Controlling Industrial Particulate Emissions: A Practical Overview of Baghouse Technology

Baghouses are widely used to control industrial particulate pollutants. The term "baghouse" refers to a filtration technology that uses cloth or synthetic filters. Baghouses are utilized in several industries, including power generation, chemicals, metal processing, cement and minerals, aggregate processing, food processing, and many other sectors.

In this article, we discuss a number of aspects related to the selection, installation, use, and maintenance of baghouses. The article is intended to provide a general explanation of baghouses and their use in controlling particulate emissions originating at industrial facilities. The reader will also find some basic information on evaluating and selecting baghouses.

We begin with a short history of the relevant regulatory background in the United States. We also summarize some findings from our review of the professional literature available on baghouses.

The discussion then moves on to a description of baghouse technology, including baghouse types and important design parameters. Also included is discussion of cost issues, maintenance and record keeping, examples of industrial baghouse use, and brief coverage of issues related to selecting the proper baghouse.

Regulatory Background

In the early days of environmental protection in the United States, control of air pollutants originating from industrial emission sources was a responsibility of municipal governments. The first federal involvement to control air pollution took place with the passage of the Air Pollution Control Act of 1955. This statute mandated federal research programs to investigate the health and welfare effects of air pollution, and authorized the federal government to provide technical assistance to the states. Additional legislation was promulgated in 1963 and 1965 (Cora & Hung, 2001).

The passage of the landmark Clean Air Act (CAA) of 1970 coincided with the creation of the United States Environmental Protection Agency (US EPA). The 1970 CAA emphasized stronger air

Mario G. Cora and Yung-Tse Hung
pollution control laws and regulations, establishing a number of mechanisms that are now familiar to practitioners in the field: National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIPs), National Emission Standards for Hazardous Air Pollutants (NESHAPs), New Source Performance Standards (NSPS), and Control Techniques Guidelines.

The 1970 CAA (as amended) established standards for total suspended particles (TSPs), sulfur dioxide, nitrogen oxides, carbon monoxide, and ozone. It also established primary and secondary air quality standards (Cora & Hung, 2000). Primary standards were intended to protect the public health, while secondary standards aimed to protect the public welfare and reduce anticipated adverse effects from air pollution. Primary and secondary standards must be achieved throughout the United States and its territories (Cora & Hung, 2000).

The basis for the control of particulate emissions rests on the establishment of NAAQS and the strategies developed in the individual SIPs to bring air quality non-attainment areas to attainment status. The 1970 CAA established an air quality standard for total suspended particles.

In 1987, this standard was redefined to apply to particulate matter with a diameter equivalent to or less than 10 micrometers. It is now widely known as the "PM10 standard." The current PM10 primary standard (24 hour) is equivalent to 150 micrograms per cubic meter (µg/m³). The secondary standard (one year) is set at 50 µg/m³.

**Literature Review**

As background for this article, we reviewed several relevant books on air pollution control, along with numerous articles in technical journals and magazines. The existing literature on baghouses offers the reader an idea of the practical air pollution control options that might be suitable at particular industrial facilities that generate considerable amounts of particulate emissions. We summarize some findings of our literature review here:

- Ulrich (2000) discusses the negative effects of moisture in the air lines servicing baghouses. The author notes that properly treated compressed air offers many benefits, including increased cartridge life, lower replacement costs, less maintenance and downtime, and increased product recovery. A selection of air dryers for dust collectors is recommended.

- Tsai and co-authors (2000) discuss the effect of filtration velocity and filtration pressure drop on the bag-cleaning performance of a pulse-jet baghouse. In this study, the filtration velocity and filtration pressure drop at the beginning of bag cleaning were used as experimental parameters to evaluate bag-cleaning performance. The filter’s final filtration resistance was found to be an important parameter in deciding whether a venturi is necessary for good bag-cleaning performance.

- Authors from the University of Tennessee Space Institute (UTSI) reviewed existing literature on the reduction of primary and secondary fine particulate matter (PM-2.5). Review findings were correlated with UTSI’s experience in capturing high loadings of sub-micron sized particulates from a pilot-scale fossil-fuel-powered steam bottoming cycle for magnetohydrodynamics (MHD) power generation development (Sheth & Giel, 2000).


- Yang (2000) discusses the effects of high fluoride waste on baghouse filter bags. Fluoride
gases were reacted with fiberglass at high temperature, and the reaction was studied as a function of percentage of moisture. Keeping the quench tower in front of the baghouse in good working condition was found to be a way of efficiently reducing the damage to the filter bags from the fluoride gases.

- Martin (2000) comments on the proper operation of baghouse equipment, and on options available for filtration media.
- Mycock (1999) discusses filter bag or fabric selection for baghouses that are suitable for different applications. Technical criteria and price/cost are correlated.
- Kasun (1999) notes the differences between a high-energy venturi wet scrubber and a pulse-jet baghouse. The article includes a comparison of cupola particulate control operating costs and discussion of the incremental cost of upgrading a wet system to a higher-efficiency baghouse.
- Lu and Tsai (1999) discuss the influence of design and operation parameters on the bag-cleaning performance of pulse-jet baghouses. The results show that the jet pump curves obtained under different operating conditions can be reduced to the same nondimensional curve, which can be used to facilitate the design and operation of a pulse-jet cleaning system.

Baghouses: The Technology
Filtration devices commonly known as “baghouses” are one of the simplest air pollution con-

---

**Some Useful Terms**

This list of terms includes some of the basic vocabulary of air pollution filtration. We include it here as a handy "quick reference" list.

- **Air (Standard):** Dry air at 70°F and 29.92 inches (Hg) barometric. This is substantially equivalent to 0.075 lb/cu ft.
  - Specific heat of dry air = 0.24 BTU/lb/F.
- **Air-to-cloth ratio:** The volumetric flow rate (amount) of gas entering the baghouse, divided by the total filtration or cloth area of the bags in the baghouse (ft²).
- **Cake:** The dust particle formation that builds on the surface of the filter medium during the filtration process.
- **Concentration:** The mass of dust in a given amount of gas volume (grains/ft³ or pounds/hour).
- **Density:** The ratio of the mass of a unit volume of a substance (lbs/ft³ or g/cm³).
- **Dust:** Small solid particles formed by the breaking up of larger particles through processes such as grinding, drilling, explosion, or crushing.
- **Dust Collector:** An air cleaning system used to remove heavy particulate loadings that originate at industrial processes.
- **Dust Loading:** The amount of dust in a given volume of gas stream (grains/ft³).
- **Fabric:** A term applied to filtering cloth, regardless of the construction material or the kind of fiber used.
- **Grain:** A dust-weight unit, defined as one grain = 1/7,000 lb.
- **Permeability:** A measure of fabric porosity, usually expressed in cfm at 0.5 inches H₂O.
- **Pressure Drop:** The resistance to airflow across the entire baghouse or the entire system.
- **Reverse-Air Baghouse:** A type of baghouse that employs a reverse-flow flushing of air to clean the dust from the bags.
- **Smoke:** Air suspension or aerosol of particles. The aerosol usually consists of very small, solid particles that often originate from a solid nucleus and are created through the processes of combustion or sublimation.
trol technologies, and have been used since well before the adoption of today's environmental laws. Baghouses can clean dirty airstreams containing small particles; their construction, installation, and operational costs make them a suitable technology for many different types of industries and applications, including steelmaking, cement, metalworking, and coal-fired boilers.

Baghouses clean airstreams by means of filtration media that hold very fine particles. The primary physical mechanism that holds the dust particles in the filtration medium is impaction. Direct impaction onto the cloth fiber accounts for almost 99 percent of the baghouse's collection of particles greater than 1 μm in aerodynamic diameter (Bethea, 1978).

Generally, baghouses can be classified as either standard or custom-made units. Standard manufactured units typically handle an airflow rate of between 100 to 100,000 standard cubic feet per minute (scfm).

Custom-made baghouses are especially designed for specific applications, and are manufactured according to a customer or designer's recommendations. These types of baghouses are designed to handle dirty gas airstreams of between 100,000 to 1,000,000 scfm.

Inlet gas temperatures may vary according to the process in use. The fabric chosen for the baghouse should be able to handle the temperature range at which the unit will operate. If the inlet airstream temperature requires cooling down, an approach such as air dilution or water spraying is recommended.

In some instances, if the amount of water injected into the inlet airstream is not properly controlled, the components in the gas may reach their dew point. This can lead to formation of sticky particles or deposition of acidic water, which may cause corrosion of the fabric.

**Baghouse Types: Shaker, Reverse-Air, and Pulse-Jet**

The baghouse technologies used at the majority of industrial facilities are of the shaker, reverse-air, and pulse-jet types. Specifics relating to these technologies are beyond the scope of this article. However, the differences in the technologies derive largely from the way the bags are cleaned:

- **Shaker baghouses**: The bags are cleaned by means of a mechanical device that shakes all the bags in the compartment, which is taken offline for cleaning.
- **Reverse-air and pulse-jet baghouses** use air currents to clean the bags: In the case of pulse-jet baghouses, the bags are cleaned by pulses of air injected through the bags after the compartment containing them is taken offline. In reverse-air baghouses, the air passes across the bags in a countercurrent motion in relation to the direction of filtration.

**Important Design Parameters**

Baghouse design is generally based on a number of variables. The primary design parameters for baghouses are air-to-cloth ratio, pressure drop, filter drag, and collection or removal efficiency.

Accurately determining these parameters is fundamental to successful operation of a baghouse. In some cases, the presence of specific or new process operations makes it difficult to determine the parameters.

In certain economic or process situations, it could be advisable to first operate a pilot-scale baghouse under conditions similar to those of the intended final use. After the pilot scale data have been gathered, a scaled-up model can be
designed, with greater assurance of successful performance. This approach might also reduce the possibility of future maintenance problems.

**Air-to-Cloth Ratio**

Air-to-cloth ratio (A/C) is often referred to as filtration velocity. This ratio is calculated by determining the amount of gas that is filtered or passed through the cloth filtering medium. The dimensions of the ratio typically are expressed as volumetric flow per square area of filtration medium. The air-to-cloth ratio may be expressed by using the following equation:

\[ V_t = \frac{Q}{A_c} \]

where

- \( V_t \) = filtration velocity of air-to-cloth ratio, ft/min (cm/s)
- \( Q \) = volumetric airflow rate, ft³/min (cm³/s)
- \( A_c \) = area of filtering cloth area, ft² (cm²)

Units may be expressed in cubic feet per minute per square foot (ft³/min/ft²) or cubic centimeter per second per square centimeter (cm³/sec/cm²). Algebraical manipulation reduces the A/C ratio to velocity units such as feet per minute or centimeters per second.

Another widely used term is “gross air-to-cloth ratio,” which refers to the total amount of cloth area used to filter the entire flue gas stream. Most baghouses are designed with several compartments. These compartments generally work in alternating modes, with some in operational mode while others are “offline” for cleaning.

The term “net air-to-cloth ratio” is used to describe the net amount of cloth available to filter an inlet airstream when one compartment is taken offline for maintenance. To determine the net air-to-cloth ratio, simply subtract the amount of cloth area in the compartment that is taken offline. The resulting number must be bigger than the air-to-cloth ratio because division occurs by a smaller cloth area \((A_{\text{total}} - A_{\text{compartment, i}})\). If two compartments are taken offline for maintenance, the term “net, net air-to-cloth ratio” may be used to refer to the resulting calculation.

**Pressure Drop**

Pressure drop (\( \Delta P \)) is one of the most important variables that must be considered in baghouse design. Pressure drop through a baghouse is caused by the airflow’s resistance that occurs when air passes through the filtering bags and the filter cake.

Pressure drop is measured by taking pressure readings at the inlet and outlet points of the baghouse. Pressure drop typically is expressed in inches or centimeters of water.

This parameter is important in large part because higher pressure drops can mean higher energy costs. Energy generally will be consumed by the fans that are used to push or pull the airstream through the baghouse.

The total pressure drop through a baghouse is a function of the pressure drop across the filter bags, plus the dust cake deposited onto the filter fabric. The pressure drop across a filter can easily be approximated by applying Darcy’s law for fluids passing through porous media. In this case, the law is applied assuming a clean filtering medium (Bethea, 1978). The relevant equation is shown below:

\[ \Delta P_f = k_1 V_f \]

where,

- \( \Delta P_f \) = pressure drop that occurs across a clean filtering material, inches H₂O (cm H₂O)
- \( k_1 \) = filter bag fabric resistance, inches H₂O (cm H₂O)
- \( V_f \) = filtration velocity, ft/min (cm/sec)
Filter bag fabric resistance is a function of particular filter characteristics (such as thickness and porosity), and gas viscosity. Porosity can be seen as a measure of the number of voids within the filter fabric.

To estimate the pressure drop across the deposited dust layer, an equation developed by Billings and Wilder (1970) can be used. It is shown below:

\[ \Delta P_t = k_0 \alpha V_t^2 t \]

where
\[ \Delta P_t = \text{pressure drop that occurs across deposited dust cake, inches } H_2O (\text{cm } H_2O) \]
\[ k_0 = \text{resistance due to deposited dust cake, inches } H_2O/(lb/ft^2-ft/min)[cm H_2O/(g/cm^2-cm/sec)] \]
\[ \alpha = \text{dust concentration in the airstream, lb/ft}^3 \ (g/cm^3) \]
\[ V_t = \text{filtration velocity, ft/min (cm/sec)} \]
\[ t = \text{filtration time, min (sec)} \]

Taking the last two equations (\( \Delta P_t, \Delta P_c \)) into consideration, the total pressure drop across the baghouse will be the sum of the pressure drop across the filter bags, plus the deposited dust cake on the filter fabric. This relationship is shown below:

\[ \Delta P_t = \Delta P_t + \Delta P_c \]

or

\[ \Delta P_t = k_1 V_t + k_0 \alpha V_t^2 t \]

The last pressure drop equation (\( \Delta P_t \)) applies to reverse-air and shaker baghouses.

It is important to mention that most manufacturers and vendors have established bag-cleaning cycles, as well as optimal operational parameters. For example, typical operating pressure drops across a baghouse can be maintained between four to ten inches H2O, based on most of the information available. Pressure drops above ten inches H2O can be indicative of high dust cake buildup on the filter bags, which might necessitate cleanup. It is always advisable to follow the manufacturer's recommendations regarding these parameters.

**Filter Drag**

Filter drag (\( S \)) is the resistance that occurs through the fabric dust layer (US EPA, 1995a). It is usually defined in terms of pressure drop per filtration velocity, \( V_t \). As explained above, pressure drop is a function of the filter medium and the amount of dust cake on the fabric. An equation showing this concept is:

\[ S = \frac{\Delta P}{V_t} \]

where
\[ S = \text{filter drag, inches } H_2O/(ft/min) \]
\[ \Delta P = \text{pressure drop across the filter cloth and dust cake} \]
\[ V_t = \text{filtration velocity, ft/min (cm/sec)} \]

An important concept to keep in mind is that the filtration capacity of a baghouse depends not
only on the filtration medium itself, but also (and often to a much greater extent) on the dust cake formed on top of the cloth medium.

**Removal Efficiency**

Baghouses typically are designed for particulate collection (removal) efficiencies of 99 percent to 99.9 percent. Actual operating removal efficiencies may differ slightly, down to the level of 95 percent. Factors that can influence collection efficiency include gas filtration velocity, particle characteristics, and the mechanism used for cleaning the bags. Generally, baghouse control efficiency increases in direct proportion to filtration velocity and particle size.

Grain loading (dust loading) is a key design parameter associated with collection efficiency. Grain loading refers to the quantity of dust in the gas stream, expressed as grains per cubic foot (gr/ft³). Typical gas streams from industrial processes contain grain loading concentrations of 0.5 to 10 gr/ft³. Under extreme dust loading conditions, concentration levels may reach 100 gr/ft³ (US EPA, 1998). Well-designed baghouses have been shown to be capable of reducing overall particulate emissions to less than 0.005 gr/ft³ (AWMA, 1992).

The grain loading concept is a crucial design parameter to consider when a baghouse is intended for use in the control of industrial emission sources that are subject to specific regulatory constraints. Regulatory limitations imposed on emissions from baghouses are frequently based on “best available technology” (BAT). For a baghouse that controls particles from industrial sources, BAT often is defined as an outlet airstream (cleaned air) containing a grain loading of approximately 0.01 gr/ft³ or less.

Any facility that is subject to this type of regulatory limitation should purchase a baghouse with the appropriate removal capabilities, as specified by the applicable regulations. In order to reduce particle emissions going into the baghouse, and decrease grain loading, it may be advisable to install cyclones or other mechanical control devices.

**Other Design Factors to Consider**

Several other baghouse design considerations are also important, as discussed below:

- Inlet gas characteristics are of extreme importance in selecting the material for the filtration medium. In addition to cost issues, special consideration must be given to the following aspects of the inlet gas stream: temperature, corrosiveness, hydrolysis, and dimensional stability (Bunicore & Davis, 1992).

  - Temperature: The filtration material must be able to withstand abrupt changes in temperature.
  - Corrosiveness: Physical corrosion of the filtration material may occur because of the levels of alkalinity and acidity in the inlet gas stream.
  - Hydrolysis: This refers to the humidity present in the inlet gas, which can sometimes cause sticky acidic or alkaline droplets to form.
  - Dimensional stability allows the material to withstand stretch forces caused by the surrounding environment.

- Most filter bag materials are classified as woven or nonwoven. Some materials have a higher resistance to heat and corrosion, depending on their characteristics.
  - Woven filters are made of yarn arranged in a repeating pattern.

Inlet gas characteristics are of extreme importance in selecting the material for the filtration medium.
Capital costs for a typical baghouse range from $6 to $26 per scfm. Annual operational and maintenance costs range from $5 to $24 per scfm.

- Nonwoven materials are subdivided into "membrane" or "felted." Membrane filters are made of special composite materials bonded to frames; these types of filters are used in systems that have inlet gases containing high moisture content, and when a very high removal efficiency is required. Felted filters are made of randomly arranged fibers compressed into a mat; the resulting configuration is similar to that of a floor mat.
- The fibers used to manufacture filtering media can be natural or synthetic.
  - Natural fibers such as cotton or wool were widely used in the past. Typically, natural fibers have average abrasion resistance and a temperature operational limitation below 212°F.
  - Synthetic fibers are now widely used because of their resistance to chemical damage and their reliability at higher operating temperatures. High-temperature operations (200–500°F) typically utilize synthetic fiber materials made of polyamide, acrylic, polyester, fluorocarbon, fiberglass, or other polymeric materials. Many of these materials are sold under trade names such as Nylon, Orlon, Dacron, Nomex, Teflon, or Ryton, and each has its unique set of characteristics.

When purchasing a baghouse, it is advisable to define early in the selection process the operational conditions under which the baghouse will operate. Information on operating conditions generally is available from the facility's process department or operations manual. Typical operational parameters that need to be considered include the pH of inlet gas stream (acidic or alkaline), the temperature range, and the abrasiveness of the particles.

**Cost Issues**

Several factors influence the cost of designing and installing baghouses. Key among these are waste stream volumetric flow rate and emission rates. Costs are also affected by the type of fabric material used, and by the kind of material used to construct the baghouse housing (Cooper & Alley, 1986).

Roughly speaking, capital costs for a typical baghouse range from $6 to $26 per scfm. Annual operational and maintenance costs range from $5 to $24 per scfm (US EPA, 1998).

Long-term operating costs can be minimized by ensuring efficient and reliable equipment operation. One prerequisite to reliable operation is good record keeping, which helps the user analyze operational problems and keep track of other pertinent information related to the equipment (Calvert & Englund, 1984).

**Maintenance and Record Keeping**

**Maintenance and Record-Keeping Challenges**

At the typical industrial facility, maintenance and operational personnel have their hands full just trying to ensure required production levels at process and production units. Because their economic and time resources are limited, they emphasize maintenance of production equipment, often devoting less time to the important maintenance procedures needed for air pollution control equipment.

Nonetheless, adequate maintenance and record keeping are a necessity. Air pollution regulatory agencies typically impose maintenance and record-keeping requirements in the permit-to-operate (PTO) that is issued to the industrial facility. The record-keeping requirements set out
in PTOs are intended to ensure that facility personnel will perform at least minimal inspections to air pollution control equipment, and that they will keep records of any malfunction that occurs and any corrective action taken.

A handy and well-filed set of maintenance records is very beneficial to facility personnel, especially on those occasions when a sudden equipment malfunction occurs. In addition, well-kept records provide evidence of good facility maintenance and operational practices in the event that a regulatory agency makes an inspection or brings an enforcement action.

Detailed maintenance records also allow facility personnel to monitor continuing equipment operation, identify abnormal operations or changing parameters, and develop historical records that can help prevent sudden failures (Bunicore & Davis, 1992).

Record-Keeping Elements

Once a facility decides to establish a record-keeping policy for a set of equipment, it is important to select the parameters that should be followed. In many instances, these record-keeping parameters will be clearly established in the PTO. The main record-keeping requirements for baghouse operational parameters typically include pressure drop, gas stream flow rate, outlet gas opacity, outlet temperature, and dust removal rate.

Pressure drop record keeping is a well-established monitoring requirement in most PTOs, since pressure drop can be indicative of irregular gas flow levels throughout an entire unit. Baghouses are designed to operate within specified pressure drop levels in direct proportion to the gas flow rate. If a sudden pressure drop is observed after prolonged use, it might be an indication of bag failure or gas flow bypassing the unit. A large pressure drop might also indicate heavy cake formation in the bags, which could eventually cause breakdown of the unit or blowers. In addition, abnormally high pressure drops can cause the unit to consume large amounts of energy.

Opacity in the outlet gas may be an indication that the baghouse is not removing particles, possibly because of baghouse failure; this may mean that the baghouse needs to be replaced.

Temperature is an important parameter to monitor because bags generally are selected to operate within a specific temperature range, and operating outside this range can create problems. For example, under corrosive gas conditions, a temperature drop below the gas dew point may lead to formation of acid mists that can deposit onto the bags.

Dust removal rates should also be monitored; abnormal dust removal rates per compartment might be another indication of bag failure.

An established inspection, monitoring, and record-keeping program is crucial to ensuring long-term baghouse service.

Inspection, Monitoring, and Record-Keeping Programs

An established inspection, monitoring, and record-keeping program is crucial to ensuring long-term baghouse service. A well-designed program can reduce maintenance requirements, along with operational and maintenance costs.

The facility personnel who handle equipment maintenance and operations generally are responsible for establishing and following the inspection, monitoring, and record-keeping program.

Industrial Baghouse Use: Some Examples

Baghouses are commonly used for controlling air pollutants throughout many industrial sectors. For example, since the 1970s, utility companies have been using baghouses to con-
control particulate emissions originating at coal-fired boilers (Cushing et al., 1990); these types of emission sources generate very fine dust particles that must be removed. Municipal waste incineration facilities also use baghouses for controlling emissions.

In the discussion below, we offer some details on the use of baghouses in aluminum processing, and then include brief descriptions of several other industrial sectors and facilities that employ baghouses for control of air pollutants.

**Aluminum Processing**

Aluminum processing produces emissions at process units (e.g., reverberatory furnaces, sweating furnaces, or dross handling equipment). The current regulatory requirements for secondary aluminum processing facilities may require the installation of lime-injected baghouses (Cora & Hung, 2001).

Emissions from aluminum processing units may produce variable amounts of compounds, including metallic particles and hydrogen chloride (HCl). The addition of lime (Ca(OH)₂) as a slurry or in dried form upstream of a fabric filter may considerably reduce emissions of these compounds. Injection at the ductwork upstream provides the necessary medium and contact time for the adsorption mechanism to work, and for the required chemical reaction to occur.

The adsorption process occurs through physical and chemical bonding of the acid gas molecules on the surfaces of the alkali particles (US EPA, 1995). The ductwork carrying the pollutants serves as the chamber in which this adsorption occurs. Lime injected into the gas stream reacts with the HCl or with sulfur dioxide, as indicated below:

\[(1) \text{Ca(OH)}_2 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + 2 \text{H}_2\text{O}\]

\[(2) \text{Ca(OH)}_2 + \text{SO}_2 \rightarrow \text{CaSO}_3 + \text{H}_2\text{O}\]

One of the authors of this article had the opportunity to observe the emissions originating at a 4,000-ton hydraulic press complex used for the production of metal (aluminum) forgings. All process emissions were collected and carried by ductwork and subsequently vented to a lime-injected baghouse. The press complex currently has the capacity to process approximately 8,000 pounds of metal per hour.

As part of the process, an oil-based lubricant material is applied between metal batch charges to lubricate the forging dies. The press complex operates at a temperature range of 600 to 800 degrees Fahrenheit. Lime is continuously injected to a 48-inch pipe from adjacent storage silos.

All the emissions from the forging line are collected by hoods, filtered in the bags, and vented through a stack. The control equipment observed was capable of maintaining compliance with the visible emission limitations of 20 percent opacity, as determined by US EPA Method 9 (40 CFR Part 60, Appendix A).

**Other Industrial Applications**

- At one engine block manufacturing plant, the particulate emissions from a 100-ton electric induction holding furnace servicing a gray iron cupola were controlled by a baghouse. All the emissions from the process were captured and vented to the baghouse, which was capable of reducing particulate emissions and complying with the opacity regulation mentioned above.

- An article by Kasun (1999) describes a pulse-jet baghouse that was used to control particulate emissions originating from a 600-ton-
per-day gray iron municipal/industrial fasting shop.

- A metal processing facility that operates two ball mills for recycling brass skims at the rate of 3,500 pounds per hour employed a baghouse for the control of particulate emissions. Emissions were captured by hoods at several points in the process (such as ball mills, mesh screens, and bucket elevators). The baghouse had an average design control efficiency of 99 percent, allowing 0.02 grains per cubic feet in the outlet stream. The collected particles were recoverable in the form of zinc oxide.

**Selecting the Appropriate Baghouse**

The selection of appropriate air pollution control equipment requires careful attention. Before any baghouse selection is made, facility personnel should study the process operational requirements specific to the facility and its industrial sector.

One key factor to consider is the type of air pollutants that must be controlled. In many instances, airstreams may contain a mixture of components, including dust particles, oil mist, or other types of fumes. The presence of these types of airstreams might necessitate pretreatment of inlet gases, or require a combination of air pollution control systems upstream of the baghouse.

It is also crucial to consider other factors, such as cost and maintenance requirements. And remember that, for many industrial sectors, the required particulate removal efficiency for air pollution control equipment can be up to 99.9 percent.

Facilities should also seek expert advice from suppliers and vendors of air pollution control equipment.

**Conclusion**

Many different industrial sectors use baghouse filtration technologies for control of air pollution. Technologies that use filtering media have been proven capable of achieving high particle removal efficiencies, retaining particles down to the range of 2.5 micrometers in diameter.

As noted in the available literature sources, the most widely used baghouses are the shaker, pulse-jet, and reverse-air types. Common process modifications include the installation of pre-cleaning equipment, such as cyclones or lower-efficiency impact separators. Other filtering configurations include the utilization of lime injection for enhancement of collection efficiencies, and the treatment of reactive gases contained in the inlet airstream.

Selecting a suitable filtration technology for a specific industrial application requires careful consideration of the facility’s specific process operational variables. In addition, the long-term operational success of a baghouse unit will depend on how well it is maintained and monitored by facility personnel.

**Bibliography**


secondary aluminum production: Determining the applicability of MACT requirements. Environmental Quality Management, 10(4), 45–56.


---

Mario G. Cora, EIT, REM, is a doctoral candidate in the Civil and Environmental Engineering Department at Cleveland State University in Cleveland, Ohio. His previous education includes an M.S. in Engineering with a management specialization from the University of Akron, Ohio, and a B.S. in Chemical Engineering from the University of Puerto Rico, Mayaguez Campus. He worked for three years in the Puerto Rico Environmental Protection Agency at the Wastewater Engineering and Permits Division. He currently works as a compliance specialist for an air pollution regulatory governmental agency in charge of environmental permitting procedures. Mr. Cora is a member of the Cleveland Engineering Society/Student Chapter and the College of Engineers and Surveyors of Puerto Rico. He may be reached by phone at 216-459-6284 or by e-mail at mariocora@hotmail.com. Yung-Tse Hung, Ph.D., PE, DEE, is a professor in the Civil and Environmental Engineering Department at Cleveland State University in Cleveland, Ohio. His education includes a B.S. and M.S. in Civil Engineering from Chung King University, Taiwan, and a Ph.D. in Environmental Engineering from the University of Texas at Austin. He is a Fellow of the American Academy of Environmental Engineers, and a registered professional engineer in Ohio and North Dakota. In addition to Cleveland State University, he has taught at the University of North Dakota, the University of Texas at Arlington, the University of Canterbury in New Zealand, Hong Kong University of Science and Technology, United Arab Emirates University, and at universities in Kazan, Russia, and Bishkek, Kyrgyzstan.