Testing of VETO-100 stokerboiler using wood pellets according to European standard EN 303-5

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Jyväskylä, May 27th 2004

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APPENDICES: 4 pc.

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Description of the task

The results of the measurements, based on the requirements of the standard SFS-EN 303-5, carried out at VTT Processes in Jyväskylä, are presented in this research report.

Equipment tested

VETO 100 stokerboiler (serial number 100181, series n:o 2, RS-decision 4110-96, max. pressure 1.5 bar, max. temperature 110 ^{o}C, water volume 0.47 m^{3}, manufactured in 2004). The fuel feeder used was VETO Turvehakemaatti (manufactured in 2004). The combustion equipment was controlled by an automatic control system FIBOX Lambda 5 (product number 039 028 04, serial number 060 manufactured by a company Fibox Tested Systems Oy. Control system is based on measuring flue gas oxygen concentration using a lambda probe, measuring boiler water temperature and adjusting the speed of fuel feeding auger and two combustion air fans. Photographs of the test arrangements used are presented in appendix 1.

The equipment consisted of following components: a fuel silo, a burner and a boiler. Fuel is discharged from the fuel silo by two discoidal unloaders on a screw conveyor, which dispenses the fuel into the burner. The burner consists of a cylinder, equipped with a metal grate. Two separate fans feed the combustion air into the burner. The maximum amount of combustion air can be adjusted by a disc valve mounted at the side of the fan. Control systems change the speeds of combustion air fans.

Principal drawing of the tested combustion equipment is shown in figure 1.

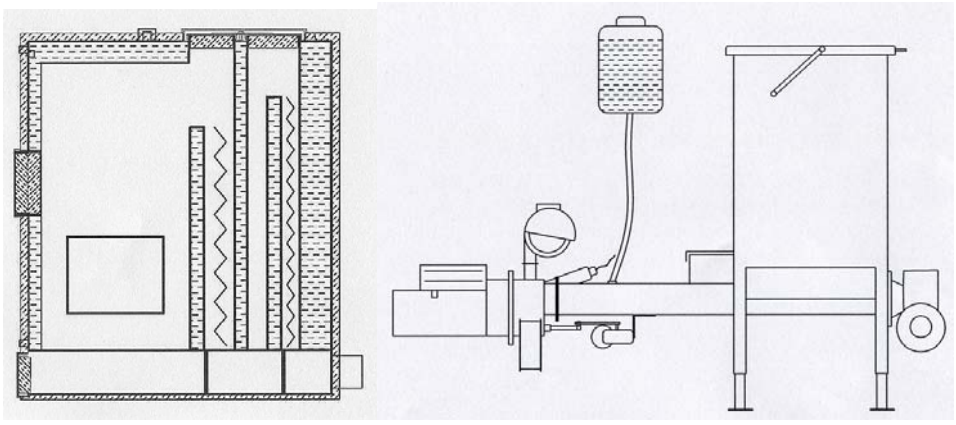

Fig 1. Principal drawing of the VETO 100 combustion equipment.

Test arrangement

The combustion equipment was measured using the heating boiler test rig, constructed to meet the requirements of EN 303-5 standard. The PI-scheme of the test rig is presented in appendix 2.

Execution of the tests

Combustion tests met the requirements of the EN 303-5 standard. Boiler efficiency was measured using so called direct method. The amount of fuel used was measured separately using a platform scale and boiler output from the water flow of the test rig. Wood pellets having moisture content of 6.48% (w.b.) was used as a fuel. The tests were carried out using both the nominal output level of the boiler (88.8 kW) and with partial load (28%) having heat output 25.2 kW. The equipment was adjusted to operate so that the set value of the thermostat was not reached during the total 6-hour measuring period with either of these heat outputs.

Boiler heat output, flue gas temperature according to the standard from five measuring points and concentrations of CO_2, O_2, CO, NO_x and OGC were measured continuously. OGC is the concentration of total hydrocarbons measured with a flame ionisation analyser (FID). Particulate concentration was measured only at the nominal output level, as required in the standard. The duration of each particulate measuring period was at least 30 minutes. Number of total measuring periods was four (4).

Measuring equipment

The list of measuring equipment used is given in the appendix 3.

The fuel

Wood pellets, purchased by Ala-Talkkari Oy, were used as a fuel in the tests. The fuel was analysed in the laboratory of VTT Processes in Jyväskylä. The results are presented in the table no. 1.

Table 1. Results of the fuel analyses.

	unit	**value**
Moisture content	% on w.b.	6.48
Ash content of DS	%	0.22
Calorific heating value of DS	kJ/kg	20330
Gross calorific value of DS	kJ/kg	19040
Net calorific value	kJ/kg	17650

Measured results

Measuring and calculation results of the nominal heat output test are presented in the table no. 2. Results are averages of the total 6 hours test period. Corresponding values of the partial output test are presented in the table no. 3. The boiler efficiency is calculated based on the amount of fuel burned and measured boiler output. CO_2, O_2, CO and NO_x concentrations were measured from dry flue gases and OGC concentration (concentration of total hydrocarbons) from moist flue gases at about 180 ºC. Concentrations are presented in % or ppm (= part per million; for example 10000 ppm = 1%) and in

mg/Nm3, as well as converted to 10% of oxygen required by the standard. Emissions are also presented in mg/MJ.

Table 2. Measured and calculated results of the nominal heat output test. All concentrations are given in dry flue gas.

	Unit	**Result**
Test period	hour	6
Temperature of outflow water	°C	77.8
Temperature of return water	°C	59.1
Ambient temperature	°C	22.8
Boiler output	kW	88.8
Amount of fuel burned	kg	119.8
Efficiency	%	90.7
Under pressure in the stack	Pa	40
Flue gas temperature	°C	114
CO_2 concentration	%	15.1
O_2 concentration	%	5.3
CO concentration	ppm	177
CO concentration	ppm (10 % O_2)	124
CO concentration	ppm (13 % O_2)	90
CO concentration	mg/Nm^3	221
CO concentration	mg/Nm^3 (10 % O_2)	155
CO concentration	mg/Nm^3 (13 % O_2)	113
CO emission	mg/MJ	94
OGC concentration	mg org C/m^3	2
OGC concentration	mg org C/m^3 (10 % O_2)	2
OGC concentration	mg org C/m^3 (13 % O_2)	1
OGC emission	mg org C/MJ	1
NO_x concentration *)	ppm	91
NO_x concentration	ppm (10 % O_2)	64
NOx concentration	ppm (13 % O_2)	46
NO_2 concentration	mg/Nm^3	187
NO_2 concentration	mg/Nm^3 (10 % O_2)	131
NO_2 concentration	mg/Nm^3 (13 % O_2)	95
NO_2 emission	mg/MJ	79
Particulate concentration	mg/Nm^3	45
Particulate concentration	mg/Nm^3 (10 % O_2)	32
Particulate concentration	mg/Nm^3 (13 % O_2)	23
Particle emission	mg/MJ	19

*) NO_x includes NO and NO converted from NO_2

Table 3. Measured and calculated results of partial load test. All concentrations are given in dry flue gas.

	Unit	**Result**
Test period	hour	6
Temperature of outflow water	°C	77.4
Temperature of return water	°C	68.8
Ambient temperature	°C	22.1
Boiler output	kW	25.2
Amount of fuel burned	kg	33.5
Efficiency	%	92.1
Under pressure in the stack	Pa	40
Flue gas temperature	°C	69.6
CO_2 concentration	%	11.2
O_2 concentration	%	9.6
CO concentration	ppm	323
CO concentration	ppm (10 % O_2)	312
CO concentration	ppm (13 % O_2)	227
CO concentration	mg/Nm^3	404
CO concentration	mg/Nm^3 (10 % O_2)	390
CO concentration	mg/Nm^3 (13 % O_2)	283
CO emission	mg/MJ	172
OGC concentration	mg org C/m^3	30
OGC concentration	mg org C/m^3 (10 % O_2)	29
OGC concentration	mg org C/m^3 (13 % O_2)	21
OGC emission	mg org C/MJ	14
NO_x concentration *)	ppm	44
NO_x concentration	ppm (10 % O_2)	42
NOx concentration	ppm (13 % O_2)	31
NO_2 concentration	mg/Nm^3	90
NO_2 concentration	mg/Nm^3 (10 % O_2)	87
NO_2 concentration	mg/Nm^3 (13 % O_2)	63
NO_2 emission	mg/MJ	38
Particulate concentration	mg/Nm^3	not measured
Particulate concentration	mg/Nm^3 (10 % O_2)	not measured
Particulate concentration	mg/Nm^3 (13 % O_2)	not measured
Particle emission	mg/MJ	not measured

*) NO_x includes NO and NO converted from NO_2

Surface temperatures

Surface temperatures of boiler during the nominal output test are presented in appendix 4. The temperature of the bottom of the boiler was not measured, because according to the manufacturer's instructions, the boiler must always be mounted on a non-combustible surface. K-type surface thermocouple and the Fluke 52 meter were used for measuring temperatures. Any temperature did not exceed the maximum allowed according to the standard.

Summary

The tested combustion equipment meets both the efficiency and emission (CO, OGC, particulates) requirements of the standard for the best class 3. The nominal heat output of the combustion equipment was 88.8 kW and total efficiency 90.7%. It could be operated with a partial load of 28 %. Then the total efficiency was 92.1%.

The temperatures of the boiler surface were lower than the allowed maximum.

A view of the test rig of VTT Processes.

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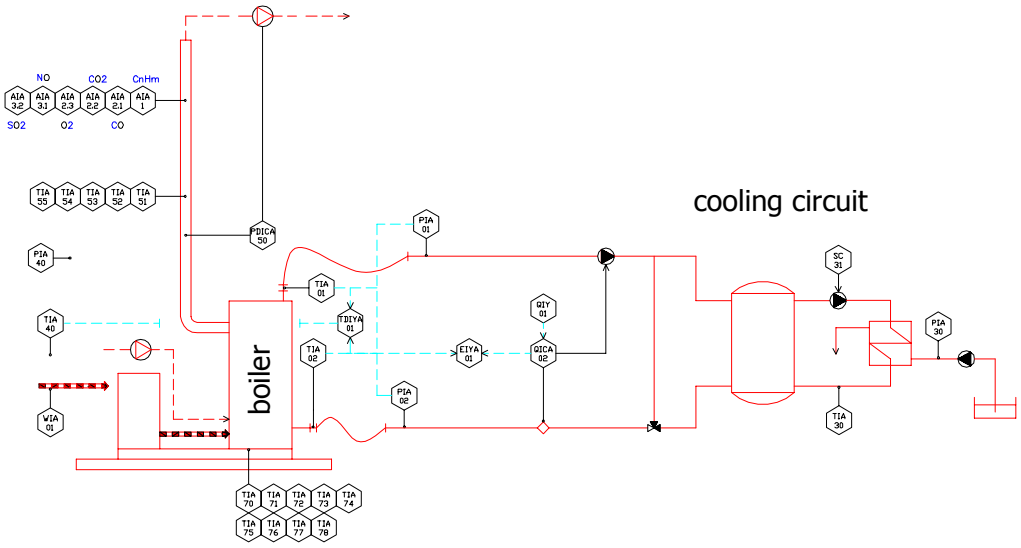
Stoker burner.

Control system FIBOX Lambda 5



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Position	Measurement	Type	Model	Size/ measuring range	Output	connector slotch ch.ch	Supplier
PIA01	**Pressure of outlet water**						
PT01	Transmitter	P transmitter	2088G2S22A1I1	0-6 bar	4-20 mA	209	
PV01	Assembly valve with outblow		N354.66.403.05+006.12.217.55				Schneider
TIA01	**Temperature of outlet water**						
TE 01	Probe	Pt-100		375mm/6mm		201.211	
TV01	Well		D4 depth 65mm				
PIA02	**Pressure of inlet water**						
PT02	Transmitter	P transmitter	2088G2S22A1I1	0-6 bar	4-20 mA	210	
PV02	Assembly valve with outblow		N354.66.403.05+006.12.217.55				Schneider
TIA02	**Temperature of inlet water**						
TE0 2	Probe	Pt-100		375mm/6mm		202.212	
TV02	Well		D4 depth 65mm				
QICA02	**Mass flow of inlet water**						
QE02	Probe		CMF100M-306NM DN25	3000…13000 kg/h			Micro Motion
QT02	Amplifier		RFT739D4EBC	3000…13000 kg/h	4-20 mA	221	Micro Motion
PIA30	**Pressure of cooling circuit**						
PT30	Transmitter	P transmitter	2088G2S22A1I1	0-6 bar	4-20 mA	209	
PV30	Assembly valve with outblow		N354.66.403.05+006.12.217.55				Schneider
TIA40	**Temperature of combustion air**						
TE40	Probe	Pt-100	RTD-W-EYI	275mm/6mm		203.213	
PIA40	**Air pressure**						
PT040	Transmitter	P transmitter	3051TA1A2B21AI1	80-120 kPa abs.	4-20 mA	219	
PDCIA50	**Flue draught**						
PDT50	Transmitter	dp transmitter	3051CD1A22A1AL4DFI1	0…-100 Pa	4-20 mA	220	
PDCIA50	Controller		902S/IC/HDC//ARE/VL/XN///	4…20 mA	4-20 mA		Eurotherm
TIA51	**Flue gas temperature 1**						
TE51	Probe	Pt-100	0065D21N0000N0275A1	275mm/6mm		204.214	
TIA52	**Flue gas temperature 2**						
TE52	Probe	Pt-100	0065D21N0000N0275A1	275mm/6mm		205.215	
TIA53	**Flue gas temperature 3**						
TE53	Probe	Pt-100	0065D21N0000N0275A1	275mm/6mm		206.216	
TIA54	**Flue gas temperature 4**						
TE54	Probe	Pt-100	0065D21N0000N0275A1	275mm/6mm		207.217	
TIA55	**Flue gas temperature 5**						
TE55	Probe	Pt-100	0065D21N0000N0275A1	275mm/6mm		208.218	
11P/12P	**Set pont for circulation water pump**			Aout	4-20 mA	223	
31P	**Set pont for cooling water pump**			Aout	4-20 mA	224	
YX01	**Data logger**	Logger	2700				Keithley
			7706-module			slot2	Keithley
			7708-module			slot1	Keithley
AIA1	**Flue gas analyser**		Multi-FID 100				Hartman & Braun
AT1.1	OGC-concentration			0-100 org.C/m3	4-20mA	117	
AT1.2	OGC-concentration			0-1000 org.C/m3	4-20mA	118	
AT1.3	OGC-concentration			0-10000 org.C/m3	4-20mA	119	
AT1.4	OGC-concentration			0-100000 org.C/m3	4-20mA	120	
AIA2	**Flue gas analyser**	NDIR	Uras 10E				Hartman & Braun
AT2.1	CO-concentration			0-1/5 %	4-20mA	121	
AT2.1	CO2-concentration			0-20 %	4-20mA	122	
AT2.1	O2-concentration			0-5/25	4-20mA	123	
AIA3	**Flue gas analyser**	NDUV	Radas 2				Hartman & Braun
AT3.1	NO-concentration			0-300/1000 ppm	4-20mA	124	

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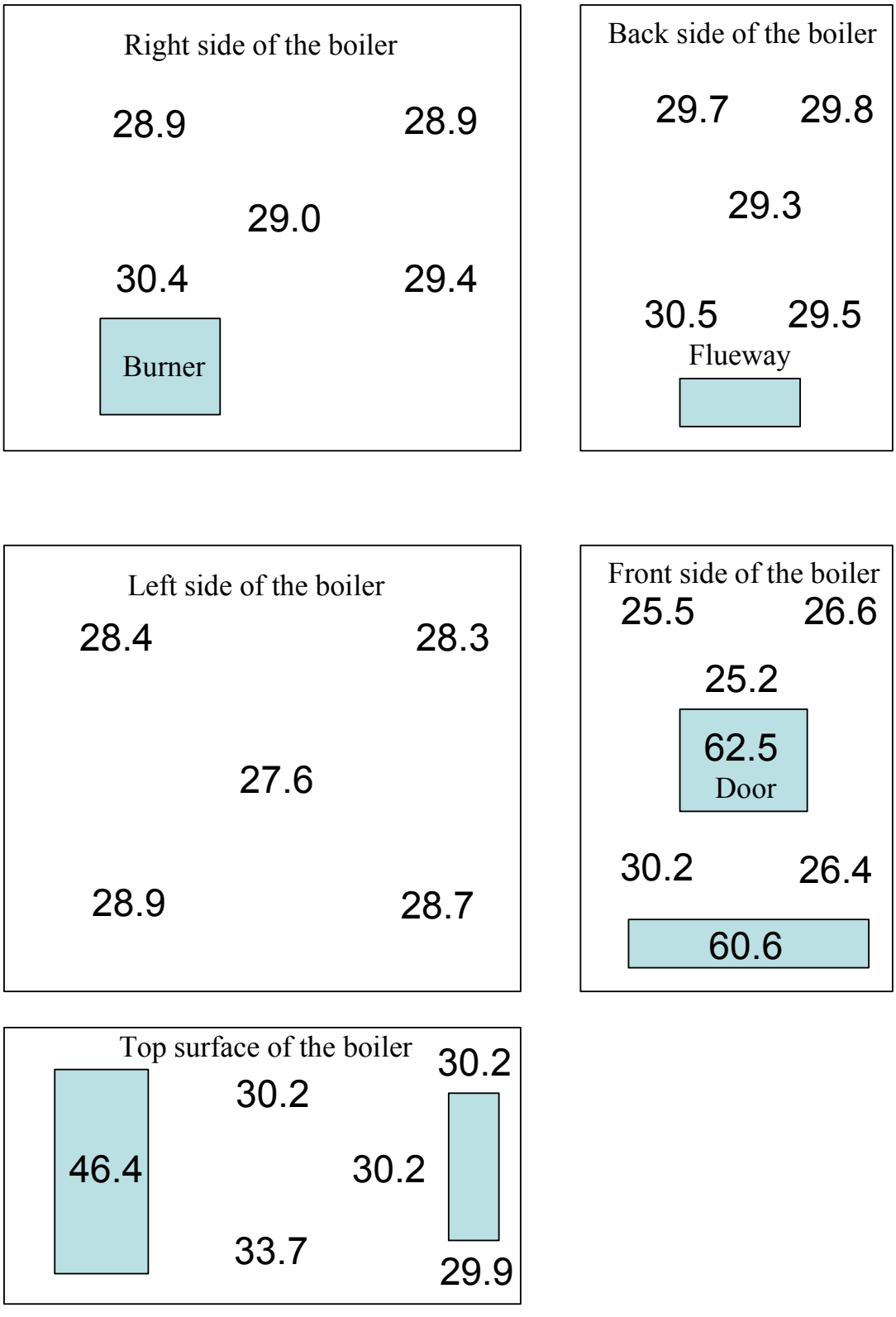
Surface temperatures at different measurement points (degree centigrade)



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