Accurate, Real-Time Multi Component Monitoring of Incineration and Co-Incineration Emissions Using Fourier Transform Infrared (FTIR)-Based Continuous Emission Monitoring System (CEMS)

An incineration plant is any stationary or mobile technical unit and equipment dedicated to the thermal treatment of wastes with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes such as pyrolysis, gasification or plasma processes. A co-incineration plant is any stationary or mobile unit, which aims at generating energy or producing material products. It uses wastes as a regular or additional fuel and treats waste thermally for the purpose of disposal.

Incineration and co-incineration processes generate emissions, which may have negative health effects on plant workers, the nearby population while also polluting the environment when present in the air in certain concentrations. Not all types of waste generate the same type of emissions. There have been noted differences when burning municipal, industrial, clinical or hazardous waste, depending on the different chemical composition or the physical form of waste. Emissions are also dependant on the conditions in the burning process.

This article will review the regulations that have been imposed on incineration and co-incineration plants to monitor emissions, it will provide an overview of the market in Europe and it will demonstrate the capabilities of FTIR as a competent method for multi-component gas analysis at waste incineration and co-incineration applications. The article will conclude by presenting one such system and its capabilities, the *i*MEGA-FT Multi-Gas Continuous Emission Monitoring System (CEMS) from Thermo Fisher Scientific.

Regulations

The European Union (EU) introduced Directive 2000/76/CE to prevent or limit the negative effects on the environment of emissions into air, soil, surface water and groundwater generated from incineration and co-incineration plants. The Directive mandates that such facilities must be designed, equipped, built and operated in a way that specific emission limit values are not exceeded in the exhaust gas. If in a co-incineration plant more than 40% of the resulting heat release comes from hazardous waste, the emission limit values set out in the Directive shall apply.

Measurement equipment must be installed and techniques used to monitor the parameters, conditions and mass concentrations relevant to the incineration or co-incineration process. The appropriate installation and the functioning of the monitoring equipment are subject to control and an Annual Surveillance Test (AST). Calibration has to be performed by means of parallel measurements with the reference methods at least every three years.

The European Standard EN14181 specifies procedures for establishing Quality Assurance Levels (QAL) for Automated Measuring Systems (AMS) or CEMS installed on industrial plants for the determination of flue gas components and parameters. Three different QALs are defined to cover the suitability of AMS or (CEMS) for their measuring tasks, their validation following installation and their ongoing operation. The QAL maintain and demonstrate the required quality of the measurement results by checking that the zero and span characteristics are consistent with those determined in the standard. An Annual Surveillance Test (AST) is also defined. The maximum maintenance interval for a three-month field test is four weeks and for a six-month field test is three months (EN 15267-3:2007).

Compound		ppm → mg/m³	Minimum measuring range		Required MDL = 2% of range (1σ) (EN15267-3:2007)	
			[mg/m³]	[ppm]	[mg/m³]	[ppm]
Carbon monoxide	CO	1.249	0 - 75	0 – 60.0	1.5	1.2
Nitric oxide (gas turbine)	NO	1.338	0 - 200 0 - 70	0 – 149.4 0 – 52.3	1.4	1.05
Sulphur dioxide	SO_2	2.854	0 - 75	0 – 26.3	1.5	0.53
Hydrogen chloride	HCl	1.628	0 - 15	0 – 9.2	0.30	0.18
Ammonia	NH_3	0.758	0 - 5	0 – 6.6	0.10	0.13
Water	H_2O	-	0 - 30 vol%	0 - 30 vol%	0.6 vol%	0.6 vol%
Nitrogen dioxide	NO_2	2.052	0 - 50	0 – 24.4	1.0	0.49
Nitrous oxide	N_2O	1.962	0 - 100	0 – 50.9	2.0	1.02
Hydrogen fluoride	HF	0.892	0 - 10	0 – 11.2	0.20	0.22
Carbon dioxide	CO_2	-	0 - 30 vol%	0 - 30 vol%	0.6 vol%	0.6 vol%

Table 1. Measuring Components with minimum measuring range and required Minimum Detection Limit (MDL)

Market Overview

Waste incineration and co-incineration play a crucial role in relieving pressure on landfills and disposing of any waste that cannot be recycled. A further important benefit is that these processes generate energy to feed back into either the plant itself or the local community. Recent market research by Frost and Sullivan published in June 2006 reveals that there are over 400 waste-to-energy plants in Europe that process approximately 50 million tonnes of municipal solid waste per annum.

The 1999/31/EC Landfill Directive sets detailed targets for the reduction of landfilling of biodegradable waste in EU Member States from 69 million tonnes in 1995 to 37 million tonnes by 2016. As a result, the number of waste-to-energy plants is expected to significantly increase with over 100 plants or lines added by 2012. Future growth opportunities lay particularly in the regions that are less developed in terms of waste-to-energy or have rising quantities of waste with no final destination. These regions include Germany, Iberia, Italy and the UK, whilst retrofit opportunities remain in some of the more mature markets.

Detailed Specifications

Annex III of Directive 2000/76/CE specifies that air pollutants, including nitrogen oxides (NO_x), carbon monoxide (CO), total dust, total organic carbon (TOC), hydrogen chloride (HCl), hydrogen fluoride (HF) and sulphur dioxide (SO_2) must be continuously measured. In addition, incineration and co-incineration plants must perform uninterrupted monitoring of process operation parameters such as temperature near the inner wall or at another representative point of the combustion chamber as authorized by the competent authority, concentration of oxygen, pressure, temperature and water vapor content of the exhaust gas. The residence time as well as the minimum temperature and the oxygen content of the exhaust gases shall be subject to appropriate verification, at least once when the incineration or co-incineration plant is brought into service and under the most unfavorable operating conditions anticipated.

The continuous measurement of HF may be omitted if treatment stages for HCl are used to ensure that the emission limit value for HCl is not being exceeded. In this case, the emissions of HF shall be subject to periodic measurements. The continuous measurement of the water vapor content shall not be required if the sampled exhaust gas is dried before the emissions are analyzed. Periodic measurements of HCl, HF and SO_2 may be authorized in the permit by the competent authority, if the operator can prove that the emissions of those pollutants can under no circumstances be higher than the prescribed emission limit values. Table 1 details the minimum detection limits (MDL) as specified by method EN 15267-3:2007.

Practical Considerations When Monitoring Emissions

There are certain elements that allow for efficient monitoring of emissions[1]. First of all, a representative sample needs to be chosen to ensure dependability of results. A further pre-requisite for the accurate measurement of the different gas components is the correct conditioning of the sample. Given the high water solubility of some compounds in the stack gas, a "Hot/Wet" sampling technique must be used because condensing moisture out of the sample would also remove key pollutants.

There are also a few safety prerequisites relating to access, facilities and services conditions existing during analysis of incineration and co-incineration emissions. These include a safe means of access to, and a safe place of work at the sampling position, a safe means of entry for sampling equipment, sufficient space for the equipment and personnel and essential services, for example, electricity, lighting and water.

FTIR Spectrometry – A Powerful Method

During recent years, FTIR-based CEMS have emerged as the prefered solution for multi-component gas analysis at waste incineration and co-incineration applications. FTIR is a particularly powerful method offering extensive benefits for these types of analyses. High-speed data acquisition at high spectral resolution allows for real-time gas analysis. This combination of speed and performance provides a system capable of collecting data at 1 scan per every 4 seconds at 0.5 cm-1 resolution, ideal for detailed analysis of rapidly changing complex gas mixtures.

Featuring a dynamically aligned interferometer, with pinned-in-place, pre-aligned components, The *i*MEGA-FT system ensures permanent optic alignment. With no instrumental variation introduced into spectral collection or calibrations, method transferability is ensured. In addition, method maintenance is virtually eliminated allowing uninterrupted operation and analysis. Competent analyzers utilize a helium neon (He-Ne) laser, equipped with a neutral-density filter to help reduce power and reflections.

The aperture of FTIR analyzers is a variable-diameter opening that optimizes spectral line shape (resolution) by defining the number and direction of the infrared rays reaching the sample. Using an aperture provides significant advantages. It improves wave number accuracy by acting as a point source of infrared radiation, and helps prevent infrared energy saturation, resulting into a more linear response of the detector.

Further components of FTIR spectrometers are the attenuator filters, which are used to reduce the amount of energy reaching the detector, as needed, during data collection. A temperature controller also ensures that the gas cell is not heated too quickly or to higher temperatures than those required for the specific analysis.

*i*MEGA FTIR

The *i*MEGA-FT Multi-Gas CEMS (Thermo Fisher Scientific), is capable of measuring up to ten gases simultaneously for almost any combustion, incineration or co-incineration application, resulting in a substantially reduced cost of ownership. This single-system, multi-gas analyzer employs the most widely used, field-proven FTIR technology in the world, achieving real-time monitoring and unsurpassed sensitivity, specificity and dynamic range for even the most complex stack gas monitoring applications. The ability to measure up to ten compounds with one technology, eliminates the need for multiple, individual, gas analyzer units, thereby reducing system cost.

The *i*MEGA-FT analyzer measures an extensive range of compounds, including carbon monoxide, nitric oxide, sulphur dioxide, hydrogen chloride, ammonia, water, nitrogen dioxide, nitrous oxide, hydrogen fluoride and carbon dioxide. The system can be also fitted with a Flame Ionization Detector (FID) for monitoring total gaseous organic carbon and an oxygen monitoring detector. A powerful optical system designed for a three month cycle of unattended operation, the longest available in the market. In addition, a dynamically aligned interferometer with pinned-in-place, pre-aligned components virtually eliminates method maintenance for uninterrupted operation and analysis.

Easy to operate, the *i*MEGA-FT features a graphic user interface (GUI) incorporating fast and simple programming even for those with little or no experience. All components are designed for on-site serviceability which are easily accessible for quick maintenance. In addition, the worldwide Thermo Scientific Air Quality customer service and technical suppport is available to provide assistance in pre-installation, installation and post-installation support.

Conclusion

Incineration and co-incineration of waste are popular methods of reducing landfilling and its negative effects. However, these processes may generate excessive concentrations of hazardous emissions, affecting both human health and the environment. As a consequence, strict regulations have been introduced that pose considerable pressure on incineration and co-incineration plants to keep their emissions down to specified levels. In order to adhere to these requirements, such facilities require a powerful, cost-effective, easy to use and maintain system capable of performing accurate, real-time multi-component gas analysis. Offering high-speed data acquisition at high spectral resolution for real-time multi-component gas analysis, an FTIR-based CEMS is the method of choice.

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