Improving environmental performance and satisfying regulatory requirements through the continuous monitoring of particulate emissions from Foundry Processes

Author: William Averdieck, PCME Ltd
williama@pcme.co.uk

1) Introduction

Operators of many ferrous and non–ferrous foundry processes have made significant environmental improvements in recent years fitting high performance fabric filter dust collectors (bagfilters) to furnace, cupula, shotblasting, sand cleaning and finishing processes. Emissions from such processes are highly abated only when bagfilters operate to their design condition, and therefore the current issue is how to effectively monitor the condition of the bagfilter to ensure it is operating to design conditions and demonstrating, on an ongoing basis, that particulate emissions are below legislative limits.

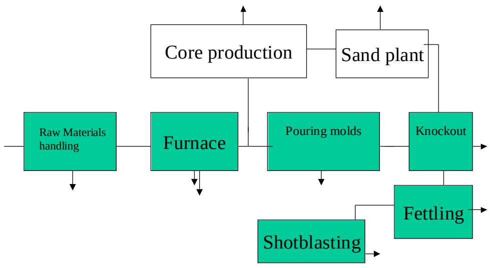
This paper focuses on how Electrodynamic type particulate monitors are used by foundries in the UK, Germany, Japan, and US to continuously monitor the performance of bagfilters as well as help maintenance personnel diagnose the location of leaking or faulty bag rows hence reducing re-bagging costs. It also covers how such monitoring satisfies environmental legislative requirements resulting from PPC (UK), IPC (Europe) and MACT (US) as well as improves environmental performance.

2) Emission sources in Foundry processes

2.1) Particulate emission applications

A foundry process has multiple sources of particulate. The major sources include furnaces, poured metal, shot-blasting, machining and fettling operations, core production and sand plant recovery. In many plant, these processes are spread across an industrial site resulting in each emission source being individually controlled, although in newer larger plant the emissions sources may be ducted to common arrestment plant. In both cases arrestment plant is used to control emissions of particulate from the plant. Arrestment plant type includes Electrostatic precipitators (now less often used to problems of meeting lower emission limits), wet scrubbers (now becoming less used due to resulting water pollution problems) and fabric filters or baghouses (the most common type of arrestment plant and one installed in most new applications).

The foundry manufacturing process and particulate emission sources



Continuous particulate monitors are fitted on the clean air side of the bagfilter or other type of arrestment plant to monitor the levels of particulate emissions from the arrestment plant, provide records of emissions for emission reporting and trigger alarms on changes in emissions (associated with arrestment plant failure).
Continuous monitoring provides these same benefits whether it is done on a large bagfilter used to control a sintering plant in a steel plant or a small bagfilter used to control emissions from a shotblasting process on a ferrous foundry.

Figure 2 : Photographs of bagfilters on Sinter plant and shotblasting applications with Electrodynamic instrument superimposed.

2.2) Oil mist applications

The emissions of Oil mists can be an added concern on large foundries with machining operation (eg automotive engine plant). This is as a result of machining oils used when machining castings, for lubrication and cooling purposes. Air in the vicinity of this machining is extracted to oil mist collectors so as to maintain a healthy working environment in the factory and these emissions are cleaned before being emitted to atmosphere.

Continuous monitors are installed after the oil mist collectors to monitor changes in emissions from the plant and indicate any changes in arrestment plant condition to avoid unwanted emission incidents.

3) Continuous particle and/oil mist monitoring instruments

3.1 Requirements

Instruments for continuous monitoring of particulate (and oil mist) exist using a variety of measurement principles. However in all cases, the instrument does not measure the mass of particles but measures a parameter which can be correlated to particle emissions. The absolute calibration in mg/m^3 is application specific. The generic accuracy of the instrument is defined in type approval schemes such as UK MCERTS and German TUV

Of key importance to operators is rugged, reliable operation since instruments are required to measure with large periods of unattended operation and require minimal maintenance.

While Opacity type instruments were historically known, over the past 15 years these types of instruments have played a less significant role in foundry processes since emissions have fallen below the resolution limits of the instruments and opacity instruments generally require high maintenance due to the optical surfaces. Meanwhile Electrodynamic instruments have been used in a growing proportion of industrial applications, since the instruments have sufficient resolution to monitor the low emissions after bagfilters, are tolerant to contamination and may be fitted with a single stack connection to an existing duct. They provide an effective method of monitoring particulate and oil mist from foundry processes.

3.2) Electrodynamic instruments

3.2.1 Principle of Operation:

In an Electrodynamic system a grounded metallic sensing probe is installed across part of the stack of interest and this rod is connected to signal processing electronics capable of amplifying and measuring an AC current of RMS magnitude in the order of 10pA. Particles in the stack to be monitored carry charge as a result of upstream activity and these particles induce an AC signal as they pass the rod. The magnitude of the AC signal is a function of the average charge per particle and the variation in the spatial distribution of the particles. This AC signal is proportional to total mass concentration in conditions where the charge per particle remains constant (a function of particle type, particle and size and the process conditions) and stack conditions where the particle number concentration is small (since the particle distribution follows a Gaussian distribution in steady flow conditions). The proportional relationship between particle concentration and instrument response has been validated in regulatory approvals in Germany by TUV and UK by MCERTS [2]. Since the AC signal is primarily derived from charge induction from particles passing the rod (unlike Triboelectric instruments which measure the direct current caused by particles colliding with the rod), the related problems of rod contamination and velocity dependence are minimised.

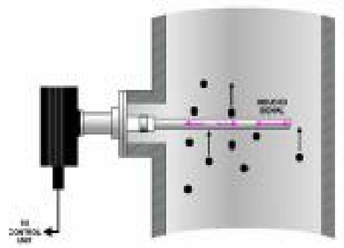


Figure 3: Schematic of charge induction in Electrodynamic sensor caused by charged particles passing the rod

In many foundry processes especially those controlled by ceramic and fabric filters where the filter element surface acts to pre-condition the particle charge, the charge per particle in the final emission stack is sufficiently constant to permit a reliable calibration in mg/m^3 by comparison to the results of an isokinetic sample (gravimetric sample under matched velocity conditions).

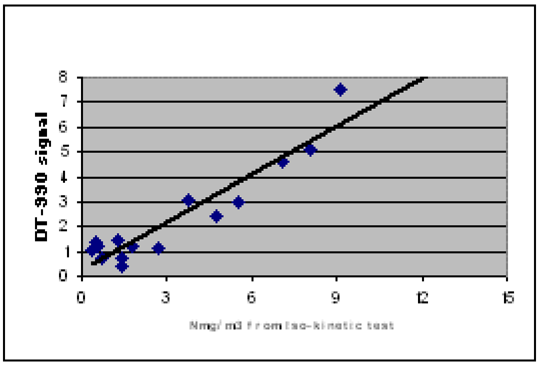


Figure 4: Calibration of DT990 Electrodynamic instrument with isokinetic test

3.2.2 Practical Considerations for foundry applications:

- The sensor rod can be made of an FeCrAl alloy which can tolerate temperatures of up to 1200ºC.
- The sensor rod can tolerate contamination without reduction in performance since the measurement signal derives from induction rather than collision. This means that as the rod becomes coated with contamination there is no reduction in measurement capability.
- In oil mist applications the rod is coated with a layer of Teflon to minimise the effects of sensor shorting due to the moisture. The induced signal still is created by this type of sensor and therefore the instrument is capable of detecting the change in oil and particulate emissions associated with the failure of oil mist eliminators.

3.2.3 Use and limitations of Technology:

Electrodynamic instruments are used to satisfy qualitative and measurement requirements on Bagfilters and ceramic filters in the metals as well as mineral and chemical industries. Their adoption in UK is extensive and their use in Europe, Japan and Australia is widespread. Regulatory approvals exist for instruments in the UK and Germany according to MCERTS and TUV (BImSchV 17) respectively. Technical limitations are as follows:

- The use of Electrodynamic technology for particulate measurement requires applications with predictable particle type and pre-charge, non-condensing conditions and a minimum velocity of 5m/s. There are only minor effects of changing velocity if the velocity is greater than 8m/s.
- The instrument cannot be used for measurement with the presence of water droplets, however, this is rarely an issue in high temperature applications. The instrument can discriminate between solid particles and water vapour.
- The process limits for the technique are that it measures all particles from 0.1micron and larger (response is inversely proportional to particle size), measures particle concentration from below 0.1mg/m^3 to over 1000mg/m^3 and should be used in applications where there is a minimum velocity of 3m/s. These conditions are met in bagfilter applications.

3.2.4 Construction of Electrodynamic instruments

An Electrodynamic instrument comprises of a sensor which is mounted in the stack via a coupling or flange connection. The version of the sensor used at temperatures to 1200ºC includes a ceramic insulation (to isolate the rod from the stack wall), a FeCrAl sensor rod and a heat shield to protect the sensor electronics from the stack temperature. Other variants of the sensor are available for operation up to 250ºC, 400ºC and 800ºC.

Figure 5 High temperature Electodynamic particulate sensor capable of monitoring in stack temperatures to 1200ºc

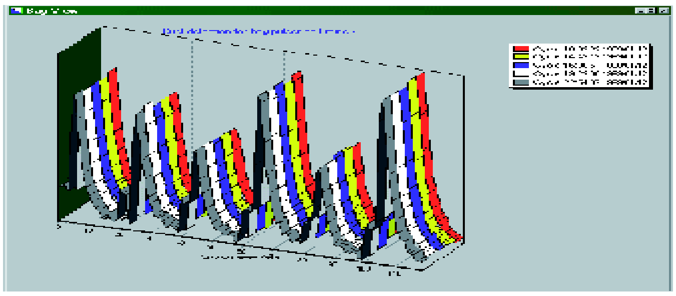
The sensor is connected to a control unit via a single cable which provides all sensor power and communication with the sensor. In versions using modbus for communication the cable length can be up to 2000m in length. The control unit is used for all user interface, instrument set up and provides 4-20mA, RS232/485 and Ethernet outputs for connection to external plant control systems, PLCs and Plant LANs. Multiple sensors can be connected to the same control unit which provides a cost effective solution for foundry processes with multiple emission points.

Figure 6 Multi-sensor Electrodynamic particle emission system

4) Reducing industrial emissions through predictive continuous monitoring

In addition to satisfying emissions legislation, installation of particulate emission monitors can significantly reduce the cost of operating large bagfilter systems by reducing the number of replacement filter bags. Instead of replacing all bags periodically, the plant can be operated so that bags are only replaced when there is a need to. The instrument assists maintenance personnel locate the leaking element in a large filter system. This is done by synchronising the output from the particulate monitor to the cleaning sequence of the filter and using the dynamics of the dust signal to pin point which row of elements when cleaned is causing high dust levels and hence is beginning to fail.

High peaks in dust are associated with the cleaning of a bag row with a failing filter bag and therefore maintenance personnel can easily determine which bag row requires maintenance before a major incidence occurs.

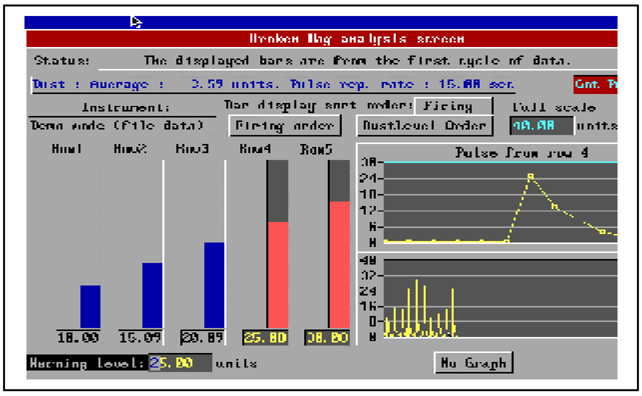


In addition in large multi-compartment bagfilters, multi-probe dust monitoring systems can be used to detect and isolate the compartment causing elevated emissions which again allows emissions to be controlled.

Plant operators use the graphics screens on Electrodynamic instruments to view emissions trends and hence diagnose filter condition. Once the row has been identified and the suspect fabric filters changed, the same method can now be used to confirm;

- Correct problem area identified and repaired.
- New fabric filters are not/have not been damaged.
- New fabric filters are fitted correctly ie Seal integrity is good.

PC software is also available to help this analysis. It is designed to clearly show the status of the baghouse at a glance and enables records to be generated.



After running this analysis for some time, a picture of how the baghouse is working can be built. The time for deterioration of filters can be assessed such that maintenance can be scheduled for natural shutdowns or when the process is least affected.

5) Legislative requirements for continuous particulate emission monitoring

5.1 Types of monitoring

Legislative requirements for continuous monitoring of particulate from foundry processes are converging in most parts of the industrial world. With the growing body of evidence linking metal and carbon particles to reduction in human health the regulatory pressures are very likely to become more stronger. Legislation is both focussed on ensuring emissions are below prescribed mg/m³ limits, but also more fundamentally on ensuring that arrestment plant is functioning correctly (in which case the emissions will be designed to be well below defined emission limits). There are therefore two types of monitoring:

- Quantitative (instruments are calibrated in mg/m³ by comparison to an isokinetic sample)

- Indicative in which the trend in emissions from the bagfilter is monitored and alarms set based on changes in emissions). This type of monitoring is referred to as Qualitative monitoring in Germany and Bag failure monitoring in USA.

The choice in monitoring can depend on the local national legislation and the size of the emission point.

An overview of legislation for Foundries in UK, Germany and US is as follows. These requirements mirror are similar to the legislative approach in most other industrial countries.

5.2 Legislation in United Kingdom

Continuous monitoring of particulate is widely implemented in the UK. With the implementation of the Environmental Protection Act in 1990, continuous monitoring of particulate was required in the majority of industrial stacks since it was considered BATNEEC (Best Available Technique Not Encurring Excessive Cost).

The regulatory focus in the UK on foundry processes is 3 levels:

1. Larger foundry processes are regulated under PPC regulations (UK implementation of the EU directive on Integrated Pollution and Control - IPPC) by the Environment Agency. Typically, continuous measurement is required but for smaller emission points broken bag detection is sufficient. Very few industrial stacks have no continuous monitor.

   The UK Environment Agency provides incentives (in the form of less regulatory attention) to industrial operators that use continuous monitoring instrumentation which are MCERTS approved. MCERTS is a certification scheme which has operated in the UK since 1999. This Scheme defines standards to which continuous monitors must perform. Instruments obtain a certificate for specific processes and measurement ranges based on a laboratory and three month field test overseen by an independent test body (SIRA). ISO-10155 is used as a basis for the test standards against which particulate monitors are tested. Measurement and qualitative instruments are covered by this scheme.

2. Smaller foundries are regulated for air emissions by local authorities and regulations require;
   - Continuous measurement in stacks with air flow greater than $300m^3/min$
   - Qualitative monitoring and broken bag detection in stacks with air flow greater than $50m^3/min$
   - No monitoring in stacks below $50m^3/m$

3. Certain foundry processes which burn waste as a fuel source for furnaces also fall under the European Waste Incineration Directive (WID). These plants are regulated by the Environment Agency and must meet emission limits and monitoring protocols defined in the EU Directives. Continuous monitoring is to be done with the measurement uncertainty assessed. CEM systems are being upgraded in the period 2005- 2008 to meet these new requirements which are detailed in the European standard EN-14181. This standard sets procedures for instrument certification (QAL1/MCERTS), calibration (QAL2) on going quality assurance (QAL3) and an annual audit (AST).

5.3) Legislation in Germany

Like in the UK, regulatory limits are based on particulate concentration limits although the need for continuous measurement is based on local air pollution issues (ie stack is close to residential area) or on stacks when the total mass emissions of particulate is likely to exceed defined limits. These limits depend on the toxicity of the particulate. As in the UK and other European countries Incineration and Power plant falling under the WID and LCPD directive must fit continuous monitors according to EN-14181.
Specific national regulations impacting the use of continuous particulate monitors are:

- BImSchV 13: Combustion Plant > 50MW
- BImSchV 17: Incineration Plant
- BImSchV 27: Qualitative monitoring of particulate after filter plant

A type approval scheme exists in Germany. This scheme is widely respected, due to the importance placed on field testing and quality assurance issues (such as instrument checks). Particulate monitors are tested by independent test authorities (eg TUV) against standards and for measurement ranges defined by each of the above regulations. Test certificates note any restrictions on the use of an instrument.

5.4) Legislation in United States

Historically the UK and Germany have led the US in terms of experience with particulate monitors, since US emission limits and monitoring methods have been specified in terms of Opacity (colour) for large power plant. However, continuous particulate monitoring is now becoming a regulatory issue on many metals processes (including foundries) due to new regulatory rules which focus on continuous monitoring of particles:

- Specified industries (including Steel and foundry processes) must apply new MACT (Maximum Achievable Control Technologies) rules. Many of these rules especially in the metals industry require that baghouses be fitted with appropriate filter failure monitors. Qualitative Particulate monitors are used to satisfy these requirements
- Title V plants (the major metals, chemical, mineral and combustion processes) are required under the new CAM (Compliance Assurance Monitoring) regulations to develop a method to ensure the continuous compliance of their particulate arrestment plant (eg Baghouses and Electrostatic Precipitators). It is likely **qualitative particulate monitoring** will be chosen by many sites as a pragmatic solution to this new requirement when Title V permits are renewed.

6) Conclusion

The emissions of particulate from foundry processes can be effectively continuously monitored using Electrodynamic type instruments. These instruments provide robust, and accurate continuous monitoring of particulate emissions and arrestment plant condition (satisfying MCERTS and TUV approvals requirements). Instruments are used to both monitor particulate from bagfilters and also oil mist from mist eliminators. Electrodynamic emission monitors can be used to satisfy specific legislative monitoring requirements in UK, Germany, US and most other industrial nations. Plant operators may use the predictive capability of continuous monitors to reduce emissions from arrestment plant by appropriate preventative maintenance and reduce the costs for replacement filter bags.

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PCME Ltd, Clearview Building, 60 Edison Road, St. Ives, Cambs PE27 3GH
Tel: Int +44(0)1480 468200 Fax: Int +44(0)1480 463400
E-mail: sales@pcme.co.uk http://www.pcme.co.uk