Practical Application of Broken Bag Detector Technology for Compliance, Operation and Maintenance

Under the Steelmaking EAF NSPS and the Iron and Steel Foundry NESHAP

This article discusses the practical installation of broken bag detection technology for cost-effective compliance with the latest emission standards. A review of the current status of these rules and their application to EAFs and melting furnaces is provided.

On Oct. 16, 2002, the U.S. Environmental Protection Agency (USEPA) published a proposal to modify the New Source Performance Standards (NSPS) for electric arc furnaces to allow for the use of bag leak detection systems to be used in place of continuous opacity monitors on EAF baghouses with single stacks. While the USEPA has never finalized this rule, they have made other proposals to utilize bag leak detection systems for monitoring baghouse performance. On April 22, 2004, the USEPA published a final rule promulgating a National Emission Standard for Hazardous Air Pollutants (NESHAP) for iron and steel foundries. While this rule, commonly known as the Foundry MACT, addresses a number of hazardous air pollutants from several different operating practices, this article will focus only on the proposal to include bag leak detection for monitoring the filter fabric baghouses at these operations.

Iron and steel foundries utilize filter fabric baghouses for controlling the particulate-laden fume generated during melting operations. This particulate is composed primarily of iron oxides; however, it does contain some metal oxides that are considered hazardous air pollutants, depending on the nature of the scrap charged to the furnace. In the final NESHAP rule for iron and steel foundries, the USEPA states their conclusion that controlling particulate matter (PM) is the most effective way of controlling metal HAPs, with the possible exception of mercury, and that it is appropriate to use PM as a surrogate for metal HAPs. While steelmaking electric arc furnaces are not subject to MACT requirements, this industry has a long history of installing and updating large filter fabric baghouses for controlling the PM generated by the scrap melting process. This has resulted in an opacity limit of 3 percent from the baghouses, one of the most stringent opacity standards applied to any industrial operation.

In the authors' opinion, it is clear that a properly designed and maintained baghouse is an extremely efficient method to control PM from the melting operations in both of these industry sectors. It also appears that the USEPA feels that utilizing bag leak detection systems is the most effective method to provide continuous compliance monitoring for these baghouses.

This article compares the bag leak detection system requirements contained in the Oct. 16, 2002, proposed NSPS rule and the April 22, 2004, final NESHAP rule. In addition, this article discusses real-world experience with leak detection systems at two electric arc furnace facilities operated by IPSCO Steel in the U.S.

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described in the site-specific monitoring plan. The proposed EAF NSPS rule has another adjustment requirement that is driven by a separate requirement to conduct Method 9 visual opacity readings on the baghouse stack. The rule states that if a Method 9 reading indicates opacity greater than zero for more than 1 minute without a corresponding broken bag detection alarm, adjustments must be made to lower the alarm setpoint.

Corrective Action Requirements

While both rules require corrective actions be taken in response to a broken bag detection system alarm, there are some differences in the two rules that are related to record keeping and reporting requirements. These differences are primarily due to the different regulatory scope of the rules. Therefore, these differences will not be included in this evaluation. Both rules, however, do include discussions about response times to alarms generated by the broken bag detection system, and those actions that would be considered corrective actions to be taken in response to alarms. These requirements are the focus of this evaluation.

Response time to alarms is different in the two rules. The proposed EAF NSPS rule requires initiation of action to address the alarm within 30 minutes, and that the cause of the alarm be alleviated within 3 hours. Any time beyond the 3 hours will require notification of the administrator or the delegated regulatory authority. In the Foundry NESHAP, the operator must initiate corrective action to determine the cause of the alarm within 1 hour and initiate corrective actions to correct the cause of the alarm within 24 hours, completing these corrective actions as soon as practicable. Both rules have a list of what the USEPA believes are the minimum actions that must be included in any facility corrective action plan. They are as follows:

- Inspecting the baghouse for air leaks, torn or broken bags or filter media, or any other condition that may cause an increase in particulate emissions.
- Sealing off defective bags or filter media.
- Replacing defective bags or filter media, or otherwise repairing the control device.
- Sealing off a defective baghouse compartment.
- Cleaning the bag leak detection probe, or otherwise repairing the BBD system.
- Shutting down the process producing the particulate matter emissions.
- The Foundry NESHAP lists making a process change as a corrective action. This action is not listed in the EAF NSPS rule.

The following sections of this article describe the practical application of BBD technology to meet these regulatory requirements. The application guidelines are based on IPSCO's experience with both negative- and positive-pressure baghouses.

Table 1

EAF and Baghouse General Specifications

Parameter	Montpelier	Mobile
EAF type	Twin shell DC electrode	Twin shell AC electrodes
EAF size	165 ton	175 ton
Baghouse type	Negative pressure	Positive pressure
Air volume (acfm)	980,000	1,600,000
Compartment no.	28	16
Cleaning mechanism	Pulse jet	Reverse air

Facilities and Fume Control Systems Used by IPSCO

IPSCO has two EAF shops located in the U.S. that use BBD systems to monitor the integrity of the fabric filters in the respective emission control baghouses. One EAF shop is located near Montpelier, Iowa, and the other is located near Axis, Ala. (north of Mobile). The Montpelier Works EAF shop uses a negative-pressure baghouse (fans located after the baghouse), and the Mobile Works EAF shop uses a positive-pressure baghouse (fans located ahead of the baghouse). The respective EAF and fume control system basic specifications are outlined in Table 1.

The general configuration of the two EAF baghouses is described in Figures 1 and 2. The Montpelier Works baghouse (Figure 1) is a negative-pressure baghouse with a stack (continuous opacity monitor, or COM, required on a stack — EAF NSPS). The Mobile Works baghouse is a positive-pressure baghouse with a stack (COM required on a stack — EAF NSPS). A positive-pressure baghouse does not typically have a stack; rather, the exhaust is discharged through a ridge vent of some type. The particular circumstance at Mobile Works is associated with local regulations unique to Alabama. Both plants produce steel plate (discrete and coil) as the finished product.

To simplify the diagrams, the location of the fans is not illustrated. The location and design of the BBD system probes is discussed in a later section of this article.

BBD System Specifications

The BBD systems installed by IPSCO use the DC-energized type of probes. Table 2 summarizes the BBD system specifications for the two facilities. Specific locations for detector probes in the respective types of baghouses are discussed in the System Application section later in this article. The BBD system located at Montpelier Works was installed in August 2000, and the BBD system at the Mobile Works was installed in March 2001. Both facilities are greenfield installations, with Mobile Works being the more recent, having begun operations in November 2000.

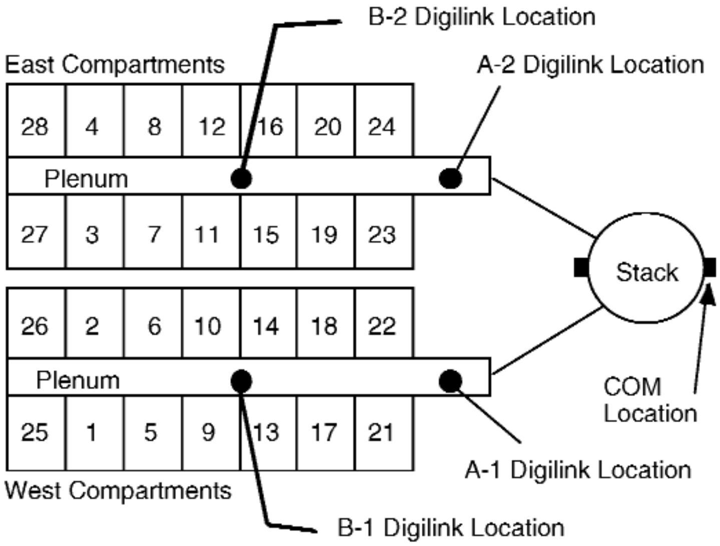
Triboelectric Monitoring Principle

The measurement principle of a triboelectric BBD system is based on measuring the small changes in electrical charge of an energized probe placed within the exhaust gas stream. Generally, there are two types of probe systems presently marketed in the U.S. Depending on the manufacturer, the system will use either DC or AC power for energizing the detector probe. AC-powered systems claim to have the triboelectric field affected by both particles striking the probe and those passing close to the detector. On the other hand, DC-powered systems claim that the majority of triboelectric effect is related to the particles striking the probe. In either case, it is the presence of particles that causes the triboelectric changes.

The probes are generally made of stainless steel or other metallic material that is energized with either AC or DC electrical voltage. The particulate present in the gas stream strikes the probe (or passes close enough to affect the probe), and the particles act to change the electric field of the probe. This mechanism is similar to the release of static electricity that has been accumulated in a person's clothing or on the skin. The small changes in the electric field associated with the passage of particles are measured in pico-amps. These pico-amp changes are the measurements that quantify the triboelectric signal.

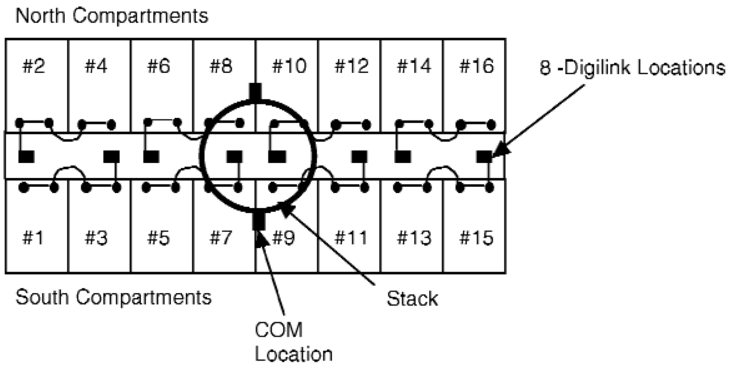
The triboelectric signal is an analog output that is displayed as a percent of scale. The absence of impacting or passing particles is measured as 0 percent, with the relative increase of particle presence (strikes or near passes) measured up to 100 percent of the scale. Because of the sensitivity of the measurement mechanism, the triboelectric BBD can detect particles as small as 2 microns in diameter.[2] These particles are

Figure 1



General arrangement of the Montpelier Works baghouse.

Figure 2



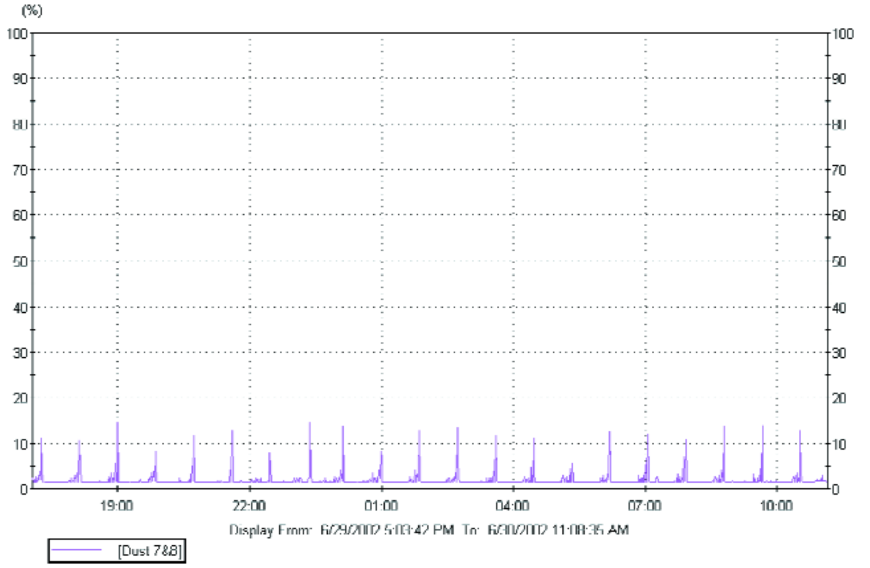
General arrangement of the Mobile Works baghouse.

Table 2

BBD System Specification Summary

Parameters	Montpelier	Mobile
Manufacturer	Auburn Systems LLC	Auburn Systems LLC
Model	Tribolink^{TM}	Tribolink^{TM}
Number of detector locations	4	8
Number of probe rods/location	2	4
Detector material of construction	316 stainless steel	316 stainless steel
Probe temperature range	–60 to 400°F	–60 to 400°F
Input/output interface	PC	PC
Operating system platform	Windows 98	Windows 98

Figure 3



Triboelectric signals: normal cleaning spikes in a positive-pressure baghouse.

invisible to the human eye and a continuous opacity monitor (COM).

The particle characteristics of size, shape and structure, as well as the quantity of particles present in the gas stream, affect the relative change in triboelectric signal. These factors have nothing to do with directly measuring the density or mass of the respective particle.

The BBD systems used by IPSCO employ the DC-based electrical power supply for the probes.

Emission Source and Effect on Triboelectric Signals

Since the triboelectric effect is dependent on changes in an electrical field, the base material composition of the particles has an effect on this measurement. Certain materials, such as metals, will have a greater effect proportionately on the triboelectric change than nonconducting materials. Since the measurements being tracked are relative (percent of scale), the output signal can be adjusted to fit a range that provides a signal that the operator can adjust to track the particles being removed by the control device at his location. Iron oxide particles, the majority portion of fume from EAF steelmaking and foundry furnaces, are a good triboelectric material. However, as noted earlier, there are several factors that affect the triboelectric signal. These include: shape, size, structure, quantity, velocity and chemical composition of the particles. These factors are independent variables that are unique to each emission source and fume control system.

The emission variability between sources is compensated for by adjusting the scale factor of the triboelectric system. Each detector (group of probes) sends a variable signal that is a measurement of the pico-amp changes affecting the probes. When the pico-amp effect of the particles is greater, the scale factor can be set lower and correspondingly adjusted if the effect is lower. The output measurement is a percent of the scale factor.

As an example, the scale factor for the Montpelier Works is 1,500 pico-amps (100 percent of scale = 1,500 pico-amps), while the scale factor at the Mobile Works is 250 pico-amps (100 percent of scale = 250 pico-amps). Both facilities produce the same type of steel product and have similar sources of raw materials; however, the design of a positive-pressure baghouse compared to a negative-pressure baghouse affects the velocity and quantity of particles passing the probes during normal operation. Even though the particles have the same basic chemistry, other independent variables affect the triboelectric system measurements at these locations. Correspondingly, each operating facility will have a unique triboelectric signature that will need to be evaluated in setting up the operating and alarm levels for the BBD system at that facility.

Figures 3 and 4 illustrate examples of real-time tracking of triboelectric signals for a probe detector on a positive- and negative-pressure baghouse, respectively. The negative-pressure baghouse signal in Figure 4 represents on-line cleaning, and the positive-pressure baghouse is off-line cleaning. The spikes shown on each of the signals are referred to as cleaning spikes and are associated with the release of dust that initially passes through a recently cleaned bag until the cake re-establishes on the surface of the fabric. In the case of the on-line cleaned row of bags (Figure 4), this spike is immediate and trails off over a short period of time. In the case of the off-line cleaned compartment (Figure 3), the spike is more discrete and drops off quickly. These figures illustrate the difference between signals of systems that are cleaned on-line (negative-pressure system) and off-line (positive-pressure system). However, the signals and the respective scale factors will vary from source to source, but the cleaning spike will be present in all systems. Monitoring of signal level and cleaning spikes will be discussed in a later section.

BBD System Application Considerations

Several factors should be evaluated when designing a BBD system to monitor a specific fume control system and emission source. The previous section explained the relative triboelectric uniqueness of each emission source. However, the successful and effective installation and operation of a BBD system needs to consider these additional factors:

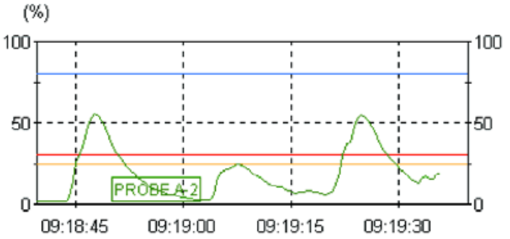
- The basic type of baghouse system ventilation: positive or negative airflow through the collector.
- The mechanism for cleaning the filter media (bags).
- Whether cleaning is done off-line or on-line.
- The degree of broken bag detection/identification: identification of the bag row or only the compartment.
- The location and number of probes.
- Environmental effects of temperature on the probes and the detectors.
- Signal output monitoring and control: use of PLC and HMI interfaces.
- Establishing the scale factor: determining what is a normal signal.
- Establishing the alarm levels: permit conditions that are reportable violations.
- Operator training.

Each of these considerations is discussed in more detail in the following sections.

Positive and Negative Flow Systems — Generally, the clean side airflow from the baghouse compartments is monitored by the triboelectric probes. A negative flow system discharges the air into a relatively small cross-section plenum that collects air from a line of compartments, and a positive-pressure system discharges air into a relative large cross-section plenum or directly to a ridge vent. The velocity of the particles in the negative-pressure plenum is typically much higher than that of particles discharging into a penthouse on top of a positive-pressure compartment. With higher velocity, the number of probes needed to monitor a given gas stream tends to decrease. A number of compartments in a negative-pressure plenum can be monitored by a single probe location, as indicated in Figure 1. In the case of a positive-pressure system, the individual compartments can discharge directly to the atmosphere through a relatively large cross-section (low-velocity) pathway. Figure 5 illustrates a typical positive-pressure baghouse compartment and the location for a monitoring probe(s).

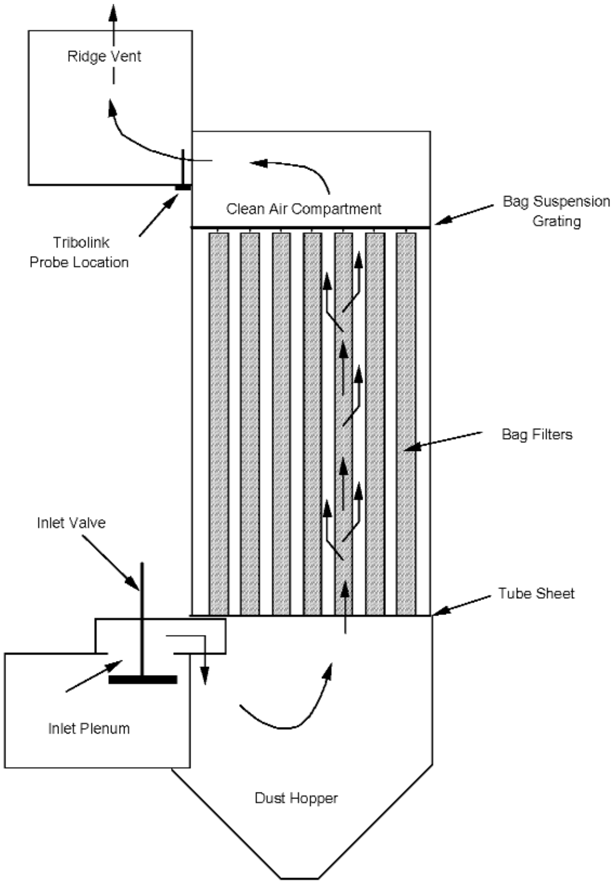
Cleaning Method — The cleaning methods for a metal fume baghouse generally use either pulse jet or reverse flow. Mechanical shaking is not typically used because of the abrasion created in bag folds that develop when the bag tensions are not kept tight. Reverse-air cleaning requires that the compartment being cleaned is isolated from the offgas stream so the compartment airflow can be reversed. Pulse-jet-cleaned units can be cleaned without isolating the compartment from the offgas. Alternatively, the pulse-jet baghouse can be cleaned off-line. This alternative for compartment isolation during cleaning will affect how the BBD system monitoring is set up. The operator of a pulse-jet-cleaning baghouse must determine whether his system will use compartment isolation or

Figure 4



Triboelectric signals: normal cleaning spikes in a negative-pressure baghouse.

Figure 5



Positive-pressure baghouse compartment probe location.

For a baghouse that will be cleaning online, the number of compartments simultaneously cleaning will directly affect the number of detector zones installed in the BBD system. Generally, the more cleaning zones there are, the more detectors are needed for the baghouse.

For positive-pressure baghouse systems, the design of the ridge vent will determine how many zones can be established. Baghouses can generally have two types of vents, either a continuous ridge vent (CRV) running along the centerline of the structure or a series of circular vents along the centerline, combining the exhaust gas from groups of compartments. As noted previously, only whole compartment exhaust gas can be monitored on positive-pressure baghouses.

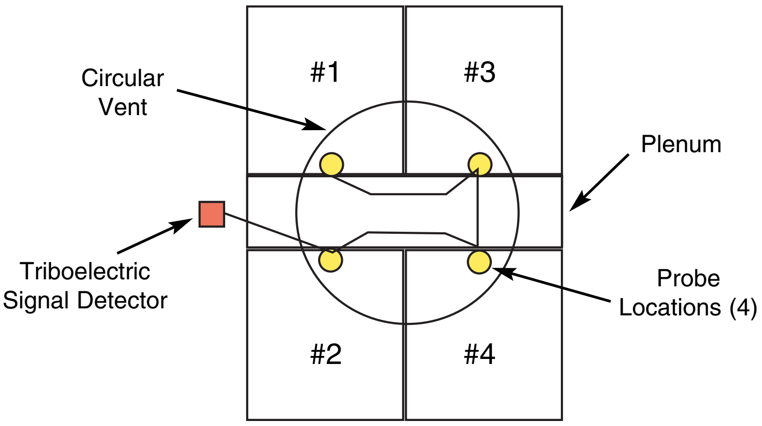
In the case of circular vents, each of the compartments under a vent can be combined into a zone, since their exhaust gas will directly affect the visibility of the emissions from that vent. The actual number of probes will be determined by the geometry of the individual compartment exhaust to the vent plenum. For example, Figure 6 illustrates a four-compartment exhaust under a circular ridge vent. A total of four probes are combined in this zone. However, since the probes are linked in series to the triboelectric signal origination device (signal detector), the output is seen as a single signal. The baghouse PLC tracks which compartment is cleaning and identifies the cleaning spike alarm so the information can be sent to a data file for operator reference, or the compartment can be isolated until it is manually inspected and returned to service by the operator. This minimum programming will optimize the number of zones needed in the BBD system.

The CRV design of exhaust configuration can be optimized in a similar manner as the circular vent arrangement. The maximum number of compartments comprising a monitoring zone can be established by the owner/operator. However, the number of compartments contributing exhaust to a given length of CRV should be used to set the number of compartments per zone.

Each facility will need to be independently evaluated to meet the objectives of the owner/operator while developing a BBD system design that is effective and provides the lowest installation cost.

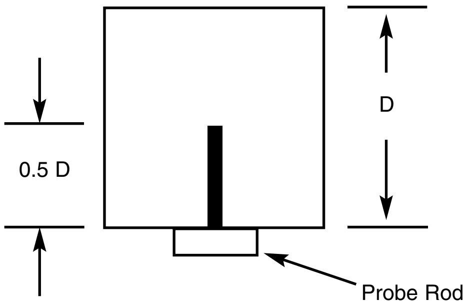
Number of Probes: The geometry of the exhaust plenum in a negative-pressure baghouse and the exhaust port geometry of a positive-pressure compartment will establish how many actual probe detector rods are installed. Since the probe rods are connected in series, the triboelectric signal detector sees the effect of each rod as a cumulative triboelectric change. The change of each rod is added to the next rod in the series, until the total change is measured by the triboelectric signal detector and transmitted as a relative 4–20 mA signal to the input/output board of the PLC.

Figure 6



Organization of a circular ridge vent broken bag detector.

Figure 7



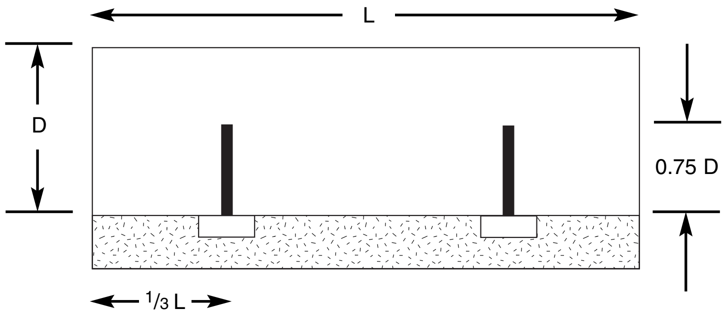
Negative-pressure plenum duct.

For example, the configuration of probe rods illustrated in Figure 6 contains a total of four probe rods. However, the PLC sees only a single probe signal (the sum of the four probe rods' individual triboelectric changes) from the triboelectric signal detector for this zone.

Figure 7 illustrates the typical probe rod geometry in the plenum of a negative-pressure baghouse. The figure is a cross-section of the plenum duct. The probe's length should reach to the midpoint of the duct and be located on the centerline of the section.

Figure 8 illustrates the location of probe rods across the exhaust port of the clean room into the plenum beneath the CRV or circular vent. The figure is a cross-section looking back into the clean room of the compartment. Exhaust gas would be flowing from the page toward the reader. Generally, the lower velocity associated with the larger cross-section of

Figure 8



Positive-pressure compartment exhaust port.

the exhaust port requires several probe rods located across the port. The probe rods would be linked in series, and as noted previously, their triboelectric change is seen as a common signal.

These illustrations are not hard design parameters, but are presented to act as guidelines that can be used for the selection of the probe rod locations. Probe rod lengths are generally limited to 6 feet when using standard 316 stainless steel. Probe rods of greater length require special construction and materials to ensure that the rod does not flex under the air loading and its own weight. Alternative detector designs using other than probe rods are being developed by some manufacturers.

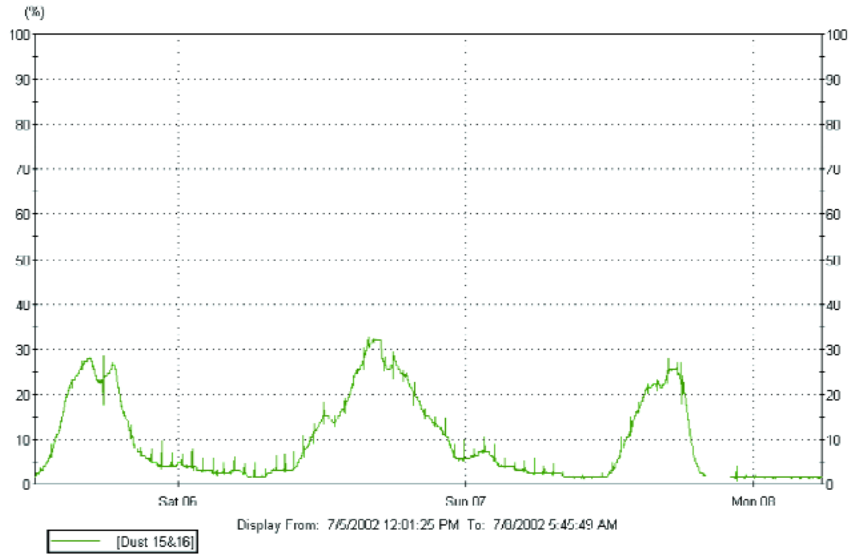
Temperature Effects on the Probe Rods and Detector Locations — The probe rods are generally not affected by temperature extremes. The ambient temperature range listed for the probe rods is –60 to 400°F. Most baghouses have offgas temperatures below 270°F, the upper temperature limit of polyester bags.

The triboelectric detector, on the other hand, is much more sensitive to temperature extremes. The operating range for the hardware of the detector is +20 to 160°F. Since the coaxial signal length from the last probe rod location to the detector is limited to 150 feet, the detector cannot be located at ground level on larger baghouses. Generally, the detector equipment is located at the penthouse or bag maintenance level of the baghouse. The detectors for multiple zones can be located in a central cabinet that can be either heated or cooled as necessary to maintain the equipment within the specification temperature range.

The location of the detectors on the sheet metal walls of the compartments, although a typical location, can present a temperature problem during summer in the warmer latitudes. An offgas temperature of +200°F can conduct a significant amount of heat through the sheet metal wall, especially when the ambient outside temperatures can exceed 100°F heat index on a daily basis. Cooling of the cabinet containing the detectors can present more of a challenge than heating. A small radiant heater or 100-watt light bulb in an insulated cabinet can provide sufficient heat during cold months, while chilled air will be necessary to cool the cabinet in seasonally high temperatures.

It is important to identify the manufacturer's temperature specification for the detector hardware, and plan to protect the equipment from the extremes in temperature that might be present in the baghouse environment. The output signal from the detector will not be reliable when it is operating outside of its temperature envelope. Figure 9 illustrates a triboelectric signal that has been affected by heat interference. The spikes in the illustration do not correspond to cleaning spikes.

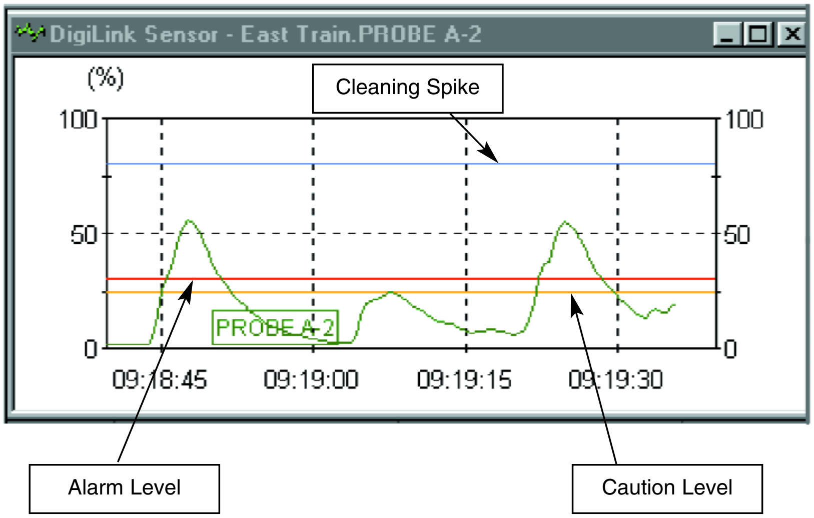
Figure 9



Effect of heat interference on triboelectric signals.

Signal Output Monitoring — The triboelectric signal is generated on a real-time basis; typically two measurements per second are generated from the detector. This quantity of data is quite large, and real-time tracking is generally set at intervals that are based on fractions of a minute. The detector output varies and can be set to monitor only for an alarm level, or a real-time tracking of a 4–20 mA signal. The signal

Figure 10



BBD system alarm levels.

surrogate testing can be done to establish protective alarm levels below the violation standard. However, this is not always necessary. Alarm levels can be set based on observation of the normal patterns and events that do result in exceedances.

The caution level is intended to give the operator an advance warning of rows or compartments that have begun to increase their signal from the normal baseline. This condition generally is an indication that a bag or bags have begun to leak at some small level. The operation program at IPSCO requires the operator to respond to the caution alarm as soon as possible and make the necessary investigation and corrective actions.

At the alarm level, the baghouse PLC sends an alarm signal to the alarm record file and triggers an alarm on the baghouse HMI screen and the EAF operator's HMI screen at the same time. The alarm level requires immediate operator response and corrective action.

A cleaning spike alarm is logged to the alarm file and announced on the baghouse operator's HMI screen. Investigation of the cleaning spike identified row or compartment is generally part of the maintenance "to do" list during the next scheduled outage for the meltshop. This proactive investigation and corrective action for cleaning spike alarms has identified problem bags long before a visible emission violation can occur.

It should also be noted that signal patterns can change over time, necessitating changes in the alarm levels. A change in the type or manufacturer of the bags used in the baghouse, and the age of the bags, will affect the normal signal characteristics.

Operator Training — Once the BBD system alarm and normal operating parameters have been established, the employees responsible for maintenance and operation of the baghouse system need to be trained to use the system. This will typically require both classroom and on-the-job training to provide the necessary information to establish operator confidence in the system. It is also important to assess operator feedback over time. Adjustments and improvements in the system can be made to enhance the BBD system's usefulness and reliability.

Quality Control and Quality Assurance Program

A written QC/QA program needs to be developed for the BBD system at a particular facility. This program should include the following considerations, at a minimum:

- The inspection frequency and cleaning of the probe rods.
- Visual inspection of the cables/conduit of the BBD system.
- Electrical calibration/verification of the system components at intervals recommended by the manufacturer.
- Backup hardware for the historic signal file records.
- The period of time that historic records should be maintained. Permits can contain minimum record retention requirements.
- Annual review of the BBD system by the manufacturer or a consultant engineer to determine whether changes need to be made in alarm levels or the system scale factor.
- The method of QC/QA record keeping.

A QC/QA program is a requirement of the standards, and specific facility permits may require specific actions. It is important to review the facility permit to ensure that any such requirements are included in the written QC/QA plan for the facility.

Operation and Maintenance Program

Several basic considerations should be determined by the owner/operator of the baghouse before finalizing the BBD system programming and interface with the baghouse PLC. These include the following:

- BBD system manufacturers provide dedicated software for application to a PC as the HMI interface. The BBD system can be effectively operated without this software; however, the decision of