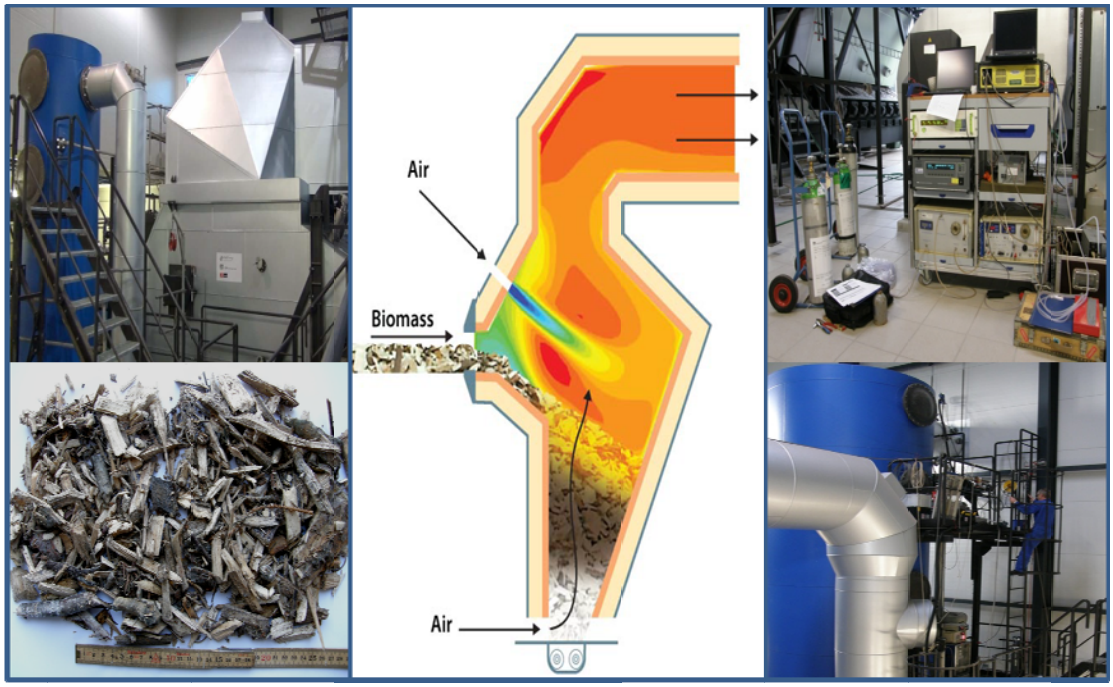
Dall Energy Biomass Furnace

Low particle, CO and NO_x emission furnace



Document	Verification Report
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Document Responsible	Marianne Kyed Ørbæk

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2. INTRODUCTION

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 quality assurance.

2.1. Name of product

The Dall Energy Biomass Furnace is a low emission and high efficiency biomass furnace, without any moving parts. The combustions principle is gasification in the bottom of the furnace and gas combustion in the upper part. This gives a very low emission of particles, CO and NO_x, which stays low during load changes, and even when operated as low as 20 % load.

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/verification responsible

The Danish Center for Verification of Climate and Environmental Technologies (DANETV), FORCE Technology DANETV, Air and Energy Center

Verification Test Centre (DANETV)	**Verification responsible**
FORCE Technology	Marianne Kyed Ørbæk
Park Allé 345	E-mail mko@force.dk
DK - 2605 Brøndby	Phone +45 4326 7062
Denmark	Cell phone +45 2269 7565

2.4. Verification and test organization

The verification was conducted by the Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for the reduction of climate changes and pollution.

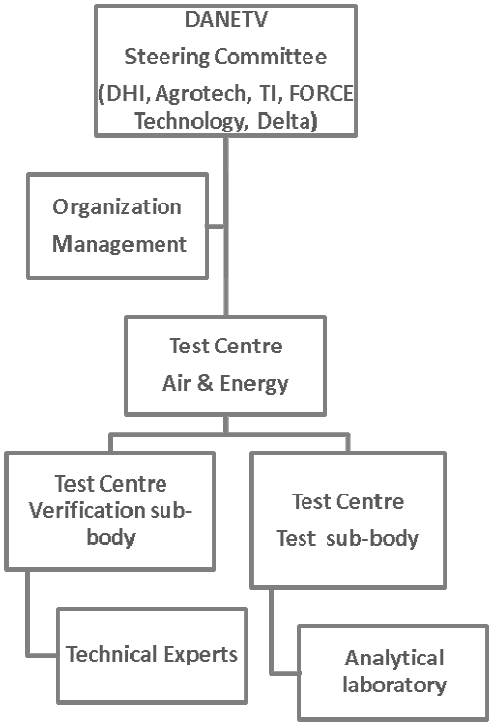
The verification was conducted by the Danish Test Centre DANETV. The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

The day to day operations of the verification and tests was coordinated and supervised by FORCE Technology, with participation of the vendor, Dall Energy. The testing was conducted at the 8 MW Dall Energy Furnace at Andelsselskabet Bogense Fjernvarme, Fynsvej 5, 5400 Bogense, Denmark. The furnace operated by the local operators, supervised by Dall Energy, which also provided the necessary documentation and operation instructions for the tests. Dall Energy also assisted FORCE Technology in the development of the protocol and test plans.

A technical expert group was established to support FORCE Technology in planning, conducting and reporting the verification and tests, and to review plans and reports.

The organization chart in Figure 1 identifies the relationships of the organization associated with this verification and tests.

Figure 1 Organization of the verification and tests



2.5. Technical experts

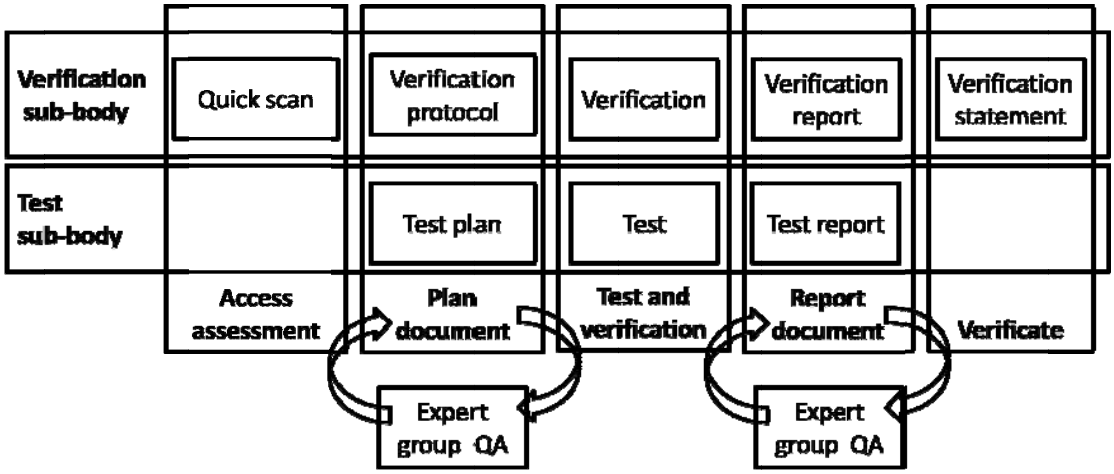
The technical expert assigned to this test and responsible for review of test plan and test report includes:

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

2.6. Verification process

Verification and tests was conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2.

Figure 2 Verification steps



References for the verification process are the Quality Management Plan for DANETV /1/.

A verification statement was issued by DANETV after completion of the verification. The verification statement, verification report and test report was seen as one consolidated verification description.

3. DESCRIPTION OF THE TECHNOLOGY

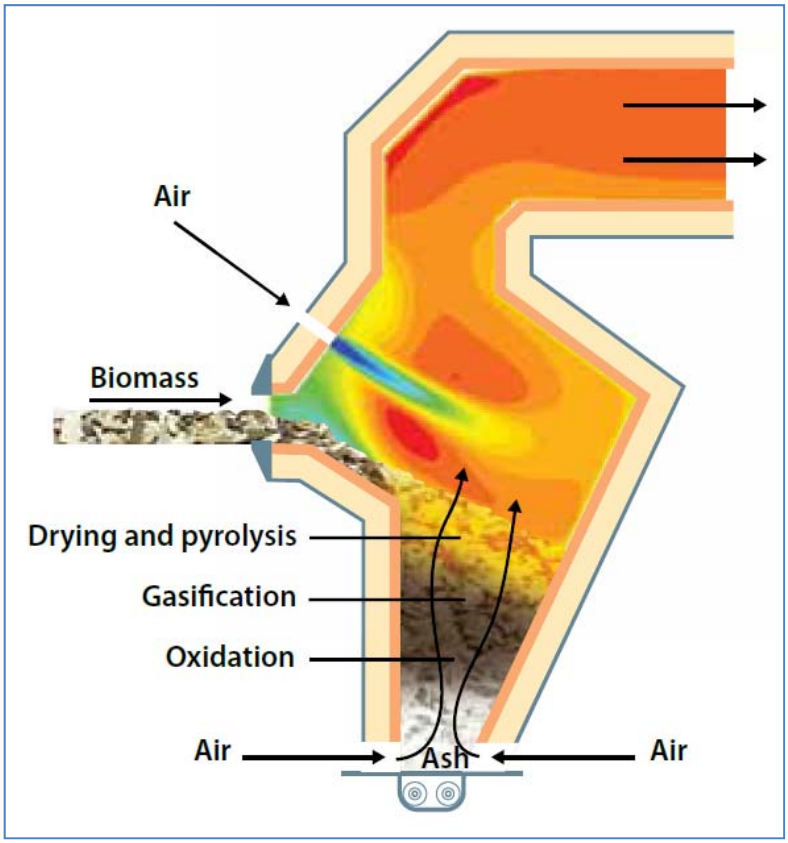
The technology to be verified is applying the well known updraft gasification technology with a gas combustion section above a gasifier

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.

4. DESCRIPTION OF THE PRODUCT

The Dall Energy multipurpose biomass furnace is a newly invented combustion design , without any hot moving parts which combines the well known updraft gasification process with a gas combustion section above the gasifier. The following Figure 3 shows the Dall Energy furnace principle diagram.

Figure 3 Dall Energy Biomass Furnace - Principle diagram



In the bottom part, the solid fuel is converted into a burnable gas and fine ash. In the top layer, the fuel is dried and pyrolysed.

The heat for the drying and pyrolysis process is a combination of convective heat from the gasification gases below and radiation heat from the gas combustion part above.

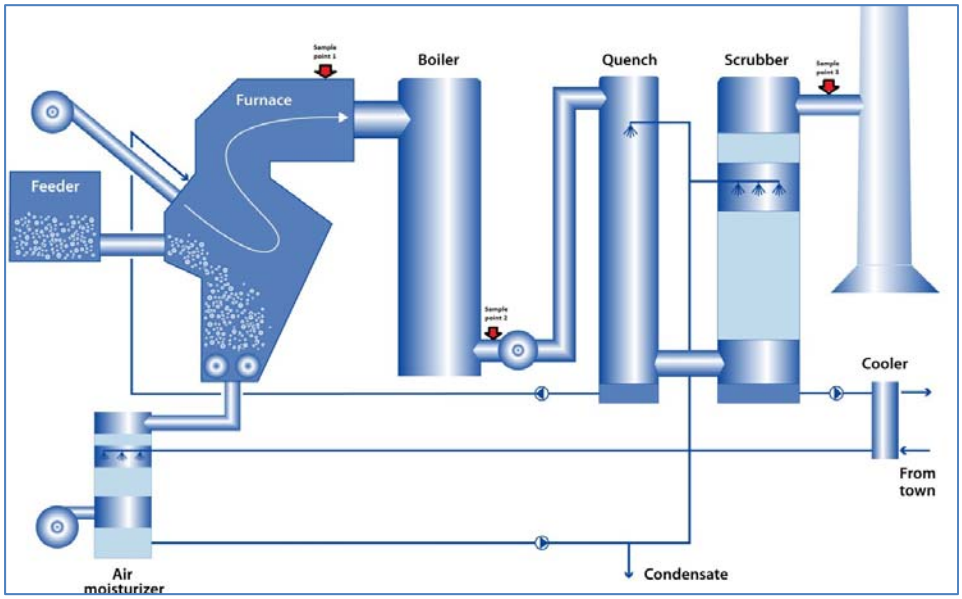
The gas velocity in the bottom part is very low. Consequently, ash particles remain here and the dust emission of the furnace is very low. Due to the very efficient gas combustion the CO emission is very low. Moreover the emission of the fuel NO_X is relatively low due to the gasification process.

Gas from the bottom part is combusted in the upper section. The gas combustion can operate at low oxygen concentration and maintain very stable flow, temperatures, emissions etc.

In combination with a flue gas condensation system and a fuel or combustion air moisturizing system, a very high thermal efficiency is achieved, and biomasses with up from 0 % to 60 % moisture can be used for fuel. The following Figure 4 gives an overview of the Dall Energy Biomass Combustion Plant.

The furnace can be delivered in sizes ranging from 1 MW to 20 MW. The furnace to be verified is 8 MW.

Figure 4 Dall Energy Biomass Combustion Plant – Flowchart



5. APPLICATION AND PERFORMANCE PARAMETER DEFINITIONS

The intended application of the Dall Energy Biomass Furnace is defined in terms of the matrix, the target and the effect of the biomass furnace.

The application is defined in the application definition appendix, Appendix 3 , in terms of matrix for use, targets and effects.

5.1. Matrix

The matrix of the application is combustion of biomass. The biomass type is wood chips.

5.2. Target

The target is the composition of the flue gas where it leaves the furnace.

5.3. Effects

The effect is:

- low concentrations of particles, CO, NO_x
- stable concentrations by operation in the whole possible operation area from 20% to 100 %
- stable concentrations of CO and NO_x during load changes

5.4. Performance parameters for verification

The performance parameters for the verification are the concentration of particles, condensable, CO and NO_x, and the stability of the concentrations of CO and NO_x when changing load, and when operating at 20 % load.

5.5. Additional parameters

Several parameters were measured or values achieved at the plant, to calculate the performance parameters into standard and reference conditions, and to verify and document the operating conditions during the verification:

- flue gas temperature and humidity
- samples of the biomass feed were collected, and analyzed for: Humidity, ash-content and nitrogen content.
- produced energy

6. EXISTING DATA

6.1. Summary of existing data

Some measurement results from operating a 2 MW test furnace are available in a EUDP report Appendix 2 /3/ and the main results are shown in Table 1.

Table 1 Existing data

Parameter	Load	Measured value	Unit
Particles	100 %	20 - 30	mg/Nm³ and 10% O_2
NO_x	100 %	175	mg/Nm³ and 10% O_2
CO	20-40-100 %	15	mg/Nm³ and 10% O_2

The results indicate that the claims of being a low emission furnace, with stable operation in a wide operational range are reliable.

6.2. Quality of existing data

The existing data has not been measured accredited according to the requirements of ISO 9001. There is no information on the instruments and methods used for the measurements, and no detailed data is available.

6.3. Accepted existing data

The existing date can only be seen as indicative values, which however clearly indicate the good performance of the furnace, and the low emission of CO, NO_X and particles.

7. TEST PLAN REQUIREMENTS

7.1. Test design

Emissions and operation parameters were measured continuously and/or manually during stable operation for the furnace at different loads.

The concentration of particles and condensable was 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 must be applied. The sampling was consequently not directly following any existing standard, and cannot be reported accredited, but all standard procedures for accredited sampling was followed.

Continuously measurement was performed for the parameters CO, O_2, NO_x and flue gas temperature. The measuring point was after the boiler, where the flue gas temperature is more suitable for measurement. The measured parameters were not affected by the reduced flue gas temperature from the furnace and to the outlet of the boiler. The flue gas temperature shall also be measured at the outlet of the furnace.

The test was carried out during two days at different loads according to this program:

- stable operation at 100 % load
- changing load from 100 % to 20 %
- stable operation 20 % load
- changing load again up to 60 %
- stable operation 60 % load
- changing load again up to 100 %

Continuously measurement was made during the whole test period, while the manual measurements of particles and condensable only was made in the two periods with stable operation.

7.2. Reference analysis

The test measurement was performed according to FORCE Technology's DANAK accreditation no. 51, except for the manual sampling of condensable, which was performed by a modified method, taken from US EPA method 202.

7.3. Data management

Data storage, transfer and control were done in accordance with the requirements described in the DANETV FORCE Technology verification centre quality manual. Similarly, filing and archiving requirements are described in the DANETV FORCE Technology verification centre quality manual Appendix 2 /1/.

7.4. Quality assurance

The quality assurance of the tests includes control of the reference system, control of the test system and control of the data quality and integrity.

The test plan and the test report were subject to review by the technical expert as part of the review of this verification protocol and the verification report, see Figure 2.

7.5. Test report

The test report was following the template of DANETV FORCE Technology verification centre quality manual with data and records from the tests presented Appendix 2 /1/.

8. EVALUATION

The evaluation includes calculation of the performance parameters, see Section 5.4 for definition, evaluation of the data quality based upon the test quality assurance, see Section 7.4 for requirements, and compilation of the additional parameters as specified in Section 5.5.

8.1. Calculation of performance parameters

Calculations are done according to generally accepted mathematical and statistical principles such as those described in the standards behind the DANAK accreditation number 51 Appendix 2/2/) and as described in Section 7.3.

8.2. Performance parameter summary

The combustion plant including the furnace was operated without any problems during the whole test period.

The test was carried out for two days with continuous operated emission measurements.

The schedule for the thermal loads and changing was followed as planned.

The overall impression of the furnace is the surprisingly stable operations and efficient combustion with hardly any CO emission, even during load changes and at such low load as 20 %.

The NO_X emission seems also relatively low for a boiler burning fresh chopped forest wood, but it is not as evidently low, as seen for the CO emission.

Normally condensate from wood combustion has a characteristic bad smell from different combustion by products, but here the condensate from any of the samples has no detectable smell, indicating a very efficient combustion.

8.2.1. Test results

The main measurement results at the outlet from the furnace as average of three one hour samples are shown in Table 2 and Table 3.

Table 2 Measurements in flue gas outlet from furnace – 20th March 2012

Parameter	Unit	Average	Average
Load	%	100	20
Measuring period	hh:mm	11:12 - 14:22	16:44 - 20:00
Temperature	°C	958	845
O_2	Vol % (dry)	4.88	5.25
H_2O	Vol %	38.0	32.4
CO	mg/m³(ref)[1]	< 2	< 2
NO_X	mg/m³(ref)	200	140
Particles	mg/m³(ref)	69	64
Condensable in rinse and condensate	mg/m³(ref)	50	68

Table 3 Average concentrations of CO and NO_X in the different operation modes

Load	Time	CO emission	NO_X emission
%	Hours	mg/m³(ref)	mg/m³(ref)
100	6½	< 2	200
100 → 20	1½	3.4	160
20	3¾	< 2	135
20 → 60	1	2.3	200
60	10	< 2	200
60 → 100	¾	< 2	230
100	2¼	< 2	240

The emission of CO was on average below the detection limit of 2 mg/m^3(ref). In short periods the concentration was above the detection limit, especially when the load was changed, but apparently also once in a while when operation was at low load. See Figure 5. The two peaks above the scale at the beginning and end of the 20 % load period is one-minute average peaks reaching 134 and 140 mg/m^3(ref).

The NO_X emission depends not only on the furnace conditions, but also on the nitrogen content in the fuel. The NO_X emission is clearly significant lower in the 20 % load period, which is related to the furnace conditions, e.g. retention time, as the nitrogen content in the fuel is anticipated to be constant. The NO_X concentration fluctuates, but it seems to be very constant values, depending on the actual load.

[1] (ref) indicates dry gas at standard conditions (0°C, 101,3 kPa) at 10 % O_2

Figure 5 Emissions of O_2, CO and NO_x including load changes

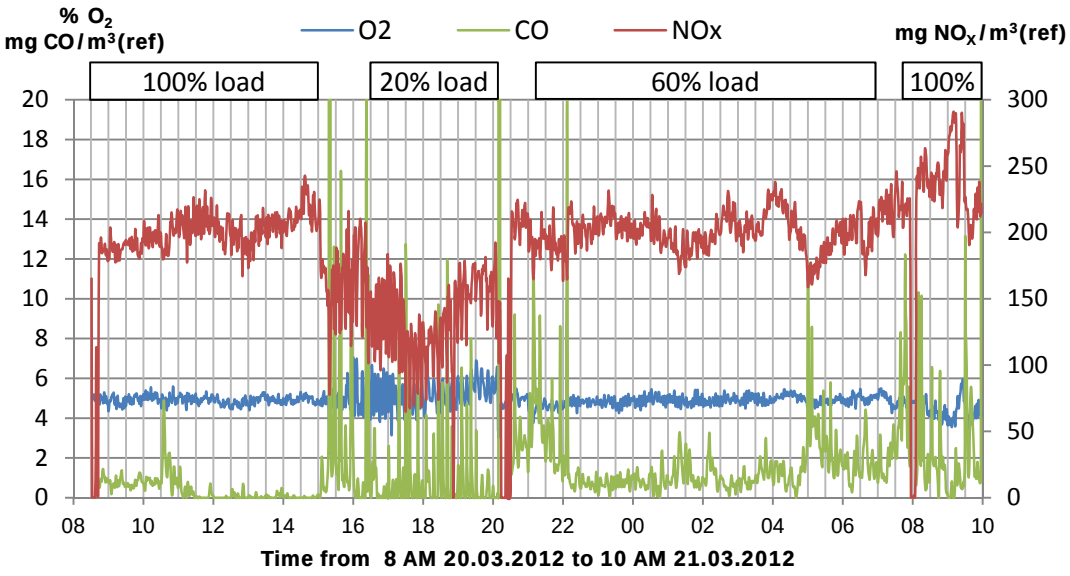


Figure 6 shows the particles on the filters and indicates a significant difference in the combustion conditions and behaviour, as the particle size, colour and distribution on the filters are very different. Some differences could also be caused by differences in the sampling conditions, where the lower temperature in the furnace, and the reduced sampling flow at the 20 % furnace load, means that the sampled flue gas will cool down faster, but there is no knowledge or evidence for such effects. However, the considerable lower temperature in the furnace at 20 % load (100 to 125 °C lower) could mean different combustion efficiency and consequently the light brownish colour could be some residual combustion by products. Despite the differences in particle appearances and colour, the emissions are the same within the uncertainty of the measurement.

Figure 6 Close up photos of filters with particles from furnace outlet

100 % load 20 % load

Analysis of wood chips samples showed a content of water of 34 % and content of ash and nitrogen of 1.5 % and 0.33 % respectively on dry sample.

The residual heat value in the ash sample was 0.27 MJ/kg, which calculated in relation to the heat value of dry wood, and the ash content in the wood chips equals app. 0.015 % of the input heat value. In Figure 7 samples of wood chip and ash is shown.

Figure 7 Photos of wood chip and ash samples

Wood chips sample

Ash sample

8.3. Evaluation of performance parameters

On the basis of this verification test of Dall Energy Biomass Furnace it is verified that regardless the load the emissions of particles, CO and NO_x are simultaneously low.

The concentrations of particles at the furnace flue gas outlet under constant load are low and the concentration of CO is significantly low at constant load as well as during load changes. The NO_x concentration is also considered low especially at low loads compared to the normal range for similar wood combustion plants.

8.4. Evaluation of test data quality

The information of the test report, the test system and data quality and integrity control were evaluated against the requirements set in the protocol and the objectives set in the test plan.

8.4.1. Control of data quality

Transfer of data from handwritten form to computer, has been subjected to 100 % control by second person.

8.4.2. Audits

No external or internal audits were undertaken for this specific verification task.

8.4.3. Deviations

According to the Test Plan, the temperature in the furnace should be measured continuously, but due to leak of sample ports, it was not possible. Instead the plant measurement of the temperature is used. This temperature was compared to the temperature measured by FORCE Technology, and a good correlation was found.

Instead of using an FTIR instrument for the continuous measurement of CO, CO_2 and NO_X standard instruments was used according to the FORCE Technology accreditation /2/.

It was only possible to collect one fuel sample, taken from a truck load. The fuel handling system is restricted area because of automatic fuel handling by an automatic crane. Fuel samples should be taken from the regular truckload of chips, but only one was delivered during the measurement campaign

8.5. Additional parameter summary

8.5.1. User manual

No user's manual are present for the Dall Energy Furnace alone, as it is part of a larger plant, having total operational and maintenance manuals. Consequently no evaluation of user manual was done as part of this verification.

8.5.2. Occupational health and environment

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 was done according to the FORCE Safety rules that are compliant with the extensive Danish rules for safe occupational health and the European regulations of work with chemicals.

8.6. Recommendations for verification statement

It is recommended to issue a verification statement based on the performance described in section 8.2.

Original signed by Marianne Kyed Ørbæk 19/6 2012
DANETV Test Centre Manager

Original signed by signed by Ole Schleicher 19/6 2012
Test responsible, FORCE Technology

Appendix 1

Terms and definitions

Condensable	Condensable particulate matter (CPM). Condensable PM is organic and inorganic compounds in vapour phase at stack conditions, which forms liquid or solid particles, when cooled down 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 product for performance and data quality
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Performance claim	The effects foreseen by the vendor on the target(s) in the matrix of intended use
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance
QA	Quality assurance
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
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

References

/1/	DANETV Centre Quality Manual, FORCE Technology. February 2009
/2/	DANAK accreditation number 51
/3/	EUDP. Multi brændselsovn, Proces verifikation. Slutrapport. Januar 2010

Appendix 3

Application and Performance parameter definitions

This appendix defines the application and the relevant performance parameters application as input for verification and test of Dall Energy Biomass Furnace following the DANETV method.

1. Application

The intended application of the Dall Energy Biomass Furnace is defined in terms of the matrix, the target and the effect of the biomass furnace.

1.1. Matrix

The matrix is the type of material that the product is intended for.

In the case of Dall Energy Biomass Furnace the matrix of the application is combustion of biomass.

The biomass furnace to be verified is suitable for many types of biomass.

In this verification the biomass type is wood chips.

1.2. Target

Targets are the measurable properties that are affected by the product for verification.

In the case of Dall Energy Biomass Furnace the target is the composition of the flue gas where it leaves the furnace.

1.3. Effects

The effects describe how the targets are affected by the product.

In the case of Dall Energy Biomass Furnace the effect is:

- Low concentrations of particles, condensable, CO, NO_x.
- Stable concentrations by operation in the whole possible operation area from 20% to 100 %.
- stable concentrations of CO and NO_x during load changes