FTIR (Fourier Transform Infrared) technology has the capability to measure more than 100 of the 189 Hazardous Air Pollutants (HAPs) listed in Title III of the Clean Air Act Amendments (USA) of 1990. In fact, when these Amendments were passed, existing measurement methods could only measure 40 of these HAPs.

In 1956, scientists from the United States Geological Survey (USGS) mounted a FTIR spectroscope on a plane to measure gases being discharged from the caldera of one of the most active volcanoes on earth – Kilauea in Hawaii.
force, ambient air quality has markedly improved in most Western countries. However, the “Global Burden of Disease” program of the World Health Organization (WHO) estimates that worldwide, 6.4 million lives are lost every year from long-term exposure to Ambient Particulate Matter (APM). Thus, environmental regulations continue to tighten.

Stricter environmental regulations and advanced technologies ensure that the emissions of harmful substances from domestic waste, hazardous waste and sewage sludge incinerators, cement plants and power stations continue to decrease. As the concentrations of harmful substances in waste gases fall, the demands on the measuring technology rise.

In addition to this, demand on the stability of an instrument over its entire operating lifetime increases at the same time as maintenance costs are being minimized. The ABB multi-component measuring system ACF-NT is an example of how innovative technologies enable the safe and stable measurement of gas concentrations in the parts per million (ppm) range.

The imperatives of Automated Measuring Systems (AMS) for continuous emission measurement

Legal provisions for the limitation of emissions have a long tradition in Germany whose standards have been setting the trend in Europe since the ‘80ies. Operators of refuse incineration and processes with co-incineration are presently preparing for the implementation of new directives in Europe.

With the introduction of EU Directives 2001/80/EC and 2000/76/EC, emission monitoring is subject to EN 14181, “Stationary source emissions – Quality assurance of automated measuring systems”. This was promulgated in September 2004. Compliance with the EN 14181 standard is a legal requirement under both the Large Combustion Plant Directive (LCPD) and the Waste Incineration Directive (WID). All vendor-supplied equipment must be EN 14181-compliant.

The quality assurance levels QAL1/2/3 were introduced to ensure this compliance. Quality level QAL3 obliges the operator to carry out regular checks for precision and drift at the zero and end-point of his analyzer measuring range. These checks are typically carried out during the maintenance interval. Longer intervals between routine maintenance minimize costs.

ACF-NT capabilities for reducing downtime and hence, cost of operation

The range of application of the ACF-NT measuring system, which is based on the FTPA 2000 FTIR spectrometer, includes complex applications for emission monitoring in domestic waste, hazardous waste and sewage sludge incinerators, and in cement plants and power stations with co-combustion. These are pursuant to European Directive 2000/76/EC, and incorporate its quality demands pursuant to EN 14181. The loss-free measurement of the lowest concentrations of water-soluble components is achieved by seamless heating of the system to 180 °C – from the probe element to the analyzer.

Seeing inside air with infrared interferometry

All molecules in the air – including pollutants – leave a “fingerprint” in the infrared by absorbing certain frequencies. The resulting infrared spectrum not only permits the molecules to be identified, but also permits their concentrations and temperatures to be evaluated. Fourier Transform Infrared (FTIR) Spectroscopy is a measurement technique that extracts this spectrum from incoming infrared light.

FTIR combines the Fast Fourier Transform (FFT) with the Michelson interferometer. The physicist, Albert A. Michelson, performed several experiments to measure the speed of light. He developed an interferometer in 1881, with which together with E.W. Morley in 1887, he showed that the speed of light is independent of the movement of the reference system (The Michelson-Morley experiment is often quoted in conjunction with Einstein’s Special Relativity Theory). It is a development of this device that is used in FTIR today1. The FFT is a mathematical operation performed on the signal obtained by the interferometer (the interferogram) to extract the infrared (IR) spectrum2.

Footnotes
1) For an explanation of the interferometer, see textbox “Principle of the interferometer” on page 53
2) For more background on Fourier Transform spectroscopy see the textbox “From waves to data: a quick guide to Fourier Transform spectroscopy” on page 60.
A low-maintenance electronically controlled air injector system conveys the sample gas from the chimney stack to the analyzers at constant pressure. In order to avoid pressure dependencies, which could arise if an uncontrolled feed pump were used, no moving parts are employed.

The spectrometer measures gaseous pollutants such as HCl, CO, NO and SO2 as well as NH3, H2O, CO2, HF, N2O and NO2. Measurements at very high moisture content are possible using a chemometric model optimized for refuse incineration processes. For measurements of O2 a zirconia sensor and organic Cx with a Flame Ionised Detector (FID) are optionally integrated in the system and are supplied with sample gas from the same sampling system.

In addition to the use of conventional analog and digital interfaces, a modern interface concept offers the possibility of serial transmission of data. This can be effected by Modbus or PROFIBUS, for instance, for a simplified connection to an emission analysis computer or control system. Data can also be transmitted via standard Ethernet – familiar from office technology – and remote maintenance can be carried out via a telephone modem connection, in order to minimize maintenance costs.

The long intervals between maintenance and the resultant low operating costs are a particular advantage of the ACF-NT. Significant costs are incurred for adjustment during the maintenance interval, especially in multi-component measuring systems. The operating costs are estimated to be approximately 70 percent of the life-cycle costs of an analyzer system. In particular, checking water-soluble sample components such as HCl, NH3 or HF means an increased outlay for the provision of a calibration gas generator for the test equipment. Typically the time taken for complete adjustment of a measuring system with up to 12 sample components is approximately eight hours.

**FTIR measurement technique with emphasis on optimum signal processing and stability**

FTIR spectrometry is a full-spectrum method. This means that absorption processes in a wide spectral range are used for analysis of the substances and not just narrow wavelength ranges, as is the case for interference filter, gas filter correlation or dispersive photometry.

In the Michelson interferometer in the FTIR instrument, each individual wavelength is modulated in extremely small sections, corresponding to the resolution of the instrument by means of interference. The modulated infrared radiation, as a sum of all the modulated (encoded) wavelengths, known as an interferogram, undergoes selective changes in the intensity distribution during interaction with the material, as it passes through the measuring cell filled with gas. The complete IR spectrum is calculated from the interferogram by means of a Fast Fourier Transformation. All the individual selective changes in intensity, based
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on emission absorption in the sample, can be qualitatively and quantitatively evaluated as a result.

The processing of a raw spectrum to an absorption (extinction) spectrum is shown in [2].

Theory put to the test

The applied theoretical stability considerations are confirmed by the experience gained from more than 600 systems that have been installed throughout the world since 1993. It has emerged from scheduled tests with test gases in the maintenance interval that the ACF-NT permits adjustment intervals of over a year. All the deviations identified so far can be attributed to incorrect handling in the test, incorrect adjustment, or the use of test gases of incorrect concentrations.

ABB’s own experience concerning the stability of the FTIR spectrometer is borne out by two independent long-term studies carried out by the German Technical Inspection Authorities (TÜV) of the Rhineland region. The latter study tested the predecessor of the current ACF-NT for the first time in 1995, and the current ACF-NT system in 2004–5. Two systems were tested in parallel in each of the field tests. The first long-term study ran for six months, the second for 12 months. Both field tests met the respective requirements with regard to stability and availability.

The results of a test on two lines of the refuse incineration plant — which ran for a year, taking the components NH₃ and SO₂ as example — further validate the findings on stability [3]. The endpoints of all sample components tested by the TÜV (CO, NO, SO₂, HCl, NH₃, H₂O) were validated at monthly intervals. The deviations of all components were always within permissible limits.

The statistical scattering of the data for ammonia [3b] clearly shows the problematic nature of this gas (the same as for HCl and HF). As a result of adsorption and desorption processes on the gas-bearing surfaces, a lengthy waiting period is required till equilibrium is reached. This clearly shows that special care is called for in the adjustment and validation of these components.

Field test results for two lines of a refuse incineration plant

The new European Standard EN 14181 defines the maintenance interval as the maximum permissible period within which compliance with the stated values of the process variables is guaranteed, without external maintenance requirement, eg, refilling, calibration or adjustment. According to this definition, a maintenance interval of 12 months results for the current ACF-NT on the basis of the field test of 2004–5, ie ACF-NT is a measuring system with proven stability in field tests of one year. Tests with test gases only have to be carried out once a year.

Remote maintenance with the AnalyzeIT Explorer

The AnalyzeIT Explorer can be used in Ethernet TCP/IP networks to display all available data in a suitable manner and make it available for remote maintenance. The extent of servicing work can, therefore, be reduced, and reliability increased by means of “look-ahead” maintenance. This results in increased system availability through rapid troubleshooting and reduced cost through planned, predictive maintenance.

Operational stress can accelerate deterioration of equipment in a corrosive environment and move both equipment and processes to the brink of failure. Limiting stresses within the operating environment maintains reliability. Hence, predictive maintenance is a crucial feature for leading environmental monitoring instruments for air quality and industrial emissions.

The ACF-NT is a leading environmental monitoring system. It is proven to be safe, stable, industry-compliant and capable of detecting gases in the lowest ppm concentrations.

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