Air Pollution Training Institute
MD 20
Environmental Research Center
Research Triangle Park, NC 27711

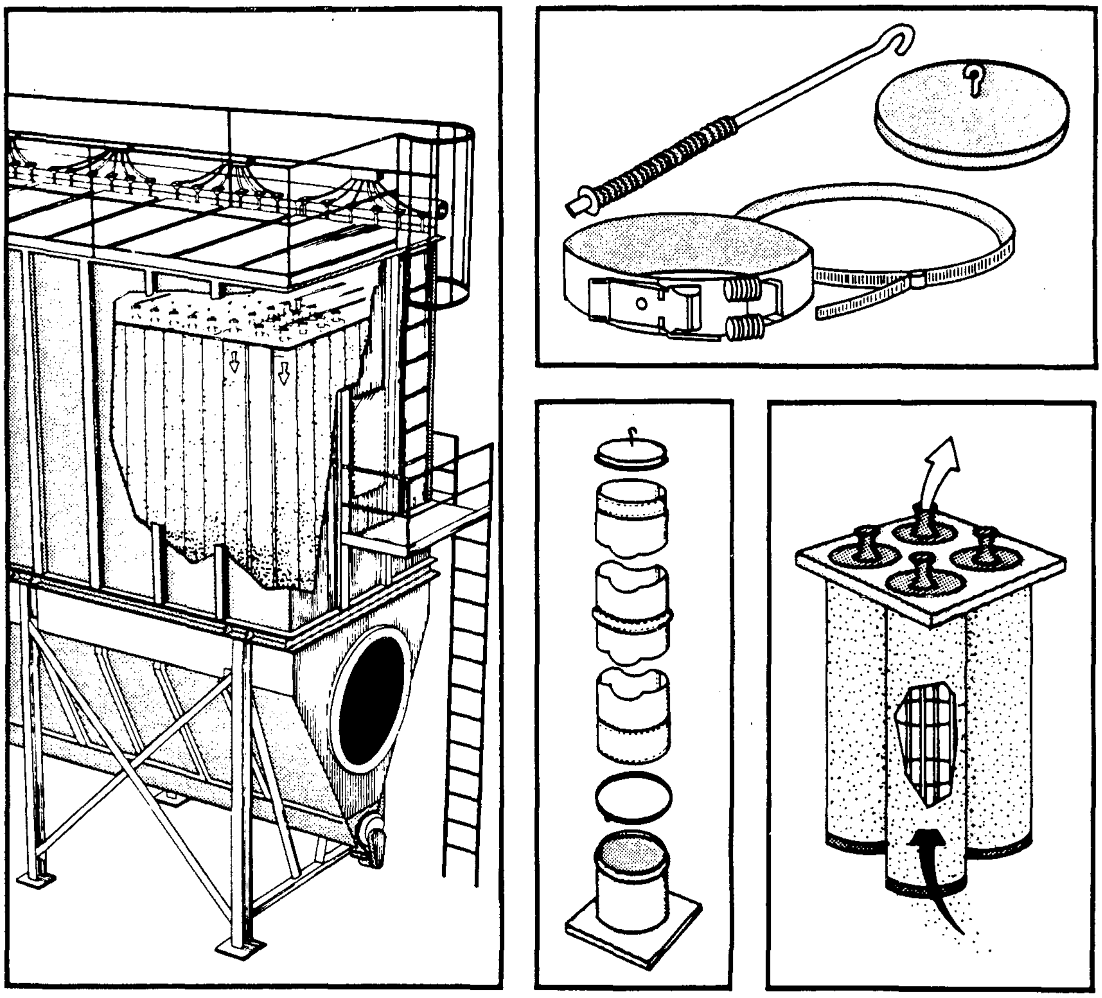
EPA 450/2-82-005
April, 1982

Air

EPA

APTI
Course SI:412
Baghouse Plan Review

Student Guidebook



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Written and designed by:
David S. Beachler
Marilyn Peterson

Northrop Services, Inc.
P.O. Box 12313
Research Triangle Park, NC 27709

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R. E. Townsend

United States Environmental Protection Agency
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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Others may obtain copies, for a fee, from the National Technical Information Service (NTIS), 5825 Port Royal Road, Springfield, VA 22161.

Sets of slides and films designed for use in the training course of which this publication is a part may be borrowed from the Air Pollution Training Institute upon written request. The slides may be freely copied. Some films may be copied; others must be purchased from the commercial distributor.

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Lesson 1

Course Introduction

Course Description

This course is designed for engineers and other technical personnel responsible for reviewing plans for installations of fabric filtration air cleaning devices. The course focuses on review procedures for baghouse devices used to reduce particulate air pollution from industrial sources. Major topics include:

- General baghouse description
- Bag cleaning methods
- Fabric selection and filter types
- Design parameters affecting collection efficiency
- Operation and maintenance problems associated with baghouses

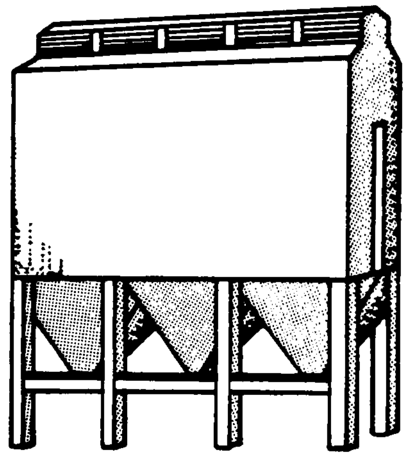

Figure 1-1. Typical baghouse.

Course Goal and Objectives

Goal

To familiarize you with the steps for evaluating a fabric filter air pollution control device used to control particulate emissions.

Objectives

Upon completion of this course, you will be able to:

1. recognize a baghouse and briefly describe its operation.
2. briefly describe the collection mechanisms for particle collection by a bag.
3. name two types of filter construction used for bags.
4. recognize three ways to remove dust particles from the bag.
5. recognize seven types of fibers used in making fabric filter material.
6. identify the key design parameters influencing collection efficiency.
7. recognize typical operation and maintenance problems associated with baghouses.

Lesson Titles

Lesson 1: Course Introduction
Lesson 2: Fabric Filtration Operation and Baghouse Components
Lesson 3: Fabric Filter Material
Lesson 4: Bag Cleaning
Lesson 5: Baghouse Design Variables
Lesson 6: Baghouse Design Review
Lesson 7: Baghouse Operation and Maintenance
Lesson 8: Industrial Applications of Baghouses
Lesson 9: Design Criteria for Permit Review: Problem Set

Requirements for Successful Completion

In order to receive 2.0 Continuing Education Units (CEUs) and a certificate of course completion, you must:

1. take one mail-in final examination.
2. achieve a final course grade of at least 70% (out of 100%) which is based on the final exam.

Materials

SI:412 Guidebook "Baghouse Plan Review"
SI:412 Lesson 7 slide/tape program, "Baghouse Operation and Maintenance"
SI:412 Final exam; approximately 50 questions

Use of the Guidebook

This guidebook directs your progress through the text material and the slide/tape presentation for this course. This first lesson introduces the rest of the course material and explains how to use it. Lessons 2 through 8 are self-paced in a text format that provides review exercises for sections of each lesson. To complete a review exercise, place a piece of paper across the page covering the questions below the one you are answering. After answering the question, slide the paper down to uncover the next question. The answer for the first question will be given on the right of the page separated by a line from the second question (Figure 1-2). All answers for review questions will appear below and to the right of their respective questions. The answers will be numbered to match the questions. Please **do not write in this book. Since the answers you give are for your information only, use the paper you cover the answers**

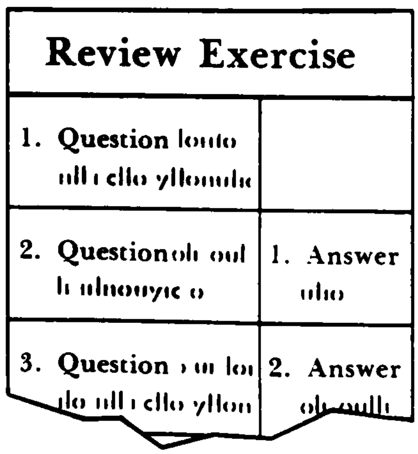

Figure 1-2. Review exercise format.

with or a scratch sheet to write on. Complete the review exercise for each section in each lesson. If you are unsure about a question or answer, review the lesson section preceding the question. Then proceed to the next section.

Lesson 9 is a baghouse design problem. One example problem will be described and the calculations necessary to complete it will be covered. Then another problem will be presented for you to complete. The solution to this problem will be included. Lesson 7 contains a slide/tape presentation that will preview the major topics on baghouse operation and maintenance presented in Lesson 7. You do not need to follow the script as you view the slides; however, you can use it to review the content.* The audiotape is designed to automatically advance the slides at the correct place in the script if your tape recorder has a mechanism for synchronizing audiotape and slides. To use the slides and tape together, advance the slides to slide 7-1-1, a focusing slide. Focus this slide and start the tape. The tape recorder will advance the slides for you.

*The script is included in the appendix.

Lesson Content

Lessons in this guidebook contain the following information:

- lesson goal
- lesson objectives
- text material
- use of audio-visual material (if applicable)
- review exercises and exercise answers

If supplementary reading material is available, it will be recommended in the appropriate lessons, but this material is not required for the course.

Instructions for Completing the Final Examination

Contact the Air Pollution Training Institute if you have any questions about the course or when you are ready to receive a copy of the final examination.

After completing the final exam return it and the answer sheet to the Air Pollution Training Institute. The final exam grade and course grade will be mailed to you.

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Lesson 2

Fabric Filtration Operation and Baghouse Components

Lesson Goal and Objectives

Goal

To familiarize you with the operation of fabric filters and the components of the baghouse.

Objectives

At the end of the lesson, you should be able to:

1. describe how a fabric filter operates to collect particulate matter.
2. briefly describe two filtration designs: interior and exterior.
3. list five major components of a baghouse.
4. recognize how bags are attached in a baghouse.

Introduction

Fabric filtration is one of the most common techniques used to collect particulate matter. Two basic types of filters are disposable and nondisposable. *Disposable* filters are similar to those used in a home heating or air conditioning system. Disposable filters can be constructed as mats or as deep beds (12 inches or more). Mat filters are usually made using fiberglass bats with a thin metal plate on the outside of the filter used for structural reinforcement. Depth filters are generally constructed using fiberglass fibers, glass fiber paper or some other inert material such as fine steel fibers to form a deep mesh. The filters are very efficient (99.97%) for the collection of 0.3 μm particles but must be replaced when they become loaded with particulate matter (when the pressure drop across the filter exceeds design specifications). Depth filters are widely useful for the collection of toxic dust materials.

Nondisposable fabric filters consist of a fabric material (nylon, wool, or other). These filters are commonly used to clean dirty exhaust gas streams from industrial processes. The particles are retained on the fabric material, while the cleaned gas passes through the material.

The collected particles are then removed from the filter by a cleaning mechanism; by shaking or using blasts of air. The removed particles are stored in a collection hopper until they are disposed of or are reused in the process.

Collection Mechanisms

Particles are collected on a filter by a combination of several mechanisms. The most important here are impaction, direct interception and diffusion. In collection by *impaction*, the particles in the gas stream have too much inertia to follow the gas streamlines around the fiber and are impacted on the fiber surface (Figure 2-1).

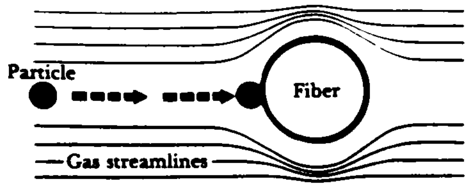

Figure 2-1. Impaction

In the case of *direct interception* the particles have less inertia and barely follow the gas streamlines around the fiber. If the distance between the center of the particle and the outside of the fiber is less than the particle radius, the particle will graze or hit the fiber and be "intercepted" (Figure 2-2).

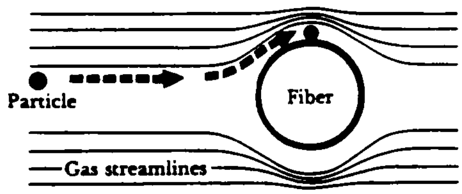

Figure 2-2. Direct interception.

Impaction and direct interception mechanisms account for 99% collection of particles greater than 1 μm aerodynamic diameter in fabric filter systems.

The third collection mechanism is that of *diffusion*. In diffusion, small particles are affected by collisions on a molecular level. Particles less than 0.1 μm aerodynamic diameter have individual or random motion. The particles do not necessarily follow the gas streamlines, but move randomly throughout the fluid. This is known as *Brownian motion*. The particles may have a different velocity than the fluid and at some point could come in contact with the fiber and be collected (Figure 2-3).

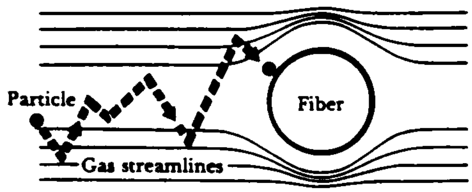

Figure 2-3. Diffusion.

Other collection mechanisms such as *gravitational settling, agglomeration,* and *electrostatic attraction* may contribute slightly to particle collection. Large particles may be overcome by the force of gravity and settle in the hopper. Particles can agglomerate or grow in size and then be more easily collected by the fibers. Some particles have a small electrostatic charge and can be attracted to a material of opposite charge. Electrostatic charges could, on the other hand, have a bad affect if the charges of the particles and fiber are the same. Electrostatic charges can be particularly useful for the capture of particles in the submicron range. The use of a selected fiber material or a specially coated material may enhance particle capture (Frederick, 1974). Different materials will develop electrostatic charges of varying degree and sign. A series of these triboelectric effects or electrostatic charges for various fabric materials was developed by Frederick and is shown in Table 2-1.

Particles also are collected by gravitational settling. Relatively large particles are overcome by the force of gravity and fall into the baghouse hopper.

This force is particularly important when dust-laden gas enters the baghouse through a hopper inlet.

Table 2-1. Triboelectric series for some production fabrics.

Positive charge	
+25	
	Wool felt
+20	
+15	Glass, filament, heat cleaned and silicone treated
	Glass, spun, heat cleaned and silicone treated
	Wool, woven felt, T-2
+10	Nylon 66, spun
	Nylon 66, spun, heat set
	Nylon 6, spun
	Cotton sateen
+ 5	Orlon 81, filament
	Orlon 42, needled fabrics
	Arnel, filament
	Dacron, filament
	Dacron, filament, silicone treated
0	Dacron, filament, M-31
	Dacron, combination filament and spun
	Creslan, spun; Azoton, spun
	Verel, regular, spun; Orlon 81, spun (55200)
	Dynel, spun
5	Orlon 81, spun
	Orlon 42, spun
	Dacron, needled
−10	Dacron, spun; Orlon 81, spun (79475)
	Dacron, spun and heat set
	Polypropylene 01, filament
	Orlon 39B, spun
−15	Fibravyl, spun
	Darvan, needled
	Kodel
−20	Polyethylene B, filament and spun
Negative charge	

Review Exercise

1. Disposable filters can be constructed as ________ or as ________ ________.	
2. Nondisposable filters consist of some type of ________ ________.	1. mats depth filters
3. Filters used to clean dirty exhaust gas streams from industrial processes are ________ ________.	2. fabric material
4. The collection forces (mechanisms) responsible for 99% collection of particles greater than 1 μm aerodynamic diameter are ________ and ________ ________.	3. nondisposable filters
5. ________ charges can help capture particles in the submicron range.	4. impaction direct interception
	5. Electrostatic

Bag Designs

Nondisposable fabric filter systems are developed for industrial application as baghouse systems. A baghouse consists of the following components:

- filter medium and support
- filter cleaning device
- collection hopper
- shell
- fan

The particle collection surface is composed of the filtering material and a support structure. Most U.S. baghouse designs employ long cylindrical tubes that contain felted fabric or woven cloth as the filtering medium. The cloth can be supported at the top and bottom of the bag by metal rings or clasps; or by an internal cage that completely supports the entire bag (Figure 2-4).

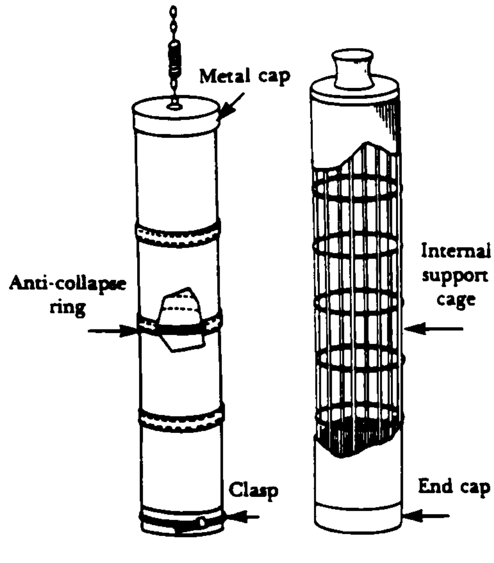

Figure 2-4. Bags and support.

Dust is collected on either the inside or outside of the fabric material depending on the baghouse design.

Some European baghouse designs employ an envelope filter arrangement as shown in Figure 2-5. The envelope filter consists of felted or woven fabric supported by a metal retaining cage. The metal cage keeps the fabric taut as the dust filters through and collects on the outside of the material. Clean air passes out the open end of the envelope.

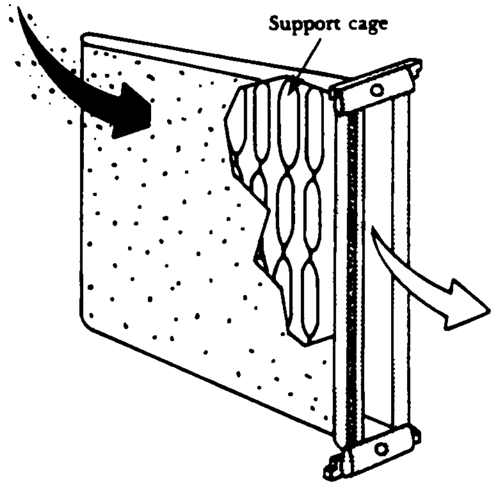

Figure 2-5. Envelope filter.

Recently, cartridge filters have been used for filtering particulate matter from small industrial processes. The cartridge filters are similar to truck filters and are approximately 2 ft long (Figure 2-6). Dust is collected on the outside of the cartridge while clean air flows on through the center.

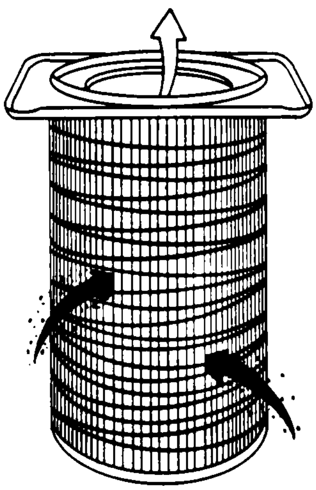

Figure 2-6. Cartridge filter.

Baghouses

Baghouses are usually constructed using many cylindrical bags that hang vertically in the baghouse (Figure 2-7). The number of bags can vary from a few hundred to a thousand or more depending on the size of the baghouse. When dust layers have built up to a sufficient thickness, the bag is cleaned, causing the dust particles to fall into a collection hopper. Bag cleaning can be done by a number of methods. Particles are stored in the hopper and are usually removed by a pneumatic or screw conveyer. The baghouse is enclosed by sheet metal to contain the collected dust and to protect the bags from atmospheric environmental conditions.

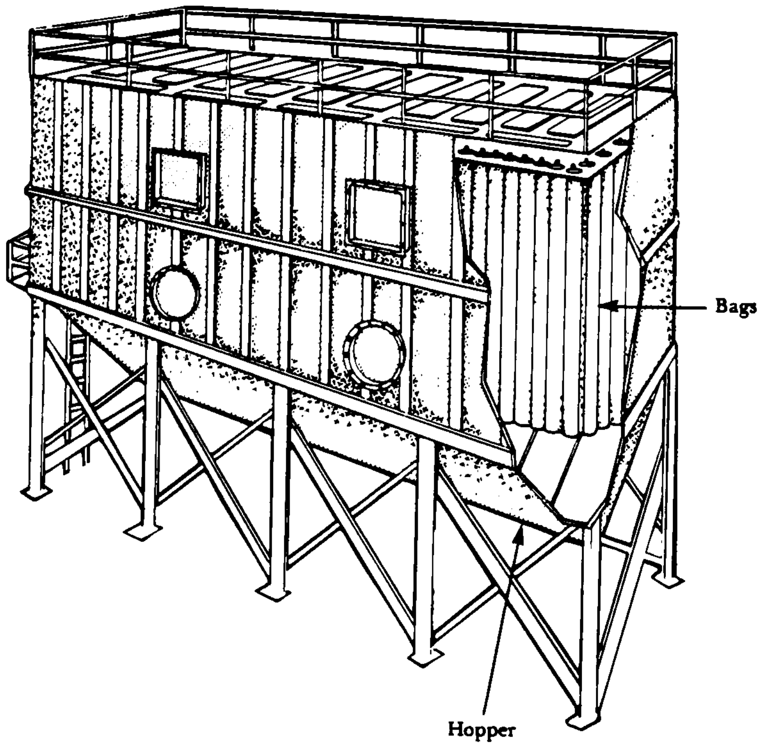

Figure 2-7. Typical baghouse.

The envelope baghouse consists of compartments that contain envelopes of fabric mounted on frames and attached to the walls of the collector (Figure 2-8).

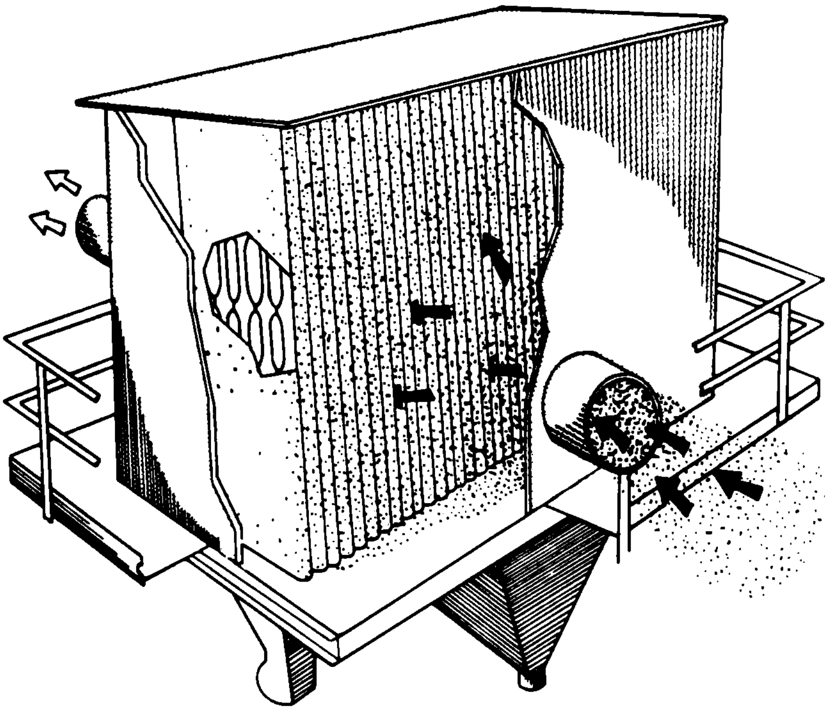

Figure 2-8. Envelope baghouse.

Cartridge systems operate similarly to a baghouse that uses bag tubes (Figure 2-9). Cartridge baghouses are usually used on smaller industrial processes handling exhaust flow rates less than 50,000 cfm.

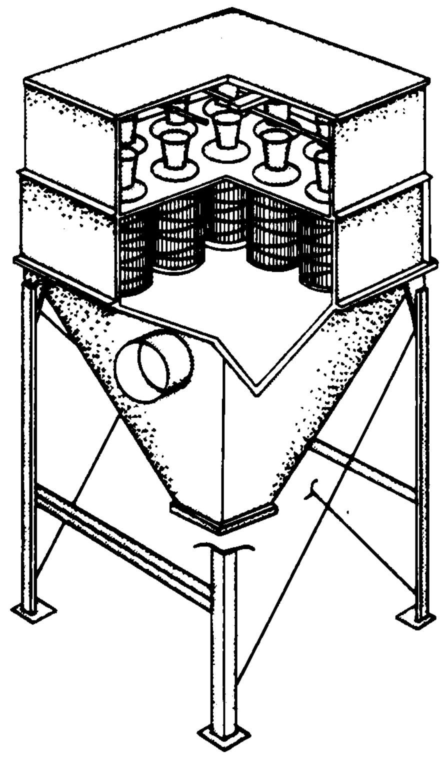

Figure 2-9. Cartridge baghouse.

Positive and Negative Pressure Baghouses

Dirty gas is either pushed or pulled through the baghouse by a fan. When the dust laden gas is pushed through the baghouse, the collector is called a *positive pressure* baghouse (Figure 2-10). Vendors can construct positive pressure baghouses with weaker support structure since the positive pressure will counterbalance the atmospheric pressure on the baghouse shell. Limitations, however, do exist since the fan is located on the dirty side of the system. Premature deterioration of fan blades, bearings, and duct work can occur in this configuration. This is very important in terms of operation and maintenance of the baghouse. The fan is an integral component; if it becomes worn out, it will cause a shutdown of the entire baghouse.

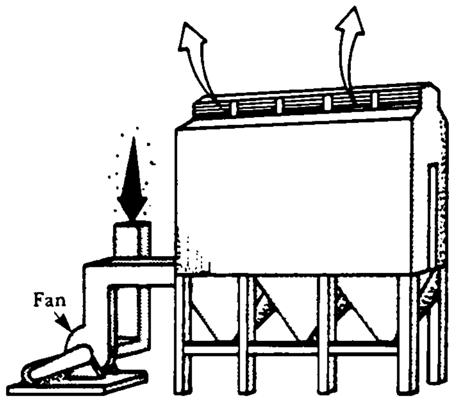

Figure 2-10. Positive pressure baghouse.

Positive pressure baghouses usually have short stubby stacks or outlets at the top of the baghouse called roof monitors. This is a problem when stack testing for determining the compliance status of the source. In this case a high volume sampler has been inserted in the stack opening or into the baghouse compartment for compliance testing. EPA is currently developing new testing methods for these baghouses. Positive pressure systems are used when filtering process streams containing low moisture content and low dust concentration of nonabrasive dusts.

When the fan is on the downstream side of the baghouse, the dirty gas is pulled through the baghouse and the collector is called a *negative pressure* baghouse (Figure 2-11). The structure of a negative pressure baghouse must be reinforced because of the suction on the baghouse shell. The construction costs will therefore be higher than for positive pressure systems. Since the baghouse housing is under negative pressure, there are no pressure leaks, so general housekeeping in the immediate vicinity is minimized. The wear and tear on the fan is much less than with positive systems since the particulate matter is removed by the bags before it can enter the fan. This may be the overriding factor in selecting a negative pressure baghouse. Negative pressure systems are used when filtering process streams containing high moisture content, corrosive gases, and high concentrations of abrasive dusts.

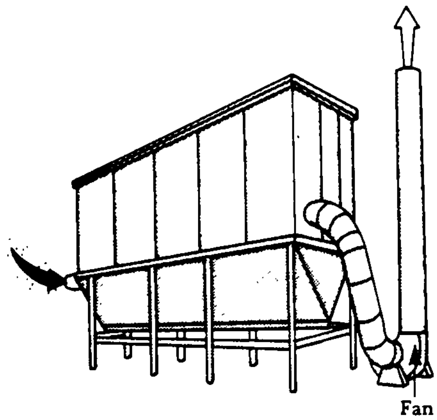

Figure 2-11. Negative pressure baghouse.

Review Exercise

1. The five major components of a baghouse are: __________, __________, __________, __________, and __________.	
2. Baghouses use either __________, __________, or __________ as the filtering media.	1. filter medium and support filter cleaning device collection hopper shell fan

3. Most U.S. baghouse designs use many cylindrical bags that __________ __________ in the baghouse.	2. bags envelopes cartridges
4. Dust cleaned from the bags is collected in a __________.	3. hang vertically
5. Baghouse systems can be grouped according to the placement of the fan before or after the baghouse. __________ pressure baghouse systems have the fan before the baghouse. __________ pressure baghouse systems have the fan after the baghouse.	4. hopper
6. Fan blades, bearings, and ductwork can deteriorate when the fan is located on the __________ __________ of the baghouse.	5. Positive Negative
7. Bag cloth is supported at the top and bottom of the bag by __________ or __________, or by an __________ that completely supports the entire bag.	6. dirty side
	7. rings or clasps internal cage

Filtration Designs

There are two filtration designs used in baghouses: ***interior filtration*** and ***exterior filtration***. In baghouses using interior filtration, particles are collected on the inside of the bag. The dust laden gas enters through the bottom of the collector and is directed inside the bag by diffuser vanes or baffles and a cell plate. The cell plate is a thin metal sheet surrounding the bag openings. The cell plate separates the clean gas section from the baghouse inlet. The particles are filtered by the bag and clean air exits through the outside of the bag (Figure 2-12).

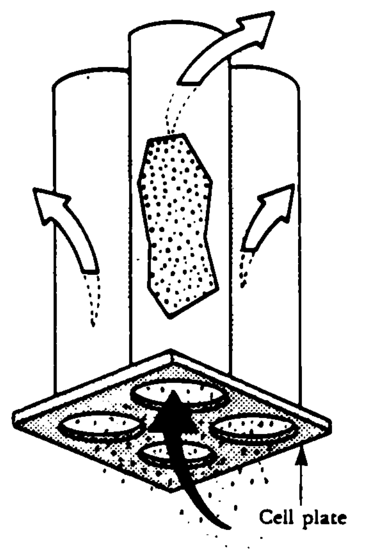

Figure 2-12. Interior filtration (particles collected on the inside of the bag).

For interior filtration the bags are held at the top by a spring and a metal cap (Figure 2-13). This arrangement is used for reverse air cleaning baghouses.

Bags for shaker cleaning baghouses (also interior filtration) are attached at the top by a hook (Figure 2-14). Shaker and reverse air cleaning will be discussed in more detail in later lessons.

In exterior filtration systems, dust is collected on the outside of the bags. The filtering process goes from the outside of the bag to the inside with clean gas exiting through the inside of the bag (Figure 2-15). Consequently, some type of bag support is necessary, such as an internal bag cage or rings sewn into the bag fabric. Bags are attached at the top to a *tube sheet* and are closed at the bottom by an *end cap*.

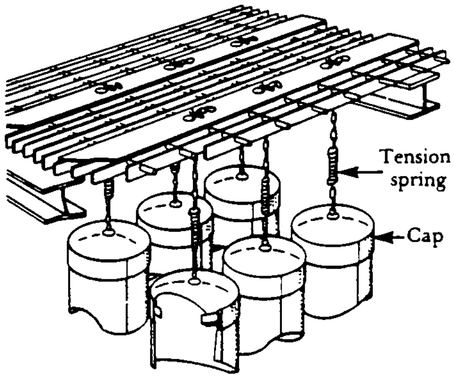

Figure 2-13. Bag attachment for reverse air baghouses.

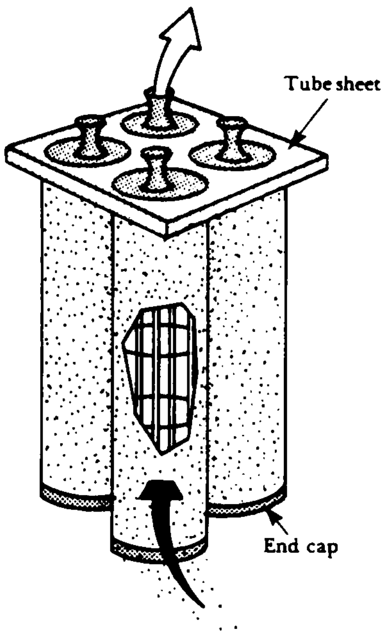

Figure 2-15. Exterior filtration (particles collected on the outside of the bag).

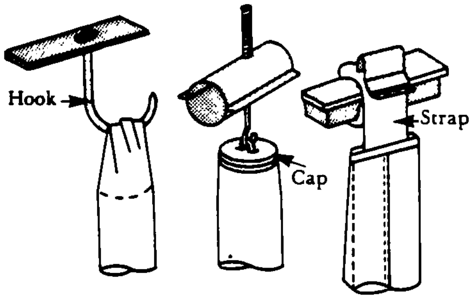

Figure 2-14. Bag attachment for shaker cleaning baghouses.

The dust-laden gas inlet position for both filtration systems often depends on the baghouse model and manufacturer. If the gas enters the top of the unit, a downwash of gas occurs which tends to clean the bags somewhat while the bags are filtering. This usually allows slightly higher gas volumes to be filtered through the baghouse before cleaning is required. If the gas enters the bottom of the unit, the inlet is positioned at the very top part of the dust hopper (Figure 2-16). Bottom or hopper inlets are easier to design and manufacture structurally than are the top inlets. However, when using hopper inlets, vendors must carefully design gas flows to avoid dust reentrainment from the hopper.

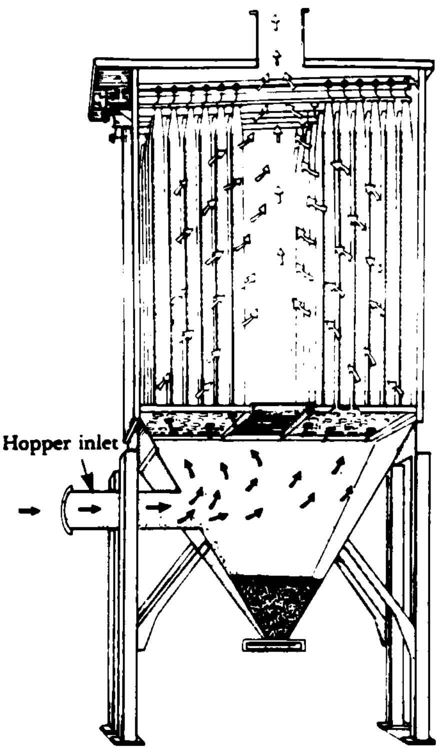

Figure 2-16. Dust inlet to the baghouse.

Review Exercise

1. When dust is collected on the inside of the bag, the filtration design is called ________ ________. When dust is collected on the outside of the bag, it is called ________ ________.	
2. For interior filtration, dust enters the bottom of the bag through a ________ ________.	1. interior filtration exterior filtration
3. The bags are attached at the top in a reverse air cleaning baghouse by a spring and a metal ________.	2. cell plate
4. The bags are attached at the bottom to the cell plate by a rubber gasket. a. True b. False	3. cap
5. For exterior filtration, bags are attached at the top to a ________ ________.	4. b. False
	5. tube sheet

6. Exterior filtration bags are supported by an internal cage. a. True b. False	
7. Exterior filtration bags are closed at the bottom by a(an) a. cell plate. b. tube sheet. c. end cap.	6. a. True
	7. c. end cap.

Baghouse Components

Bags

Tubular bags vary in length and diameter depending on baghouse design and manufacturer. The length varies from 10 to 40 feet and the diameter is usually between 4 and 18 inches. Bags are hung vertically in the baghouse (Figure 2-17). Reverse air baghouses use long bags, 20 to 40 feet, with large diameters, 12 to 18 inches. Pulse jet baghouses use smaller bags, 8 to 12 feet with 4 to 6 inch diameters.

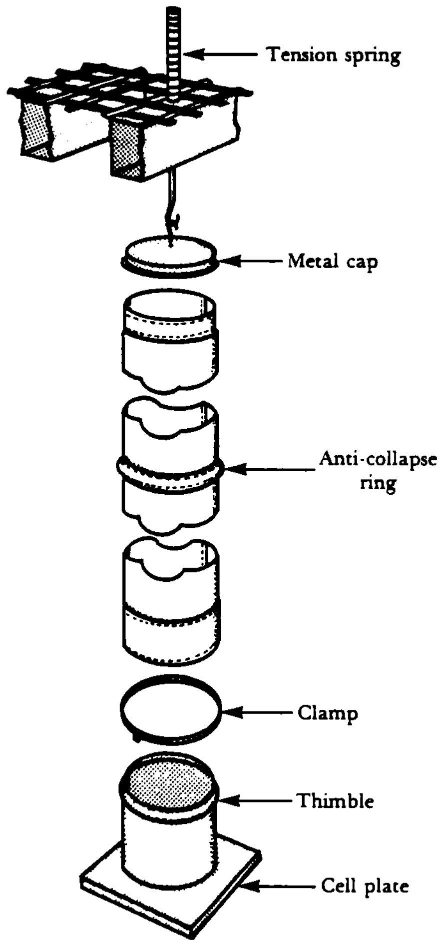

Figure 2-17. Bag construction (for a reverse air baghouse).

Housing

Baghouses are constructed as single or compartmental units. The single unit is generally used on small processes that are not in continuous operation such as grinding and paint spraying processes. Compartmental units consist of more than one baghouse compartment and are used in continuous operating processes with large exhaust volumes such as electric melt steel furnaces and industrial boilers. In both cases, the bags are housed in a shell made of a rigid metal material. Occasionally it is necessary to include insulation with the shell when treating high temperature flue gas. This is done to prevent moisture or acid mist from condensing in the unit, causing corrosion and rapid deterioration of the baghouse.

Hoppers

Hoppers are used to store the collected dust temporarily before it is disposed in a landfill or reused in the process. Dust should be removed as soon as possible to avoid packing which would make removal very difficult. They are usually designed with a 60° slope to allow dust to flow freely from the top of the hopper to the bottom discharge opening. Some manufacturers add devices to the hopper to promote easy and quick discharge. These devices include strike plates, poke holes, vibrators, and rappers. Strike plates are simply pieces of flat steel which are bolted or welded to the center of the hopper wall. If dust becomes stuck in the hopper, rapping the strike plate several times with a mallet will free this material. Hopper designs also usually include access doors or ports. Access ports provide for easier cleaning, inspection, and maintenance of the hopper (Figure 2-18).

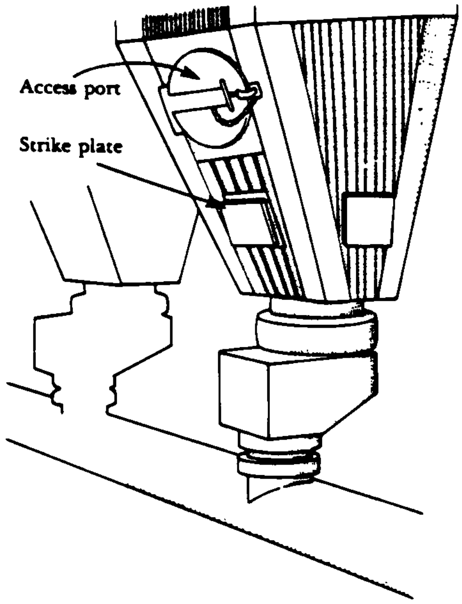

Figure 2-18. Hopper.

Discharge Devices

A discharge device is necessary for emptying the hopper. Discharge devices can be manual or automatic. The simplest manual discharge device is the ***slide gate,*** a plate held in place by a frame and sealed with gaskets (Figure 2-19). When the hopper needs to be emptied, the plate is removed and the material discharges. Other manual discharge devices include ***hinged doors*** or ***drawers.*** The collector must be shut down before opening any manual discharge device. Thus, manual discharge devices are used on baghouses that operate on a periodic basis.

Automatic continuous discharge devices are installed on baghouses that are used in continuous operation. Some devices include ***trickle valves, rotary airlock valves, screw conveyors*** or ***pneumatic conveyers.*** Trickle valves are shown in Figure 2-20. As dust collects in the hopper, the weight of the dust pushes down on the counterweight of the top flap and dust discharges downward. The top flap then closes, the bottom flap opens, and the material falls out. This type of valve is available in gravity-operated and motorized versions.

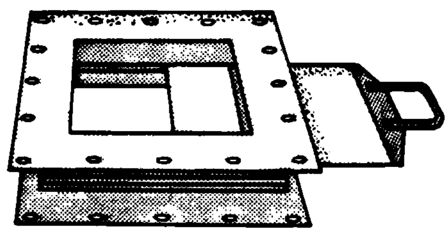

Figure 2-19. Slide gate.

Rotary airlock valves are used on medium or large sized baghouses. The valve is designed with a paddle wheel which is shaft-mounted and driven by a motor (Figure 2-21). The rotary valve is similar to a revolving door: the paddles or blades form an airtight seal with the housing; the motor slowly moves the blades to allow the dust to discharge from the hopper.

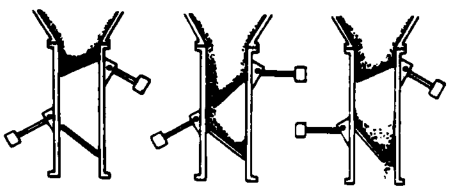

Figure 2-20. Trickle valve discharge device.

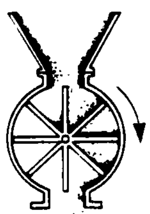

Figure 2-21. Rotary airlock discharge device.

Other automatic dust discharge devices include screw and pneumatic conveyers. Screw conveyers employ a revolving screw feeder located at the bottom of the hopper to remove the dust from the bin (Figure 2-22).

Pneumatic conveyers use compressed air to blow (remove) dust from the hopper (Figure 2-23).

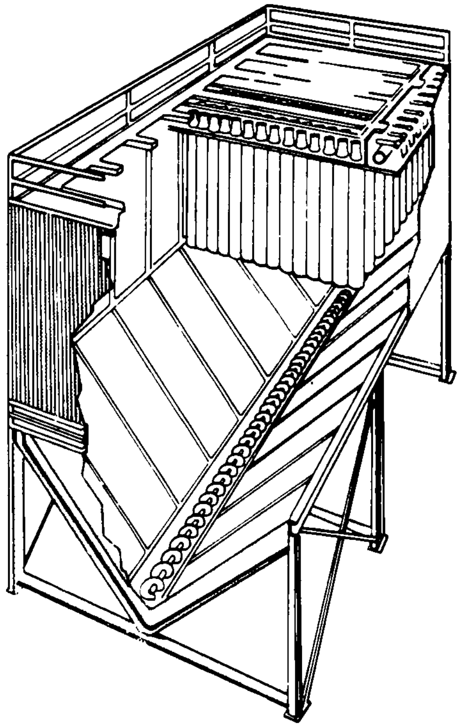

Figure 2-22. Screw conveyor.

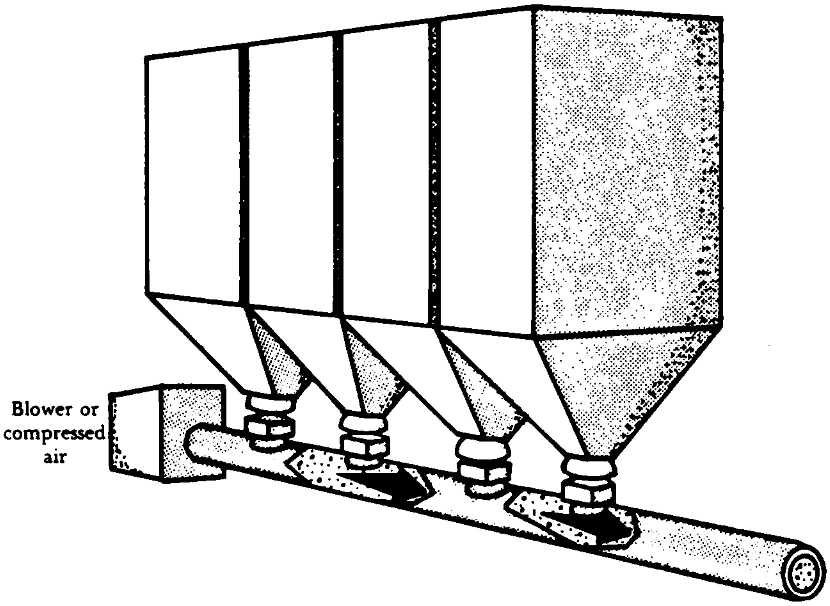

Figure 2-23. Pneumatic conveyer.

Review Exercise

1. The bags in a baghouse are housed in a __________ that is usually made of metal (steel).	
2. Sometimes it is necessary to use __________ with the shell to prevent moisture or acid from condensing in the baghouse.	1. shell
3. __________ units are used on small processes that aren't in continuous use.	2. insulation
4. __________ units are used on large industrial processes.	3. Single
5. The dust is temporarily stored in a __________.	4. Compartmentalized
6. One continuous discharge device that uses the weight of collected dust in the hopper to operate the flaps is a __________ __________.	5. hopper
	6. trickle valve

7. A __________ __________ discharge device works similar to a revolving door.	
8. A __________ __________ uses a screw feeder located at the bottom of the hopper to remove dust from the bin.	7. rotary airlock
9. A __________ __________ uses a blower or compressed air to remove dust from the hopper.	8. screw conveyer
	9. pneumatic conveyer

Lesson 3

Fabric Filter Material

Lesson Goal and Objectives

Goal

To familiarize you with the construction of fabric filter material, fibers used, and problems affecting fabric life.

Objectives

At the end of the lesson, you should be able to:
1. name two ways filters are constructed.
2. list at least five natural or synthetic fibers used to make filters and recall the conditions under which they are used.
3. name three failure mechanisms that reduce filter life.

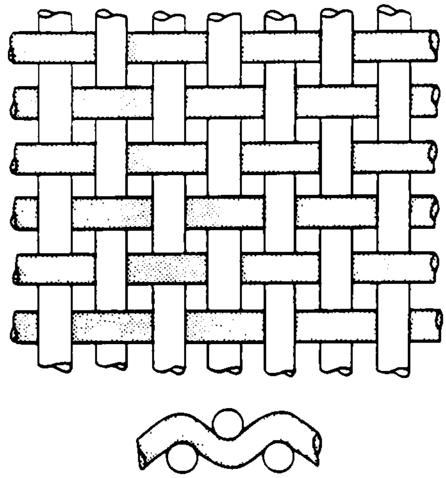

Figure 3-1. Plain weave or checkerboard.

Filter Construction

Woven and *felted* materials are used to make bag filters. Woven filters are made of yarn with a definite repeated pattern. Felted filters are composed of randomly placed fibers compressed into a mat and attached to some loosely woven backing material. Woven filters are used with low energy cleaning methods such as shaking and reverse air. Felted fabrics are usually used with higher energy cleaning systems such as pulse jet cleaning.

Woven Filters

Woven filters have open spaces around the fibers. The weave design used will depend on the intended application of the woven filter. The simplest weave is the *plain weave*. The yarn is woven over and under to form a checkerboard pattern (Figure 3-1). This weave is usually the tightest, having the smallest pore openings in the fabric. Consequently, it retains particles very quickly. This weave is not frequently used.

Other weaves include the twill and sateen (satin). In the *twill weave* (2/1), yarn is woven over two and under one, but in one direction only (Figure 3-2).

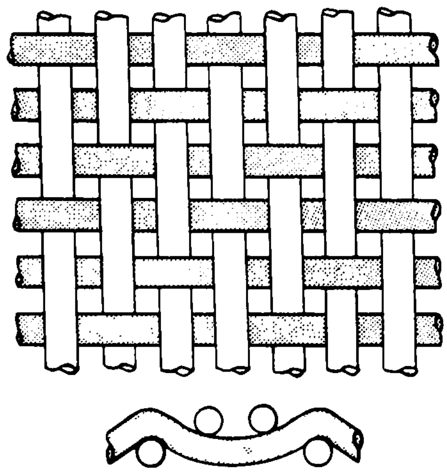

Figure 3-2. Twill weave (2/1).

The twill weave does not retain particles as well as the plain weave, but does not tend to blind as fast. It allows good flow rates through the filter and high resistance to abrasion. The *satin weave* goes one over and four under in both directions. Sateen weave does not retain particles as well as the plain twill weave, but has the best (easiest) cake release when the fabric is cleaned (Figure 3-3).

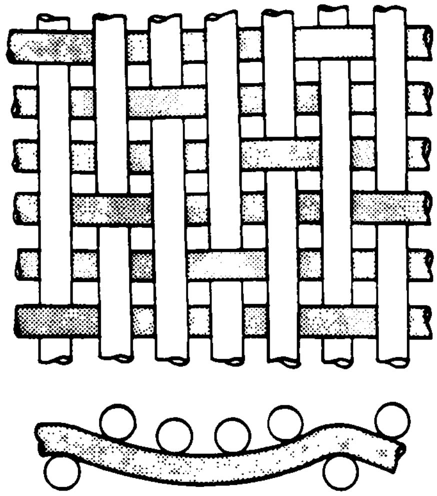

Figure 3-3. Sateen weave (satin weave).

Different weaving patterns increase or decrease the open spaces between the fibers. This will affect both fabric strength and permeability. Fabric permeability affects the amount of air passing through the filter at a specified pressure drop. A tight weave, for instance, has low permeability and is better for the capture of small particles at the cost of increased pressure drop.

The true filtering surface for the woven filter is not the bag itself, but the dust layer or filter cake. The bag simply provides the surface for capture of larger particles. Particles are collected by impaction or interception and the open areas in the weave are closed. This process is referred to as sieving (Figure 3-4). Some particles escape through the filter until the cake is formed. Once the cake builds up, effective filtering will occur until the bag becomes plugged and cleaning is required. At this point the pressure drop will be exceedingly high and filtering will no longer be cost effective. The effective filtering time will vary from a time of approximately 15 to 20 minutes to as long as a number of hours, depending on the concentration of particulate matter in the gas stream.

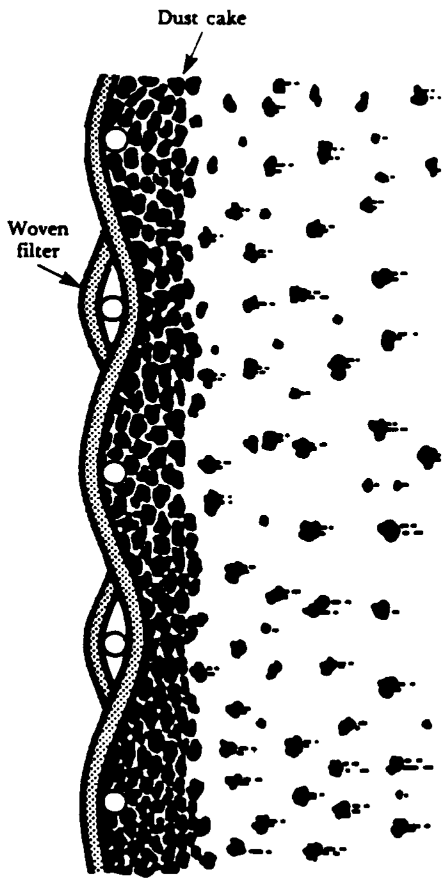

Figure 3-4. Sieving (on a woven filter).

Felted Filters

Felted filters are made by needle punching fibers onto a woven backing called a scrim. The fibers are randomly placed as opposed to the definite repeated pattern of the woven filter. The felts are attached to the scrim by chemical, heat, resin, and stitch-bonding methods.

To collect fine particles, the felted filters depend to a lesser degree on the initial dust deposits than do woven filters. The felted filters are generally 2 to 3 times thicker than woven filters. Each individual randomly oriented fiber acts as a target for particle capture by impaction and interception. Small particles can be collected on the outer surface of the filter (Figure 3-5).

Felted filters are usually used in pulse jet baghouses. A pulse jet baghouse generally filters more air per cloth area (higher air-to-cloth ratio) than a shaker or reverse air unit. Felted bags should not be used in high humidity situations, especially if the particles are hydroscopic. Clogging or blinding could result in such situations.

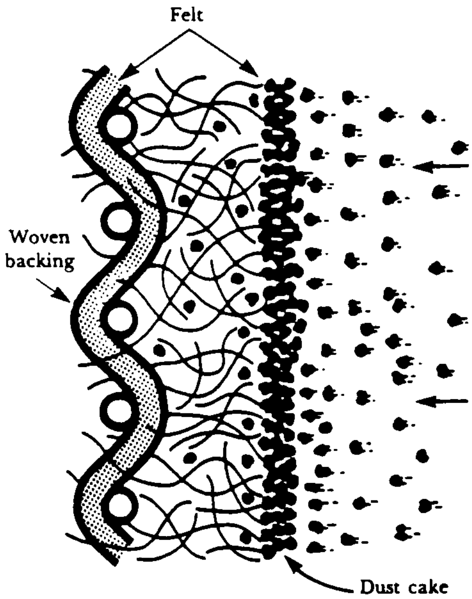

Figure 3-5. Felted fabric filter.

Review Exercise

1. Bag filters (bags) are made from __________ or __________ materials.	
2. __________ filters are made from yarn with a definite repeated pattern.	1. woven felted
3. The __________ and __________ weaves have better cake release than the simple weave.	2. Woven
4. In a woven filter, the woven material is not the true filtering surface. The dust __________ provides the surface for filtering particles.	3. twill sateen
5. __________ filters are made by needle punching fibers onto a woven backing called a scrim.	4. cake
	5. Felted

Fibers

The fibers used for fabric filters vary depending on the industrial application to be controlled. Some filters are made from natural fibers such as cotton or wool. These fibers are relatively inexpensive but have temperature limitations ($<212\,°F$ or $100\,°C$) and only average abrasion resistance. Cotton is readily available making it very popular for low temperature simple applications. Wool withstands moisture very well and can be made into thick felts easily.

Synthetic fibers such as nylon, Orlon® and polyester have slightly higher temperature limitations and chemical resistances. Synthetic fibers are more expensive than natural fibers. Polypropylene is the most inexpensive synthetic fiber and is used in many industrial applications such as foundries, coal crushers and food industries. Nylon is the most abrasive resistant synthetic fiber making it useful in applications filtering abrasive dusts. Polyester or Dacron® has good overall qualities to resist acids, alkalines, and abrasion and is relatively inexpensive, making it useful for many industrial processes such as smelters, foundries, and other metal industries.

Nomex® is a registered trademark of fibers made by DuPont. DuPont makes the fibers, not the fabrics or bags. Nomex is widely used because of its relatively high temperature resistance and its resistance to abrasion. It is used for filtering dusts from cement coolers, asphalt batch plants, ferroalloy furnaces, and coal dryers.

Other fibers such as Teflon® and Fiberglas® or glass can be used in very high temperature situations. Teflon has very good resistance to acid attack (except fluorine) and can withstand continuous temperatures up to 445 °F (230 °C). Fiberglas or glass is often used in baghouses that handle very high temperatures (up to 500 °F or 260 °C) for continuous operation. Glass fibers are usually lubricated in some fashion so they will slide over one another without breaking or cutting during the cleaning cycle. Graphite is commonly used as a lubricant and will help retain the upper service temperature limits. Glass fibers are susceptible to breakage and require a very gentle cleaning cycle. Both Teflon and glass have been used to remove particulate emissions generated from industrial and utility coal fired boilers.

Note: Orlon®, Dacron®, Teflon®, and Fiberglas® are registered with the U.S. Patent Office. In this manual the name without the registered symbol (®) will be used.

Another material used to make bags is Gore-tex membrane manufactured by W. G. Gore and Associates, Inc. Gore-tex membrane is laminated with a variety of fibers such as Fiberglas, polyester and Nomex to produce felt and woven filters. Some reports have indicated very good emission reduction (99.99⁺%), low pressure drops, increased bag life and higher air-to-cloth ratios using this material in metal industries, chemical industries, food industries, and coal fired boilers.

Table 3-1 lists a number of typical fibers used for fabric filters. The properties of the listed fibers include temperature limits, acid and alkali resistance, abrasion resistance, and relative bag costs.

Table 3-1. Typical fabrics used for bags.

Generic name	Fiber	Maximum temperature				Acid resistance	Alkali resistance	Flex abrasion resistance	Relative cost
		Continuous		Surges					
		°F	°C	°F	°C				
Natural fiber cellulose	Cotton	180	82	225	107	poor	very good	very good	2.0
Polydefin	Polypropylene	190	88	200	93	good to excellent	very good	excellent	2.0
Natural fiber protein	Wool	200-216	93-102	250	121	very good	poor	fair to good	3.0
Polyamide	Nylon	200-225	93-107	250	121	poor to fair	good to excellent	excellent	2.5
Acrylic	Orlon	240	116	260	127	good to excellent	fair to good	good	2.75
Polyester	Dacron	275	135	325	163	good	good	very good	2.8
Aromatic polyamide	Nomex	400	204	425	218	poor to good	good to excellent	excellent	8.0
Fluorocarbon	Teflon	400-450	204-232	500	260	excellent except poor to fluorine	excellent except poor to trifluoride, chlorine and molten alkaline metals	fair	20.0
Glass	Fiberglas or glass	500	260	550	288	fair to good	fair to good	fair	6.0

Sources: Bethea, 1978; EPA, 1979; Theodore and Buonicore, 1976.

The cost (1982) of a polypropylene bag 12 feet long and 6 inches in diameter is approximately $10 to $12. From Table 3-1 the price of a Teflon bag of the same size is approximately $100 to $120.

Review Exercise

1. Two natural fibers used for fabric filters are ________ and ________.	
2. Wool and cotton are inexpensive but are susceptible to failure at ________ ________.	1. wool cotton
3. Two fabrics that are good for use in high temperature (>200 °C) industrial processes are a. Teflon and Fiberglas b. nylon and wool c. cotton and Orlon d. polypropylene and Dacron	2. high temperature
	3. a. Teflon and Fiberglas

Fabric Treatment

Fabrics are usually pretreated to improve their mechanical and dimensional stability. They can be treated with silicone to give them better cake release properties. Natural fabrics (wool and cotton) are usually preshrunk to eliminate bag shrinkage during operation. Both synthetic and natural fabrics usually undergo processes such as calendering, napping, singeing, glazing, or coating.

These processes increase fabric life and improve dimensional stability and ease of bag cleaning.

- *Calendering* is the high pressure pressing of the fabric by rollers to flatten, smooth, or decorate the material. Calendering pushes the surface fibers down onto the body of the filter medium. This is done to increase surface life, dimensional stability and to give a more uniform surface to bag fabric.
- *Napping* is the scraping of the filter surface across metal points or burrs on a revolving cylinder. Napping raises the surface fibers, creating a "fuzz", that provides a large number of sites for particle collection by interception and diffusion. Fabrics used for collecting sticky or oily dusts are occasionally napped to provide good collection and bag cleaning ease.
- *Singeing* is done by passing the filter material over an open flame, removing any straggly surface fibers. This provides a more uniform surface.
- *Glazing* is the high pressure pressing of the fiber at elevated temperatures. The fibers are fused to the body of the filter medium. Glazing improves the mechanical stability of the filter and helps reduce bag shrinkage that occurs from prolonged use.

- *Coating*, or resin treating, involves immersing the filter material in natural or synthetic resin such as polyvinyl chloride, cellulose acetate, or urea-phenol. This is done to lubricate the woven fibers, or to provide high temperature durability or chemical resistance for various fabric material. For example, glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning.

A summary of pretreatment processes for fabrics is presented in Table 3-2.

Table 3-2. Summary of pretreatment processes.

Pretreatment	Method	Result	Reason for use
Calendering	High pressure pressing by rollers	Flattens, smooths, or decorates	Increases surface life Increases dimensional stability Provides more uniform fabric surface
Napping	Scraping across metal points	Raises surface fibers	Provides extra areas for interception and diffusion
Singeing	Passing over open flame	Removes straggly surface fibers	Provides uniform surface area
Glazing	High pressure pressing at elevated temperatures	Fibers fused to filter medium	Improves mechanical stability
Coating	Immersing in natural or synthetic resin	Lubricates woven fibers	Provides high temperature durability Provides chemical resistance for various fabric material

Review Exercise

1. Fabrics are pretreated to improve their mechanical and dimensional stability. a. True b. False	
2. The filter surface of fabric material is sometimes scraped with metal points or burrs on a revolving cylinder to create a "fuzz" on the material. This treatment is called a. singeing. b. glazing. c. napping. d. resin treating.	1. a. True
	2. c. napping

3. Glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning. a. True b. False	
4. When fabric material is passed over an open flame to remove straggly fibers, the treatment is called ________.	3. a. True
	4. singeing

Bag Failure Mechanisms

Three failure mechanisms can shorten the operating life of a bag. They are related to abrasion, thermal durability and chemical attack. The chief design variable is the upper temperature limit of the fabric. The process exhaust temperature will determine which fabric material should be used for dust collection. Exhaust gas cooling may be feasible, but one must be careful to keep the exhaust gas hot enough to prevent moisture or acid from condensing on the bags.

Another problem frequently encountered in baghouse operation is that of abrasion. Bag abrasion can result from bags rubbing against each other, or from the type of bag cleaning employed in the baghouse or where dust enters the bag and contacts the fabric material. For instance, in a shaker baghouse, vigorous shaking may cause premature bag deterioration, particularly at the points where the bags are attached. In pulse jet units, the continual, slight motion of the bags against the supporting cages can also seriously affect bag life. As a result, a 25% per year bag replacement rate is usually encountered. This is the single biggest maintenance problem associated with baghouses.

Bag failure can also occur by chemical attack to the fabric. Changes in dust composition and exhaust gas temperatures from industrial processes can greatly affect the bag material. If the exhaust gas stream is lowered to its dew point or a new chemical species is created, the design of the baghouse (fabric choice) may be completely inadequate. Proper fabric selection and good process operating practices can help eliminate bag deterioration caused by chemical attack.

Gas Conditioning

Occasionally it is necessary to cool the process gas stream before the gas goes to the baghouse. Since there is an upper temperature limit on the fabrics used for bags, gas cooling is sometimes necessary to preserve bag life. This can be accomplished by a number of cooling methods.

Dilution of the exhaust gas stream by air is the easiest and cheapest method, especially at very high temperatures. However, air dilution requires the use of a larger baghouse to handle the increased volume of air. Other problems can arise due to the difficulty of controlling the intake of ambient moisture and other contaminants from the dilution air intake.

Radiation cooling can also be used to lower the process exhaust gas temperature. Radiation cooling involves the use of long uninsulated ducts that allow the gas stream to cool as heat radiates from the duct walls. Ducts can be designed in "U" shapes to allow more duct surface area to be exposed for radiation cooling (Figure 3-6). Radiation cooling would not normally be very effective to cool gas temperatures below 572°F or 300°C. This would require substantial surface area, lengthy duct runs, and increased fan horsepower. Precise temperature control is difficult to maintain and there is a possibility of the ducts becoming plugged due to particle sedimentation.

Evaporative cooling is also used to reduce exhaust gas stream temperature. Evaporative cooling is accomplished by injecting fine water droplets into the gas stream. The water droplets absorb heat from the gas stream as they evaporate. Spray nozzles are located in a quench chamber or somewhere in the duct preceding the baghouse (Figure 3-7). Evaporative cooling gives a great amount of controlled cooling at a relatively low installation cost. Temperature control can be flexible and accurate. However, this cooling method may increase the exhaust volume to the baghouse. The biggest problem with evaporative cooling is keeping the gas temperature above the dew point of the gas (SO_2, NO_2, HCl, etc.). Otherwise, gases may condense on the bags causing rapid bag deterioration. In addition, all moisture injected into the gas must be evaporated to prevent corrosion of metal parts and blinding or plugging of caked dust on the bags.

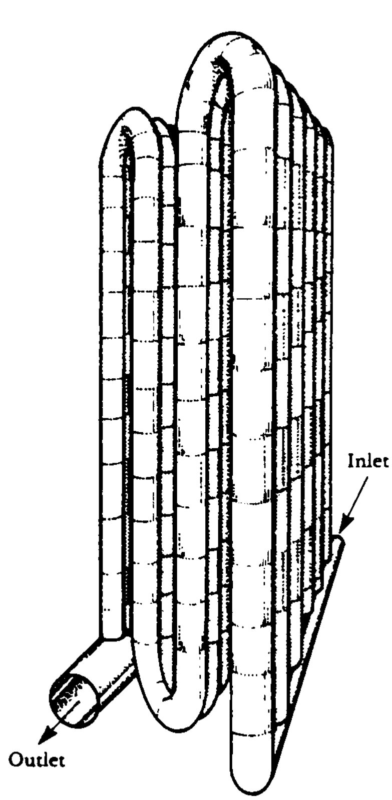

Figure 3-6. U-tube cooler (radiation cooling).

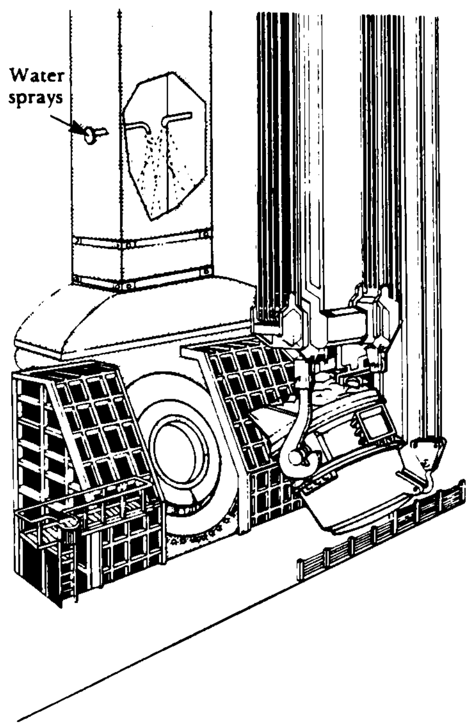

Figure 3-7. Evaporative cooling using water sprays.

Review Exercise

1. Three failure mechanisms that shorten bag operating life are __________, __________ __________, and __________ __________.	
2. The chief design variable for prolonged bag life is the upper temperature limit of the bag. a. True b. False	1. abrasion thermal durability chemical attack
3. Cooling the process exhaust stream by dilution does not increase the air volume to be handled by the baghouse. a. True b. False	2. a. True
4. When long uninsulated ducts are used for cooling process exhaust the cooling is called a. radiation cooling. b. evaporative cooling. c. dilution cooling. d. condensation.	3. b. False
5. __________ cooling is accomplished by spraying fine water droplets into the process exhaust stream.	4. a. radiation cooling.
6. The biggest problem with evaporative cooling is a. the long duct runs needed for cooling. b. keeping the gas temperature above the dew point. c. the increased volume of air to handle as a result of cooling.	5. Evaporative
	6. b. keeping the gas temperature above the dew point.

Lesson 4

Bag Cleaning

Lesson Goal and Objectives

Goal

To familiarize you with mechanisms to clean collected dust from the bags.

Objectives

At the end of the lesson, you should be able to:

1. name two bag cleaning sequences and briefly discuss the conditions under which they are used.
2. list three major cleaning methods and briefly describe how each method is used to remove dust from bags.

Cleaning Sequences

Two basic sequences are used for bag cleaning: intermittent, or periodic cleaning; and continuous filter cleaning.

Intermittently cleaned baghouses consist of a number of compartments or sections. One compartment at a time is removed from service and cleaned on a regular rotation basis. The dirty gas stream is diverted from the compartment being cleaned to the other compartments in the baghouse, so it is not necessary to shut down the process. Occasionally, the baghouse is very small and consists of a single compartment. The flow of dirty air into the baghouse is stopped during bag cleaning. These small single compartment baghouses are used on batch processes that can be shut down for bag cleaning.

Continuously cleaned baghouses are fully automatic and can constantly remain on-line for filtering. The filtering process is momentarily interrupted by a blast of compressed air that cleans the bag, called pulse jet cleaning. In continuous cleaning, a row of bags is always being cleaned somewhere in the baghouse. The advantage of continuous cleaning is that it is not necessary to take the baghouse out of service. Large continuous cleaning baghouses are built with compartments to help prevent total baghouse shutdown for bag maintenance and failures to the compressed air cleaning system or hopper conveyers. This allows the baghouse operator to take one compartment off-line to perform necessary maintenance.

Types of Bag Cleaning

A number of cleaning mechanisms are used to remove caked particles from bags. The three most common are *shaking, reverse air,* and *pulse jet*. Another mechanism called *blow ring* or *reverse jet* is normally not used in modern bag cleaning systems.

Shaking

Shaking can be done manually, but is usually performed mechanically in industrial-scale baghouses. Small baghouses handling exhaust streams less than 500 cfm (14.2 m^3/min) are frequently cleaned by hand levers. However, thorough cleaning is rarely achieved since a great amount of effort must be used for several minutes to remove dust cakes from the bags. In addition, these small units do not usually have a manometer installed on them to give pressure drop readings across the baghouse. These readings are used to determine when bag cleaning is necessary. Therefore, manual shaker baghouses are not recommended for use in controlling particulate emissions.

Mechanical shaking is accomplished by using a motor that drives a shaft to move a rod connected to the bags. It is a low energy process that gently shakes the bags to remove deposited particles. The shaking motion and speed depends upon the vendors' design and the composition of dust deposited on the bag. The shaking motion can be either in a horizontal or vertical direction, with the horizontal being the most often used. The tops of the bags in shaker baghouses are sealed or closed and supported by a hook or clasp. Bags are open at the bottom and attached to a cell plate. The bags are shaken at the bottom by moving the cell plate or at the top by moving the frame where the bags are attached. This causes the bags to ripple and release the dust (Figure 4-1). The flow of dirty gas is stopped during the cleaning process. Therefore the baghouse must be compartmentalized to be useable on a continuous basis. Shaker baghouses usually use interior filtration (dust collected on the inside of the bags).

Shaking should not be used when collecting sticky dusts. The forces needed for removing sticky dust can cause the bag to be torn or ripped.

Bag wear on the whole can be a problem at the bottom of the bag which is attached to the cell plate; the greatest wear is usually at the top of the bag where the support loop attaches to the bag. Proper shaking frequency is therefore important to prevent premature bag failure.

In a few systems, shaking is accomplished by sonic vibration (Figure 4-2). A sound generator is used to produce a low frequency sound that causes the bags to vibrate. The noise level produced by the generator is barely discernable outside the baghouse. This type of cleaning, however, is not used on many newer baghouse systems.

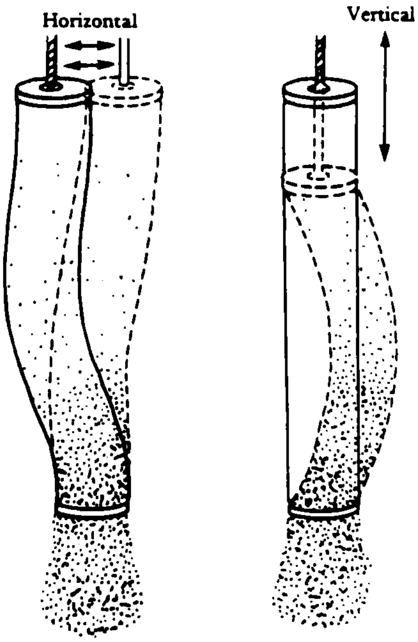

Figure 4-1. Shaking.

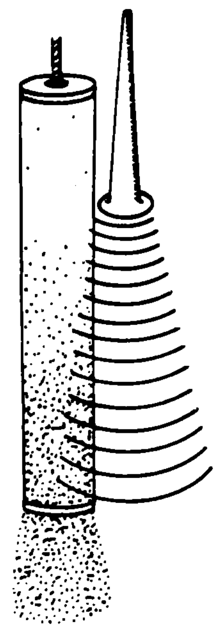

Figure 4-2. Sonic vibrations.

A typical shaker baghouse is shown in Figure 4-3. The bags are attached to a shaft that is driven by an externally mounted motor. The bags are shaken, and the dust falls into a hopper located below the bags. The duration of the cleaning cycle is usually from 30 seconds to a few minutes.

The frequency of the cleaning depends on the type of dust, the concentration, and the pressure drop across the baghouse. The baghouse usually has two or more compartments to allow one compartment to be shut down for cleaning.

Figure 4-4 is a detailed view of the shaking mechanism. The bags are attached in sets of two rows to mounting frames across the width of the baghouse. A motor drives the shaking lever, which in turn causes the frame to move and the bags to shake. Typical design parameters for shaking cleaning are given in Table 4-1.

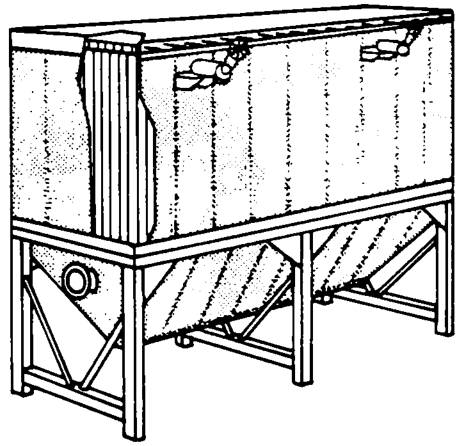

Figure 4-3. Typical shaker baghouse.

Table 4-1. Shake cleaning—parameters.

Frequency	Usually several cycles per second; adjustable
Motion	Simple harmonic or sinusoidal
Peak acceleration	1 to 10 g
Amplitude	Fraction of an inch to few inches
Mode	Off-stream
Duration	10 to 100 cycles, 30 sec to few minutes
Common bag dimensions	5, 8, 12 inch diameters; 8 to 10, 22, 30 foot lengths

Source: McKenna and Greiner, 1981.

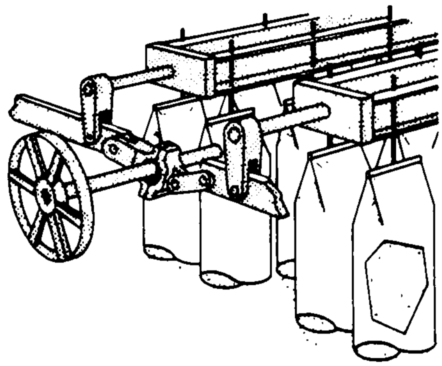

Figure 4-4. Detail of a shaking lever.

Review Exercise

1. Two basic sequences for bag cleaning are __________ and __________ cleaning.	
2. Intermittent baghouses consist of compartments that are all cleaned simultaneously. a. True b. False	1. intermittent continuous
3. It is not necessary to take a continuously cleaned baghouse off-line for bag cleaning. a. True b. False	2. b. False
	3. a. True

4. Mechanical shaking is accomplished by using a ________ that drives a shaft to shake the dust-laden bags.	
5. The flow of dirty air into a compartment is shut down for bag cleaning in a shaker baghouse. a. True b. False	4. motor
6. Bags are not sealed or closed at the top in a shaker baghouse. a. True b. False	5. a. True
7. The shaking motion causes the dust cake to break and fall into the ________.	6. b. False
8. Bag cleaning frequency depends on dust type, dust concentration, and the ________ ________ across the baghouse.	7. hopper
	8. pressure drop

Reverse Air

Reverse air, the simplest cleaning mechanism, is accomplished by stopping the flow of dirty gas into the compartment and backwashing the compartment with a low pressure flow of air. Dust is removed by merely allowing the bags to collapse, thus causing the dust cake to break and fall into the hopper. The cleaning action is very gentle, allowing the use of less abrasion resistant fabrics such as Fiberglas (Figure 4-5). Reverse air cleaning is generally used for cleaning woven fabrics. Cleaning frequency varies from 30 minutes to several hours, depending on the inlet dust concentration. The cleaning duration is approximately 10 to 30 seconds; the total time is 1 to 2 minutes for valve opening and closing, and dust settling.

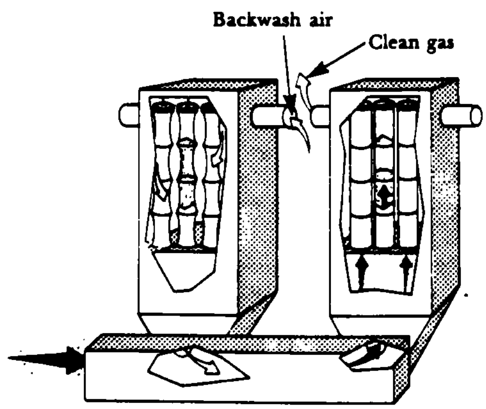

Figure 4-5. Reverse air cleaning.

Reverse air cleaning baghouses are usually compartmentalized to permit a section to be off-line for cleaning. Dust can be collected on either the inside or outside of the bag. Normally dust is collected on the inside of the bag, the bag being open at the bottom and sealed by a metal cap at the top. The bag contains rings to keep it from completely collapsing during the cleaning cycle. Complete collapse of the bag would prevent the dust from falling into the hopper. Bags are supported by small steel rings sewn to the inside of the bag. The rings are placed every 4 to 18 inches throughout the bag length depending on the length and diameter of the bag. Reverse air baghouses use very large bags (as compared to shaker or pulse jet baghouses) ranging from 8 to 18 inches in diameter and from 20 to 40 feet in length.

Cleaning air is supplied by a separate fan which is normally much smaller than the main system fan, since only one compartment is cleaned at a time. A typical reverse air cleaning baghouse is shown in Figure 4-6. Typical design parameters for reverse air cleaning are given in Table 4-2.

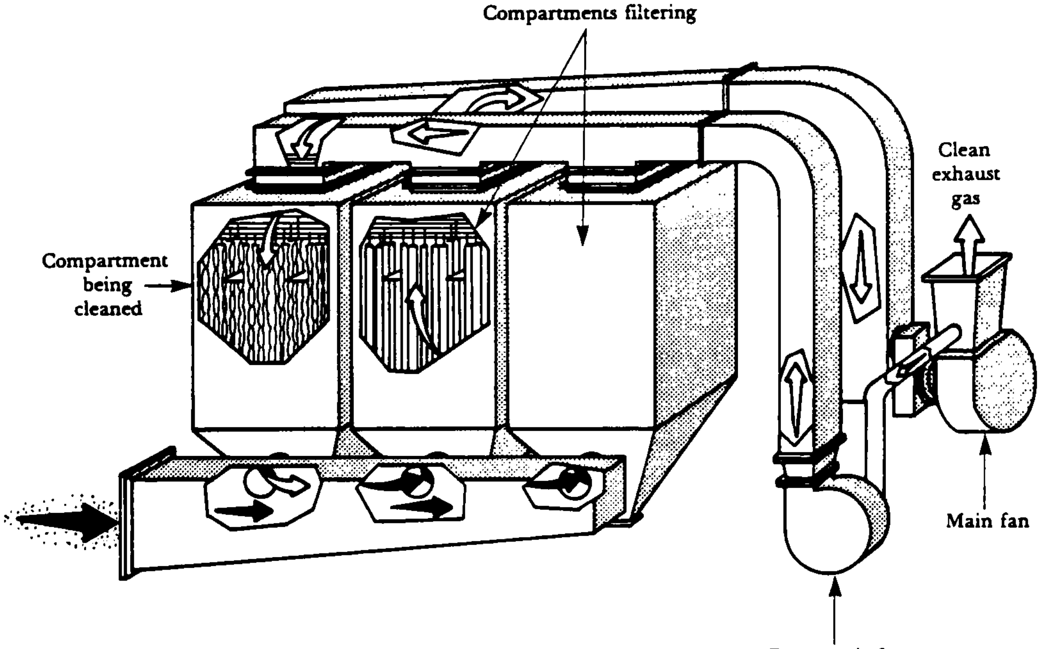

Figure 4-6. Typical reverse air baghouse.

Table 4-2. Reverse air cleaning—parameters.

Frequency	Cleaned one compartment at a time, sequencing one compartment after another; can be continuous or initiated by a maximum-pressure-drop switch
Motion	Gentle collapse of bag (concave inward) upon deflation; slowly repressurize a compartment after completion of a back-flush
Mode	Off-stream
Duration	1 to 2 min, including valve opening and closing and dust settling periods; reverse air flow itself normally 10 to 30 sec
Common bag dimensions	8, 12, 18 inch diameters; 22, 30, 40 foot lengths
Bag tension	50 to 75 lbs typical, optimum varies; adjusted after on-stream

Source: McKenna and Greiner, 1981.

Review Exercise

1. Reverse air cleaning is accomplished by a blast of air into each bag. a. True b. False	
2. Reverse air cleaning is very gentle allowing the use of less abrasion resistant fabrics such as woven ________ (or ________).	1. b. False
3. Cleaning duration is approximately a. 1 to 2 hours. b. 10 to 20 minutes. c. 10 to 30 seconds. d. less than 1 second.	2. glass (or Fiberglas)
4. Cleaning air in reverse air baghouses is usually supplied by a ________ ________.	3. c. 10 to 30 seconds.
5. Reverse air baghouses use large bags whose lengths range from a. 3 to 5 feet. b. 20 to 40 feet. c. 5 to 10 feet. d. 75 to 100 feet.	4. separate fan
6. During reverse air cleaning the flow of dirty air into the compartment is stopped. a. True b. False	5. b. 20 to 40 feet.
7. The bag in a reverse air baghouse usually has rings sewn into the inside of the bag every a. 10 to 15 inches. b. 1 to 2 inches. c. 4 to 6 inches.	6. a. True
	7. c. 4 to 6 inches.

Pulse Jet

The third bag cleaning mechanism most commonly used is the pulse jet or pressure jet cleaning. Baghouses using pulse jet cleaning make up approximately 40 to 50 percent of the new baghouse installations in the U.S. today. The pulse jet cleaning mechanism uses a high pressure jet of air to remove the dust from the bag. Bags in the baghouse compartment are supported internally by rings or cages. Bags are held firmly in place at the top by clasps and have an enclosed bottom (usually a metal cap). Dust-laden gas is filtered through the bag, depositing dust on the **outside surface** of the bag. Pulse jet cleaning is used for cleaning bags in an exterior filtration system.

The dust cake is removed from the bag by a blast of compressed air injected into the top of the bag tube. The blast of high pressure air stops the normal flow of air through the filter. The air blast develops into a standing or shock wave that causes the bag to flex or expand as the shock wave travels down the bag tube. As the bag flexes, the cake fractures and deposited particles are discharged from the bag (Figure 4-7). The shock wave travels down and back up the tube in approximately 0.5 seconds.

The blast of compressed air must be strong enough for the shock wave to travel the length of the bag and shatter or crack the dust cake. Pulse jet units use air supplies from a common header which feeds into a nozzle located above each bag (Figure 4-8). In most baghouse designs, a venturi sealed at the top of each bag is used to create a large enough pulse to travel down and up the bag. This occurs in approximately 0.3 to 0.5 sec. The pressures involved are commonly between 60 and 100 psig (414 kPa and 689 kPa). The importance of the venturi is being questioned by some pulse jet baghouse vendors. Some baghouses operate with only the compressed air manifold above each bag.

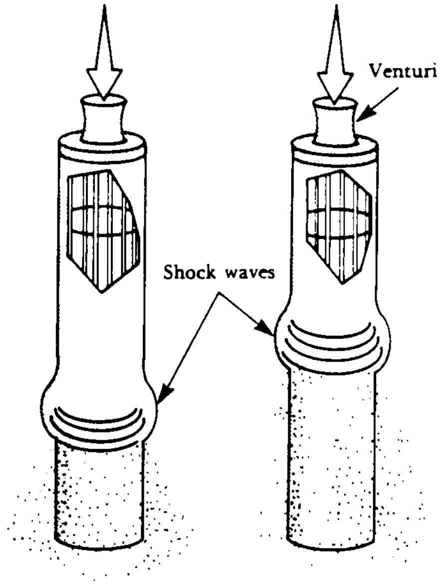

Figure 4-7. Pulse jet cleaning.

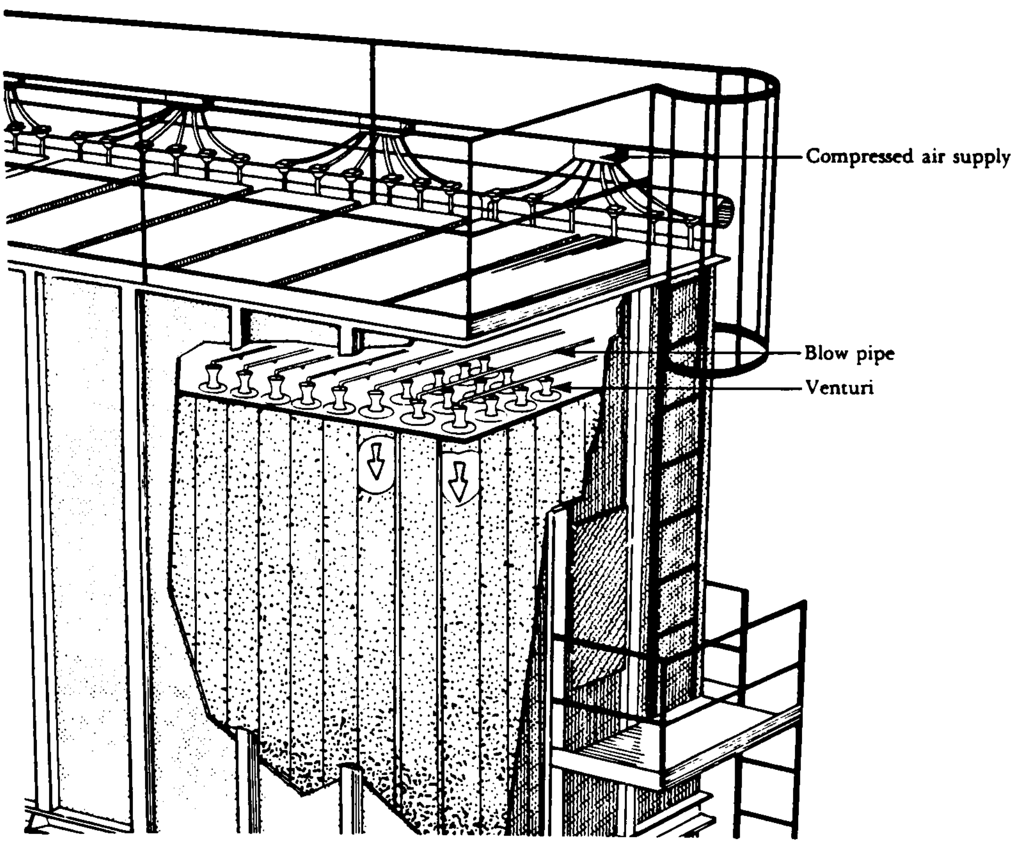

Figure 4-8. Typical pulse jet baghouse with air supply.

Most pulse jet baghouses use bag tubes that are 4 to 6 in. (10.2 to 15.2 cm) in diameter. The length of the bag is usually around 10 to 12 ft (3.05 to 3.66 m), but can be as long as 25 ft (7.6 m). The shaker and reverse air baghouses use larger bags than the pulse jet units. The bags in these units are 6 to 18 in. (15.2 to 45.7 cm) in diameter and up to 40 ft (12.2 m) in length. Typical design parameters for pulse jet cleaning are given in Table 4-3.

Table 4-3. Pulse jet cleaning—parameters.

Frequency	Usually, a row of bags at a time, sequenced one row after another; can sequence such that no adjacent rows clean one after another; initiation of cleaning can be triggered by maximum-pressure-drop switch or may be continuous
Motion	Shock wave passes down bag; bag distends from cage momentarily
Mode	On-stream; in difficult-to-clean applications such as coal fired boilers, off-stream compartment cleaning being studied
Duration	Compressed-air (100 psi) pulse duration 0.1 sec; bag row effectively off-line
Common bag dimensions	5 to 6 inch diameters; 8 to 20 foot lengths

Source: McKenna and Greiner, 1981.

Compartmentalized Pulse Jet Baghouses

Pulse jet baghouses can also be compartmentalized. In this case it is possible to stop the flow of dirty air into the compartment by using poppet valves located in the clean air plenum. Each compartment is equipped with a single pulse valve that supplies compressed air to the group of bags. During the cleaning cycle the poppet valve closes, stopping the air flow through the compartment. The pulse valve opens for about 0.1 sec, supplying a burst of air into the bags for cleaning. The poppet valve then automatically reopens, bringing the compartment back on stream. Alternate compartments are cleaned successively until all the bags in the baghouse have been cleaned (Figure 4-9). The cleaning cycle in each compartment lasts about 4.0 sec.

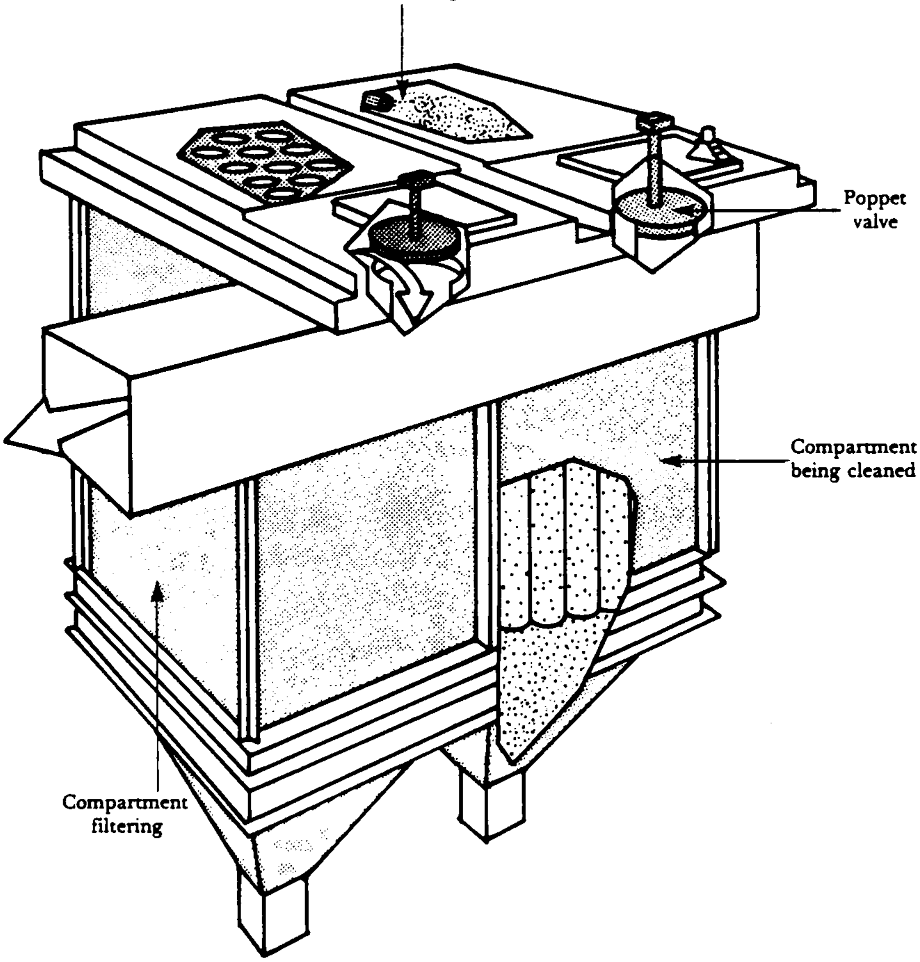

Figure 4-9. Compartmentalized pulse jet baghouse (plenum pulse baghouse).

Review Exercise

1. Pulse jet cleaning is accomplished by a. shaking each bag in the compartment while the damper is closed. b. a blast of compressed air into each bag. c. reversing the flow of air into the baghouse compartment and gently shaking the bags.	
2. In a pulse jet baghouse dust is removed from the _________ of the bag when the bag is cleaned.	1. b. a blast of compressed air into each bag.
3. The dust collects on the outside of the bag, therefore the bag must be supported, usually by a _________ _________.	2. outside
	3. metal cage.

4. The shock wave travels down and then back up the bag tube in approximately a. 1 to 2 minutes. b. 10 to 30 seconds. c. 0.5 seconds.	
5. Pulse jet air is supplied from a common header which feeds into a nozzle located above each bag. a. True b. False	4. c. 0.5 seconds.
6. Pulse jet baghouses use bags that are usually a. 12 to 16 inches in diameter and 20 to 40 feet long. b. 4 to 6 inches in diameter and 10 to 12 feet long. c. 16 to 24 inches in diameter and 15 to 25 feet long.	5. a. True
7. In pulse jet cleaning, the flow of dirty air into the compartment must be stopped before cleaning is initiated. a. True b. False	6. b. 4 to 6 inches in diameter and 10 to 12 feet long.
	7. b. False

Reverse Jet or Blow Ring

Another bag cleaning mechanism is reverse jet cleaning using a blow ring. Some older baghouse designs employed this method, but it has lost popularity due to the great number of moving parts inside the baghouse. Blow ring cleaning involves reversing the air flow on each bag. This cleaning method does not depend on the collapse of each bag to crack the cake as in the reverse air baghouse. A traveling blow ring carriage moves up and down the bag compartment (Figure 4-10). Each ring has a number of slots where high velocity air jets penetrate the bag tube and dislodge the accumulated dust layer (Figure 4-11). The expense and complication of the blow ring mechanism (motors, drives, and switches for both ring and fan) limits the applicability of this equipment for air pollution control.

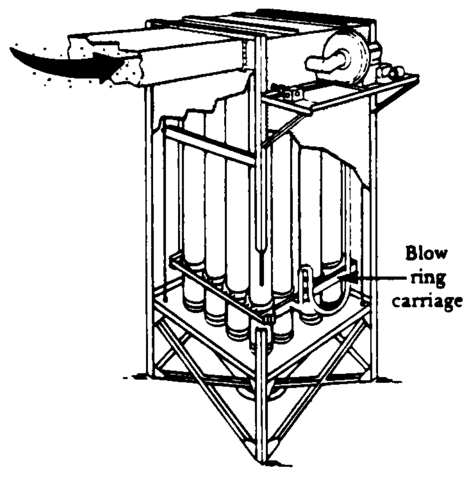

Figure 4-10. Reverse jet cleaning using blow rings.

Bag Cleaning Comparisons

One way to compare bag cleaning mechanisms is by examining air-to-cloth ratios. *Air-to-cloth* (A/C) *ratios* describe how much dirty gas passes through a given surface area of filter in a given time. A high air-to-cloth ratio means a large volume of air passes through the fabric area. A low air-to-cloth ratio means a small volume of air passes through the fabric. The A/C ratios are usually expressed in units of $(ft^3/min)/ft^2$ of cloth [(cm^3/sec)/cm^2 of cloth]. The A/C ratio can be used interchangeably with a term called *filtration velocity*. The units for filtration velocity are ft/min (cm/sec). When using the A/C ratios for comparison purposes one should use the units (ft^3/min)/ft^2 or (cm^3/sec)/cm^2. Likewise, when using filtration velocities one should use the units ft/min or cm/sec. Air-to-cloth ratios are also called gas-to-cloth ratios.

Reverse air cleaning baghouses generally have very low air-to-cloth ratios.

For reverse air baghouses, the filtering velocity (filtration velocity) range is usually between 1 and 4 ft/min (0.51 and 2.04 cm/sec). For shaker baghouses, the filtering velocity ranges between 2 and 6 ft/min (1.02 and 3.05 cm/sec). More cloth is generally needed for a given flow rate in a reverse air baghouse than in a shaker baghouse. Hence, reverse air baghouses tend to be larger in size.

Occasionally, baghouse cleaning is accomplished by two methods in combination. Many baghouses have been designed with both reverse air and gentle shaking to remove the dust cake from the bag.

Pulse jet baghouses are designed with filtering velocities between 5 to 15 ft/min (2.5 to 7.5 cm/sec). Therefore, these units usually use felted fabrics as bag material. Felted material holds up very well under the high filtering rate and vigorous pulse jet cleaning. Pulse jet cleaning methods have the advantage of having no moving parts within the compartment. In addition, pulse jet units can clean bags on a continuous basis without isolating a compartment from service. The duration of the cleaning time is short (< 1.0 sec) when compared to the time length between cleaning intervals (approximately 20 minutes to several hours). The major disadvantage of high pressure cleaning methods is that the bags are subjected to more mechanical stress. Fabrics with higher dimensional stability and high tensile strength are required for these units. Air-to-cloth ratios for the various cleaning methods are given in Table 4-4. Comparisons of the cleaning methods are given in Table 4-5.

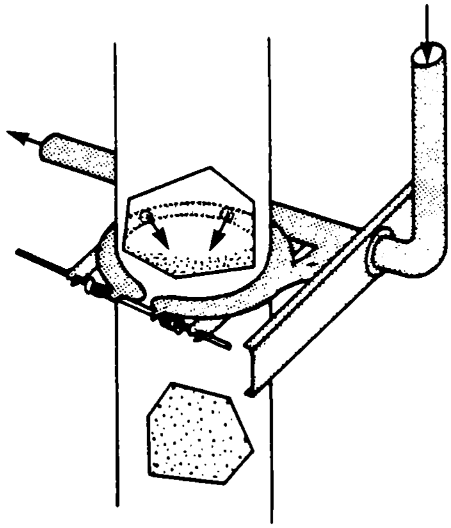

Figure 4-11. Blow ring.

Table 4-4. Air-to-cloth ratio (filtration velocity) comparisons for three cleaning mechanisms.

Cleaning mechanism	Air-to-cloth ratio		Filtration velocity	
	(cm^3/sec)/cm^2	(ft^3/min)/ft^2	cm/sec	ft/min
Shaking	1 to 3:1	2 to 6:1	1 to 3:1	2 to 6
Reverse air	0.5 to 2.0:1	1 to 4:1	0.5 to 2.0:1	1 to 4:1
Pulse jet	2.5 to 7.5:1	5 to 15:1	2.5 to 7.5:1	5 to 15:1

Table 4-5. Comparison of bag cleaning parameters.

Parameter	Shake cleaning	Reverse air cleaning	Pulse jet cleaning
Frequency	Usually several cycles second, adjustable	Cleaned one compartment at a time, sequencing one compartment after another; can be continuous or initiated by a maximum-pressure-drop switch	Usually, a row of bags at a time, sequenced one row after another; can sequence such that no adjacent rows clean one after another; initiation of cleaning can be triggered by maximum-pressure-drop switch or may be continuous
Motion	Simple harmonic or sinusoidal	Gentle collapse of bag (concave inward) upon deflation, slowly repressurize a compartment after completion of a back-flush	Shock wave passes down bag; bag distends from cage momentarily
Peak acceleration	1 to 10 g	–	–
Amplitude	Fraction of an inch to few inches		–
Mode	Off stream	Off-stream	On-stream; in difficult-to-clean applications such as coal fired boilers, off-stream compartment cleaning being studied
Duration	10 to 100 cycles, 30 sec to few minutes	1 to 2 min, including valve opening and closing and dust settling periods, reverse air flow itself normally 10-30 sec	Compressed-air (100 psi) pulse duration 0.1 sec; bag row effectively off-line
Common bag dimensions	5, 8, 12 in. diam; 8 to 10, 22, 30 ft length	8, 12 in. diam; 22, 30, 40 ft length	5 to 6 in. diam; 8 to 20 ft length
Bag tension		50 to 75 lbs typical, optimum varies, adjusted after on-stream	–

Source: McKenna and Greiner, 1981

Review Exercise

1. Reverse jet or blow ring cleaning involves reversing the air flow on each bag. a. True b. False	
2. In reverse jet or blow ring cleaning a. air jets enter the top of the bag fracturing the dust cake. b. the air flow into the entire baghouse compartment is reversed causing bags to deflate. c. high velocity air jets penetrate the bag tube and dislodge the accumulated dust layer.	1. a. True
3. Air-to-cloth ratios a. describe how much dirty gas passes through a given surface area of filter in a given time. b. describe how efficiently bags are cleaned by a pulse of reverse air. c. indicate how fast the dirty air passes through a square foot of cloth material.	2. c. high velocity air jets penetrate the bag tube and dislodge the accumulated dust layer.
4. The air-to-cloth ratio is frequently used interchangeably with a term called filtration velocity. a. True b. False	3. a. describe how much dirty gas passes through a given surface area of filter in a given time.
5. Air-to-cloth ratios are usually expressed in units of a. ft^2/min. b. $(ft^3/min)/ft^2$. c. $(ft/min)/ft^2$.	4. a. True
6. A high air-to-cloth ratio means that a ________ volume of air passes through the fabric.	5. b. $(ft^3/min)/ft^2$.
7. The baghouses that usually have the highest air-to-cloth ratios are a. pulse jet. b. reverse air. c. shaker.	6. large
	7. a. pulse jet.

Lesson 5

Baghouse Design Variables

Lesson Goal and Objectives

Goal

To familiarize you with the variables used by vendors to design baghouse systems.

Objectives

At the end of the lesson you should be able to:

1. define pressure drop and recognize the equations used to calculate pressure drop.
2. define filter drag.
3. define the terms air-to-cloth ratio and filtration velocity, and recall the typical air-to-cloth ratios for various baghouse designs.

Introduction

Baghouses are designed by considering a number of variables: *pressure drop, filter drag, air-to-cloth ratio,* and *collection efficiency*. Although not always possible or practical, it is a good idea to use a pilot scale baghouse during the initial stages of the baghouse design. However, previous vendor experience with the same or similar process to be controlled will generally be adequate for design purposes. Careful design will reduce the number of baghouse operating problems and possible air pollution violations.

Pressure Drop

Pressure drop (Δp), a very important baghouse design variable, describes the resistance to air flow across the baghouse. Pressure drop is usually expressed in mm of mercury or inches of water. The pressure drop of a system (baghouse) is determined by measuring the difference in total pressure at two points, usually the inlet and outlet. It can be related to the size of the fan that would be necessary to either push or pull the exhaust gas through the baghouse. A baghouse with a high pressure drop would need a larger fan and more energy to move the exhaust gas through the baghouse.

Many different relationships have been used to estimate the pressure drop across a fabric filter. In a baghouse the total pressure drop is a function of the pressure drop across both the filter and the deposited dust cake. Some minor pressure losses due to friction also occur as the gas stream moves through the baghouse.

The simplest equation used to predict pressure drop across a *filter* is derived from Darcy's law governing the flow of fluids through porous materials and given as:

(Eq. 5-1) $$\Delta p_f = k_1 v_f$$

Where: Δp_f = pressure drop across the clean fabric, in. H_2O (cm H_2O)
k_1 = fabric resistance, in. H_2O/(ft/min) [cm H_2O/(cm/sec)]
v_f = filtration velocity, ft/min (cm/sec)

Pressure drop across the filter:
$\Delta p_f = k_1 v_f$

The term k_1 is the fabric resistance and is a function of exhaust gas viscosity and filter characteristics such as thickness and porosity. Porosity describes the amount of void volume in the filter.

The pressure drop across the ***deposited dust cake*** can be estimated by using Equation 5-2 (Snyder and Pring, 1955). This formula is also derived from Darcy's law and the simplified form is given as:

(Eq. 5-2) $$\Delta p_c = k_2 c_i v_f^2 t$$

Where: Δp_c = pressure drop across the cake, in. H_2O (cm H_2O)
k_2 = resistance of the cake, in. H_2O/(lb/ft^2•ft/min) [cm H_2O/(g/cm^2•cm/sec)]
c_i = dust concentration loading, lb/ft^3 (g/cm^3)
v_f = filtration velocity, ft/min (cm/sec)
t = filtration time, min (sec)

Pressure drop across the deposited dust cake:
$\Delta p_c = k_2 c_i v_f^2 t$

The term k_2 is the dust-fabric filter resistance coefficient and is determined experimentally. This coefficient depends on gas viscosity, particle density and dust porosity. The dust porosity is the amount of void volume in the dust cake. The porosity is related to the permeability. Permeability for the fabric only is defined in ASTM standard D737-69 as the volume of air which can be passed through one square foot of filter medium with a pressure drop of no more than 0.5 inches of water. The term k_2 is dependent on the size of particles in the gas stream. If the particles are very small ($< 2\ \mu m$) k_2 is high. If k_2 is high, then the pressure drop will tend to increase and the bags will have to be cleaned more frequently.

Dust-fabric filter resistance coefficient:
k_2

The total pressure drop equals the pressure drop across the filter plus the pressure drop across the cake and is given as:

(Eq. 5-3) $$\Delta p_T = \Delta p_f + \Delta p_c$$

$$\Delta p_T = k_1 v_f + k_2 c_i v_f^2 t$$

Total pressure drop across a shaker or reverse air baghouse:
$\Delta p_T = k_1 v_f + k_2 c_i v_f^2 t$

Equation 5-3 should be used as only an estimate of pressure drop across shaker and reverse air cleaning baghouses. In the industrial filtration process, complicated particle-fabric interactions are occurring just after the filtration cycle begins. In addition, the filter resistance factor k_1 can take on two values; one value for the clean filter and another after the filter has been cleaned. When the dust cake builds up to a significant thickness the pressure drop will become exceedingly high (>10 in. H_2O or 30.5 cm H_2O). At this time the filter must be cleaned. Some dust will remain on the cloth even after cleaning; therefore, the filter resistance level will be higher than during original conditions. A baghouse is normally operated with a pressure drop across the unit of 3 to 10 in. H_2O or less. Bag cleaning is usually initiated when the pressure drop approaches this point.

Review Exercise

1. The ________ ________ of a system is determined by measuring the difference in total pressure at two points.	
2. Compared to a baghouse with a high pressure drop, a baghouse with a **low** pressure drop would need a **large** fan and require **more** energy to move the gas through the baghouse. a. True b. False	1. pressure drop
3. What is the formula used to estimate the pressure drop across the clean fabric? a. $\Delta p_f = k_1 v_f$ b. $\Delta p_c = k_2 v_f$ c. $\Delta p_f = v_c^2 c_i t$	2. b. False
4. In the formula, $\Delta p_c = k_2 c_i v_f^2 t$, used to estimate the Δp across the dust cake, the term k_2 is the dust-fabric filter resistance coefficient. If the dust particles are very small ($< 2\ \mu m$), k_2 is large. In this case, the pressure drop will a. generally decrease. b. generally increase. c. stay the same.	3. a. $\Delta p_f = k_1 v_f$
	4. b. generally increase.

5. A baghouse is normally operated with a pressure drop
   a. between 15 and 20 in. H_2O.
   b. greater than 20 in. H_2O.
   c. of approximately 3 to 10 in. H_2O.

5. c. of approximately 3 to 10 in. H_2O.

Filter Drag

Filter drag is the filter resistance across the fabric-dust layer. The equation for filter drag essentially gives the pressure drop occurring per unit velocity. It is a function of the quantity of dust accumulated on the fabric and given as:

(Eq. 5-4) $$S = \frac{\Delta p}{v_f}$$

Filter drag: $S = \frac{\Delta p}{v_f}$

Where: S = filter drag, in. H_2O/(ft/min) [cm H_2O/(cm/sec)]
Δp = pressure drop across the fabric and dust cake, in. H_2O (cm H_2O)
v_f = filtration velocity, ft/min (cm/sec)

As previously mentioned, the true filtering surface of a woven filter is not the bag itself, but the dust layer. Dust bridges the pores or openings in the weave, increasing the drag rapidly.

Single Bag

A filter performance curve of a single bag of a fabric is shown in Figure 5-1. The drag is plotted versus the dust mass deposited on the filter.

The point c_r on the graph is the residual drag of the clean filter medium. The filter drag increases exponentially up to a constant rate of increase. This is the period of cake repair and initial cake buildup. Effective filtration takes place while the filter drag increases at a constant rate. When the total pressure drop reaches a value set by the system design, bag cleaning is initiated. At this point, the pressure drop decreases (almost vertically on the performance curve) to the initial point. Cake repair begins when the cleaning cycle stops and the cycle repeats. Baghouses are designed to remove most of the dust cake during the cleaning process. However, shaking or reverse air baghouses are designed so that during the cleaning cycle some dust will remain on the bags. Therefore, a dust layer will not have to be built up again on the openings in the weave of

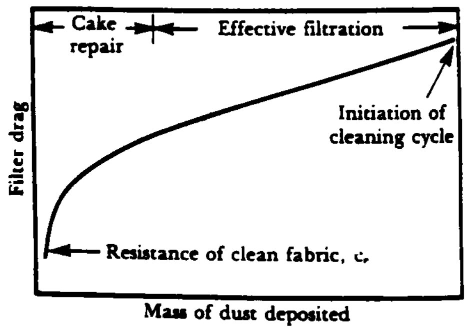

Figure 5-1. Performance curve for a single woven bag.

the fabric. If the fabric is cleaned too efficiently, the cake repair cycle would be as long as the initial cake buildup, lessening the overall effective filtration time of the baghouse.

Multicompartment Baghouse

In multicompartment baghouses where the various compartments are cleaned one at a time, the performance curve takes on a different shape. In this case the change in the curve is less pronounced than in Figure 5-1. The performance curve has a slight saw tooth shape for the net pressure drop across the entire baghouse (Figure 5-2). Each of the minima points on the curve represents the cleaning of an entire compartment. The average pressure drop would be represented by the dotted line. For optimum filtration rate and collection efficiency, the baghouse should be designed to operate at a pressure drop that approaches a constant value. This involves careful selection of fabrics and cleaning mechanisms for the baghouse. The weave, and any pretreatment of the fabric can affect the cake repair time. Poor cleaning will increase the filter drag; therefore, it is essential to thoroughly clean the bags to reduce the filter drag effect. If cake repair time can be minimized, the pressure drop will be lower. Consequently, the effective filtration rate will be longer for optimum filtering use.

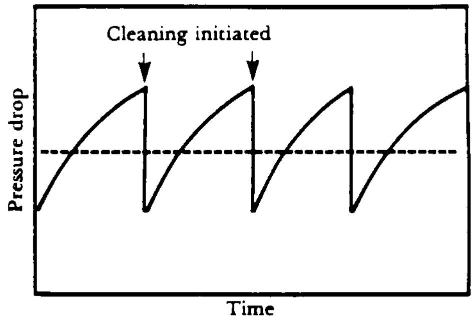

Figure 5-2. Overall pressure drop of a multicompartment baghouse.

Pulse Jet Baghouse

In a pulse jet baghouse, felted filters are usually used as bag material. Since there are no openings in the fabric material, there is no initial cake buildup period. Effective filtration begins immediately as the dust is filtered by the bag. The performance curve of a pulse jet bag (or row of bags) is given in Figure 5-3. The pressure drop across the bags is slightly higher than with woven filters. The baghouse is usually operated with pressure drops of 5 to 9 in. H_2O. In a pulse jet baghouse one row of bags is cleaned at a time. Some of the dust is knocked off the bags being cleaned while adjacent rows are still filtering. Bag cleaning cycles are initiated to keep the overall pressure drop across the baghouse within the designed range.

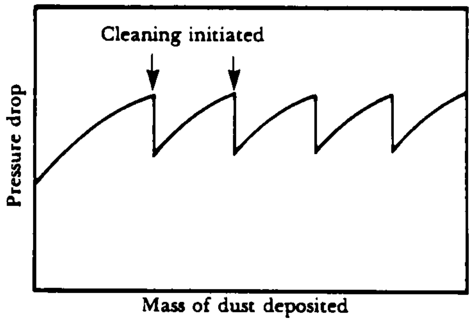

Figure 5-3. Performance curve of a pulse jet bag or a row of bags.

Review Exercise

1. The filter resistance across a fabric-dust layer is called ________ ________.	
2. In a shaker baghouse using woven filters, effective filtration begins as soon as the baghouse is turned on. a. True b. False	1. filter drag.
3. In a reverse air or shaker baghouse, bags are cleaned a. to remove all dust completely. b. to leave a small amount of dust on the bag. c. to leave approximately 60% of the dust cake on the bag.	2. b. False
4. The pressure drop across a pulse jet baghouse is generally higher than across a reverse air baghouse. a. True b. False	3. b. to leave a small amount of dust on the bag.
	4. a. True

Filtration Velocity: Air-to-Cloth Ratio

The terms filtration velocity and air-to-cloth ratio can be used interchangeably. The formula used to express filtration velocity is:

(Eq. 5-5)
$$v_f = \frac{Q}{A_c}$$

Where: v_f = filtration velocity, ft/min (cm/sec)
Q = volumetric air flow rate, ft^3/min (cm^3/sec)
A_c = area of cloth filter, ft^2 (cm^2)

Filtration velocity: $v_f = \frac{Q}{A_c}$

Air-to-cloth ratio is defined as the ratio of gas filtered in cubic feet per minute (cfm) to the area of filtering media in square feet. Typical units used to express the A/C ratio are:

$$(ft^3/min)/ft^2 \text{ or } (cm^3/sec)/cm^2$$

These A/C ratio units essentially reduce to velocity units.

The A/C ratio (filtration velocity) varies for various baghouse designs (Table 5-1). Shaker and reverse air baghouses generally have small A/C ratios. (Shaker units <3:1 (cm^3/sec)/cm^2 and reverse air units <2.0:1 (cm^3/sec)/cm^2). On the other hand, pulse jet units usually operate at A/C ratios between 2.5 and

Table 5-1. Air-to-cloth ratios for three cleaning mechanisms.

Cleaning mechanism	Air-to-cloth ratio	
	(cm^3/sec)/cm^2	(ft^3/min)/ft^2
Shaker	<3:1	< 6:1
Reverse air	<2:1	< 4:1
Pulse jet	2.5 to 7.5:1	<15:1

7.5:1 $(cm^3/sec)/cm^2$ For a given flow rate, pulse jet units can be smaller in size (fewer bags) than the shaker and reverse air baghouse.

The A/C ratio (filtering velocity) is a very important factor used in the design and operation of a baghouse. Improper ratios can contribute to inefficient operation of the baghouse. Operating at an A/C ratio that is too high may lead to a number of problems. Very high ratios can cause compaction of dust on the bag resulting in excessive pressure drops. In addition, breakdown of the dust cake could also occur which in turn results in reduced collection efficiency. The major problem of a baghouse using a very low A/C ratio, is that the baghouse will be larger in size.

Collection Efficiency

Extremely small particles can be efficiently collected in a baghouse. Baghouse units designed with collection efficiencies of 99.99% are common. Exhaust air from baghouses can even be recirculated back into the plant for heating purposes, as long as the gas stream is not toxic.

Baghouses are not normally designed with the use of fractional efficiency curves as are some of the other particulate emission control devices. Vendors design and size the units strictly on experience. The baghouse units are designed to meet particulate emission outlet loading and opacity regulations. There is no one formula that can determine the collection efficiency of a specific baghouse. Some theoretical formulas for determining collection efficiency have been suggested, but these formulas contain numerous (3 to 4) experimentally determined coefficients in the equations. Therefore, these efficiency equations give at best only an estimate of baghouse performance.

Review Exercise

1. The terms filtration velocity, v_f, and air-to-cloth ratio can be used interchangeably. a. True b. False	
2. Air-to-cloth ratio is defined as the ratio of gas filtered in ________ to the ________ of ________ ________ in square feet (ft^2).	1. a. True
	2. cfm area filter media

3. The air-to-cloth ratios for shaker baghouses are typically less than ________ $(cm^3/sec)/cm^2$.	
4. What are the usual air-to-cloth ratios for reverse air baghouses? a. less than 4:1 $(ft^3/min)/ft^2$ b. greater than 5:1 $(ft^3/min)/ft^2$ c. between 3:1 and 8:1 $(ft^3/min)/ft^2$	3. 3:1
5. The air-to-cloth ratios for pulse jet baghouses are usually **less than** reverse air and shaker baghouses. a. True b. False	4. a. less than 4:1 $(ft^3/min)/ft^2$
6. For a given exhaust flow rate, pulse jet baghouses are usually smaller than reverse air baghouses. a. True b. False	5. b. False
7. Operating the baghouse at air-to-cloth ratios greater/less than the designed values can cause problems in the baghouse.	6. a. True
	7. greater

Lesson 6

Baghouse Design Review

Lesson Goal and Objectives

Goal

To familiarize you with the factors to be considered when reviewing baghouse design plans for the permit process.

Objectives

At the end of the lesson you should be able to:

1. recall at least four factors important in good baghouse design.
2. estimate the cloth area needed for a given gas process flow rate.

Introduction

The design of an industrial baghouse involves consideration of many factors including space restriction, cleaning method, fabric construction, fiber, air-to-cloth ratio; and many construction details such as inlet location, hopper design and dust discharge devices. Air pollution control agency personnel who review baghouse design plans should consider these factors during the review process.

A given process might often dictate a specified type of baghouse for particulate emission control. The manufacturers' previous experience with a particular industry is sometimes the key factor. For example, a pulse jet baghouse with its higher filter rates would take up less space and would be easier to maintain than a shaker or reverse air baghouse. But if the baghouse was to be used in a high temperature application (500°F or 260°C), a reverse air cleaning baghouse with woven Fiberglas bags might be chosen. This would prevent the need of exhaust gas cooling for the use of Nomex felt bags (on the pulse jet unit) which are more expensive than Fiberglas bags. All design factors must be weighed carefully in choosing the most appropriate baghouse design.

Review of Design Criteria

The principal design criterion is the gas flow rate to the baghouse, measured in cubic meters (cubic feet) per minute. The gas volume to be treated is set by the process exhaust, but the filtration velocity or air-to-cloth ratio is determined by the baghouse vendor's design. The air-to-cloth ratio depends on a number of variables. Figure 6-1 depicts a number of these design variables. A thorough review of baghouse design plans should consider the following factors.

Physical and chemical properties:

type, shape, and density of dust; average and maximum concentrations; chemical properties such as abrasiveness, explosiveness, electrostatic charge and agglomerating tendencies. These are important for selecting the fabric that will be used. For example, abrasive dusts will deteriorate fabrics such as cotton or glass very quickly. If the dust has an electrostatic charge, the fabric choice must be compatible to provide maximum particle collection yet still be able to clean the bags without damaging them.

Gas flow rate:

average and maximum flow rate, temperature, moisture content, chemical properties such as dew point, corrosiveness and combustibility. If the baghouse is going to be installed on an existing source, a stack test should be performed to determine the process gas stream properties. If the baghouse is being installed on a new source, data from a similar plant or operation may be used, but the baghouse should be designed conservatively. Once the gas stream properties are known, the designers will be able to determine if the baghouse will require extras such as shell insulation, special bag treatment, or corrosion-proof coatings on structural components.

Fabric construction:

woven or felt filters, filter thickness, fiber size, fiber density, filter treatments such as napping, resin and heat setting, and special coatings. Once dust and gas stream properties have been determined, filter choice and special treatment of the filter can be properly made. For example, if the process exhaust from a coal fired boiler is 400°F (204°C), with a fairly high sulfur oxide concentration, the best choice might be to go with woven glass bags that are coated with silicon graphite.

Fiber type:

natural, synthetic, Nomex, Teflon, etc. The design should include a fiber choice dictated by any gas stream properties that would limit the life of the bag. (See Lesson 3 for typical fabrics and fibers used for bags).

Proper air-to-cloth (A/C) ratio:
reverse air lowest, shakers next, pulse jet baghouses allow the highest A/C ratio.

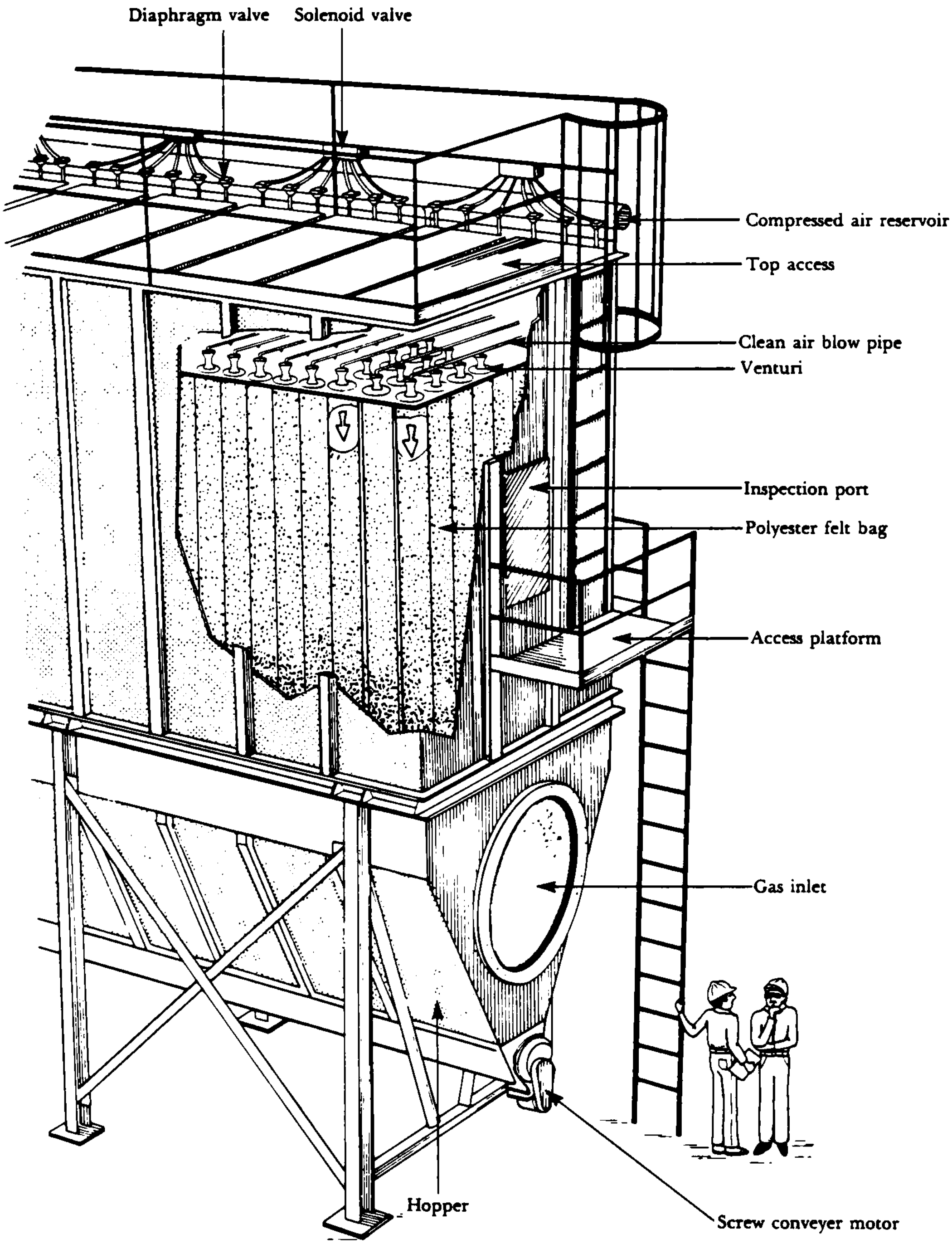

Figure 6-1. Design considerations for a pulse jet baghouse.

Cleaning methods:
low energy which are shaker and reverse air cleaning; high energy which is pulse jet cleaning. The cost of the bag, filter construction, and the normal operating pressure drop across the baghouse help dictate which cleaning method is most appropriate.

Cleaning time:
ratio of filtering time to cleaning time is the measure of the percent of time the filters are performing; this should be at least 10:1 or greater. For example, if the bags need shaking for 2 minutes every 15 minutes they were on-line, the baghouse should be enlarged to handle this heavy dust concentration from the process.

Cleaning and filtering stress:
amount of flexing and creasing to the fabric; reverse air is the gentlest, shaking and pulse jet have the most vigorous stress on the fabric. For example, it would probably not be advisable to use woven glass bags on a shaker or pulse jet baghouse. These bags would normally not last very long due to the great stress on them during the cleaning cycle. However, some heavy woven glass bags (16 to 17 oz) are being used on pulse jet units and shaker units.

Bag spacing:
bags must be properly spaced to eliminate rubbing against each other; bags must be accessible for inspection and maintenance service. The design should include access ladders, walkways, and doors to get at bags for periodic inspection and replacing.

Compartment design:
allowance for proper cleaning of bags; design should include an extra compartment to allow for reserve capacity and inspection and maintenance of broken bags. Shaker and reverse air cleaning baghouses that are used in continuous operation require an extra compartment for cleaning bags while the other compartments are still on-line filtering.

Space and cost requirements:
baghouses require a good deal of installation space; initial costs, and operating and maintenance costs can be high. Bag replacement will average between 25 and 50% of the original number installed per year. This can be very expensive if the bags are made of Teflon which are approximately $100 for a 5-inch, 9-foot long bag.

Emission requirements:
efficiency in terms of opacity and grain-loading regulations. Baghouses are very efficient, collection efficiency is usually greater than $99^{+}\%$.

Typical Air-to-Cloth Ratios

During a permit review for baghouse installations the reviewer should check the A/C ratio. Typical A/C ratios for shakers, reverse air and pulse jet baghouses are listed in Table 6-1.

Baghouses should be operated within a reasonable design A/C ratio range. For example, assume a permit was submitted indicating the use of a reverse air cleaning baghouse using woven Fiberglas bags for reducing particulate emissions from a small foundry furnace. If the information supplied indicated that the baghouse would operate with an A/C ratio of 6 $(cm^3/sec)/cm^2$ [12 $(ft^3/min)/ft^2$] of fabric material, one should question this information. Reverse air units should be operated with a much lower A/C ratio. The fabric would probably not be able to withstand the stress from such high filtering rates and could cause premature bag deterioration. Too high an A/C ratio results in excessive pressure drops, reduced collection efficiency, blinding, and rapid wear. In this case a better design might include reducing the A/C ratio within the acceptable range, thus adding more bags. Another alternative would be to use a pulse jet baghouse with the original design A/C ratio of 6 $(cm^3/sec)/cm^2$ [12 $(ft^3/min)/ft^2$] and use felted bags made of Nomex fibers. However, Nomex is not very resistant to acid attack and should not be used where a high concentration of SO_2 or acids are in the exhaust gas. Either alternative would be more acceptable to the original permit submission.

Typical air-to-cloth ratios for baghouses used in industrial processes are listed in Tables 6-2 and 6-3. These values should be used as a **rule of thumb** or **guide only**. Actual design values may need to be reduced if the dust loading is high or the particle size is small. When compartmental baghouses are used, the design A/C ratio must be based upon having enough filter cloth available for filtering while one or two compartments are off-stream for cleaning.

Table 6-1. Typical air-to-cloth ratios.

Baghouse cleaning method	Air-to-cloth ratios	
Shaking	1-3 $(cm^3/sec)/cm^2$	2-6 $(ft^3/min)/ft^2$
Reverse air	0.5-2.0 $(cm^3/sec)/cm^2$	1-4 $(ft^3/min)/ft^2$
Pulse jet	2.5-7.5 $(cm^3/sec)/cm^2$	5-15 $(ft^3/min)/ft^2$

Note: Air-to-cloth ratios are occasionally given as 2.0:1 instead of 2.0 $(cm^3/sec)/cm^2$

Table 6-2. Typical A/C ratios [(ft³/min)/ft²] for selected industries*.

Industry	Fabric filter air-to-cloth ratio		
	Reverse air	Pulse jet	Mechanical shaker
Basic oxygen furnaces	1.5-2.0	6-8	2.5-3.0
Brick manufacturing	1.5-2.0	9-10	2.5-3.2
Castable refractories	1.5-2.0	8-10	2.5-3.0
Clay refractories	1.5-2.0	8-10	2.5-3.2
Coal fired boilers			
Conical incinerators			
Cotton ginning			
Detergent manufacturing	1.2-1.5	5-6	2.0-2.5
Electric arc furnaces	1.5-2.0	6-8	2.5-3.0
Feed mills		10-15	3.5-5.0
Ferroalloy plants	2.0	9	2.0
Glass manufacturing	1.5		
Grey iron foundries	1.5-2.0	7-8	2.5-3.0
Iron and steel (sintering)	1.5-2.0	7-8	2.5-3.0
Kraft recovery furnaces			
Lime kilns	1.5-2.0	8-9	2.5-3.0
Municipal incinerators			
Petroleum catalytic cracking			
Phosphate fertilizer	1.8-2.0	8-9	3.0-3.5
Phosphate rock crushing		5-10	3.0-3.5
Polyvinyl chloride production		7	
Portland cement	1.2-1.5	7-10	2.0-3.0
Pulp and paper (fluidized bed reactor)			
Secondary aluminum smelters		6-8	2.0
Secondary copper smelters		6-8	
Sewage sludge incinerators			
Surface coatings spray booth			

*High efficiency a sufficiently low grain loading to expect a clear stack.

Source EPA 1976 EPA 450 3-76-014.

Table 6-3. Typical A/C ratios for fabric filters used for control of particulate emissions from industrial boilers.

Size of boiler (10^3 lb steam per hour)	Temperature (°F)	Air-to-cloth ratio [(ft³/min)/ft²]	Cleaning mechanism	Fabric material
260 (3 boilers)	400°	4.4:1	On- or off-line pulse or reverse air	Glass with 10% Teflon coating (24 oz/yd²)
170 (5 boilers)	500°	4.5:1	Reverse air with pulse jet assist	Glass with 10% Teflon coating
140 (2 boilers)	360°	2.0:1	Reverse air	No 0004 Fiberglas with silicone-graphite-Teflon finish
250	338°	2.3:1	Shake and deflate	Woven Fiberglas with silicone-graphite finish
200 (3 boilers)	300°	3.6:1	Shake and deflate	Woven Fiberglas with silicone-graphite finish
400 (2 boilers)	Stoker. 285° to 300°: pulverized coal. 350°	2.5:1	Reverse air	Glass with Teflon finish
75	150°	2.8:1	Reverse air	Fiberglas with Teflon coating
50	350°	3.0:1	On-line pulse	Glass with Teflon finish
270 (2 boilers)	330°	3.7:1	On-line pulse	Teflon felt (23 oz)
450 (4 boilers)	330°	3.7:1	On-line pulse	Teflon felt (23 oz)
380	NA	2.0:1	Reverse air vibrator assist	Glass with 10% Teflon coating
645	NA	2.0:1	Reverse air vibrator assist	Glass with 10% Teflon coating
1440 (3 boilers)	360°	3.4:1	Shake and deflate	Woven Fiberglas with silicone-graphite finish

Source: EPA, 1979

Simple Cloth Size Check

Baghouse sizing is done by the manufacturer. A simple check or estimate of the amount of baghouse cloth needed for a given process flow rate can be computed by using Equation 6-1.

(Eq. 6-1) $$v_f = \frac{Q}{A_c} \text{ or } A_c = \frac{Q}{v_f}$$

Where: A_c = cloth area
Q = process exhaust rate
v_f = filtration velocity

For example, the process gas exhaust rate is given as 4.72×10^6 cm^3/sec (10,000 ft^3/min) and the filtration velocity is 4 cm/sec (A/C is 4:1 $(cm^3/sec)/cm_2$). Calculate the cloth area.

Example:

$$A_c = \frac{4.72 \times 10^6 \text{ cm}^3/\text{sec}}{4 \text{ cm/sec}}$$

$= 1,179,875$ cm^2 (cloth required)
$= 117.98$ m^2 (cloth required)

To determine the number of bags required in the baghouse, one would simply use the formula:

$$A_b = \pi dh$$

Where: A_b = area of bag, m (ft)
$\pi = 3.14$
d = bag diameter, m (ft)
h = bag height, m (ft)

The bag diameter is 0.203 m (8 in.) and bag height is 3.66 m (12 ft). Calculate the area of each bag.

$A_b = 3.14 \times 0.203 \text{ m} \times 3.66 \text{ m}$
$= 2.33$ m^2

Calculate the number of bags in the baghouse.

$$\text{Number of bags} = \frac{117.98 \text{ m}^2}{2.33}$$

$= 51$ bags

A very important point to remember is that the bag length may not be exactly that given in the published specifications. For example, most 12-inch diameter bags are 11 5/8 inches in diameter. The effective filtering area should be calculated using the exact bag dimensions.

Review Exercise

1. From the baghouses listed below, which would take up less space and be easier to maintain because of high filter rates?
   a. Shaker
   b. Pulse jet
   c. Reverse air

2. The principal design criterion to consider is the:
   a. bag length.
   b. access to bag compartments.
   c. gas flow rate.
   d. bag diameter.

1. b. Pulse jet

3. Gas and dust stream properties influence filter choice.
   a. True
   b. False

2. c. gas flow rate.

4. An appropriate ratio of filtering time to cleaning time should be at least:
   a. 3:1.
   b. 1.5:1.
   c. 5:1.
   d. 10:1.

3. True

5. An air-to-cloth ratio that is too high results in reduced pressure drops.
   a. True
   b. False

4. d. 10:1.

6. Nomex is not very resistant to:
   a. H_2O.
   b. CO_2.
   c. SO_2.
   d. lead.

5. b. False

7. Calculate the area of a bag (A_b) given a bag diameter of 15 inches and a bag height of 20 feet.
   a. 942 feet
   b. 70.5 inches
   c. 78.5 feet
   d. 25 feet

6. c. SO_2.

8. If the cloth area (A_c) is known to be 4050 ft², how many bags would be used in a baghouse with the bag area (A_b) given above?
   a. 52 bags
   b. 519 bags
   c. 120 bags
   d. 10 bags

7. c. 78.5 feet

$$\frac{15}{12} \times 20 \times 3.14 = 78.5$$

8. a. 52 bags

$$4050 \div 78.5 = 52$$

Lesson 7

Baghouse Operation and Maintenance

Lesson Goal and Objectives

Goal

To familiarize you with typical baghouse operation and maintenance problems.

Objectives

At the end of the lesson you should be able to:

1. recall typical steps for baghouse inspection prior to starting up.
2. recall typical factors to examine while operating the baghouse.
3. recall typical maintenance steps for proper operation of the baghouse.

Use of the Slide/Tape

This presentation will preview the major topics on baghouse operation and maintenance presented in the text. You do not need to follow the script as you view the slides; however, you can use it to review the content.* The audiotape is designed to automatically advance the slides at the correct place in the script if your tape recorder has a mechanism for synchronizing audiotape and slides. To use the slides and tape together, advance the slides to slide 7-1-1, a focusing slide. Focus this slide and start the tape. The tape recorder will advance the slides for you.

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*The script is included in the appendix.

Suggested Readings

McKenna, J. D. and Greiner, G. P. 1981. "Baghouses". *Air Pollution Control Equipment—Selection, Design, Operation and Maintenance*. Ed. by Theodore, L. and Buonicore, A. J. Englewood Cliffs, N.J.: Prentice Hall, Inc.

Reigel, S. A. and Applewhite, G. D. 1980. "Operation and Maintenance of Fabric Filter Systems". *Operation and Maintenance for Air Particulate Control Equipment*. Ed. by Young, R. A. and Cross, F. L. Ann Arbor, MI: Ann Arbor Science.

Baghouse Capacity

Baghouses can be grouped not only by the method used to clean them, but also by the capacity of exhaust volume they can handle. The three capacity ranges are *low, medium,* and *high*. Low capacity baghouses are small off-the-shelf units that normally handle 100 to 3000 cfm exhaust volume. These units are prebagged and require little or no field assembly. Cleaning methods used are pulse jet (cartridge) or shaking.

Medium capacity units handle from approximately 3000 to less than 100,000 cfm exhaust volume. These units are generally prebagged and require little field assembly. Most medium capacity baghouses use pulse jet cleaning with high air-to-cloth ratios.

High capacity baghouses handle from 100,000 to 1,000,000 or more cfm exhaust volume. These units are usually field assembled and bagged. Most high capacity baghouses use reverse air or shake cleaning with low air-to-cloth ratios.

Installation

Depending on the baghouse chosen, installation and operation startup may take from a few days to a few months. In any case, proper installation procedures will save time and money and will also help in future operation and maintenance (O&M) of the baghouse.

Good coordination between the baghouse designer and the installation and maintenance personnel will help keep the baghouse running smoothly for years. Occasionally this coordination is overlooked. The baghouse is installed, turned on, and forgotten about until it stops working completely. At this point it may be too late to keep the unit going and the baghouse may have to be rebuilt or even scrapped. Some key features to reevaluate during the installation period are listed here:

Easy access to all potential maintenance areas: fans, motors, conveyors, discharge valves, dampers, pressure and temperature monitors, and bags.

Easy access to all inspection and test areas: stack testing ports and continuous emission monitors (opacity monitors).

Weather conditions: the baghouse must be able to withstand inclement weather such as rain or snow.

ETS Inc., baghouse consultants, have suggested the following features for a properly designed and installed baghouse (McKenna and Greiner, 1982):

1. *Uniform air and dust distribution to all filters.* Duct design, turning vanes, and deflection plates all assist in obtaining this. Often, they arrive loose and are field-installed. If improperly installed, they can induce high airflow regions that will abrade the duct or bag filters or cause reentrainment and induce high-dust-concentration regions that can produce uneven hopper loading and uneven filter bag dust cake.

2. *Total seal of system from dust pickup to stack outlet.* Inleakage at flanges or collector access points either adds additional airflow to be processed or short-circuits the process gases. Inleakage to a high-temperature system is extremely damaging, as it creates cold spots and can lead to dew point excursions and corrosion. If severe, it can cause the entire process gas temperature to pass through the dew point and result in condensate on the bags. Early bag failure and high pressure drop will generally result. The best check for leaks is to inspect the walls from inside the system during daylight. Light penetration from outside isolates the problem areas. It is particularly important to seal the dust discharge points in negative systems. Inleakage here will result in incomplete or no discharge, which can lead to reentrainment problems, yielding high pressure drop and hopper fires.

3. *Effective coatings and paint.* Most systems are painted on the exterior surfaces only. Take extra care to touch up damaged areas with a good primer and if equipment is not delivered finish-painted, apply it as soon as possible following erection. Unprotected primers will soon allow corrosion and require sandblasting plus many dollars to repair. If your system has been *internally* protected with a coating, thoroughly inspect for cracks or chips, particularly in corners, and repair before operating. A poor interior coating can be worse than none at all because it will trap corrosive elements between the coating and the surface it was intended to protect.

4. *Properly installed filter bags.* The filter bags are the heart of any fabric filter collection system. Improper installation can result in early bag failure, loss of cleaning effectiveness, and thus high pressure drop and operating costs or increased stack emission. Each manufacturer provides instructions on the proper filter bag installation and tensioning (where required). These must be explicitly followed. Very often, early bag failures can be traced to improper installation. Remember, it is much easier to check and recheck bag connections, tensioning, locations, and so on, in a clean, cool, dry collector than it will be one day after startup. Bag maintenance usually accounts for 70% of annual maintenance time and money. Extra efforts in this area during installation can have a significant effect.

5. *Proper insulation installation.* High-temperature collector systems require special consideration in order to prevent O&M problems. When handling high-temperature gases, it is important to maintain the temperature of the gas and all collector components coming in contact with it above the gas dew point. Insulation is usually employed. Much of the time, all or a part of the insulation is field-installed. Check to see that all surfaces and areas of potential heat loss are adequately covered. In particular, check to see that field flashing also has insulation beneath it. Cold spots cause local corrosion. Gross heat loss may cause excessive warm-up time or lower the gas temperature below the dew point.

6. *Total seal between dirty side and clean side of collector.* Remember, the primary purpose of the dust collector is to separate the particulate matter from the gas by means of fabric filtration. This means that *all* the gas must pass through the fabric. Any leaks bypassing the fabric filters will directly emit dust to the stack and therefore reduce the collection efficiency of the system. The time to inspect "bypass leaks" is *before* startup, when everything is clean and accessible. The best technique is to utilize a bright light on one side of the plenum and visually observe for light penetration on the other. This is the most effective in total darkness. Take that extra time to check this important area. Tracking down stack emissions not associated with bag failures can be extremely difficult after startup.

7. *Properly installed and operating dampers.* Most systems employ several dampers to isolate areas of the system or control the volume of air flow. Proper alignment is important both in the case of internal blades and the operating linkage. In high-temperature applications, special care must be taken to allow for proper operation and sealing at the operating temperatures. Some dampers may require readjusting after reaching high-temperature operation. In modular systems, single modules are normally isolated for bag cleaning and maintenance. Leakage through these isolation dampers can cause improper bag cleaning. It will also create a very poor ambient condition for

maintenance workers to work in. This, in some applications, can pose a health hazard, and in all applications results in lower-quality workmanship or incomplete maintenance.

8. *Properly operating mechanical components.* Most mechanical components are designed with a normal operating direction. Cylinder rod location, motor rotation, and so on, must be checked. Remember, when hooking up an AC motor, one has a 50% chance of being correct on the first try. Not only will a backward-moving conveyor produce no discharge, but it can pack material so that it bends the screw. Left uncorrected, a reversed screw conveyor will result in a full hopper. The industry abounds with horror stories where full hoppers have led to burned bags, or dust set up, requiring jackhammers to remove it.

9. *Smoothly running fans.* Fans must be checked for proper rotation, drive component alignments, and vibration. Fans should be securely mounted to sufficient mass to eliminate excessive vibration.

10. *Clean, dry compressed air.* Most systems employ compressed air to operate dampers, controls, instruments, and so on. Probably more systems suffer shutdowns and maintenance problems due to poor-quality compressed air than for any other reason. Clean, dry air is necessary to maintain proper operation of the pneumatic components. In installations where the ambient temperature drops below 32°F, a desiccant dryer system is generally employed. Sometimes, insulation of air lines and pneumatic components will be required. Often, these considerations are not included in the dust collector system, with "clean, dry compressed air to be supplied by owner." Remember, the air must be clean and dry when it reaches the pneumatic component.

Each baghouse installation should have its own checklist reflecting the unique construction components of the unit. The installation crew should prepare a checklist before beginning the final inspection and initial startup. ETS, Inc. has suggested one typical inspection and startup checklist as shown in Table 7-1.

Table 7-1. Inspection and startup checklist.

1. Visually inspect:	
Structural connections for tightness	
Duct flanges for proper seal	
Filter bags for proper seating in tube sheet	
Dampers for operation and sequence	
System fan, reverse air fan, and conveyors—check for proper rotation	
Electrical controls for proper operation	
Rotary valves or slide gates for operation	
2. Remove inspection door and check conveyor for loose items or obstructions	
3. Adjust ductwork dampers—open or at proper setting	
4. Remove any temporary baffles	
5. Test horn alarm system, if included, by jumping connected sensors	
6. Start screw conveyors and check for proper operation	
7. Start reverse air fan, if included	
8. Start system fan	
9. Log manometer and temperature (if appropriate) readings at 15-minute intervals; log readings	
10. Check to see that reverse air dampers are cycling	
11. Adjust Δp switch, if included	
12. Determine system air volume and adjust dampers, as required	
13. Check cells for dust leaks	
14. Check to see that dust is being discharged from hopper.	

Source: McKenna and Griener, 1982.

Installation errors can have a disastrous effect on the operation and maintenance of the baghouse. Typical installation errors and their effect on O&M are given in Table 7-2.

Table 7-2. Typical installation errors and their effect on O&M.

Item	Immediate potential effect	Long term
Baffle plates and turning vanes improper installation or left out	Uneven dust distribution; uneven hopper loading; higher pressure loss	Bag wear, duct wear, hopper fires
Poor seal of flanges and access areas	Inleakage resulting in: reduced inlet volume higher fan volume higher operating costs lower baghouse temperature	Localized cold spots resulting in: component corrosion bag degradation
Poor seal at dust discharge flanges	Incomplete discharge, reentrainment; hopper fires	Reentrainment; creeping Δp
Cracked or chipped paint and coatings	Esthetics	Corrosion
Improper bag tensioning	Ineffective cleaning; bag collapse	Bag wear; high Δp
Improper bag seating	Stack emission	Compliance failure; bag wear; high Δp
Incomplete insulation	Cold spots	Corrosion
Seal between dirty and clean air compartments	Stack emission; dirtying of clean side of plenum	Compliance failure
Duct damper alignment	Loss of flow control	Poor maintenance ambient
Screw conveyor direction reversed	No discharge	Bent screw; full hopper; fires
Fan mount	Noise—vibration	Broken components
Fan belt alignment	Noise—improper fan volume	Broken belts
Exposed compressed-air lines without dryer	Freeze-up—condensation	Damaged downstream components
Lack of inspection access	Lack of early warning signs	Major problems
Lack of maintenance access	Lack of regular preventative maintenance	Major breakdowns

Source: McKenna and Greiner, 1982.

Review Exercise

1. Baghouses can be grouped by cleaning method or by
   a. air pollutants for which they are designed.
   b. length of bags.
   c. capacity of exhaust volume handled.
   d. number of bags.

2. Low capacity baghouses are usually field assembled and bagged.
   a. True
   b. False

3. Inleakage at flanges or collector access points can cause __________ on the bags which may result in early __________ __________ and high __________ __________.

Answers:

1. c. capacity of exhaust volume handled.

2. False

3. condensate
   bag failure
   pressure drop

4. A poor interior coating is worse than none at all. a. True b. False	
5. High capacity baghouses (> 100,000 cfm) use reverse air or shake cleaning and are usually field assembled. a. True b. False	4. True
6. Gas streams of high temperature should be maintained above the a. ignition temperature. b. gas dew point. c. concentration limit.	5. True
7. Cold spots in the baghouse can cause a. local corrosion. b. fires. c. explosions.	6. b. gas dew point.
8. Many systems suffer shutdown and maintenance problems due to a. low pressure drop. b. low air-to-cloth ratio. c. low dew point. d. poor-quality compressed air.	7. a. local corrosion.
9. Before the baghouse is started up, the installation crew should prepare and use a ________.	8. d. poor-quality compressed air.
	9. checklist

Operation and Maintenance Training

Before the baghouse is started up the plant engineer should schedule training sessions for all plant employees that operate and maintain the baghouse. In these training sessions the following subjects should be covered: systems design, system controls, critical limits of equipment, function of each baghouse component, operating parameters that should be monitored, good operating practices, preventive maintenance, startup and shutdown procedures, emergency shutdown procedures, and safety considerations.

O&M training sessions should be attended by supervisors, operators, and maintenance people. The training could be provided by the baghouse vendor or by a consulting company specializing in baghouses. The length of training would vary depending on the complexity of the system design. Average training will ordinarily take at least 40 manhours for full-time maintenance people.

Baghouse Startup and Shutdown

A specific startup and shutdown procedure should be supplied by the baghouse vendor. Improper startup and shutdown can damage the equipment. If hot moist gases are to be filtered, the baghouse must be preheated to raise the interior temperature in the baghouse above the dew point in order to prevent condensation and potential corrosion problems. This can be done by using heaters in each compartment or by burning a clean fuel such as natural gas before filtering gases from a coal fired boiler.

The baghouse must also be brought on line slowly to avoid permanent damage to the fabric. Clean filters do not have a protective dust cake on them and are sensitive to dust abrasion and penetration by fine particles. Penetration can lead to permanent residual pressure drop. In some applications, bags are precoated with a protective dust layer prior to bringing the unit on-line. The filter velocity should always be kept low until a sufficient dust cake is built up on the bags. This is indicated by a pressure drop of 1 to 2 inches H_2O. The gas flow can then be slowly increased to the designed rate (McKenna and Greiner, 1982).

Some general rules for routine startup and shutdown suggested by ETS, Inc. are:

Startup

Make sure all collector components are in working order and in proper mode.

Do not allow higher-than-design filtering velocities or air flow.

Avoid passing through (below) the dew point within the baghouse when dirty gases are present. The system should be preheated to above the dew point with clean, hot air before the introduction of flue gas. During normal operation, maintain the temperature above the dew point level.

Operate the bypass system to assure its readiness in an emergency situation.

Check all indicating and monitoring devices for proper operation.

Shutdown

Purge the collector with clean (hot when necessary) dry air before allowing temperature to descend below the dew point. When the collector cools at night it is possible that moisture will condense on the bags once the dew point is reached.

Do not store dust in the collector. Many maintenance workers have resigned after spending a day with pick and shovel inside a dust collector hopper.

Allow bags to clean down after dust flow ends, but do not overclean.

Check to see that all components are in the proper shutdown mode.

Routine Monitoring

The two indicators of the performance of a baghouse are collection efficiency and pressure drop. If the pressure drop is satisfactory, the proper amount of air is moving through the baghouse. If the stack is clean, the baghouse is doing the job it was intended to do. Pressure drop is monitored by using a manometer or magnehelic gage. Recorders can also be used to give permanent pressure drop records. This can be useful for determining maintenance needs and charting tendencies over prolonged time periods. The opacity can be monitored by visual observation or by using continuous monitors. Continuous opacity monitors used in conjunction with a recorder will provide the data necessary for determining collector efficiency for varying process conditions and for monitoring baghouse malfunctions to determine maintenance needs. Typical monitoring devices are listed in Table 7-3.

Table 7-3. Typical baghouse monitoring and indicating devices.

Item	Function
Pilot lights	To show motors operating, compartments on- or off-line, row of bags being pulsed
Opacity monitor	To measure continuous opacity of stack
Manometer or magnehelic gages	To determine pressure drop at various points in the baghouse. Recorders are useful to give permanent pressure drop readings
Temperature indicators	To determine temperature at critical points in the baghouse
Gas flow meters	To measure actual gas flow rate through the baghouse
Fan current, fan bearing temperature and fan vibrator indicators	To identify early warning signs indictating maintenance to the fan

Review Exercise

1. Who should supply a specific startup and shutdown procedure for baghouses? a. The inspection team b. The baghouse vendor c. The process plant owner d. The air pollution agency	
2. Bringing a baghouse on-line quickly helps seal woven bags and prevents damage to the fabric. a. True b. False	1. b. The baghouse vendor
3. To operate properly, bags must be coated sufficiently with a. paint. b. condensate. c. dust. d. all of the above.	2. b. False
4. Before allowing the collector temperature to descend below the dew point, purge it with a. clean dry air. b. cool sprays. c. an alcohol cleaner. d. all of the above.	3. c. dust
5. The two indicators of the performance of a baghouse are __________ __________ and __________ __________.	4. a. clean dry air
6. An opacity monitor is useful to baghouse maintenance because a. inspectors can monitor bag cleaning inside the baghouse. b. inspectors can monitor the process stack gas plume. c. inspectors can monitor operations of motors and on-and off-line compartments.	5. collection efficiency pressure drop
	6. b. inspectors can monitor the process stack gas plume.

Routine Maintenance

Good recordkeeping is the key to an effective maintenance program. The logging of actual inspections, observations of the collector, and preventive maintenance will help determine how the baghouse is operating.

Inspection frequencies of all baghouse components should be established. Vendors' recommendations of an inspection schedule should be followed. A listing of typical periodic maintenance follows.

Daily Maintenance

1. Check pressure drop.
2. Monitor gas flow rate.
3. Observe stack outlet; visually or with a continuous monitor.
4. Monitor cleaning cycle; pilot lights or meters on control panel.
5. Check compressed air on pulse jet baghouses.
6. Monitor discharge system; make sure dust is removed as needed.
7. Walk through baghouse to check for normal or abnormal visual and audible conditions.

Weekly Maintenance

1. Check all moving parts on discharge system; screw-conveyor bearings.
2. Check damper operation; bypass, isolation, etc.
3. Spot check bag tensioning; reverse air and shake bags.
4. Check compressed air lines including line oilers and filters.
5. Blow out manometer lines.
6. Verify temperature-indicating equipment.
7. Check bag-cleaning sequence to see that all valves are seating properly.
8. Check drive components on fan.

Monthly Maintenance

1. Spot check bag-seating condition.
2. Check all moving parts on shaker baghouses.
3. Check fan for corrosion and blade wear.
4. Check all hoses and clamps.
5. Spot check for bag leaks and holes.
6. Inspect baghouse housing for corrosion.

Quarterly Maintenance

1. Thoroughly inspect bags.
2. Check duct for dust buildup.
3. Observe damper valves for proper seating.
4. Check gaskets on all doors.
5. Inspect paint on baghouse.
6. Calibrate opacity monitor.
7. Inspect baffle plate for wear.

Annual Maintenance

1. Check all welds and bolts.
2. Check hopper for wear.
3. Replace high-wear parts on cleaning system.

Sources: Reigel and Applewhite, 1980; McKenna and Greiner, 1981.

Bag Maintenance

Inspecting and changing bags takes a long time and are the highest maintenance costs in a baghouse. Bag failures occur at varying times depending on the operation of the collector. The longer the time before bag changeout, the lower the maintenance cost to the owner. Typical bag life is from two to five years.

Bag failures can be spotted through daily monitoring and inspection. Stack opacity is a good indication of bag failure. If the plume is dirty, then some problem exists, either in a single compartment or throughout the baghouse. In a compartmentalized baghouse it is possible to monitor the stack while isolating a compartment. Stack emissions would be reduced if the compartment with broken bags were taken off-line. In a noncompartmentalized baghouse it may be necessary to check the entire unit for broken bags.

Three ways to search for broken bags are (Reigel and Applewhite, 1980):

1. hunt for the hole.
2. hunt for the accumulation of dust which can be related to a nearby hole.
3. use a detecting device.

In shaker and reverse air baghouses where dust is collected on the inside of the bags, bag failures occur frequently at the bottom of bags. Accumulation of dust on the cell plate is sometimes visible, making it relatively easy to spot the failure. It may be necessary to inspect the entire circumference and length of the bag if the hole is higher up on the bag tube. In reverse air baghouses, other bag failures can also occur near the anti-collapse rings and at the top cuff where the bags were attached. In shaker baghouses, bags tend to fail at the top where they are attached to hooks or clamps.

In pulse jet baghouses it is normally very difficult to locate bags that have failed. However, in many baghouses dust accumulation on the top tube sheet or in the blow pipe above the failed bag will be readily noticeable (Reigel and Applewhite, 1980).

A recent technique for locating torn bags is to use fluorescent powder and a black light. Fluorescent powder is injected in the inlet to the baghouse. An ultraviolet light is used to scan the clean air side of the baghouse. Leaks can be detected by the glow of the powder getting through a torn bag. This technique is useful for spotting broken welds or leaks in the cell plates, tube sheets or housing.

The importance of detecting broken bags depends on the baghouse design. In reverse air and shaker units, leaks in the bags can cause air streams or jets of dust to abrade adjacent bags. This causes what is known as the "domino effect", where one torn bag creates another torn bag. In pulse jet baghouses, torn bags are not as great a problem since the dust leaves the inside (clean side) of the bags. If opacity limits are exceeded, the bag must be changed. It may take several broken bags to cause an opacity violation. Maintenance can then be scheduled for some other convenient time.

In the past, bags were usually replaced as they failed. Recently, however, it has been found that a new bag in the vicinity of old ones will be forced to take on more dust (air will tend to follow the path of least resistance) and will become worn-out quicker than the old "seasoned" bags (Reigel and Applewhite, 1980). It has become accepted practice in reverse air and shaker baghouses to simply tie off a torn bag and stuff it into the cell plate. If the failure is close to the cell plate then the hole should be plugged. This can be accomplished by steel plate plugs with gaskets or sand bags to seal off the hole. In pulse jet baghouses with top access, a plug is placed over the tube sheet hole of the failed bag.

It is most important to keep track of the bag failure rate of individual bags. This can be helpful to correct any conditions that would cause premature bag failure. In addition, it is helpful in scheduling complete changeout of bags at a convenient time.

Troubleshooting

When a baghouse begins to have problems, it is extremely advisable to contact the vendor to identify and correct the problem. A typical troubleshooting guide is listed in Table 7-4. This table was prepared by ETS, Inc. and should be used only as a general guide.

Table 7-4. Troubleshooting guide.

Symptom	Possible cause	Remedy
High collector pressure drop	Malfunction of bag-cleaning system	Check all cleaning-system components
	Ineffective cleaning	Modify cleaning cycle Review with designer
	Reentrainment of dust in collector due to low-density material or inleakage at discharge	Check discharge valves Lower A/C ratio
	Wetting of bags	Control dew point excursions Dry bags with clean air Clean bags with vacuum or wet wash
	Too high A/C ratio either through added capacity or improper original design	Verify gas volume Reduce inlet volume if possible Review with designer
	Change in inlet loading or particle distribution	Test Review with designer
Abnormally low pressure drop	Manometer line(s) plugged	Blow back through lines Protect sensing point from dust or water buildup Incorporate autopurging system in sensing lines
	Manometer line(s) broken or uncoupled	Verify with local manometer Inspect and repair
	Overcleaning of bags	Reduce cleaning energy and/or cycle time
Stack emission	Broken bag	*See* bag maintenance section
	Bag permeability increase	Test bag Check cleaning energy/cycle and reduce if possible
	Clean-to-dirty plenum leakage	Inspect and repair
	Change of inlet conditions	Test and review
Puffing	High pressure drop across baghouse	*See above*
	Low system fan speed	Check drive system Increase speed
	Improper duct balancing	Rebalance system
	Plugged duct lines	Clean out
	Poor hood design	Evaluate temporary modifications and implement
	Improper system fan damper position	Check and adjust
Low dust discharge	Inleakage at discharge points	Inspect and repair seals or valves
	Malfunction of discharge valve, screw conveyor or material transfer equipment	Inspect and repair
	Reentrainment of dust within collector	Lower A/C ratio
	Retainment of dust on filter bags	Increase cleaning
Loud or unusual noises	Vibrations Banging of moving parts Squealing of belt drives	
Corrosion	Improper paint material or application Improper insulation Emission of nearby equipment Dew point excursions Improper shutdowns	

Spare Parts

An inventory of spare parts suggested by the baghouse vendor should be on hand for baghouse maintenance. A typical listing as suggested by Reigel and Applewhite (1980), is given in Table 7-5.

Table 7-5. Suggested spare parts.*

Bags
Bag support cages (pulse jet and plenum pulse)
Bag clamps
Seals and caulking material
Solenoids
Diaphragms
Timer components
Baffle plates or wear plate sections for baffle
Bag connecting rods (shaker and reverse air)
Tensioning springs (reverse air)
Belts for shaker mechanism (shaker)
Motor for shaker mechanism (shaker)
Fan belts
Spare bearings and gasketing for all mechanical components

*Quantities of parts will vary as to manufacturer's suggestion and the type of process.

Review Exercise

1. The longer the time before the bag changeout, the __________ the maintenance cost to the owner.	
2. Bag failure can often be indicated by observing __________ __________.	1. lower
3. Broken bags can be discovered by a. using a detecting device b. visually searching out holes c. looking for an accumulation of dust d. all of the above	2. stack opacity
4. In reverse air baghouses, bag failures occur most frequently a. at the bag bottom and around the anti-collapse rings. b. near the hook. c. along the internal support cage. d. all of the above.	3. d. all of the above
5. In reverse air and shaker baghouse design, the "domino effect" means that one torn bag creates another torn bag. a. True b. False	4. a. at the bag bottom and around the anti-collapse rings.
6. In a pulse jet baghouse, when one bag is torn, the opacity limits are usually exceeded. a. True b. False	5. a. True
	6. b. False

Lesson 8

Industrial Applications of Baghouses

Lesson Goal and Objectives

Goal

To familiarize you with the typical industrial uses and basic cost estimates of baghouses.

Objectives

At the end of the lesson you should be able to:

1. recall four process industries that use baghouses to control particulate emissions.
2. recognize the use of baghouses in industrial and utility applications.
3. recall how to use charts and figures to estimate the cost of baghouses.

Introduction

Fabric filters have been used for particulate emission reduction for many industrial applications. Baghouses have been designed to collect particles in the submicron range with 99.9+% control efficiency. They have occasionally been used to remove particles and then recirculate the clean air back into the plant to help supplement heating needs. Baghouses have been used in the chemical, steel, cement, food, pharmaceutical, metal working, aggregate, and carbon black industries. Shaker, reverse air, and pulse jet baghouses have been used in a number of industrial applications as shown in Table 8-1.

Table 8-1. Typical industrial applications for baghouses.

Shaker	Reverse air	Pulse jet
Screening, crushing, and conveying of rock products Low temperature steel applications Metal working Mining operations Textiles Woodworking processes Chemical industry Food industry Coal fired boilers	Cement kilns Lime kilns Electric steel furnaces Gypsum calcining Ore smelters and roasters Sintering plants Rock dryers Foundries Carbon black Magnesium oxide kilns Coal fired boilers	Pharmaceuticals Food industry Woodworking Sinter plants Metal working Foundries Textiles Chemical industry Coal fired boilers Asphalt batch plants

One recent baghouse application is filtering flyash in both industrial and utility boilers. Here, baghouses are becoming as popular as electrostatic precipitators for removing 99.7 to 99.9⁺% of the particulate matter from the flue gas.

Table 8-2 lists some coal fired boilers that use a baghouse for controlling particulate emissions.

Table 8-2. Selected baghouses used for fly ash control from coal fired boilers.

Plant	Boiler size		Baghouse	Fabric	Temperature (°F)	Air-to-cloth ratio (cfm/ft^2)
	(MW)	(acfm)				
Pennsylvania Power and Light						
Sunbury Station	87	888,000	(4 total) Reverse air	Glass coated with Teflon	325	3.0:1
Holtwood Station		220,000	Combined shake and reverse air	Glass coated with Teflon	350	2.4:1
Brunner Island Station			Reverse air	Glass coated with Teflon		2.0:1
Nebraska Public Power District						
Kramer Station		3@120,000 1@192,000	(4 total) Reverse air	Glass coated with Teflon	325	2.0 to 2.4:1
Southwestern Public Service Company						
Harrington Station	350	1,650,000	Reverse air	Glass coated with silicon/graphite	313	3.2 to 3.3:1

Source: JAPCA, 1979.

Examples of typical baghouse installations are given in Table 8-3. This table lists the industry, exhaust gas temperature, dust concentration, baghouse cleaning method, fabrics, and air-to-cloth ratios. This list is by no means inclusive of the industries using baghouses for controlling particulate emissions. Typical air-to-cloth ratios of shaker, reverse air, and pulse jet baghouses for various industries are also given in Tables 6-2 and 6-3.

Table 8-3. Typical baghouse installations.

Industry	Process dust concentration (gr/ft³)	Baghouse	Fabrics	Temperature (°F)	Air-to-cloth ratio (cfm/ft²)
Aluminum furnaces scrap conveyor	 6 to 20	 Shaker Pulse jet	 Nomex, Orlon Polyester	 250 to 375 100	 2.0 to 2.5:1 7.0 to 8.0:1
Asphalt batch plants		Pulse jet	Nomex	250	4.0 to 6.0:1
Coal fired boilers (1.5% sulfur coal)		Reverse air Pulse jet	Glass Teflon	350 to 450 300 to 450	2.0:1 4.0:1
Coal processing pulverizing mill dryer roller mill crusher		 Pulse jet Pulse jet Pulse jet Pulse jet	 Nomex felt Nomex felt Polyester felt Polypropylene felt	 240 400 225 100	 4 to 6:1 5 to 7:1 6:1 7 to 8:1
Carbon black		Reverse air	Glass-Teflon treated or Teflon		1.5:1
Cement clinker cooler crusher venting kiln	 10 to 12	 Pulse jet Reverse air and shake Reverse air	 Nomex felt Polyester felt, Gore-tex Glass	 400 to 500	 5:1 5:1 2:1
Clay calcining kiln or dryers	25	Pulse jet	Glass felt, Nomex	300 to 400	6:1
Copper smelter	< 2	Shaker	Dacron, Teflon	130	
Cupola furnace (gray iron)	1 to 2	Reverse air shaker	Glass-Teflon treated Nomex	550	1.9:1
Chemical polyvinyl chloride (PVC) spray dryer		Reverse air	Acrylic, Gore-tex	350 to 425	2 to 3.6:1
Food sugar storage bin		Pulse jet	Polyester, Gore-tex		10:1
Ferro alloy plant silicon metal electric arc furnace	< 1.0	Reverse air with shaker assist	Nomex	350	
Foundry sand casting operation	5 to 10	Pulse jet	Polyester felt	275	6 to 7:1
Glass melting furnaces		Reverse air Reverse air and shake	Glass Nomex	400 to 500 375 to 400	< 2:1
Gypsum building materials		Pulse jet	Nomex		
Lead smelting (battery lead)		Pulse jet	Nomex, Teflon	320 to 325	
Lime calcining		Pulse jet	Nomex	280	
Metals lead oxide processing		Shaker	Dacron, Gore-tex		1.5 to 3:1
Municipal incinerators	0.5	Reverse air Pulse jet	Glass Teflon	300° 300°	2:1 4:1
Steel electric arc furnace canopy hood over steel furnace	 0.1 to 0.5 0.1 to 0.5 1.0 or less	 Shaker Reverse air Pulse jet	 Dacron Dacron Polyester felt	 275 125 to 250 250	 8:1
Secondary copper and brass rotary kiln		Shaker	Nomex	350	
Woodworking furniture manufacturing		Pulse jet	Polyester		10:1
Zinc refining coker (zinc oxide)		Pulse jet	Glass felt, Nomex	350 to 450	4 to 6:1

Review Exercise

1. Baghouses cannot be used for the collection of flyash from coal fired boilers since the flue gas deteriorates the bags. a. True b. False	
2. For baghouses used on coal fired boilers, the bags are usually made of a. cotton b. glass c. wool	1. b. False
3. Baghouses with bags made of woven glass usually have air-to-cloth ratios a. greater than 6.0:1 b. approximately 7.5:1 c. less than 4.0:1	2. b. glass
4. Pulse jet baghouses with polyester felt bags cannot be used to collect iron oxide dusts from steel furnaces. a. True b. False	3. c. less than 4.0:1
5. Baghouses have been used for filtering dust-laden gas from cement kilns, clinker coolers, and crushing operations. a. True b. False	4. b. False
	5. a. True

Dry Sulfur Dioxide (SO_2) Control Systems

One promising new technology for reducing sulfur dioxide (SO_2) emissions from combustion sources is using dry flue gas desulfurization (FGD). In dry FGD, the flue gas containing SO_2 is contacted with an alkaline material to produce a dry waste product for disposal. This technology includes:

- injection of an alkaline slurry in a spray dryer with collection of dry particles in a baghouse or electrostatic precipitator (ESP);
- dry injection of alkaline material into the flue gas stream with collection of dry particles in a baghouse or ESP;
- addition of alkaline material to the fuel prior to combustion.

These technologies are capable of SO_2 emission reduction ranging from 60 to 90% depending on which system is used. Table 8-4 summarizes the key features of each of these technologies. These technologies have been used on boilers burning low sulfur coal (usually less than 2%) and are attractive alternatives to wet scrubbing technology, particularly in the arid western U.S.

Table 8-4. Key features of dry flue gas desulfurization systems.

Process	Sorbents	SO_2 emission removal efficiency (%)	Particulate emission removal efficiency (%)	Development status
Spray dryer with a baghouse or ESP	Sodium carbonate Lime Limestone	60-90	99+	Three utility boilers (400-500 MW) to be started up 1981, 1982, 1983. Two industrial boilers on-line.
Dry injection with a baghouse or ESP	Sodium carbonate Sodium bicarbonate Nahcolite	60-90	99+	No commercial installations planned as of 1980.
Combustion of coal/limestone mixture with a low NO_x burner	Limestone pellet Lime	75-80	99+*	EPA currently funding pilot tests on small industrial boiler.

*Note: a baghouse or ESP is used for particulate emission control.

Source: EPA, February 1980.

Spray Dryer with a Baghouse or ESP

The only commercial dry FGD installations in the U.S. at this time use a spray dryer. Alkaline is injected into a spray dryer with dry particle collection in a baghouse or ESP. Spray dryers have been used in the chemical, food processing, and mineral preparation industries over the past 40 years. Spray dryers are vessels where hot flue gases are contacted with a finely atomized wet alkaline spray. The high temperatures of the flue gas, 250 to 400°F, evaporate the moisture from the wet alkaline sprays, leaving a dry powdered product. The dry product is collected in a baghouse or ESP (Figure 8-1).

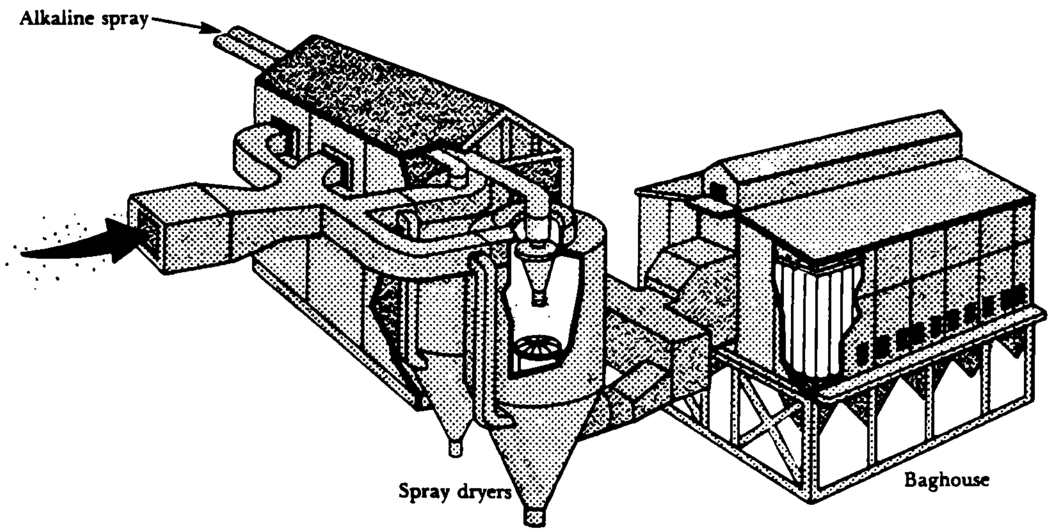


Figure 8-1. Spray dryers with baghouse.

Flue gas enters the top of the spray dryer and is swirled by a fixed vane ring to cause intimate contact with the slurry spray (Figure 8-2). The slurry is atomized into extremely fine droplets by rotary atomizers. The turbulent mixing of the flue gas with the fine droplets results in rapid SO_2 absorption and evaporation of the moisture. A small portion of the hot flue gas is added to the spray-dryer-discharge duct to maintain the temperature of the gas above the dew point. Reheat prevents condensation and corrosion in the duct. Reheat also prevents bags in the baghouse from becoming plugged or caked with moist particles.

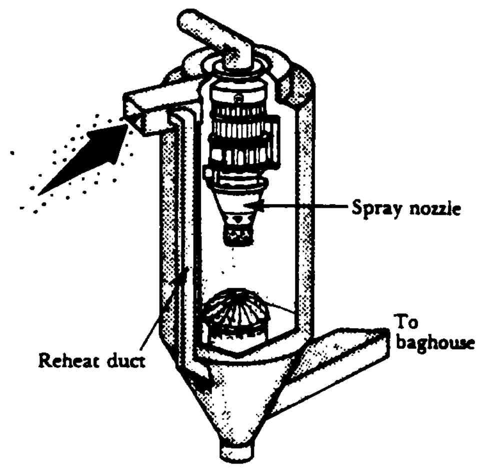


Figure 8-2. Spray dryer.

Sodium carbonate solutions and lime slurries are the most common absorbents used. A sodium carbonate solution will generally achieve a higher level of SO_2 removal than lime slurries (EPA, February 1980). When sodium carbonate is used, SO_2 removal efficiencies are approximately 75 to 90%, lime removal efficiencies are 70 to 85% (EPA, February 1980). However, vendors of dry scrubbing systems claim that their units are capable of achieving 90% SO_2 reduction using a lime slurry in a spray dryer. Lime is very popular for two reasons: lime is less expensive than sodium carbonate; sodium carbonate and SO_2 form sodium sulfite and sodium sulfate which are very soluble causing leaching problems when landfilled.

Some of the evaporated alkaline spray will fall into the bottom of the spray dryer and be recycled. The majority of the spray reacts with SO_2 in the flue gas to form powdered sulfates and sulfites. These particles, along with fly ash in the flue gas, are then collected in a baghouse or electrostatic precipitator (see 413 Student Manual, EPA 450/2-80-066). Baghouses have an advantage because unreacted alkaline material collected on the bags can react with any remaining SO_2 in the flue gas. Some process developers have reported SO_2 removal on bag surfaces on the order of 10% (Kaplan and Felsvang, 1979). However, since bags are sensitive to wetting, a 35 to 50°F margin above the saturation temperature of the flue gas must be maintained (EPA, February 1980). ESPs have the advantage of not being as sensitive to moisture as baghouses. However, SO_2 removal is not quite as efficient using ESPs.

In a spray dryer, finely atomized alkaline droplets are contacted with flue gas which is at air preheater outlet temperatures (250 to 400°F). The flue gas is humidified to within 50°F of its saturation temperature by the moisture evaporating from the alkaline slurry. Reaction of the SO_2 with the alkaline material proceeds both during and following the drying process, although to what degree is not completely understood. Since the flue gas temperature and humidity are set by air preheater outlet conditions, the amount of moisture that can be evaporated into the flue gas is also set. This means that the amount of alkaline slurry that can be evaporated in the dryer is limited by flue gas conditions. Alkaline slurry sprayed into the dryer must be carefully controlled to avoid moisture in the flue gas from condensing in the ducting, particulate emission control equipment, or the stack. SO_2 removal efficiencies are generally <85% (EPA, February 1980).

A number of spray dryer systems have been planned for or installed on industrial and utility boilers. These are listed in Table 8-5. Spray dryers will become more popular as experience with existing units is further documented. They will be particularly useful in meeting NSPS regulations for utility boilers burning low sulfur coal that require only 70% SO_2 scrubbing.

Table 8-5. Commercial spray dryer FGD systems using a baghouse.

Station or plant	Size (MW)	Installation date	System description	Sorbent	Coal sulfur content (%)	SO_2 emission removal efficiency (%)
Otter Tail Power Company; Coyote Station No. 1, Beulah, ND	410	6/81	Rockwell/Wheelabrator-Frye system; four spray towers in parallel with 3 atomizers in each; reverse air—shaker baghouse with Dacron bags	Soda ash (sodium carbonate)	0.78	70
Basin Electric; Laramie River Station No. 3, Wheatland, WY	500	Spring 1982	Babcock and Wilcox; four spray reactors with 12 "Y-jet" nozzles in each; electrostatic precipitator	Lime	0.54-0.81	85-90
Strathmore Paper Co.; Woronco, MA	14	12/79	Mikropul; spray dryer and pulse jet baghouse	Lime	2-2.5	75
Celanese Corp.; Cumberland, MD	31	2/80	Rockwell/Wheelabrator-Frye; one spray tower followed by a baghouse	Lime	1-2	85

Source: EPA, February 1980.

Dry Injection

In dry injection systems, a dry alkaline material is injected into a flue gas stream. This is accomplished by pneumatically injecting the dry sorbent into a flue gas duct, or by precoating or continuously feeding sorbent onto a fabric filter surface. Most dry injection systems use pneumatic injection of dry alkaline material in the boiler furnace area or in the duct that precedes the ESP or baghouse. Sodium-based sorbents are used more frequently than lime. Many dry injection systems have used nahcolite, a naturally occurring mineral which is 80% sodium bicarbonate found in large reserves in Colorado. Sodium carbonate (soda ash) is also used but is not as reactive as sodium bicarbonate (EPA, February 1980). The major problem of using nahcolite is that it is not presently being mined on a commercial scale. Large investments must be made before it will be mined commercially. Other natural minerals such as raw trona have been tested; trona contains sodium bicarbonate and sodium carbonate.

Dry injection systems have been tested at a number of power stations throughout the U.S. Descriptions of these pilot systems can be found in *Survey of Dry SO_2 Control Systems* (EPA, February 1980). The major problems with dry injection systems are the low sodium utilization in the process and the disposal of leachable sodium-sulfur compounds. EPA reports that only 40 to 60% of the dry alkaline injected material is used at high SO_2 removal conditions (EPA, February 1980).

Review Exercise

1. One promising technology for reducing both SO_2 gas and particulate emissions involves the injection of an __________ slurry in a spray __________ with dry particle collection in a baghouse.	
2. In a spray dryer, moisture is __________ from the wet alkaline sprays, leaving a __________ powdered product.	1. alkaline dryer
3. In dry sulfur dioxide control systems using a spray dryer, the most common alkaline absorbents used are a. sodium citrate and magnesium oxide. b. sodium carbonate and lime. c. sodium bisulfate and sodium hydroxide.	2. evaporated dry
4. Dry FGD systems using lime injected in a spray dryer and a baghouse for dry particle collection are capable of 70% SO_2 reduction and 99^+% particulate matter removal efficiency. a. True b. False	3. b. sodium carbonate and lime.
	4. a. True

Capital and Operating Cost Estimations

This section contains generalized cost data for baghouse systems described throughout this manual. These data should be used only as an estimate to determine systems costs. In some cases the cost of the control device may represent only a very small portion (<20%) of the total installed cost; in other cases it may represent the total cost. Variations in the total cost can be attributed to a number of variable factors such as cost of auxiliary equipment, new or retrofitted installation, local labor costs, engineering overhead, location and accessibility of plant site, and installation procedure (factory or field assembled).

This cost estimation data, included in this appendix, first appeared in an EPA publication (EPA, 1976) and then in a series of articles published in the Journal of the Air Pollution

Control Association (JAPCA, 1978). The reader should refer to these publications for additional information concerning this subject. These estimations represent equipment costs based on a reference date of December 1977 and are estimated to be accurate to within ± 20% on a component basis, except where noted (JAPCA, 1978).

The cost data for fabric filters is based on the *net cloth area*. The net cloth area is the total filter area available for on-stream filtration. This would not include the isolated compartment being cleaned in the case of an intermittently cleaned baghouse. For intermittently cleaned baghouses requiring an off-line compartment, the total cloth area must be calculated as the *gross cloth area*. The gross cloth area is the net cloth area of the baghouse plus the cloth area for an extra compartment. The gross cloth area can be calculated for various values of net cloth area from Table 8-6.

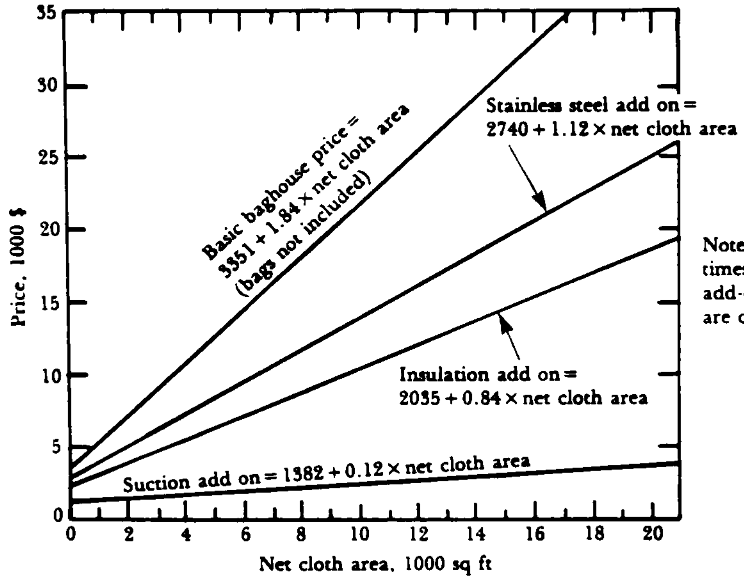
Table 8-6. Approximate guide to estimate gross cloth area.

Net cloth area (ft^2)	Gross cloth area (ft^2)
1 – 4000	Multiply by 2
4401 – 12000	1.5
12001 – 24000	1.25
24001 – 36000	1 17
36001 – 48000	1 125
48001 – 60000	1.11
60001 – 72000	1 10
72001 – 84000	1.09
84001 – 96000	1.08
96001 – 108000	1 07
108001 – 132000	1.06
132001 – 180000	1.04

The cost for various baghouses—shaker, reverse air, or pulse jet units—are listed in Figures 8-3 through 8-7. These figures include curves of additional prices for stainless steel construction, insulation, suction baghouses, and standard or custom designed units. Suction baghouses are negative pressure systems with the fan located on the clean side of the baghouse. Standard baghouses are predesigned and built as modules which can be operated singly or combined to form units for larger capacity. Custom baghouses are designed for a specific application, are erected in the field, and are used most often for large capacity applications. The cost of the baghouse units in Figures 8-3 through 8-7 are for the baghouse only (bags are not included). The costs for bags using various fabrics can be calculated from Table 8-7.

Table 8-7. Bag prices ($\$/ft^2$). Data valid for December 1977.

Class	Type	Dacron	Orlon	Nylon	Nomex	Glass	Polypropylene	Cotton
	Mechanical shaker, < 20,000 ft^2	0.36	0.62	0.73	1.14	0.47	0.62	0.43
	Mechanical shaker, > 20,000 ft^2	0.31	0.57	0.67	1.04	0.42	0.52	0.38
Standard	Pulse jet	0.57	0.93	—	1.30	—	0.67	—
	Reverse air	0.31	0.57	0.67	1.04	0.42	0.52	0.38
	Mechanical shaker	0.21	0.31	0.42	0.62	0.26	0.31	0.38
Custom	Reverse air	0.21	0.31	0.42	0.62	0.26	0.31	0.38



Note: Baghouse price = $3351 + 1.84 times the net cloth area. All price add-ons in Figures 8-3 through 8-7 are calculated in this manner.

Figure 8-3. Intermittent, pressure, mechanical shaker baghouse prices versus net cloth area. Data valid for December 1977.

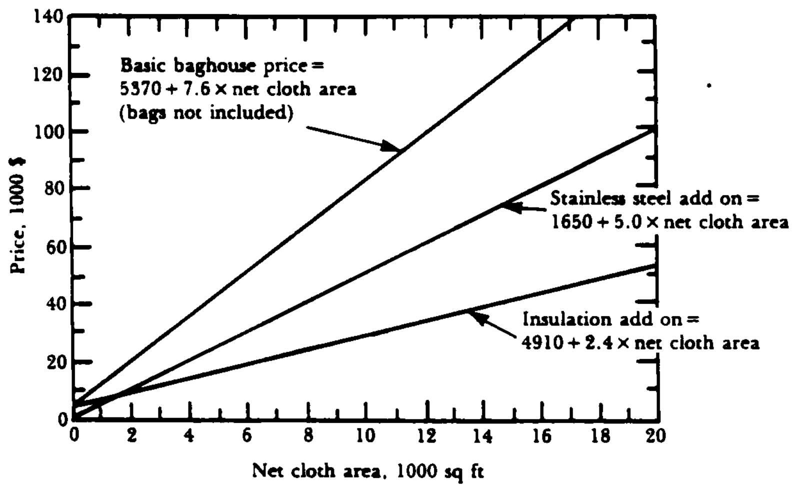


Figure 8-4. Continuous, suction or pressure, pulse jet baghouse prices versus net cloth area. Data valid for December 1977.

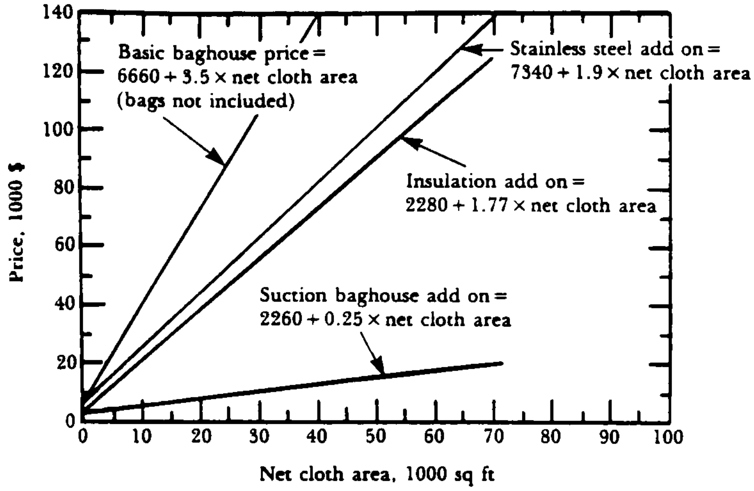


Figure 8-5. Continuous, pressure, mechanical shaker baghouse prices versus net cloth area. Data valid for December 1977.

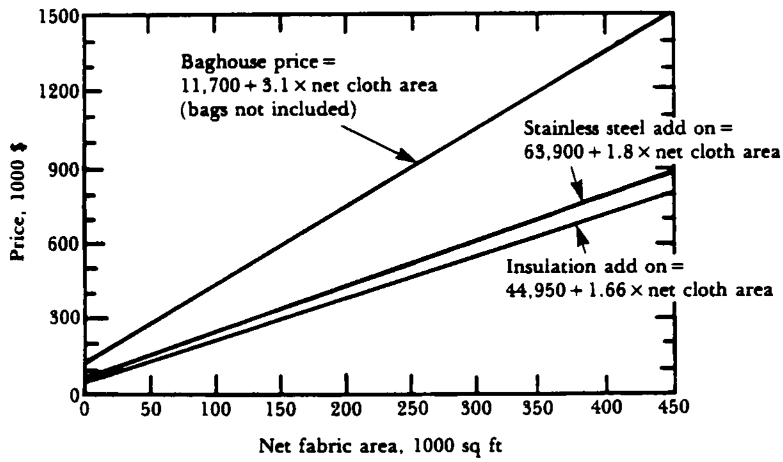


Figure 8-6. Custom pressure or suction baghouse prices versus net cloth area. Data valid for December 1977.

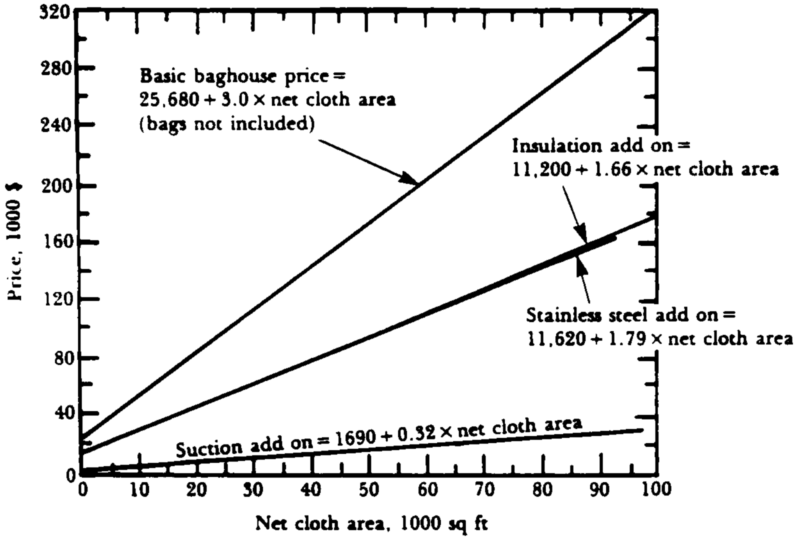


Figure 8-7. Continuous, pressure, reverse air baghouse prices versus net cloth area. Data valid for December 1977.

Example:

A baghouse is used to clean the exhaust from an industrial boiler with a flow rate of 50,000 cfm. The baghouse is a reverse air unit, suction type, using glass bags and an air-to-cloth ratio of 1.5. The baghouse should include an extra compartment for off-line cleaning.

$$\text{Net cloth area} = \frac{\text{gas volume}}{\text{air-to-cloth ratio}}$$

$$\text{Net cloth area} = \frac{50{,}000}{1.5} = 33{,}333 \text{ ft}^2$$

Calculate the gross cloth area from Table 8-6.

$$\text{Gross cloth area} = 33{,}333 \times 1.17 = 39{,}000 \text{ ft}^2$$

Table 8-6. Approximate guide to estimate gross cloth area.

Net cloth area (ft^2)	Gross cloth area (ft^2)
1 – 4000	Multiply by 2
4401 – 12000	1.5
12001 – 24000	1.25
24001 – 36000	1.17
36001 – 48000	1.125
48001 – 60000	1.11
60001 – 72000	1.10
72001 – 84000	1.09
84001 – 96000	1.08
96001 – 108000	1.07
108001 – 132000	1.06
132001 – 180000	1.04

The price of the unit is:

Baghouse from Figure 8-7	Baghouse	$142,680
Suction from Figure 8-7	Suction	14,170
Insulation from Figure 8-7	Insulation	75,940
Bags from Table 8-7	Bags	16,380
	Total	$249,170

Table 8-7. Bag prices ($/ft^2). Data valid for December 1977.

Class	Type	Dacron	Orlon	Nylon	Nomex	Glass	Polypropylene	Cotton
Standard	Mechanical shaker, < 20,000 ft^2	0.36	0.62	0.73	1.14	0.47	0.62	0.43
	Mechanical shaker, > 20,000 ft^2	0.31	0.57	0.67	1.04	0.42	0.52	0.38
	Pulse jet	0.57	0.93	—	1.30	—	0.67	—
	Reverse air	0.31	0.57	0.67	1.04	0.42	0.52	0.38
Custom	Mechanical shaker	0.21	0.31	0.42	0.62	0.26	0.31	0.38
	Reverse air	0.21	0.31	0.42	0.62	0.26	0.31	0.38

Lesson 9

Design Criteria for Permit Review: Problem Set

Lesson Goal and Objectives

Goal

To familiarize you with the review of baghouse plans by using a problem set.

Objectives

At the end of the lesson you should be able to:

1. determine the fabric filter material to use for a given set of data.
2. determine the bag cleaning method appropriate to a given set of data.

Introduction

This lesson contains an example of the review of a typical baghouse installation plan submitted to an air pollution control agency for approval. This example is designed using the topics covered in the previous seven lessons. The information supplied by the owner and/or operator of the air pollution source must be sufficient in order for the review to be complete.

You should refer to various lessons in this course to complete this review exercise.

Example

The Joe Magarac Steel Company is planning to install two 150-ton electric steel furnaces. The furnaces will be charged with molten iron and cold scrap. The company is installing a baghouse to control particulate emissions. The pertinent process and baghouse data is given below. The main question here is—should this plan for construction of this air pollution source be approved by the State review engineer?

Process Information

Process equipment:	two 150-ton 3-phase electric arc furnaces
Operating schedule:	24 hours/day, 7 days/week, 52 weeks/year
Exhaust gas temperature:	at canopy hood and furnace tap = 2730°F
Exhaust gas conditioning:	water cooled by evaporation and air dilution
Exhaust gas volume handled:	2,290,000 acfm at 150°F (total from both furnaces)
Inlet dust concentration (to baghouse):	1.5 to 5.0 gr/dscf

Particle size data:

Size (μm)	Percent (%)
>44	7
20-44	7
10-20	6
5-10	8
<5	72

Baghouse Information

Positive pressure baghouse

Reverse air cleaning:	from a separate fan 48,000 cfm at 15 in. H_2O, 70°F
Air-to-cloth ratio:	3:1
Pressure drop:	6 to 8 in. H_2O
Bags:	34.7 ft long, 11.75 in. diameter
Fabric:	Dacron woven bags, silicon treated
Compartments:	34
Bags/compartment:	228
Dust/outlet concentration:	0.0052 gr/dscf
Collection efficiency:	99.77%

Solution

The particle size data shows that the selection of baghouse is very good since the majority of the particles are very small (<5 μm) in diameter. The exhaust volume to the baghouse is 2,290,000 (total from both furnaces) at 150°F. The air-to-cloth ratio is 3:1.

A/C ratio = 3:1

1. To determine the cloth area needed, use the formula:

$$A_c = \frac{Q}{v_f}$$

$$A_c = \frac{2,290,000 \text{ ft}^3/\text{min}}{3 \text{ ft/min}}$$

$$= 763,334 \text{ ft}^2$$

2. To determine the area of the bags required in the baghouse, use the formula:

$$A_b = \pi dh$$

Where: A_b = area of bag, ft^2
$\pi = 3.14$
d = bag diameter, ft
h = bag height, ft

$$A_b = 3.14 \times \frac{11.75}{12} \text{ ft} \times 34.7 \text{ ft}$$
$$= 106.7 \text{ ft}^2$$

3. To calculate the number of bags needed in the baghouse:

$$\text{Number of bags} = \frac{A_c}{A_b}$$

$$\text{Number of bags} = \frac{763{,}334 \text{ ft}^2}{106.7 \text{ ft/bag}}$$
$$= 7154 \text{ bags}$$

4. There are 228 bags per compartment. A good baghouse design would include 2 extra compartments; 1 for bag cleaning, and 1 for bag maintenance.

$$\text{Number of compartments} = \frac{\text{Number of bags}}{\text{Number bags/compartment}}$$

$$\text{Number of compartments} = \frac{7154}{228}$$
$$= 31.3$$

Since it is impossible to have a partial compartment, the design should have 34 compartments; 32 for filtering, 1 for cleaning, and 1 for maintenance.

5. From Tables 6-1 and 6-2, the air-to-cloth ratio of 3:1 seems to be reasonable.

A/C ratio = 3:1

6. From Table 3-1, woven Dacron bags can withstand continuous temperatures up to 275°F or 135°C. Since the gas temperature to the baghouse is less than 150°F, then the use of Dacron bags is fine.

Dacron bags

7. This baghouse is a positive pressure system and will probably have roof vents at the top of the unit. This will present some minor inconvenience in stack testing for source compliance validation. The agency should require the source operator to conduct compliance tests by using a high volume filter in the top of the baghouse or some other appropriate testing method.

Baghouse system = Positive pressure

8. The agency should require that the source owner submit an operation and maintenance schedule that will help keep the baghouse on-line.

9. It appears that this baghouse construction plan meets the design criteria given in Lesson 6. This plan should be approved.

Plan approved

Review Exercise

The Cheeps Brewing Co. is planning to install a coal fired industrial boiler for producing process steam and heat. The boiler information and control equipment data are given below. Should this plan be approved by the air pollution control agency?

Boiler Information

1 pulverized coal fired boiler

Heat input:	152×10^6 Btu/hr
Coal:	sulfur content 2% ash content 10% heat content 13,000 Btu/lb
Operating schedule:	24 hours/day, 7 days/week, 40 weeks/year
Exhaust gas volume:	48,000 acfm
Exhaust gas temperature:	360 to 390°F
Inlet dust concentration (to baghouse):	10 gr/scf

Particle size data:

Size (μm)	Percent (%)
>60	5
20-60	7
10-20	20
5-10	30
<5	38

Baghouse Information

Negative pressure baghouse

Pulse jet cleaning:	4 compartments
Air-to-cloth ratio:	4.5:1
Pressure drop:	6 in. H_2O
Bags:	12 ft long, 5¼ in. diameter
Fabric:	23 oz Teflon felt
Number of compartments:	5
Number of bags/compartment:	144

The baghouse is insulated to prevent condensation. Dust is removed from the hopper by a pneumatic conveyor.

Stack height:	89 ft
Stack diameter:	4 ft 6 in.
Fan is induced draft:	100 hp and 580 rpm

Solution

From examining the boiler and baghouse data a number of points can be made.

1. The choice of fabric material used to make the bags can be obtained from Figure 3-1. The logical choice can be the following since the gas temperature is 360 to 390°F:

   glass bags
   Teflon bags
   Nomex bags

   Using Nomex bags would probably be ruled out because the sulfur content is 2% and the sulfur oxides and acids formed destroy this material. Glass bags could be used for this unit. Teflon bags would also be a good choice with the only deterrent being their high cost.

   Glass
   Teflon

2. The air-to-cloth ratio can be checked from Tables 6-1 and 6-3. For a pulse jet baghouse an air-to-cloth ratio of 4.5:1 (cfm/ft²) is well within the limits of the typical range. The use of a pulse jet baghouse will also enable the designer to push the air-to-cloth ratio a little higher than if a reverse air baghouse with woven glass bags were used.

3. The exhaust gas volume is 48,000 acfm at 360 to 390°F. The air-to-cloth ratio is 4.5:1. Calculate the cloth area:

$$A_c = \frac{Q}{v_f}$$

A/C ratio = 4.5:1

$$A_c = \frac{48{,}000\ \text{ft}^3/\text{min}}{4.5\ \text{ft/min}}$$

$$= 10{,}667\ \text{ft}^2$$

4. Calculate the bag area:

$$A_b = \pi dh$$

$$A_b = 3.14 \times \frac{5.25}{12}\ \text{ft} \times 12\ \text{ft}$$

$$= 16.49\ \text{ft}^2$$

5. Calculate the number of bags needed:

$$\text{Number of bags} = \frac{A_c}{A_b}$$

$$\text{Number of bags} = \frac{10{,}667\ \text{ft}^2}{16.49\ \text{ft}^2}$$

$$= 647\ \text{bags}$$

6. There are 144 bags in each compartment. The design plan calls for 5 compartments, which give a total of 720 bags. This would be adequate in terms of filtering the fly ash. If one compartment needed maintenance, the gas flow rate into the other 4 would be higher, pushing up the air-to-cloth ratio. Maintenance could also be performed during scheduled boiler down time, or by reducing the steam load to approximately 80%. An operation and maintenance schedule should be included in the design plan.

   Number of compartments = 5

   Number of bags (from plan) = 720

7. This baghouse is a negative pressure system with an induced draft fan, 89-foot stack and 4.5-foot stack diameter. This unit could easily be tested for compliance and the agency **should** request a stack test before issuing an operating permit.

8. This plan should be approved. Plan approved

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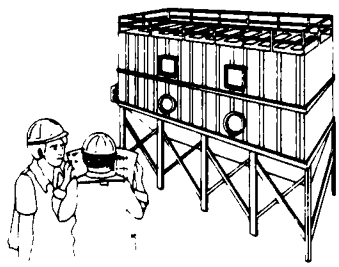
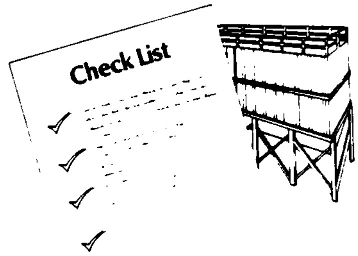
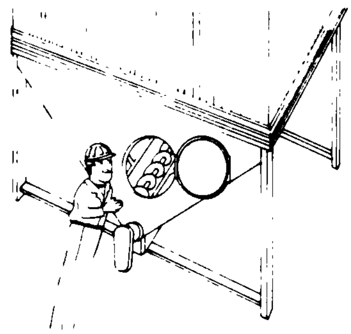
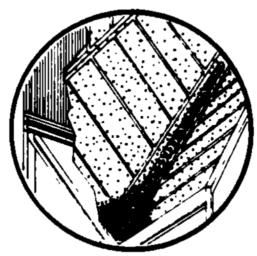
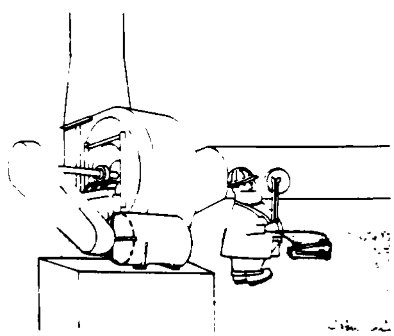
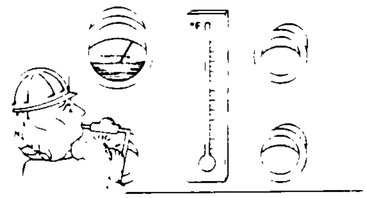
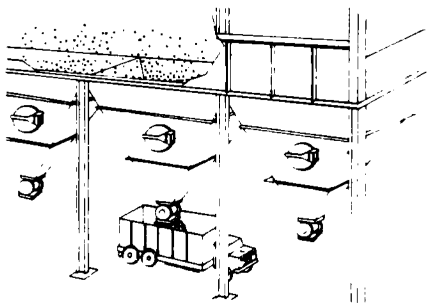
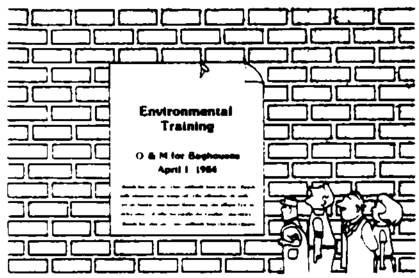
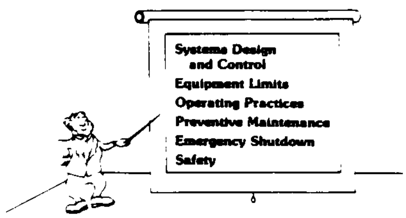
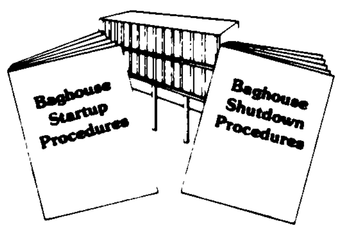
Appendix

Baghouse Operation and Maintenance

Slide	Script	Selected Visuals*
1.		
2.		
3.		
4.		BAGHOUSE OPERATION AND MAINTENANCE
5.	Baghouse installation and operation startup may take from a few days to a few months. Using proper installation procedures will save time and money and will reduce future operation and maintenance expenses.	Installation
6.	Good coordination between the baghouse designer and the installation and maintenance crews will help keep the baghouse running smoothly for years. Some key features should be reevaluated during the installation period. Is there easy access to all potential maintenance areas	
7.	such as fans, motors, conveyors, discharge valves, dampers, pressure and temperature monitors, and bags.	
8.	Is there easy access to all inspection and test areas such as stack testing ports and opacity monitors. Will the baghouse be able to withstand inclement weather such as rain or snow.	
9.	Each baghouse should have its own checklist reflecting its unique construction components. The installation crew should prepare the checklist ***before*** beginning the final inspection and initial startup.	

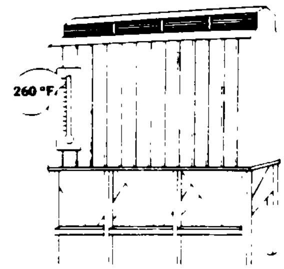
*illustrations included here, no live shots.

Slide	Script	Selected Visuals
10.	The installation crew should visually inspect the essential baghouse components to ensure that they are properly installed. Are the structural connections securely welded or bolted?	
11.	Are duct flanges sealed?	
12.	Are filter bags seated properly on tube sheet or cell plate thimbles?	
13.	Do all dampers operate, and do they operate in the correct sequence?	
14.	Do all system fans, reverse air fans, and conveyors rotate properly?	
15.	Are all electrical controls operating?	
16.	And, do the rotary or trickle valves discharge the dust efficiently?	
17.	You should also perform other checklist functions. Remove the inspection door to check conveyors for loose items or obstructions.	
18.	Start screw conveyors to check rotation direction.	
19.	Start the fans. Check to see if air is blowing in the right direction and measure the air flow.	

Slide	Script	Selected Visuals
20.	Log the pressure drop and temperature readings.	
21.	And, check to see if dust is being discharged from the hopper.	
22.	Before the baghouse is started up, the plant engineer should schedule training sessions for ***all*** plant employees who will operate and maintain the baghouse.	
23.	These training sessions should cover systems design and controls; maximum and minimum equipment limits; good operating practices; ***preventive*** maintenance; startup, shutdown, and emergency shutdown procedures; and safety considerations.	
24.	The baghouse vendor should always supply a specific startup and shutdown procedure.	

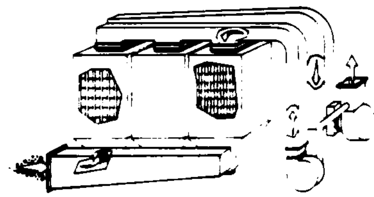
Slide | **Script** | **Selected Visuals**

25. If hot moist gases are to be filtered, the baghouse must be preheated to raise the interior temperature in the baghouse above the dew point. This will prevent condensation and potential corrosion problems.

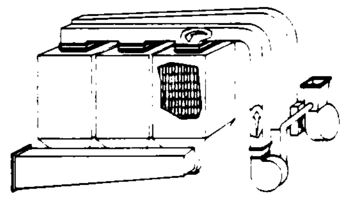


26. To avoid permanent damage to the fabric, bring the baghouse on-line slowly. In some applications, bags are precoated with a protective dust layer. Keep the filter velocity low until a sufficient dust cake is built up on the bags.

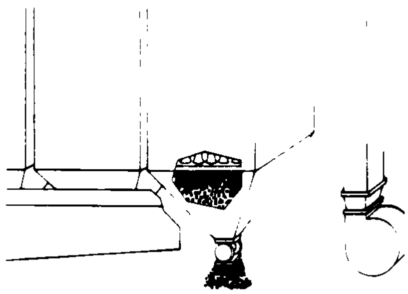
27. To keep the baghouse in top operating condition, the entire baghouse or individual compartments must be shut down for periodic maintenance. Before allowing the internal baghouse temperature to fall below the dew point, purge the baghouse with clean, hot, dry air.



28. Clean the bags by initiating the cleaning cycle. Be careful not to overclean, or the original dust cake on woven filters will be destroyed.



29. And finally, empty the hopper of all dust.



30. Once a baghouse is operating, it needs to be routinely monitored to be sure it is operating efficiently.

Routine Monitoring

31. The two primary indicators of baghouse performance are collection efficiency and pressure drop. A clean stack indicates good collection efficiency.

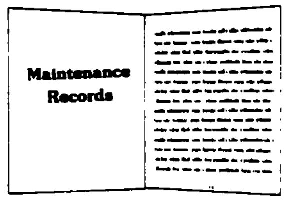
Collection Efficiency
Pressure Drop

Slide	Script	Selected Visuals

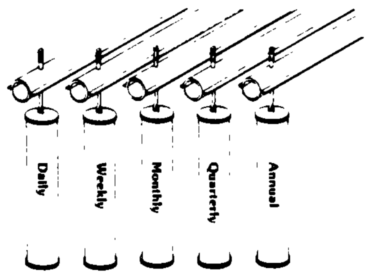
32. Stack plume opacity can be monitored by visual observation or by using continuous monitors.

33. Pressure drop is monitored by using a manometer or magnehelic gauge. Stripchart recorders can also be used to give permanent pressure drop records. They can be useful for determining maintenance needs and for charting tendencies over prolonged time periods.

34. Good recordkeeping is the key to an effective maintenance program. If you keep a log of actual inspections, observations, and preventive maintenance, it should be easy to determine how the baghouse is operating.



35. Establish a schedule for inspecting all baghouse components. It is best to follow the vendor's recommendations. You will need to perform daily, weekly, monthly, quarterly, and annual inspections.



36. Perform the following inspections every day:
   - •walk through the baghouse to check for normal or abnormal visual and audible conditions

Daily

37.
   - •check the pressure drop
   - •monitor the gas flow rate
   - •check the cleaning cycle

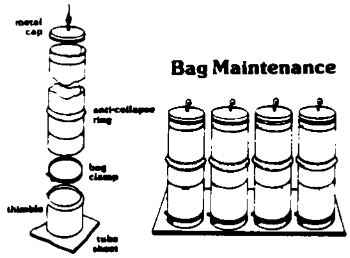
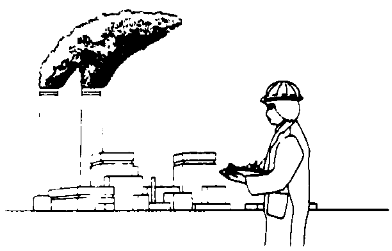
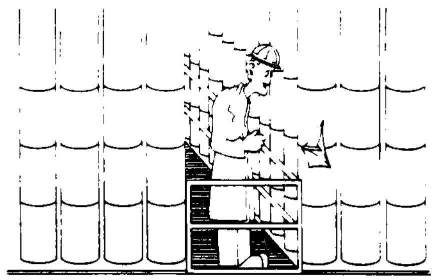
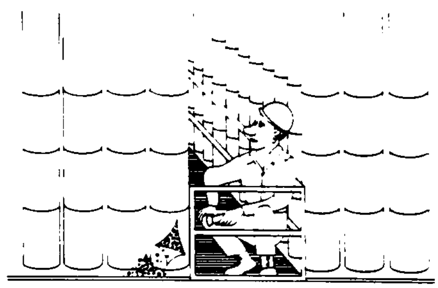
38.
   - •check compressed air on pulse jet baghouses

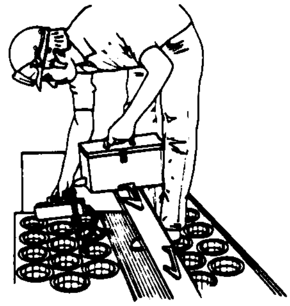
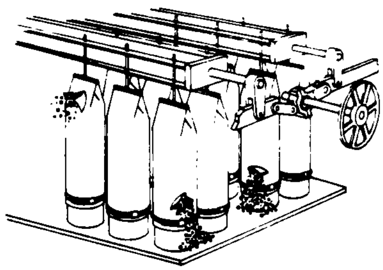
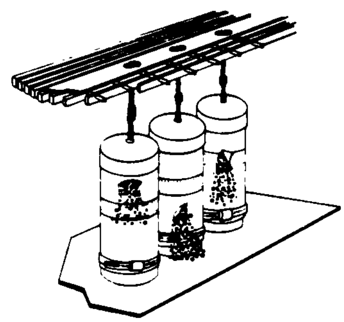
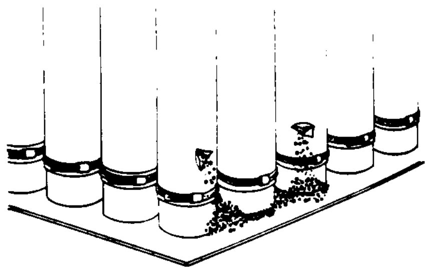
39.
   - •monitor the discharge system by making sure dust is removed as needed,
   - •and observe the stack plume opacity

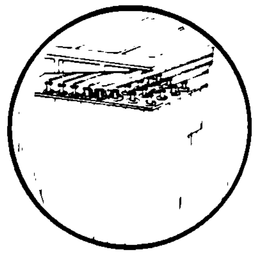
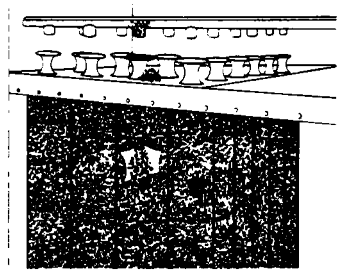
40. Once a week,
   - •spot check bag seating conditions
   - •spot check for bag leaks and holes
   - •check all moving parts on shaker baghouses

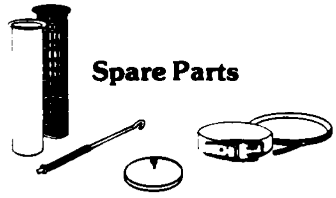
Weekly

Slide	Script	Selected Visuals
41.	•check fans for corrosion and blade wear •check all hoses and clamps •inspect the baghouse housing for corrosion	
42.	In addition to daily and weekly, other inspections must be made once a month: •spot check bag tensioning in reverse air and shaker baghouses •blow out the manometer lines •verify the working order of temperature-indicating equipment	Monthly
43.	•check the compressed air lines, including line oilers and filters •check the bag cleaning sequence to see that all valves are seating properly	
44.	•check all moving parts on the discharge system and check the screw conveyor bearings •and, check the drive components on a fan.	
45.	At least once every three months, •thoroughly inspect all bags •calibrate the opacity monitor	Quarterly
46.	•check gaskets on all doors •inspect the paint on the baghouse	

Slide	Script	Selected Visuals
47.	•inspect the baffle plate for wear, •observe the dampers for proper seating, •and, check the ducts for dust buildup.	
48.	And, once a year, •check all welds and bolts •check the hoppers for wear, and •replace high-wear parts on the cleaning system.	Annual
49.	Because of the time involved, the highest maintenance cost in a baghouse involves inspecting and changing the bags. Failures can occur in different places on the bag depending on the operation of the dust collector.	
50.	Stack opacity is a good indication of bag failure. If the plume is dirty, then some problem exists, either in a single compartment or throughout the baghouse.	
51.	You can search for a broken bag in three ways: •you can hunt for the hole,	
52.	•you can hunt for the accumulation of dust that is often associated with a nearby hole,	

Slide	Script	Selected Visuals
53.	•or you can use a detecting device.	
54.	In shaker baghouses, where dust is collected on the inside of the bags, failures occur frequently at the bottoms of bags and also at the top where they are attached to hooks or clamps.	
55.	In reverse air baghouses, failures occur most frequently at the bottom of the bags, and also near the anti-collapse rings and top cuffs where the bags are attached.	
56.	In both shaker and reverse air baghouses, an accumulation of dust on the cell plate is sometimes visible, making it relatively easy to spot the bag that failed. However, to find the actual hole, it may be necessary to inspect the *entire* circumference and length of the bag.	

Slide	Script	Selected Visuals
57.	In pulse jet baghouses, it is usually very difficult to locate bags that have failed.	
58.	However, in many pulse jet units, dust accumulation on the top tube sheet or in the blowpipe above the failed bag will be readily noticeable.	
59.	Recently, a new and effective technique has been developed for locating torn bags. Fluorescent powder and a black light are used to search for torn bags.	
60.	Fluorescent powder is injected in the inlet to the baghouse. An ultraviolet light scans the clean air side of the baghouse.	
61.	Leaks are detected by observing the glow of the powder that leaks through a torn bag. This technique is useful for spotting broken welds or leaks in the cell plates, tube sheets, or housing.	

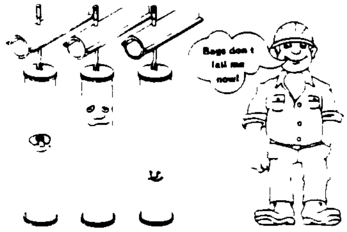
Slide	Script	Selected Visuals
62.	An inventory of spare parts suggested by the baghouse vendor should be on hand for baghouse maintenance. After operating the baghouse a few years, the maintenance crew will know which parts fail most frequently.	
63.	Some parts can be easily replaced and save shutdown time. A complete bag changeout is needed every three to four years.	
64.	The rings welded on the support cages for pulse jet bags may separate after continual use.	
65.	Bag clamps may wear out or corrode.	
66.	Baffle plates may wear out, particularly when they are used with heavy dust concentrations.	
67.	In reverse air baghouses, bags must occasionally be realigned on their thimbles. Tensioning springs must also be adjusted periodically to prevent bags from sagging.	
68.	Fan belts, bearings, and gaskets for all mechanical components will also wear and need to be replaced. Thus, a collection of spare parts will save time and money and will encourage preventive maintenance practices.	

Slide	Script	Selected Visuals

69. Preventive maintenance safeguards against baghouse problems that may cause shutdowns by detecting them early. Once detected, many problems can be eliminated before they become major.

70. Routine maintenance will keep the baghouse functioning and ***prevent total*** plant shutdown.

71. If the baghouse remains operational on a continuing basis, the process emissions are controlled and the plant can keep operating within the emission limits specified by the standards for protecting the environment.



72.

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73.

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Technical Content:	David S. Beachler
Instructional Design:	Marilyn M. Peterson
Graphics:	Betsy Huber
Photography/Audio:	David Churchill
Narration:	Rick Palmer

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16. ABSTRACT

This Student Guidebook is a self-instructional course, APTI Course SI:412 "Baghouse Plan Review." This course is designed for engineers and other technical personnel responsible for reviewing plans for installations of fabric filtration air cleaning devices. The course focuses on review procedures for baghouse devices used to reduce particulate air pollution from industrial sources. Major topics include: general baghouse description, bag cleaning methods, fabric selection and filter types, design parameters affecting collection efficiency, and operation and maintenance problems associated with baghouses.

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