EPA-452/F-03-024

Air Pollution Control Technology Fact Sheet

Name of Technology: Fabric Filter - Mechanical Shaker Cleaned Type
- Mechanical Shaker Cleaned Type with Sonic Horn Enhancement
(also referred to as Baghouses)

Type of Technology: Control Device - Capture/Disposal

Applicable Pollutants: Particulate Matter (PM), including particulate matter less than or equal to 10 micrometers (µm) in aerodynamic diameter (PM_{10}), particulate matter less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$), and hazardous air pollutants (HAPs) that are in particulate form, such as most metals (except mercury is the notable exception, as a significant portion of emissions are in the form of elemental vapor).

Achievable Emission Limits/Reductions:

Typical new equipment design efficiencies are between 99 and 99.9%. Older existing equipment have a range of actual operating efficiencies of 95 to 99.9%. Several factors determine fabric filter collection efficiency. These include gas filtration velocity, particle characteristics, fabric characteristics, and cleaning mechanism. In general, collection efficiency increases with increasing filtration velocity and particle size.

For a given combination of filter design and dust, the effluent particle concentration from a fabric filter is nearly constant, whereas the overall efficiency is more likely to vary with particulate loading. For this reason, fabric filters can be considered to be constant outlet devices rather than constant efficiency devices. Constant effluent concentration is achieved because at any given time, part of the fabric filter is being cleaned. As a result of the cleaning mechanisms used in fabric filters, the collection efficiency is constantly changing. Each cleaning cycle removes at least some of the filter cake and loosens particles which remain on the filter. When filtration resumes, the filtering capability has been reduced because of the lost filter cake and loose particles are pushed through the filter by the flow of gas. As particles are captured, the efficiency increases until the next cleaning cycle. Average collection efficiencies for fabric filters are usually determined from tests that cover a number of cleaning cycles at a constant inlet loading. (EPA, 1998a)

Applicable Source Type: Point

Typical Industrial Applications:

Fabric filters can perform very effectively in many different applications. Common applications of fabric filter systems with mechanical shaker cleaning are presented in Table 1, however, fabric filters can be used in most any process where dust is generated and can be collected and ducted to a central location. Sonic horn enhancement of mechanical shaker cleaning is generally used for applications with dense particulates such as utility boilers, metal processing, and mineral products.

Table 1. Typical Industrial Applications of Shaker Cleaned Fabric Filters (EPA, 1998a)

Application	Source Category Code (SCC)
Utility Boilers (Coal)	1-01-002...003
Non-Ferrous Metals Processing (Primary and Secondary):	
Copper	3-03-005, 3-04-002
Lead	3-03-010, 3-04-004
Zinc	3-03-030, 3-04-008
Aluminum	3-03-000...002 3-04-001
Other metals production	3-03-011...014 3-04-005...006 3-04-010...022
Ferrous Metals Processing:	
Coke	3-03-003...004
Ferroalloy Production	3-03-006...007
Iron and Steel Production	3-03-008...009
Gray Iron Foundries	3-04-003
Steel Foundries	3-04-007,-009
Mineral Products:	
Cement Manufacturing	3-05-006...007
Coal Cleaning	3-05-010
Stone Quarrying and Processing	3-05-020
Other	3-05-003...999
Asphalt Manufacture	3-05-001...002

Emission Stream Characteristics:

a. **Air Flow:** Baghouses are separated into two groups, standard and custom, which are further separated into low, medium, and high capacity. Standard baghouses are factory-built, off the shelf units. They may handle from less than 0.10 to more than 50 standard cubic meters per second (sm^3/sec) ("hundreds" to more than 100,000 standard cubic feet per minute (scfm)). Custom baghouses are designed for specific applications and are built to the specifications prescribed by the customer. These units are generally much larger than standard units, i.e., from 50 to over 500 sm^3/sec (100,000 to over 1,000,000 scfm). (EPA, 1998b)

b. **Temperature:** Typically, gas temperatures up to about 260°C (500°F), with surges to about 290°C (550°F), can be accommodated with the appropriate fabric material. Spray coolers or dilution air can be used to lower the temperature of the pollutant stream. This prevents the temperature limits of the fabric from being exceeded. Lowering the temperature, however, increases the humidity of the pollutant stream. Therefore, the minimum temperature of the pollutant stream must remain above the dew point of any condensable in the stream. The baghouse and associated ductwork should be insulated and possibly heated if condensation may occur. (EPA, 1998b)

c. **Pollutant Loading:** Typical inlet concentrations to baghouses are 1 to 23 grams per cubic meter (g/m^3) (0.5 to 10 grains per cubic foot (gr/ft^3)), but in extreme cases, inlet conditions may vary between 0.1 to more than 230 g/m^3 (0.05 to more than 100 gr/ft^3). (EPA, 1998b)

d. **Other Considerations:** Moisture and corrosives content are the major gas stream characteristics requiring design consideration. Standard fabric filters can be used in pressure or vacuum service, but only within the range of about ± 640 millimeters of water column (25 inches of water column). Well-designed and operated baghouses have been shown to be capable of reducing overall particulate emissions to less than 0.05 gr/m^3 (0.010 gr/ft^3), and in a number of cases, to as low as 0.002 to 0.011 g/m^3 (0.001 to 0.005 gr/ft^3). (AWMA, 1992)

Emission Stream Pretreatment Requirements:

Because of the wide variety of filter types available to the designer, it is not usually required to pretreat a waste stream's inlet temperature. However, in some high temperature applications, the cost of high temperature-resistant bags must be weighed against the cost of cooling the inlet temperature with spray coolers or dilution air (EPA, 1998b). When much of the pollutant loading consists of relatively large particles, mechanical collectors such as cyclones may be used to reduce the load on the fabric filter, especially at high inlet concentrations (EPA, 1998b).

Cost Information:

Cost estimates, expressed in 2002 dollars, are presented below for mechanical shaker cleaned fabric filters and for sonic horn enhancement. Both the shaker cleaned and sonic horn cost estimates assume a conventional design under typical operating conditions. The costs do not include auxiliary equipment such as fans and ductwork.

The costs for shaker cleaned systems are generated using EPA's cost-estimating spreadsheet for fabric filters (EPA, 1998b). The cost estimate for sonic horn enhancement is obtained from the manufacturer quote given in the OAQPS Control Cost Manual (EPA, 1998b). Sonic horns are presented as an incremental cost to the capital cost for a shaker cleaned system. The operational and maintenance (O&M) cost for shaker cleaned systems are reduced by 1% to 3% with the sonic horn enhancement.

Costs are primarily driven by the waste stream volumetric flow rate and pollutant loading. In general, a small unit controlling a low pollutant loading will not be as cost effective as a large unit controlling a high pollutant loading. The costs presented are for flow rates of 470 m^3/sec (1,000,000 scfm) and 1.0 m^3/sec (2,000 scfm), respectively, and a pollutant loading of 9 g/m^3 (4.0 gr/ft^3) .

Pollutants that require an unusually high level of control or that require the fabric filter bags or the unit itself to be constructed of special materials, such as Gore-Tex or stainless steel, will increase the costs of the system (EPA, 1998b). The additional costs for controlling more complex waste streams are not reflected in the estimates given below. For these types of systems, the capital cost could increase by as much as 30% and the O&M cost could increase by as much as 7%.

a. **Capital Cost:** \$17,000 to \$153,000 per m^3/sec (\$8 to \$72 per scfm)
\$1,000 to \$1,300 per m^3/sec (\$0.51 to \$0.61 per scfm), additional cost for sonic horns

b. **O & M Cost:** \$9,300 to \$51,000 per m^3/sec (\$4 to \$24 per scfm), annually

c. **Annualized Cost:** \$11,000 to \$95,000 per m^3/sec (\$5 to \$45 per scfm), annually

d. **Cost Effectiveness:** \$41 to \$334 per metric ton (\$37 to \$303 per short ton)

Theory of Operation:

In a fabric filter, flue gas is passed through a tightly woven or felted fabric, causing PM in the flue gas to be collected on the fabric by sieving and other mechanisms. Fabric filters may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are most common type of fabric filter. The dust cake that forms on the filter from the collected PM can significantly increase collection efficiency. Fabric filters are frequently referred to as baghouses because the fabric is usually configured in cylindrical bags. Bags may be 6 to 9 m (20 to 30 ft) long and 13 to 31 centimeters (cm) (5 to 12 inches) in diameter. Groups of bags are placed in isolable compartments to allow cleaning of the bags or replacement of some of the bags without shutting down the entire fabric filter. (STAPPA/ALAPCO, 1996)

Operating conditions are important determinants of the choice of fabric. Some fabrics (e.g., polyolefins, nylons, acrylics, polyesters) are useful only at relatively low temperatures of 95 to 150°C (200 to 300°F). For high-temperature flue gas streams, more thermally stable fabrics such as fiberglass, Teflon®, or Nomex® must be used (STAPPA/ALAPCO, 1996).

Practical application of fabric filters requires the use of a large fabric area in order to avoid an unacceptable pressure drop across the fabric. Baghouse size for a particular unit is determined by the choice of air-to-cloth ratio, or the ratio of volumetric air flow to cloth area. The selection of air-to-cloth ratio depends on the particulate loading and characteristics, and the cleaning method used. A high particulate loading will require the use of a larger baghouse in order to avoid forming too heavy a dust cake, which would result in an excessive pressure drop As an example, a baghouse for a 250 megawatt (MW) utility boiler may have 5,000 separate bags with a total fabric area approaching 46,500 m^2 (500,000 square feet). (ICAC, 1999)

Determinants of baghouse performance include the fabric chosen, the cleaning frequency and methods, and the particulate characteristics. Fabrics can be chosen which will intercept a greater fraction of particulate, and some fabrics are coated with a membrane with very fine openings for enhanced removal of submicron particulate. Such fabrics tend to be more expensive. Cleaning intensity and frequency are important variables in determining removal efficiency. Because the dust cake can provide a significant fraction of the fine particulate removal capability of a fabric, cleaning which is too frequent or too intense will lower the removal efficiency. On the other hand, if removal is too infrequent or too ineffective, then the baghouse pressure drop will become too high. (ICAC, 1999)

Mechanical shaking has been a popular cleaning method for many years because of its simplicity as well as its effectiveness. In typical operation, dusty gas enters an inlet pipe to the shaker cleaned fabric filter and very large particles are removed from the stream when they strike the baffle plate in the inlet duct and fall into the hopper. The particulate-laden gas is drawn from beneath a cell plate in the floor and into the filter bags. The gas proceeds from the inside of the bags to the outside and through the outlet pipe. The particles are collected on the inside surface of the bags and a filter cake accumulates. In mechanical shaking units, the tops of bags are attached to a shaker bar, which is moved briskly (usually in a horizontal direction) to clean the bags. The shaker bars are operated by mechanical motors or by hand, in applications where cleaning is not required frequently. (EPA, 1998a)

The vibration cleaning method is similar to mechanical shaking units. It utilizes a pneumatically driven high frequency, low amplitude vibration of the bag frame to clean the bags. This method has limited application due to its low cleaning energy and smaller baghouse design (Billings, 1970).

Sonic horns are increasingly being used to enhance the collection efficiency of mechanical shaker and reverse-air fabric filters (AWMA, 1992). Sonic horns utilize compressed air to vibrate a metal diaphragm, producing a low frequency sound wave from the horn bell. The number of horns required is determined by fabric area and the number of baghouse compartments. Typically, 1 to 4 horns per compartment operating at 150 to 200 hertz are required. Compressed air to power the horns is supplied at 275 to 620 kiloPascals (kPa) (40 to 90 pounds per square inch gage (psig)). Sonic horns activate for approximately 10 to 30 seconds during each cleaning cycle (Carr, 1984) .

Sonic horn cleaning significantly reduces the residual dust load on the bags. This decreases the pressure drop across the filter fabric by 20 to 60%. It also lessens the mechanical stress on the bags, resulting in longer operational life (Carr, 1984). As stated previously, this can decrease the O&M cost by 1 to 3%, annually. Baghouse compartments are easily retrofitted with sonic horns. Sonic assistance is frequently used with fabric filters at coal-burning utilities (EPA, 1998a).

Advantages:

Fabric filters in general provide high collection efficiencies on both coarse and fine (submicron) particulates. They are relatively insensitive to fluctuations in gas stream conditions. Efficiency and pressure drop are relatively unaffected by large changes in inlet dust loadings for continuously cleaned filters. Filter outlet air is very clean and may be recirculated within the plant in many cases (for energy conservation). Collected material is collected dry for subsequent processing or disposal. Corrosion and rusting of components are usually not problems. Operation is relatively simple. Unlike electrostatic precipitators, fabric filter systems do not require the use of high voltage, therefore, maintenance is simplified and flammable dust may be collected with proper care. The use of selected fibrous or granular filter aids (precoating) permits the high-efficiency collection of submicron smokes and gaseous contaminants. Filter collectors are available in a large number of configurations, resulting in a range of dimensions and inlet and outlet flange locations to suit installation requirements. (AWMA, 1992)

Disadvantages:

Temperatures much in excess of 290°C (550°F) require special refractory mineral or metallic fabrics, which can be expensive. Certain dusts may require fabric treatments to reduce dust seepage, or in other cases, assist in the removal of the collected dust. Concentrations of some dusts in the collector, approximately 50 g/m^3 (22 gr/ft^3), may represent a fire or explosion hazard if a spark or flame is accidentally admitted. Fabrics can burn if readily oxidizable dust is being collected. Fabric filters have relatively high maintenance requirements (e.g., periodic bag replacement). Fabric life may be shortened at elevated temperatures and in the presence of acid or alkaline particulate or gas constituents. They cannot be operated in moist environments; hygroscopic materials, condensation of moisture, or tarry adhesive components may cause crusty caking or plugging of the fabric or require special additives. Respiratory protection for maintenance personnel may be required when replacing fabric. Medium pressure drop is required, typically in the range of 100 to 250 mm of water column (4 to 10 inches of water column). (AWMA, 1992)

Other Considerations:

Fabric filters are useful for collecting particles with resistivities either too low or too high for collection with electrostatic precipitators. Fabric filters therefore may be good candidates for collecting fly ash from low-sulfur coals or fly ash containing high unburned carbon levels, which respectively have high and low resistivities, and thus are relatively difficult to collect with electrostatic precipitators. (STAPPA/ALAPCO, 1996)

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