How difficult can particulate monitoring be?

The European Standard BS EN 13284-1 concerns low-range concentrations of dust from stationary sources, and is based on isokinetic sampling. One of the key components of this is the sampling nozzle. Four years ago the STA began three projects looking at their design

BS EN 13284-1 is entitled *Stationary Source Emission – Determination of low range concentration of dust – Part 1 Manual gravimetric method.* It was published in 2002. The scope of the standard states: This European Standard describes a reference method for the measurement of low dust content in ducted gaseous streams in the concentrations below 50mg/m^3 standard conditions. This method has been validated with special emphasis around 5mg/m^3 on an average half-hour sampling time."

This European Standard is primarily developed and validated for gaseous streams emitted by waste incinerators. More generally, it may be applied to gases emitted from stationary sources, and to higher concentrations.

The method is based on isokinetic sampling, which means sampling at a flow rate such that the velocity and direction of the gas entering the sampling nozzle (V_N) are the same as that of the gas in the duct at the sampling point (V'_a) (see Figure 1). The velocity ratio (V_n | V_a) expressed in percentage is an indication of the deviation from isokinetic sampling.

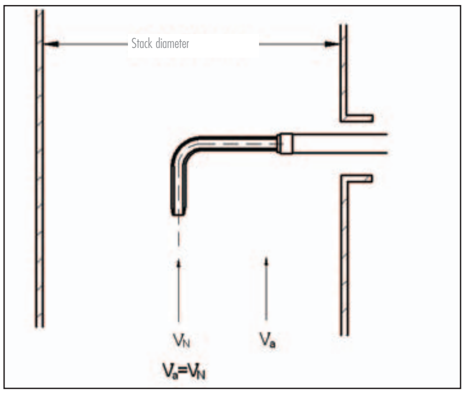

Figure 1: Isokinetic sampling

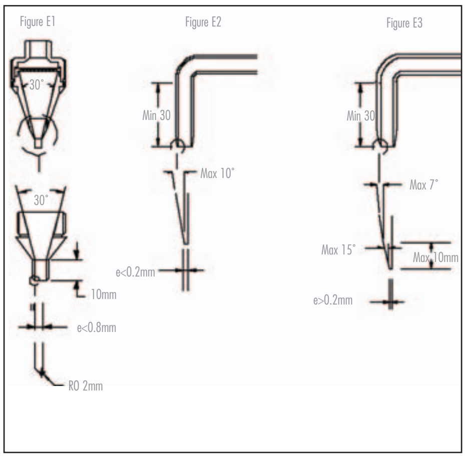

Figure 2: BS EN13284-1 sampling nozzles

One of the key components in the isokinetic sample train is the sampling nozzle and the standard contains three designs of nozzle which are acceptable. (See Figure 2.)

Although these nozzles were made available in the UK, there were existing designs that had been used for many years based on US EPA methods. Alternative nozzles can be used for sampling to the European Standard providing they have been validated against the standard's requirements.

So, four years ago, the STA in collaboration with the National Physical Laboratory (NPL) decided on the first of what became three projects to validate other designs of sampling nozzle.

Project 1

Validation of sampling nozzles

The project was funded under UK government JIP funding and involved NPL, STA and the support of a number of STA member companies – stack testing teams, equipment suppliers, manufacturers and plant operators.

The project was a field-study to compare UK nozzles against validated nozzles. It took place at a cement plant with low dust emissions, circa 2mg/m^3. We should have realised things were not going to go to plan when the first test was cancelled because the plant was struck by lightning.

Finally, four teams monitored the stack (see Figure 3) over a five-day period following prescriptively the procedures laid down in BS EN 13284-1. All the filters used were conditioned and weighed by the same laboratory.

The results from the tests were inconclusive. The results from the field trials raised several issues with one of the major ones being the handling of filters on site. Comparisons of the results were difficult to draw and some of the tests even indicated that filters had lost weight.

The sampling plane at the stack had been well characterised and we were confident that all the teams were measuring the same particulate concentration at the same equal area and that the flow pattern was the same. This suggested that there must have been another factor which influenced these results. We traced back through the procedure and, after discussion with manufacturers of filters, carried out laboratory trials on various filter types.

Around this time, the STA was starting to receive reports from suppliers of continuous particulate monitors that calibrations taking place using BS EN 13284-1 were providing varying calibration functions on the same processes with the same load with no varying emissions.

Was this due to the same phenomenon that we had witnessed on our field trials? Consideration of this and other issues led us into Project 2.

Project 2

Investigation into filter losses

This was a laboratory-based set of tests funded by the Environment Agency with technical support supplied by STA. It was based on a series of comprehensive laboratory tests at NPL to try to understand the issues causing loss of mass on filter media.

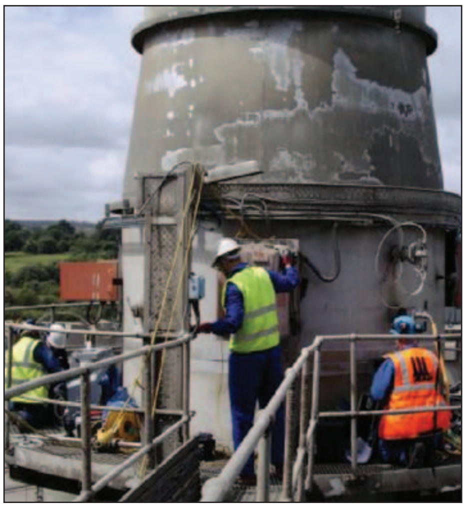

Figure 3: Sampling at the stack on the cement plant

Discussions with filter manufacturers indicated that the manufacturing process could cause filters to contain an amount of loose material on them and therefore they may require conditioning before use. The aims of the project were to:

- Determine the level of filter loss that could occur
- Define, if required, a pre-conditioning phase for the filters.

The filter types tested were two quartz fibre filters and one new-style laser-cut type. Five types of filter holder were used, each with a different design of filter support. The filter manufacturers stated that different supports would influence the results and so another variable factor entered the equation. The test rig used is shown in Figure 4.

The filters were conditioned and weighed in accordance with the requirements laid down in BS EN 13284-1. In addition to investigating the loss of fibres with different holders and filters, the tests also assessed the effect of:

- Continued flow
- Weighing procedure
- Higher flow rate
- Filter handling

Results and findings

Laser cut filters had the largest losses which, we identified, is due to the clamping arrangements of the filter holders. Losses on other filters were measured to

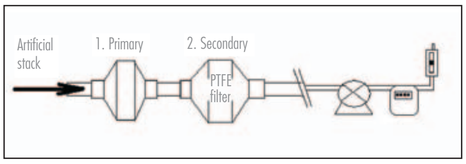

Figure 4: Test rig to determine filter losses

be in the range 0.3-0.6mg/m³. This can be significant depending on the overall dust capture on the filter. When sampling ducts with low particulate emissions (<5mg/m³) and using the low-volume sampling strategies (say 10-15 l/min) typically employed in the UK, over typical sampling times, overall dust capture on the filter is about 1-2mg. Thus, losses on filters in the range 0.3-0.6 mg/m³ are significant.

High volume sampling, i.e. 30-50 l/min, significantly improves the results as more dust is captured during the sample period. Pre-conditioning of the filters by drawing air through them before use is also recommended as this reduces fibre loss.

Mechanical handling of the filters must be minimised – especially at the sample location. Filters held in cartridge assemblies minimise these losses as they can all be prepared in the laboratory. The conclusions from this study led us on to the final project.

Project 3

Wind tunnel trials

The project was funded by STA, the Environment Agency and PCME and took place at the HSL wind tunnel at Buxton. The project was to carry out sampling using four sample trains on the wind tunnel with controlled velocity and dust loading (see Figure 5).

Fourteen tests were carried out over a one-week period. Up to four sample trains were used simultaneously with various configurations and flow rates. Two continuous particulate monitors from different manufacturers were fitted, un-calibrated, to monitor the particulate concentration. Tests were conducted with two main flow rates on the manual sample trains:

- 20l/min
- 40l/min

Results

The results have confirmed that filter holders fitted with different supports do give varying results.

Operating at higher flow rates significantly reduces the effect of initial filter loss due to the additional weight gain. In addition, pre conditioning, filter handling and weighing of complete assemblies give results closer to the true value. It was also noted that the continuous dust monitor results followed the exact profile of the varying dust loading in the duct. This is despite the instruments being installed with initial set up procedures only and without calibration using isokinetic tests.

Conclusions

- Measurement of very low dust concentration (<5mg/m³) is extremely difficult with manual isokinetic sample trains
- Handling of filters must be reduced to a minimum and they must not be changed at the stack location but in a clean environment
- Use of cartridge assemblies should be encouraged. High volume sampling significantly improves the measurement of mass concentration
- Pre-conditioning of filters by drawing air through should be a requirement when sampling dust levels below 10mg/m³
- Calibration of dust monitors using isokinetic sampling on processes that are significantly below their emission limit value (ELV) should not be required. For example, a process with an ELV of 10mg/m³ and operating at a particulate emission concentration of below 3mg/m³
- Compliance with the sample plane and sample point location as stated in BS EN 13284-1 is of prime importance. A sample location that does not meet the requirements can influence the particulate result significantly
- Sample trains (particularly pumps) must be kept in a good state of repair so that high volume sampling can be performed

Acknowledgments

The STA wishes to thank the following companies who have put in time, effort and equipment during the last four years to make these projects possible:

- CES Environment Instruments
- PCME
- Environment Agency
- NPL
- Whatman
- Quantitech/TCR Tecora
- AGL Air Testing/Millennium Instruments
- Enviro Technology Services/Zambelli
- Westech Instrument Services/Apex
- JS Holdings
- HSL Laboratory
- AEA Technology
- Redwing Environmental
- Scientifics
- PB Power

Figure 5: Location of sampling systems within the wind tunnel