Dall Energy Biomass Furnace

Test Plan

Low particle, CO and NO_x emission furnace

Maj 2011

Project Manager: Marianne Kyed Ørbæk

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2. INTRODUCTION

This test plan is the implementation of a test design developed for verification of the performance of an environmental technology following the DANETV method. See the verification protocol /1./ for details on organization and implications.

2.1. Verification protocol reference

Dall Energy Biomass Furnace, Low particle, CO and NO_x emission furnace, DRAFT 1, March 2011.

2.2. Name and contact of vendor

Dall Energy
Venlighedsvej 2
2970 Hørsholm
Denmark
Phone: +45 29 87 22 22
Contact: Jens Dall Bentzen
E-mail: info@dallenergy.com

2.3. Name of centre / test responsible

Verification Test Centre (DANETV)	Test responsible
FORCE Technology Park Allé 345 DK - 2605 Brøndby Denmark.	Ole Tvede Larsen E-mail otl@force.dk Phone +45 4326 7168 Cell phone +45 4082 9873

2.4. Technical experts

The expert group assigned to this test and responsible for review of test plan and test report includes:

Arne Oxbøl
FORCE Technology
Phone: +45 4326 7130
E-mail: aox@force.dk

3. TEST DESIGN

Emissions and operation parameters shall be measured continuously and/or manually during stable operation for the furnace at different loads, and during load changes.

3.1. Test site

The testing will be conducted at the newly constructed 8 MW Dall Energy Furnace, at Andelsselskabet Bogense Fjernvarme in Denmark. The furnace will be operated by the local operators, supervised by Dall Energy, which also will provide the necessary documentation and operation instructions for the tests.

3.2. Test type

The technology is the furnace, which is an integrated part of a biomass district heating plant, and consequently the test must be carried out as On-site test.

3.3. Addresses

Andelsselskabet Bogense Fjernvarme
Fynsvej 5
5400 Bogense
Denmark

3.4. Descriptions

The Dall Energy furnace is a newly invented combustion design, which in one special designed unit combines the well known updraft gasification technology with a gas combustion section above the gasifier.

The technology can only work as an integrated part of a biomass combustion plant, consisting of a fuel feeding system, a system to utilize heat and a chimney. To achieve the highest energy efficiency the heat utilizing system includes a wet condensation system. Several other units, e.g. blowers, instrumentation and a process control system are necessary to operate the plant. Only the furnace is included in the ETV verification test, as all the surrounding equipment can be selected among different technologies and suppliers.

3.5. Tests

The Dall Energy biomass furnace is tested for its ability to keep the emission of CO, particles and NO_x low, during stable operation at both high and low load, as well as keeping it stable and low during load changes.

The main test parameters are the concentrations of CO, particles and NO_x, but also the concentration of O_2, CO_2, water, and the flue gas temperature and flow will be measured, to normalize the measured value to the reference conditions, and to verify the operational conditions during the test.

Only the furnace are included in the verification, as the system for heat recovery can be very different in different plants. The flue gas temperature out of the furnace is around 1000°C, and the concentration of particles at such high temperature, is not the same as at the normal temperature lower than 150°C, which is normal out of the heat recovery system. This difference in particle concentration is due to condensable,

which is salts and organic compounds on vapor form, which condenses to form particles at lower temperature. To verify the load of particles from the furnace to the heat recovery system, the concentration of condensable is also measured and presented as a part of the emission of particles.

The concentration of particles and condensable will be measured manually, by isokinetic sampling of flue gas, and subsequent analysis. The flue gas is app. 1000 °C, and special equipment and adjusted sampling procedure according to the US EPA Method 202 is applied. The sampling will consequently not directly follow any existing standard, and cannot be reported accredited, but all standard procedures for accredited sampling will be followed.

Continuous measurement will be performed for the parameters CO, O_2, NO_x and flue gas temperature. The measurement point will be after the boiler or after the scrubber, where the flue gas temperature is more suitable for the measurement. The scrubber could affect the concentration of NO_X and the two point will be tested for deviations, and the referred measuring point after the scrubber will only be used for NO_X if the deviation is insignificant.

3.5.1. Test methods

The testing consists of two types of measurements: Continuous and manual measurements.

See appendix 3 for a short description of the applied accredited measurement methods, limits of detection, references and uncertainty. The design of the sampling site has an influence on the measurement uncertainty.

3.5.2. Test staff

The test staffs are:
Test responsible: Ole Tvede Larsen (OTL)
Field responsible: Steen Meldorf (SME)
Test technician: Steen Meldorf (SME)

3.5.3. Test schedule

Table 1. Test Schedule

	Week number 2011																		
Task	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Draft Test plan	X	X																	
Draft Test plan, review & QA			X	X	X	X													
Plant stability test				X	X	X	X	X											
Test period									X	X									
Analysis										X	X	X							
Data handling and calculation									X	X		X	X						
Draft Test Report, review & QA												X	X	X	X				
Final Test Report																X			

3.5.4. Test equipment

Only equipment for normal emission measurement is used, except for the modified equipment for measuring particles and condensable at the furnace outlet.

3.5.5. Type and number of samples

The measurement program is listed in the following Table 2.

Table 2. Measurement program

Operation Conditions	Measuring point	Measuring principle	Measured parameters
Stable operation at 100 % load	Outlet furnace	Continuous	Flue gas temperature
		Three 1 hour samples	Particles - including condensable
	After the boiler	Continuous with FTIR instrument	Gas parameters: O_2, CO, CO_2, NO_X, water
	After scrubber	Continuous	Flue gas temperature and flow
Changing from 100 % to 20 % load	Outlet furnace	Continuous	Flue gas temperature
	After the boiler	Continuous with FTIR instrument	Gas parameters: O_2, CO, CO_2, NO_X, water
	After scrubber	Continuous	Flue gas temperature and flow
Stable operation at 20 % load	Outlet furnace	Continuous	Flue gas temperature
		Three 1 hour samples	Particles - including condensable
	After the boiler	Continuous with FTIR instrument	Gas parameters: O_2, CO, CO_2, NO_X, water
	After scrubber	Continuous	Flue gas temperature and flow
Changing from 20 % to 100 % load	Outlet furnace	Continuous	Flue gas temperature
	After the boiler	Continuous with FTIR instrument	Gas parameters: O_2, CO, CO_2, NO_X, water
	After scrubber	Continuous	Flue gas temperature and flow

Also subsamples of the fuel and will be collected during the test period, and one combined samples of each will be analyzed (see prescription in section 3.5.6).

Continuous measuring of flue gas temperature in the measuring point Outlet furnace, presuppose that the dimension of the sampling port is large enough for the

high temperature pyrometer to be introduced. If this is not possible, the furnace temperature will be delivered from the plant monitoring system.

The continuous measurement of flue gas temperature, water content and concentration of O_2, CO, CO_2 and NO_x will run around the clock during the whole test period of 3-4 days, to be able to verify the operation and emission stability for the whole period. The sampling point for these measurements will be after the scrubber or after the boiler, where the temperature is suitable for sampling.

Manual samplings of particles and condensable will be carried out in the sampling point at the outlet from the furnace, where the flue gas temperature are around 1000°C.

The manual samples with the duration of one hour will be taken during two periods with stable operation at 1005 and 20% load respectively.

3.5.6. Fuel and ash samples

A fuel sample will be collected during the sampling time, by collecting samples of app. five kilos with regular intervals during day time on the sampling days. Preferable at least five samples on two days should be collected, to have at least 10 samples, which will be mixed, and one subsample will be taken for analysis of humidity, heat value and content of nitrogen and ash. The sample will also be described for visual appearance, including wood types and parts of the trees, chip sizes and color, which also will be documented by pictures. Information from the plant about origin of the fuel and possible fuel analysis will also be presented.

A sample of ash from the furnace will be collected by the end of the sampling campaign. The ash is transported by eight screws conveyers from the bottom of the furnace to a watering trough, where the ash is soaked, to cool it, and to prevent dust problems. The ash sample will be collected by collecting subsamples from between two and five of these conveyers.

The ash sample will be described for visual appearance, including color and content of larger and maybe unburned particles, which also will be documented by pictures. The sample will be analyzed for residual heat value.

3.5.7. Operation conditions

The test shall be carried out during 3 – 4 days, with different loads and during load changes, according to this program:

1. Stable operation at 100 % load (maybe also at 120 %?)
2. Changing load from 100 % to 20 % and if possible further down to 10 %.
3. Stable operation 20 % load (or 10 % load if possible)
4. Changing load again up to 100 % (maybe also up to 120 %)

The exact loads will first be fixed during the last week before the test, because the furnace has only been in operation since late in March, and the operation capability has to be tested thoroughly.

3.5.8. Operation measurements

During the test several operating parameters will be measured and logged by the test team, and some additional parameters will be delivered from the plant instrumentation and monitoring system in a data file covering the whole test period.

The data to be delivered from the plant are at least data for the fuel feed, the load and produced energy.

Also the plant measurement of flue gas temperature, O_2 concentration and eventually CO concentrations would be reasonable to compare and verify by means of the accredited verification measurements.

3.5.9. Product maintenance

No regular maintenance is required for a furnace, which normally can operate for several years without maintenance. However, the inside fireproof bricks lining should be inspected regularly for cracks and depositions, and repaired or cleaned if necessary.

3.5.10. Health, safety and wastes

The use of the product does not imply special health, safety and waste issues different from the operation of other furnaces.

The work during testing will be done according to the FORCE Technology Safety Rules that are compliant with the extensive Danish rules for safe occupational health and the European regulations of work with chemicals.

4. REFERENCE ANALYSIS

4.1. Analytical laboratory

Analysis will be carried out by the FORCE Technology laboratory according to DANAK accreditation no. 65.

Analysis of condensable is not covered by the accreditation, but it will be performed according to well known and accepted standards and within the same QA system as the accredited analysis.

4.2. Analytical parameters

Analysis will be carried out for:

- Particles collected on plain filters
- Condensable collected in cooled Impinger bottles

4.3. Analytical methods

The analytical methods are:

- Conditioning the filters to constant weight and weighing them according to EN 15384-1.
- Evaporation of liquid from the condensable samples and weighing the residue according to US EPA Method 202.

4.4. Preservation and storage of samples

There are no special requirements for preservation and storage for the plain filters used for collecting particles and the absorption water used for collecting condensable, as they are not sensitive for degradation or chemical reactions, caused by normal temperature and light. The only requirements are the basics, to keep the samples in clean and sealed containers or bottles in a dark and cool place.

5. DATA MANAGEMENT

Handling of data and calculation of results is performed according to the FORCE Technology DANAK accreditation no. 51 (also for parameters not covered by the accreditation).

Calculations will be performed by means of approved spread sheets and controlled spread sheet calculations.

5.1. Data storage, transfer and control

All manually read data from instruments, observations and information's about the plant operation during the test, will be stored in handwritten form on paper and schemes.

All the data stored in data loggers will be transferred to the FORCE Technology computer system, which is regularly backed up for data safety.

6. QUALITY ASSURANCE

All measuring, handling of data and calculation of results is performed according to the FORCE Technology DANAK accreditation no. 51 (also for parameters not covered by the accreditation).

All handwritten data and notes will be present in the original forms.

Approved spread sheets for calculations of results will be subjected to an intensive control, to assure correct calculations, and consequently no further control is necessary.

6.1. Test plan review

The test plan has been reviewed by the verification responsible from FORCE Technology Test Centre:

Ole Schleicher
E-mail: osc@force.dk
Phone: +45 4326 7540
Cell phone: +45 2269 7540

Review of the test plan will be done by the expert group assigned to this verification (see section 2.4).

6.2. Performance control – reference analysis

One field blank sample and one laboratory blank will be performed for each of the manually sampled parameters during the sampling campaign.

6.3. Data integrity check procedures

All transfer of data from handwritten form to computer, will be subjected to 100 % control by another person.

New calculations in spread sheets will be subjected to 100 % check of all new formulas and spot check of copies of the formulas.

6.4. Test report review

The test report will be subject to internal review by the verification responsible from FORCE Test Centre (see section 6.1).

Review of the test report will be done by the expert group (see section 2.4) as part of the re-view of the verification report, which will include the full test report as an Appendix.

7. TEST REPORT

The test report will correspond to the template of the FORCE Technology verification centre quality manual /2./ and will be included as an Appendix in the verification report. The test report will contain the test plan, except for this Chapter 7, which will be replaced by the test results, including data and records.

7.1. Test site report

All relevant data which is not recorded in a scheme will, together with other relevant information and observations, e.g. deviations from the test plan during the test, be noted in a test journal.

7.2. Test data report

The test data will include all data recorded during the test and the data reported by the analytical laboratories.

7.3. Deviations report

The report section on deviations will compile all deviations from this test plan with justification of deviations and evaluation of any consequences for the test data quality.

APPENDIX 1

TERMS AND DEFINITIONS

Word	DANETV
Condensable	Condensable particulate matter (CPM). CPM is organic and inorganic compounds in vapor phase at stack conditions, which forms liquid or solid particles, when cooled to below 30 °C.
Effect	The way the target is affected
ETV	Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and adequate quality assurance.
Evaluation	Evaluation of test data for a technology or product in relations to the performance and data quality
Performance claim	The effects foreseen by the vendor on the target(s) in the matrix of intended use
Performance parameters	Measurable and quantitatively documentable parameters, which is equivalent to the performance of the product, or describes the performance, and can provide all the relevant and necessary information on the performance
QA	Quality assurance
Standard	Generic document established by consensus and approved by a re-cognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Test/testing	Determination of the performance of a product for parameters defined for the application
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

APPENDIX 2

REFERENCE

/1./ Dall Energy Verification Protocol.
/2./ DANETV Centre Quality Manual, FORCE Technology. February 2009.
/3./ DANAK accreditation number 51.
/4./ DANAK accreditation number 65.
/5./ Method 202 Dry Impinger bottle method for determining condensable particulate emissions from stationary sources.
/6./ EUDP. Multi brændselsovn. Proces verifikation. Slutrapport. Januar 2010.

APPENDIX 3

SAMPLING METHODS

In the following a short description of the applied measurement methods, limits of detection, references and uncertainty are given. The design of the sampling site has an influence on the measurement uncertainty.

The testing consists of two types of measurements: Continuous and manual measurements.

Continuous emission monitoring (monitors, thermo couples etc.):

The limit of detection is given as the normal achievable at emission measurements. For monitors it is three times the average of monitor drift in the span point at repeated field measurements. Lower limits of detection can be achieved by optimized choice of calibration gas and higher frequency in the calibrations.

The uncertainty is based on measurements performed in a homogeneous gas stream as described in EN 15259. The uncertainty is given in % of the measured value (95 % confidence level). At low concentrations between 5 and 1 time the limit of detection, the uncertainty will increase from the stated %-value (at 5 times the limit of detection) up to 100 % of the measured value at the limit of detection.

Gas temperature:

The gas temperature is measured with a NiCr/NiAl-thermocouple connected to a data logger.

Range: -40 - 600 °C
Uncertainty: 4 °C (absolute)
FORCE Technology method: EM-03-01
Reference/standard: VDI 3511 bl. 1-5, IEC 584-2, IEC 584-2 amd. 1

Flue gas temperature above 600°C:

A Nicosil (type N) thermocouple connected to a digital thermometer (accuracy 1°C) is applied in a water cooled suction pyrometer with 2 ceramic shields. Flue gas is aspirated through the ceramic shields/Nicosil thermocouple with a velocity >75m/s and traversed in the selected points of the cross section. After moving to a selected point, the thermocouple comes to thermal equilibrium within 3 minutes, and a sample period of 5 minutes begins.

Range: 600 - 1200 °C
Uncertainty: 20 °C (absolute)
FORCE Technology method: EM-03-01
Reference/standard: VDI 3511 bl. 1-5, IEC 584-2, IEC 584-2 amd.1

O_2-concentration:

In a dry partial flow of the flue gas free of particles the O2-concentration is determined by means of a paramagnetic pilot cell.

Range: 0 - 25 Vol %
Limit of detection: 1 Vol %
Uncertainty: 5 % of measured value (95% confidence interval).
FORCE Technology method: EM-06-03
Reference/standard: EN 14789

FTIR-determination of CO, NO, NO_2, CO_2 and H_2O:

The sample gas is extracted through a heated sampling system consisting of filter, probe, heated tube, heated pump and heated monitor. The complete system is heated to 180 °C, meaning that the measurements are performed in a particle free and wet flue gas. The gas is

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SAMPLING METHODS

analyzed by Fourier Transform InfraRed Spectroscopy (FTIR). The FTIR-analyser is online with a PC. The FTIR is calibrated with zero gas (N_2) and span gas (CO_2).

Limit of detection: 1 ppm
Uncertainty: 10 % of measured value (95% confidence interval).
FORCE Technology method: EM-20-01
Reference/standard: USEPA M 320, USEPA performance specifications no. 15

Manual methods

The limit of detection is stated as the normal achievable at 60 minutes sampling time, normal suction level and accredited analysis. In some cases the limit of detection can be either lower or higher than the stated value. The limit of detection can be improved by higher suction flow and longer sampling time. The limit of detection is defined as the average of repeated blank values plus three times the standard deviation of the same blank values.

The uncertainty is based on measurements performed in a sampling site that meets the requirements in EN 15259 for grid measurements. When the demands in EN 15259 are not fulfilled, the uncertainty rises to an unknown level. The uncertainty is given in % of the measured value (95 % confidence level). At low concentrations between 5 and 1 time the limit of detection, the uncertainty will increase from the stated %-value (at 5 times the limit of detection) up to 50-100 % of the measured value at the limit of detection.

Flow:

The gas velocity is measured by means of a pitot tube connected to an inclined tube manometer or a micro manometer, reading the dynamic pressure. The velocity is measured in a number of points in the cross section of the duct. From the velocity and the cross section area, the flow is calculated.

Range: 0 - 40 m/s
Limit of detection: 2.3 m/s
Uncertainty: 10 % of measured value (95% confidence interval).
FORCE Technology method: EM-02-01
Reference/standard: ISO 10780

Particles:

A partial gas stream is aspirated isokinetic through a planar filter and a drying column. The gas flow is aspirated by means of a pump unit consisting of a gas tight pump, a calibrated gas meter and a flow meter. Sampling can be either in-stack or out-stack (the filter in the stack at stack temperature or the filter outside the stack in an oven).

Range: 0 - 50 mg/m³(n,t)
Limit of detection: 0,05 mg/m³(n,t)
Uncertainty: 10 % of measured value (95% confidence interval).
FORCE Technology method: EM-01-05
Reference/standard: EN 13284-1

The method for sampling particle is modified to make the sampling in a 1000°C hot flue gas, and to include sampling of condensable, according to the US EPA Method 202[1] by means of:

[1] US EPA Method 202. Dry impinger method for determining condensable particulate emissions from stationary sources.

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SAMPLING METHODS

1. The nozzle and probe will be made of quarts glass, which can tolerate the high temperature.
2. A cooling system with air will be adapted to the probe, to cool the flue gas down to between 120 and 180 °C where it enters the filter.
3. After the filter a condensation system to collect condensable according to US EPA Method 202 will be applied.

This modified particle and condensable measuring system are combining methods from well known and international accepted standards, which guarantee the applicability and quality. The only parts which are not according to any standard are the system to cool the flue gas, but this part is only critical for the results if particles are deposited in the probe. To include these possible depositions in the measurements, the probe will be washed with ultra pure water after the sampling, and the content of particles and condensable in the wash water will be measured by evaporating the water, and weighing the residue. The weight will be distributed to the samples in proportion to their sampling volume