Dynamic Opacity – A New Proven Technique for Continuous Dust Emissions Monitoring

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Under the new requirements from IPPC and the Environmental Protection Act, industrial emissions of dust must be continuously monitored to ensure compliance with statutory limits. Operators are required to carry out these measurements, to provide data for the local authorities and The Environment Agency which prove emissions are below a specified limit and ensure pollution abatement plans are operating satisfactorily, figure 1.

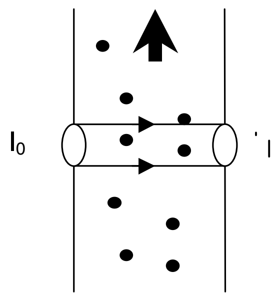
Figure 1 A new continuously monitoring technique, Dynamic Opacity, can be used for large stack/combustion applications.

The traditional technique for monitoring dust emissions in both fabric filter dust collectors and large stack applications is opacity measurement. Opacity monitors work on the principal of a light beam passing across the airflow; the extent to which the light intensity is reduced is a measure of the particulate concentration.

Modern opacity systems are accurate and reliable, but there are two certain limitations inherent in the technique – and at least two of these are becoming increasingly problematic because of current trends in industry:

1 Opacity systems require a high level of maintenance to prevent dust contamination on the lens, which seriously reduces their performance. Furthermore, at a time when process plants are actively demanding, industry requires systems which need as little maintenance as possible.

2 Their resolution is realistically limited to around 25mg/m^3 dust concentration. This is already inadequate for some applications, and is likely to become inadequate for many others as statutory emission limits continue to fall.



Particles absorb light
Distribution of particles → flicker
Scintillation = (I – I) / I
Scintillation = f (concentration)

Figure 2 Principals of operation for scintillation (Developed Opacity)

Dynamic Opacity

For the past 10 years there has been a new proven monitoring technique on the market – Dynamic Opacity. It is a sophisticated development of the opacity system, offering a tenfold increase in

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resolution and enormously less stringent maintenance requirements.

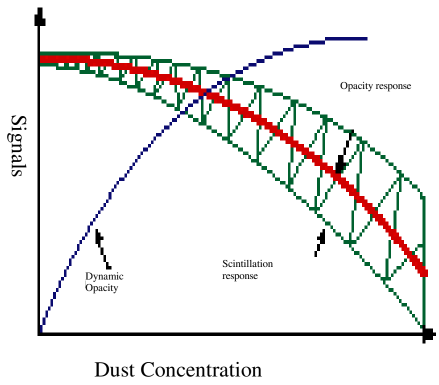

Figure 3 Variations in transmitted light due to statistical distribution of particles

Like opacity monitors, Dynamic Opacity monitors are based on a light beam passing across the airflow (Fig 2). The essential difference is that they measure not the beam intensity as such, but the temporal variation – scintillation – in its intensity. This scintillation results from the statistical variations in the distribution of particles in the airstream (Fig 3). The higher the concentration of particles, the greater the range of variation. Empirical results confirm a very simple relationship (Fig 4).

$$\text{Scintillation} = \frac{\text{variation in intensity}}{\text{Intensity}} = kc$$

Where C is the dust concentration and k is the empirical constant.

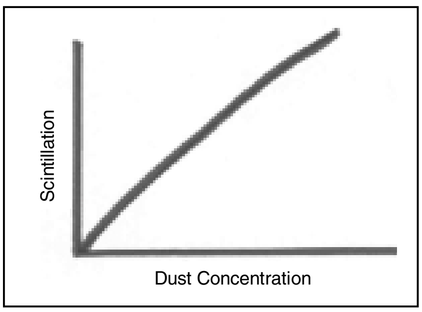

Figure 4 Empirical relationship between light scintillation and dust concentration

The scintillation is substantially independent of the absolute value of the light intensity, down to very low light levels. Scintillation measurements are both reliable and repeatable. The monitor can be calibrated by an isokinetic sample test to give concentration readouts directly in mg/m^3.

The essential proviso is that the empirical constant k must not vary. Its value is a function of the installation, the type of dust and the particle size, and is effectively constant in a wide range of large stack and combustion applications including incineration plants, electrostatic precipitators, dust arrestment plants and cement kilns.

In principal therefore, Dynamic Opacity is an ideal alternative to traditional opacity techniques for emission monitoring. So how does it measure up as a practical instrument?

Requirements for a practical dust monitor

The primary requirements a dust monitor must meet for any specific application include:

- Repeatable response to dust concentration
- Resolution sufficient for the emission limits
- Minimal calibration drift
- Reliable operation for extended periods

The Dynamic Opacity monitor meets the first of these as a matter of empirical fact. Laboratory tests – including those performed by Warren Spring Laboratory (the now formed NETC – National Environmental Technology Centre) – show that there is a linear and repeatable relationship between scintillation response and dust concentration. Mathematical models are currently being developed to explain these relationships.

Resolution

Dynamic Opacity instruments are capable of resolving dust concentrations as low as 2.5mg/m^3 – at least ten times better than opacity monitors. This level of performance is already required for arrestment plants, for example, where the emission levels can be well below 5mg/m^3 and are likely to be required much more widely in the future as abatement technology improves and emission limits are reduced.

The reason for the superior resolution of the scintillation technique is that measurements are made relative to a baseline of zero variation in intensity, whereas the opacity monitor makes its measurements relative to 100% intensity – ie, that of the unobstructed beam. The proportional changes involved are therefore much greater in the case of scintillation: it is obviously easier to design an instrument which can accurately measure 0.2 with respect to 0 than one required to measure 99.8 with respect to 100 (fig 5).

On a practical note, the resolution specifications for opacity instruments may suggest a better performance than can be realised in practice. For example, taking specifications from a typical manufacturers data sheet where the resolution is 0.2% opacity, the zero drift is + 1% opacity. This in practice, might be as large as + 25mg/m^3.

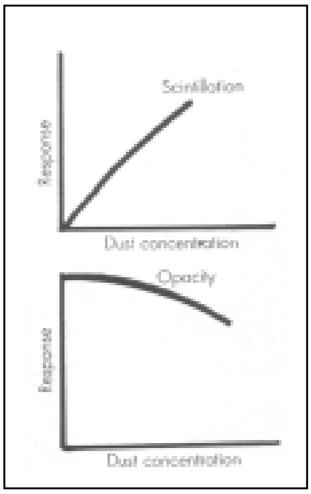

Figure 5. Response characteristics of scintillation and opacity instruments

Calibration drift

The calibration of a Dynamic Opacity instrument will shift only if there are changes in parameters affecting the attenuation of light by a particle (ie, the opacity). These include:

- Particle size and shape
- Particle material

In many applications, these parameters normally remain constant. If, however, changes occur for any reason, the instrument must be recalibrated. This requirement also applies to the traditional opacity monitor. It has been said that velocity affects instrument calibration. However, laboratory tests at the National Environmental Technology Centre (Warren Spring Laboratory) have shown no effect above 10m/s and minimal practical effect between 5 and 10m/s. (Dynamic Opacity instruments are not normally used below 5m/s in standard scintillation mode).

Reliability

One of the most significant advantages of the Dynamic Opacity technique is its remarkable tolerance of instrument contamination. A Dynamic Opacity monitor will continue to function even when its lenses are heavily coated with dust. Provided sufficient light is getting through for the instrument to make its measurements, its response will not be affected by the contamination. To see why, suppose a particular dust concentration produces a variation x in a light intensity I when the lenses are clean. If the light intensity is reduced by a contaminant coating on the lenses, the variation in intensity will be affected in the same proportion, giving no net effect. See Table 1.

Dynamic Opacity monitors will continue to work even if lens contamination reduces the transmitted intensity to just 10% of its starting value. With regular air purging, contamination to this extent would not normally be reached for many years. Other factors affecting the transmitted intensity, such as source ageing or system misalignment, will similarly have no effect on the instrument's operation.

Effect of contamination in traditional Opacity instruments

To appreciate just how big a benefit the Dynamic Opacity monitor's insensitivity to lens contamination is, it is worth seeing how reduced transmission affects a traditional opacity instrument.

Lens Condition	Light Intensity	Variation	Dynamic Opacity
100% transmission	I	x	x / I
90% transmission	0.9I	0.9x	0.9x / 0.9I = x / I
50% transmission	0.5I	0.5x	0.5x / 0.5I = x / I

Suppose a particulate concentration of 50mg/m^3 produces 2% opacity, so that the measured beam has 98% of its maximum intensity (Fig 6). Now imagine that the lens becomes contaminated with dust. A relatively minor contamination might reduce the beam intensity by 2% - but this is as large as the signal itself ! In other words, a dust build-up on the lens of just 2% could produce an error measurement of nearly 100% without compensation.

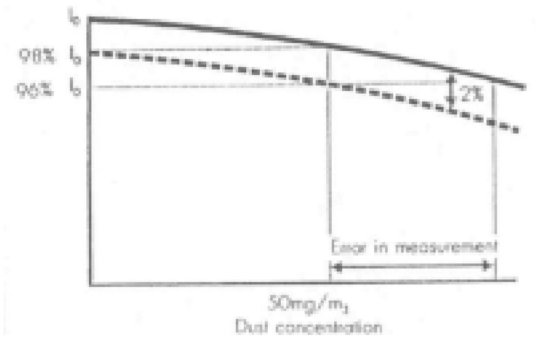

Figure 6 Opacity variation with dust concentration, showing 98% I_O at 50mg/m^3 and effect of further 2% reduction from lens contamination.

This is why traditional opacity systems must include sophisticated and expensive cleaning and compensation arrangements to minimise the catastrophic effects of lens contamination. Dynamic opacity instruments avoid this problem entirely.

Suitability of Dynamic Opacity

Where the Dynamic Opacity technique can be applied, it clearly offers considerable advantages. There are, however, some circumstances in which Dynamic Opacity will not function, and opacity is the only viable alternative. These include:

- Applications where emissions are black, ie where there is no variation in intensity. This sets a practical upper concentration limit of around 100mg/m^3.
- Conditions in which short-term process changes cause variation in particle distribution greater than the statistical variations. In practice this means that the start-up of certain processes may not be accurately monitored by Dynamic Opacity.
- There are also certain applications in which measurements must be made in terms of opacity and Ringelmann (colour) characteristics as well as mg/m^3. To allow for such applications, Dynamic Opacity monitors can be switched into opacity mode.

Dynamic Opacity Instruments

Dynamic Opacity technology is available in the form of proven commercial instruments. A particular instrument is the SC620/680 which is approved under the UK MCERTS scheme for compliance in particulate monitoring. The instrument is certified for measurement over the range 0-150mg/m^3 approved for use in combustion, electrostatic precipitator and baghouse applications. It was certified based on testing in a 600MW coal fired power station.

Key advantages of dynamic opacity

To summarise, these are the key advantages this new dust emissions monitoring technology has to offer:

- No significant deterioration in performance until lenses are over 90% coated.
- Ten times the resolution of opacity monitors (2.5 against 25 mg/m^3)
- Suitable for dust concentrations from 2.5 to 1000mg/m^3.
- Tolerant of extended periods of operation without maintenance.