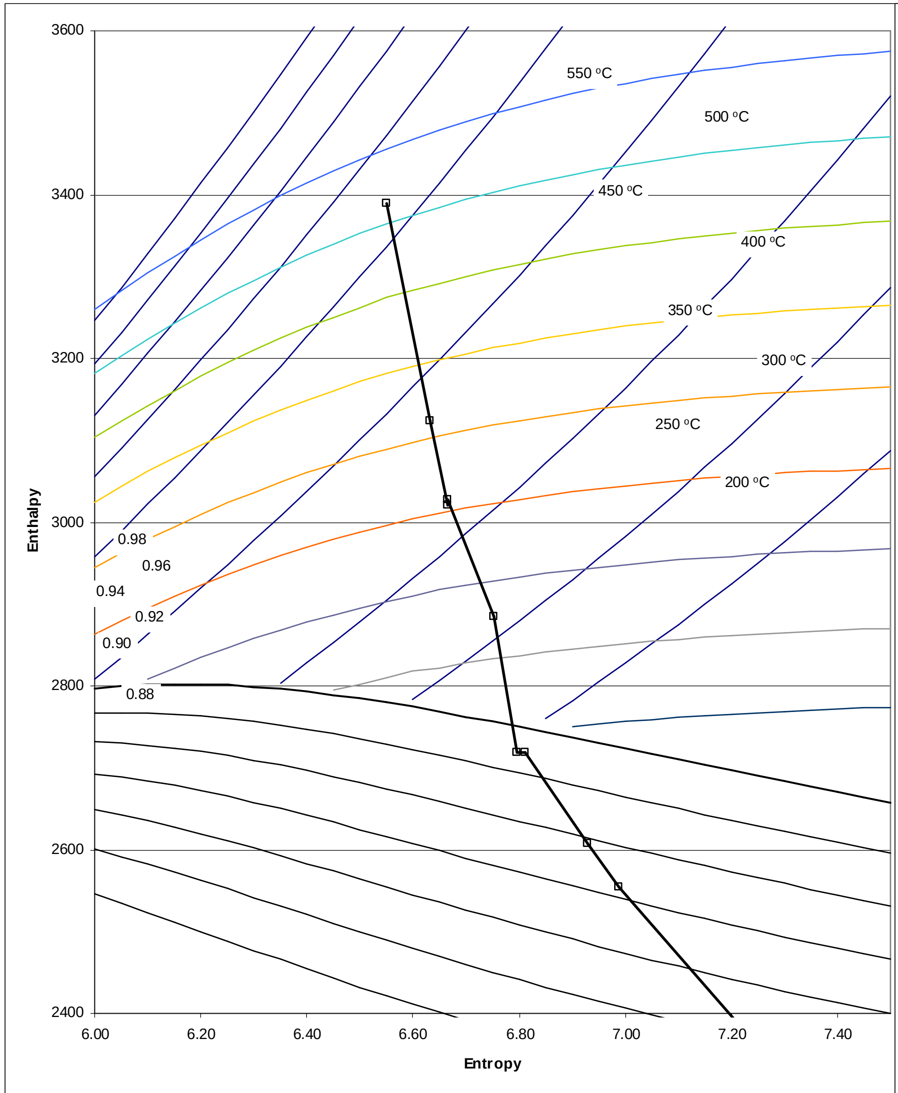
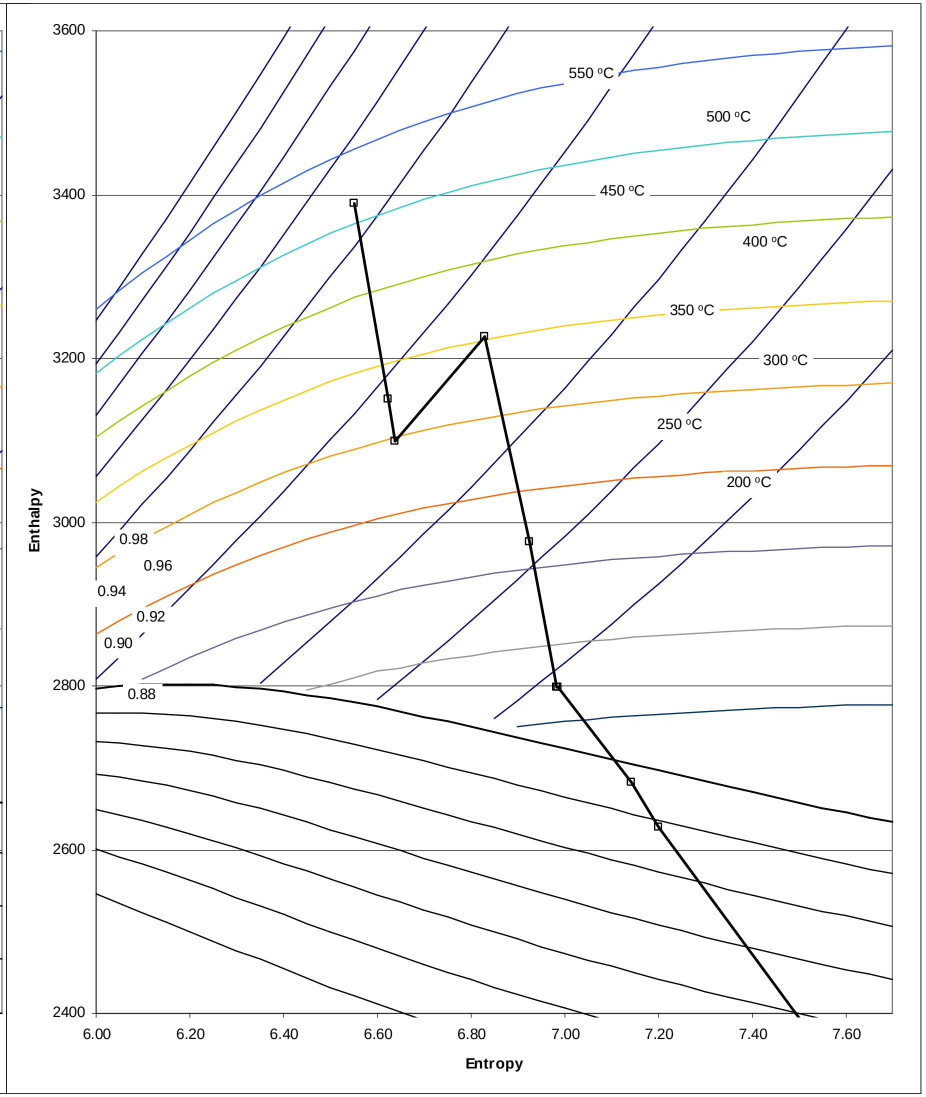
Case C



Case E

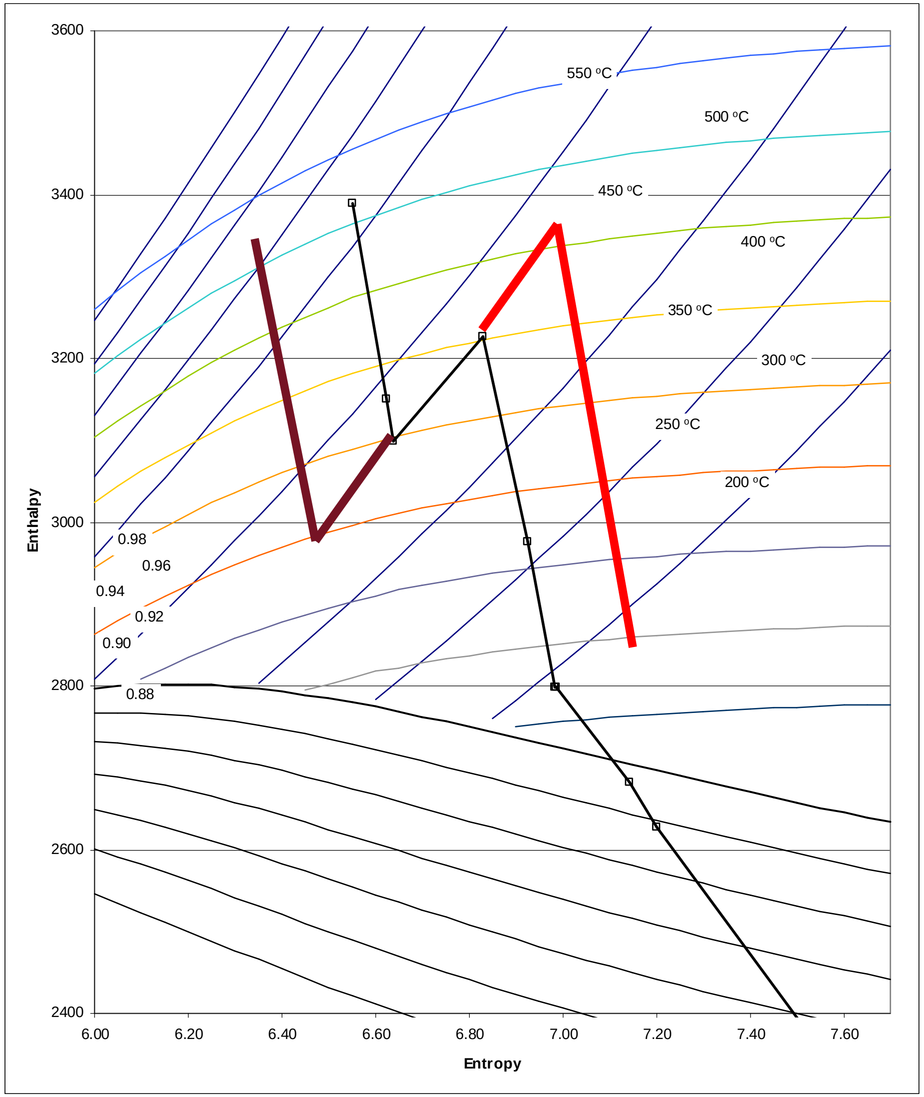


Comparison expansion Case C vs E

- Both start expansion at h=3389.2 kJ/kg at 514/118
- at h=3098.9 kJ/kg at 348/34 reheater goes back for more heat
- Case C expands to h=2726.1 kJ/kg at 149.5/4.5
- while case E expands from h=3227.3 kJ/kg at 400/32 to h=2799.1 kJ/kg at 173/4.5
- Because 3098.9- 2726.1= 372.8 and 3227.3-2799.1= 428.2 the extra from reheat is not that great

Improving Reheat

- One can increase reheating, but then the LP steam gets more and more superheated
- Or increase main steam pressure to e.g. 160 bar resulting in larger expansion and ~3 MWe



APROS calculations

- Calculations for 100 % and 80 % for Case F
- Calculations 100 % -> 80 %
- To be presented

Dimensions and economies

- Dimensions for each Case
- Prices for each Case
- Economies for each Case
- To be presented

Effect of preheating

- Will be done during September and October

APPENDIX V

Åbo Akademi:
Corrosion behaviour of four steels under reducing conditions, an intermediate report

Finnish Recovery Boiler Committee
SkyRec – project intermediate report
August 28, 2009

Part 1: Co-firing of black liquor and biomass – laboratory combustion tests

Part 2: Corrosion behaviour of four steels under reducing conditions

Patrik Yrjas
Åbo Akademi

References:
Part 1: Agreement 16A0913/S82
Part 2: Agreement 16A0913/S82

Part 1 – present status

All experiments have been done.

The final report has been sent out and will be reported at the next meeting, Sept. 8 2009.

Part 2 – present status

The corrosion tests have been started and the status is described in the test plan table. Earlier it was already reported that it was decided to use active carbon instead of BL-char in the tests since it has been found that even small impurities e.g. Cl in the chars may influence on the corrosion behaviour. The project is planned to the end of year 2009.

Test plan.

Explanations:

SEM	has been studied in scanning electron microscope (SEM), but not necessarily evaluated
Corrosion	evaluated after SEM and corrosion was detected
No corr.	evaluated after SEM and no corrosion was detected
No coloring done yet	has been in SEM, but not yet evaluated
Oven	has been or is in the oven, but not yet studied in the SEM
Empty	test not yet started

Test no.	Oven no.	Material	Salt	Temp.	Gas atmosphere	Comments		
1	1	10CrMo	**ash 5 + char**	450	5% CO, 95% N2		SEM	no corr.
2		T91	Na2SO4				SEM	no corr.
3		Sanicro 28	To = 884				SEM	no corr.
4		HR11N					SEM	no corr.
5		10CrMo				repetition	SEM	no corr.
6	2	10CrMo	ash 5 + BL-char	500	5% CO, 95% N2		SEM	no corr.
7		T91					SEM	no corr.
8		Sanicro 28					SEM	no corr.
9		HR11N					SEM	no corr.
10		T91				repetition	SEM	no corr.
11	3	10CrMo	ash 5 + BL-char	550	5% CO, 95% N2		SEM	no corr.
12		T91					SEM	no corr.
13		Sanicro 28					SEM	no corr.
14		HR11N					SEM	no corr.
15		Sanicro 28				repetition	SEM	no corr.
16	4	10CrMo	ash 5 + BL-char	600	5% CO, 95% N2		SEM	No coloring done yet
17		T91					SEM	No coloring done yet
18		Sanicro 28					SEM	No coloring done yet
19		HR11N					SEM	No coloring done yet
20		HR11N				repetition	SEM	No coloring done yet
21	5	10CrMo	**ash 8 + char**	450	5% CO, 95% N2		Oven	
22		T91	NaCl, KCl	(0.3 % Cl)			Oven	
23		Sanicro 28	Na2SO4, K2SO4				Oven	
24		HR11N	To = 526				Oven	
25		10CrMo				repetition	Oven	
26	6	10CrMo	ash 8 + BL-char	500	5% CO, 95% N2			
27		T91						
28		Sanicro 28						
29		HR11N						
30		T91				repetition		
31	7	10CrMo	ash 8 + BL-char	550	5% CO, 95% N2			
32		T91						
33		Sanicro 28						
34		HR11N						
35		Sanicro 28				repetition		
36	8	10CrMo	ash 8 + BL-char	600	5% CO, 95% N2		Oven	
37		T91					Oven	
38		Sanicro 28					Oven	
39		HR11N					Oven	
40		HR11N				repetition	Oven	
41	9	10CrMo	**ash 9 + char**	450	5% CO, 95% N2		SEM	to be re-studied
42		T91	NaCl	(1.3 mol% Cl)			SEM	corrosion
43		Sanicro 28	Na2SO4				SEM	no.corr.
44		HR11N	To = 621				SEM	no.corr.
45		10CrMo				repetition	SEM	corrosion
46	10	10CrMo	ash 9 + BL-char	500	5% CO, 95% N2		SEM	Small points?
47		T91					SEM	no.corr.
48		Sanicro 28					SEM	no.corr.
49		HR11N					SEM	no.corr.
50		T91				repetition	SEM	no.corr.
51	11	10CrMo	ash 9 + BL-char	550	5% CO, 95% N2		SEM	corrosion
52		T91					SEM	no.corr.
53		Sanicro 28					SEM	no.corr.
54		HR11N					SEM	no.corr.
55		Sanicro 28				repetition	SEM	no.corr.
56	12	10CrMo	ash 9 + BL-char	600	5% CO, 95% N2		SEM	no.corr.
57		T91					SEM	no.corr.
58		Sanicro 28					SEM	no.corr.
59		HR11N					SEM	to be re-studied
60		HR11N				repetition	SEM	to be re-studied
61	13	10CrMo	**ash 10 + char**	450	5% CO, 95% N2		SEM	no corr.
62		T91	KCl	(1.3 mol% Cl)			SEM	no corr.
63		Sanicro 28	Na2SO4, K2SO4				SEM	no corr.
64		HR11N	To = 522				SEM	no corr.
65		10CrMo				repetition	SEM	no.corr.
66	14	10CrMo	ash 10 + BL-char	500	5% CO, 95% N2		SEM	no.corr.
67		T91					SEM	no corr.
68		Sanicro 28					SEM	no corr.
69		HR11N					SEM	no corr.
70		T91				repetition	SEM	no corr.
71	15	10CrMo	ash 10 + BL-char	550	5% CO, 95% N2		SEM	corrosion
72		T91					SEM	corrosion
73		Sanicro 28					SEM	corrosion
74		HR11N					SEM	corrosion
75		Sanicro 28				repetition	SEM	corrosion
76	16	10CrMo	ash 10 + BL-char	600	5% CO, 95% N2		SEM	corrosion
77		T91					SEM	corrosion
78		Sanicro 28					SEM	corrosion
79		HR11N					SEM	corrosion
80		HR11N				repetition	SEM	corrosion

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APPENDIX VI

Tanja Pentinsaari:
Transient phenomena in recovery boiler char bed

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TRANSIENT PHENOMENA IN RECOVERY BOILER CHAR BED

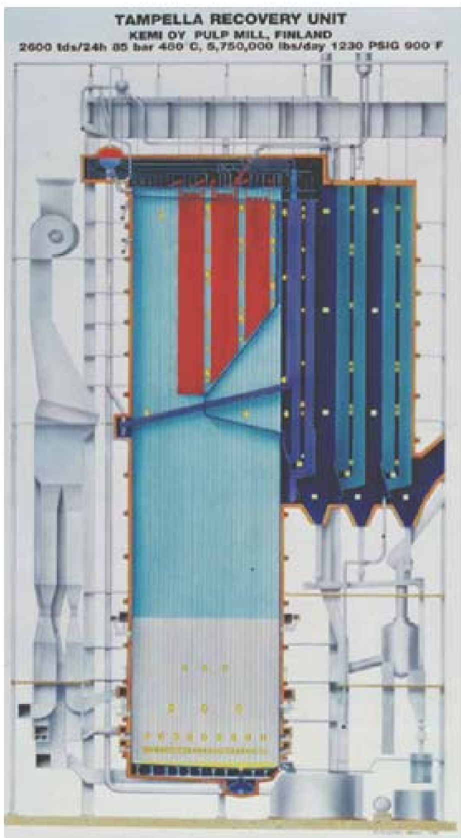
Tanja Pentinsaari

7.9.2009

Preface

- Unstable behaviour and long cooling time have been a problem for economical and safe use
- CFD-models of recovery boilers typically contain only the active surface of the char bed
- Behaviour of the char bed is not tied to time

The smelt water explosion of Kemi recovery boiler in 2008



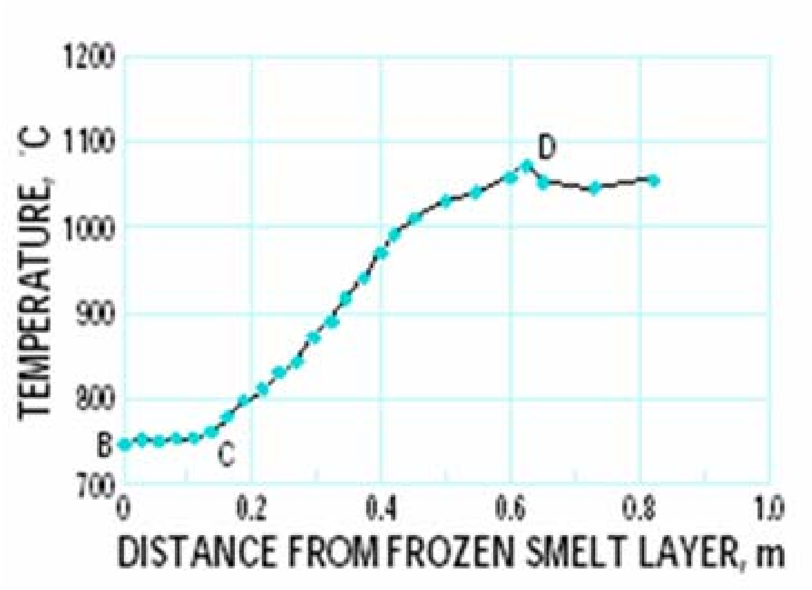
The contents of this work

- The transient phenomena in char bed during operation and the factors causing change
- The thermal properties which have an effect to cooling
- The cooling methods
- Simulation of the cooling by using 1-dimensional ADL-model

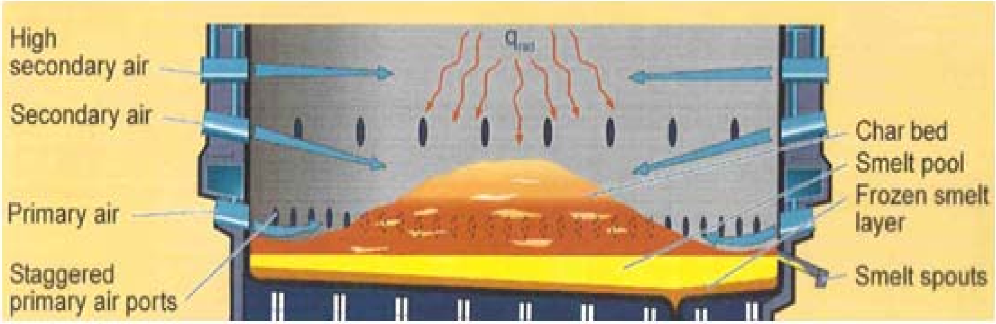
The structure and the thermal properties of the char bed

- Composition:

Element		Sample 1	Sample 2	Sample 3
Carbon, C	%	0.5	2.4	0.3
Sulfur (tot), S	%	10.5	11.1	11.6
Sodium, Na	%	40.8	40.1	42.2
Potassium, K	%	3.9	4.0	4.2
Chloride, Cl	%	0.3	0.4	0.3
Magnesium, Mg	%	2.7	2.6	0.7
Calcium, Ca	-	$45.3*10^{-6}$	$47.3*10^{-6}$	$68.5*10^{-6}$
Iron, Fe	-	$69.8*10^{-6}$	$161.*10^{-6}$	$161.*10^{-6}$
Phosphor, P	-	$18.7*10^{-6}$	$9.6*10^{-6}$	$32.5*10^{-6}$
Carbonate, Na_2CO_3	%	66.2	74.1	63.6
Sulfate, Na_2SO_4	%	6.8	3.7	8.3
Sulfide, Na_2S	%	21.6	24.9	23.3
Thiosulfate, $Na_2S_2CO_3$	%	0.9	1.0	0.8



- Shape and structure:
- Burning surface layer (point D) and below it dense, unreaction char bed
- Frozen smelt layer in bottom of the furnace (point B)

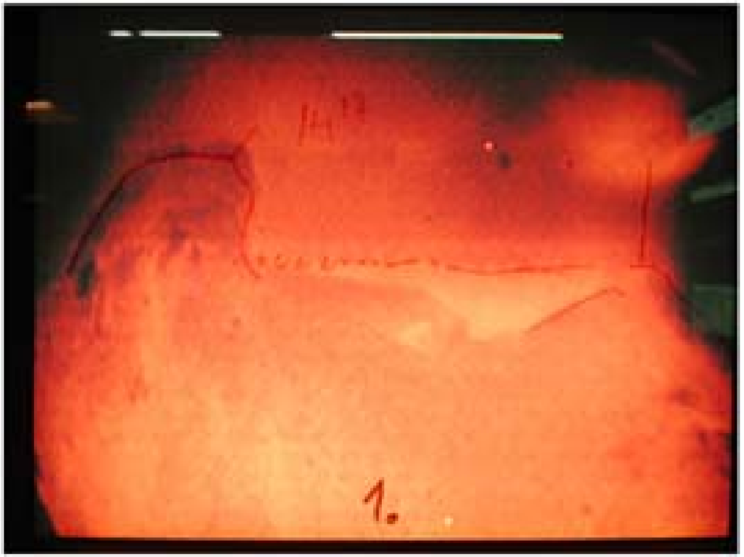


- Thermal properties:
- the heat in the char bed is about 4200 MJ/m^2
- the heat in the smelt per char bed unit area is about 340 MJ/m^2

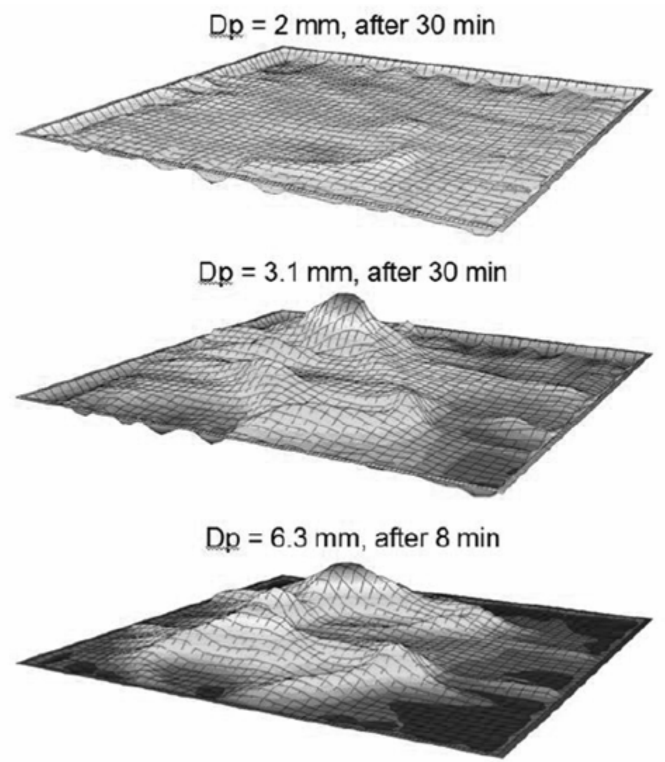
Material	Density	Heat capacity	Thermal conductivity	Thermal diffusivity
	kg/m^3	J/kg°C	W/m°C	10^9 m^2/s
Inactive char	400-1330	1254	0.078	50-75
Active char	290-460	1254	0.28-0.38	500-1000
Smelt, liquid	923	1338	0.450	181
Smelt, solid	2163	1421	0.882	284

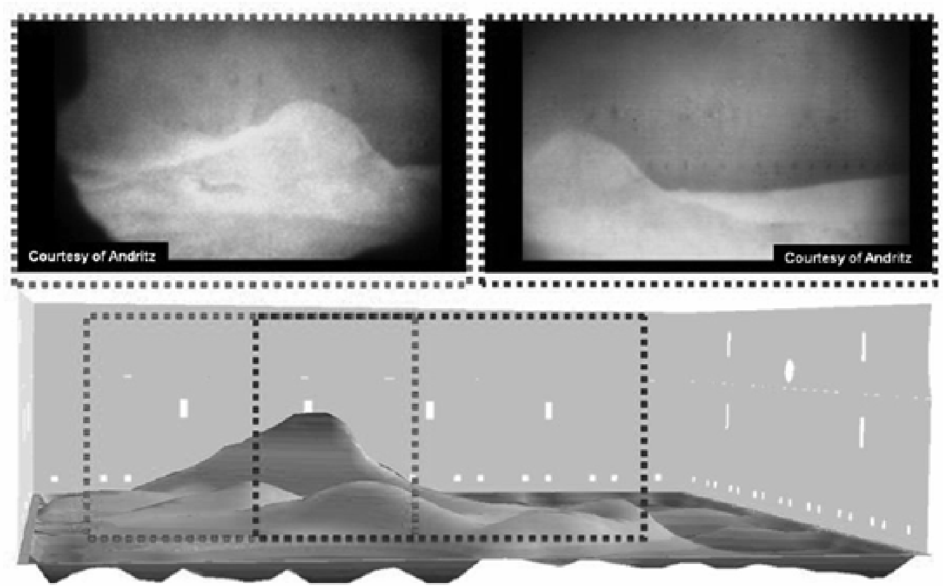
The phenomena of transformation in operation

- The changes in the char bed surface shape:
- landing of the liquor drops in the bed surface → spraying settings
- pile up of the liquor causing a hump, which grows until the spraying settings are changed or the structure of the hump breaks down

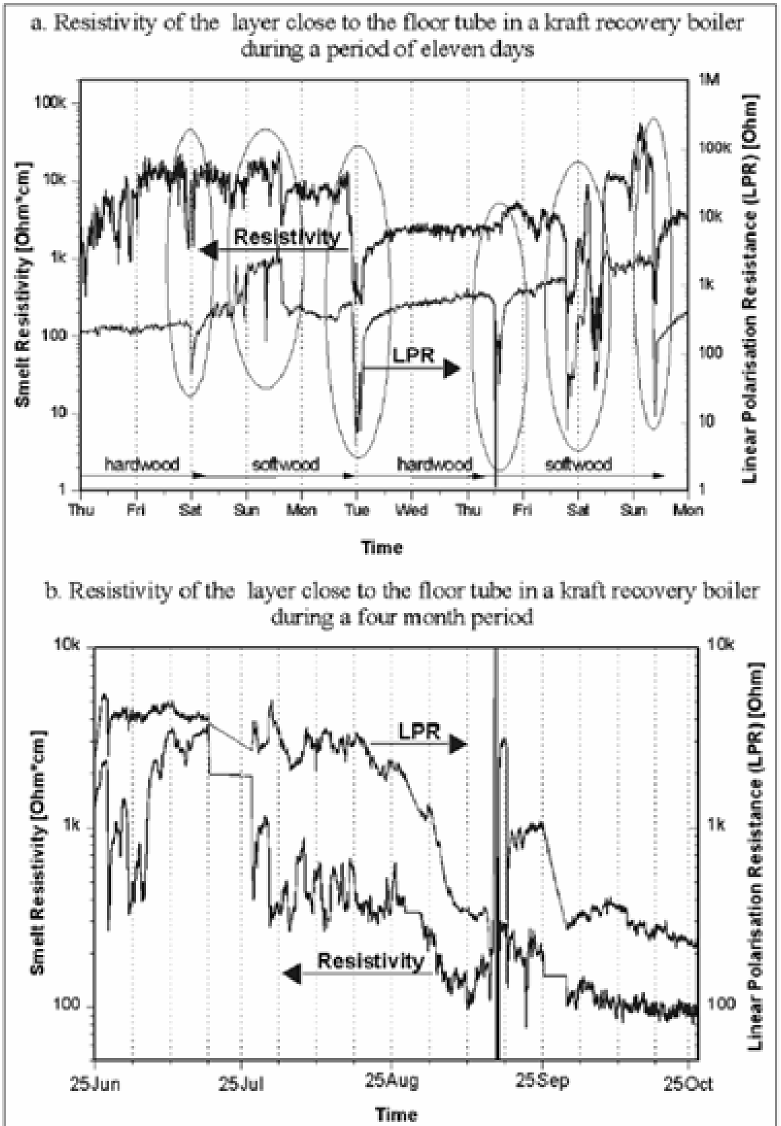


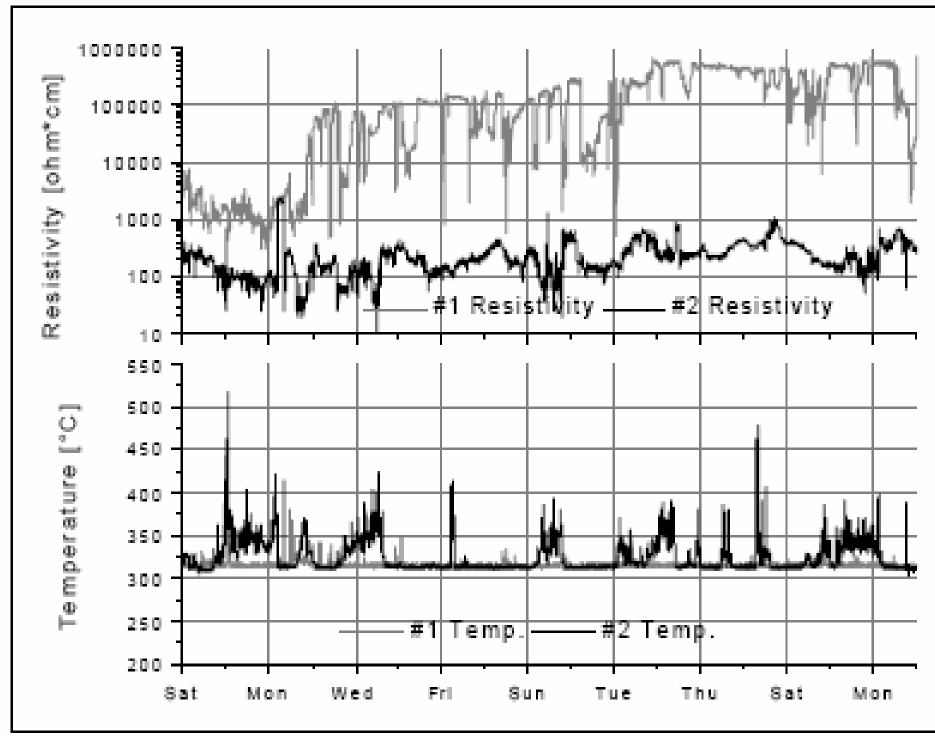
- time pending CFD-model → the effect of the liquor drop size in the char bed shape
- Best similarity was found at drop size 3.1mm





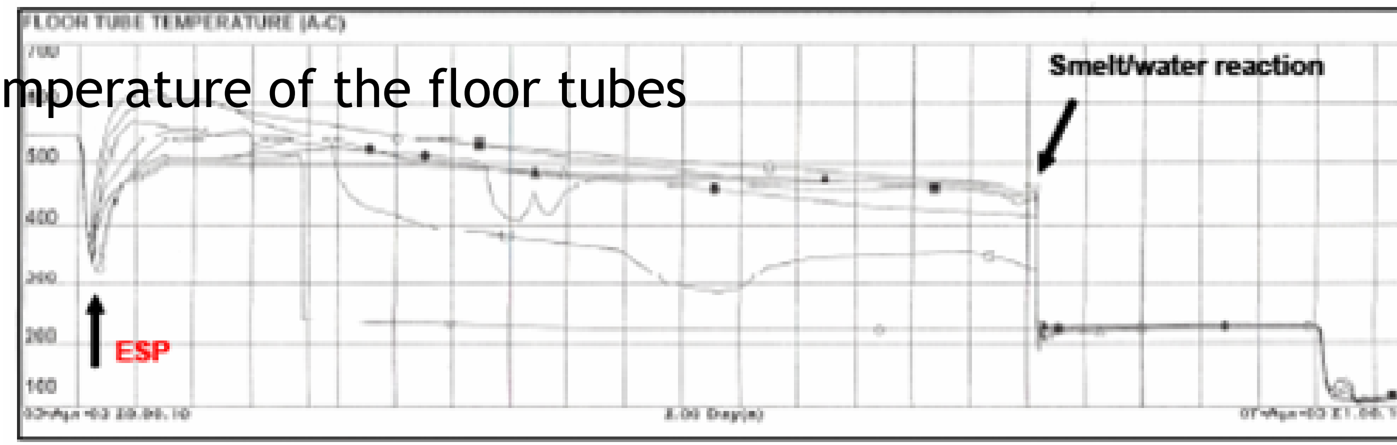
- Resistivity and temperature changes of floor tubes:
- formation of a molten phase at cooled floor tube is caused by enrichment of sulfur, chloride and potassium → corrosion risk
- the smelt properties can be observed by electro-chemical measurements → electrical resistivity and linear polarization resistance (LPR), temperature changes

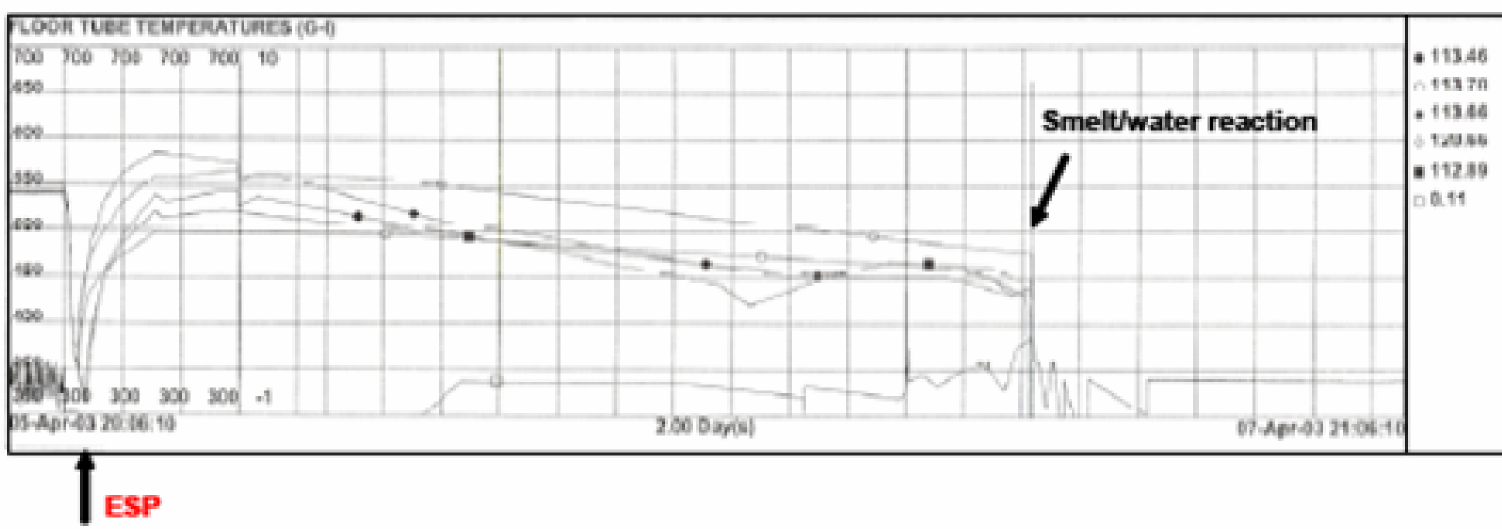

a. Resistivity of the layer close to the floor tube in a kraft recovery boiler during a period of eleven days
Smelt Resistivity [Ohm*cm]
Linear Polarisation Resistance (LPR) [Ohm]
Resistivity
LPR
hardwood
softwood
hardwood
softwood
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Mon
Time
b. Resistivity of the layer close to the floor tube in a kraft recovery boiler during a four month period
Smelt Resistivity [Ohm*cm]
Linear Polarisation Resistance (LPR) [Ohm]
LPR
Resistivity
25Jun
25Jul
25Aug
25Sep
25Oct
Time


Resistivity [ohm*cm]
#1 Resistivity
#2 Resistivity
Temperature [°C]
#1 Temp.
#2 Temp.
Sat
Mon
Wed
Fri
Sun
Tue
Thu
Sat
Mon

- Changes by using sodium bicarbonate ($NaHCO_3$) as a char bed cooling method:
- small-scale smelt water explosion has been occured while using sodium bicarbonate to cool the bed following an ESP

- temperature of the floor tubes





- Factors which cause the phenomena of transformation:
- changes inside the char bed
  → chemical prosesses, thermal and physical changes
  → temperature differences, temperature tensions
  → structure changes, density distribution
- outside factors
  → pieces of solid ash dropping from the superheaters
  → changes in boiler load or operating situation

Simulation of char bed cooling

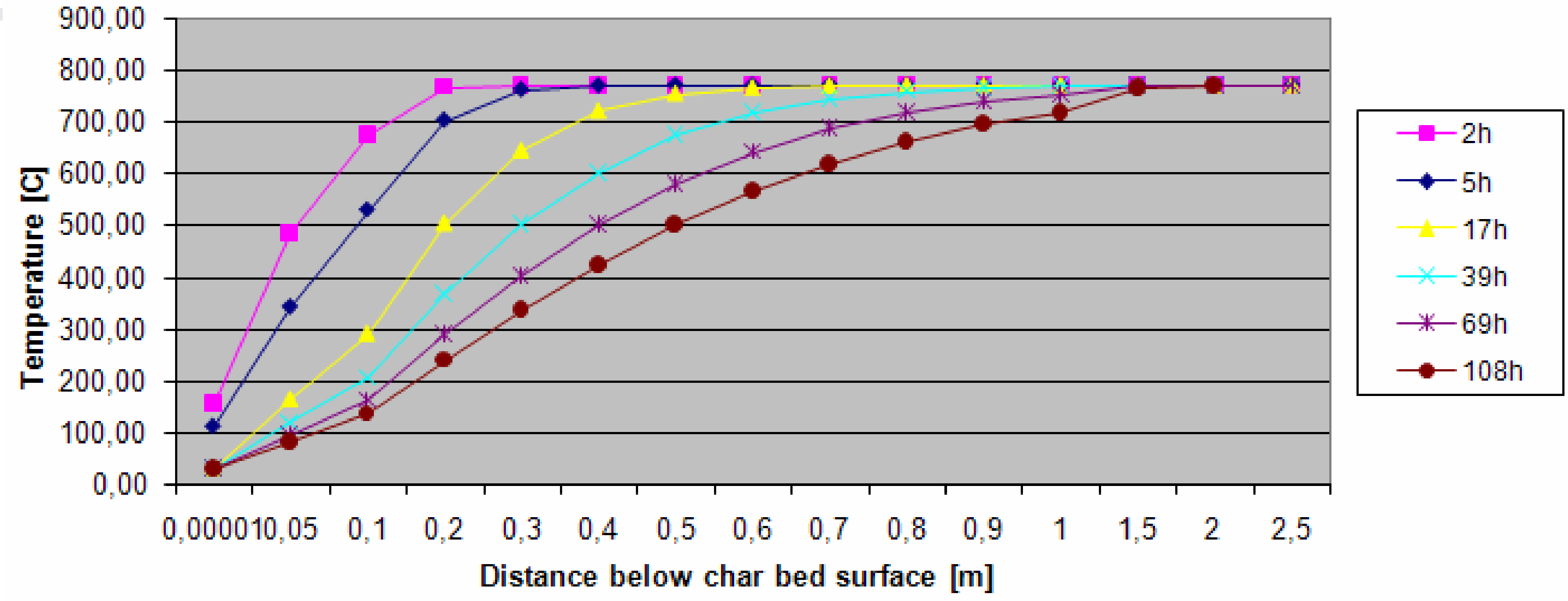
- ADL-model:
- simulation of the char bed temperature profile by using 1-dimensional transient heat conduction

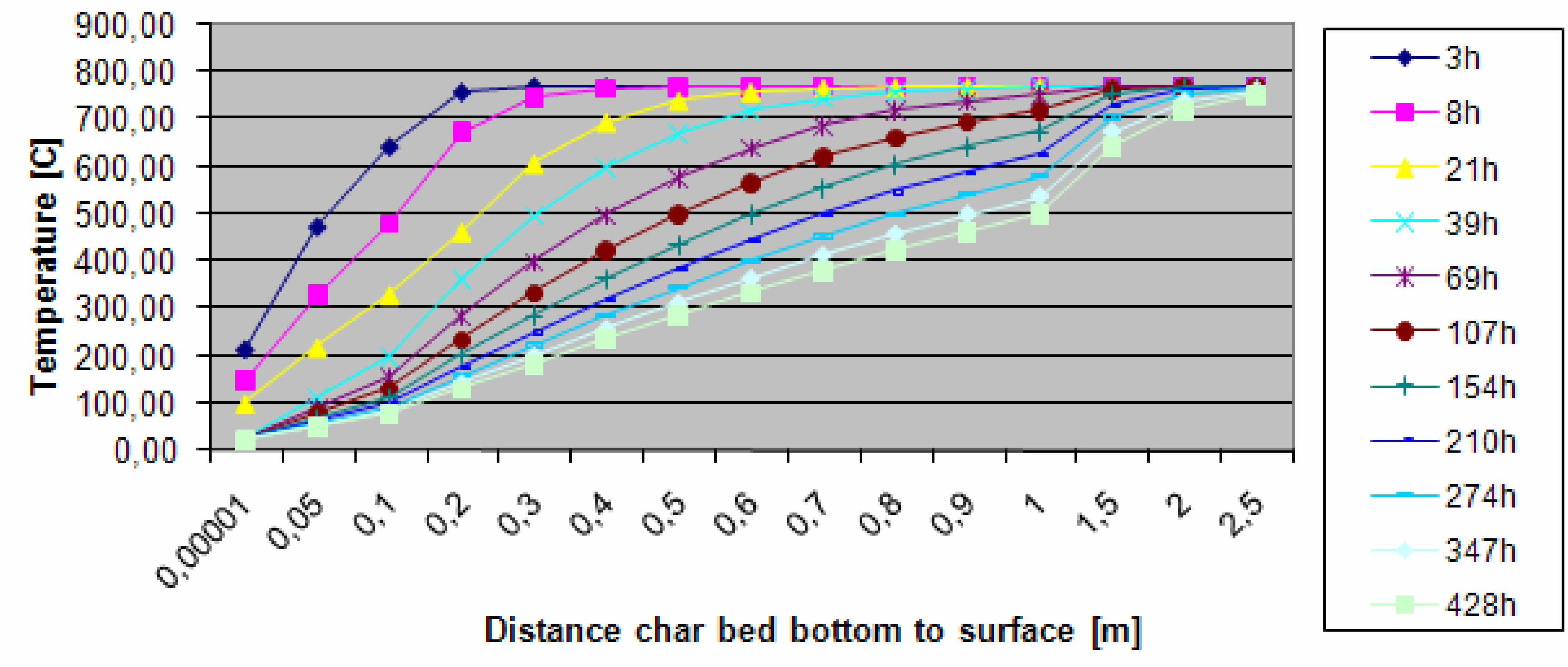
$$\frac{T(x,t)-T_\infty}{T_0-T_\infty} = erf\left\{\frac{x}{2\sqrt{\alpha t}}\right\} + \exp\left\{\frac{hx}{k}+\frac{h^2\alpha t}{k^2}\right\}\left[1-erf\left\{\frac{x}{2\sqrt{\alpha t}}+\frac{h\sqrt{\alpha t}}{k}\right\}\right]$$

where

T(x,t) = temperature at depth x and time t [K]
T_0 = initial slab uniform temperature [K]
T_∞ = temperature of the convective environment [K]
x = depth below the slab surface [m]
t = time [s]
α =thermal diffusivity of the slab material [m2/s]
h = heat transfer coefficient [W/m2K]
k = thermal conductivity of the slab material [W/mK]

- char bed is assume to be 0.6m high and symmetrical





900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
Temperature [C]
0,00001
0,05
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
1,5
2
2,5
Distance char bed bottom to surface [m]
3h
8h
21h
39h
69h
107h
154h
210h
274h
347h
428h

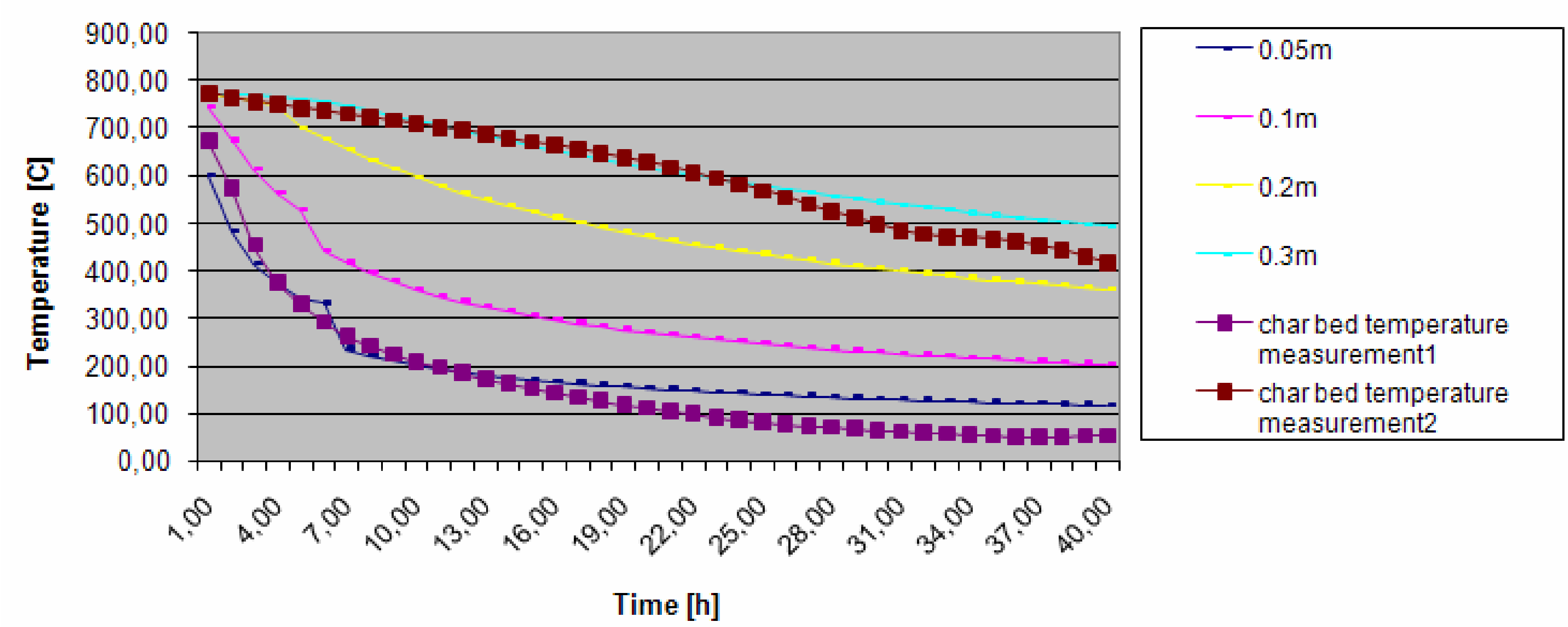
- cooling times, to temperature below 500¤C

Distance char bed bottom to surface [m]	Cooling time [h]
0,05	3
0,1	8
0,2	21
0,3	39
0,4	69
0,5	107
0,6	154
0,7	210
0,8	274
0,9	347
1	428

Distance below char bed surface [m]	Cooling time [h]
0,05	2
0,1	5
0,2	17
0,3	39
0,4	69
0,5	108
0,6	153
0,7	193
0,8	235
0,9	278
1	336

- overall cooling times, temperature below 500¤C

Size of the char bed [m]	Cooling time [h]
0,1	2,5
0,2	6,5
0,4	19
0,6	39
0,8	69
1	108
1,2	154
1,4	202
1,6	255
1,8	313
2	382


900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
Temperature [C]
1,00
4,00
7,00
10,00
13,00
16,00
19,00
22,00
25,00
28,00
31,00
34,00
37,00
40,00
Time [h]
0.05m
0.1m
0.2m
0.3m
char bed temperature measurement1
char bed temperature measurement2

Char bed cooling methods

- Sodium bicarbonate ($NaHCO_3$)
- Liquid carbon dioxide (CO_2)
- Steam
- Nitrogen

→ Most used are $NaHCO_3$ and liquid CO_2

- Sodium bicarbonate ($NaHCO_3$):
- solid powder chemical → injected in to the bed with a carrier gas (nitrogen)
- decomposes rapidly at about 110¤C, decomposition completes at about 170¤C
- requires a waiting period of 12-14h after an ESP before starting cooling
- only one bicarbonate lance can be used at a time


JUL 25 2000
8:34:47 AM


JUL 25 2000
8:34:48 AM

- Liquid carbon dioxide (CO_2):
- expansion from the storage pressure to atmospheric pressure is done within the bed → cooling
- same general procedures for using lances as $NaHCO_3$ → several lances can be used at a time
- piping plugging and frost burns are a risk

- Steam:
- ready availability at the mill, procedures for using same as $NaHCO_3$ and liquid CO_2
- precautions need to be taken to ensure against the introduction of condensate into the bed through the steam lances → risk of smelt water explosion
- less effective as a coolant than $NaHCO_3$ or CO_2

- Nitrogen:
- no heat sinks, cooling happens because of the mechanical disruption of the bed
- not very effective

Conclusions

- Reasons for the unstable behaviour of the char bed is not known → studying structure of the bed
- The calculation model stops working when depth and time grows
- Cooling times was read in the model and by using slope
- The values of char bed materials changing depend on source

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- The only parameter which can be determined is thermal diffusivity

Thank you for your interest!

APPENDIX VII

Teollisuuden Vesi Oy, offer for an extra work:
TOC-removal methods and applicability for recovery boiler make-up water treatment (in Finnish)

Soodakattilayhdistys ry

TARJOUS NRO 130/09

TOC-poistomenetelmät ja niiden soveltuvuus soodakattiloiden lisäveden valmistukseen

- **lisätyötarjous**

Tausta

Soodakattilayhdistys on tilannut Teollisuuden Vedeltä aiemmin tänä vuonna selvityksen TOC-poistomenetelmistä ja niiden soveltuvuudesta soodakattiloiden lisäveden laadun parantamiseen. Tämä lisätyötarjous liittyy tähän tilaukseen (16A0913/S88) ja vertailuun otettavat menetelmät ovat kirjallisuusselvityksessä läpikäytäviä menetelmiä.

Työn tavoite

Työn tavoitteena on tuoda esiin TOC-poistomenetelmien kustannukset ja tekninen sovellettavuus soodakattiloiden lisäveden laadun parantamiseksi esimerkkilaitoksen avulla.

Työn sisältö

Työ sisältää esisuunnitteluaineiston TOC-tason 0,1…0,2 mg/l saavuttamiseksi lisävedessä UPM:n Pietarsaaren laitoksella. Työssä tuodaan esille eri menetelmien (käänteisosmoosi eri tavoin, UV-TOC, aktiivihiilisuodatus ja ioninvaihto sekä mahdollisesti muita selvityksessä esille tulevia menetelmiä) soveltuvuus ja kustannukset vanhan demivesilaitoksen päivittämiseksi:

- Laitteiden mitoitus ja suunnittelu
    - uudet hankittavat prosessit
    - ioninvaihdon mitoitus syöttöveden laadun muuttuessa (virtauksen, suola- tai TOC-pitoisuuden muutokset)
- investointikustannukset budjettitasolla
    - tarjouspyyntöjen teko
    - tarjousten vertailu ja tarvittavat neuvottelut toimittajien kanssa
- arvio käyttökustannuksista
    - kemikaalit
    - kalvot/hartsit
    - sähkö
    - käytön seuranta
- tilavaatimukset
- toimitusaika
- pilot-mittakaavan kokeiden tarve

Työn dokumentointi

Tulokset dokumentoidaan Word- ja Excel-dokumentteina.

Tilaajan vastuut ja muut varaukset

Toimittajalla on riittävät esitiedot Pietarsaaren vesilaitokselta.

Aikatauluehdotus

Esisuunnittelua tehdään rinnan TOC-poistomenetelmistä tehtävän kirjallisuusselvityksen kanssa niin, että työ on valmis vuoden 2010 tammikuun loppuun mennessä. Esim. mahdollista laitteiden budjetointia varten esitietoja voidaan luovuttaa Tilaajalle aiemminkin. Aiemmin tilattujen töiden aikataulu pysyy ennallaan.

Hinta €, alv 0%

Lisätyöhinta esisuunnittelulle on 38 000 €.

Yhteyshenkilö

Maija Vidqvist
Puh. 040 503 1258
E-mail maija.vidqvist@teollisuudenvesi.fi

Tarjouksen voimassaoloaika

Tarjous on voimassa syyskuun loppuun 2009.

Maksuehdot

Maksuehto on 14 pv netto.

Maksupostit:
40 % tilauksesta
60 % työn valmistuttua

Muut ehdot

KSE 1995 mukaan.

Kunnioittaen,

Teollisuuden Vesi Oy

Maija Vidqvist

APPENDIX VIII

University of Oulu, offer:
Ceramics in furnace (in Finnish)

KOKEELLINEN VERTAILEVA TUTKIMUS TULENKESTÄVISTÄ MASSOISTA SOODAKATTILASSA

1 TAUSTAA

Oulun yliopiston prosessi- ja ympäristötekniikan osaston prosessimetallurgian laboratoriossa tutkittiin syksyllä 2005 soodakattilan tulenkestäviä materiaaleja. Tutkimuksen tilaajana oli Suomen Soodakattilayhdistys ry. [1]

Kokeellisessa osassa testattiin osittain spinelliin pohjautuvaa materiaalia altistamalla se soodakattilan sulalle Stora Enson Oulun tehtaalla. Vertailukohteena käytettiin nykyisin käytössä olevaa samottista materiaalia. Spinelliä sisältäneet koekappaleet kestivät soodakattilan olosuhteita paremmin kuin nykyisin käytetystä materiaalista valmistettu kappale. Spinelliä sisältävän materiaalin lisäksi jatkotutkimuksiin suositeltiin myös ZrO_2-pohjaista materiaalia sekä forsteriitin ja ceriumoksidin soveltuvuuden arviointia.

2 TUTKIMUSSUUNNITELMA

Testit on tarkoitus suorittaa Stora Enson Oulun tehtaiden soodakattilassa ajon aikana. Suoritusajaksi on kaavailtu vuoden 2009 loppua ja 2010 alkua.

2.1 Materiaalit

Tutkittaviksi materiaaleiksi on valittu seuraavat:

- Vertailu materiaali (Hassle)
- Spinelliä muodostavaa massaa (Betker)
- Valmista spinelliä sisältävää massaa
- ZrO2 kaupallista massaa (Zircoa-Cast™ Castable Refractory, 0872-8D)
- CeO2 pohjainen massa tai pinnoite
- Forsteriitti pohjainen massa
- Tiivis aloksimassa (tehtaalla bloki).

2.2 Koekappeleiden valmistus

Koekappaleet valmistetaan massanvalmistajien ohjeiden mukaisesti.

Tulenkestävistä massoista valmistetaan noin 100-150mm pitkä neliöprofiilinen tanko jonka sivu on noin 50mm. Koekappale kiinnitetään teräs tankoon ”tikkariksi”.

Ensimmäinen erä vain kuivataan 110° C valun ja sidoksen muodostuksen jälkeen. Tarkoitus on simuloida korjausmassoja.

Toinen erä poltetaan valmistajan ohjeen mukaan. Aloksiblokin asennuksen hoitaa Stora Enso.

2.3 Kokeiden suorittaminen

Tikkareita mahtuu 250mm x 100mm ruiskutusaukkoon noin kolme kappaletta kerrallaan, jotka asetetaan samaan tasoon kattilan sisälle. Yksi ”tikkareista” on vertailumateriaalia. Mitataan upotussyvyys ja erillisellä termoelementillä lämpötila.

Toimitaan samoin seuraavien materiaalien kanssa.

Koekappaleita pidetään kattilassa kunnes havaittavia eroja on syntynyt. Tämän toteamiseksi kappaleita täytyy käyttää pois kattilasta.

Testin läpikäyneet koekappaleet merkitään ja säilötään jatkotutkimusta varten.

2.4 Koekappaleiden analysointi

Koekappaleet mitataan sekä kuvataan ennen ja jälkeen kokeen. Tästä saa jo käsityksen mikä vertailtavista materiaaleista on paras. Jos halutaan edetä tutkimuksessa ja vastata kysymykseen, miksi kyseinen materiaali kesti kokeessa, täytyy koekappaleen mikrorakenne tutkia.

Mikrorakenteen tutkiminen on oma projektinsa

2.5 Aikataulu

Koekappaleen muotin yms. valmisteluaika 1 vko.

Koekappaleen teko varsineen 6 kpl testattavia massoja ja yksi referenssi/koe vaativat 3 kpl referesssejä. Yhteensä 9 kpl valmistus arviolta viikko. Toinen viikko kuluu toisen satsin valmistukseen ja polttoon.

Kappaleiden kulumien mittaus ja valokuvaus 1 vko.

Raportointi havainnoista ja suositukset jatkosta 2 vko.

Yhteensä tehollista työaikaa arvi oidaan kuluvan 6 vko.

2.6 Lähteet

Hannu Makkonen ja Riku Mattila. Soodakattilan keraamiset rakenteet. 2005. Luottamuksellinen.

3 KUSTANNUKSET

Tehokasta työaikaa kuluu arviolta noin 1,5 henkilökuukauden verran.

Koemateriaalien hankinta ja valmistukseen kuluu jonkin verran rahaa samoin matkoihin jne. Arvio muihin kuluihin on noin 1000 euroa. Kokonaiskustannus on 15200 euroa alv 0 %.

TARJOUS TUTKIMUKSEN SUORITTAMISESTA

Tarjoamme tulenkestävien soodakattimateriaalien tutkimuksen suorittamista alla mainituin ehdoin.

1 Tarjouksen tekijä

Oulun yliopisto, prosessimetallurgian laboratorio.

2 Tarjouksen kohde ja suoritusaika

On liitteellä 1.

3 Maksuehdot

Tutkimus laskutetaan sopimushintaan 15 200 € ALV 0 %
Maksu suoritetaan kertasuorituksena loppuraportoinnin jälkeen.

4 Muut ehdot

Tarjous on voimassa 2 kuukautta tarjouskirjeen päiväyksestä.

Mikäli tarjous tulee hyväksytyksi, sopimukseen sovelletaan Oulun yliopiston tilaajarahoitteisen tutkimuksen yleisiä sopimusehtoja (Liite 2).

5 Tutkimuksen tekijää koskevat tiedot

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Allekirjoitus
Oulun yliopisto 03/09 2009

Jouko Härkki

____
Tutkimuksen vastuullinen johtaja