Designation: D7392 – 07 (Reapproved 2013)

Standard Practice for
PM Detector and Bag Leak Detector Manufacturers to Certify Conformance with Design and Performance Specifications for Cement Plants[1]

This standard is issued under the fixed designation D7392; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the procedure for certifying particulate matter detectors (PMDs) and bag leak detectors (BLDs) that are used to monitor particulate matter (PM) emissions from kiln systems at Portland cement plants that burn hazardous waste. It includes design specifications, performance specifications, test procedures, and information requirements to ensure that these continuous monitors meet minimum requirements, necessary in part, to monitor reliably PM concentrations to indicate the need for inspection or corrective action of the types of air pollution control devices that are used at Portland cement plants that burn hazardous waste.

1.2 This practice applies specifically to the original manufacturer, or to those involved in the repair, remanufacture, or resale of PMDs or BLDs.

1.3 This practice applies to (*a*) wet or dry process cement kilns equipped with electrostatic precipitators, and (*b*) dry process kilns, including pre-heater pre-calciner kiln systems, equipped with fabric filter controls. Some types of monitoring instruments are suitable for only certain types of applications.

NOTE 1—This practice has been developed based on careful consideration of the nature and variability of PM concentrations, effluent conditions, and the type, configuration, and operating characteristics of air pollution control devices used at Portland cement plants that burn hazardous waste.

1.4 This practice applies to Portland cement kiln systems subject to PM emission standards contained in 40 CFR 63, Subpart EEE.

NOTE 2—The level of the PM emission limit is relevant to the design and selection of appropriate PMD and BLD instrumentation. The current promulgated PM emission standards (70 FR 59402, Oct. 12, 2005) are: (*a*) 65 mg/dscm at 7 % O_2 (0.028 gr/dscf at 7 % O_2) or approximately 30 mg/acm (0.013 gr/acf) for "existing sources" and (*b*) 5.3 mg/dscm at 7 % O_2 (0.0023 gr/dscf at 7 % O_2) or approximately 2.5 mg/acm (0.001 gr/acf) for "new sources." On March 23, 2006 (71 FR 14665) EPA proposed to revise the PM standard for new cement plants to 15.9 mg/dscm at 7 % O_2 (0.0069 gr/dscf at 7 % O_2), or about 6-9 mg/acm (0.0026-0.0039 gr/acf). The emission standards may change in future rulemakings, so users of this practice should check the current regulations. Some types of monitoring instruments are not suitable for use over the range of emissions encountered at both new and existing sources.

1.5 The specifications and test procedures contained in this practice exceed those of the United States Environmental Protection Agency (USEPA). For each monitoring device that the manufacturer demonstrates conformance to this practice, the manufacturer may issue a certificate that states that monitoring device conforms with all of the applicable design and performance requirements of this practice and also meets all applicable requirements for PMDs or BLDs at 40 CFR 63, Subpart EEE, which apply to Portland cement plants.

NOTE 3—40 CFR 63.1206 (c)(8) and (9) requires that BLDs and PMDs "be certified by the manufacturer to be capable of detecting particulate matter emissions at concentrations of 1.0 milligrams per actual cubic meter unless you demonstrate under §63.1209(g), that a higher detection limit would routinely detect particulate matter loadings during normal operations." This practice includes specific procedures for determination and reporting of the detection limit for each PMD or BLD model.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D6216 Practice for Opacity Monitor Manufacturers to Certify Conformance with Design and Performance Specifications

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[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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D6831 Test Method for Sampling and Determining Particulate Matter in Stack Gases Using an In-Stack, Inertial Microbalance

2.2 *U.S. Environmental Protection Agency Documents:*[3]

40 CFR 63, Subpart EEE National Emission Standards for Hazardous Air Pollutants: Final Standards for Hazardous Air Pollutants for Hazardous Waste Combustors

2.3 *Other Documents:*[4]

ISO/DIS 9004 Quality Management and Quality System Elements-Guidelines

ANSI/NCSL Z 540-1-1994 Calibration Laboratories and Measuring Equipment - General Requirements

3. Terminology

3.1 For terminology relevant to this practice, see Terminology D1356.

3.1.1 Definitions for transmittance measurement equipment (that is, opacity monitors) are provided in Practice D6216.

3.2 *Definitions of Terms Specific to This Standard:*

Analyzer Equipment

3.2.1 *bag leak detector [BLD], n*—an instrument installed downstream of a fabric filter control device that interacts with a PM-laden effluent stream and produces an output signal of sufficient accuracy and repeatability to track changes in PM control device performance and, together with appropriate data analysis, indicates the need to inspect the fabric filter as referenced in the Federal Register, 40 CFR 63, Subpart EEE. BLDs are used to track rapid changes in PM concentration and must have sufficient dynamic range to track both "peaks" and baseline PM levels and include provisions for adjusting the averaging period, alarm delay, and alarm set point appropriate for source-specific conditions. BLDs must also include provisions to detect faults or malfunctions of the measurement system.

3.2.2 *particulate matter detector [PMD], n*—an instrument that interacts with a PM-laden effluent stream and produces an output signal of significant accuracy and repeatability so as to indicate significant changes in the concentration of particulate material entrained in the effluent downstream of an electrostatic precipitator or fabric filter as referenced in the Federal Register, 40 CFR 63, Subpart EEE. PMDs are used to track changes in PM concentrations using six-hour rolling averages, updated each hour with a new one-hour block average. PMDs must also include provisions to activate an alarm and detect faults or malfunctions of the measurement system.

3.2.2.1 *Discussion*—PMDs and BLDs are inherently inferential monitoring devices that sense some parameter which, in the absence of interfering effects, is directly related to PM concentrations.

3.2.2.2 *Discussion*—This practice does not discriminate between measurement techniques but instead provides design specifications and performance standards that all devices must satisfy to be acceptable as a PMD or BLD for a cement kiln that burns hazardous waste. Techniques for continuously measuring PM include optical transmittance ("opacity"), dynamic opacity ("scintillation"), optical scatter (side, forward and back scatter), and probe electrification (sensors based on induction, contact charge transfer, or combination of effects).

NOTE 4—Extractive systems using Beta attenuation to sense PM deposited on filters are used as PM CEMS but can not meet the sampling and analysis frequency required by EPA regulations for PMDs and BLDs.

3.2.2.3 *Discussion*—PMD and BLD instruments that conform to the requirements of this practice include automated internal mechanisms that are used to verify proper performance of the measurement device on a daily basis, or more frequent basis if recommended by the manufacturer. PMD instruments include mechanisms to facilitate external periodic audits of the measured parameter.

3.2.3 *light-scatter, n*—the extent to which a beam of light is reflected, refracted, or diffracted via interaction with PM in a medium such that a measurable portion of the original beam's energy is redirected outside the original angle of projection.

3.2.3.1 *Discussion*—Back-scatter is generically defined as scattering in excess of 150 degrees from the direction of the original projected beam, side-scatter is generically defined as scattering between 30 degrees and 150 degrees from the original direction, and forward-scatter is generically defined as scattering of less than 30 degrees from the projected beam.

3.2.3.2 *Discussion*—Because the correlation between the intensity and angular distribution of light scattering and the actual PM mass concentration is dependent on factors such as particle size, particle shape, wavelength of light, particle density, etc., this practice is limited to: (*a*) verification of the stability, linearity, and interference rejection of the measurement of scattered light, and (*b*) verification of the instrument sensitivity and detection limit. This practice does not recommend any specific light-scattering technology, and leaves the evaluation of the application to the discretion of the user of a BLD or PMD.

3.2.3.3 *Discussion*—A light-scatter BLD or PMD may include the following: (*a*) sample interface equipment such as filters and purge air blowers to protect the instrument and minimize contamination of exposed optical surfaces, (*b*) shutters or other devices to provide protection during power outages or failure of the sample interface, and (*c*) a remote control unit to facilitate monitoring the output of the instrument, initiation of zero and upscale calibration checks, or control of other BLD or PMD functions.

3.2.4 *dynamic opacity, n*—the amount of light variation caused by particles traversing a cross-stack beam of transmitted light.

3.2.4.1 *Discussion*—Dynamic opacity instruments measure the alternating component of the transmitted light and are sometimes referred to as scintillation instruments.

3.2.4.2 *Discussion*—In certain dynamic instruments the measured alternating signal (light variation) is divided by the average transmitted light intensity signal to provide a ratio measurement. This ratio is unaffected by optics contamination.

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[3] Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20004, http://www.epa.gov.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.2.5 *probe electrification, n*—methods by which the charge carried on PM creates a signal in a grounded sensing rod through charge induction, contact, or combination.

3.2.5.1 *Discussion*—Probe electrification instruments measure the current produced by charged particles passing or impacting a grounded sensing rod. Certain instruments measure the DC component of the signal, the AC component of the signal or both the DC and AC components of the signal.

3.2.5.2 *Discussion*—Probe electrification instruments can be used after fabric filters where the particle charge is relatively constant. The influence of changing velocity should be considered when considering using probe electrification devices in applications with variable speed fans or variable flow.

3.2.6 *BLD or PMD measuring volume, n*—the spatial region in which the particles interact with the instrument to produce a measurable signal.

3.2.6.1 *Discussion*—For light scattering or transmittance instruments, the measuring volume is the spatial region where the projected light and the field of view of the detector optics overlap in which the PM concentration can be detected via scattering of light or reduction of transmittance. For probe electrification instruments the measuring volume is the area near the sensing probe.

3.2.7 *nominal full scale, n*—the default, as-shipped full scale calibration of a BLD or PMD, based on standard gains and offset settings established during field performance tests under Section 7.

3.2.7.1 *Discussion*—The nominal full scale (NFS) will be determined by the manufacturer by means of data taken as part of the verification of instrument sensitivity and detection limit on at least one representative cement kiln installation.

3.2.8 *BLD or PMD model, n*—a specific BLD or PMD configuration identified by the specific measurement system design, including: (*a*) the use of specific source, detector(s), lenses, mirrors, and other components, (*b*) the physical arrangement of principal components, (*c*) the specific electronics configuration and signal processing approach, (*d*) the specific calibration check mechanisms and drift/dust compensation devices and approaches, and (*e*) the specific software version and data processing algorithms, as implemented by a particular manufacturer and subject to an identifiable quality assurance system.

3.2.8.1 *Discussion*—Minor changes to software or data outputs that do not affect data processing algorithms or status outputs are not be considered as a model change provided that the manufacturer documents all such changes and provides a satisfactory explanation in a report.

3.2.8.2 *Discussion*—Software installed on external devices, including external computer systems, and used for processing of the PMD or BLD output to generate average values or activate alarms is not considered part of the PMD or BLD monitoring device.

3.2.8.3 *Discussion*—For the purposes of this practice, the BLD or PMD includes the following components which are described in subsequent sections: (*a*) internal zero and upscale performance check devices to evaluate instrument drifts while installed on a stack or duct; (*b*) apparatus and means to quantify, independent of the internal zero and upscale performance check devices, the degree to which the response of the BLD or PMD has changed over a period of time.

Analyzer Zero Adjustments and Devices

3.2.9 *external zero audit device, n*—an external device for checking the zero alignment or performance of the measurement system either by simulating with a surrogate the zero-PM condition for a specific installed BLD or PMD or by creating the actual zero-particulate condition.

3.2.10 *internal zero performance check device, n*—an automated mechanism within a BLD or PMD that simulates a zero PM condition while the instrument is installed on a stack or duct using a surrogate appropriate to the measurement technique.

3.2.10.1 *Discussion*—The internal zero performance check device may be used to check zero drift daily, or more frequently if recommended by the manufacturer, and whenever necessary (for example, after corrective actions or repairs) to assess BLD or PMD performance.

3.2.10.2 *Discussion*—The proper response to either the external zero audit device or the internal zero performance check device are established with the PMD set up in a clean environment and in such a way that no interference or stray signal reaches the detector. The internal zero performance check device thereby provides the surrogate, simulated zero PM condition while the PMD is in service and the external zero audit device provides a check, which is independent of the internal zero performance check, of the proper performance of the PMD.

3.2.11 *zero alignment, n*—the process of establishing the quantitative relationship between the internal zero performance check device and the zero PM responses of a PMD.

3.2.12 *zero compensation, n*—an automatic adjustment of the BLD or PMD to achieve the correct response to the internal zero performance check device.

3.2.12.1 *Discussion*—Zero compensation adjustment is fundamental to the BLD or PMD design and may be inherent to its operation (for example, continuous adjustment based on comparison to reference values/conditions, use of automatic control mechanisms, rapid comparisons with simulated zero and upscale calibration drift check values, and so forth) or it may occur each time a control cycle (zero and upscale performance check) is conducted by applying either analog or digital adjustments within the BLD or PMD.

3.2.13 *zero drift, n*—the difference between the BLD or PMD responses to the internal zero performance check device and its nominal value after a period of normal continuous operation during which no maintenance, repairs, or external adjustments to the BLD or PMD took place.

3.2.13.1 *Discussion*—Zero drift may occur as a result of changes in the energy source, changes in the detector, variations in internal scattering, changes in electronic components, or varying environmental conditions such as temperature, voltage or other external factors. Depending on the design of the BLD or PMD, PM (that is, dust) deposited on optical surfaces or surface of a probe may contribute to zero drift. Zero drift may be positive or negative. The effects (if any) of dust deposition on optics or deposits on probes will be a monotonically increasing or decreasing function depending on the type of instrument. Particular designs may separate dust compensation and other causes of zero drift.

3.2.14 *light trap, n*—A device used to absorb the projected light from a light scattering BLD or PMD, so as to eliminate false optical scattering due to reflections from the inner walls of a duct or stack.

Analyzer Upscale Calibrations and Adjustments

3.2.15 *internal upscale performance check device, n*—an automated mechanism within a BLD or PMD that (*a*) simulates an upscale value of the parameter sensed by the BLD or PMD while the instrument is installed on a stack or duct and (*b*) provides a means of quantifying consistency or drift in the BLD or PMD response.

3.2.15.1 *Discussion*—The internal upscale performance check simulates the parameter sensed by the PMD that is related to dust concentration and provides a check of all active analyzer internal components including optics, active electronic circuitry including any light source and detectors, electric or electro-mechanical systems, and hardware, or software within the nominal operating ranges of the instrument.

3.2.15.2 *Discussion*—The internal upscale performance check for a BLD may include one or a series of checks in order to evaluate all of the active components of the measurement device and provide for the detection of conditions that adversely affect the measurement system performance.

3.2.16 *external upscale audit device, n*—an external device for verifying the stability of the upscale calibration of the BLD or PMD by applying a reference signal or condition independent of the internal simulated upscale calibration device.

3.2.17 *reference signal source, n*—a device that can be used to simulate a signal that the PMD measures, corresponding to a given PM concentration, as established when testing to set up the NFS. In the case of a BLD, the reference signal source may be one or a combination of test signals/conditions that are applied and, taken together, provide a comprehensive test the correct operation of the instrument.

3.2.17.1 *Discussion*—For a light scattering instrument, the reference signal may be a glass or grid filter that reduces the transmittance of light, or a reflective target of defined reflectivity, such as a photographer's standard, commercially available photo-gray material, or an adjustable iris, or any combination of such elements, that can be used to simulate a given intensity of scattered light corresponding to a given concentration of PM, as established when testing to set up the NFS. Care should be taken to select materials with properties that are not affected by aging.

3.2.17.2 *Discussion*—The PMD reference signal source or attenuator, components need not be NIST-traceable materials, but need to be commercially available and subject to testing and verification for consistency.

3.2.17.3 *Discussion*—The PMD external zero audit device and the external upscale audit device may be combined into one device, where the use of design-appropriate PMD reference signal source are used both to create a zero-PM condition and to simulate two or more upscale conditions. For light scattering instruments, the external upscale audit device or combination device may generate the required reference signals by utilizing one or more attenuators, reflectance targets, or other reference materials in any combination to change the intensity of the projected light, or the scattered light reaching the detector.

3.2.17.4 *Discussion*—The key attributes of the PMD audit device are that: (*a*) it uses the same active components as are used for making the PM measurement; (*b*) it is capable of monitoring any credible change in instrument response not caused by changes in determinant or stack conditions; and (*c*) it checks the instruments components in the same physical and measurement condition as that in making the PM measurement.

3.2.17.5 *Discussion*—The reference signals applied to the BLD must challenge all of the key active components of the instrument. They are not necessarily a surrogate for dust (as in a PMD), but the reference signals must check the correct operation of the instrument.

3.2.18 *calibration drift, n*—the difference between the BLD or PMD responses to the internal upscale performance check device and its nominal value after a period of normal continuous operation during which no maintenance, repairs, or external adjustments to the BLD or PMD took place.

3.2.18.1 *Discussion*—Calibration drift may be determined either before or after determining and correcting for zero drift.

3.2.19 *linearity error, n*—the differences between the BLD or PMD readings and the values of two reference signal sources under zero-PM conditions, using the external zero and upscale audit device(s).

3.2.19.1 *Discussion*—The linearity error indicates the fundamental calibration status of the BLD or PMD.

3.2.20 *instrument response time, n*—the time required for the electrical output of a BLD or PMD to achieve greater than 95 % of a step change in the parameter sensed.

4. Summary of Practice

4.1 This practice provides a comprehensive series of specifications and test procedures that BLD and PMD manufacturers must use to certify systems prior to shipment to the end user. The specifications are summarized in Table 1. Certification of conformance with the requirements of this practice requires providing information or test results, or both, in four parts.

4.2 To satisfy the certification requirements of Part 1 "Manufacturer's Disclosure," the manufacturer is required to provide certain information about the monitoring equipment and written procedures for certain activities to the end user. The specific requirements are included in Section 6.

4.3 To satisfy the certification requirements of Part 2, "Field Demonstration" the manufacturer must conduct a one-time field test at a Portland cement plant for each model (and whenever there is a change in the design that may significantly affect performance) and demonstrate that the BLD or PMD monitoring equipment meets the applicable specifications as provided in Section 7.

4.4 To satisfy the certification requirements of Part 3, "Design Specifications" the manufacturer must certify that the

TABLE 1 Summary of Manufacturer's Specifications and Requirements

Specification	Requirement	PMD	BLD
Part 1 Manufacture's Disclosure		Subsections	
Provide written description of monitor principles, internal calibration checks procedure and limitations, and external audit procedures and limitations	Provide non-proprietary information for review by users	6.1	6.1
Provide written operation, maintenance and quality assurance recommendations	Provide information for review and reference by users	6.2	6.2
Provide written procedures for setting BLD alarms	Provide information for review and reference by users	NA	6.3
Part 2 Field Demonstration (Test each model once)	90 days field test at cement plant	**PMD**	**BLD**
		Subsections	
Availability (excluding start-up period)	≥95 % of source operating time	7.3	7.3
Internal Zero Drift	≤2 % NFS or manufacturer's specification, whichever is most restrictive	7.4	7.4
Internal Upscale Drift	≤2 % NFS or manufacturer's specification, whichever is most restrictive	7.4	7.4
Repeatability (comparison of two instruments)	STD of paired differences ≤ 10 % of mean or ≤ 3 % NFS, whichever is least restrictive	7.5	7.5
External Zero and Upscale Audit Error	≤3 % NFS or manufacturer's specification, whichever is most restrictive	7.6	7.6
Analytic Function (comparisons to co-located gravimetric test method results during the first and last month of test period)	PMD Correlation Coefficient ≥0.85 BLD Correlation Coefficient ≥0.75 Confidence Interval ≤1 % Tolerance Interval ≤25 %,	7.7.10	7.7.10
	Optional Specification 1 (when test concentrations are limited by operational constraints): Relative Accuracy ≤20 %	7.7.11	7.7.11
	Optional Specification 2 (when the mean test concentrations are less than 5 mg/acm [0.002 gr/acf]): Correlation Coefficient ≥0.75	7.7.12	7.7.12
Field Detection Limit	Determine and report as specified: Noise Limited Detection Limit Observed Detection Limit	7.8	7.8
Part 3 Design Specifications (Test representative instrument once per year for each model)		**PMD**	**BLD**
		Subsections	
Measurement output resolution	≥0.5 % NFS	8.2	8.2
Measurement frequency	15 seconds	8.2	8.2
Data recording	60 seconds	8.2	8.2
PMD data averaging	15 minute periods and hourly averages (External devices may be used for averaging and recording data)	8.2	NA
BLD data averaging	Manufacture to specify based on alarm procedure	NA	8.2
Internal zero performance check device	Automated mechanism required	8.3.1	8.3.3
Internal upscale performance check device	Automated mechanism required	8.3.2	8.3.3
External zero audit device	Required	8.4	8.4
PMD external upscale audit device	Must provide upscale check of parameter sensed by PMD at two levels and include source, detector, and all active measurement components	8.4	NA
BLD external upscale audit device	A check, or series of checks when combined, which test the status of the upscale response and integrity of measurement device	NA	8.4
External audit device repeatability	±2.0 % NFS	8.4	8.4
Status indicators	Manufacturer to identify and specify	8.5	8.5
Insensitivity to supply voltage variations	±1.0 % NFS change over specified range of supply voltage variation, or ±10 % variation from the nominal supply voltage	8.6	8.6
Thermal stability	±2.0 % NFS change per 22ºC (40°F) change over specified operational range	8.7	8.7
Insensitivity to ambient light (optical instruments only)	±2.0 % NFS max. change for solar radiation level of ≥900 W/m^2	8.8	8.8
Part 4 Performance Specifications (Test Each Instrument)		**PMD**	**BLD**
		Subsections	
PMD instrument response time	≤15 seconds to 95 % of final value	9.3	NA
BLD instrument response time	≤1 second to 95 % of final value	NA	9.3
Linearity error	≤3 % NFS for two upscale values	9.4	9.4
Calibration device repeatability	≤1.5 % NFS	9.5	9.5

"NFS" is nominal full scale as defined 3.2.6.2

BLD or PMD design meets the applicable requirements for (*a*) measurement output resolution, (*b*) measurement frequency, (*c*) data recording and data averaging, (*d*) internal zero and upscale performance checks, (*e*) external zero audit device, (*f*) external upscale audit capability, and (e) status indicators. In addition, the manufacturer must demonstrate conformance with design specifications for thermal stability, insensitivity to line voltage variation, and insensitivity to ambient light (optical systems) by testing a representative instrument annually (and whenever there is a change in the design, manufacturing process, or component that may affect performance) and demonstrate that the BLD or PMD monitoring equipment meets the applicable specifications as provided in Section 8.

4.5 To satisfy the certification requirements of Part 4 "Performance Specifications" the manufacturer must demonstrate conformance with specifications provided in Section 9 for instrument response time, linearity error and calibration device repeatability by testing each BLD or PMD instrument prior to shipment to the end user. The manufacturer must include procedures for establishing the value for the PMD internal upscale performance check device.

4.6 Guidance and recommendations for determining PMD 15-minute averages, one-hour block averages, and six-hour rolling averages are provided in Appendix X1.

4.7 Guidance and recommendations for setting BLD averaging period, alarm delay, and alarm levels are provided in Appendix X2.

4.8 This practice establishes appropriate guidelines for QA programs for manufacturers of BLDs and PMDs. These guidelines include corrective actions when information provided by the manufacturer is determined to be incorrect or non-representative based on field applications, or when non-conformance with specifications is detected through periodic tests. Non-conformance with the design or performance specifications requires corrective action and retesting of the affected model(s)

5. Significance and Use

5.1 EPA regulations require Portland cement plants that burn hazardous waste to use BLDs or PMDs to provide either a relative or an absolute indication of PM concentration and to alert the plant operator of the need to inspect PM control equipment or initiate corrective action. EPA and others have not established for these applications specific design and performance specifications for these instruments. The design and performance specifications and test procedures contained in this practice will help ensure that measurement systems are capable of providing reliable monitoring data.

5.2 This practice identifies relevant information and operational characteristics of BLD and PMD monitoring devices for Portland cement kiln systems. This practice will assist equipment suppliers and users in the evaluation and selection of appropriate monitoring equipment.

5.3 This practice requires that tests be conducted to verify manufacturer's published specifications for detection limit, linearity, thermal stability, insensitivity to supply voltage variations and other factors so that purchasers can rely on the manufacturer's published specifications. Purchasers are also assured that the specific instrument has been tested at the point of manufacture and shown to meet selected design and performance specifications prior to shipment.

5.4 This practice requires that the manufacturer develop and provide to the user written procedures for installation start-up, operation, maintenance, and quality assurance of the equipment. This practice requires that these same procedures are used for a field performance demonstration of the BLD or PMD monitoring equipment at a Portland cement plant.

5.5 The applicable test procedures and specifications of this practice are selected to address the equipment and activities that are within the control of the manufacturer.

5.6 This practice also may serve as the basis for third party independent audits of the certification procedures used by manufacturers of PMD or BLD equipment.

6. Manufacturer's Disclosure

6.1 The equipment manufacturer shall provide a written statement and relevant information for each BLD or PMD model as part of the manufacturer's certification of conformance with this practice in response to the issues identified below. (In the event the manufacturer has no reliable information about a particular area, the certification shall explicitly state that it is "unknown" or information is "not available.")

6.1.1 Measurement principle description and specific parameter(s) monitored. (For example, a light transmittance measurement system may be used and the optical density output may be monitored.)

6.1.2 Nominal PM concentration measurement range(s) (in units of mg/acm) over which monitoring device can meet all specifications in this practice and corresponding instrument output units. The minimum detection limit, minimum practical quantification level, and nominal maximum PM concentration level should be indicated.

6.1.3 *Analytic Function*—Linear or other output that can be corrected to provide a linear system response.

6.1.4 Description of internal zero and upscale performance checks. Identification of components or influences excluded from these checks and explanation of the underlying assumptions, and other relevant limitations.

6.1.5 Description of external audit capabilities and audit materials that can be used for periodic independent checks. Identification of components or influences excluded from such external audits and explanation of the underlying assumptions, and other relevant limitations.

6.1.6 Identification and description of known uncontrollable effluent or PM variables that affect the PMD or BLD response. Quantitative information should be provided if available from the manufacturer conducted tests or appropriately referenced based on TUV, MCERTS, or other similar tests or evaluations, if available.[5]

6.1.7 A description of cross sensitivities and interferences due to changing effluent conditions that are expected to occur when monitoring kiln emissions at cement plants burning hazardous waste. This shall include statements regarding the PMD or BLD response to changes in effluent (*a*) flow rate or velocity at the point of measurement, (*b*) effluent temperature, (*c*) effluent moisture content, (*d*) effluent gas composition, and

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[5] (Note: TÜV (Technischer Überwachungs Verin) is an internationally recognized certification and testing organization in the Federal Republic of Germany (with offices word wide) that performs laboratory and field tests of environmental monitoring instrumentation for TUV approaval. MCERTS is the Monitoring and Certification Scheme of the United Kingdom and includes laboratory and field testing of environmental monitoring systems.)

(*e*) other known factors, if any. Table 2 provides nominal measurements and effluent values and ranges of variation for several representative applications at Portland cement plants.

6.1.8 Explicit statements regarding the applicability of the monitoring device (*a*) downstream of electrostatic precipitators, (*b*) downstream of fabric filters, (*c*) where water droplets or condensed mists are present at the monitoring location, or (*d*) other applicable limitations.

6.2 The manufacturer shall provide written procedures for installation, start-up, operation and maintenance, and quality assurance of BLDs and PMDs. The manufacturer shall identify those activities, and/or QA check/maintenance intervals, or other factors that may need to be adjusted based on site-specific conditions.

6.3 BLD manufacturers shall provide detailed written procedures for establishing alarm levels for BLDs including provisions for adjustment of the averaging period, alarm delay, and alarm set point, and any other parameters appropriate for source-specific conditions. The manufacturer shall specify the minimum (or range) BLD monitoring period necessary to establish the alarm set point. The manufacturer shall provide criteria for re-setting the alarm point.

TABLE 2 Typical Portland Cement Effluent Characteristics

Wet process cement kiln with ESP control		
PM concentrations	10–40 mg/acm (0.004–0.017 gr/acf) with short term variability due to rapping in ESP	
Six-Minute Opacity	4–20 % opacity	
Moisture Content	30 % (water droplets may be present during start-up or while shutting down.	
Effluent Temperature (at stack testing location)	180–232ºC (350–450°F)	
Flow Rate	80 000–100 000 acfm Varying ±10 % and proportional to production rate (except for start-up and shut down, or waste fuel cut off transients)	
SO_2	300–800 ppm (2–10 ppm H_2SO_4)	
NO_x	300–1200 ppm	
HCl	1 to 13 ppm	
NH_3	1–10 ppm	
Contemporary pre-heater pre-calciner kiln system with in-line raw mill		
	Mill On (90 % of operating time)	Mill Off (10 % of operating time)
PM concentrations	3–8 mg/acm (0.0013–0.0034 gr/acf)	4–10 mg/acm (0.0017–0.0043 gr/acf)
6-Minute Opacity	2–20 % opacity	2–20 % opacity
Moisture Content	12–18 %	May decrease 1–2 % H_2O
Effluent Temperature (at stack testing location)	120–180ºC (250–350°F)	May increase 30ºC (50°F)
Flow Rate	400 000 acfm	May increase 5–15 %
SO_2	200–300 ppm (2–3 ppm H_2SO_4)	May increase 50–100 ppm
NO_x	200–400 ppm	200–400 ppm
HCl	2–50 ppm	10–60 ppm
NH_3	1–10 ppm	May have five fold transient increase when mill shuts down
May have co-mingled emissions from coal mill, alkali bypass, or clinker cooler PM control systems at kiln system test location.		

7. Field Demonstration

7.1 *Representative Instrument*—Perform the field performance specification verification procedures in this section for each representative model or configuration involving substantially different sources, detectors, active components, electronics, or software and include the results in a report. Perform the tests on a representative instrument installed to monitor kiln emissions at a Portland cement plant.

7.2 *Operational Period*—Operate the BLD or PMD for a period of at least 90 days in accordance with the manufacturer's written installation, operation and maintenance procedures, as provided in response to the requirement in 6.2 during the test program.

7.3 *Monitor Availability*—Report all malfunctions or breakdowns, maintenance and corrective actions performed during the test period. After completing all BLD or PMD start-up activities (not to exceed 14 days), calculate and report the percent monitor availability achieved (excluding, all invalid data, monitor downtime, monitor maintenance time, etc.) as a fraction of source operating hours during the test period. Percent monitor availability $\geq$95 % is acceptable.

7.4 *Drift Test*—Perform internal zero and upscale performance check cycles daily, or more frequently if recommended by the manufacturer's written procedures, for at least seven consecutive days and verify that the instrument drift (difference between current value and reference value) is within ±2 % NFS or the manufacturer's published specification, whichever is more restrictive. Intrinsic and automatic adjustments may be performed at any time, and prescribed maintenance may be performed in accordance with the manufacturer's written procedures.

7.5 *Repeatability Test*—Perform a repeatability test by installing two PMDs or two BLDs of the same model at sampling locations expected to provide comparable results. Summarize the concurrent one-hour average outputs (or other representative period) of the two instruments recorded at approximately eight-hour intervals (three times per day) for a period including at least 60 days of concurrent operation. Reject non-representative data, missing pairs of data during maintenance or other downtime. The repeatability is acceptable if the standard deviation of the differences between the monitor responses is less than 10 % of the average of the two instruments, or 3 % of NFS, whichever is less restrictive.

7.6 *External Audit*—Conduct audits of the installed BLD(s) or PMD(s) using the external audit device two or more times at least 30 days apart during the field test. Verify that the linearity error at zero and two upscale levels during the external audits is $\leq$3 % NFS or the manufacturer's published specification, whichever is more restrictive.

7.7 *Analytic Function Testing*—Conduct independent PM concentration tests to verify the ability of the BLD or PMD to indicate PM Concentrations. Using Test Method D6831 is strongly recommended, especially for sources with low PM concentrations and sources with significant temporal variability as indicated by the PMD or BLD. Other in-stack filtration manual test methods may be used, such as 40 CFR 60,

Appendix A, Method 17, or EN 13284-1, etc. These methods may provide acceptable comparisons for sources with emissions above 20 mg/acm (0.0086 gr/acf). However, the apparent acceptability of the monitoring instrument may be adversely affected by the test method limitations, including poor precision at low concentrations and as well as actual PM concentration variability during the sample run. Out-of-stack filtration methods, such as 40 CFR 60, Appendix A, Method 5 or 5I may also be used. However, these methods are subject to the same limitations as Method 17 and may also result in the measurement of condensable or reactive compounds that are not present in the effluent stream as PM. For example, gaseous ammonia may react with HCl or sulfur compounds and form PM that is not present in the effluent stream and thus not seen by the PMD or BLD.

7.7.1 *Discussion*—Test Method D6831 can resolve in-situ PM concentrations of 0.5 mg/acm (0.0002 gr/acf). If actual PM concentrations during the test are below 5 mg/acm (0.002 gr/acf), it is very likely that measurement error will adversely affect any attempt to establish a statistical correlation. In these cases, extra care is required in performing the tests.

7.7.2 *Filter Temperature*—Operate the D6831 with the filter temperature 5°C (9°F) above the effluent temperature.

7.7.3 *Sampling Points*—Co-locate the D6831 sampling probe as close as practical to the BLD or PMD sampling point, volume, or path, as applicable. For path measurement devices, perform a stratification traverse parallel to the BLD or PMD path. If stratification is indicated, select multiple measurement points (four or more evenly spaced traverse points) to represent the average PM concentration along the measurement path.

NOTE 5—The purpose of the test is to determine the analytical function of the PMD or BLD relative to the PM concentration passing through the measurement volume. Therefore, the reference sampling probe is positioned as close as practical to the measurement volume and traverses of the stack cross-section are not performed.

7.7.4 Conduct tests during periods that are representative of the normal range of emissions, and normal range of process and control equipment operations (raw mix or slurry feed rate, raw mix or slurry composition, waste feed rate, waste feed composition, dust re-injection, etc.) as selected by the plant operator. For plants with ESP controls, conduct tests at two or more ESP power settings. For plants with in-line raw mills, conduct testing under both "mill on" and "mill off" conditions.

7.7.5 Select sample run durations to provide representative measurement results as indicated by the variability of emissions on the D6831 instrument's real-time output. Typically, sample run durations range from 5 to 20 minutes. Multiple consecutive test runs can be performed without removal of the microbalance from the duct or stack and without filter replacement. For high level emissions, sample periods may range from 1 to 3 hours before filter replacement is necessary. For low level emissions, sampling may be performed for 8 hours, or longer before filter replacement is necessary.

7.7.6 If upset or transient conditions occur during a particular test period, discard the D6831 data and the concurrent BLD or PMD data for those sample runs or periods, or adjust the run start and stop times to avoid including the emission anomaly in the comparison.

7.7.7 For sources without water droplets, perform the comparison of the D6831 results and BLD or PMD data without desiccation of the filter. Perform filter stabilization and nozzle recovery procedures only between consecutive sampling periods when it is necessary to change filters or when tests are performed at sources with water droplets. If the nozzle recovery is greater than 3 % of the total mass collected, apportion the mass evenly over the sampling time. Otherwise, ignore the nozzle recovery results.

7.7.8 Continue testing until sufficient data has been acquired to achieve satisfactory results. (Typically, sufficient data can be obtained by D6831 testing for three hours at each test condition under two or more operating conditions.)

7.7.9 Reduce the test data to concurrent sets of D6831 concentration measurement data reported at actual conditions and BLD or PMD output data.

7.7.10 If data are available over a sufficient range, calculate the correlation coefficient, confidence interval, and tolerance interval for the data sets using a linear function. Acceptable results are obtained for a PMD if (*a*) correlation coefficient ≥ 0.85, (*b*) confidence interval <10 %, and (*c*) tolerance interval is <25 %. Acceptable results are obtained for a BLD if (*a*) correlation coefficient ≥ 0.75, (*b*) confidence interval <10 %, and (*c*) tolerance interval is <25 %.

7.7.11 *Optional Specification 1*—If data can not be acquired over a sufficient range to establish a valid correlation because of process or control equipment operational constraints, use the following approach for comparison of reference PM concentration measurements and BLD or PMD data. Assume the BLD or PMD response is linear and passes through zero unless there is another means to establish the zero offset. Determine the BLD or PMD response slope based on evaluation of the test data. Using the optimal value for the slope, calculate the equivalent PM concentration values at actual stack conditions. Calculate the relative accuracy between the BLD or PMD responses and D6831 test data. Acceptable results are obtained if the relative accuracy is ≤ 20 % of the mean D6831 value. The relative accuracy is calculated from the paired differences as the sum of the absolute value of the mean difference plus the 95 % confidence coefficient. (See for example, 40 CFR 60 Appendix B, Performance Specification 2.)

7.7.12 *Optional Specification 2*—If the mean of measured PM concentrations is less than 5 mg/acm it is unlikely that the acceptance criteria in 7.7.10 can be achieved. If they are not achieved, either: (*a*) repeat the tests at higher PM concentrations or (*b*) conduct additional test runs, reject outlier data pairs, until sufficient data are available to establish an acceptable correlation. For sources with emissions below 5 mg/acm (0.002 gr/acf), acceptable performance is demonstrated if the correlation coefficient is ≥ 0.75.

7.7.13 Conduct the initial analytic function test during the first 30 days of the test period. Conduct a second analytic function test 30 to 60 days after the initial test. Report the results from both tests.

7.8 *Field Detection Limit*—Determine the field detection limit by (*a*) evaluating the results of internal simulated zero checks over the duration of the operational test period, and (*b*) using the analytic function test results and BLD or PMD data obtained during the 90 day operational test period.

7.8.1 Calculate the "measurement noise" as two times the standard deviation of the responses to all internal zero performance checks during the field demonstration, excluding all periods of instrument malfunction and excluding zero checks exceeding the zero drift specification. For instruments that apply zero compensation during the zero check, calculate the noise based on the pre-adjusted response or the amount of adjustment.

7.8.2 Determine the PMD or BLD "noise limited" detection limit as twice the measurement noise and express it in units of PM concentration using the relationship developed from the analytical function test.

7.8.3 Determine the PMD or BLD "observed" detection limit from the instrument responses recorded during the field demonstration which corresponds to the minimum PM concentration. Identify the minimum non-zero output of the monitoring device. Estimate the background noise from the raw data at the minimum PM concentration as the symmetrical bandwidth including 95 % of the observed values. The "observed" detection limit is the equivalent PM concentration corresponding to signal-to-noise ratio of 2.0 based on the values for the minimum instrument response and the background measurement noise.

7.8.4 Report both the "noise limited" and "observed" detection limit results. The manufacturer's certification of BLD or PMD detection limit is based on the greater of the two results.

8. Design Specification Verification

8.1 Applicable specifications and test procedures for transmittance based BLD or PMD systems are contained in Practice D6216. Certification of conformance with Practice D6216 for those applicable requirements satisfies the requirements of this section.

8.2 Certify that the BLD or PMD design meets the applicable requirements for: (*a*) measurement output resolution, (*b*) measurement frequency, (*c*) data recording and data averaging. Certify that the BLD or PMD design meets the applicable requirements for (*a*) internal zero and upscale performance checks, (*b*) external zero and upscale audit capability, and (*c*) external audit device repeatability, as described in subsections 8.3-8.4. Certify that the BLD or PMD status indicators perform properly as provided in 8.5. In addition, certify that the BLD or PMD is designed to meet the specifications for (*a*) thermal stability, (*b*) insensitivity to line voltage variation, and (*c*) for optical systems only, insensitivity to ambient light. Demonstrate conformance with these three design specifications by testing a representative instrument annually (and whenever there is a change in the design, manufacturing process, or component that may affect performance), as described in subsections 8.6 – 8.8. If any result is unacceptable, institute corrective action in accordance with the established quality assurance program and remedy the cause of unacceptability for all affected BLD or PMD instruments. In addition, retest another representative BLD or PMD after corrective action has been implemented to verify that the problem has been resolved. Maintain documentation of all information, tests conducted, and test data necessary to support certification.

8.3 *Internal Performance Check Devices*—This practice requires monitors to include automated mechanisms to provide calibration checks of the installed BLD or PMD. However, there are differences between the PMD and BLD requirements as set forth in the following subsections:

8.3.1 *PMD Internal Zero Performance Check Device*—Establish the proper response to the internal zero check device under zero PM conditions while the PMD is calibrated for NFS. Certify that the internal zero performance check device conforms to the following:

8.3.1.1 The internal zero performance check produces a simulated zero dust condition, with the instrument otherwise in normal operation.

8.3.1.2 The internal zero performance check device provides a check of all active analyzer internal components including any optics, all active electronic circuitry including any light source and detector assembly, electric or electro-mechanical systems, and hardware or software, or both, used during normal measurement operation.

NOTE 6—The simulated zero device allows the zero drift to be determined while the instrument is installed on the stack or duct. Simulated zero checks, however, do not necessarily assess the status of the installation or the correlation between measured signal and the PM loading.

8.3.2 *PMD Internal Upscale Performance Check Device*—Certify that the device conforms to the following:

8.3.2.1 The internal upscale performance check device measures the upscale instrument drift under the same optical, electronic, software, and mechanical components as that of the internal zero performance check.

8.3.2.2 The internal upscale performance check device evaluates the measurement system response where the signal level reaching the detector is between the signal levels corresponding to 50 % and 80 % of NFS.

8.3.2.3 The upscale calibration check response is not altered by electronic hardware or software modification during the calibration cycle and is representative of the gains and offsets applied to normal PM measurements.

8.3.3 *BLD Internal Zero and Upscale Performance Check Devices*—For some BLDs, the zero PM condition can not be simulated and a series of checks must be conducted on various portions or aspects of the monitoring device. The results of the series of checks taken together can demonstrate that the device is functioning properly. At a minimum, certify that the internal zero and upscale performance check devices conforms to the following:

8.3.3.1 The internal performance check devices provide evaluations of all active analyzer internal components including any optics, all active electronic circuitry including any source or detector assembly, electric or electro-mechanical systems, and hardware or software, or both, used during normal measurement operation.

8.3.3.2 The internal upscale performance check device evaluates the measurement system response where the signal level reaching the detector is between the signal levels corresponding to 50 % and 80 % of NFS.

8.3.3.3 The upscale calibration check response is not altered by electronic hardware or software modification during the calibration cycle and is representative of the gains and offsets applied to normal particulate measurements.

8.4 *External Audit Devices*—The BLD or PMD design must include an external, removable zero and upscale audit device for checking the upscale response and repeatability of the BLD or PMD. Such a device may provide an independent means of simulating the normal upscale condition for a specific installed BLD or PMD over an extended period of time and can be used by the operator to periodically verify the accuracy of the internal upscale performance check. The external audit device must be designed to: (*a*) simulate the upscale PM condition based on the same signal level reaching the detector as when actual upscale PM conditions exist; (*b*) produce the same response each time it is applied to the BLD or PMD; and (*c*) minimize the chance that inadvertent adjustments will affect the upscale response produced by the device.

NOTE 7—The monitor operator is responsible for the proper storage and care of the external audit device and for re-verifying the proper calibration of the device when appropriate.

8.4.1 *Test Frequency*—Select and perform this test for one representative external audit device manufactured each year for the BLD or PMD model certified by this practice.

8.4.1.1 *Specification*—The BLD or PMD output must not deviate more than ±2.0 % of NFS for five consecutive applications of the external audit device on a BLD or PMD.

8.5 *Status Indicators*—BLDs should include alarms or fault condition warnings to facilitate proper operation and maintenance of the BLD or PMD. Such alarms or fault condition warnings may include lamp/source failure, purge air blower failure, excessive zero or upscale calibration drift, excessive zero or dust compensation, and so forth.

8.5.1 Specify the conditions under which the alarms or fault condition warnings are activated.

8.5.2 Verify the conditions of activations in 8.5.1 on an annual basis.

8.5.3 Certify that the system's visual indications, or audible alarms, as well as electrical outputs can be recorded as part of the BLD or PMD data record and automatically indicate when either of the following conditions are detected:

8.5.3.1 A failure of a sub-system or component, which can be reasonably expected to invalidate the measurement, or

8.5.3.2 A degradation of a subsystem or component, which requires maintenance to preclude resulting failure.

8.6 *Insensitivity to Supply Voltage Variations*—The BLD or PMD must be designed so that the output (both measurement and performance check responses) must not deviate more than ±1 % of the NFS value for variations in the supply voltage over ±10 % from nominal or the range specified by the manufacturer, whichever is greater.

NOTE 8—This practice does not address rapid voltage fluctuations (that is, peaks, glitches, or other transient conditions), emf susceptibility, or frequency variations in the power supply.

8.6.1 Use a variable voltage regulator and a digital voltmeter to monitor the rms supply voltage to within ±0.5 %. Measure the supply voltage over ±10 % from nominal, or the range specified by the manufacturer, whichever is greater.

8.6.2 Set-up and align the BLD or PMD. Calibrate the instrument using external zero and upscale devices appropriate for the BLD or PMD design at the nominal operating voltage. Insert an external attenuator or reflector, or otherwise create an appropriate reference condition (an upscale reading between 25 % and 75 % of the NFS of the instrument) and record the response. Initiate a performance check cycle and record the low level and upscale responses.

8.6.3 Do not initiate any performance check cycle during this test procedure except as specifically required. Decrease the supply voltage from nominal voltage to minimum voltage in at least three evenly spaced increments and record the stable measurement response to the reference condition at each voltage. Initiate a performance check cycle at the minimum supply voltage and record the low level and upscale responses. Reset the supply voltage to the nominal value. Increase the supply voltage from nominal voltage to maximum voltage in at least three evenly spaced increments and record the stable measurement response to the reference condition at each voltage. Initiate a calibration check cycle at the maximum supply voltage and record the low level and upscale responses, both with and without compensation, if applicable.

8.6.4 Determine conformance to the insensitivity to supply voltage variation specification.

8.7 *Thermal Stability*—The BLD or PMD must be designed so that the output (both measurement and performance check responses, both with and without compensation, if applicable) does not deviate more than ±2.0 % of the NFS for every 22°C (40°F) change in ambient temperature over the range specified by the manufacturer.

8.7.1 Determine the acceptable ambient temperature range from the manufacturer's published specifications for the model of BLD or PMD to be tested. Use a climate chamber capable of operating over the specified range. If the climate chamber cannot achieve the full range (for example, cannot reach minimum temperatures), clearly state the temperature range over which the BLD or PMD was tested and provide additional documentation of performance beyond this range to justify operating at lower temperatures.

8.7.2 Set-up and align the BLD or PMD. If the BLD or PMD design introduces purge air through the housing that contains active optical components internal to a non-focusing exit window, operate the purge air system during this test. If the purge air does not contact internal optics and electronics, the air purge system need not be operative during the test.

8.7.3 Establish proper calibration of the instrument to the NFS using the external zero and upscale audit devices at a moderate temperature that is, 22 ± 3°C (70 ± 5°F). Initiate a performance check cycle and record the low level and upscale responses.

8.7.4 Do not initiate any performance check cycle during this test procedure except as specifically stated. Insert an external attenuator or reflector, or otherwise create an appropriate reference condition (an upscale reading between 25 % and 75 % of the NFS of the instrument) and record the response. Continuously record the temperature and measurement response during this entire test. Decrease the temperature in the climate chamber at a rate not to exceed 11°C (20°F) per hour until the minimum temperature is reached. Note data recorded during brief periods when condensation occurs on optical surfaces due to temperature changes. Allow the BLD to remain at the minimum temperature for at least one hour and then initiate a performance check cycle and record the low level and upscale responses with and without compensation, if applicable. Return the BLD to the initial temperature and allow sufficient time for it to equilibrate and for any condensed moisture to evaporate. Increase the temperature in the climate chamber at a rate not to exceed 11°C (20°F) per hour until the maximum temperature is reached. Allow the BLD to remain at the maximum temperature for at least one hour and then initiate a performance check cycle and record the low level and upscale responses.

NOTE 9—Notations when condensation occurs are for explanatory purposes only.

8.7.5 Determine conformance to the thermal stability specification.

8.8 *Insensitivity to Ambient Light*—For optical instruments, the BLD or PMD must be designed so that the output does not deviate more than ±2.0 % of NFS when exposed to an artificial light source described herein. This artificial light source is deemed to be sufficiently equivalent to solar radiation for the purpose of demonstrating insensitivity to ambient outdoor light.

8.8.1 Perform this test for a specific BLD or PMD that has previously and successfully completed the supply voltage and thermal stability tests, and other design specification verification procedures.

8.8.2 Calibrate the BLD or PMD for NFS. Set up the BLD or PMD in a PM-free environment with the orientation corresponding to a normal installation. Align the BLD or PMD such that any optics that receive scattered light are facing a white surface that: (*a*) is located at a distance from the BLD or PMD greater than the measuring volume, and greater than any distance specified for a light trap; (*b*) is normal to the optical axis of the viewing optics; (*c*) subtends the entire cross-sectional area viewed by the optics. Under this set-up, the BLD or PMD should read zero, since there will be no PM, or any other reflecting surfaces, within the measuring volume.

8.8.3 Use a cosine corrected total solar radiation monitor that (*a*) is capable of detecting light from 400 to 1100 nm, (*b*) has been calibrated under natural daylight conditions to within ±5 % against industry standards, (*c*) has a sensitivity of at least 75 μA/100 W/m^2, and (*d*) has a linearity with a maximum deviation of less than 1 % up to 3000 W/m^2. Mount the solar radiation monitor on the white surface simulating the inside of the stack on the opposite side from the BLD or PMD such that the radiation monitor is aligned parallel to the axis of the viewing optics of the BLD or PMD.

8.8.4 Using a halogen lamp spotlight with nominal color temperature of 2950°K, illuminate the white surface. A suitable spotlight for this purpose is a halogen 1000-watt bulb on a flagpole fixture.

8.8.5 Record the BLD or PMD response, in the presence of the added radiation. Repeat the process three times by turning the spotlight on and off three times.

8.8.6 Verify that the BLD or PMD does not, in the presence of the illuminated white surface, exhibit a response of greater than 2 % of NFS.

9. Performance Specification Verification

9.1 Applicable specifications and test procedures for transmittance based BLD or PMD systems are contained in Practice D6216. Certification of conformance with Practice D6216 for those applicable requirements satisfies the requirements of this section.

9.2 *Required Performance Tests*—Test each instrument prior to shipment to ensure that the BLD or PMD meets manufacturer's performance specifications for instrument response time, linearity, and external upscale audit device repeatability.

9.3 *Instrument Response Time and Test Procedure*—The upscale and downscale PMD response times must be less than or equal to 15 seconds for a minimum of four out of five consecutive tests. The upscale and downscale BLD response times must be less than or equal to one second for a minimum of four out of five consecutive tests.

NOTE 10—The purpose of the instrument response time test is to demonstrate that the instantaneous output of the BLD or PMD is capable of tracking rapid changes in effluent particulate for the purpose of addressing the set-up procedures, which may have requirements for averaging and time delays on alarms. It includes the BLD or PMD components and the control unit if one is included for the particular installation.

9.3.1 Perform the test with all BLD or PMD internal settings, adjustments or software values, or both that affect the BLD or PMD time constant, response time, or data averaging set at the same positions or values as to be used for effluent monitoring. Record the internal settings, or software values, or both, used for the response time test and report this information with the response time test results. Install the upscale audit device such that the upscale reading is <15 % of NFS. Using the upscale audit device, and following manufacturer's instructions, alternately insert into and remove from the BLD or PMD a signal that will produce a reading >70 % of NFS.

9.3.2 For each signal insertion and removal, determine the amount of time required for the BLD or PMD to display >95 % of the step change in reading on the data recorder used for the test. For upscale response time, determine the time it takes to reach >95 % of the change in getting to the final, steady upscale reading. For downscale response time, determine the time it takes for the display reading to fall to <5 % of the change in getting to the final, steady downscale reading.

9.3.3 Determine conformance with the response time specification. If the response time is not acceptable, take corrective action and repeat the test.

9.4 *Linearity and Test Procedure*—The linearity error must be ≤3 % of NFS, for each of two reference materials or signals, for five sequential measurements.

NOTE 11—The linearity test is performed to demonstrate that the BLD or PMD is properly calibrated and can provide reliable and accurate measurements.

9.4.1 Install the external zero audit device and verify system zero. Install the external upscale audit device. Alternately insert two upscale attenuators or provide two reference signals (one between 20 % and 40 % of NFS, and the other between 60 % and 90 % of NFS) using the external audit device and record a stable reading.

9.4.2 Make a total of five non-consecutive readings for each reference condition.

9.4.3 Determine conformance with the linearity specification. If the linearity error test results are not acceptable, take corrective action, recalibrate the BLD or PMD according to the manufacturer's written instructions, and repeat the calibration error test.

9.5 *Internal Upscale Device Repeatability and Value and Test Procedure*—The variation in readings for repeated installations of the internal upscale device must be less than 1.5 % of NFS (from the average of all the readings) for five consecutive installations and removals of the internal upscale audit device. The average reading obtained then becomes the assigned value for the device.

9.5.1 Perform this test for an instrument that meets the linearity specification. Consecutively command the device into and out of its upscale performance check mode five times. Do not make any adjustments to the BLD or PMD until after this procedure has been completed. Record the BLD or PMD responses.

9.5.2 Determine conformance to the specification.

9.5.3 Assign the average value(s) to the simulated upscale calibration device.

10. Quality Assurance Guidelines for BLD and PMD Manufacturers

10.1 *General*—The products shall be manufactured under a quality program that ensures that like products, subsequently made, have the same reliability and quality as those originally examined to determine compliance with this design specification. To establish and maintain such a program, the manufacturer shall be guided by industry practice, its quality controls, and by this set of guidelines. These guidelines are supported by various standards and by industry practice.

10.1.1 *Applicable Documents*—This practice is an adaptation of and referred to the following standards for additional guidance:

ISO/DIS 9004 Quality Management and Quality System Elements-Guidelines

ANSI/NCSL Z 540-1-1994, Calibration Laboratories and Measuring Equipment - General Requirements

10.1.2 *General Vocabulary*—Terms used in this document are defined by ISO 842, Quality Vocabulary.

10.2 *Quality System:*

10.2.1 *Management Responsibility:*

10.2.1.1 *Quality Policy*—The management of a company shall develop and promulgate a corporate quality policy. Management shall ensure that the corporate policy is understood, implemented, and maintained.

10.2.1.2 *Quality Objectives*—Based on this policy, key quality objectives shall be defined, such as fitness for use, performance, reliability, safety, and so forth.

10.2.1.3 *Quality Management Systems*—A documented system shall be developed, established and implemented for the product as a means by which stated quality policies and objectives can be realized. The quality system should ensure that: (*a*) it is understood and effective; (*b*) products actually do satisfy customer expectations; (*c*) emphasis is placed on problem prevention rather than dependence on detection after occurrence; (*d*) causes, not only symptoms, of a problem are found, and that corrections are comprehensive, touching any activity that has a bearing on quality; and (*e*) feedback is generated that can be used at the product or process design stage for correcting problems and improving product. Management shall provide the resources essential to the implementation of quality policies and objectives.

10.2.2 *Quality System Documentation and Records*—The elements requirements and provisions adopted for the quality management system shall be documented in a systematic and orderly manner.

10.2.2.1 Documentation shall be legible, clean, readily, identifiable, and maintained in an orderly manner.

10.2.2.2 The quality management system shall establish and require the means for identification, collection, filing, storage, maintenance, retrieval and disposition of pertinent quality documentation and records. Methods shall be established for making changes, modifications, revisions, or additions to the contents of applicable documentation in a controlled manner.

10.2.3 *Corrective Action Program:*

10.2.3.1 There shall be a comprehensive defect analysis/corrective action program for reporting and following up on product and program deficiencies.

10.2.4 *Assignment of Responsibility:*

10.2.4.1 The responsibility and authority for instituting corrective action shall be defined as part of the quality system.

10.2.4.2 The coordination, recording, and monitoring of corrective action shall be assigned to a specific person or group within the organization. (The analysis and execution of any corrective action may involve a variety of people from such areas as sales, design, production engineering, production, and/or quality control.)

10.2.5 *Deficiencies:*

10.2.5.1 Deficiencies shall be evaluated in terms of their potential impact on product quality, reliability, safety, performance, and customer satisfaction.

10.2.5.2 The relationship between cause and effect should be determined. The root cause should be determined before planning and implementing corrective measures. Careful analysis shall be given to the product and all related processes, operations, records, and so forth.

10.2.5.3 Controls of processes and procedures shall be implemented to prevent recurrence of the problem. When the corrective measures are implemented, their effect shall be monitored in order to ensure desired goals are met.

10.2.5.4 Permanent changes resulting from corrective action shall be incorporated into the work instructions, manufacturing processes, product specifications and/or the quality manual.

10.2.5.5 *Quality System Certification*—Companies with ISO 9001/9002 certification, companies meeting the requirements of ANSI/ASQC Q90 (Q91 or Q92), companies meeting the requirements of nationally recognized test laboratories, or companies with an equivalent independently and periodically verified quality system, and that adopt this practice as part of their product definition shall be deemed to meet all of the above quality assurance guidelines. Companies meeting these conditions shall attach the applicable certification to the manufacturer's certification of conformance report as proof of such designation.

11. Keywords

11.1 bag leak detector (BLD); cement kiln emissions; design specifications; fabric filter; particulate matter; particulate matter detector (PMD); performance specifications; Portland cement

APPENDIXES

(Nonmandatory Information)

X1. PMD ALARM SET-POINT AND DATA AVERAGING

X1.1 This appendix specifies procedures for data averaging and recording for PMDs and describes the procedures used to establish the alarm point. Data recording and averaging can be performed using external devices connected to the PMD output.

X1.1.1 The PMD shall sense the parameter it measures at least once every 15 seconds and shall provide an output representing a one-minute average for data recording. Data recorded during calibration check cycles, calibration adjustments, QA checks, maintenance, or during periods of breakdown or malfunction of the measurement equipment shall be flagged in the recorded data.

X1.1.2 All valid one-minute averages (excluding flagged data as identified above) shall be used to compute 15-minute clock averages.

X1.1.3 A valid clock hour average shall be computed as the average of the four 15-minute averages, except for one hour per day when daily calibration checks are performed, when the clock hour average may be calculated from at least three 15-minute periods during the hour.

X1.1.4 A six hour rolling average shall be calculated from a minimum of five, and using all available clock hour averages, for the six preceding clock hours. The six hour rolling average shall be updated at the end of each clock hour.

X1.1.5 Prior to conducting performance tests which will be used to establish the alarm set-point, the source operator should perform an evaluation of the PMD to ensure that it is functioning properly. The evaluation shall include: (*a*) an inspection of the measurement system, (*b*) internal simulated zero and upscale calibration checks, and (*c*) an external audit to determine linearity (calibration error) at two upscale levels. If problems are identified, corrective action shall be taken and the evaluation repeated until performance of the PMD is within the specifications of this practice and the written specifications of the manufacturer.

X1.1.6 Calibration checks and other activities that reduce data availability during the source performance test shall be avoided and minimized to the extent practicable.

X1.1.7 The source operator may adjust the process or control system performance to achieve emission levels approaching the regulatory emission limit during the performance test, or may conduct a series of tests at different process or control system operating conditions to determine the PMD output corresponding to the PM emission limit.

X1.1.8 During source performance tests, the beginning of test runs may be synchronized to coincide with clock hours, or the PMD output may be manually calculated from the particular 15-minute periods corresponding to the test run(s).

X1.1.9 Three or more runs are usually performed for each source performance test.

X1.1.10 The PMD alarm set-point can be established as the average of the PMD output during a source performance test that demonstrates compliance with the emission limit. If multiple test are performed that demonstrate compliance with the emission limit, the alarm set point can be set at the PMD output level corresponding to the tests with the greatest PM concentrations.

X1.1.11 For sources with PM emissions significantly below the emission limit and where it is not practical to increase PM emissions to levels approaching the emission standard, the PMD alarm set-point can be extrapolated using appropriate procedures. The procedure used to extrapolate the PMD alarm set-point should account for site-specific conditions, such as: (*a*) results of analytic function tests for the PMD, (*b*) results of PM tests conducted at the facility, (*c*) the proximity of PM emission levels to the standard, (*d*) the variability of PM emission levels over time and with source operating conditions.

X2. BLD ALARM SET—POINT AND DATA AVERAGING

X2.1 This appendix provides general guidance for setting the BLD alarm level, which shall be considered by the manufacturers in the development of detailed written procedures for establishing alarm levels for BLDs.

X2.1.1 *Terminology*—The following terminology is specific to setting BLD alarms. Other terms having similar or identical meanings are used by different manufacturers.

X2.1.1.1 *alarms delay, n*—the amount of time that dust readings must be above the alarm set-point before an alarm event is initiated.

X2.1.1.2 *alarm set-point, n*—the value or trigger point related to the level of the BLD output that initiates an alarm event in conjunction with the alarm delay.

X2.1.1.3 *sensitivity adjustment, scaling factor, calibration factor, n*—any of these or similar terms are used to describe an adjustment that affects the gain of the instrument output or the slope of a linear relationship between the instrument output and the parameters that is sensed.

X2.1.1.4 *averaging period, n*—the time period over which the BLD or an associated data processing device integrates the instrument output or determines the mathematical average or some other parameter indicative of the central tendency of the measurements during consecutive periods.

X2.1.1.5 *rolling averages, n*—mathematical technique which updates the "average value" on a specific time frequency where the result is based on the most recent values during the period.

X2.1.2 *General Considerations*—The BLD alarm shall be established by adjusting or selecting the BLD averaging period, alarm delay, and alarm set point appropriate for source-specific conditions, including:

X2.1.2.1 Type and configuration of fabric filter including: type of filtration material, number and arrangement of compartments, number of bags per compartment or section, presence of co-mingled emissions from multiple baghouses, and so forth.

X2.1.2.2 Cleaning cycle specifics including on-line or off line cleaning, frequency of cleaning cycles, number of bags per compartment cleaned simultaneously, pressure or time triggered cleaning, or any combination of these factors.

X2.1.2.3 Presence or absence of cleaning cycle peaks apparent in the instrument output.

X2.1.2.4 Presence of other data anomalies or interfering effects in the BLD output that are not related to performance of the fabric filter.

X2.1.2.5 Level and variability of estimated PM emissions.

X2.2 *General Approach*—Some baghouses are expected to have virtually no PM emissions except during cleaning cycles or when compartments are returned to service. Other baghouses may have relatively constant emissions where peaks/spikes in the data are not present. (See Appendix X3 for examples). Therefore, the general approach for setting the BLD alarm may be based on (*a*) shifts or changes in the baseline emissions, (*b*) the relative or absolute magnitude or changes in the frequency or duration of periodic or recurring peaks, (*c*) the peak shape or rate of decay in apparent PM emissions after compartments are returned to service, (*d*) changes in an integrated or average value representing combined baseline and peak emissions over some interval, or (*e*) any combination of the above. Mathematical data processing or transformations, statistical process control calculations, or other techniques may be applied to the raw BLD output for the purpose of generating a measurement output consistent with the general approach.

X2.2.1 *Measurement Frequency and Recording*—The BLD shall sense the parameter it measures at least once every 15 seconds and shall record a value representing the output of the BLD relative to the alarm set point at least once per minute.

NOTE X2.1—The alarm level for some BLDs is based on the analysis of one second time resolution data and computation of 5-15 second rolling averages. It is not necessary or required to record all of these measurements. However, recording data at a higher frequency during the period when the alarm level is established and during subsequent periods when the alarm is activated may be appropriate.

X2.2.2 *Data Period*—The manufacturer shall specify the minimum (or range) of BLD monitoring periods necessary to establish the alarm set point and shall specify the data recording frequency to be used during this period for the purposes of setting the alarm.

X2.2.3 *Preparations*—Prior to setting the alarm, the source operator should perform an evaluation of the BLD to ensure that it is functioning properly. The evaluation shall include: (*a*) and inspection of the measurement system, (*b*) internal simulated zero and upscale calibration checks, and (*c*) an external zero and upscale checks. If problems are identified, corrective action shall be taken and the evaluation repeated until performance of the BLD is within the specifications of this practice and the written specifications of the manufacturer.

X2.2.4 *Data Collection*—After the source operator has determined that the fabric filter and process equipment are functioning properly, and all other preparations have been completed, the BLD output shall be recorded for the period and frequency specified by the manufacturer for setting the alarm level.

X2.2.5 *Data Inspection*—Each data set used to set the alarm level shall be inspected to determine the presence of anomalies or erroneous data, the need for additional data processing, and to verify that the process and control device appears to be operating correctly. If the data set is found to be acceptable, a graph of all data shall be prepared and retained for future reference.

X2.2.6 *Data Analysis*—The acceptable data sets shall be analyzed in accordance with the manufacturers written procedures, which may include calculations of parameters such as mean, maximum, minimum, standard deviation, coefficient of variation, for multiple averaging periods. The data may be screened to remove peaks or other data, and may be manipulated through data transformations in a manner consistent with the general approach selected for the particular application.

The data analysis procedures that are used shall be documented. The appropriate averaging period and alarm delay shall be established based on the data analysis.

X2.2.7 *Alarm Set-Point*—The specific procedures to be used for the alarm set-point depend on the type and configuration of the fabric filter together with the characteristics of its cleaning cycle. Using the established averaging period and alarm delay, the alarm set-point shall be adjusted so that the alarm will be activated when there is an indication of deterioration in performance of the fabric filter in accordance with the manufacturer's written specifications. (For example, the alarm set-point may be established as equivalent to some multiple of the sum of the mean value plus three standard deviations, or other appropriate function.) The alarm set-point procedure and actual setting shall be documented.

X2.2.8 *Alarm Confirmation Procedure* —After setting the BLD alarm, data for a second or additional data period(s) shall be obtained. The entire process and analysis shall be repeated applying the same procedures as used to establish the initial averaging period, alarm delay, and alarm level. The results of the alarm confirmation procedure shall be documented. A comparison of the initial and confirmation results shall be performed. If the results of the two processes are consistent, the alarm level is established. If the results are inconsistent, the data shall be reanalyzed or appropriate corrective action shall be taken and the process shall be repeated.

X2.2.9 The manufacturer shall provide criteria for re-setting the alarm point periodically, after instrument malfunctions or repairs, or when the alarm is found to activate when there are no problems with the fabric filter.

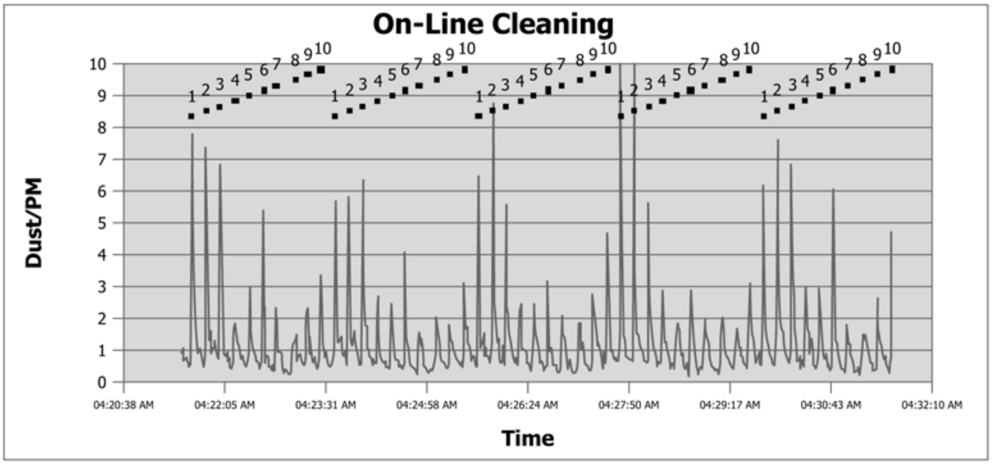
X3. EXAMPLE BLD PROFILES FOR FABRIC FILTERS

ON-LINE CLEANING WITH PEAKS – SINGLE COMPARTMENT

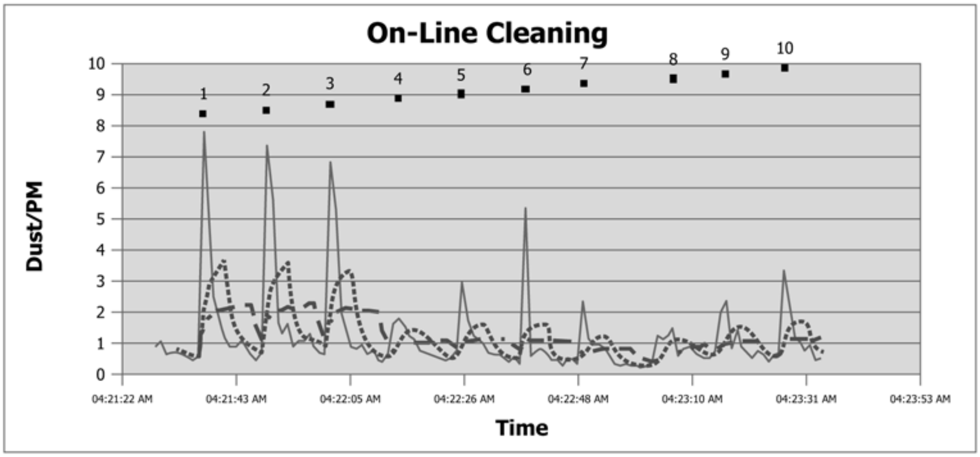
The following charts show normal cleaning cycles for a single filter/compartment that conducts on-line cleaning. Note the variability of the peaks. The peaks themselves are relative short in duration, 5 – 12 seconds. The second normal profile chart shows one cleaning cycle in more detail.

Normal Profile

The chart below provides 1-second data, covering approximately 10 minutes, from a baghouse that has 10 rows. The data from rows 1, 2 3, & 6 seem to be showing the early stages developing a leak. Rows 5, 7, 9 & 10 indicate peaks that are normally expected. The small peaks on rows 4 & 8 are not leaks, but could be an indication of filter material blinding-off or poorly operating valves.

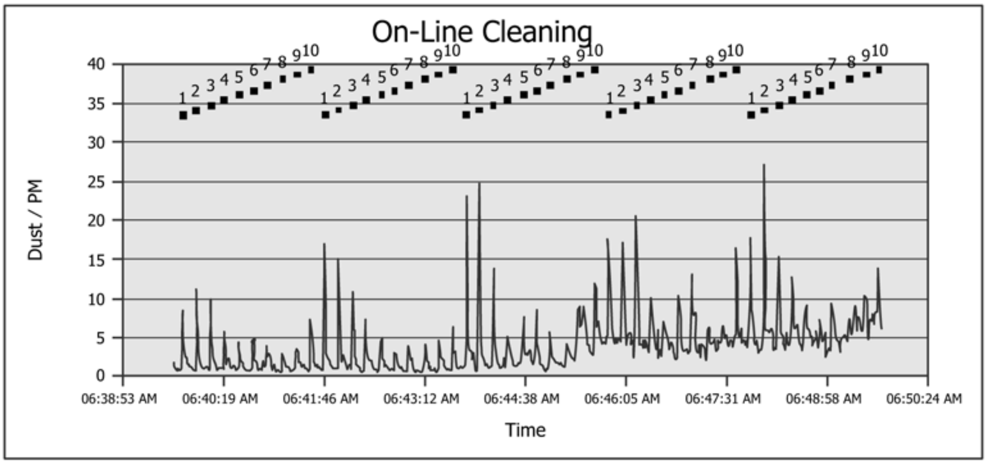


The following chart expands the first cleaning cycle from the previous chart and shows additional trend lines for 5-second (green line) and 10-second (orange line) rolling averages.

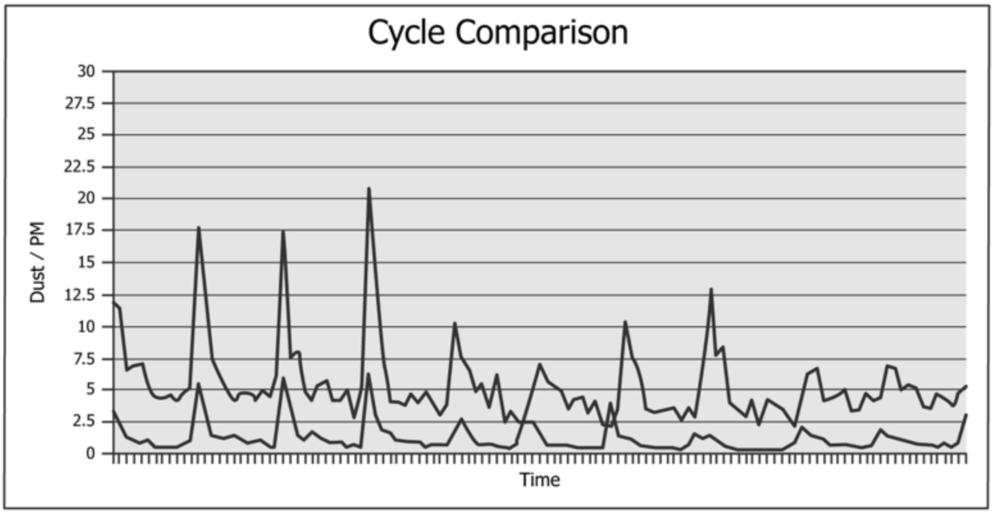


Leaking Profile

This is the same baghouse showing the big break though of a leak. You will notice that the baseline starts to shift upward after the cleaning of rows 1, 2 & 3 in the third cleaning cycle. This is the time where the hole(s) were finally big enough to allow PM to pass-through continuously. The final two cleaning cycles shows an even greater increase in the baseline PM. The previous trends for this baghouse showed pulse peaks from healthy bags to be about a reading of 3 – 5. and a baseline of about 0.5 counts. As the leak(s) begins, the graph below shows the peaks increasing to >20 and the baseline is near 4 counts.



The following chart is an attempt to overlay a healthy cleaning cycle and a leaking cleaning cycle from the previous data sets. You can see that the baseline for the leaking cycle is almost the same as the peaks from a healthy cycle.



ON-LINE CLEANING WITH PEAKS – MULTI-COMPARTMENT

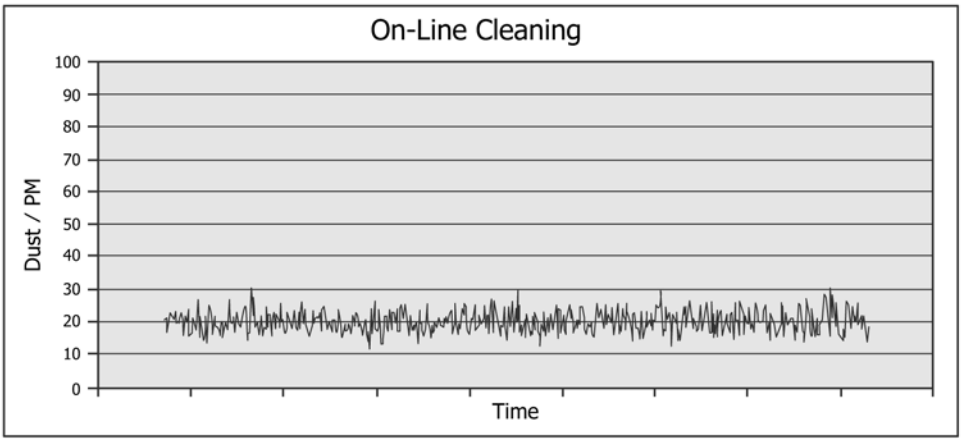
We do not know of any baghouse operation like this, therefore any data provided at this time would be simulated.

ON-LINE CLEANING WITHOUT PEAKS – SINGLE-COMPARTMENT

The following charts show normal cleaning cycles for a single filter/compartment that conducts on-line cleaning, but does have any of the characteristic peaks related to the cleaning process.. Note the data is almost a constant noise level.

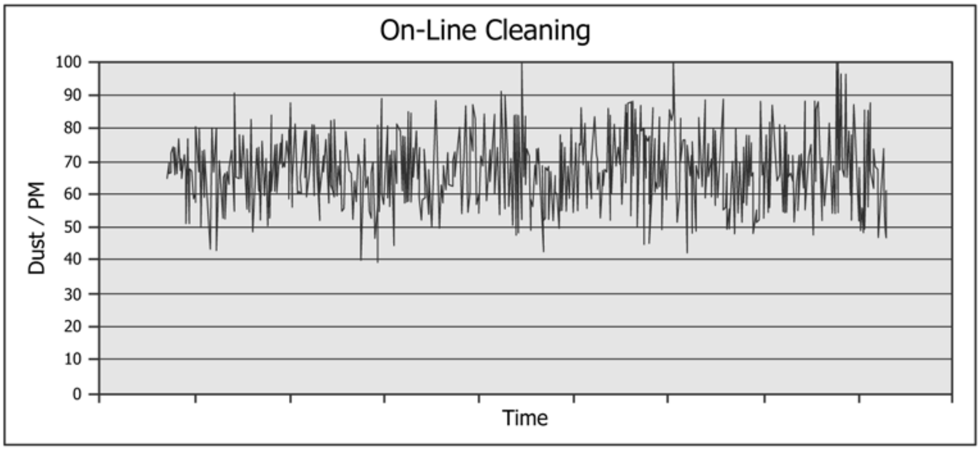
Normal Profile

The following profile is actual data from baghouse that conducts on-line cleaning.



Leaking Profile

The following chart is data from the same baghouse during a leak.



An operation like is shown above just indicates an increase in base-line dust as well as having higher variability in the data.

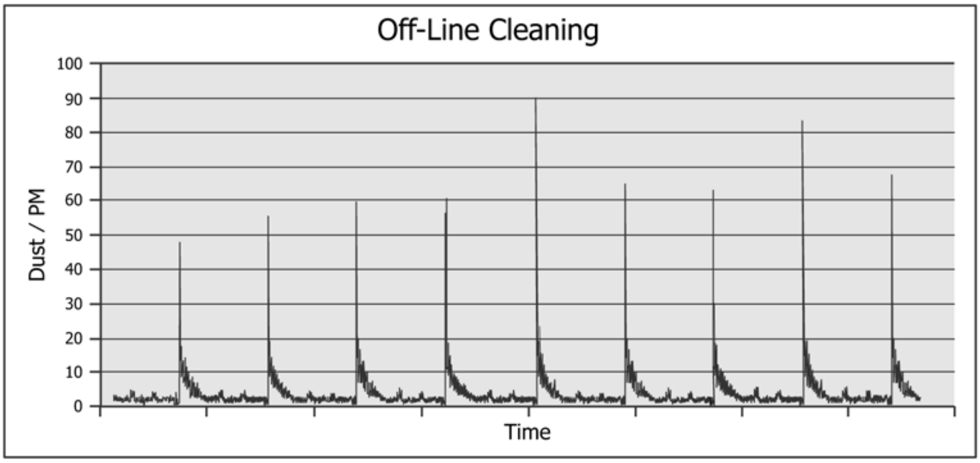
ON-LINE CLEANING WITHOUT PEAKS – MULTI-COMPARTMENT

These charts look the same as the previous ones. It should be noted that the results from leaking compartments will be diluted from the clean gases from non-leaking compartments.

OFF-LINE CLEANING – SINGLE COMPARTMENT

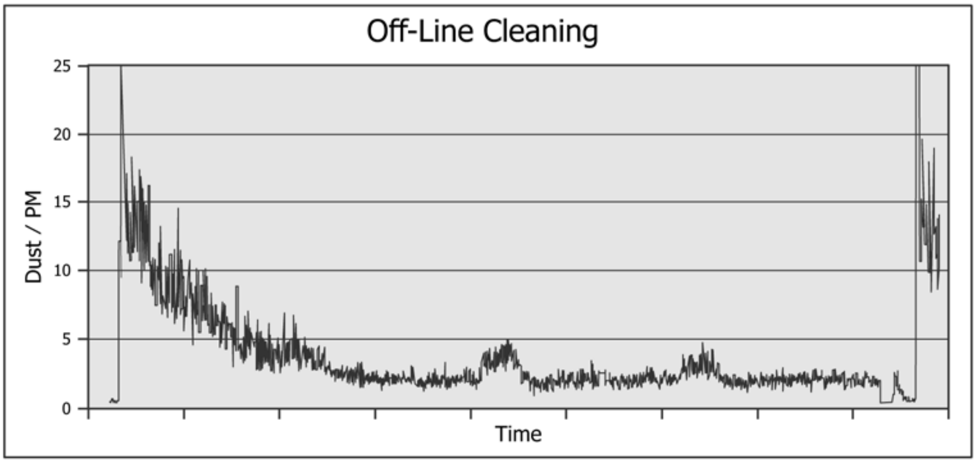
The following charts show normal cleaning cycles for a single filter/compartment that conducts off-line cleaning. Note the variability of the peaks. The peaks themselves are relatively short in duration, 5 – 12 seconds. The peaks for baghouses that conduct off-line cleaning are actual PM emissions, but are not bag leaks and therefore can not be used for diagnostics as they were in a pulse-jet baghouse with on-line cleaning.

Normal Profile



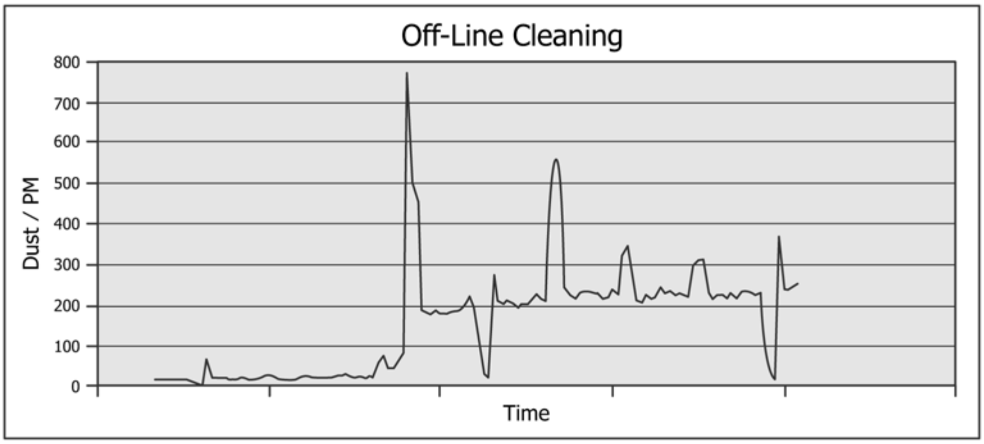
The following chart shows a single cleaning cycle with an expanded time axis. You can more easily see that the initial peak is very short in duration. As the bags start to build-up a cake, the dust readings decay and show less variation. It should be noted that the two bumps near the middle and just right of the middle of the chart are periods when adjacent compartment are cleaning. We do not know if this is due to the shaking/sonic horn or the increased velocity due to removing a compartment from the process, but it is a repeatable pattern.

Another notable pattern is the flat-line dip at the far right. This is when the compartment is taken off-line which results in no air-flow.



Leaking Profile

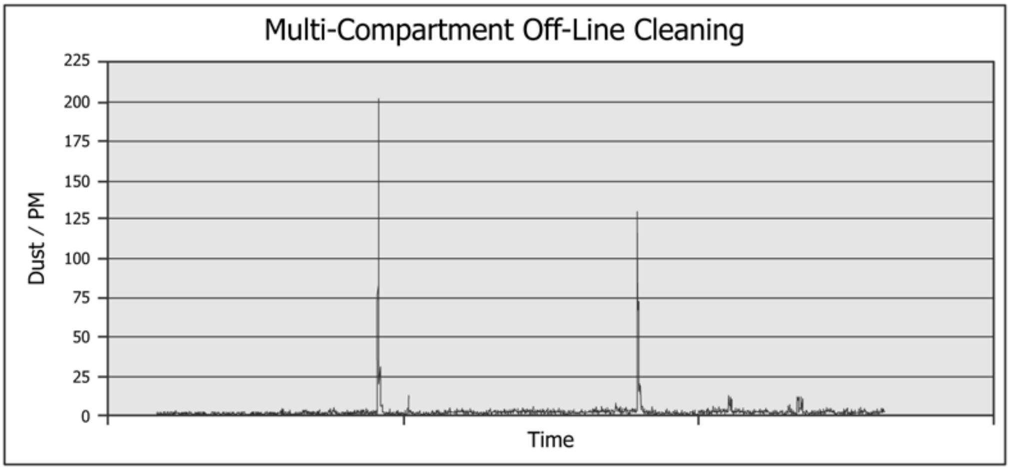
The following chart is based on one-minute average data, but shows the dust levels when a leak occurs in a baghouse of this type. The small peak on the left of the chart is a normal cleaning cycle peak. When the leak occurs, the PM levels increase dramatically indicating almost a 100 fold increase over baseline levels. The two areas of the chart, after the leak occurs, that shows the levels dropping very low is the same characteristic drop in the readings when the compartment isolates for cleaning.



OFF-LINE CLEANING – MULTI-COMPARTMENT

The following charts show normal cleaning cycles for a multi-compartment baghouse that conducts off-line cleaning. Note the variability of the peaks. The peaks themselves are relatively short in duration, 5 – 12 seconds. The peaks for baghouses that conduct off-line cleaning are actual PM emissions, but are not bag leaks and therefore can not be used for diagnostics as they were in a pulse-jet baghouse with on-line cleaning.

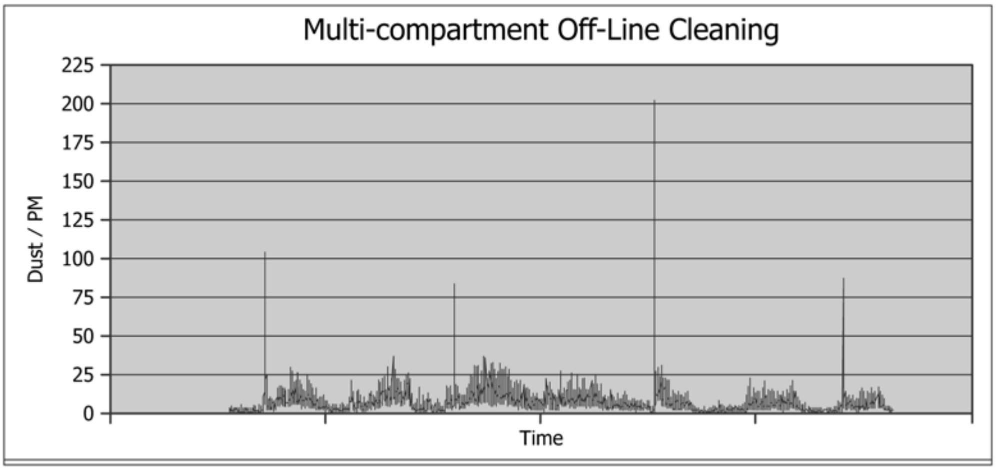
Normal Profile



The previous chart (1-second data) is from a baghouse with 10 compartments and a long cleaning cycle. The large spikes of dust are when compartments come back on-line. You can see that these spikes look similar to that of single compartment off-line cleaning baghouses.

Leaking Profile

The following profile is from the same baghouse as the previous chart and is the result of a single hole in one bag in one compartment. The dilution of the leak with clean gases provides an interesting profile that varies with pressure and flow changes in the baghouse.



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