EPA-452/F-03-004

Air Pollution Control Technology Fact Sheet

Name of Technology: Paper/Nonwoven Filters - Cartridge Collector Type with Pulse-Jet Cleaning (also referred to as Extended Media)

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 (mercury is the notable exception, as a significant portion of emissions are in the form of elemental vapor).

Achievable Emission Limits/Reductions:

Older existing cartridge collector types have a range of actual operating efficiencies of 99 to 99.9% for PM_{10} and $PM_{2.5}$. Typical new equipment design efficiencies are between 99.99 and 99.999+% (EPA, 1998b). In addition, commercially available designs are able to control submicron PM (0.8 µm in diameter or greater) with a removal efficiency of 99.999+% (AAF, 1999; Torit, 1999). Several factors determine cartridge filter collection efficiency including gas filtration velocity, particle characteristics, filter media 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 cartridge collector is nearly constant, whereas the overall efficiency is more likely to vary with particulate loading. For this reason, cartridge collectors 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 filter media is being cleaned. As a result of the cleaning mechanisms used in cartridge collectors, the collection efficiency is constantly changing. Each cleaning cycle removes at least some of the filter cake and loosens particles that remain on the filter. When filtration resumes, the filtering capability has been reduced because 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 cartridge collectors 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:

Cartridge collectors perform very effectively in many different applications. Common applications of cartridge filter systems with pulse-jet cleaning are presented in Table 1. In addition to these applications, cartridge collectors can be used in any process where dust is generated and can be collected and ducted to a central location.

Table 1. Typical Industrial Applications of Cartridge Collectors with Pulse-Jet Cleaning (EPA, 1997; Heumann, 1997)

Application		Source Category Code (SCC)
Fabricated Metal Products:		
	Abrasive Blasting	3-09-002
	Machining	3-09-300
	Welding	3-09-005, 3-09-040...059
Pigment Grinding and Milling		3-01-014-30...41, 3-01-020-30...41, 3-01-035-50..54
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
Grain Milling		3-02-007

Emission Stream Characteristics:

a. **Air Flow:** Cartridge collectors are currently limited to low air flow capacity applications. Standard cartridge collectors are factory-built, off the shelf units. They may handle air flow rates from less than 0.10 to more than 5 standard cubic meters per second (sm^3/sec) ((“hundreds” to more than 10,000 standard cubic feet per minute (scfm)). (EPA, 1998b)

b. **Temperature:** Temperatures are limited by the type of filter media and sealant used in the cartridges. Standard cartridges utilizing paper filter media can accommodate gas temperatures up to about 95°C (200°F) (EPA, 1998b). Cartridge filters utilizing synthetic, nonwoven media such as needle-punched felts fabricated of polyester or Nomex®, can withstand temperatures of up to 200°C (400°F) with the appropriate sealant material (IFF, 1999).

Spray coolers or dilution air can be used to lower the temperature of the pollutant stream. This prevents the temperature limits of the filter media from being exceeded. Lowering the temperature can result in higher 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 cartridge collector and associated ductwork should be insulated and possibly heated if condensation may occur. (EPA, 1998b)

c. **Pollutant Loading:** Typical inlet concentrations to cartridge collectors are 1 to 23 grams per cubic meter (g/m^3) (0.5 to 10 grains per cubic foot (gr/ft^3)) (EPA, 1998b). Cartridge filters, which utilize synthetic, nonwoven media such as needle-punched felts fabricated of polyester or Nomex®, are able to handle inlet concentrations up to 57 g/m^3 (25 gr/ft^3) (IFF, 1999).

d. **Other Considerations:** Moisture and corrosives content in the gas streams are the major design considerations. Standard cartridge 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) (AWMA, 1992). Baghouses have been shown to be capable of reducing overall particulate emissions to less than 0.05 g/m^3 (0.010 gr/ft^3) (AWMA, 1992). Penetration of PM in cartridge collectors is generally many times less than in traditional baghouse designs (Heumann, 1997).

Emission Stream Pretreatment Requirements:

Because of the wide variety of filter types available to the designer, the inlet temperature of the waste stream usually does not require pretreatment. However, in some high temperature applications, the cost of high temperature-resistant cartridge filters 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 filter media, especially at high inlet concentrations (EPA, 1998b).

Cost Information:

Cost estimates, expressed in 2002 dollars, are presented below for cartridge collectors with pulse-jet cleaning. The cost estimates assume a conventional design under typical operating conditions. Auxiliary equipment, such as fans and ductwork, is not included. The costs are generated using EPA's cost-estimating spreadsheets for fabric filters (EPA, 1998b).

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. Cartridge collectors are currently limited to low flow rate applications. The capital cost for a cartridge collector is significantly lower than for a baghouse, however, the operational and maintenance (O&M) cost tends to be higher. The costs presented are for flow rates of 5 m^3/s (10,000 scfm) and 1.0 m^3/s (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 filter media or the unit itself to be constructed of special materials, such as Nomex® 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 75% and the O&M cost could increase by as much as 10%.

a. **Capital Cost:** $15,000 to $28,000 per sm^3/s ($7 to $13 per scfm)

b. **O & M Cost:** $20,000 to $52,000 per sm^3/s ($9 to $25 per scfm), annually

c. **Annualized Cost:** $26,000 to $80,000 per sm^3/s ($13 to $38 per scfm), annually

d. **Cost Effectiveness:** $94 to $280 per metric ton ($85 to $286 per short ton)

Theory of Operation:

Cartridge filters contain either a paper or nonwoven fibrous filter media. Paper media is generally fabricated of natural or synthetic materials such as cellulose and fiberglass. Nonwoven media is generally fabricated from synthetic materials such as Nomex®, polyester, or polypropylene (EPA, 1998a; Heumann, 1997). The media is supported by inner and outer wire frameworks. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. The dust cake that forms on the filter media from the collected PM can significantly increase collection efficiency (EPA, 1998a).

In general, the filter media is pleated to provide a larger surface area to volume flow rate. For this reason, cartridge filters are also referred to as extended media filters. Close pleating, however, can cause PM to bridge the pleat bottom, effectively reducing the surface area (EPA, 1998a). Corrugated aluminum separators are often employed to prevent the pleated media from collapsing (Heumann, 1997). The pleat depth can vary anywhere from 2.5 cm (1 inch) up to 40 cm (16 inches) (EPA, 1998a). Pleat spacing generally ranges between 12 to 16 pleats per inch, with certain conditions requiring fewer pleats, 4 to 8 pleats per inch (EPA,1998b).

There are a wide variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs (Heumann, 1997). Commercially available cylindrical packs are approximately 15 to 35 centimeters (cm) (6 to 14 inches) in diameter and 40 to 122 cm (16 to 48 inches) in length (EPA, 1998a).

The cartridge is closed at one end with a metal cap. The media is sealed to the cap using polyurethane plastic, epoxy, or other commercially available sealant. For certain applications, two cartridges may be placed in series. The cartridges are placed in a frame constructed of wood or metal. A neoprene or silicone gasket seals the frame to the clean air plenum of the collector. The cartridges may be mounted horizontally or vertically, if retrofitting a baghouse. (EPA, 1998a)

Replacement of the cartridges is generally performed outside of the collector. This reduces the risk of exposure to PM by the maintenance workers. This feature is especially important for HAP applications. The Occupational Safety and Health Administration (OSHA) requires special filter replacement procedures, commonly referred to as bag in/bag out procedures, for many HAP applications. (Heumann, 1997)

Operating conditions are important determinants of the choice of filter media and sealant used in the cartridges. Some filter media, such as cellulose paper filters, 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 filter media, such as nonwoven polyester, polypropylene, or Nomex®, must be used (EPA, 1998a). A variety of commercially available sealants such as polyurethane plastic and epoxy will allow for operating temperatures up to150°C (300°F). Selected sealants such as heat cured Plasitcol® will withstand operating temperatures up to 200°C (400°F) (EPA, 1998a; IFF, 1999).

Practical application of cartridge collectors requires the use of a large media area in order to avoid an unacceptable pressure drop across the filter media. The number of cartridges utilized in a particular collector is determined by the choice of air-to-cloth ratio, or the ratio of volumetric air flow to filter media area (ICAC, 1999). The selection of air-to-cloth ratio depends on the particulate loading, particulate characteristics, and the cleaning method used. A high particulate loading will require the use of a larger number of cartridges in order to avoid forming a heavy dust cake, which results in an excessive pressure drop (ICAC, 1999). The paper and nonwoven filter media used in cartridge filters have a larger pressure drop across the filter than the woven fabric used in bags. For this reason, cartridge collectors are utilized at lower air flow rates and particulate loadings than traditional baghouse designs (Heumann, 1997).

Determinants of cartridge collector performance include the filter media chosen, the cleaning frequency and methods, and the particulate characteristics. Filter media can be chosen which will intercept a greater fraction of particulate, and some filter media are coated with a membrane with very fine openings for enhanced removal of submicron particulate. Such filter media tend to be more expensive. (ICAC, 1999)

Pulse-jet cleaning of cartridge filters is relatively new, having only been used for the past 30 years. This cleaning mechanism has consistently grown in popularity because it can treat high dust loadings, operate at constant pressure drop, and occupy less space than traditional bag-type fabric filters. Pulse-jet cleaned cartridge filters can only operate as external cake collection devices. The cartridges are closed at the bottom, and open at the top. Particulate-laden gas flows into the collector, with diffusers often used to prevent oversized particles from damaging the filter media. The gas flows from the outside to the inside of the cartridges, and then out the gas exhaust. The particles are collected on the outside of the filter media and drop into a hopper below the cartridge after cleaning. (EPA, 1998b)

During pulse-jet cleaning, a short burst, 0.03 to 0.1 seconds in duration, of high pressure, 415 to 830 kiloPascals (kPa) (60 to 120 pounds per square inch gage (psig)), air is injected into the cartridges (EPA, 1998b; AWMA, 1992). The pulse is blown through a venturi nozzle at the top of the cartridges and establishes a shock wave that continues onto the bottom of the cartridges. The wave flexes the filter media, dislodging the dust cake. The cleaning cycle is regulated by a remote timer connected to a solenoid valve. The burst of air is controlled by the solenoid valve and is released into blow pipes that have nozzles located above the cartridges (EPA, 1998b).

There are several unique attributes of pulse-jet cleaning. Because the cleaning pulse is very brief, the flow of dusty gas does not have to be stopped during cleaning. The other cartridges continue to filter, taking on extra duty because of the cartridges being cleaned. In general, there is no change in filter pressure drop or performance as a result of pulse-jet cleaning. This enables the cartridge collectors with pulse-jet cleaning to operate on a continuous basis with solenoid valves as the only significant moving parts. Pulse-jet cleaning is also more intense and occurs with greater frequency than the other filter cleaning methods. This intense cleaning dislodges nearly all of the dust cake each time the cartridge is pulsed. As a result, pulse-jet filters do not rely on a dust cake to provide filtration. Paper and nonwoven filter media are used in pulse-jet cleaned cartridge collectors because they do not require a dust cake to achieve high collection efficiencies. (EPA, 1998b)

Since cartridges cleaned by the pulse-jet method do not need to be isolated for cleaning, the collector does not need extra compartments to maintain adequate filtration during cleaning. In addition, the pleating of the filter media provides increased filter area per housing volume. Consequently, cartridge collectors cleaned by the pulse-jet method can be smaller than traditional fabric filter baghouses in the treatment of the same amount of gas and dust (EPA, 1998b). A cartridge collector is approximately 4 times smaller than baghouse designs for similar gas streams (Heumann, 1997).

Advantages:

Cartridge 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). PM is collected dry for subsequent processing or disposal. Corrosion and rusting of components are usually not problems. Operation is relatively simple. Unlike electrostatic precipitators, cartridge 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. Cartridge 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 95°C (200°F) require special filter media, which can be expensive (EPA, 1998a). Certain dusts may require filter media 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. Cartridge filters can burn if readily oxidizable dust is being collected. Cartridge filters have relatively high maintenance requirements (e.g., periodic cartridge replacement). Filter 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 filter media or require special additives. Medium pressure drop is required, typically in the range of 100 to 250 mm of water column (4 to 10 in. of water column) (AWMA, 1992).

A specific disadvantage of pulse-jet units that use very high gas velocities is that the dust from the cleaned cartridges can be drawn immediately to the other cartridges. If this occurs, little of the dust falls into the hopper and the dust layer on the cartridges becomes too thick. To prevent this, cartridge collectors with pulse-jet cleaning can be designed with separate compartments that can be isolated for cleaning. (EPA, 1998b)

Other Considerations:

Cartridge collectors are useful for collecting particles with resistivities either too low or too high for collection with electrostatic precipitators (STAPPA/ALAPCO, 1996). They are ideal for HAP applications due to the cartridge replacement procedure being performed outside the collector housing. For similar air flow rates, cartridge collectors are compact in size compared to traditional baghouses. The application of cartridge collectors is limited to low air flow rates (Heumann, 1997).

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