Electrodynamic Technology for Particulate Monitoring

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Electrodynamic Technology

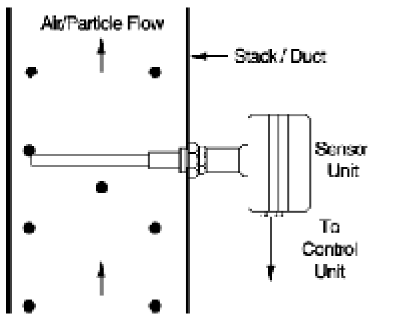
The Electrodynamic principle of operation is based on the measurement of the electrical signature derived from the interaction of particles in the air stream and the sensor rod installed across the duct of stack. Distributions in the particle stream result in a frequency charge induction response, which is directly proportional to the concentration of particulate*. Unlike Triboelectric systems the measurement is not affected by build up on the probe surface, which can cause zero and calibration drift. Very low dust concentrations can also be measured due to this unique Electrodynamic technique. Various independent laboratories have validated this relationship. This Electrodynamic technique also enables the use of fully insulated probes essential for use in high humidity and wet gas streams as well as applications with high conductive dust loadings.

In such a system the sensing probe is installed across part of the stack in a position to be exposed to a representative profile of the particle emissions. The particles induce a frequency response in the probe as a result of two kinds of interaction;

1. Direct collision
2. Charge induction (charge on the particle repels charge in the probe as it passes)

The variation in the particle distribution results in an alternating frequency of the current, and since the particle distribution follows a Poisson distribution, the amount of variation is directly proportional to the number of particles. Hence the frequency response is proportional to the dust concentration*.

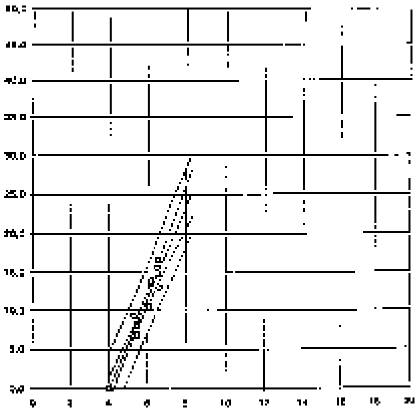
In making the Electrodynamic measurement, a dc or Triboelectric current is also generated by the particles colliding with the sensor rod, however this is specifically filtered out by the electronics leaving the frequency induced current.



The proportional and repeatable relationship between the Electrodynamic signal and dust concentration* has been validated by independent bodies such as The Warren Spring Laboratory, German TUV and the UK Environment Agency's MCERTS Accreditation Scheme.

TUV's evaluation of PCME's Electrodynamic instrument led to the instruments approval as suitable to satisfy legislative requirements for particle emission monitoring in Germany. It demonstrated a linear calibration between instrument output and dust concentration. It also importantly demonstrated that this calibration was stable and did not change during the 3-month field trial on an industrial bag filter.

* within parameters (see section on limitations)



Output in m/A

Results from the linearity test

Difference between Electrodynamic and Triboelectric Systems

Triboelectric systems work on the principle of amplifying and measuring the magnitude of the dc Triboelectric current produced by particles colliding or rubbing with a grounded sensor rod inserted in a stack. This dc current, derived from the impact of particles on the probe, is the same signal that is specifically filtered out in an Electrodynamic system. The magnitude of the dc current can be related to dust concentration however it is also dependent on any parameter which affects the amount of charge transfer including type of dust, energy of particle impact and probe surface material, probe contamination and velocity.

Electrodynamic and Triboelectric instruments have significantly different operating characteristics, because the Electrodynamic signal derives from the induced frequency response from variations in distributions of particles *passing* a probe whereas the Triboelectric signal derives from the total number of particles *hitting* a probe.

Electrodynamic systems have operating advantages over dc Triboelectric in applications where the following conditions apply:

- Low dust concentration (<1mg/m^3)
- Humid conditions (after process dryers)
- Dusts that coat the probe
- Varying velocity in bag filters
- High accuracy requirements

The reasons for these differences relate directly to the difference in measurement principles and the advanced electronic design characteristics. These are summarised below and described in detail in the following sections:

	Electrodynamic	**Triboelectric**
Lowest Detection Level	0.01mg/m^3	Approx 1mg/m^3
Effect of dust build up on probe	None	Calibration drift
Reliability in humid applications	Good using insulated probe	Susceptible to false signals even with air purge
Effect of velocity	Virtually none	Unpredictable, non-linear
Stability of signal	Good*	Unpredictable

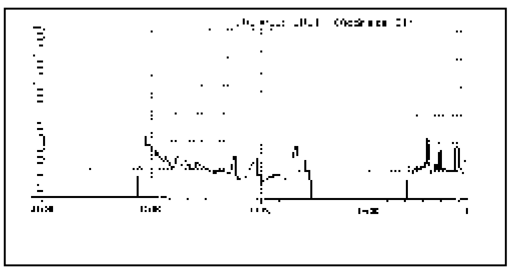
*Assuming particle velocity is greater than 8 m/s

Lowest Detection Level

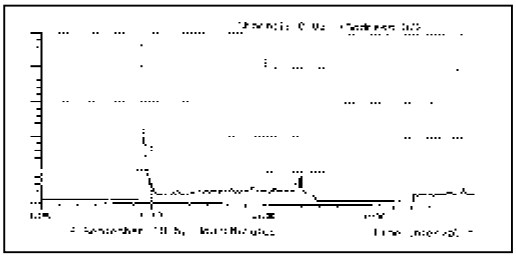
Electrodynamic instruments can measure lower concentrations of dust than Triboelectric systems, as they operate at higher levels of amplification without electronic noise interference. The high gain amplification process (up to 10^{15}:1) in a DUSTALERT system manufactured by PCME is not affected by dc temperature offsets within the amplifiers while in a Triboelectric system these offsets cause measurement errors which cannot be zeroed out.

The following graphs compare the output from an Electrodynamic and Triboelectric instrument when the dust collector is switched on and off. The dc offset in the Triboelectric system when there is no dust is as a result of amplifier offsets.

Electrodynamic Output



Triboelectric Output

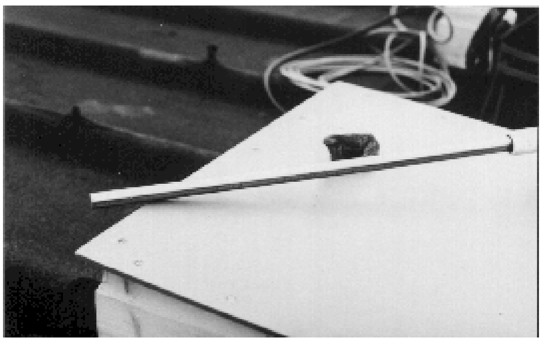


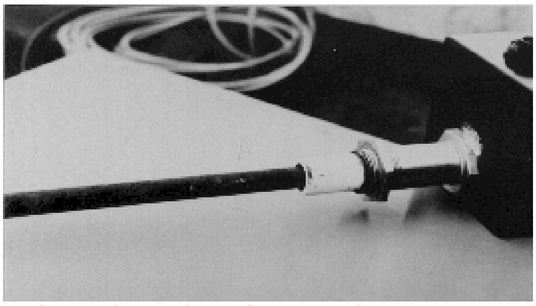
Comparison between Electrodynamic and Triboelectric

The offset of the Triboelectric system reduces its signal/noise ratio, limiting its resolution to around $1mg/m^3$, in good instruments, compared to around $0.01mg/m^3$ for an Electrodynamic system

Effect of dust buildup

In Electrodynamic systems most of the signal derives from the induction effect as particles pass the probe. This phenomenon depends solely on the pre-charge on the particles and their distribution, and is independent of the cleanliness of the probe surface. The situation is different with Triboelectric systems where the amount of charge transfer is dependent on the surface material with which the particles collide. Build up on the probe changes the probe surface material and affects the Triboelectric systems probe response.



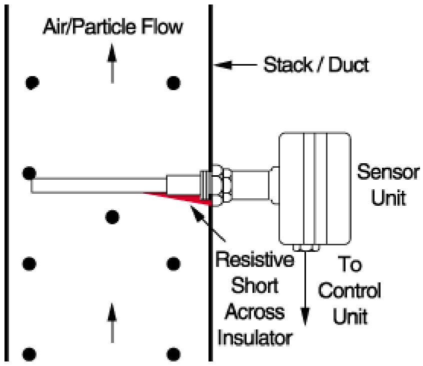


The Electrodynamic probe gave the same response after cleaning.

Reliability in humid and conductive dust (high loading) applications

One mechanism of failure for Triboelectric systems when used with moisture and conductive dusts is the formation of a resistive short across the insulator which results in false signals due to:

1. Signal leakage to stack
2. Interference from currents in stack
3. Charge generation in the cell which is formed



In Electrodynamic systems this problem can be minimised by using a completely insulated probe (sensor rod is insulated over full length) which has no resistive path to ground. The insulated probe continues to measure in spite of its insulated coating since the induction phenomena does not require direct contact between particles and sensor rod. The insulated probe is covered by separate PCME patents.

For Triboelectric systems, however, the principle method used to stop resistive shorting is the use of an air purge. This method, in practice, is not 100% dependable, since it is problematic to keep the insulator clean and dry with air which itself may contain moisture as a result of expansion.

Generally Electrodynamic systems give better performance in humid applications as they are unaffected by the dust build up which occurs in the humid conditions*+.

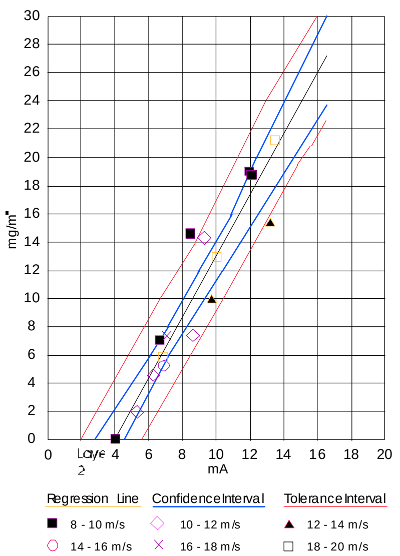
Influence of Velocity

Until 1995 a form of TriboACE® technology was generally used only in applications with relatively constant velocity (+/- 30%). This was because of experimental results obtained with larger particles

(>100µm) and at low velocities (1-2 m/s) which showed a velocity dependence. Since the introduction of PCME's Electrodyamic technique more extensive tests have shown that in the velocity range found after Bagfilters (› 8 m/sec), velocity has no significant effect on the signal. This is as a result of the frequency induced signal being relatively unaffected by changing velocities. This non-velocity affect has now been independently verified by TUV laboratories in Germany.+

Triboelectric systems are influenced by changes in particle velocity since the charge transfer on collision is dependent on the energy of impact of the particle. The Triboelectric current is stated by most manufacturers to be proportional to velocity squared for most types of materials.

*See Gyproc test report 04/96
+See TUV DA60 test report

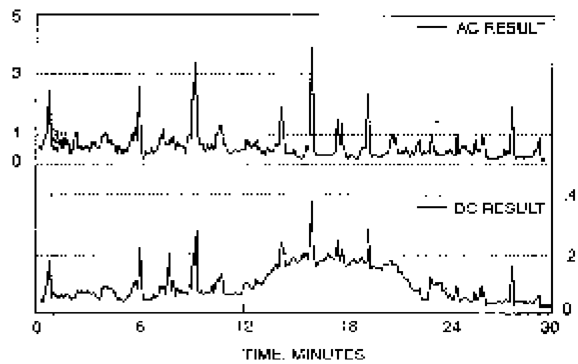


Graph showing no velocity effect for Dustalert

Stability of Signal

Empirical results have shown that the Triboelectric signal sometimes suffers from signal shifts unrelated to particle concentration. This manifests itself as a change in magnitude or sometimes even as a change in polarity. The Electrodynamic response is not effected by dc signal shifts and therefore is more stable. The explanation for the dc shift phenomena may be linked to the probe contamination mentioned above.

It is interesting to note that the field test used to accredit PCME's Electrodynamic system for monitoring emissions after bag filters in Germany was with T_1O_2, a sticky powder.



Comparison between Electrodynamic and Triboelectric

Nominally constant process dust input rate showing improved stability of the induced frequency response as compared with the dc response.

Limitations of Electrodynamic Technology

As is the case with all other types of particulate emission monitoring techniques, there are limitations on the usage and capability of Electrodynamic technology. These in practice do not restrict the technologys' use in the majority of particulate measurement applications.

The limitations on the use of the technology are two-fold:

1 The instrument's calibration against dust concentration will shift with changes in the following process conditions:

a) Changing particle size distribution
b) Changing particle type
c) Changing pre-charge on particles
d) Presence of water droplets

In practice this tends to restrict electrostatic precipitator applications where pre-charge on the particles can change and therefore instruments are only indicative. It also makes applications with changing particle type and water droplets problematic.

Caution is also required in combustion applications where changing particle charge caused by gas ionization effects can result in different calibrations.

2 The validity of Electrodynamic techniques is dependent on the process not continuously varying dramatically from one second to another. This would invalidate the Poisson distribution relationship.

However, such situations only occur in very few applications and changes arising from the cleaning cycle of the bag filter are dealt with by appropriate selection of signal bandwidth.

Summary

A major commercial outlet for Electrodynamic technology is in dust emission monitors for dust arrestment plants. In this growing application area the inherent characteristics of Electrodynamic technology are of valued benefit:

- Reliable and accurate measurement at the low levels of dust (* typically $\leq$ 5mg/m^3 after bag filters).
- Sensor requires only a single connection and is unaffected by vibration.
- Low cost of ownership due to negligible maintenance and reasonable purchase price.

Electrodynamic systems often provide a more practical, reliable and cost effective solution than that provided by Triboelectric and Opacity type instruments.

Opacity instruments tend to be relatively costly to purchase and install, require ongoing maintenance and even then are unsuitable for measurement after a bag filter due to their inherent resolution limit of no better than 20mg/m^3/m. Typical dust loadings after a bag filter are 1mg/m^3 to 10mg/m^3 and, therefore, much more suited to non-contact Electrodynamic technology.

The measurement advantages of Electrodynamic sensors over Triboelectric systems are summarised below:

Electrodynamic	Triboelectric
Not velocity dependent due to induced frequency response*	Triboelectric signal dependent on a factor of velocity not easily defined due to energy on collision
Increased signal to noise ratio (resolution)	Triboelectric approximately 50 times less sensitive due to dc amplifiers
No detrimental effect due to dust accumulation on probe	Dust accumulation changes response due to changes in probe surface characteristics
Stable signal correlates with dust concentration	Triboelectric signal not always stable
Insulation probe eliminates false signals by not allowing resistive ‘short’ path across insulator in wet or conductive dust applications	Cannot fully insulate probe, plus any increase length of insulating material reduces effective probe length for signal generation

*see TUV test report