Baghouses and Fabric Filters for Particulate Control

An Online Continuing Education Course for Engineers

Course Number: EN-4033

Credit: 4 Hours / 4 PDH / 4 CPD

1.1 Introduction

A fabric filter unit consists of one or more isolated compartments containing rows of fabric bags in the form of round, flat, or shaped tubes, or pleated cartridges. Particle-laden gas passes up (usually) along the surface of the bags then radially through the fabric. Particles are retained on the upstream face of the bags, and the cleaned gas stream is vented to the atmosphere. The filter is operated cyclically, alternating between relatively long periods of filtering and short periods of cleaning. During cleaning, dust that has accumulated on the bags is removed from the fabric surface and deposited in a hopper for subsequent disposal.

Fabric filters collect particles with sizes ranging from submicron to several hundred microns in diameter at efficiencies generally in excess of 99 or 99.9 percent. The layer of dust, or dust cake, collected on the fabric is primarily responsible for such high efficiency. The cake is a barrier with tortuous pores that trap particles as they travel through the cake. Gas temperatures up to about 500°F, with surges to about 550°F can be accommodated routinely in some configurations. Most of the energy used to operate the system appears as pressure drop across the bags and associated hardware and ducting. Typical values of system pressure drop range from about 5 to 20 inches of water. Fabric filters are used where high-efficiency particle collection is required. Limitations are imposed by gas characteristics (temperature and corrosivity) and particle characteristics (primarily stickiness) that affect the fabric or its operation and that cannot be economically accommodated.

Important process variables include particle characteristics, gas characteristics, and fabric properties. The most important design parameter is the air- or gas-to-cloth ratio (the amount of gas in ft^3/min that penetrates one ft^2 of fabric) and the usual operating parameter of interest is pressure drop across the filter system. The major operating feature of fabric filters that distinguishes them from other gas filters is the ability to renew the filtering surface periodically by cleaning. Common furnace filters, high efficiency particulate air (HEPA) filters, high efficency air filters (HEAFs), and automotive induction air filters are examples of filters that must be discarded after a significant layer of dust accumulates on the surface. These filters are typically made of matted fibers, mounted in supporting frames, and used where dust concentrations are relatively low. Fabric filters are usually made of woven or (more commonly) needlepunched felts sewn to the desired shape, mounted in a plenum with special hardware, and used across a wide range of dust concentrations.

Another type of fabric filter developed in the 1970s and 1980s is the electrostatically enhanced filter. Pilot plant baghouses employing this technology have shown substantially lower pressure drops than conventional filter designs. Further, some cost analyses have shown that electrostatically enhanced baghouses could have lower lifetime costs than convention baghouses. The purpose of this course, however, is to focus only on currently available commercial filters.

1.2 Process Description

In this section, the types of fabric filters and the auxiliary equipment required are discussed first from a general viewpoint. Then, fabric filtration theory as applied to each type of filter is discussed to lay a foundation for the sizing procedures. Fabric filters can be categorized by several means, including type of cleaning (shaker, reverse-air, pulse-jet), direction of gas flow (from inside the bag towards the outside or vice versa), location of the system fan (suction or pressure), or size (low, medium, or high gas flow quantity). Of these four approaches, the cleaning method is probably the most distinguishing feature. Fabric filters are discussed in this section based on the type of cleaning employed.

1.2.1 Shaker Cleaning

For any type of cleaning, enough energy must be imparted to the fabric to overcome the adhesion forces holding dust to the bag. In shaker cleaning, used with inside-to-outside gas flow, energy transfer is accomplished by suspending the bag from a motor-driven hook or framework that oscillates. Motion may be imparted to the bag in several ways, but the general effect is to create a sine wave along the fabric. As the fabric moves outward from the bag centerline during portions of the wave action, accumulated dust on the surface moves with the fabric. When the fabric reaches the limit of its extension, the patches of dust have enough inertia to tear away from the fabric and descend to the hopper.

For small, single-compartment baghouses, usually operated intermittently, a lever attached to the shaker mechanism may be operated manually at appropriate intervals, typically at the end of a shift. In multi-compartment baghouses, usually operated continuously, a timer or a pressure sensor responding to system pressure drop initiates bag shaking automatically. The compartments operate in sequence so that one compartment at a time is cleaned. Forward gas flow to the compartment is stopped, dust is allowed to settle, residual gas flow stops, and the shaker mechanism is switched on for several seconds to a minute or more. The settling and shaking periods may be repeated, then the compartment is brought back on-line for filtering. As a result of no forward flow through the compartment, the baghouse collecting area must be increased to compensate for that portion being out of service at any time for cleaning. Figure 1.1 illustrates a shaker-cleaned baghouse.

Parameters that affect cleaning include the amplitude and frequency of the shaking motion and the tension of the mounted bag. The first two parameters are part of the baghouse design and generally are not changed easily. The tension is set when bags are installed. Typical values are about 4 Hz for frequency and 2 to 3 inches for amplitude (half-stroke).[4] Some installations allow easy adjustment of bag tension, while others require that the bag be loosened and reclamped to its attaching thimble.

Compared with reverse-air cleaned bags (discussed below) the vigorous action of shaker systems tends to stress the bags more, which requires heavier and more durable fabrics. In the United States, woven fabrics are used almost exclusively for shaker cleaning.[5] European practice allows the use of felted fabrics at somewhat higher filtering velocities. These higher velocities allow construction of a smaller baghouse, which requires less capital. However, the higher velocities lead to higher pressure drop, which increases operating costs. For any given application, an economic balance exists that must often be found by estimating costs for both types of fabric. Significant research has been done with shaker baghouses and the woven fabrics used in them, and many shaker baghouses remain in service. However, the majority of newly erected baghouses are pulse jets. Where baghouses larger than typical pulse jets are required, they are often custom-built, reverse-air units. The pulse-jet baghouses have become popular because they occupy less space than the equivalent shaker baghouse and are perceived as being less expensive. For high-temperature applications using glass bags, longer bag life may be expected than would be found with shaker baghouses.

1.2.2 Reverse-air Cleaning

When glass fiber fabrics were introduced, a gentler means of cleaning the bags, which may be a foot in diameter and 30 feet in length, was needed to prevent premature degradation. Reverse-air cleaning was developed as a less intensive way to impart energy to the bags. In reverse-air cleaning, gas flow to the bags is stopped in the compartment being cleaned and reverse (outside-in) air flow is directed through the bags. This reversal of gas flow gently collapses the bags toward their centerlines, which causes the cake to detach from the fabric surface. The detachment is caused by shear forces developed between the dust and fabric as the latter changes its shape. Metal caps to support the bag tops are an integral part of the bag as are several sewn-in rings that encircle the bags to prevent their complete collapse during cleaning. Without these rings, falling collected dust tends to choke the bag as the fabric collapses in on itself while cleaning. As with multi-compartment shaker baghouses, a similar cycle takes place in reverse-air baghouses of stopping forward gas flow and allowing dust to settle before cleaning action begins. Also, as with shaker baghouses, extra filtering capacity must be added to reverse-air baghouses to compensate for that portion out of service for cleaning at any time. Some reverse-air baghouses employ a supplemental shaker system to assist cleaning by increasing the amount of energy delivered to the bag.

The source of reverse air is generally a separate system fan capable of supplying clean, dry air for one or two compartments at a gas-to-cloth ratio as high or higher than that of the forward gas flow. Figure 1.2 illustrates a reverse-air cleaned baghouse.

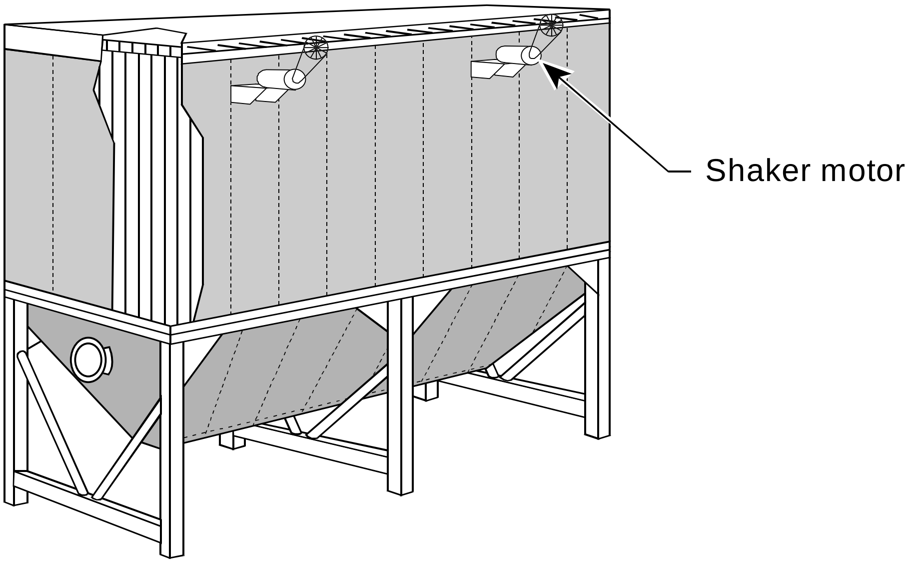


Figure 1.1: Typical Shaker Baghouse
(Courtesy of North Carolina State University)

1.2.3 Pulse-jet Cleaning

An advantage of pulse-jet cleaning compared to shaker or reverse-air baghouses is the reduction in baghouse size (and capital cost) allowed by using less fabric because of higher gas-to-cloth ratios and, in some cases, by not having to build an extra compartment for off-line cleaning. However, the higher gas-to-cloth ratios cause higher pressure drops that increase operating costs. This form of cleaning uses compressed air to force a burst of air down through the bag and expand it violently. As with shaker baghouses, the fabric reaches its extension limit and the dust separates from the bag. Air escaping through the bag carries the separated dust away from the fabric surface. In pulse jets, however, filtering gas flows are opposite in direction when compared with shaker or reverse-air baghouses (i.e., outside-in). Figure 1.3 illustrates a pulse-jet cleaned baghouse.

1.2.3.1 Caged Filters

In conventional pulse-jet baghouses, bags are mounted on wire cages to prevent collapse while the dusty gas flows from outside the bag to the inside during filtration. Instead of attaching both ends of the bag to the baghouse structure, the bag and cage assembly generally is attached only at the top. The bottom end of the assembly tends to move in the turbulent gas flow during filtration and may rub other bags, which accelerates wear.

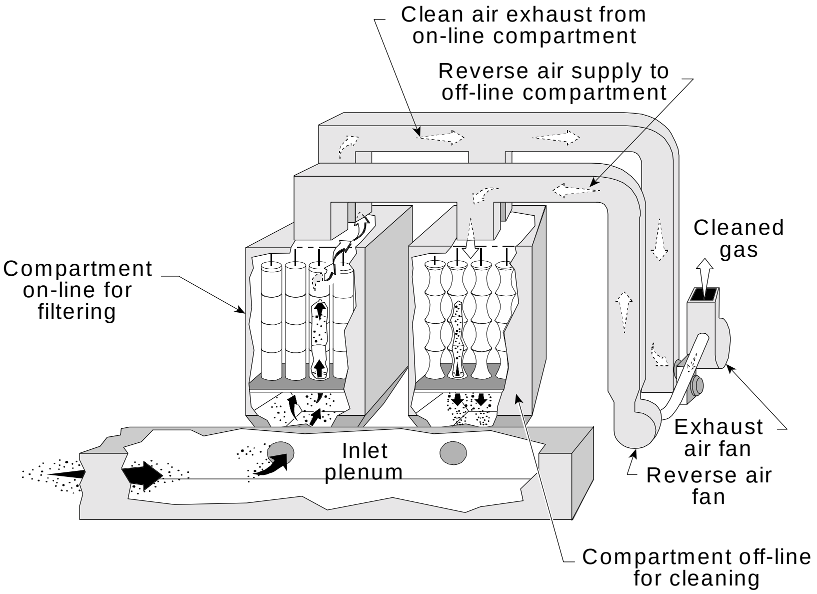
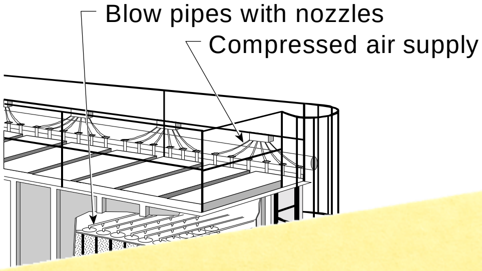


Figure 1.2: Typical Reverse-Air Baghouse
(Courtesy of North Carolina State University)

Often, pulse-jet baghouses are not compartmented. Bags are cleaned one row at a time when a timer initiates the burst of cleaning air through a quick-opening valve. A pipe across each row of bags carries the compressed air. The pipe has a nozzle above each bag so that cleaning air exits directly into the bag. Some systems direct the air through a short venturi that is intended to entrain additional cleaning air. The pulse opposes and interrupts forward gas flow for only a few tenths of a second. However, the quick resumption of forward flow redeposits most of the dust back on the clean bag or on adjacent bags. This action has the disadvantage of inhibiting dust from dropping into the hopper, but the advantage of quickly reforming the dust cake that provides efficient particle collection.

To increase filter area in the same volume of baghouse, star-shaped and pleated (in cross section) bag/cage configurations have been developed. The bag/cage combination is designed as a unit to be installed similarly to a standard bag and cage unit. Such units can be used as replacements for standard bags and cages when additional fabric area is needed, or may be used in original designs. Normal pulse cleaning is used, i.e., no special changes to the cleaning equipment are required. Costs for star-shaped bags and cages are about three to three-and-a-half times normal bags and cages.



1.2.3.2 Cartridge Filters

Further increases in filter area per unit of baghouse volume are obtained by using finely pleated filter media supported on a wire framework. This cartridge can be mounted vertically as a nearly direct replacement for standard bags and cages in existing baghouses, or mounted horizontally in original designs. When used as a direct replacement for standard bags and cages, retrofit costs for one case are 70 % of the cost of building a new baghouse.[6] Cleaning of early cartridge baghouse designs is by typical pulse equipment using a blow pipe across a row of cartridges. More recent designs use individual air valves for each pair of cartridges.

One type of cartridge[7] contains an inner supporting core surrounded by the pleated filter medium and outer supporting mesh. One end of the cartridge is open, which allows gas passing through the filter from the outside to exit to a clean air plenum. Cleaning air is pulsed through the same open end, but in a reverse direction from the gas being cleaned. The other end of the cartridge is closed by an end cap. The manufacturing process requires