CHAPTER 3

FABRIC FILTERS

Fabric filters, also referred to as baghouses, are capable of high-efficiency particulate matter removal in a wide variety of industrial applications. Uses for fabric filters have steadily expanded since the 1960s, because of the development of new, highly effective fabrics capable of efficiently collecting particles over the size range of 0.1 μm to 1,000 μm. This particle collection efficiency, even in the difficult-to-control range of 0.2 μm to 0.5 μm, is due to the multiple opportunities for a particle to be captured as it attempts to pass through a dust cake and fabric and the multiple modes of particle capture that occur within the dust cake and fabric. These modes of capture include impaction, Brownian diffusion, and electrostatic attraction.

The conceptual simplicity of fabric filters belies the complexity of the equipment design and the operating procedures necessary to achieve and maintain high particulate removal efficiencies. Serious performance problems can develop relatively rapidly. Holes and tears in the bags can develop due to chemical attack, high temperature excursions, or abrasion and flex damage. Cleaning system problems can result in excessive static pressure drops. Particles can also seep through the dust cake and fabric due to improper design or cleaning.

This chapter emphasizes four of the major types of fabric filters: shaker, reverse air, pulse jet, and cartridge. There are many other types that are not explicitly discussed in this manual. However, the operating principles and inspection procedures discussed are generally applicable to all types of fabric filters. All fabric filters designs typically operate with a static pressure drop of about 4-6 in. H₂O.

Operating Principles

Particle Collection

Multiple mechanisms are responsible for particle capture within dust layers and fabrics. Impaction is an inertial mechanism that is most effective on particles larger than about 1 μm. It is effective in fabric filters because there are many sharp changes in flow direction as the gas stream moves around the various particles and fibers. Unlike some types of particulate collection devices, there are multiple opportunities for particle impaction due to the numbers of individual dust cake particles and fabric fibers in the gas stream path.

Brownian diffusion is moderately effective for collecting submicrometer particles because of the close contact between the gas stream and the dust cake. The particle does not have to be displaced a long distance in order to come into contact with a dust cake particle or fiber.
Furthermore, the displacement of submicrometer particles can occur over a relatively long
time as the gas stream moves through the dust cake and fabric.

Electrostatic attraction is another particle collection mechanism. Particles can be attracted to
the dust layer and fabric due to the moderate electrical charges that accumulate on the
fabrics, the dust layers, and the particles. Both positive and negative charges can be
generated, depending on the chemical make-up of the materials. Particles are attracted to the
dust layer particles or fabric fibers when there is a difference in charge polarity or when the
particle has no electrical charge.

Sieving of particulate matter can occur after the dust cake is fully established. The net result
of the various types of collection mechanisms is shown in Figure 3-1, which indicates
relatively high removal efficiency levels even in the difficult-to-control particle size range of
0.2 μm to 0.5 μm.

For new bags, the initial particle removal efficiency is not nearly as high as suggested in
Figure 3-1. Time is needed to establish residual dust cakes on the surfaces of the fabric.
These particles provide the foundation for the accumulation of the operating mode dust cake,
which is ultimately responsible for the high efficiency particulate matter removal. The
particles on the fabric surface are termed the *residual dust cake* because they remain after
normal cleaning of the bag.

The fractional efficiency curve shown in Figure 3-1 applies only when an adequate dust cake
has been established. Immediately after cleaning, patchy areas of the fabric surface may be
exposed. Only the residual dust cake remains in these patchy areas. Depending on the
particulate matter concentration, it may take several seconds to a minute for the dust cake to
repair over these patchy areas and thereby reduce emissions. During the time that the dust
cake is being reestablished, particle removal efficiency can be low, especially for small
particles. For this reason, excessive cleaning intensity, frequency, or duration can increase particulate emissions.

Particulate matter emissions can be increased dramatically by related phenomena such as particle seepage and pore collapse. Both phenomena are related to the quantity of gas passing through a given area of the cloth. This gas flow rate is normally expressed as the air-to-cloth ratio, as defined in Equation 3-1:

\[
\frac{A/C \text{ Ratio}}{\text{ft}^3/\text{min}} = \frac{\text{Actual Gas Flow Rate} \text{ ft}^3/\text{min}}{\text{Fabric Surface Area} \text{ ft}^2}
\]

(3-1)

As the air-to-cloth ratio increases, the localized gas velocities through the dust cake and fabric increase. At high air-to-cloth values, some particles, especially small particles, can gradually migrate through the dust layer and fabric. This is possible because dust particles within the cake are retained relatively weakly. After passing through the dust cake and fabric, these particles are re-entrained in the clean gas stream leaving the bag. Some of the factors that increase the tendencies for particle bleed-through include the following:

- Small particle size distribution
- Fabric flexing and movement
- Small dust cake quantities

Pore collapse in woven fabrics is also caused by high air-to-cloth ratios. At high air-to-cloth ratios, the forces on the particle bridges that span the holes in the fabric weave can be too large. Once a bridge is shattered and pushed through the fabric, an uncovered hole is created. The gas stream channels through this low resistance path through the bag.

The net result of seepage and pore collapse is increased particulate matter emissions at high air-to-cloth ratios. The general nature of the relationship is shown in Figure 3-2. The effect is relatively minor until a threshold air-to-cloth ratio is reached. Above this value, emissions can increase rapidly. A baghouse that is severely undersized for the gas flow being treated (high air-to-cloth ratio) can have abnormally low removal efficiency.

**Emissions Through Holes, Tears and Gaps**

Low resistance paths for gas flow are created when holes or tears develop in the bags. Gaps in bag seals or in the welds around the tube sheet also create paths for unfiltered gas to pass through the baghouse. The fraction of the total gas stream passing through these openings will increase until the pressure drop across the opening is equivalent to the average pressure drop across the undamaged bags in the compartment.

It is important to note that holes, tears, and gaps can allow significant particulate emissions without major changes in the observed static pressure drop across the fabric filter. Because of the balancing of the gas flows between the opening and the undamaged cloth, the overall
static pressure drop does not decrease dramatically. It is often difficult to identify these slight drops since the static pressure drop across a baghouse is not usually a constant value.

![Figure 3-2. Emissions as a function of air-to-cloth ratio](image)

**Filter Media Blinding and Bag Blockage**

Water droplets in the dust cake can severely increase the resistance to gas flow. At the very least, the water can fill the voids in the dust cake where the gas would normally flow. If the quantity of water is high, the dust cake can be packed tightly together or even form a muddy layer. At this point, the affected portion of the bag is essentially impervious to gas flow. This is termed *fabric blinding*.

Water is not the only substance that can cause blinding, but it is one of the most common. Condensed water droplets can be entrained from the process being treated, or they can be carried in with the compressed air in pulse jet fabric filters. Excessive gas cooling in baghouses serving combustion sources and other sources generating high vapor concentrations can cause water condensation in the dust cakes.

Another common blinding agent is the lubricating oil often present in pulse jet fabric filter compressed air supplies. The oil droplets can deposit in the upper, clean side surfaces of the bags and prevent gas flow. The entire inlet gas stream must, therefore, be filtered in the unaffected lower portions of the pulse jet bag.

Wet materials are not the only blinding agents. Submicrometer particles can be driven deep into the fabric if the bag is exposed to a high velocity particulate-laden gas stream before a protective residual dust layer is present. This type of blinding often occurs when a new bag is installed in a compartment with a large number of seasoned bags. Due to the resistance caused by the seasoned bags’ residual dust cakes, the gas velocities through the new bag are excessively high. Submicrometer particle blinding can also occur following the installation of new bags at sources that generate high concentrations of submicrometer particulate matter.
In these cases, the new bags can be conditioned prior to service by exposing them to resuspended large diameter particles.

Hopper overflow or solids bridging in hoppers can cause high dust levels. A portion of the filtering area will be inadvertently isolated if these solids block some of the bag inlets in shaker or reverse air baghouses. This occurs most often around the exterior walls of the hoppers where cooling of the solids is most severe. If moisture is present, these deposits can become crusty and remain even after the solids in the hopper have been removed. Proper hopper design and frequent emptying are important in minimizing the occurrence of this condition.

The net effect of these operating problems is to remove fabric area from service. This increases the air-to-cloth ratio in the unaffected fabric and can lead to seepage or pore collapse problems. The higher air-to-cloth ratios will also result in increased pressure drop across the baghouse.

**Fabric Filter Applicability Limitations**

There are several limitations that should be considered when working with fabric filters. Clogging or blinding of the fabric can occur when the particulate is sticky or if moisture is present. Blinding can also occur when large quantities of small particles (0.1 μm to approximately 2 μm) pass through new bags that are not protected by a dust cake. Fabric filters can be designed to operate with moderate blinding conditions. However, they may not be appropriate for very sticky conditions.

Excessive quantities of large particles moving at high velocities can be abrasive and cause erosion of the fabric, especially near the bottoms of the bags. The gas velocities are usually highest near the bottom because of the way the particulate-laden gas stream enters the baghouse. Large particles are the most abrasive and can strike exposed fabric yarns and fibers with considerable force.

Fires and explosions can occur in fabric filters due to the high concentration of dust on the bags and in the upper elevations of the hoppers. These fires and explosions can be ignited by embers from process equipment and even by static electricity generated inside the baghouse. Baghouses can be designed to minimize the risks of fires and explosions. However, when the risk is very high, alternative particulate control systems or combinations of control systems may be necessary.

There are gas temperature limits to the application of fabric filters because of the limits of the fabric itself. At high temperatures, the fabric can thermally degrade, or the protective finishes can volatilize. Accordingly, fabric filters have usually been limited to gas temperatures below approximately 500°F, which is the maximum long-term temperature of the most temperature-tolerant fabric. Recently commercialized fabrics can tolerate much higher temperatures.
Fabric Filter Systems

One way of distinguishing between different types of fabric filter collectors is the method used to clean the filter material. As dust builds up on the filter surface, the pressure drop across the filter increases. In order to avoid excessively high pressure drops, the filter material is cleaned periodically. The most common methods of cleaning are shaking, reverse air, and reverse pulse or pulse jet.

Another way of distinguishing between different types of fabric filter collectors is based on the way they operate. The three modes of operation are intermittent, periodic and continuous. Intermittent collectors are used on processes that operate intermittently. When the process shuts down, the collector goes through a cleaning cycle and then shuts down and waits for the next processing cycle before starting up. Most intermittent collectors clean by shaking, but could also clean by reverse pulse.

Periodic collectors are used on processes that operate continuously. The total fabric is divided between several modules or compartments. This allows a compartment to be taken off line and cleaned, while the remaining compartments stay on line to provide filtration. Most periodic collectors clean by shaking or reverse air, but could also clean by reverse pulse.

Continuous collectors are also used on processes that operate continuously, but they do not have compartments that shut down for cleaning. Instead, individual rows of bags in the collector are cleaned, while the remaining bags continue to provide filtration. Continuous collectors usually clean by reverse pulse, but could also clean by reverse air.

Shaker Fabric Filters

Figure 3-3 shows the typical components of a shaker cleaned fabric filter. The tube sheet provides the seal which separates the bags in the upper portion of the collector from the hoppers. The open bottoms of the bags are attached to the tube sheet and the closed tops are attached to the shaker mechanism. The dust laden gases enter through the hopper, where some of the larger particles in the gas stream settle out. Most of the dust will be carried by the gas stream as it passes up through the filter bag and will be deposited on the inside of the bag. The cleaned gases then exit the collector through an outlet duct or through louvers, if the collector is operating under positive pressure. Shaker collectors use woven fabrics and generally operate with an air-to-cloth ratio of 2-4 ft/min.

During the cleaning cycle, gas flow to the collector is stopped. In compartmentalized collectors, this is accomplished with a shut-off damper in the inlet duct, for a positive pressure unit, or in the outlet duct, for a negative pressure unit. It is critically important that this damper seals effectively, so that there is no air flow through the compartment during cleaning. A leaking damper will cause the bag to remain inflated during shaking and will significantly reduce the cleaning effectiveness. It may also cause particles to be driven through the fabric and carried out of the collector.
After a null period of 15-30 seconds to allow the bags to relax, the bags are mechanically shaken, and the dislodged dust cake falls into the hopper. This type of cleaning usually involves the use of a rocker-arm lever assembly to produce a motion at the top of the filter bag that is roughly horizontal. However, other shaker mechanisms may impart vertical motion or may follow an arc. The bags are usually installed slightly slack to be able to accommodate the shaking motion without tearing or pulling loose from the tube sheet. Typically, the bags are shaken from 10 to 100 cycles at a rate of 1 to 5 cycles per second with an amplitude of up to 2 inches. After shaking is completed, a second null period of 1-2 minutes is provided to allow the dust to settle before the collector or compartment is returned to service. In compartmentalized collectors, the cleaning interval for each compartment is typically 30 minutes to 2 hours.

**Reverse Air Fabric Filters**

The construction and operation of reverse air fabric filters is very similar to shaker collectors. There is a tube sheet that separates the bags in the upper portion of the collector from the hoppers. The open bottoms of the bags are attached to the tube sheet and the closed tops are attached to an upper support structure (see Figure 3-4). The dust laden gases enter through the hopper and pass up through the filter bag, depositing the dust cake on the inside of the bag. The cleaned gases then exit the collector through an outlet duct. Reverse air collectors usually use woven fabrics; however, membrane bags and felted bags may be used in some applications. They typically operate with an air-to-cloth ratio of 1½-3½ ft/min.
The main components of the cleaning system for a reverse air fabric filter are shown in Figure 3-5. The system consists of one or more reverse air fans, a set of dampers to control gas flow to each compartment, and instrumentation to monitor compartment conditions before and after cleaning.

The cleaning cycle is initiated by closing the outlet damper on the compartment to be cleaned, stopping the gas flow into the compartment. After a null period of 15-30 seconds to allow the bags to relax, the reverse air damper is opened. For a period of 30 seconds to a few minutes, filtered gas is passed from the outside of the bags to the inside in order to remove some of the dust cake. The dislodged dust cake drops into the hopper, and the reverse gas
passes through the open inlet damper and enters the gas stream inlet duct leading to other compartments that are in the filtering mode. To prevent the bag from collapsing during the reverse air flow, it is held under a tension of 60-120 pounds of force and has anti-collapse rings sewn into it every 4-6 feet. After cleaning is completed, there is a second null period of 1-2 minutes to allow time for particles to settle before the compartment is returned to filtering service. As with shaker collectors, the cleaning interval for each compartment is typically 30 minutes to 2 hours.

Sealing the outlet and reverse air dampers is critical to the performance of the baghouse. If the reverse air dampers do not seal properly, the cleaning air supplied by the reverse air fan can be lost to compartments in filtering service. If the outlet dampers do not seal properly, the cleaning gas short-circuits through these openings rather than passing through the bags to be cleaned.

**Pulse Jet Fabric Filters**

There are two major types of pulse jet collectors: top access and side access. The top access design includes a number of large hatches across the top of the baghouse for bag replacement and maintenance. The side access design has one large hatch on the side for access to the bags. The side access units often have a single small hatch on the top of the baghouse for routine inspection.

A cutaway drawing of a typical top access type pulse jet fabric filter is shown in Figure 3-6. In pulse jet collectors, the tube sheet is located near the top of the unit and the bags are suspended from it. In top access designs, the bags are clamped and sealed to the top of the tube sheet to allow for bag removal and replacement from the top of the unit. A proper bag seal is very important to prevent dust-laden gases from short-circuiting to the clean side of the baghouse without passing through the dust cake and bag.

The gas stream enters either into the side of the casing or into the hopper. The gas flows into the bags and moves upward into the clean gas outlet plenum at the top, leaving the dust cake on the outside of the bag. The bags are supported on metal cages to prevent them from collapsing. Because the fabric flexes around the cage wires during filtering, some fabric wear is possible. To minimize this potential problem, cages with closely-spaced wires are used for fabrics that are especially vulnerable to flex-type wear. More economical cages are used for fabrics that are very tolerant of flex. There are no frames or attachments at the bottom of the pulse jet bags. Pulse jet collectors use felted fabrics and generally operate with an air-to-cloth ratio of 3-10 ft/min.

A portion of the dust must occasionally be removed from the bags in order to avoid excessively high pressure drops. The bags are cleaned by introducing a high-pressure pulse of compressed air at the top of each bag. The sudden pulse of air generates a pressure wave that travels down inside the bag. The pressure wave also induces some filtered gas to flow downward into the bag. Because of the combined action of the pressure wave and the induced gas flow, the bags are briefly deflected outward. This cracks the dust cake on the outside of the bags and causes some of the dust to fall into the hopper. Cleaning is normally
performed on a row-by-row basis while the baghouse is operating. However, with this operating practice, dust released from one row of bags can either return to the bag because of settling problems or be recollected on a bag in an adjacent row that remains in filtering service. Both problems can be avoided by using off-line cleaning. This is accomplished by dividing the pulse jet baghouse into compartments and isolating the compartment being cleaned to prevent gas flow through it.

Excessive cleaning of pulse jet bags can simultaneously cause higher-than-normal emissions, higher-than-normal static pressure drop, and accelerated bag wear. If there is insufficient dust cake on the bag when it is cleaned, particles or small agglomerates of particles can be dispersed. These particles do not settle by gravity and simply return to the bag at an area where the dust cake is thin. Here, they can accumulate as a low porosity cake, increasing the pressure drop. Over time, these fine particles can seep through the bag and cause opacity spiking after the cleaning pulse. The seeping of emissions is caused, in part, by the
deceleration shock occurring when the just-pulsed bag snaps back against the cage as the bag returns to filtering service.

The main components of the pulse jet cleaning system are illustrated in Figure 3-7. The major components include (1) a source of compressed air, (2) a drier, (3) a coalescing oil filter, (4) a compressed air header, (5) diaphragm and solenoid valves, (6) a solenoid valve controller, (7) compressed air delivery tubes, and (8) instrumentation.

![Diagram of pulse jet cleaning system](image)

**Figure 3-7. Components of a pulse jet cleaning system**

The source of compressed air for bag cleaning can be an air compressor dedicated to the specific baghouse or the plant air system. Dedicated compressors usually include an aftercooler to reduce the high temperature caused by compression, a pressure regulator to control the compressor, and a compressed air storage tank. The compressed air is piped from the storage tank to the compressed air header mounted on the side wall of the pulse jet unit. A drier is usually used on the compressed air supply to reduce the water content, and a coalescing filter is used to remove entrained oil droplets.

A typical compressed air header is shown in Figure 3-8. This provides a reservoir of compressed air to support the operation of the diaphragm valves during a cleaning cycle. There is a connection to each diaphragm valve serving each row of the baghouse. It is important that these connections and the header itself be leak free to ensure that the header remains at the necessary air pressure. In most systems, the compressed air pressure is in the range of 60 to 90 psig.
The opening and closing of the diaphragm valve serving each row of bags is controlled by a solenoid valve. The cleaning cycle controller sends an electrical signal to the solenoid to open the valve. This allows compressed air to flow from the trigger line that connects the diaphragm valve to the solenoid valve. The release of compressed air from the back of the diaphragm valve causes the diaphragm valve to open, allowing the compressed air to enter the delivery tube passing above the row of bags.

The compressed air delivery tube, usually called a lateral or blow tube, transports the compressed air from the discharge side of the diaphragm valve to the inlet of each bag in the row. These tubes have either a small orifice or an extension tube on the lower side. This hole or extension tube directs the compressed air to the center of the bag. After a period of 0.1-0.2 seconds, the cleaning cycle controller sends a signal to close the solenoid valve. This causes pressure to build up in the trigger line, closing the diaphragm valve. Bags are cleaned on a relatively frequent basis, with each row being cleaned from once every few minutes to once every several hours. Cleaning usually starts with the first row of bags and continues through the remaining rows in order.

It is important that the delivery tube be oriented so that the orifice or extension tube points straight into the bag. Rotation of the delivery tube causes the compressed air pulse to strike the side of the bag near the top and holes are created. It is also important to securely fasten the compressed air delivery tube. This tube experiences a pressure rise from ambient pressure to more than 60 psig in a time period of 10 to 50 milliseconds. If this tube is not firmly secured, it can break free.

Breakage of the trigger lines between the diaphragm valve and solenoid valve can adversely affect cleaning by leaking compressed air needed for cleaning other bag rows. When the solenoid valve is closed, compressed air fills the trigger line and a small portion of the diaphragm valve. This pressure keeps the diaphragm valve closed. If the trigger line is
broken, the diaphragm valve cannot be closed, and compressed air continues to flow through the affected valve.

The instrumentation for the compressed air pulsing system is usually quite limited. There is usually a compressed air pressure gauge on the storage tank of the compressor and on the compressed air header serving the baghouse. The compressed air pressure data can be used in conjunction with the overall static pressure drop data for the baghouse to confirm that the baghouse cleaning system is performing properly.

**Cartridge Filters**

Cartridge filter systems are similar to pulse jet fabric filter systems. The filter elements are supported on a tube sheet that is usually mounted near the top of the filter housing. The gas stream to be filtered passes from the outside of the filter element to the inside. Filtering is performed by the filter media and the dust cake supported on the exterior of the filter media. The filter media is usually a felted material composed of cellulose, polypropylene, or other flex-resistant material.

The unique feature of a cartridge filter is the design of the filter element. Essentially all cartridges are shorter than pulse jet bags. Some cartridges have simple cylindrical designs. Others can have a large number of pleats as shown in Figure 3-9 or other complex shapes as shown in Figure 3-10 in order to increase the filtering surface area. Due to the shortness of the cartridge filter elements, they are usually less vulnerable to abrasion caused by the inlet gas stream. The shorter length also facilitates cleaning by a conventional compressed air pulsing system identical to those used on pulse jet collectors.

![Figure 3-9. Pleated cartridge filter element](image)
Cartridge filter elements are used in a wide variety of industrial applications. Due to their inherently compact design, they can be used in small collectors located close to the point of particulate matter generation. They are generally used on gas streams less than approximately 400°F. This temperature limit is due to the capabilities of the flex resistant, high temperature fabrics and by the limitation of the gasket material used to seal the cartridge filter element to the tube sheet.

**Fabrics**

There is a wide variety of commercially available filtration media. These can be categorized into five different groups:

- Woven fabric
- Felted fabric
- Membrane fabric
- Sintered metal fiber
- Ceramic cartridge

A **woven fabric** is composed of interlaced yarns, as shown in Figure 3-11. The yarns in the warp direction provide strength to the fabric, and the yarns in the fill direction determine the characteristics of the fabric. The pores, which are the gaps between the yarns, can be more than 50 μm in size. Small particles can easily pass through these pores until particles are captured on the sides of the yarns and bridge over the openings. The dust cake is critical for proper filtration by woven fabrics.
There are a variety of weave types used to modify the characteristics of the fabric. For example, the twill weave shown in Figure 3-11 is less vulnerable than other weaves to fabric blinding due to the penetration of fine particles into the fabric. Overall, the weave characteristics influence the strength of the cloth, the difficulty of dust cake release during cleaning, and the resistance to gas flow.

**Felted fabrics** are composed of randomly oriented fibers attached to a very open weave termed the *scrim*. The felted fabrics are usually much thicker than woven cloths because of the layer of fibers on both sides of the scrim. With this type of fabric construction, there are no pores as indicated in Figure 3-12. The fibers on the filtering side provide a large number of targets for particle impaction, Brownian diffusion, and electrostatic attraction. However, even with felted fabrics, the dust cake that accumulates on the surface is primarily responsible for particle capture.

**Membranes** are another major category of fabrics used in air pollution control. These are composed of a polytetrafluoroethylene (PTFE) membrane that is laminated to either a woven or felted support fabric. The membrane is placed on the filtering side of the fabric. Particle collection occurs primarily due to the sieving action of the membrane’s very small pores (less than 5 μm). In membrane fabrics, the dust layer is not especially important in particulate removal. Furthermore, static pressure drop is relatively low due to the good dust cake release properties.

**Sintered metal fiber** bags are composed of small metal fibers randomly oriented on a cylindrical surface. The bags are heated to high temperatures to bond the fibers together. The bags are rigid and require specially designed pulse jet type cleaning systems. Sintered metal fiber bags can be used for hot gas streams. They can also be aggressively cleaned if they become blinded by sticky or moist dust.
Ceramic cartridge filters are fabricated in cylindrical candle or honeycomb forms. Particle capture occurs as the dust passes through the dust cake on the exterior surface and through the pores through the ceramic media. These filters are designed for applications where the gas temperatures are extremely hot.

The fabrics used for baghouses can be composed of a variety of synthetic and natural materials. Selection of the fabric material is based primarily on three criteria:

- Maximum gas temperatures of the gas stream
- Corrosive chemical concentrations in the gas stream
- Physical abrasion and fabric flex conditions

The various fabrics differ substantially with respect to their ability to tolerate temperature, chemical attack, and physical abrasion and flex. The temperature and acid-resistant capabilities of some of the commercially available types of fabrics are summarized in Table 3-1. The continuous temperature rating shown in the table is intended only as a general indicator of the fabric’s capability. To optimize bag life, the normal operating temperatures should be slightly below this limit. The resistance to acids primarily involves inorganic acids such as sulfuric acid and hydrochloric acid.

The ability to handle temperature surges is a function mainly of the fabric’s dimensional stability and protective coatings. For example, the limiting maximum surge temperature for fiberglass fabrics is due, in part, to the need to avoid volatilization of lubricants on the fiber surfaces. These lubricants are necessary to prevent fiber-fiber abrasion during cleaning. Also, the ability of the fabric to withstand short-term temperature spikes depends on the quantity of dust cake present. The dust can absorb some of the heat and thereby moderate the
maximum temperature while slightly extending the time period that the fabric is exposed to elevated temperature.

<table>
<thead>
<tr>
<th>Generic</th>
<th>Common or Maximum Temperature, °F</th>
<th>Acid Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Fiber, Cellulose</td>
<td>Cotton 180 225</td>
<td>Poor</td>
</tr>
<tr>
<td>Polyolefin</td>
<td>Polyolefin 190 200</td>
<td>Good to Excellent</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>Polypropylene 200 225</td>
<td>Excellent</td>
</tr>
<tr>
<td>Polyamide</td>
<td>Nylon® 200 225</td>
<td>Excellent</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Orlon® 240 260</td>
<td>Good</td>
</tr>
<tr>
<td>Polyester</td>
<td>Dacron® 275 325</td>
<td>Good</td>
</tr>
<tr>
<td>Aromatic Polyamide</td>
<td>Nomex® 400 425</td>
<td>Fair</td>
</tr>
<tr>
<td>Polyphenylene Sulfide</td>
<td>Ryton® 400 425</td>
<td>Good</td>
</tr>
<tr>
<td>Polyimide</td>
<td>P-84® 400 425</td>
<td>Good</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Fiberglass 500 550</td>
<td>Fair</td>
</tr>
<tr>
<td>Fluorocarbon</td>
<td>Teflon® 400 500</td>
<td>Excellent</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>Stainless Steel 750 900</td>
<td>Good</td>
</tr>
<tr>
<td>Ceramic</td>
<td>Nextel® 1300 1400</td>
<td>Good</td>
</tr>
</tbody>
</table>

The ability of fabrics to withstand physical abrasion and flex is summarized in Table 3-2. Fabrics listed as fair must be cleaned gently, and the bags must be handled carefully during installation. Most of the fabrics have good to excellent capability with respect to abrasion and flex. The three main exceptions are fiberglass, Teflon®, and ceramic fabrics which are often used for moderate-to-high gas temperature applications.

Some of the fabrics are coated to improve their ability to withstand acid attack and abrasion and flex type physical damage. All fiberglass fabrics must have coatings to protect the relatively brittle fibers that can easily be broken by fiber-to-fiber abrasion. Silicone-graphite finishes for fiberglass fabrics have been used for more than 40 years. Other coatings that have been developed and used successfully over the last 20 years include Teflon-B® coating, I-625®, Blue Max®, and Chemflex®. Some of these newer coatings also protect the fabric from acid attack.
### Table 3-2. Fabric Resistance to Abrasion and Flex

<table>
<thead>
<tr>
<th>Generic Name</th>
<th>Common or Trade Name</th>
<th>Resistance to Abrasion and Flex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Fiber, Cellulose</td>
<td>Cotton</td>
<td>Good</td>
</tr>
<tr>
<td>Polyolefin</td>
<td>Polyolefin</td>
<td>Excellent</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>Polypropylene</td>
<td>Excellent</td>
</tr>
<tr>
<td>Polyamide</td>
<td>Nylon®</td>
<td>Excellent</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Orlon®</td>
<td>Good</td>
</tr>
<tr>
<td>Polyester</td>
<td>Dacron®</td>
<td>Excellent</td>
</tr>
<tr>
<td>Aromatic Polyamide</td>
<td>Nomex®</td>
<td>Excellent</td>
</tr>
<tr>
<td>Polyphenylene Sulfide</td>
<td>Ryton®</td>
<td>Excellent</td>
</tr>
<tr>
<td>Polyimide</td>
<td>P-84®</td>
<td>Excellent</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Fiberglass</td>
<td>Fair</td>
</tr>
<tr>
<td>Fluorocarbon</td>
<td>Teflon®</td>
<td>Fair</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>Stainless Steel</td>
<td>Excellent</td>
</tr>
<tr>
<td>Ceramic</td>
<td>Nextel®</td>
<td>Fair</td>
</tr>
</tbody>
</table>

### Inspection

The inspection of fabric filter systems is divided into Basic and Follow-up Level 2 procedures. The relatively time-consuming follow-up procedures are conducted only when a basic inspection indicates that compliance problems are present or anticipated in the immediate future.

**Basic Level 2**

- Stack visible emissions
- Opacity monitor data
- Static pressure drop
- Inlet and outlet gas temperatures
- Compressed air pressures (pulse jet systems)
- Air infiltration
- Corrosion
- Fugitive emissions

**Follow-up Level 2**

- Opacity monitor quality assurance checks
- Operating and cleaning cycle times
- Compressed air leaks (pulse jet systems)
• Inoperative diaphragm valves (pulse jet systems)
• Clean side conditions
• Bag failure records
• Internal inspection reports
• Start-up/shut-down practices
• Tracer dust test results

**Basic Level 2: Stack Visible Emissions**

If weather conditions permit, the average opacity should be determined in accordance with
USEPA Method 9 or other required procedures. The observations should be long enough or
frequent enough to account for compartment-by-compartment cleaning cycles. The timing
and duration of all significant opacity spikes should be noted.

In the case of pulse jet baghouses, short duration puffs of approximately 10 to 30 percent
opacity are usually due to small holes in the bags. The opacity spikes cease when the dust
bridges over the hole and reestablishes an effective dust cake. In most cases, these holes will
increase in size over time and will eventually cause continuous emissions.

As part of the visible emission observations, condensing plume characteristics at the stack
discharge should be evaluated. This type of plume is often indicated by a clear zone directly
above the stack in a portion of the plume that is still too hot to cause vapor nucleation.
Immediately following the clear zone, the opacity increases rapidly due to the formation of
particulate matter from the vapors in the gas stream. These vapors can rarely be collected in
a baghouse; therefore, the presence of a condensing plume indicates the need to evaluate
process operating conditions that could contribute to the formation of the vaporous material.

**Basic Level 2: Opacity Monitor Data**

There are two basic types of opacity monitors used on fabric filter systems: (1) bag break
indicators, and (2) double pass transmissometers that comply with 40 CFR Part 60
requirements for continuous emission monitors. The double pass transmissometers are used
only on the moderate-to-large systems subject to specific regulatory requirements. The bag
break indicators are used on some small-to-medium sized units.

The bag break indicators provide only a qualitative measure of the operating status. They do
not provide accurate opacity measurements. Furthermore, they can be subject to operational
problems that indicate a false emission limit exceedance reading. The data from the bag
break indicators should be noted on the inspection forms but should not be used as a
substitute for the more accurate visible emission observation.

Double pass transmissometers are used at plants subject to specific opacity monitoring
requirements. In many cases, the data from these units is directly enforceable. In other
cases, the data is used simply to determine if there has been a shift from the baseline
performance levels. Even slight increases in the opacity could indicate problems that could
lead to noncompliance in the future.
The compartment-by-compartment cleaning cycle opacities should be checked as part of the evaluation of the opacity monitoring data. Short term spikes immediately after a compartment is brought on-line for filtering could indicate damper sealing problems or small holes or tears developing in the bags of the compartment.

**Basic Level 2: Static Pressure Drop**

The first step in evaluating the static pressure drop is to qualitatively confirm that the monitoring instrument is working properly. In the case of shaker and reverse air systems, normal fluctuations in the static pressure drop occur as compartment after compartment is taken off-line for cleaning. The lack of any fluctuations usually indicates a malfunctioning static pressure drop gauge. In the case of pulse jet units, normal operation of the static pressure drop gauge is indicated by small fluctuations in the static pressure drop during pulsing of each row.

The baghouse overall static pressure drop should usually be less than 6 in. H₂O. An increase of 1 to 2 in. H₂O from baseline operating levels could indicate important changes in baghouse operating conditions. If the baghouse static pressure drop is high (>6 in. H₂O), gas flow rates through the system could have been suppressed by the high flow resistance. Fugitive emissions are possible from the process equipment, and the inspection should include a check of all process areas that can be observed safely. If the baghouse static pressure drop is low, severe air infiltration could be occurring. This is addressed in one of the later inspection points included in the scope of the Basic Level 2 inspection.

For shaker and reverse air collectors, and any other collector that cleans off line, there is a normal cycle in the static pressure drop. The pressure drop is lowest after a unit comes back on line after cleaning and is highest just before a unit goes off line for cleaning. The difference between the high and low pressure drops depends of the number of compartments in the collector. In comparing the static pressure drop on off-line cleaning units to baseline values and values obtained in other inspections, it is important that these values are taken at the same point in the normal cycle.

For shaker and reverse air filtration systems, the static pressure drops during the cleaning of each compartment should be observed. For reverse air collectors, the compartment static pressure drop data should have the general pattern indicated in Figure 3-13. The pattern for shaker collectors should be similar; however, the static pressure drop should remain at zero all the time the collector is off line.

If the static pressure drop is not below zero during the cleaning cycle of a reverse air collector, as indicated by line labeled normal profile in Figure 3-13, then cleaning air is not passing backward through the bags in that compartment. If the static pressure drop does not remain at zero during the cleaning cycle of a shaker unit, air is continuing to flow through the bags during shaking. In both cases, cleaning will be significantly impaired by the continued in-flow of particulate-laden air.
Damper leakage causes these abnormal profiles. In shaker collectors, a leaking inlet or outlet damper allows process gas to continue to flow through the collector during the cleaning period. The severity of damper leakage is indicated by the pressure drop during cleaning. In reverse air collectors, the reverse air flow passes out of the poorly sealed outlet damper, rather than passing through the bags. Here, the severity of the damper leakage is indicated by the null period pressure drops. Null period static pressure drops that are above zero in reverse air collectors and cleaning period static pressure drops that are above zero in shaker collectors indicate that the damper has not fully closed.

**Basic Level 2: Inlet and Outlet Gas Temperatures**

Filter bags are not tolerant of either very high or very low gas temperatures. The inlet and outlet gas temperatures must be maintained within the moderate range.

Short term excursions of more than approximately 25°F above the filter media temperature limits shown in Table 3-1 can cause volatilization of protective coatings, yarn degradation, fabric shrinkage, or fabric stretching. All these conditions lead to premature bag failure. These same problems can develop slowly even if the bags are operated at their rated temperatures for long time periods. Generally, the inlet gas temperature should be slightly below the maximum temperature rating of the fabric.

Acid attack occurs when the gas temperature drops below the acid vapor dewpoint. Baghouse outlet gas temperatures should be checked to confirm that they are well above the normal dewpoint temperatures, especially during low flow rate periods when the gas stream may be cooler. A slight margin of safety is needed with respect to gas temperatures because they are not necessarily uniform throughout the baghouse, as indicated in Figure 3-14.
Basic Level 2: Compressed Air Pressures (Pulse Jet Systems)

The compressed air pressure in the compressed air manifold should be recorded during the inspection and compared with baseline levels. Overcleaning is possible if the pressure has increased substantially since the baseline period. Inadequate cleaning could be occurring if the compressed air pressure has decreased. In most designs, the normal air pressures range from 60 to 90 psig. However, there are a number of commercial pulse jet baghouses that operate with much lower compressed air pressures and higher compressed air flow rates. Accordingly, shifts from the baseline values for the specific unit are generally the most reliable means of evaluating bag cleaning conditions.

The compressed air pressure is available from a gauge on the compressed air manifold. Compressed air pressure data are virtually never converted to an electrical signal and transmitted back to the main control room. If there is no compressed air gauge on the manifold, the discharge pressure gauge on the air compressor can be used as a general indicator. The compressor discharge pressure is higher than the pressure in the compressed air manifold.

If the compressed air pressure is much lower than the baseline value, the follow-up inspection should include an evaluation of compressed air leaks in the pipe fittings and diaphragm valves.

Basic Level 2: Air Infiltration

One of the most useful ways to evaluate air infiltration into negative pressure collectors is to compare the difference between the inlet and outlet gas temperatures to the baseline difference. If the temperature difference is significantly higher than during the baseline condition, excessive air infiltration may be occurring. If baseline data are not available,
excessive air infiltration may be indicated by an inlet and outlet temperature difference that is
greater than about 25°F.

A visual inspection of the fabric filter system is often useful for identifying conditions that
could be contributing to air infiltration. Areas that commonly have air leakage include solids
discharge valves, hopper poke holes, hopper access hatches, compartment access hatches,
broken welds or corrosion in the casing and hopper walls, and expansion joints in the
ductwork upstream and downstream of the baghouse. In severe cases, air infiltration sites
can be identified by the sound of in-rushing air.

The top access hatches on a pulse jet collector are especially prone to leakage because they
are usually at the highest negative static pressure in the system. When the fan is downstream
of the baghouse, the static pressure in the clean gas plenum and the outlet duct is almost
identical to the fan inlet static pressure. Large quantities of air can leak through small gaps in
the gaskets because of the large difference between the ambient air pressure and the clean gas
plenum static pressure.

**Basic Level 2: Corrosion**

Corroded areas on the casing and hopper walls, top access hatches, and other portions of the
baghouse should be noted during the visual inspection of the unit. The presence of corrosion
indicates that the unit is occasionally operating at a low temperature and that moisture or acid
vapors are condensing and chemically attacking the baghouse shell. Blinding and chemical
attack of the bags is also possible.

**Basic Level 2: Fugitive Emissions**

Fugitive emissions from the baghouse solids handling system and from the process
equipment served by the baghouse should be checked. Solids accumulation in areas adjacent
to the equipment provides an indication that fugitive emissions have occurred recently.

**Follow-up Level 2: Opacity Monitor Quality Assurance Checks**

Units with double pass transmissometers should be checked if the opacity monitoring data is
not similar to the visible emission observations. The source and retroreflector units of the
instruments should have operating purge air blowers, intact purge air holes, and dust filters.
On new units, it is possible to check the alignment of the source and retroreflector with the
permission and assistance of plant personnel.

Output data from strip charts or data loggers should be reviewed to confirm that the daily
span and zero checks are being conducted. Fault codes in the data should also be checked for
to confirm that there have been no major malfunctions. If the instrument has been working
properly, the opacity monitoring records since the previous inspection should be reviewed.
Follow-up Level 2: Operating and Cleaning Cycle Times

The frequency and duration of cleaning should be compared to baseline values. For the pulse jet this is simply the frequency and duration of the pulse. For units that clean offline, the frequency of cleaning should be noted, as well as the null period and cleaning period times. Changes in these parameters can significantly change dust cake thickness, and, as a result, the pressure drop and, potentially, the collection efficiency.

Follow-up Level 2: Compressed Air Leaks (Pulse Jet Systems)

A visual inspection for compressed air pipe leaks should be conducted if the static pressure drop across the baghouse is higher than baseline levels or the compressed air pressure is lower than baseline levels. The most common leak sites include the threaded fittings leading to the compressed air manifolds and the threaded fittings leading from the manifolds to the diaphragm valves. Severe leaks can be detected audibly. Small leaks are often indicated by localized oil deposition and dust accumulation on the outside of the fittings.

Fluctuations in the compressed air pressure can occur when there is competition for compressed air between the baghouse and the process equipment. Since the compressed air pressure is rarely recorded, the only way to identify these fluctuations in pressure is to observe the baghouse compressed air pressure gauge for a reasonable period of time when the process equipment is operating.

Follow-up Level 2: Inoperative Diaphragm Valves (Pulse Jet Systems)

The operating status of the diaphragm valves should be checked if the static pressure drop across the baghouse is significantly above baseline levels. The simplest way to do this is to listen for a regular sequence in the pulsing sound as the solenoid and diaphragm valves are actuated. Any time break or unusual sound in the sequence, except at the end of the cycle, indicates that the valve is not actuating properly.

During cold weather, it is possible for moisture that condensed in the compressed air lines to drain into the diaphragm valve and freeze it in the closed position. When this happens, the row of bags served by the frozen diaphragm valve is not cleaned. If a large number of the diaphragm valves are affected, cleaning is impaired, and the static pressure drop across the unit increases. Diaphragm valve freezing is usually a problem only on those units that do not have compressed air dryers and that have the diaphragm valves mounted below the compressed air manifolds. The arrangement allows the condensed water to drain into the back side of the diaphragm valve.

Follow-up Level 2: Clean Side Conditions

When the baghouse is offline, it is possible to open one or more of the access hatches to check clean side conditions. Plant personnel must give permission for this check because opening the unit requires significant effort to lock-out all of the associated equipment. If it is
possible to conduct a clean side check, agency personnel should not enter the baghouse, but simply look in from the outside. Breaking the plane of the open hatch constitutes confined space entry and is strictly regulated by the OSHA Permit Required Confined Space Regulation.

Inspection of the clean side conditions in a shaker or reverse air baghouse will be limited, since it must be done from access doors located in the side of the casing. To the extent possible, the evaluation should include the following items:

- Quantity and distribution of fresh dust deposits
- Bag tension
- Bag attachment leakage
- Bag holes and tears
- Tube sheet holes and weld failures
- Hopper overflow indications

There is good access to clean side of a top access pulse jet baghouse; however, access to the clean side of a side access unit will be limited. Evaluation of the clean side conditions should include the following items:

- Quantity and distribution of fresh dust deposits
- Misaligned blow tubes
- Disconnected or broken blow tubes
- Poor bag sealing
- Oil or moisture blinding of the bags
- Tube sheet holes and weld failures

A view of the clean side of a top access pulse jet baghouse is shown in Figure 3-15.

![Figure 3-15. Clean side of a top access pulse jet baghouse](image)
Follow-up Level 2: Bag Failure Records

If there are indications of frequent bag failures, bag failure records should be reviewed. Simply replacing the bags is usually not sufficient because each failure can result in excessive emissions before the maintenance staff can replace or tie-off the bag. Furthermore, the installation of a new bag in a compartment with seasoned bags can lead to the rapid failure of the new bag due to high air-to-filter ratio conditions. For these reasons, it is important to solve the fundamental problem causing the bag failures.

One commonly used type of bag failure record is shown in Figure 3-16. This is a plan view drawing of a compartment showing the bag layout. A letter and number system is used to assign a unique identification code to each bag location. When a bag is removed or tied off, a mark is placed in the affected location. They may also use a code to identify the portion of the bag where the failure occurred. The date can also be recorded so that the timing of the bag failures can be evaluated in the future. After several failures in a compartment have been entered, the spatial pattern of the failures can be evaluated. This is helpful for identifying the fundamental problems leading to the bag failures.

Figure 3-16. Compartment bag layout sketch

The frequency of bag failure can be plotted on a time line. As shown in Figure 3-17, there is usually a long time period after the installation of new bags when there are few failures.
During this period, failures are typically address by replacing individual bags. It would be helpful for plant personnel to send bag samples to a fabric testing laboratory if there have been chronic excess emission problems caused by frequent bag failures. Identifying the cause of bags failures should help plant personnel to reduce their frequency. The results of any bag testing should be reviewed while on site. When the rate of failure begins to increase significantly, this is an indication that the bag set is reaching the end of its useful life and it is time to replace all of the bags in the compartment.

The rip test is a test that can be applied to failed bags in order to determine their general mode of failure. Take a failed bag that has been removed from the collector and search its surface to locate the point of failure—the hole. Go a few inches away from the hole and jab a screwdriver through the fabric. While holding the bag with one hand, try to tear the fabric with the screwdriver. If the fabric does not tear easily, it indicates that the fabric is in good condition and the hole likely formed through some sort of abrasive action. If the fabric tears easily or shreds, it indicates that all of the fabric has been damaged, either by high-temperature or chemical exposure.

**Follow-up Level 2: Internal Inspection Reports**

For many health and safety reasons, agency personnel should not conduct internal inspections of baghouses. However, the inspection reports prepared by the plant maintenance staff could be helpful in confirming that the plant has identified the fundamental operating problems and has taken the appropriate steps to prevent future excess emission incidents.

**Follow-up Level 2: Start-up/Shut-down Practices**

Baghouses may be bypassed during the early stages of process start-up and the later stages of process shut-down. During these time periods, the gas temperatures may be below the moisture or acid vapor dewpoint, and the particulate matter may be sticky or otherwise
difficult to remove from filter surfaces. The frequency of start-up/shut-down cycles should be reviewed with plant representatives to confirm that all reasonable efforts are being made to reduce the time that the baghouse is bypassed.

**Follow-up Level 2: Tracer Dust Test Results**

Many plant operators use tracer dusts and black light kits to locate small bag holes and gas leak sites. These tests are conducted by injecting fluorescent dust into the baghouse inlet duct while the unit is operating. In less than one minute after injection, the baghouse is shut-down, and the clean side area of the baghouse is checked for traces of the dust. Bag holes or gas leak sites are indicated by deposits of the fluorescent dye. These tests are usually conducted at night or under moderately dark conditions and are usually helpful in locating emission points. Reports concerning these tests may be helpful to agency inspectors in confirming that the plant is correcting conditions that have previously contributed to excessive emission incidents.
**Review Problems**

**Video Problem**

This inspection concerns two relatively small material handling type sources at a foundry. In addition to the sources shown, there is a cupola controlled with a reverse air baghouse and a variety of small sources. The plant is located in a residential community that has grown around this facility and several other plants.

The pulse jet baghouse is a top access, single compartment unit with four rows of bags. The induced draft fan for the baghouse and the sand reclaim unit are mounted beside the baghouse.

The reverse air baghouse is an old multi-compartment unit. The bags are cylindrical envelopes mounted horizontally. Each horizontal row of bags is subject to reverse air flow by a moving cartridge containing a reverse air blower. The induced draft fan for the reverse air baghouse is mounted inside the main structure that includes the three compartments. A single screw conveyor is used to collect the solids from the three compartments and transport them to a waste bin for eventual disposal.

1. What instruments would be helpful in monitoring the compliance status of the pulse jet baghouse serving the sand reclaim operation?
   a. A thermocouple
   b. A compressed air pressure gauge
   c. A differential static pressure gauge
   d. All of the above

2. Should the operator of the pulse jet baghouse be asked to install on-site, permanently mounted instruments?
   a. Yes. This is necessary to facilitate future Level 2 inspections.
   b. No. This information could be obtained during future Level 2 inspections by plant personnel using portable gauges.

3. Are the measurement ports shown in the videotape in the appropriate locations for measuring the baghouse inlet and outlet static pressures during a Level 3 inspection?
   a. Yes
   b. No
4. Does the plant representative accompanying the inspector have the right to refuse to open the top access hatches to observe clean side deposits and other internal conditions?

   a. Yes
   b. Yes. But only when the unit is operating during the inspection and can not be conveniently and safely shut down.
   c. No

5. Should the inspector demand that the plant repair the misrotated compressed air tubes and the top access hatch air infiltration problems?

   a. Yes. This can lead to fugitive emissions from the process equipment.
   b. Yes. The air pollution control equipment should be in perfect working condition at all times.
   c. No. There are no indications of noncompliance.
   d. No. Inspectors are on-site to gather information, not to make demands or to initiate actions that may obligate the agency or create liabilities for the agency.

**General Problems**

6. A reverse air baghouse serving a 300 megawatt pulverized coal-fired boiler is having visible emissions of 60% to 70% opacity for 3 to 5 minutes after each compartment is cleaned. The Level 2 inspection data are provided below. What are possible causes of the opacity problem and how would you check each possibility?

<table>
<thead>
<tr>
<th>Stack Visible Emissions$^1$, %</th>
<th>Inspection Data</th>
<th>Baseline Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opacity Monitor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Opacity (6-min.), %</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Spiking Opacity, %</td>
<td>60-70%</td>
<td>None</td>
</tr>
<tr>
<td>Condensing Plume</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Overall Pressure Drop, in. H$_2$O</td>
<td>5.5</td>
<td>4</td>
</tr>
<tr>
<td>Gas Inlet Temperature, °F</td>
<td>300</td>
<td>310</td>
</tr>
<tr>
<td>Gas Outlet Temperature, °F</td>
<td>289</td>
<td>301</td>
</tr>
</tbody>
</table>

$^1$Non-spiking periods

7. An operator of a multi-compartment pulse jet baghouse has been attempting to correct a high baghouse static pressure problem in order to reduce fugitive emissions from the process system. The operator plans to convert to offline cleaning. Is this a reasonable action?
8. A clinker cooler pulse jet baghouse has a stack opacity that ranges between 0% and 5% opacity. There have been some shifts from the baseline operating conditions. What are possible causes of the decrease pressure drop and how would you check each possibility?

<table>
<thead>
<tr>
<th>Inspection Data</th>
<th>Baseline Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Pressure Drop, in. H$_2$O</td>
<td>2.5</td>
</tr>
<tr>
<td>Inlet Gas Temperature, °F</td>
<td>260</td>
</tr>
<tr>
<td>Compressed Air Pressure, psig</td>
<td>85</td>
</tr>
</tbody>
</table>

9. Opacity from a pulse jet fabric filter on a coal-fired industrial boiler has increased substantially from previously recorded levels. The static pressure drop across the collector is now 11 in. H$_2$O, and the operator has found it necessary to operate at reduced boiler load due to fan limitations. The compressed air system includes an oil filter, but no drier. The compressed air pressure is at the baseline value of 90 psig. The baghouse inlet temperature is presently 354°F; however, records indicate that the temperature sometimes drops to 295°F. The boiler is fired with low sulfur coal. What are possible causes of the increased pressure drop and how would you check each possibility?

10. A reverse air unit serving a cupola is now operating with an average opacity of 12%, compared with historical levels of 1-3%. The static pressure drop has increased from 6 in. H$_2$O to 7 in. H$_2$O. The gas inlet temperature is normally 495°F, but there are 15-30 minute excursions to 600°F. There are no signs of air infiltration through the shell or the solids discharge valves. What are possible causes of the increase in opacity?

11. A shaker fabric filter serving a drier has an average opacity of 25%, with short-term spikes to 60% during the cleaning of certain compartments. The gas inlet temperature is 240°F and the outlet temperature is 125°F. The compartment-by-compartment static pressure drops during cleaning are as follows:

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Pressure Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.3</td>
</tr>
<tr>
<td>2</td>
<td>-1.9</td>
</tr>
<tr>
<td>3</td>
<td>-0.9</td>
</tr>
<tr>
<td>4</td>
<td>-0.2</td>
</tr>
<tr>
<td>5</td>
<td>-0.2</td>
</tr>
<tr>
<td>6</td>
<td>-1.2</td>
</tr>
<tr>
<td>7</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

The pressure drop during operation is 3.3 in. H$_2$O. The baseline pressure drop is 3.1 in. H$_2$O. The shaker motors operate for a period of 5 minutes, beginning immediately after the compartment is isolated. What are possible causes of the high opacities?
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