Employer
SAKO BRNO A.S.

Project
High-efficient combined heat and power facility utilizing renewable sources (OHB II - line K1)

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PART III, APPENDIX A20
PROCEDURE FOR GUARANTEE TESTS

SAKO

RAMBOLL

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1. PERFORMANCE TESTS

This schedule describes the performance tests. For the performance guarantees, refer to Part II.h *Guarantees*.

1.1 Objectives

The purpose of the performance tests is to determine whether the performance guarantee requirements have been met. The test shall also demonstrate that the overall function of the Line is fulfilled for the specific conditions prevailing during the tests. The responsibilities of the Contractor in the completion of these tests are described in section 1.2.2.

The performance tests shall be conducted in the course of the Trial operation period and the report shall be submitted and approved before signing of Preliminary Take Over certificate by both contractual parties. Tests are repeated (second test) in the Guarantee Period.

The tests comprise the demonstration of performance of the Line; including, as a minimum, all of the guarantees (see Part II.h *Guarantees)* and the most important performance-related technical data (refer to Appendix A13 *Process and Design Data*), including but not limited to:

Line as a whole:

- net power production
- internal power consumption
- district heating output
- summer cooler performance
- water consumption
- compressed air consumption

Incinerator/boiler:

- waste throughput capacity, as detailed in the capacity diagram
- live steam data
- flue gas residence time after last air injection
- TOC and ignition loss of Incinerator Bottom Ash (IBA)
- dioxin content of IBA
- ignition loss of boiler ash
- flue gas data downstream of the boiler (flow and O2-level)
- flue gas side pressure loss
- SNCR-performance, urea consumption, NOx and NH3 downstream SNCR-system

Flue gas treatment (FGT) system:

- all guaranteed emissions
- consumption of absorbents, adsorbents and other chemicals (e.g., hydrated lime, HOK/activated carbon and sodium hydroxide)
- performance of the LT-ECO (DH output)
- performance of the flue gas condensation system (DH output)

Turbine/generator:

- electric gross power output
- district heating output of turbine condenser

Performance tests shall furthermore comprise those necessary to demonstrate that an acceptable working environment is provided with respect to:

- ambient temperatures and ventilation within Line areas
- control of fugitive emissions
- noise criteria
- surface temperatures; and
- health and safety requirements

All tests shall be performed with waste according to contract specifications as fuel (i.e. the primary fuel) unless otherwise agreed with the Employer, refer also to Appendix A1 *Overall Scope of Works* and A13 *Process and Design Data*.

The performance tests will consist of a series of tests to demonstrate (without causing excessive wear and tear of the Line components) that the Line can operate such that the performance guarantees identified as per Part II.h *Guarantees* are met and that the Line complies with all contractual requirements and conditions of relevant Legal regulation and permits (particularly the requirements and conditions of the Authorities, e.g. integrated permit).

Tests of individual components and tests of subsystems (e.g. fans, pumps, CMS system and IBA transport system) are not expected to take place during the Guarantee period (and performance test period therein). The Contractor is expected to carry out such tests during commissioning and prior to the Trial operation period. However, if specific components or subsystems appear not to be functioning properly, the Employer reserves the right to carry out component / subsystem tests at any time during the Guarantee period.

1.2 Responsibilities

1.2.1 THIRD PARTY / INDEPENDENT TESTING HOUSE

The performance tests may, at the discretion of the Employer, be carried out by a recognised / authorised, independent testing house, appointed by the Employer and acceptable to the Contractor, such acceptance not to be unreasonably withheld.

The cost of employing the independent testing house will be the responsibility of the Employer.

The independent testing house shall make a report of the tests based on the principles of this Appendix (refer to section 4 *Execution of Tests*) and according to mutual agreement between the parties involved. In addition, the independent testing house shall calculate any liquidated damages due according to the Contract.

1.2.2 THE CONTRACTOR

The Contractor shall prepare and submit to the Employer for its approval a detailed test plan not later than 3 months prior to the planned date for Trial operation period. The Contractor shall furthermore assist in the planning of the guarantee tests and be on Site and available during execution of the tests.

It is the Contractor’s responsibility to intervene should it note any incorrect or improper control and operation of the Line. The extent of the Contractor’s participation is further described in section 4 *Execution of Tests*.

The Contractor shall ensure that the Contract Object is always in compliance with all authority permits including the integrated permit.

The Contractor shall not instruct any party to carry out actions that are contrary to the approved testing plan. Should an abnormal or emergency situation arise the Contractor shall provide such support and advice as required to help ensure the safety of personnel and equipment.

The Contractor's participation in the performance test according to the present specifications is included in the Contract Object.

1.2.3 THE EMPLOYER

The Employer's operators shall operate the Line in accordance with the information provided within the O&M Documentation and the Contractor's reasonable instructions.

The Employer shall supply the waste for the operation of the Line during the tests.

1.3 Re-tests

Any expenses arising for re-testing due to Defects in the Works, and / or errors in the test sequence, which should have been pointed out by the Contractor before or during the test, will be borne by the Contractor. This could for instance be the case if the test must be interrupted or if operational pre-conditions are not fulfilled due to any malfunction or improper operation for which the Contractor is responsible. If the test is rejected due to conditions for which the Contractor is responsible, a re-test will be carried out at the Contractor's expense.

2. PRECONDITIONS OF PERFORMANCE TESTS

2.1 Guaranteed Data to be verified

The guaranteed data to be verified is stated in Part II.h *Guarantees*.

In addition, data that is needed for the determination of the overall function of the Line shall also be verified. The extent of such measurements / tests shall be agreed prior to the tests.

2.2 Preconditions of Guaranteed Data

The specification of the preconditions of guaranteed data is described in section 4 *Execution of Tests* (with reference to appendix A13 *Process and Design Data* and part II.h *Guarantees*).

The guaranteed data must be based on specified standard conditions (refer to Table 1 and section 2.2.2 below and appendix A13 *Process and Design Data* and part II.h *Guarantees*) and must be stated in each of the points, LP1, LP2, LP5, LP6, LP7, LP8 and LP9, in the capacity diagram (see appendix A13 *Process and Design Data*.) The guaranteed data must apply for operation in the whole capacity diagram / range and allow for deviations from the standard conditions of input parameters, thermal input, raw gas composition, and other input variables as indicated in Appendix A13 *Process and Design Data*, e.g. according to the capacity diagram and variation range of raw gas composition. This is to be achieved by the employment of correction methods stated below.

The guaranteed data must be stated on the basis of the methods of calculation and possible corrections presented in the sections below.

Corrections may be made to parameters outside the influence of the Contractor.

The Contractor shall submit correction curves or equations that defines guarantee values applicable for all points in the Capacity diagram and all operating conditions that are outside the Contractor's control, such as HCl content in the raw gas. The correction curves or equations shall as a minimum cover the "expected range" as read from Table 1. Only correction curves and equations included within the Contract will be accepted at the performance tests. The Employer may, at its sole discretion, accept other correction curves and equations provided that the Contractor properly and reasonably justifies the reason for changing the correction curves and equations.

The principal purpose of the curves / formulas shall be the correction of guaranteed values to corrected guarantee values applicable at the conditions actually prevailing during the tests.

Table 1, Standard conditions of selected variables and expected range of possible test deviations.

Variable	Unit	Standard condition	Expected range of possible test deviations
Steam temperature at inlet side of ESV (Emergency Shut-off Valve)	°C	Nominal, i.e. 400 °C	± 5
Steam pressure at inlet side of ESV (Emergency Shut-off Valve)	bara	Nominal, i.e. 40 bara	± 1
Feed water temperature	°C	130	± 3
Primary air temperature at forced draught fan inlet	°C	25	10-35
Secondary air temperature at forced draught fan inlet	°C	25	20-45
Blow down	kg/h	0	0- Nominal
Mass flow rate of IBA (dry) relative to waste (as fed to incinerator)	%	16	10-30
Temperature of IBA at grate exit	°C	500	-
TOC (Total Organic Carbon) of IBA on dry basis	%, dry basis	1% w/w	≤ 3% w/w
Net calorific value of IBA loss on ignition	MJ/kg	27.2	no
Radiation and convection loss from incinerator, boiler	% of nominal thermal input	1.5 %	no
Other energy loss/consumption, e.g. energy extracted by use of cooling water	MJ/h	If specified elsewhere in the Contract	
Reference temperature regarding enthalpy calculations in flue gas	°C	25	-
Reference temperature regarding enthalpy calculations in the water / steam cycle	°C	0	-
District heating temperature forward return	 °C °C	Nominal, i.e. 90 67	 80-105 °C 60-70 °C
Ambient air temperature	°C	25°C	0-35 °C
Raw gas concentrations (dry flue gas at 11% O2)	mg/Nm³	Nominal values as defined in Appendix III, A13 *Process and Design Data*	From zero to design values as defined in Appendix III, A13 *Process and Design Data*

2.2.1 PRECONDITIONS OF GUARANTEED NET POWER PRODUCTION

The guaranteed net power production shall be based on the standard conditions contained in Table 1 and Appendix A13 *Process and Design Data.* The input to and output from figures will be as indicated by the supply limits. For variables not included in Table 1, the standard condition is the nominal value.

The guaranteed net power production shall be calculated as the gross power production measured at the generator P_{gross}, subtracted the power consumption measured at the distribution transformers $P_{Distribution\_trans}$, subtracted the loss of the normal operation transformers T24 and T25 $P_{T24,T25\_loss}$.

$$P_{net} = P_{gross} - P_{Distribution\_trans} - P_{T24,T25\_loss}$$

During the test all applicable equipment shall be at the standard conditions of Table 1, and other equipment in normal operation. The measurements may need correction for consumption of waste cranes and district-heating pumps which are not considered parasitic consumption with respect to guarantee values. All environmental requirements shall be complied with.

The power consumption of building services is included in the guarantee value for net power production.

Correction curves may be accepted for the following parameters should the actual value of the respective variable measured during the test be different from the standard condition stated:

- mass flow rate of IBA
- ambient air temperature
- district-heating output

The Contractor shall submit correction curves or equations applicable for all points in the Capacity diagram and other conditions outside the Contractor's control. The correction curves or equations shall as a minimum cover the "expected range" as read from Table 1.

For tests regarding the turbine, the overall principles of the guarantee test are laid out in DIN 1943, "Wärmetechnische Abnahmeversuche an Dampfturbinen".

2.2.2 PRECONDITIONS OF THE GUARANTEED CONSUMPTIONS

The guaranteed consumptions shall be based on the standard conditions, refer to Table 1 above. All permits and environmental requirements shall be complied with.

The Contractor shall state the consumptions for the nominal point of operation.

Corrections may be made of certain guaranteed values stated in Part II.h *Guarantees* in the case that the actual values of input variables measured during the test are different from the standard conditions stated.

The correction curves and equations shall be applicable for the expected range of the variable in question. For the raw flue gas data, such a range shall as a minimum cover the "dimensioning data" of Appendix A13 *Process and Design Data*.

As a starting point, the corrections presented in Table 2 are foreseen.

Table 2, Foreseen corrections for guaranteed consumptions

Guarantee value	Correction for variable
Urea consumption	• Thermal input to incinerator (MW)
$Ca(OH)_2$ / CaO consumption	• Thermal input to incinerator (MW) • HCl content in raw flue gas* • SO_2 content in raw flue gas* *: in mg/Nm³, dry flue gas at 11% O_2
Boiler ash and FGT residue output	• Thermal input to incinerator (MW) • HCl content in raw flue gas* • SO_2 content in raw flue gas* *: in mg/Nm³, dry flue gas at 11% O_2
Water consumption	• Thermal input to incinerators (MW)

2.3 Extent of performance testing

Testing is to be performed on the Line as a whole, as described below. The tests may be combined if mutually agreed between the Employer and the Contractor.

2.3.1 LINE AS A WHOLE

The extent of testing foreseen is described below:

Test 1: To be carried out no sooner than 1000 hours after cleaning (or 1000 hours after first waste fire of virgin boiler) and no later than 8000 hours after cleaning of the incinerator / boiler

Test 1 is of 24 hours effective duration and the operation shall be as close as possible to nominal thermal load of the incinerator / boiler.

The term "effective duration" means that for every ½ hour in which the operating conditions (refer to section 2.4 *Conditions of operation*) are not met, the test is prolonged by one hour.

The blow down may be closed during the test.

Possible Additional tests:

Additional tests may be carried out, in addition to the above-mentioned tests, if the Employer finds it necessary. This includes e.g. tests at different turbine loads, district-heating output, different mechanical or thermal loads or using waste with different calorific values. The total duration of such tests is expected to be 48 hours effective duration and they are to be carried out in conjunction with Test 1, if possible.

The Contractor and the Employer shall decide by mutual agreement whether the effective duration is accomplished.

During all tests, data is collected for the purpose of determining the fulfilment of Guaranteed Data, including data necessary for determining the thermal input of the Line.

2.3.2 THROUGHPUT CAPACITY AND IBA QUALITY (TEST 2)

For the purpose of determining the waste throughput capacity, waste with suitable heating value may be selected to allow reaching the waste throughput limitation of the capacity diagram. The operation shall be as close as possible to nominal thermal load of the incinerator / boiler.

Test duration is no less than 96 hours effective duration.

Testing to be carried out at any time during the performance test period.

For the purpose of determining the IBA quality, IBA shall be collected during the test.

IBA sampling (refer to Appendix 3) is performed by the independent testing house under the supervision of the Employer and the Contractor.

2.3.3 CONSUMPTIONS AND RESIDUE OUTPUT

As the starting point, the following tests shall be conducted:

Test 3: To be carried out at any time during the performance test period.

Test 3 is of minimum 96 hours effective duration and the operation shall be as close as possible to nominal thermal load of the incinerator / boiler, and hence as close as possible to nominal flue gas conditions.

During the tests, the consumption is measured of all consumables represented by guarantee values e.g. $Ca(OH)_2$, CaO, urea, activated carbon and other possible consumables. Furthermore, samples of all consumables are taken for the purpose of determining the quality / purity / concentration.

For the test of lime consumption and residue generation, the test duration shall be no less than five times the average residence time of recirculating FGT residue, which is calculated as total storage within the bag house filter, hoppers and recirculation system (in tonnes) divided by the guaranteed rate of residue generation at nominal conditions (in tonnes per hour).

The guaranteed consumptions are revised on the basis of the actual quality / purity / concentration and the Contractor's correction curves / formulas and deviations of other inlet variables to the extent that this has been agreed. The measured consumptions are then compared with the revised guaranteed consumptions.

For lime consumption, the guaranteed consumption may be calculated by the hour based on hourly average thermal input and raw gas content of HCl, SO_2 and HF using the applicable correction curves. The guaranteed consumption of Test 3 shall be the sum of guaranteed hourly consumptions over the effective duration of the test.

For boiler ash and FGT residue output, the guaranteed output may be calculated by the hour based on hourly average thermal input and raw gas content of HCl, SO_2 and HF using the applicable correction curves. The guaranteed output of Test 2 shall be the sum of guaranteed hourly outputs over the effective duration of the test.

Possible additional tests:

In the case that the Employer finds it necessary, in addition to the above-mentioned tests, other tests may be carried out. This includes for instance tests at different mechanical or thermal loads of the incinerator / boiler or using waste with different composition. The total duration of such tests is expected to be 36 hours effective duration and if possible, they are to be carried out in conjunction with Test 2.

During all tests, data is collected for the purpose of determining the fulfilment of Guaranteed Data, including data necessary for determining the thermal input and for environmental compliance.

2.4 Conditions of operation

To obtain useful results and determine the effective duration of the tests certain conditions of operation must be fulfilled, as detailed in the following sections.

The Contractor shall present its supporting information and the Employer shall review this evidence and confirm whether the effective duration has been accomplished.

2.4.1 INCINERATOR / BOILER, TURBINE / GENERATOR AND FLUE GAS TREATMENT (FGT) SYSTEM

The incinerator / boiler and flue gas treatment system must hold "stable operation" at least 12 hours before the start of the test and continue for the duration of the test. The stable conditions are indicated by, inter alia, the following:

1. Operation is considered to be stable if the steam flow rate to the turbine varies within the range ±5% of the steam temperature and steam pressure stated in Table 1. The indicated range represents the standard deviation.

2. The lime injection rate is running at its normal level in accordance with the raw gas measurements during at least 12 hours before the start of the test

3. The waste being fed to the furnace shall be municipal type waste and shall not be of a specific composition and homogeneity. However, selected waste may be used during specific tests provided these are agreed in advance with the Employer, and only where this is necessary to reach certain parameters.

4. All instruments of the Line (those that are relevant for the test, including temperature and pressure sensors, flow measurements) shall be serviced, cleaned and calibrated by an approved company at the Contractor's expense prior to the tests.

5. Blow-down is to take place during the tests with the Line running at its normal rate, with the potential for exception during Test 1.

2.4.2 OPERATING CONDITIONS FOR IBA QUALITY TEST

During the testing of IBA quality, the incinerator / boiler shall be held at "stable operation" (see section 2.4.1 above) and as close as possible to nominal thermal load.

3. EVALUATION OF RESULTS

3.1 General

The results obtained during the performance tests shall be compared with the guaranteed values.

No measurement tolerance shall be accepted when comparing the obtained results with the guaranteed values. Therefore, the comparison shall be carried out without any correction for measurement tolerance and the Contractor shall consider this when designing and constructing the incinerator / boiler / turbine / generator and flue gas treatment system stating guarantee values.

In case the Contractor finds that non-acceptance of tolerances is conflicting with guidelines/instructions in norms and/or standards the Contractor shall in Part II.h Guarantees inform the Employer about any use of tolerances in connection with stated guarantee values before Contract signing.

3.2 Correction of Guarantee Values

3.2.1 CORRECTION 1: GUARANTEE VALUES AT THE ACTUAL POINT OF OPERATION

If the actual point of operation does not coincide with a point in the capacity diagram, the linear interpolation procedure detailed in Appendix 2 shall be used to find the revised Guarantee values valid for the actual point of operation.

It should be noted that such a correction is needed only when the Guarantee Value depends on the point of operation.

3.2.2 CORRECTION 2: GUARANTEE VALUES WHEN INPUT VARIABLES DEVIATE FROM STANDARD CONDITIONS

In the case that the actual conditions deviate from the standard conditions on which basis the guarantees are stated, the Guarantee values may be corrected using correction curves, refer to section 2.2, *Preconditions of Guaranteed Data*. No other correction may be performed unless accepted by the Employer.

3.3 Calculation procedures

All hours in which the operation conditions (refer to section 2.4 *Conditions of operation*) are not fulfilled (refer to the definition of "effective duration" in section 2.3.1) are excluded from the calculations. Hence, the results represent the "effective duration" of the tests.

3.3.1 DETERMINATION OF THE THERMAL INPUT TO THE INCINERATOR

The thermal input by waste, and hence the net calorific value of waste, shall be determined by use of the so-called indirect method which is based on defining a closed volume enclosing the incinerator, boiler, and possible air pre-heaters and flue gas recirculation system, refer to the diagram in Appendix 1. Establishment of a mass and energy balance over the closed volume allows for determination of the thermal input, when accounting for all other in and outgoing processes over the boundary of this closed volume.

The formulas below apply to hourly average values, and enthalpy flows shall be calculated as the sum of hourly average values of all hours, in which the operation conditions are fulfilled, refer to the definition of effective duration above.

The thermal input to the incinerator / boiler is determined by:

$$Q_{th} = \Sigma Q_u + \Sigma Q_{loss} + \Sigma Q_{inj} - \Sigma Q_{rec} - \Sigma Q_{ca} - \Sigma Q_{waste}$$

in which: Σ is the sum of all approved hourly average values, refer to the definition of the "effective duration".

Q_u is the useful energy, refer to section 3.3.2.

Q_{ca} is the energy content of combustion air, refer to section 3.3.7

Q_{waste} is the heat content of waste, which equals 0 for practical reasons.

$Q_{loss} = Q_{fg} + Q_{IBA} + Q_{rad\ con} + Q_{cool}$

Q_{fg} is the flue gas heat loss, refer to section 3.3.4.

Q_{IBA} is the loss caused by the IBA through heat loss and heating value of combustibles in IBA, refer to section 3.3.6.

$Q_{rad\ con}$ is the radiation and convection loss from the external surfaces of the incinerator/boiler, refer to section 3.3.5.

Q_{cool} is loss from cooling of the incinerator/boiler or auxiliary equipment, including heat output by use of cooling water, refer to section 3.3.8.

Q_{inj} is the loss from the evaporation of the water injected, if any.

Q_{rec} is the input from the injection of recirculated flue gas (in case of flue gas recirculation).

Other losses such as heat loss from boiler ash, combustible matter in boiler ash, combustible matter in flue gas (CO, TOC), heat loss from fly ash leaving the boiler, combustible matter in fly ash leaving the boiler are judged to be negligible for the energy balance and they are therefore not measured or accounted for.

In case of air pre-heating the temperature of combustion air may be taken downstream of the air pre-heater or it may be taken upstream of the air pre-heater. The heat input to the air pre-heater may be included in the balance depending on the chosen thermal boundary. The heat input to the air pre-heater may be calculated from respective steam and condensate flows and enthalpies.

For steam or heat extracted to outside of the thermal boundary, the enthalpy difference of the outflow stream and the corresponding returning stream shall be included in the "useful energy" when determining the thermal input.

The Net Calorific Value is determined by

$$H_u = \frac{Q_{th}}{m_{waste}}$$

in which:

m_{waste} is the mass of waste fired in the incinerator during the "effective duration" of the test.

The thermal input per effective hour determines together with the mass flow rate of waste a point within the limits of the capacity diagram. Revised guarantee values, refer to section 3.2.1 shall refer to this point.

3.3.2 STEAM PRODUCTION

The energy content of produced steam at the test is determined by use of the following formula:

$$Q_{s,tot} = m_s * h_s(P_s, T_s) + m_{ex} * h_{ex}(P_{ex}, T_{ex})$$

in which:

m_s = steam production measured at the supply limits in kg/s

h_s = the steam enthalpy in kJ/kg is a function of steam pressure and steam temperature, measured at the supply limits.

m_{ex} = steam flow rate (possibly live steam or steam extracted from the boiler drum) for purposes outside the supply limits

h_{ex} = the steam enthalpy (in kJ/kg) of steam to be used outside the supply limits. h_{ex} is a function of steam pressure and steam temperature.

The useful energy shall be calculated on basis of the steam data and feed water data applicable downstream of the feed water pumps:

$$Q_u = Q_{s,\,tot} - m_f * h_f(T_f)$$

in which:

m_f = Feed water flow (including injections) in kg/s ($m_f = m_s + m_{ex}$)

h_f = The feed water enthalpy in kJ/kg is a function of feed water temperature.

Enthalpies must be based on a reference temperature of 0 °C and they must be calculated according to reference 1 (see section 6 *References*).

3.3.3 FLUE GAS HEAT LOSS

The flue gas heat loss is calculated as:

$$Q_{fg} = F_{fg} * \rho_{fg} * c_p * (t_{fg} - 25\ ^\circ C) \qquad [kW]$$

in which

F_{fg} is the flue gas flow in Nm³/s. The flue gas flow is determined downstream of the boiler, e.g. by back-calculation from stack measurement and measurement of O_2 and moisture in flue gas in the stack and downstream of the boiler, respectively.

t_{fg} is the flue gas temperature in °C, measured downstream the boiler

c_p is the heat capacity in kJ/kg/°C (average over the temperature range 25 °C to t_{fg}), calculated from flue gas composition.

ρ_{fg} is the density of the flue gas in kg/Nm³, calculated from flue gas composition.

3.3.4 RADIATION AND CONVECTION LOSS

The radiation and convection loss from the surfaces of the incinerator and boiler is calculated as 1.5 % of the energy content of waste fired (equal to the thermal input) in the nominal point of operation:

$$Q_{red.con} = 0{,}015 * Q_{th}$$

3.3.5 IBA LOSS

IBA heat loss and loss from the ignition loss of the grate IBA is calculated as:

$$Q_{IBA} = m_{IBA} * (c_{IBA} * (T_{IBA,o} - 25\,^\circ C) + NCV_{Ig,loss} * U_{IBA}) \ [kW]$$

in which:

m_{IBA} = dry IBA flow rate in kg/s.

U_{IBA} = weight fraction of ignition loss in dry IBA.

c_{IBA} = IBA specific heat capacity, which is assumed to be 1.00 kJ/kg °C

$T_{IBA,o}$ = IBA outlet temperature is assumed to be 500 °C.

$NCV_{Ig,loss}$ = The net calorific value of ignition loss is assumed to be 27.2 MJ/kg

3.3.6 COMBUSTION AIR

The heat content of the combustion air is calculated as

$$Q_{ca} = V_{ca} * \rho_{ca} * c_p * (t_{ca} - 25\ ℃)\ \text{[kW]}$$

In which:

V_{ca} is the flow of combustion air in Nm³/s

t_{ca} is the temperature of combustion air in °C

c_p is the heat capacity in kJ/kg/°C

ρ_{ca} is the density of air in kg/Nm³.

3.3.7 WATER INJECTION

The energy loss by evaporation of water injected is calculated as:

$$Q_{inj} = m_{inj} * \Delta H_{vap} \qquad \text{[kW]}$$

In which:

m_{inj} is the mass flow of water in kg/s

ΔH_{vap} is the heat of evaporation = 2 443 kJ/kg

The evaporation of urea water and the energy release by oxidation of urea shall be neglected.

3.3.8 COOLING

Cooling by use of a separate water-cooling system is calculated as:

$$Q_{cool} = m_{cool} * (T_{c.ret} - T_{c.forw}) * c_{p.cool} \quad \text{[kW]}$$

In which:

m_{cool} = flow rate of cooling water or media to incinerator/boiler in kg/s.

$T_{c.ret}$ = the temperature in °C of cooling water flow from the incinerator/boiler.

$T_{c.forw}$ = the temperature in °C of cooling water flow to the incinerator/boiler.

$c_{p.cool}$ = heat capacity of cooling water or media in kJ/kg°C.

Possible other cooling loss shall be considered, e.g. blow down and grate cooling (in the case of a water-cooled grate).

3.3.9 CONDENSATE

The enthalpy content of condensate originating from steam supplied to purposes outside the scope of Works shall be calculated as.

$$Q_c = m_c * h_c(T_c)$$

in which:

m_c = condensate flow in kg/s

h_c = The condensate enthalpy in kJ/kg is a function of temperature.

Enthalpies must be based on a reference temperature of 0 °C and they must be calculated according to reference 1 (see section 6 *References*).

3.4 District heating water

The district heating generation shall be calculated as.

$$Q_{dh} = m_{dh} * (h_{dh.f}(T_{dh.f}) - h_{dh.r}(T_{dh.r}))$$

in which:

m_{dh} = District heating water mass flow rate in kg/s

$h_{dh.f}$ = The district heating water enthalpy (forward) in kJ/kg is a function of temperature.

$h_{dh.r}$ = The district heating water enthalpy (return) in kJ/kg is a function of temperature.

Enthalpies must be based on a reference temperature of 0 °C and they must be calculated according to reference 1 (see section 6 *References*).

3.5 Procedure for determination of ignition loss and TOC - IBA and boiler ash

Samples of IBA and boiler ash representing the effective duration of each test (refer to section 2.3.1) is analysed as follows

1. Dry matter content determined through heating (approx. 105 °C) and it is reported in % of the weight of the total sample of IBA or boiler ash respectively.

2. The ignition loss is determined by heating the dry sample at 550°C to constant weight (i.e. approximately 2 hours). The result is reported as weight loss in % of the sample weight on dry basis

The results are compared with the guarantee requirements.

The ignition loss of the IBA is used for the determination of the IBA loss, refer to section 3.3.6. The TOC of IBA is determined by the applicable EN-norm, CEN EN 13137:2001 Characterization of waste - Determination of total organic carbon (TOC) in waste, sludges and sediments.

3.6 Determination of the fulfilment of guarantees of air emissions

All emissions to the air are corrected to 11% O_2, dry flue gas.

Continuous measurements
Emissions to the air that are measured continuously are averaged to yield ½-hour average and 24-hour average values.

The guaranteed emissions to the air of each component are fulfilled only if the corrected ½-hour value and the 24-hours average value are no higher than the guaranteed ½-hour and 24-hours average values, respectively.

Spot sampling
If more than one sample is taken during each test period, the result is the average of spot tests taken over the effective duration of each test period. The result is compared with the Guarantee Value of the component in question. Each spot test or the average value must not exceed the guaranteed emission.

The dioxin requirement shall be evaluated using the equivalence factors for dibenzo-p-dioxins and dibenzofurans of reference 2 (see section 6 *References)*. The guarantee requirement is fulfilled only if the calculated toxic equivalent does not exceed the Guarantee Value.

3.7 Consumptions

The procedures for determining the consumptions during the effective duration of the tests shall be agreed prior to the tests.

4. EXECUTION OF TESTS

This description does not apply to the testing of IBA quality, refer to section 2.3.2.

4.1 Activities before testing

The Contractor shall prepare and submit to the Employer for its approval a detailed test plan not later than 3 months prior to the planned date for Trial operation period.

The instrumentation installed on the Line as part of the Contract Object is to be used as far as possible. Any correction needed shall be determined prior to the tests.

The Contractor is responsible for servicing and calibrating the Line instrumentation prior to the performance tests to the extent agreed with the Employer. The Contractor shall also prepare the CMS system for making available all data that is required for the subsequent evaluation of the performance tests.

Prior to testing, the independent testing house, as appointed under section 1.2.1 is responsible for:

- Inspecting the Line for the purpose of clarification of practical issues
- Supply of documentation to the Employer addressing measurements for which no Line instrumentation exists
- Mounting of measurement equipment needed to perform the measurements

4.2 Activities during testing of incinerator/boiler

During the tests of incinerator / boiler (refer to section 2.3), the Contractor is responsible for:

- Ensuring that all data that is needed for the subsequent evaluation of the tests is recorded in the CMS system and submitted in electronic form and/or printed to the agreed extent
- Calculation and presentation on a continuous-basis of the preliminary results for e.g. thermal load, mechanical load, and calorific value

During testing, the independent testing house is responsible for

- Collecting samples, e.g. of IBA and boiler ash
- Ensuring the operational conditions are fulfilled and collection of the Documentation needed regarding operation.
- Performance of measurements and collection of data needed for calculations.

4.2.1 ACTIVITIES AFTER TESTING OF INCINERATOR/BOILER

After testing, the Contractor is responsible for:

- Submitting data collected by the CMS system (electronic and paper prints) to the Employer and independent testing house for use in the evaluation of results and preparation of a test report.

After testing, the independent testing house is responsible for:

- Providing samples of IBA and boiler ash from the Line, weighing and preparing for subsequent analyses, including division of samples and identification.
- Testing and analysis of samples
- Carrying out the necessary calculations according to the procedures in section 3
- Presentation of the results in a report, which includes an evaluation of the fulfilment of guaranteed data and calculation of possible liquidated damages.

4.2.2 ACTIVITIES DURING TESTING OF FGT SYSTEM

During the tests of the flue gas treatment system the Contractor is responsible for:

- Ensuring that all data that is needed for the subsequent evaluation of the tests is recorded in the CMS system and submitted in electronic form and/or printed to the agreed extent.
- Calculation and presentation on a continuous basis of preliminary results e.g. flue gas data and heat generation.

During testing, the independent testing house is responsible for:

- Collecting samples of consumables and residues
- Verification of the fulfilment of the operational conditions and collection of the documentation needed regarding operation
- Performance of measurements and collection of data needed for calculations.

4.2.3 ACTIVITIES AFTER TESTING OF FGT SYSTEM

After testing, the Contractor is responsible for:

- Submitting data collected by the CMS system (electronic and paper prints) to the Employer and Independent testing house for use of the evaluation of results and preparation of a test report.

After testing, the independent testing house is responsible for:

- Providing from the Line samples of consumables and residues.
- Testing and analysis of samples
- Carrying out the necessary calculations according to the procedures in section 3
- Presentation of the results in a report, which includes an evaluation of the fulfilment of Guaranteed Data and calculation of possible liquidated damages.

5. TEST OF CONTINUOUS OPERATIONAL PERIOD

The continuous operation period test starts immediately after a full manual boiler cleaning (not including the first waste fire during commissioning) and ends when, due to boiler fouling, one or more of the following occur:

- 100% thermal load cannot be reached anymore
- The temperature before the convection part exceeds 650 ºC + 25ºC (at the evaporator) (calculated as an average – based on 12 hours value)
- The temperature before the first super heater exceeds 625ºC + 10ºC (calculated as an average – based on 12 hours value)
- The temperature after the boiler is higher than 190ºC (design requirement) (calculated as an average – based on 12 hours value)

Operating time relative to the continuous operation period is the time during which the boiler heating surfaces are in contact with flue gas from either burner operation or waste combustion.

Cleaning measures like rapping of cold boiler and measures that can be taken without entering the boiler are allowed and are not considered as termination of the period between manual boiler cleaning.

It is specifically emphasised that use of explosives in the radiation passes and/or the convection pass and the like shall not be accepted during this test.

If the guaranteed continuous operational period between manual boiler cleaning obtained is less than the value specified in Part II.h *Guarantees*, the Contractor shall carry out the improvements

necessary and document the continuous operational period in a prolonged Guarantee Period of up to a further two years so that the requirement is demonstrated for a continuous period of two years.

6. REFERENCES

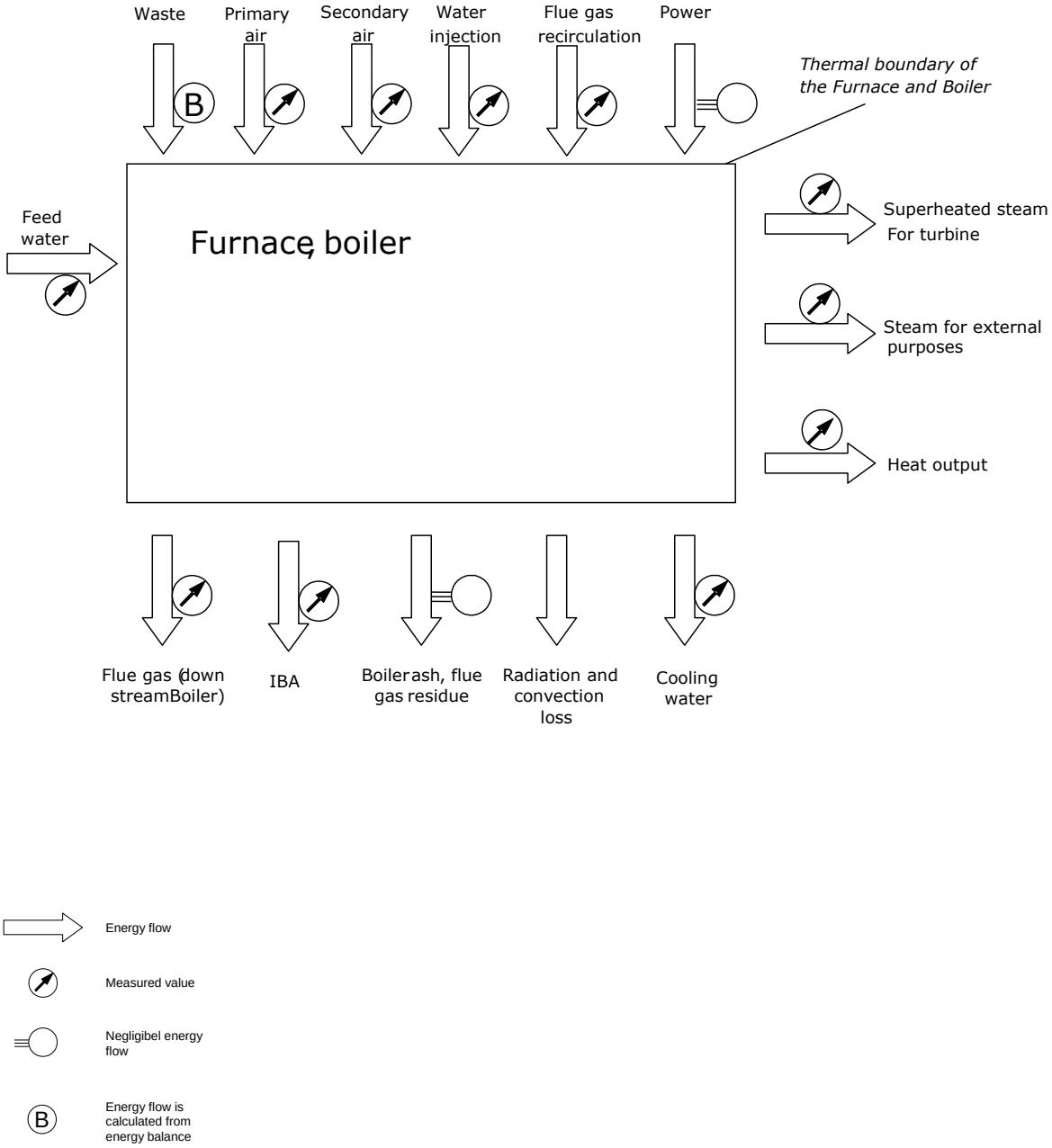
Reference 1:

Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam. The International Association for the Properties of Water and Steam, Revision 2012.

Reference 2:

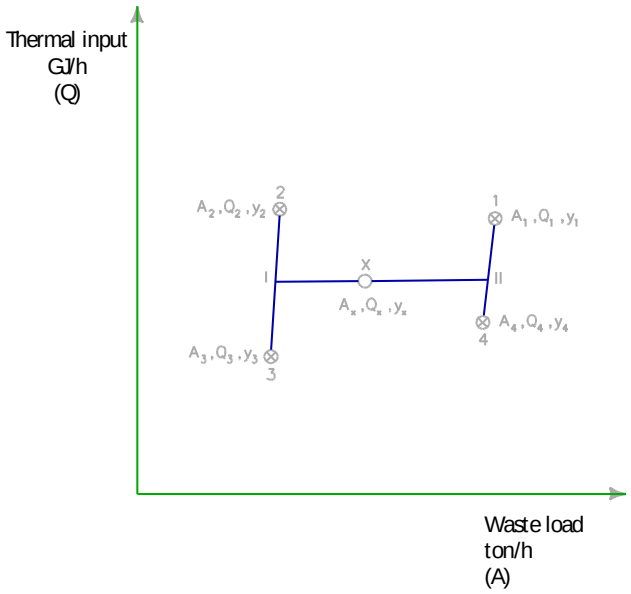
Frederik Neuwahl, Gianluca Cusano, Jorge Gómez Benavides, Simon Holbrook, Serge Roudier; Best Available Techniques (BAT) Reference Document for Waste Incineration; EUR 29971 EN; doi:10.2760/761437

Appendix 1: Mass and Energy Balance of Incinerator/Boiler



Appendix 2: Linear Interpolation

Linear interpolation of variable y (e.g. steam production, thermal efficiency):



The linear interpolation of a point x on the Capacity diagram is performed on the basis of data at the four points (chosen from the points LP1 to LP11 of the Capacity diagram) that forms the smallest possible quadrangle surrounding the point. The principle of selection of points and interpolation is shown in the figure above. No extrapolation may occur. The interpolation is made in two dimensions, starting with interpolation in the ordinate direction followed by interpolation in the direction of the abscissa:

First the auxiliary variables y_I,A_I and y_{II},A_{II} are determined.

$$y_I = \frac{y_2 - y_3}{Q_2 - Q_3}(Q_x - Q_3) + y_3 \;,\; A_I = \frac{A_2 - A_3}{Q_2 - Q_3}(Q_x - Q_3) + A_3$$

$$y_{II} = \frac{y_1 - y_4}{Q_1 - Q_4}(Q_x - Q_4) + y_4 \,, A_{II} = \frac{A_1 - A_4}{Q_1 - Q_4}(Q_x - Q_4) + A_4$$

Then the interpolated variable may be determined as:

$$y_x = \frac{y_{II} - y_I}{A_{II} - A_I}(A_x - A_I) + y_I$$

Appendix 3: Procedure for Taking IBA Samples and Determination of IBA Quality

The characterisation of IBA is performed using one sample representing 8 days of operation. The sample is composed of 48 spot samples (2 samples per shift, 3 shifts per day) each taken immediately downstream of the IBA pusher and each weighing 10 kg. Each spot sample shall be taken so that it represents the actual IBA.

Material larger than 45-50 mm, which may not easily be broken down to smaller pieces, is laid aside and registered. Large material that may easily be broken into smaller pieces is broken down and is combined with the IBA to be characterised. The IBA sample is then reduced in a representative manner to a sample size of approximately 50 kg, and three small samples are extracted for the purpose of determining the water content. The remaining IBA is registered and discarded.

The 50 kg sample is dried at 60°C, and ferromagnetic material and other metals are laid aside and registered. A part of the dried sample is used for the physical tests with no further treatment, whereas further pre-treatment may be required for the chemical analyses and leaching tests, depending on the actual test to be performed.

The samples are analysed according to the methods of TA Siedlungsabfall. The results are compared with the guarantee requirements, including the requirements of TA Siedlungsabfall, Deponieklasse 1.