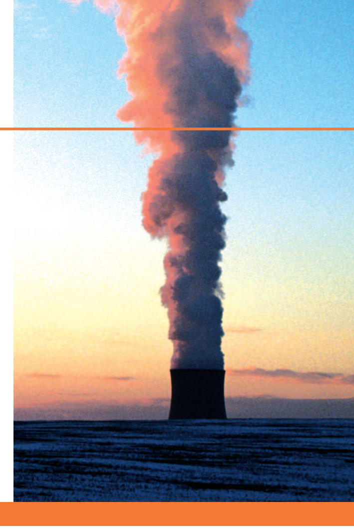

Stack Testers
DO IT IN REAL TIME!

AIR Monitoring

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Stack particulate testing has always been a challenging occupation and life is about to get even more interesting with EN14181 on the horizon. The current reference methods rely on extractive sampling onto a filter which is then transported to a laboratory for weighing on a balance and if all goes to plan you get the result a week or so after the test and in the intervening time, hope and pray you passed.
In a way it's a little like old fashioned photography. Remember the days when you had to put film in a camera, take a few shots, send them away for developing only to find out, a couple of weeks later that they didn't turn out and you had lost the lot? Nowadays we have digital cameras that not only give instant results but can deliver high quality movies in real time all on something the size of a "box brownie" Current stack testing methods are a bit like film based photography, one exposes a filter to the stack sample which then goes off for weighing and after some considerable time you get the results back, if your lucky! The introduction of a new type of stack particulate monitor promises to do for stack testing what the digital camera did for photography, as it provides instant results, provides a "moving picture" of the PM concentration and gives assurance that the test is progressing to plan.

The TEOM-SPM (Source Particulate Monitor) operates on the same basis as the reference methods. It samples and weighs the particulate matter on a filter. The difference is it does all this inside the stack, with better precision, in real time and provides results as you go. Too good to be true? The US EPA don't think so, they have recently designated the new method approved the new method as an alternative to the reference method and in Europe tests carried out by the German TUV show that the system is able to match the accuracy of the European reference methods and in most cases provide better precision and lower detection limits.

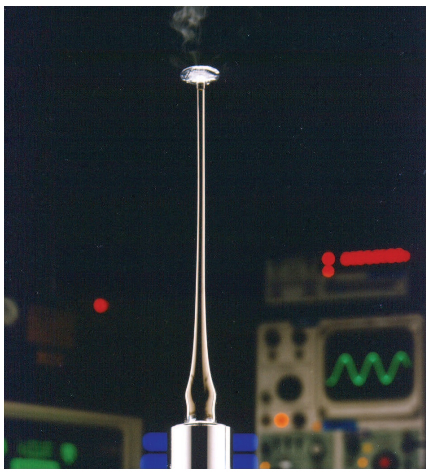
With the strict quality assurance requirements of EN14181 coming into force later this year it will be very difficult to meet the requirements for PM using conventional sampling technology, even with the most skilled of stack testing personnel. Imagine the horror of conducting a three day long QAL2 test, with all the associated costs, such as the stack testing team, plant disruption, special running conditions, etc. only to find after the tests were concluded that the results did not meet requirements and have to be repeated possibly at even greater cost! Would it not be a great advantage to be able to see what the results are as they develop, to be sure that you are "in spec" as the test progresses and be able to take corrective action to ensure that the test is successful in every sense? The following article describes in detail how the TEOM - SPM is able to achieve this.

Overview

The measurement of particulate matter (PM) emissions from stationary sources has historically been accomplished in the United Kingdom & Europe using methods such as BS-EN13284-1, BS-6069 or ISO-9096 or in the U.S. using similar methodology such as USEPA Methods 5 or 17. These methods are labour intensive, subject to uncertainty from filter handling, transport, conditioning and weighing and cannot provide quick turnaround of results. Using TEOM technology, R&P has developed the Series 7000 Source Particulate Monitor (TEOM-SPM) which provides high resolution, direct mass measurement in real-time. For the first time, the monitor integrates methodology, hardware and software allowing reports to be generated on-site during and immediately following testing. In light of the new EU standard, EN-14181, governing the quality assurance requirements for automated emissions measuring systems (AMS), the TEOM-SPM's capabilities promise significant advantages over manual test methods when certifying or auditing PM - AMS. (Automated Monitoring Systems)

Stack testing with the TEOM-SPM

The TEOM-SPM Inlet with Pitot tube



The TEOM Mass Transducer

Principle of Operation

The Series 7000 allows sample collection inside a stack or duct through a filter while automatically maintaining iso-kinetic sampling conditions. The filter is affixed to one end of the mass transducer thereby allowing the collected particles to be weighed continuously resulting in a real-time measurement of the particle mass concentration.

The TEOM mass transducer uses a short, straight inlet nozzle tube to isokinetically sample the flue gas and transports it just a few millimetres to the filter. The mass transducer is a hollow tube, clamped on one end and free to vibrate at the other. An exchangeable filter cartridge is place over the tip of the free end. This "tapered element" vibrates precisely at its natural resonant frequency. A precise electronic counter measures the frequency that has a direct relationship with mass. The relationship, expressed below, between mass and frequency can be derived from the simple harmonic oscillator equation.

$f^2 = K0 / m$ (1)

where f = frequency of oscillation
K0 = calibration constant
m = mass

The calibration constant of the tapered element can be established by measuring the frequency of the tapered element with a filter of known mass installed and without a filter. Applying the relationship described by equation 1, the value of K0 can be calculated as shown below:

$K0 = (m2 - m1) / (1/f2^2 - 1/f1^2)$ (2)

The tapered element system is constructed using non-fatiguing inert material and since K0 is a function of the (non-changing) physical characteristics of the tapered element system, the tapered element retains its calibration indefinitely.

Once K0 has been determined for a particular tapered element, it can be used for mass measurements. If the element is oscillating at the frequency of f_a and has a frequency response of f_b after an unknown mass is collected on the filter ($\Delta m'$), $\Delta m'$ can be obtained as a function of f_a, f_b and K_o using the following equation:

$\Delta m' = K_o\ (1/f_b^2 - 1/f_a^2)$ (3)

The TEOM-SPM Sensor in open position showing filter

Tracking frequency with time provides the mass rate. When the mass rate is combined with the sample flow rate through the filter, mass concentration of the sampled gases can be directly calculated and in real-time.

During normal operation, the temperature of the mass transducer is maintained a few degrees above the stack temperature to provide the frequency stability necessary for measurement of very small mass changes with high temporal resolution.

To automatically control iso-kinetic sampling rates, the system incorporates measurement of source gas velocity, temperature and gas density / molecular weight. Velocity is measured with a "S" type Pitot tube assembly while the gas temperature is measured with a "K" type thermocouple. The gas density / molecular weight determination is provided by measuring carbon dioxide with a non-dispersive, infrared monitor, oxygen with a paramagnetic monitor and moisture using a differential flow technique patented by R&P. All of these parameters are measured in real-time and input into the system's onboard computer to automatically perform the necessary calculations to determine iso-kinetic sampling rates. This information is then used to set and control the sampling rate using a measurement-control feedback loop.

Compliance Testing

The traverse sampling mode allows the instrument to be used to more accurately characterize actual emissions from the stationary source by taking samples from several discrete sample points in the process exhaust duct or stack in a manner similar to manual reference methods. An example of this mode is as follows.

The instrument is configured to provide a two minute average concentration. The operator inserts the probe and positions the mass transducer at the first sampling location. The instrument then enters the initial filter desiccation/stabilisation period during which the instrument purges the filter with clean dry air. After the filter mass stabilizes, the filter mass is tared (zeroed) and sampling is initiated. After at least two minutes of sampling elapses, the monitor suspends data collection, prompts the operator to move the probe to the next sampling location, after which the operator prompts the monitor to resume sample measurements. Sampling at each traverse point continues in this manner until all desired sampling points on all traverse lines have been tested. The TEOM SPM then reverts to purging the filter and undergoes the final desiccation process to dry the filter and any collected particulate matter. The sample probe is then withdrawn from the stack and the mass reading is allowed to re-stabilise. Once the mass sensor has re-stabilised, the inlet recovery procedure is performed to capture any particulate matter that may have been retained in the inlet during sampling. Particulate matter mass measured as the result of the inlet "brushdown" procedure is added to the dry mass collected during sample collection to compute the final, average mass concentration representing the entire test period.

As indicated previously, in conducting compliance tests, the TEOM SPM method affords several significant advantages over manual methods. By virtue of its inherently more precise methodology due to limitation of operator influenced parameters on test procedures, elimination of sample transport, handling and lab analysis requirements, the probability of obtaining acceptable test results is higher than with the manual methods.

A representative example of typical test results is shown in Figure 1 to illustrate the difference in precision between the TEOM SPM and a manual reference method.

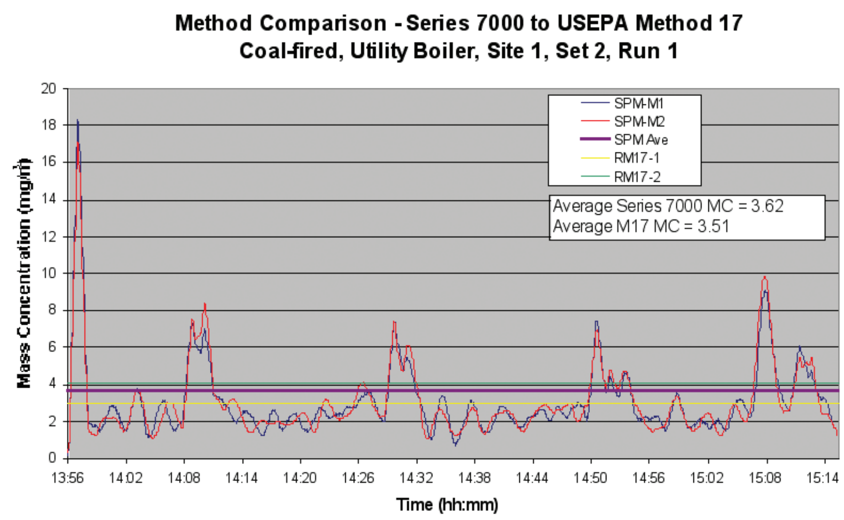


Figure 1 - Method Precision

The figure shows the test average mass concentration for each of the reference method systems plotted with the two minute average data reported by the TEOM SPM. The probes of all four sampling trains were placed in close proximity to one another but with sufficient spacing to prevent cross-interference. All systems were operated for the same length of time and in accordance with each method's standard operating procedures. Note that agreement of the two minute average data reported by the TEOM SPM is higher than the run averages reported by the manual method trains.

Secondly, when using the manual methods, final results are often not available for several weeks. In the event that results prove unacceptable, expensive, time-consuming retests may have to be performed which will require the plant to again stop normal operations and set up for the retests. With the TEOM SPM, immediate feedback during the test and fully qualified results following the completion of testing are available onsite thereby allowing the compliance status to be determined while the test team is still at the plant. If results show compliance with emissions standards, plant operators can be assured that retesting several weeks in the future will not be required. If results show the emissions unit to be operating outside of performance specifications, it may be possible to take immediate action to restore the unit to compliance followed closely by confirmatory testing to demonstrate that the unit is not operating within compliance limits.

Calibration of PM AMS

Another application of the Series 7000 monitor relates to the implementation and operation of PM continuous emissions monitoring programs. All continuous monitors presently available employ measurement technologies such as opacity, tribo-electric, acoustic and beta attenuation that, unlike the TEOM system, do not possess a direct relationship with particulate mass. These methods only infer PM mass thereby requiring the development of factors correlating AMS measurement output to actual mass measurement. Therefore, the automated continuous measurement systems must be correlated to mass measurements made with direct measuring techniques such as the gravimetric, manual methods or the TEOM SPM method. Accordingly, directives now being implemented, such as BS-EN14181 in the UK and Europe or PS-11 in the US, procedures and specifications are included for developing correlation factors and subsequent periodic factor verification.

The TEOM SPM can be employed to satisfy both initial and periodic correlation requirements such as those described in EN -14181 under QAL2 and QAL3. QAL2 governs the quality assurance of AMS installation and includes performance tests, functionality checks and a comparison of the AMS measurements against a qualified reference method. This includes at least 15 repetitions of the reference method to develop the correlation between the AMS output and the actual source mass concentration. Although the application of QAL2 statistical techniques are designed to qualify the performance of the AMS, in actuality, the requirements inherently demand high quality, repeatable performance from the reference method. Given the significantly improved repeatability of the Series 7000 method due to the elimination of filter handling and transport along with greatly reduced operator influence on test operations, the probability of an AMS meeting the requirements is greatly improved by the reduced uncertainty inherent in the TEOM SPM method. Again, as with the system's use in a compliance test, results will be available immediately upon completion of a test allowing the test and plant operators to build the AMS correlation function as testing progresses. Very quickly following the end of the initial 15 test runs, a complete calibration function can be computed and assessed against EN 14181's uncertainty requirements. If the AMS correlation tests meet the requirements, no further testing will be required and the plant can resume normal operations. The uncertainty in the test outcome is eliminated since the plant will not have to wait days or weeks for sample analysis. Furthermore, with the Series 7000 method, if test results indicate further correlation tests

Large Power and Incineration Plants will benefit from TEOM-SPM

are required, the plant and testers can resume testing immediately rather than having to make a second mobilisation for a return visit, with coincident impact on plant operations at some later date. Overall efficiency of the complex test program required by EN-14181 is thereby significantly enhanced.

QAL3 and the AST (Annual Surveillance Test) are less rigorous than QAL2 procedures that require to be carried out on as an ongoing check of calibration of AMS's and as with QAL2, reference method data quality is very important for a successful outcome. Once again, the improved precision that can be achieved with the TEOM SPM can reduce the risk of obtaining unacceptable results while providing more timely results and potentially lowers the impact on plant operations.

The TEOM SPM can also be very useful during for initial positioning of continuous monitors. For example, a traverse test can be conducted at the proposed monitor location. Because the monitor provides a real-time data output, PM concentration at each traverse test point is available and combined with test data for all of the traverse points, a PM stratification assessment can be easily and rapidly accomplished. Evaluating the stratification results with the average mass concentration measurement determined for the entire test can then be used to install the AMS in representative sampling location.

The instrument can also be configured with size selective inlets using impaction to measure PM10 or PM2.5 rather than total particulate matter.

Conclusion

Anyone who has climbed a stack in in the wintertime when it's either raining or snowing horizontally, or both and it's windy enough to blow your hard hat into the next county will know that getting the best results from a manual sampling system is not easy. The TEOM-SPM promises to change that for the better and although initial costs may be a bit more, it will more than pay for itself over time by eliminating repeat tests, improving the certainty of results and perhaps even making the lot of the stack tester just that little bit more bearable.

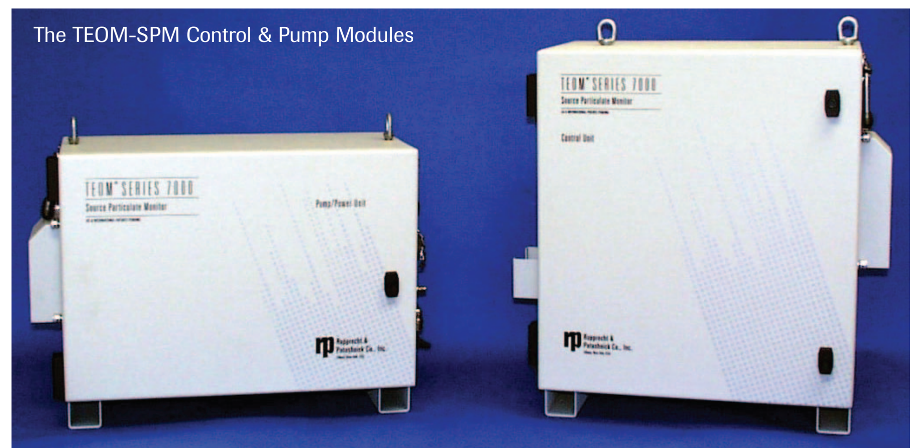
The stack testing equivalent of the digital camera has now arrived, sit back and enjoy the movie!

Summary

The TEOM-SPM offers significant advantages over the traditional, manually operated reference methods including;

* Reduced measurement uncertainty through minimized operator involvement in the test method,
* Substantial gains in measurement information, such as PM stratification in the sampling planes or PM emission transients,
* Integrated measurements of gas constituents and integrated quality assurance mechanisms, and
* Onsite availability of test results that can allow test and plant operators to determine acceptability of results at the time of testing.

Additionally, the TEOM-SPM method has undergone extensive method comparison and validation studies against recognised reference methods. The success of the comparisons is evidenced by acceptance as an alternative reference method by the US EPA and via qualification as an equivalent method by TUV Rhineland.



The TEOM-SPM Control & Pump Modules