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Stationary source emissions — Determination of the biogenic fraction in CO_2 in stack gas using the balance method

Émission des sources fixes — Détermination de la fraction biogénique de CO_2 dans les gaz de cheminées en utilisant la méthode des bilans

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions*.

Introduction

During the combustion of solid fuels, O_2 is consumed and CO_2 is simultaneously produced. Biogenic and fossil organic matter do not only show strong differences regarding O_2 consumption and CO_2 production, but also differences in their respective calorific value and carbon content are observable.

The balance method can be used when the elementary composition of moisture and ash free biomass and fossil matter present in the fuel used is known and online stack gas composition measurements (O_2 and CO_2) are available at high accuracy. It will enable online modelling of biomass fossil ratio's in stack gas giving the user the opportunity to control or report that ratio. The generated model data can be verified using the radiocarbon (^{14}C) determined biomass fuel ratio. The results obtained using this document will be complementary to the results obtained with ISO 13833. In ISO 13833, the biogenic fraction in stack gas from plants with unknown fuel composition is determined using the ^{14}C method. If the chemical composition of pure biogenic and fossil matter (contents of C, H, N, S, O referred of moisture and ash free biomass and fossil organic matter, respectively) present in the fuel used is known, the biogenic CO_2 fraction can be calculated utilizing different operating data of the Waste for Energy (WfE) plant. When the chlorine content is sufficiently high, it can be additionally used to optimize the mass balances.

Stationary source emissions — Determination of the biogenic fraction in CO_2 in stack gas using the balance method

1 Scope

This document enables the determination of the biogenic fraction in CO_2 in stack gas using the balance method. The balance method uses a mathematical model that is based on different operating data of the Waste for Energy (WfE) plant (including stack gas composition) and information about the elementary composition of biogenic and fossil matter present in the fuel used.

NOTE Use only mixed fuels when using the calculation method.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12039, *Stationary source emissions — Determination of carbon monoxide, carbon dioxide and oxygen — Performance characteristics and calibration of automated measuring systems*

EN 14181, *Quality assurance of automated measuring systems*

EN 15259, *Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report*

EN 15267-3, *Air quality — Certification of automated measuring systems — Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1
biogenic
produced in natural processes by living organisms but not fossilized or derived from fossil resources

3.2
biomass
material of biological origin excluding material embedded in geological formation or transformed to fossil

3.3
radiocarbon
radioactive isotope of the element carbon, ^{14}C, having 8 neutrons, 6 protons, and 6 electrons

3.4
sample
quantity of material, representative of a larger quantity for which the property is to be determined

3.5
sample preparation
all the actions taken to obtain representative analyses, *samples* (3.4) or *test portions* (3.6) from the original sample

3.6
test portion
quantity of material drawn from the test sample (or from the laboratory sample if both are the same) and on which the test or observation is actually carried out

3.7
balance method
numerical procedure to calculate the fraction of *biogenic* (3.1) matter in waste continuously by solving a set of equations

4 Symbols and abbreviated terms

$C^{(f)}$	organic carbon content of the waste fuel derived from operating data (kg C/kg waste fuel)
ΔH	net enthalpy of steam cycle of the Waste for Energy (WfE) plant (MJ/kg)
J_x	Jacobian matrix of range 6xN, with N representing the number of the measured variables
J_y	Jacobian matrix of range 6xK, with K representing the number of the unknown variables
L_{vap}	evaporation heat (MJ/kg)
w_B, w_F, w_{H_2O}, w_I	mass fractions of moisture and ash free biogenic and fossil matter, water and inert matter (kg/kg waste fuel)
M_C	relative molecular mass of carbon (12,010 7 g/mol)
M_H	relative molecular mass of hydrogen (1,007 94 g/mol)
M_O	relative molecular mass of oxygen (15,999 4 g/mol)
M_N	relative molecular mass of nitrogen (14,006 7 g/mol)
M_S	relative molecular mass of sulfur (32,065 g/mol)
M_{gas}	molecular weight of auxiliary gas fuel (g/mol)
M_{H_2O}	molecular weight of water (g/mol)
$O^{(f)}$	oxygen consumption of the waste fuel derived from operating data (mol O_2/kg waste fuel);
p_v	vapour pressure of the inlet combustion air (Pa);
$\bar{q}_{LHV_w}$	average lower heating value of the waste feed within a defined period Δt (MJ/kg)
$\bar{q}_{LHV_k}$	elemental lower heating value of the combustible fractions (*k* is carbon, hydrogen, oxygen, nitrogen and sulfur) (MJ/kg)
$\bar{q}_{LHV_{gas}}$	average lower heating value of the auxiliary gas fuel ($MJ/m^3_{273,15\ K,\ 1,013\ 25\ bar}$)

$\bar{q}_{LHV_{oil}}$	average lower heating value of the auxiliary oil fuel (MJ/kg)
R_{as}*	specific gas constant for the dry air [287,0558 14 J/(kg K)]
S_{vap}	steam production of the Waste for Energy (WfE) plant within a defined period (kg/Δt)
Δt	defined time period (arbitrary time unit, e.g. days)
T_{air}	temperature of the inlet combustion air (°C);
V_{air}	volume of the inlet combustion air ($m^3{}_{273.15\ K,\ 1.01325\ bar}$);
V_{fg}	dry flue gas volume of the Waste for Energy (WfE) plant within a defined period ($m^3{}_{273,15\ K,\ 1,013\ 25\ bar}/\Delta t$)
V_{gas}	auxiliary gas fuel volume into the Waste for Energy (WfE) plant within a defined period ($m^3{}_{273,15\ K,\ 1,013\ 25\ bar}/\Delta t$)
V_m	molar volume of ideal gas under standard temperature and pressure (22,414 $dm^3{}_{273,15\ K,\ 1,013\ 25\ bar}$/mol)
m_{oil}	mass of auxiliary oil fuel into the Waste for Energy (WfE) plant within a defined period (kg/Δt)
m_{tot}	mass of waste feed into the Waste for Energy (WfE) plant within a defined period (kg/Δt)
W_v	vapour mass in the combustion air
ΣW_S	sum of solid residues (dry substance) of the Waste for Energy (WfE) plant within a defined period (kg/Δt)
c_B^k	elemental concentration of the combustible fractions of the biogenic matter (ash and moisture free; k is carbon, hydrogen, oxygen, nitrogen and sulfur) (kg/kg)
c_F^k	elemental concentration of the combustible fractions of the fossil organic matter (ash and moisture free; k is carbon, hydrogen, oxygen, nitrogen and sulfur) (kg/kg)
c_{gas}^k	elemental concentration of the auxiliary gas fuel (k is carbon, hydrogen, oxygen, nitrogen and sulfur) (kg/kg)
c_{oil}^k	elemental concentration of the auxiliary oil fuel (k is carbon, hydrogen, oxygen, nitrogen and sulfur) (kg/kg)
$x_{O_2,fg}$, $x_{CO_2,fg}$	average O_2 and CO_2 content in the dry flue gas of the Waste for Energy (WfE) plant within a defined period Δt (vol %)
$x_{O_2,air}$, $x_{CO_2,air}$	average O_2 and CO_2 content of dry combustion air of the Waste for Energy (WfE) plant within a defined period Δt (vol %)
x_{H_2O}	average water content in the flue gas of the Waste for Energy (WfE) plant within a defined period Δt (vol %)
$\boldsymbol{x}_S$	vector of N estimated values of the measured variables
$\boldsymbol{y}_S$	vector of the K unknown variables
η	energy efficiency of the steam boiler of the Waste for Energy (WfE) plant

ε	vapour molecular weight/dry air molecular weight (0,621 98)
σ_{B}^{k}	weighted standard deviation for the *k*-th content of the moisture and ash free biogenic matter present in the waste feed (k = C, O, N, H, S)
σ_{F}^{k}	weighted standard deviation for the *k*-th content of the moisture and ash free fossil matter present in the waste feed (k = C, O, N, H, S)
σ_{wk}	standard deviation associated to the mass flow of the k-th type of waste
SRF	solid recovered fuel
WfE	waste for energy plant

5 Requirements

5.1 Input stream parameters

For the application of the balance method, the following input parameters are required:

— mass of waste feed (within a defined period, Δt);

— mass/volume of auxiliary fuels such as fuel oil or gas (within a defined period, Δt);

— elemental composition of the auxiliary fuels (fuel oil or gas) used (for carbon, hydrogen, oxygen, nitrogen and sulfur);

— total mass and elementary composition of fuels that are either composed of biogenic matter or fossil matter only (e.g. sewage sludge, wood waste);

— elemental composition (probable range) of moisture and ash free biogenic and fossil organic matter (with respect to the content of carbon, hydrogen, oxygen, nitrogen and sulfur) present in the waste feed;

— ratio of different waste types present in the waste feed such as municipal solid waste (MSW) or hospital waste (in case that the waste types are characterized by different elemental composition of biogenic and fossil organic matter);

— energy efficiency of the boiler;

— average temperature of feed water for the boiler (within defined period, Δt);

— amount of air used for the combustion (within defined period, Δt), not compulsory.

5.2 Output stream parameters

For the application of the balance method, the following output stream parameters are required:

— CO_2 concentration in dry flue gas (within defined period, Δt);

— O_2 concentration in dry flue gas (within defined period, Δt);

— flue gas flow volume within defined period, Δt (standardized to 273 K and 101,325 kPa);

— moisture content within defined period, Δt;

— temperature in stack at measurement point of flue gas flow, within defined period, Δt (in order to convert flue gas flow to standard temperature of 273 K), not compulsory;

— pressure in stack at measurement point of flue gas flow, within defined period, Δt (in order to convert flue gas flow to standard pressure of 101,325 kPa), not compulsory;

— total dry mass of solid residues (e.g. bottom ash, boiler ash and fly ash) produced within defined period, Δt;

— steam produced within defined period, Δt;

— temperature of steam produced within defined period, Δt;

— pressure of steam produced within defined period, Δt.

6 Sampling

6.1 Sampling of input streams

For determining of the necessary input stream parameters, use the following procedures:

— amount of waste combusted (by crane weight data and the adjustment of this data to the waste amount delivered into the waste bunker within a longer time period);

— amount of auxiliary fuels (by volume flow measurements);

— ratio of different waste types present in the waste feed [data provided by trucks delivering waste to the Waste for Energy (WfE) plant];

— elemental composition of biogenic and fossil organic matter present in the waste feed (either reference data provided in Annex A).

6.2 Sampling of output streams

For determination of the necessary output streams parameters, use the following procedures:

— amount of flue gas (by volume flow measurements);

— amount of CO_2 and O_2 in the dry flue gas (by concentration);

— amount of residues (all kind of ashes, by content);

— amount of steam (by content).

7 Test methods

7.1 General

In this subclause, methods are described which define how data shall be generated and collected when they exist. However, more data might be needed than what appears below which is mainly due to lack of relevant method descriptions and standards for data generation and collection.

For all data not covered specifically below, it is expected that these will be generated and collected according to established industry standards and an acceptable level of accuracy. This shall be documented.

7.2 Process input

7.2.1 Amount of fuel that is combusted

The amount of fuel that is combusted is continuously determined by the crane weight which is calibrated according to internal procedures. More precise results might be produced using the weighbridge data for a period (e.g. yearly) and this is calibrated using relevant CEN and ISO standards, e.g. EN 45501.

7.2.2 Amount of combustion air

The amount of air used for combustion is determined using a calculation including the measured flue gas flow and the combustion products (this is more precise than the regular measurement data available). For an average combustion air temperature (15 °C) and average relative humidity (70 %), the relationship between combustion air and flue gas flow is the following: Wet combustion air flow = 1,035 times the dry flue gas flow.

7.2.3 Auxiliary fuel or oxygen enrichment

Metering of auxiliary fuel or oxygen enrichment shall be in accordance with industry best practice and undergo regular maintenance and periodic calibration.

7.3 Process output

7.3.1 Stack emissions

The quality of all air emissions shall follow EN 14181 or similar national or industry equivalents (needs documentation and evaluation of differences).

Determine the concentration of water, CO_2, CO and O_2 in the stack gas using ISO 12039.

Determine the stack gas flow using EN 15259 and EN 15267-3 or similar national or industry equivalents (needs documentation and evaluation of differences).

7.3.2 Energy production

Metering of steam and feed-water shall be in accordance with industry best practice and undergo regular maintenance and periodic calibration.

The energy efficiency of the boiler is typically only measured at the guarantee test of the facility. This value can be used if no other and more recent value is available and if the following is ensured: a) the boiler is well maintained, b) the boiler is cleaned according to industry practice, and c) the boiler design is unchanged. If a measurement is not available, a total energy balance including all energy losses and a detailed flue gas loss calculation can be used to establish a boiler efficiency. The value used shall always be documented together with its source.

7.3.3 Solid outputs

The production of bottom ash and fly ash is to be measured periodically and documented. The method of measurement shall be in accordance with industry best practice or follow a relevant standard if available.

8 Balance calculation

8.1 General

The balance calculation is a method to calculate the fraction of biogenic matter in waste continuously by solving a set of formulae. All data required are either available from literature or from operating data routinely measured (see 5.1 and 5.2).

When hydrogen is used as auxiliary fuel, special care should be taken regarding the use of the different balance formulae.

The balance method is based on five mass balances and one energy balance. If combustion air data are available, an additional water balance formula can be included. The result of each balance, which describes a certain waste characteristic (e.g. content of organic carbon, heating value), are attuned to physical or chemical waste characteristics derived from routinely measured operating data. In order to

