REPORT

Contact person RISE
Henrik Persson
Energy and circular economy
+46 10 516 55 21
henrik.persson@ri.se

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7P05926-1

Testing

Fröling Heizkessel- und Behälterbau
Ges.m.b.H.
Industriestrasse 12
AT-4710 Grieskirchen
Austria

Testing a solid fuel fired hydronic heater

(8 appendices)

This test report is a revised version of the test report dated 2017-10-05 and rev 2017-10-18. Under comments and observations (page 5)the information about boiler models having different heat output has been removed.

The assignment

Testing the wood pellet hydronic heater model PE1 Pellet 35 in accordance with test method E2618-13 and ASTM 2515-11 for compliance with EPA 40 CFR Part 60, March 16, 2015.

Item for testing

Wood pellet hydronic heater – PE1 Pellet 35 (serial nr.: 200220478), manufactured by Fröling Heizkessel- und Behälterbau, Austria. The hydronic heater arrived at RISE on 05th September 2017. The hydronic heater was in used condition.

This test report relates only to the actual item tested.

Technical description

The pellets fuel are transported from the pellet storage by a suction turbine via the suction hose into the hopper. The pellets are transported to the downpipe by the stoker screw and fall in a metered quantity onto the combustion grate of the sturdy steel combustion chamber. Hot air is added by the automatic ignition rod to ignite the pellets. The heat generated during combustion is used in the heat exchanger to heat the water. The flue gases produced during the combustion process are channelled outside through the chimney. The movement of the integrated spiral springs automatically cleans the heat exchanger. The ash from the steel combustion chamber falls through an automatic sliding grate into an ash chamber where it is transported via the ash screw into a large ash container. The boiler is equipped with a lambda sensor.

The hydronic heater PE1 Pellet 35 is intended for indoor installation.

Informative material supplied

Owner´s manual, Pellet boiler PE1 Pellet 15-35, B1570017_en-us

Drawings listed in table 1 were supplied by the manufacturer (see also appendix 9):

Table 1. Drawings

Drawing number	Date
Z005059-IDW	15.02.2006
Z011565-IDW	13.01.2012

Z011576-IDW	13.01.2012
Z011581-IDW	13.01.2012
Z011596-IDW	13.01.2012
Z008155-IDW	22.03.2006
Z022603-IDW	18.06.2008
Z023662-IDW	14.11.2007
Z063542-IDW	15.02.2013
Z053043-IDW	26.02.2013
Z063623-IDW	06.02.2013
Z067112-IDW	03.10.2013
Z067239-IDW	09.10.2013
Z069583-IDW	03.02.2014
Z068481-IDW	27.11.2013
Z069605-IDW	04.02.2014
Z068487-IDW	27.11.2013
Z069135-IDW	17.02.2014
Z068498-IDW	28.11.2013
Z068488-IDW	27.11.2013
Z067630-IDW	17.02.2014
Z067117-IDW	27.01.2014
Z0068489-IDW	28.11.2013
Z0071552-IDW	15.04.2014
Z071797-IDW	24.04.2014
Z071872-IDW	15.05.2014
Z071700-IDW	18.04.2014
Z072525-IDW	27.05.2014
Z073752-IDW	17.07.2014
Z078576-IDW	09.02.2015
Z078577-IDW	16.02.2015
Z083466-IDW	14.08.2015
Z083541-IDW	17.08.2015
Z083540-IDW	17.08.2015
Z083538-IDW	17.08.2015
Z083522-IDW	17.08.2015

Z083529-IDW	17.08.2015
Z083524-IDW	17.08.2015
Z083523-IDW	17.08.2015
Z083518-IDW	17.08.2015
Z083546-IDW	18.08.2015
Z083542-IDW	17.08.2015
Z083550-IDW	18.08.2015
Z088778-IDW	10.03.2016
Z100305-IDW	08.06.2017
Z100289-IDW	08.06.2017
Z100294-IDW	08.06.2017
Z100288-IDW	08.06.2017
Z100296-IDW	08.06.2017
Z100268-IDW	08.06.2017

Test arrangement

The hydronic heater was connected to a test rig according to method E 2618-13. The chimney was connected to a dilution tunnel (see appendix 7).

The chimney diameter was 150 mm, with a height of about 5 m above the upper surface of the scale. The dilution tunnel diameter was 200 mm.

The manufacturer conducted a minimum of 50 hours of pre-test burning to condition the unit before testing. The wood pellet hydronic heater PE1 Pellet 35 is a non-catalytic appliance. The convection part in the heater was equipped with turbulators. The lambda sensor was set at 8 % O_2 during the tests.

Test procedure

Testing was carried out at/by RISE Department for Energy and Circular Economy during September 2017 in accordance with the EPA regulations 40 CFR Part 60 subpart QQQQ and test methods ASTM E 2618-13 and ASTM 2515-11.

Calculation of the average overall thermal efficiency (η_{SLM}) was done in accordance with Canadian standard CSA B415.1-10, clause 13.7 except for 13.7.2 (e), (f), (g), and (h) where the following average fuel properties for oak was used: %C = 50.0, %H = 6.6, %O = 43.2, % Ash = 0.2.

The CO emissions were measured continuously during the test period in the chimney. Emissions of CO in g/min were calculated according to the Canadian standard CSA B415.1-10 clause 13.9 (using the spreadsheet in annex F).

The test fuel used was the Premium pellet manufactured by Sturmberger Pelletsproduktions GmbH and was classified as EN plus. The fuel was delivered in 15 kg plastic bags (see appendix 5 for fuel analysis).

The fuel analysis was performed by RISE, Department for Chemistry, Materials and Surfaces.

Particulate filters used are made of glass fiber with a diameter of 47 mm.

Leakage check of the particulate sampling trains was carried out before and after the tests.

Instead of the thermopile on the load side of the heat exchanger one pair of PT-100 sensors was used to measure the temperatures. This was communicated with EPA by email (17/05/2016) and was approved. The PT-100 sensor has a higher accuracy and higher sensitivity compared to the thermocouple.

The appliance was in operation at the specified draw rate one hour before the test started. The test period lasted 4 hours at each heat output rate category according to method E2618-13 clause 12.3.3.

A representative from the company Fröling was present as an observer during the tests.

Summary of test results (Hangtag information)

The table below shows a summary of the results and hangtag information. For complete results see appendix 2.

Table 2. Additional (Hangtag) information

MANUFACTURER:	**Fröling Heizkessel- und Behälterbau Ges.m.b.H. Industriestrasse 12 AT-4710 Grieskirchen Austria**		
MODEL NUMBER:	**PE1 Pellet 35 kW**		
8-HOUR OUTPUT RATING	$Q_{out\text{-}8hr}$	**N.A**	Btu/hr
8-HOUR AVERAGE EFFICINCY	$\eta_{avg\text{-}8hr}$	**N.A**	(Using higher heating value)
		N.A	(Using lower heating value)
MAXIMUM OUTPUT RATING	Q_{max}	**119,500**	BTU/HR
ANNUAL EFFICIENCY RATING:	η_{avg}	**80.1**	(Using higher heating value)
		86.2	(Using lower heating value)
PARTICLE EMISSIONS:	E_{avg}	**0.678**	Grams/hr (Average)
		0.053	Lbs/mmBtu/hr Output
CO EMISSIONS	CO_{avg}	**0.074**	Grams/minute

N.A = Not Applicable because the hydronic heater is an automatic pellet fuelled appliance.

Comments and observations

The hydronic heater PE1 Pellet 35 manufactured by Fröling Heizkessel- und Behälterbau, Austria, meets the step 2 requirement 2020 for PM emissions in EPA 40 CFR Part 60 of 0.10 lb/mmBtu heat output (average) and at each individual test rate.

The model PE1 Pellet 35 is safety tested by OMNI –Test Laboratories, Inc and listed to UL 2523-2013 and CAN/CSA B366.1-2011.

Quality assurance

RISE Research Institute of Sweden AB is accredited according to ISO/IEC 17025 as well as accredited by EPA as a test lab to perform tests according to EPA 40 CFR Part 60 subpart QQQQ.

RISE Research Institutes of Sweden AB
Energy and circular economy - Combustion and Aerosol Technology

Performed by

Signed by: Henrik Persson
Reason: I am the author of this document
Date & Time: 2018-02-07 12:33:46 +01:00

Henrik Persson

Examined by

Signed by: Andreas Johansson
Reason: I have reviewed this document
Date & Time: 2018-02-07 11:07:29 +01:00

Andreas Johansson

Appendices

Appendix 1 Identification

Appendix 2 Results

Appendix 3 Pretest dilution tunnel traverse run

Appendix 4 Sampling equipment leakage check

Appendix 5 Test fuel specification

Appendix 6 Instrumentation and uncertainty of measurement

Appendix 7 Test setup

Appendix 8 Drawing

Appendix 1

Identification

Figure 1. PE1 Pellet 35 kW

Technical data

Table 3. Technical data

Nominal output, Btu/h (kW)	119.500 (35)
Weight empty, lbs (kg)	840 (380)
Water content, gal (l)	16 (60)
Dimensions, (height x depth x width), inch (mm)	58 x 33.5 x 29.5 (1470 x 850 x 750)
Pellet container capacity, gal (l)	20 (76)
Ash box capacity, gal (l)	7.4 (28)
Maximum boiler temperature setting °F (°C)	194 (90)
Airborne sound level, db(A)	< 70

Appendix 2

Results

Table 4 shows the test results for the pellet fired hydronic heater PE1 Pellet 35. Further test results are presented in table 5 to 9.

Table 4. Test results from Category I and IV

	Unit	Category I	Category II	Category III	Category IV
Test date		14/09/2017	15/09/2017	18/09/2017	13/09/2017
Atmospheric pressure	mm Hg (mbar)	727 (969)	734 (979)	(992)	(973)
Test duration	minute	240	240	240	240
Absolute average gas static pressure in dilution tunnel	mm Hg	728	736	746	731
Average tunnel velocity	m/s	4.2	4.2	4.7	5.0
Average gas tunnel temperature (at Pitot tube)	°F (°C)	73 (23)	68 (20)	73 (23)	73 (23)
Average temperature at PM filter, system 1	°F (°C)	70 (21)	70 (21)	70 (21)	70 (21)
Average temperature at PM filter, system 2	°F (°C)	70 (21)	70 (21)	72 (22)	70 (21)
Flue gas temp (chimney)	°F (°C)	142 (61)	162 (72)	198 (92)	286 (141)
Average temperature of the appliance and water at start of the test	°F (°C)	145 (63)	154 (68)	156 (69)	162 (72)
Average temperature of the appliance and water at the end of the test	°F (°C)	145 (63)	158 (70)	156 (69)	162 (72)
Average temperature of return water as it enters the appliance	°F (°C)	135 (57)	136 (58)	140 (60)	144 (62)
Average temperature of supply water as it leaves the appliance	°F (°C)	156 (69)	172 (78)	172 (78)	180 (82)
Average inlet temperature load side of the heat exchanger	°F (°C)	131 (55)	131 (55)	131 (55)	133 (56)
Average outlet temperature load side of the heat exchanger	°F (°C)	151 (66)	165 (74)	163 (73)	167 (75)
Test load as fired	lb (kg)	11.3 (5.1)	16.5 (7.5)	32.1 (14.6)	69.9 (31.7)
Fuel moisture content on fired basis	%	7.0	7.0	7.0	7.0
Diameter of pellet	mm	6	6	6	6
Water flow rate on the load side	gal/min (l/min)	1.73 (6.53)	1.57 (5.93)	3.48 (13.2)	7.06 (26.73)
Heat output (supply side)	Btu/hr (kW)	18,426 (5.4)	27,638 (8.1)	56,300 (16.5)	121,131 (35,5)
Heat output (load side)	Btu/hr (kW)	17,255 (5.0)	26,194 (7.7)	54,796 (16.0)	121,300(35.6)

Appendix 2

Efficiency delivered (HHV)	%	76.5	79.2	85.2	86.8
Efficiency delivered (LHV)	%	82.4	85.3	91.8	93.5
Stack loss efficiency (HHV)[1]	%	87.2	87.0	86.1	84.5[2]
CO (average, chimney)	ppm	133	75	57	178
CO (average, chimney)	%	0.013	0.008	0.006	0.018
CO2 (average, chimney)	%	7.1	8.0	9.5	12.7
CO, average[3]	g/min	0.054	0.018	0.111	0.298
Room air blank filter	mg	0	0	0	0.1
Total amount of particulate matter collected in dilution tunnel	mg	1.2	0.5	1.5	2.5
Average gas flow rate in dilution tunnel	dscm/min	7.34	7.52	8.47	8.70
Absolute average dry gas meter temperature	K	294	294	294	294
Volume of gas sample measured corrected to standard conditions	dscm	0.846	0.826	0.953	0.630
Volume of room air gas sample measured corrected to standard conditions	dscm	2.438	2.355	2.485	2.300

[1] Stack loss efficiency calculated according to B415.1-10.

[2] The Stack loss efficiency is lower than the efficiency delivered and the reason for that can be that the jacket losses from the appliance is relatively lower at rated output than from the other part loads. Thus, this will lead to a higher delivered efficiency at rated output but the stack loss method do not take that into account. Further, the flue gas temperature is also much higher on the rated output than on the other part loads which will lead to higher stack losses and give lower stack loss efficiency.

It is also to be noted that the rated heat output at supply side is about 0.1 % lower than the load side which indicates that the relative losses in the test rig is lower on higher heat outputs, while the stack losses do not take that into account.

[3] CO emission in g/min calculated according to B415.1-10.

Appendix 2

The tables 5 to 8 refers to the corresponding tables in ASTM E2618-13.

Table 5 Test condition summary

						Θ	W_{fuel}	MC_{ave}	Q_{in}	Q_{out}
Category	Run No	Load % Capacity	Target Load	Actual Load	Actual Load	Test Duration	Wood Weight as-fired	Wood Moisture	Heat Input	Heat Output
			Btu/hr	Btu/hr	% of max	hrs	lb	% DB	Btu	Btu
I	2	<15	<17,914	17,255	14	4	11.27	7.5	90,165	69,019
II	3	16 - 24	19,108 – 28,662	26,194	22	4	16.54	7.5	132,290	104,775
III	4	25 - 50	29,856 – 59,713	54,796	46	4	32.14	7.5	257,130	219,182
IV	1	100	119,425	121,300	102	4	69.86	7.5	558,868	485,200

Table 6. Test results summary

			T2 min	E_T	E	E	$E_{g/hr}$	$E_{g/kg}$	η_{del}	η_{SLM}
Category	Run No	Load % Capacity	Min return water temp	Total PM emissions	PM output based	PM output based	PM rate	PM factor	Delivered efficiency	Stack loss efficiency
			°F	g	lb/mmBtu out	g/MJ	g/hr	g/kg	%	%
I	2	<15	134	2.62	0.084	0.036	0.655	0.551	76.5	87.2
II	3	16 - 24	135	1.09	0.023	0.010	0.273	0.156	79.2	87.0
III	4	25 - 50	138	3.28	0.033	0.014	0.819	0.241	85.2	86.1
IV	1	100	144	8.20	0.037	0.016	2.049	0.278	86.8	84.5

The difference in emission factors ($E_{g/kg}$) between the two sampling trains were less than 0.5 g/kg according to ASTM E2515-11 clause 11.7.

Appendix 2

Table 7. Heating season weighting

Category	Weighting factor	$\eta_{del,i}$ x F_i	$E_{g/MJ,i}$ x F_i	$E_{g/kg,i}$ x F_i	$E_{lb/mmBtu\ Out,i}$ x F_i	$E_{g/hr,i}$ x F_i	$CO_{g/min}$ x F_i
I	0.175	13.39	0.006	0.096	0.015	0.115	0.009
II[1]	0.275	21.78	0.003	0.043	0.006	0.075	0.005
III[1]	0.450	38.34	0.006	0.108	0.015	0.368	0.050
IV	0.100	8.68	0.002	0.028	0.004	0.205	0.030
Totals	**1.000**	**82.2**	**0.017**	**0.275**	**0.040**	**0.763**	**0.094**

Table 8. Year-Round use weighting

Category	Weighting factor	$\eta_{del,i}$ x F_i	$E_{g/MJ,i}$ x F_i	$E_{g/kg,i}$ x F_i	$E_{lb/mmBtu\ Out,i}$ x F_i	$E_{g/hr,i}$ x F_i	$CO_{g/min}$ x F_i
I	0.437	33.43	0.016	0.241	0.037	0.286	0.024
II[1]	0.238	18.85	0.002	0.037	0.005	0.065	0.004
III[1]	0.275	23.43	0.004	0.066	0.009	0.225	0.031
IV	0.050	4.34	0.001	0.014	0.002	0.102	0.015
Totals	**1.000**	**80.1**	**0.023**	**0.358**	**0.053**	**0.678**	**0.074**

Table 9 shows the PM emissions from the first hour of measurement measured with one of the two sampling trains.

Table 9. 1st hour emissions

Category	1st hour emissions (g/hr)
I	0.47
II	0.32
III	0.64
IV	1.28

Appendix 2

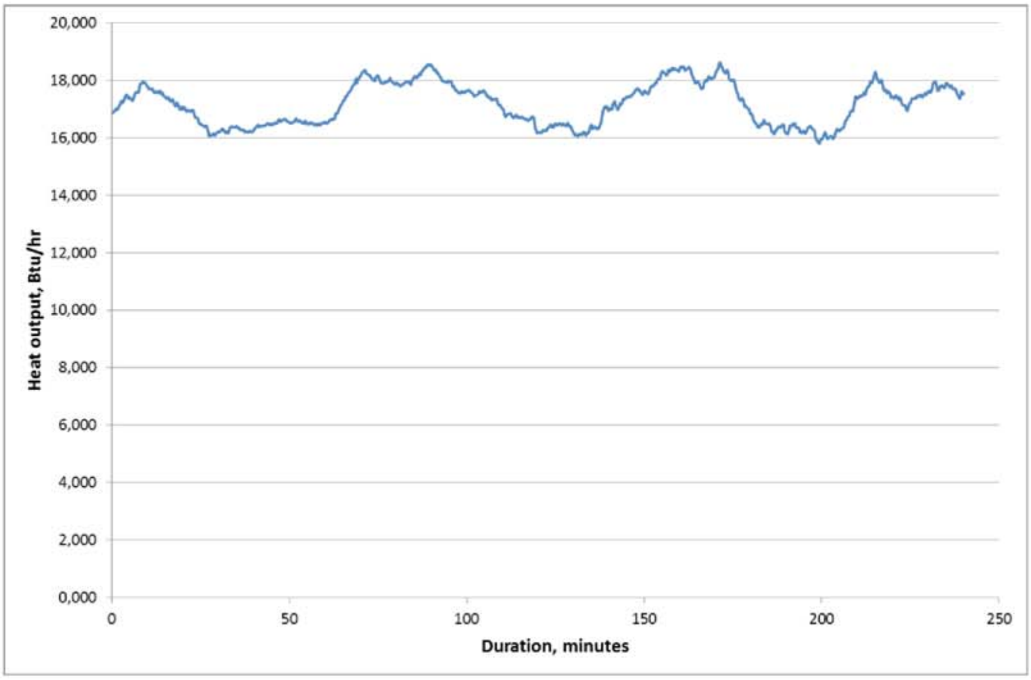

Figure 1. Heat output load Category I

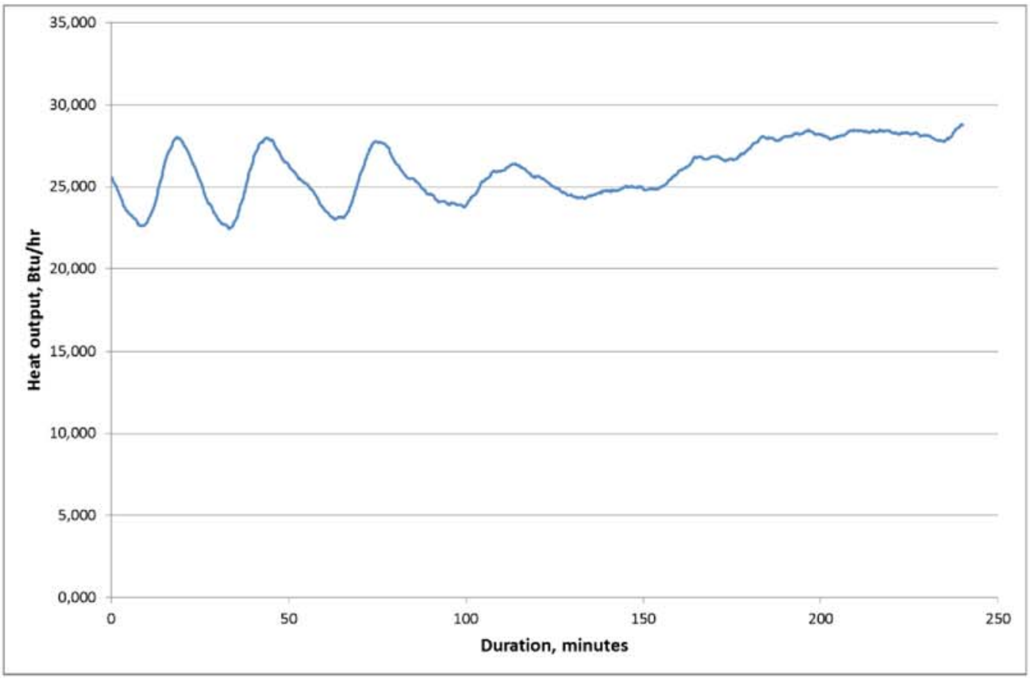

Figure 2. Heat output load Category II

Appendix 2

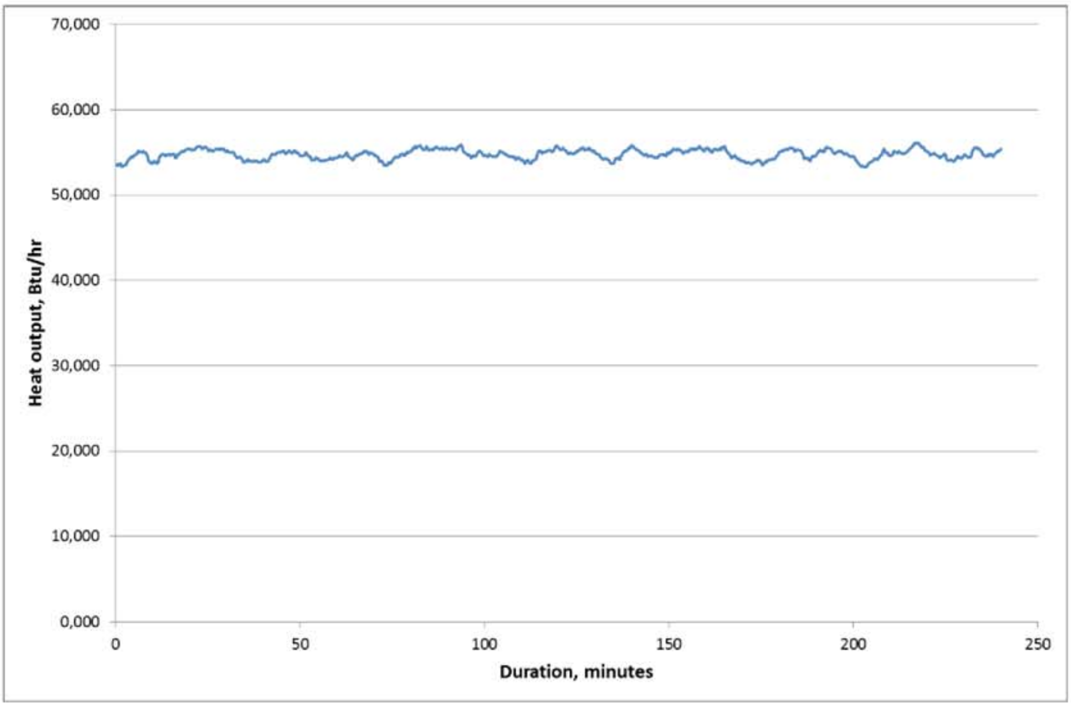

Figure 3. Heat output load Category III

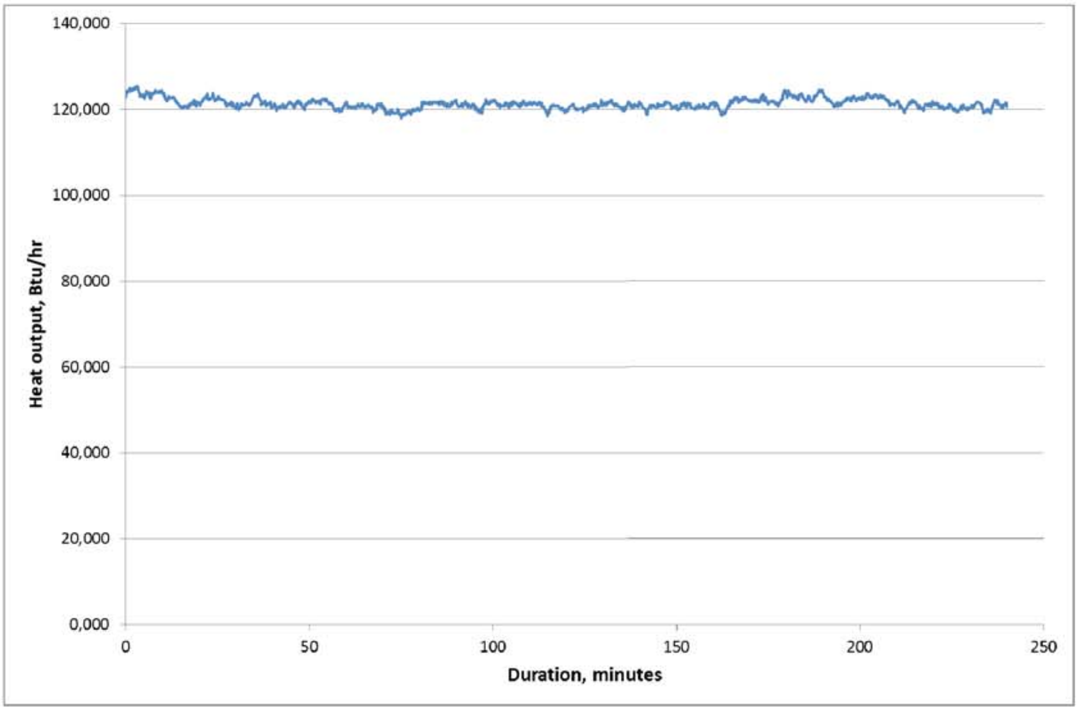

Figure 4. Heat output load Category IV

Appendix 3

Pretest dilution tunnel traverse run

The dilution tunnel inside diameter was 200 mm (7.87 inch) and cross sectional area was 0.03 m^2 (0.32 ft^2).

Table 10. Dilution tunnel traverse

Traverse point	Position, mm (inches)	Velocity, m/s
Y1	186.6	5.28
Y2	150.0	5.51
Center	100.0	5.55
Y3	50.0	5.54
Y4	13.4	5.35
X1	186.6	5.40
X2	150.0	5.53
Center	100.0	5.55
X3	50.0	5.51
X4	13.4	5.32
V_{strav}, average (Y + X)		5.43
V_{scent}, average (Center)		5.55

$$F_p = \frac{Vstrav}{Vscent} = \frac{5.43}{5.55} = 0.9786$$

The F_p factor has been included in the calculations of the particulate results.

Appendix 4

Sampling equipment leakage check

The leakage check of the sampling trains were performed at a vaccum of 150 mm Hg (5.9 in Hg). This vacuum was not exceeded during the tests.

Table 11. sampling train leakage check

	Leakage rate m^3/min		Check
	Pre-test	Post-test	
Sample system 1	0.0002	0.0002	OK
Sample system 2	0.0002	0.0003	OK
Ambient system	0.0002	0.0002	OK

Appendix 5

Test fuel specifications

Test methods

Water content:	SS-EN-ISO 18134-2
Ash content:	SS-EN-ISO 18122
Sulphur content:	SS EN-ISO 16994
Carbon, hydrogen and nitrogen content:	SS-EN-ISO 16948
Oxygen content:	Calculated as a difference
Calorific value:	SS-EN 14918

Results

Test fuel as fired basis

Water content, % of mass	7.0
Ash content, % of mass	0.3
Sulphur content, S, % of mass	<0.01
Carbon content, C, % of mass	46.8
Hydrogen content, H, % of mass	6.5
Nitrogen content, N, % of mass	0.05
Gross calorific (HHV) value at constant volume, MJ/kg	18.76
Net calorific (LHV) value at constant pressure, MJ/kg	17.35

Test fuel as dry basis

Ash content, % of mass	0.3
Sulphur, S, % of mass	<0.01
Carbon content, C, % of mass	50.4
Hydrogen content, H, % of mass	6.1
Nitrogen content, N, % of mass	0.06
Oxygen content, O, (diff) % of mass	43.0
Gross calorific (HHV) value at constant volume, MJ/kg	20.18
Net calorific (LHV) value at constant pressure, MJ/kg	18.84

Appendix 6

Instrumentation and uncertainty

The designations listed below refer to RISE quality system

Resistance thermometer, PT-100	ETf-QD Db 2
Thermocouple, type K	ETf-QD Db 3
Water flow meter Valmet 9V-MP150	Inv.nr. 201 414
Data logging system	Inv.nr. 201 673
Particulate sampling equipment (system 1)	Inv.nr. 901 070
Particulate sampling equipment (system 2)	Inv.nr. 202 743
Particulate sampling equipment (ambient)	Inv.nr. 200 399
Differential pressure gauge Furness FCO 14 (static pressure)	Inv.nr. 200 628
Differential pressure gauge Furness FCO 12 (Dynamic pressure tunnel)	Inv.nr. 202 747
CO/CO2- analyzer XStream (CO 0-5000 ppm)	Inv.nr. 901 077

Calibration gases

The calibration gases used to calibrate the gas analyser were accredited and delivered from AGA.

Table 12. Calibration gases

	Concentration	Uncertainty	Id. No.
CO	4040 ppm	1.0 % rel.	100408441
CO_2	16.0 %	1.0 % rel.	100408441

Uncertainty of measurement

Temperature difference, load side	±0.05 °C
Flue gas temperature	±3 °C
Ambient temperature	±1 °C
Static pressure in chimney	±10 %
Liquid flow, load side	±1 %
Fuel quantity	±0.01 kg
PM Filter weight	±0.1 mg
CO_2-concentration	±0.3 %-points
CO-concentration	±33 ppm
Boiler efficiency[1]	±2.0 %-points

[1] Do not include the losses in the test rig.

The uncertainty has been calculated according to EA-4/16 with coverage factor k=2

Appendix 7

Test setup

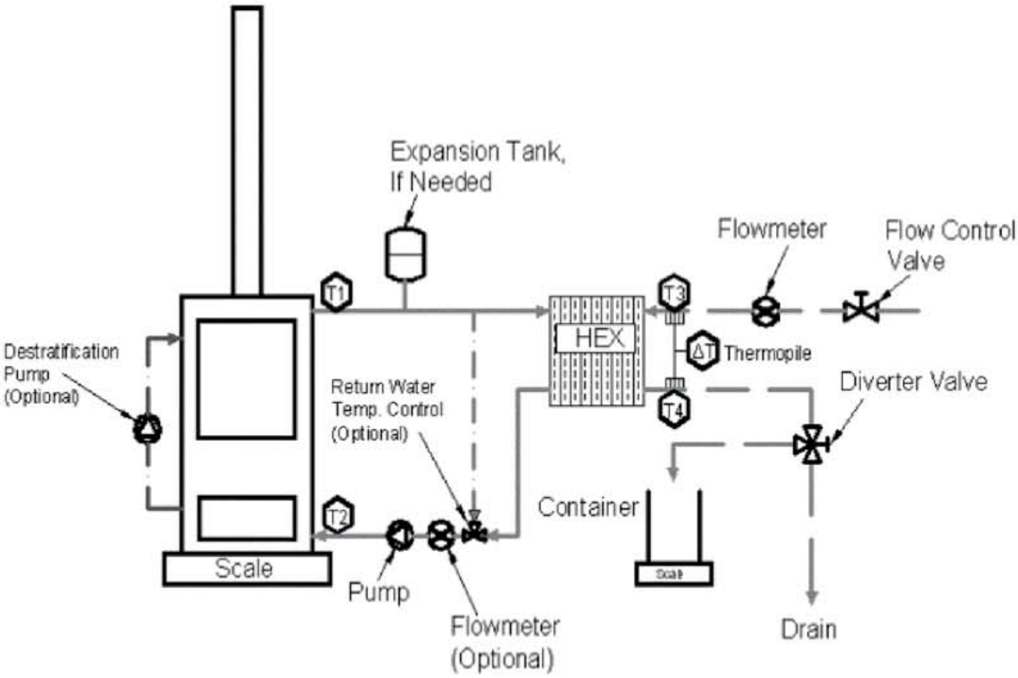

Figure 5. Test rig

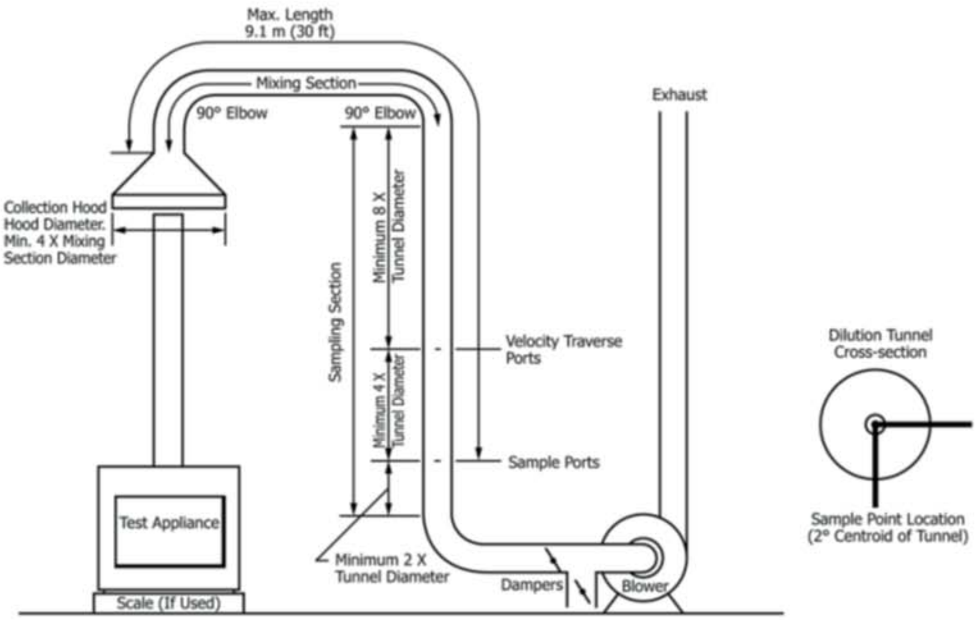

Figure 6. Dilution tunnel