# The Emergence of Triboelectric Technology

*Triboelectric monitoring, now accepted by the U.S. Environmental Protection Agency, provides continuous monitoring of particulates.*

For almost two decades, opacity monitoring and periodic stack testing were the only methods of particulate monitoring accepted by the U.S. Environmental Protection Agency (EPA). Although a patented triboelectric technology was invented more than 25 years ago and more than 20,000 installations worldwide were using triboelectric products to monitor baghouses for leak detection prior to the Clean Air Act Amendments (CAAA) of 1990, EPA continued to view it as somewhat experimental.

Along with the CAAA came the requirement for EPA to develop National Emission Standards for Hazardous Air Pollutants (NESHAPs) under Title III, and the Compliance Assurance Monitoring (CAM) Rule under Title V. Both of these regulatory actions involve particulate monitoring definition in the form of bag leak detection.

The recently promulgated maximum achievable control technology (MACT) standard for the secondary lead smelting industry was the first regulatory action to change the requirement from exclusively opacity monitoring and periodic stack testing to triboelectric bag leak detection. Most of the secondary lead smelters had been using triboelectric bag leak detectors for many years and had demonstrated their successful use on blast and reverb furnaces, as well as on the general ventilation baghouses. This significant action came only after extensive, independent field testing of triboelectric technology by EPA, which lid to the preparation and publication of an EPA document titled *Fabric Filter Bag Leak Detection Guidance*. This document provides guidance on the use of triboelectric monitors as fabric filter bag leak detectors.

The recently proposed MACT standard for the mineral wool production industry has followed a similar direction. In this proposal, EPA states that "opacity is not a good indicator of performance at the low, controlled levels characteristic of these sources."

**Opacity**

Opacity, or optical technology, measures the reduction in light transmittance across a stack, using a transmitter and a receiver (lenses). The process uses a single- or double- pass light path to analyze the presence of dust particles in the gas stream. Opacity monitors compare the amount of lost light energy to the total energy of the transmitted light, and translate the signal into a percentage of opacity.

Opacity monitors were the first instruments able to continuously monitor opacity. However, they provide only a relative indication of gross change in particulate concentration in a stack. If two facilities have opacity levels of 10 percent, their actual particulate emissions still can be different. The reading can be affected by misalignment of the lenses, clouding of the lenses, atmospheric conditions, the color of the particulate, fumes in the gas stream and other factors. Opacity is not an accurate or reliable method for detecting the early onset of bag leaks.

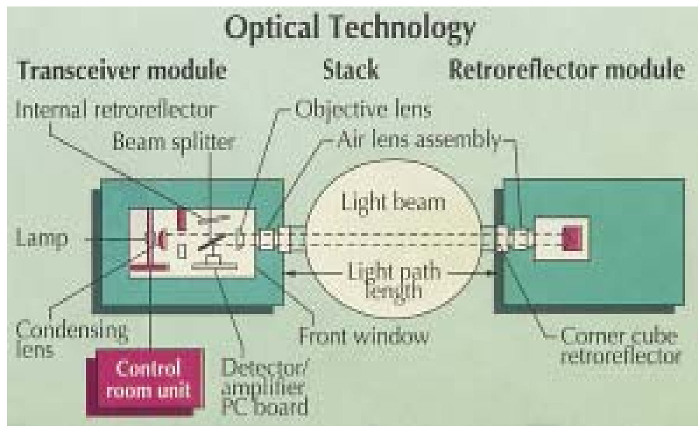



***Figure1. Opacity uses a light path to analyze dust particles in the gas stream.***

As EPA has recognized, opacity is not appropriate for monitoring low-level bag leaks. The minimum detection ranges of the various methods are:

| | |
|---|---|
| Opacity monitors | 0.0010 g/dscf (grains per dry cubic foot) |
| Method 5 stack test | 0.0030 g/dscf |
| Triboelectric | 0.000002 g/dscf [0.005 milligrams/ meters$^3$ (mg/m$^3$)] [1] |

The table on the next page provides results of a test comparing sidescatter opacity technology with triboelectric technology at an aluminum reduction facility. The shaker baghouse system included 12 compartments of 300 filter bags each, for a total of 3600 filter bags. All 12 compartments exhausted through a 17-foot diameter stack in which both the opacity device and the triboelectric probe were installed. A ¼-inch hole was punched in one of the 3600 filters bags and was detected by the triboelectric device in the first 50-minute cleaning cycle; the leak was not detected for two days by the opacity device.

## The triboelectric effect

Static electricity is a familiar phenomenon. Not so commonly known is the reason why materials become statically charged. The charging mechanism is the principle of triboelectric measurement. Static electrification depends upon an excess or imbalance of electrical charge, which may be produced by the transfer of charge when two materials are brought together and then separated or rubbed together. This phenomenon is referred to as the triboelectric effect.

When particles conveyed in a pipe or duct collide, or come close to an electrically isolated and earth-grounded intrusive probe, a charge transfer results between the particles in the gas stream and the probe. It takes place on a continuous basis, because of the continuous stream of particles.

The CAAA bag leak detection requirements have given rise to patented triboelectric technologies. The primary difference between them is the type of circuits.

The triboelectric signal is made up of:

- The DC component generated by the particulate striking the sensor. It is proportional to the mass flow and varies with the actual flow rate.
- The low frequency AC component generated by short-term intermittent variations of fluctuations in the mass flow rate of particulate, and by particulate passing near the probe, but not impacting the probe.
- The high-frequency AC component. This is the high-frequency modulation resulting from equipment, vibration and other factors.

The high-frequency AC component must be filtered out. Only the DC component and the low-frequency AC component are useful. Early in the development of triboelectric devices, engineers recognized the advantages of the DC measurement in providing robust and linear signals. They also found that at low velocities and concentrations, the DC component becomes smaller than the AC component of the signal. For this reason, some triboelectric technology incorporates a special circuit that automatically reports the larger of the two components. The technologies utilizing subsets of traditional triboelectric measurement (non-contact electrification and electrodynamic measurement) also filter out the high-frequency AC component, but they rely completely on the low-frequency AC component for a signal.

The factors that affect all triboelectric signals can be expressed as $I=KCV^2$, where:

I = the triboelectric signal or current
K = the calibration factor of the particulate material
C = mass concentration of the particulate impinging on the probe
V = velocity of the gas stream

Each material exhibits a different K factor. The signal also increases with velocity by a square root relationship, whether using DC or AC components. The material and velocity are fairly constant in most baghouses, with the result that the signal follows the changes in the mass concentration, except when only the AC component is used.

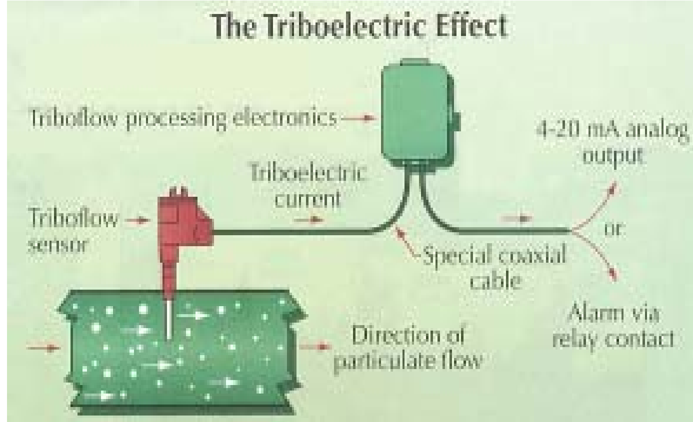



*Figure 2. A charge transfer results when particles come close to an electrically isolated probe.*

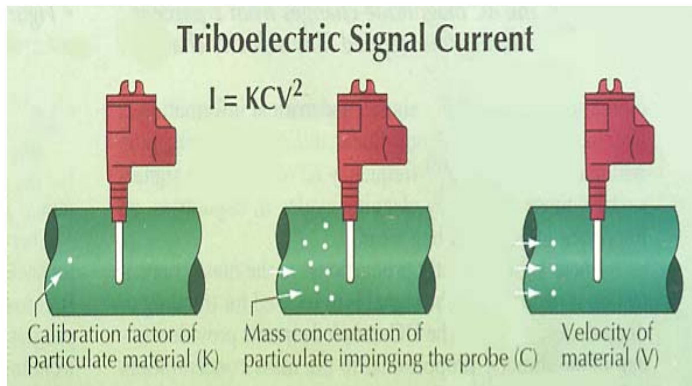



*Figure 3. Several factors affect the triboelectric signal.*

AC-coupled circuits utilizing only the AC components are completely dependent on fluctuations in the dust flow signal to function. If fluctuation or turbulence does not exist in the case of laminar flow, the dust will not be detected.

If the degree of fluctuation varies to any extent, the dust flow will be detected as significantly lower or higher amounts than actually are present. Significant changes take a long time to settle down. These can be interpreted as changes in particulate concentration because there is no way to know the difference.

The AC magnitude changes from 2 percent to 6 percent during the stepped flow velocity changed from 1000 feet/minute to 8000 feet/minute. See Figure 4. One would not expect to see this kind of change in a baghouse, but the magnification helps to demonstrate the huge anomalies that occur with significant changes in turbulence or air flow. Notice that after the changes, which occurred over a three-minute period, the baseline was 20 percent higher.

Over time, it will return to normal, but in the interim, it could be interpreted as an increase in particulate concentration, leading the facility to report an exceedance when none occurred.

**Optical Technology vs. Triboelectric Technology**

| Time to: | Optical sensor | Triboflow sensor |
|---|---|---|
| Detect leak | Two days | Less than one hour |
| Locate leak | Two to three man-hours | Less than one minute |
| Clean up leak | Eight to 10 man-hours | Less than one man-hour |
| Puncture detected | 8" hole | ¼" hole |
| Dust cleanup | 60+ cubic feet | 2.5 cubic feet |
| Cleanup tool | Shovels | Shop vacuum |

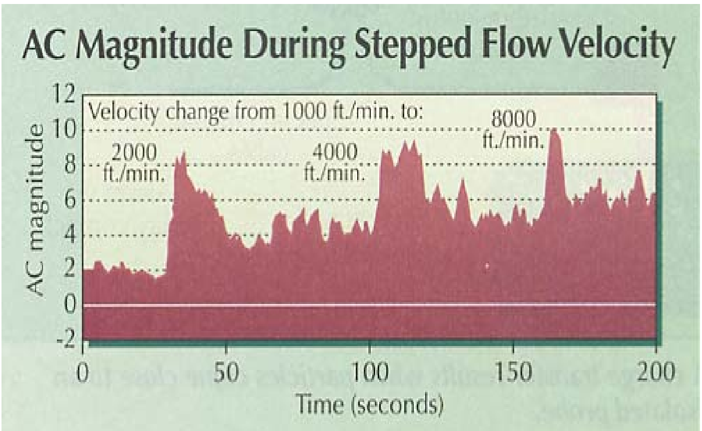



***Figure 4. The AC magnitude changes from 2 percent to 6 percent during this stepped flow velocity change.***

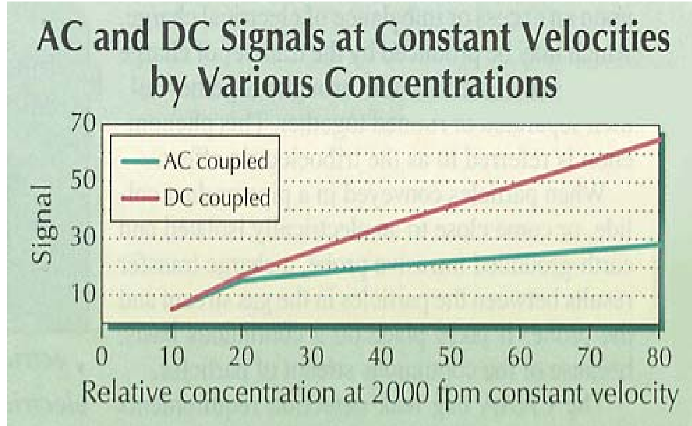
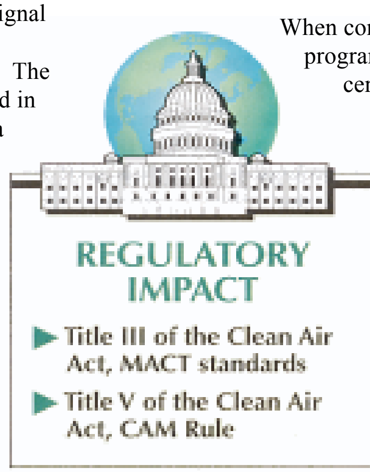



***Figure 5. A linear signal directly proportional to the mass concnetration is necessary for diagnostic purposes.***

AC-coupled devices try to detect the small flow deviations while filtering out all high-frequency AC noise. To correct for this inadequacy, a fairly large averaging time is required to obtain a steady signal, and critical information is lost. In addition to being non-linear, the long averaging time will mask important low-frequency AC component signals such as those caused by cleaning cycles in baghouses, an important indicator of bag wear.

A linear signal directly proportional to the mass concentration is necessary if the signal is to be used for trending or diagnostic purposes. The DC-coupled circuits provide a linear signal directly proportional to the mass concentration. AC-coupled signals reflect a square root of concentration. The DC signal is linear with concentration as demonstrated in Figure 5, which shows the AC and the DC signals at a constant velocity but various concentrations.




AC-coupled circuits make acceptable broken bag detectors. They can indicate gross failure and can be used quite effectively for small nuisance collectors or bin vents. But to comply with EPA regulations, which require continuous 4-20 milliamps (mA) bag leak detectors and accurate records able to prove continuous compliance, AC-coupled circuits might not work. In EPA's *Fabric Filter Bag Leak Detection Guidance*, the Agency concludes "Charge transfer (triboelectric) monitors based on electrostatic induction (AC coupled are also potentially applicable, but sufficient information was not available to include them in this guidance."

Without large numbers of AC-coupled triboelectric devices in various industries over an acceptable evaluation period, it would be irresponsible for EPA to embrace this technology.

The NESHAPs standards are specific about monitoring technology requirements. CAM, finalized in October 1997, allows more flexibility in the selection of a monitoring protocol. A facility is not required to select instrumentation monitoring. It can select visual observation, differential pressure, mass balance formulas, combustion source feed rates, or another method. It can write a CAM plan around any monitoring technology that will provide information which reliably indicates potential problems in the air pollution control equipment and allows the facility to act in a timely fashion.

If the method alerts the facility to a problem at about the same time visible emissions begin to occur, the facility might report exceedances rather than excursions. Visual observation and opacity monitoring may be unacceptable for low-level particulate rate limits. Differential pressure monitoring is only an indication of blinded filter bags.

There are more reasons for installing bag leak detection technologies than complying with specific requirements. It is not possible to have an effective dust collector O & M program that can be sued for predictive maintenance and trending without continuous monitoring. Triboelectric bag leak detection is more reliable in detecting early bag leaks than opacity monitoring.

When considering improved operating and maintenance programs for air pollution control equipment, annual certification of continuous compliance under the Title V permit program should be considered, as well as the implications of the

Any Credible Evidence (ACE) Rule. When selecting a monitoring method or technology, facility managers should ask themselves the following questions:

1. Does the monitoring method selected provide a reliable (95 percent or better) method of detecting bag leaks?

2. Does the monitoring method selected provide the level of assurance necessary for a corporate executive to sign a certification of continuous compliance with complete confidence?

3. Does the monitoring method provide the data needed to demonstrate continuous compliance?

If these questions can be answered confidently, then the correct choicehas been made.

References

Rust Report prepared for the Institute of Polyacrylate Absorbents, Inc.

*Reprint of article in the September, 1998 issue of Polution Engineering. Written by Kay Ramsey, Auburn Environmental, Inc.*