CHAPTER 4

FILTRATION

Terminology

Air Filtration

Surface Filtration

Bag Filters

Bag Houses

General

General

General

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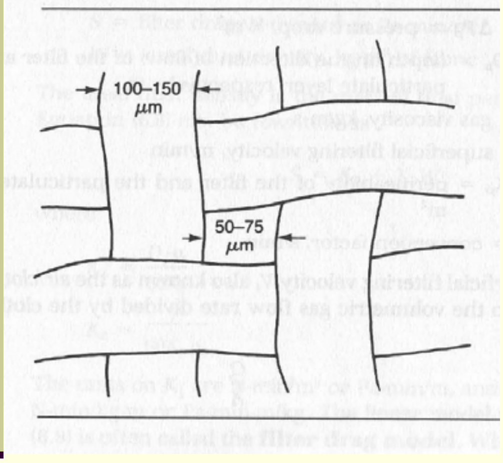
General

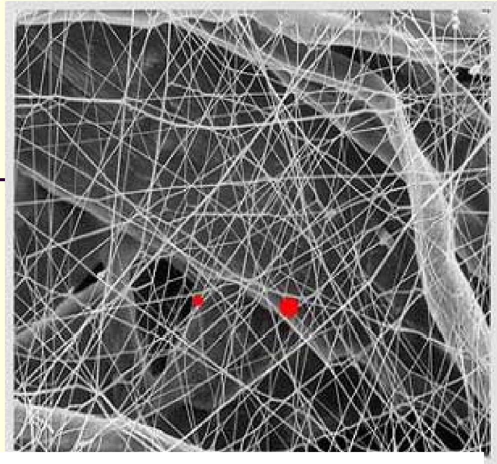
- **Filtration** is one of the oldest and most widely used methods of separating particulate from a carrier gas, including ambient air.

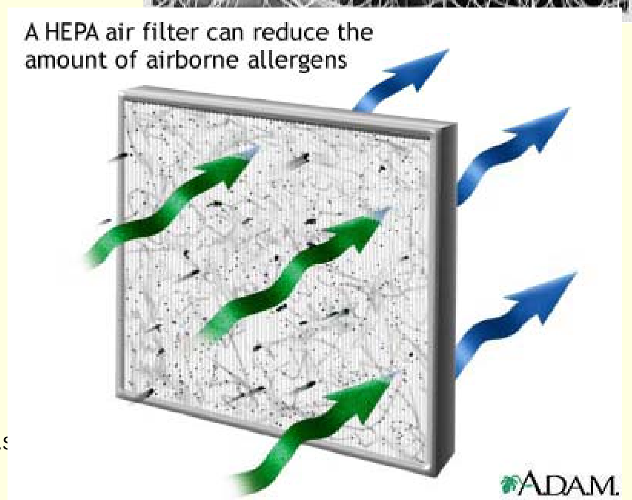
- **A fllter** generally is any porous structure composed of granular or flbrous material that tends to retain the particulate matter as the carrier gas passes through the voids of the fllter.

General

Figure 6.1 A new, clean woven filter cloth.







General

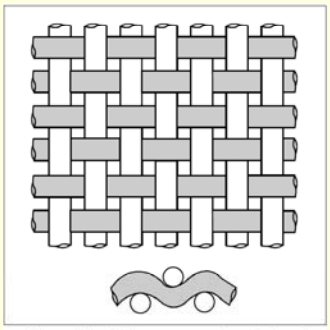


Figure 4-1. Plain weave or checkerboard

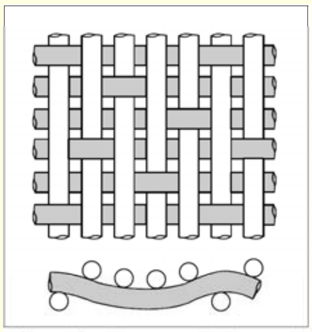


Figure 4-3. Sateen weave (satin weave)

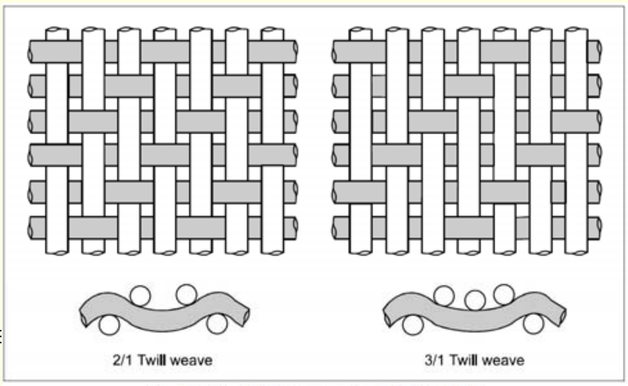


Figure 4-2. Twill weave patterns (2/1 and 3/1)

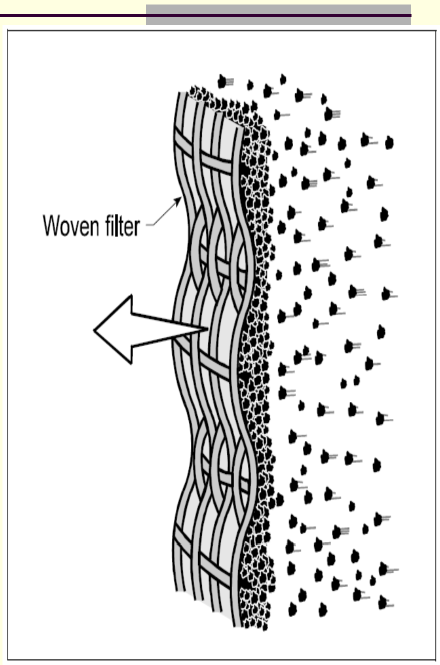


Figure 4-4. Sieving (on a woven filter)

General

- The fllter is constructed of any material compatible with the carrier gas and particulate matter and,
- It may be arranged as a deep bed, mat (keçe) , pleated (pileli) fllter, or as fabric fllter.
- It may be noncleanable (throwaway) or cleanable.

General

- Mat and deep bed filters have large void space amounting to from 97 to 99 percent of the total volume.
- They are used in light dust loads, such as in residential heating and air conditioning filters, or may be used upstream of highly efflcient and more expensive fllters to extend the life ol the latter.

General

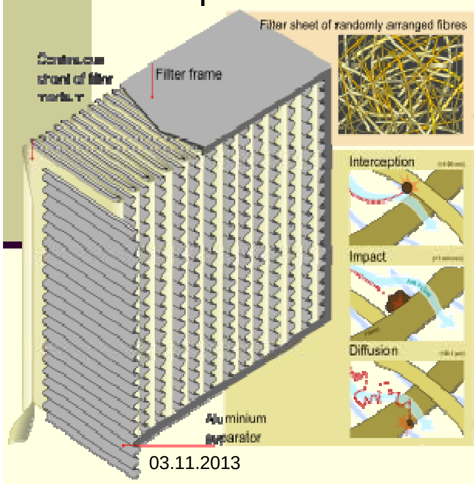
In applications requiring <u>extremely high efflciencies</u>, such as clean rooms and facilities handling radioactive materials or toxic particles, noncleanable pleated media such as

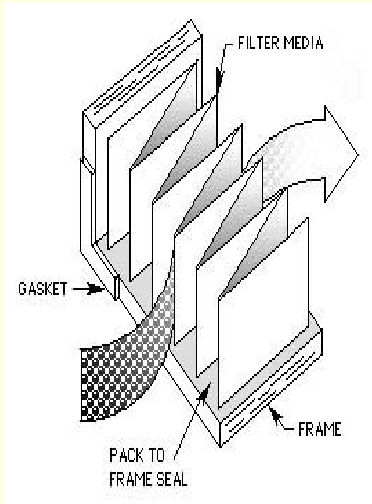
- High Efflciency Particulate Air Filters (**<u>HEPA</u>** fllters) and
- Ultra High Efflciency Particulate Air Filters (**<u>ULPA</u>** filters)

may be employed.

General

- Figures illustrate the HEPA Filters which come in a variety of sizes ranging up to 80cm(W)x 80cm(H) x 30cm(D).
- The HEPA filter, made from flberglass flbers, is typicalty 99.9 percent efficient at 0.1 micron, while the ULPA is 99.9999 percent.





HEPA and ULPA Efficiencies

- An example for mathematical trick of efficiency values of decimal digits:
- 0.1 mic. diameter particles having the concentration of 100 mg/m^3 is to be filtered by HEPA and ULPA filters. The former has an efficiency of 99.9% while the latter has 99.9999%.
- Calculate the particle concentrations of filtered air for each case and compare the results.

Operation Principle

- The important fIltering mechanisms are the three aerodynamic capture mechanisms as
  - inertial impaction,
  - direct interception, and
  - diffusion.
  - electrostatic attraction may also play a role with certain types of dusts/fIber combinations.
- Particles larger than 1 mic. are removed by impaction and direct interception, whereas
- Particles from 0.001 to 1 mic. are removed mainly by diffusion and electrostatic separation

Operation Principle

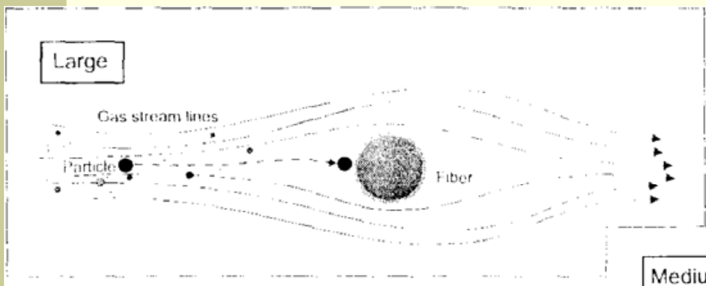


Figure 1-1. Impaction

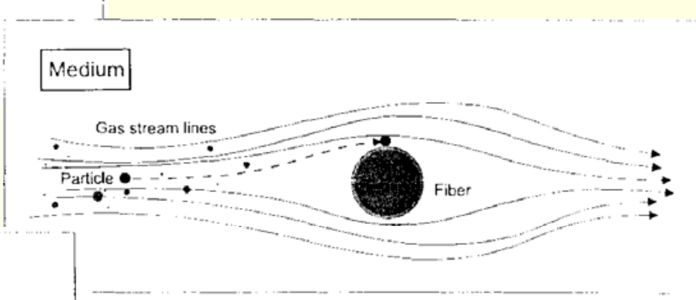


Figure 1-2. Direct interception

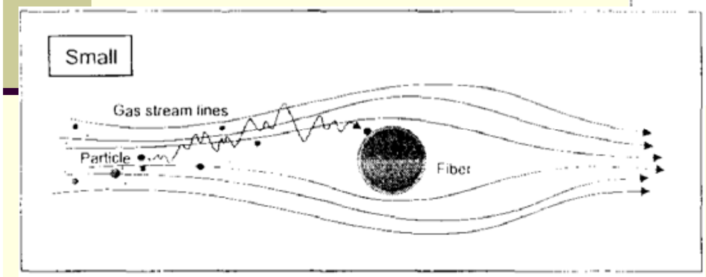
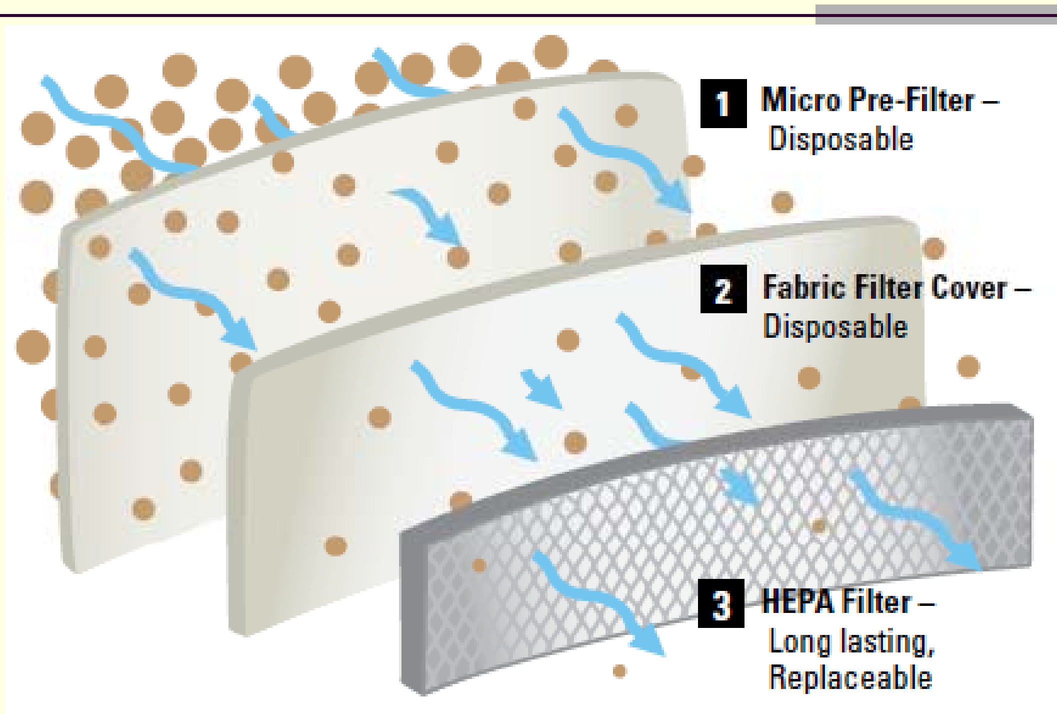
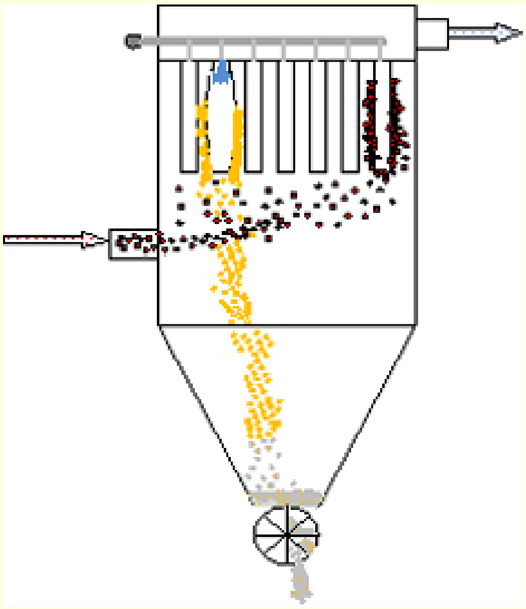


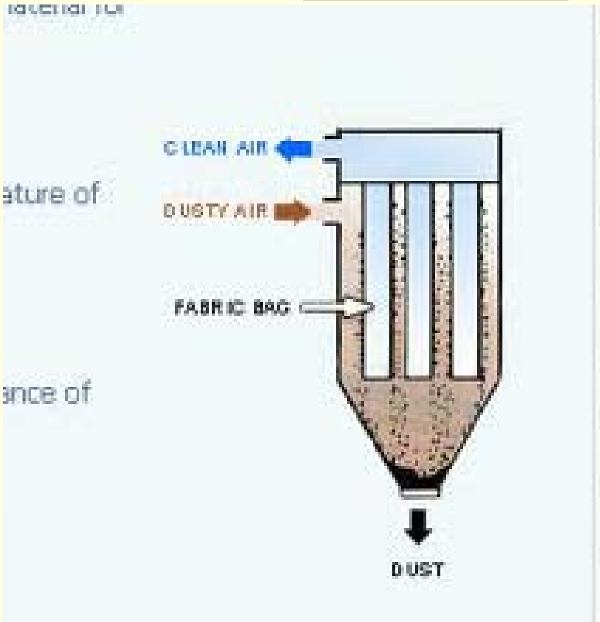
Figure 1-3. Diffusion

Operation Principle



Operation Principle





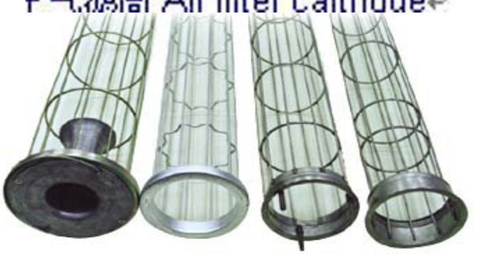
Fabric Filters

- <u>Cleanable fabric fllters</u> have been used extensively for the control of particulate matter <u>in industrial applications</u>.

- <u>The fabric fllters</u> are usually formed into **cylindrical tubes** (or **bags**) and hung in multiple rows to provide large surface areas for gas passage.

Fabric Filters

Fabric Filters



Fabric Filters

Fabric Filters

- <u>The housing</u> is frequently referred to as a <u>baghouse</u>.
- Fabric filters have overall efflciencies that typically range from 99 to 99.99 % on particle size distributions in industrial applications.
- Efflciencies are typically 99 % when collecting 0.5 micron PMs, and substantial quantities of 0.01 micron particles can be removed.

- Typical **dust loadings** are from **0.1 to 25 gr/m^3**).

Fabric Filters

- Fabric fllters are made from woven (dokuma), felted (keçe), and knitted (örme) materials with filter weights that generally range from as low as 0,15 kg/m^2 to as high as 0.85 kg/m^2.

- Fibers used in the construction of the fllters and their maximum continuous temperatures of operation are given in the following Table

Fabric Filters

TABLE 23.1
Filter Material Properties

Material	Recommended Max Operating Temp (°F)	Recommended Max Excursion Temp (°F)	Chemical Resistance Acid	Chemical Resistance Base	Abrasion Resistance	Cost (per 8-ft bag)
Cotton	180	200	Poor	Good	Good	$8
Wool	200	230	Good	Poor	Fair	—
Nylon	200	250	Poor	Good	Excellent	—
Polypropylene	200	200	Excellent	Excellent	Excellent	$8
Polyester	275	300	Good	Fair	Excellent	$9
Acrylic	260	285	Good	Fair	Good	$13
Nomex®	375	400	Fair	Good	Excellent	$22
Ryton®	375	400	Excellent	Excellent	Excellent	—
Teflon®	450	500	Excellent	Excellent	Fair	$26
Fiberglass	500	550	Good	Good	Fair	$24
Coated high-purity silica	900	1050	Good	Good	Fair	$150
Ceramic candle	1650	1830	—	—	—	$1000[a]

[a] 60 mm diameter × 1.5 m.

Fabric Filters

- The advantages of hlgher operating temperatures are
  - the concomitant reduction in thermal control requirements and
  - the reduced likelihood of approaching the dew point or the acid dew point.
- That is, less precooling of a hot gas stream before it enters the fabric fllter is required.

Fabric Filters

- The choice of fabric is based on
  - the type of fabric filter collector,
  - the cost of the media,
  - the operating temperature and
  - the physical-chemical characteristics of the particulate matter and carrier gas such as corrosiveness, abrasiveness, combustibility, resistance to alkalinity and moisture content.

These characteristics affect the useful life of the materials.

Fabric Filters

- More recently, materials have been developed, such as ceramic flbers, which have made it possible to operate cleanable fllters at temperatures as high as 980 C.
- Operation of the fllters at a higher temperature reduces the cost of gas cooling; however, the fllter housing is necessarily larger due to the increase in gas flowrate passing through the fllter and may require special materials of construction and expansion joints.

Structure

- An array of bag filters in a housing.
- Inlet and outler ducts for gas passage.
- A dust collection hopper and a suitable dust removal mechanism.
- Bag cleanin mechanism

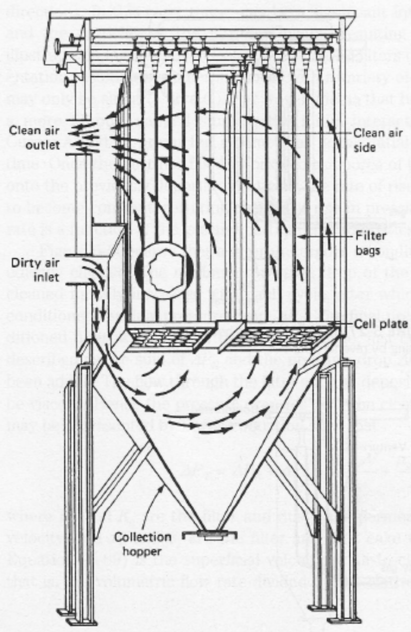


FIGURE 5-26 Typical bag house with mechanical shaking. (Courtesy of Wheelabrator Frye, Inc., Mishawaka, Ind.)

Bag Cleaning Systems

- Reverse air flow cleaning
- Pulse jet cleaning
- Mechanical cleaning
- Sonic horn

Reverse air flow cleaning

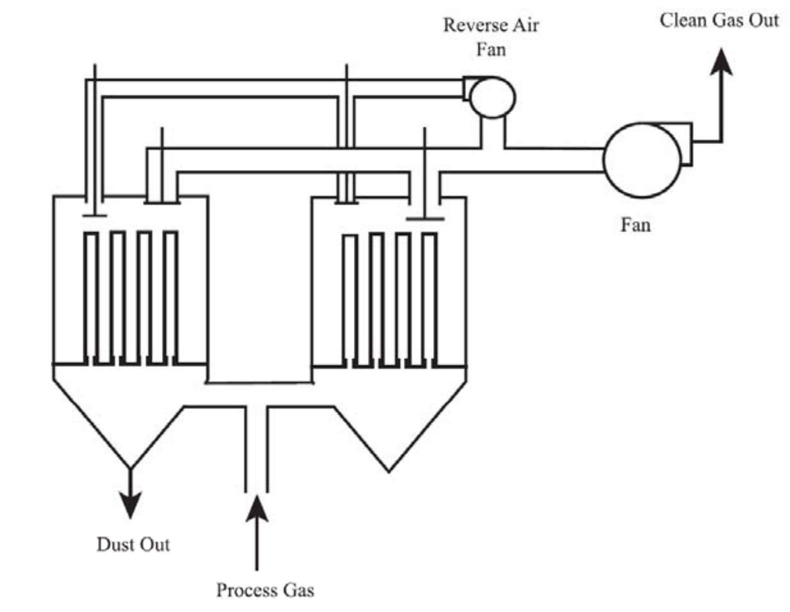
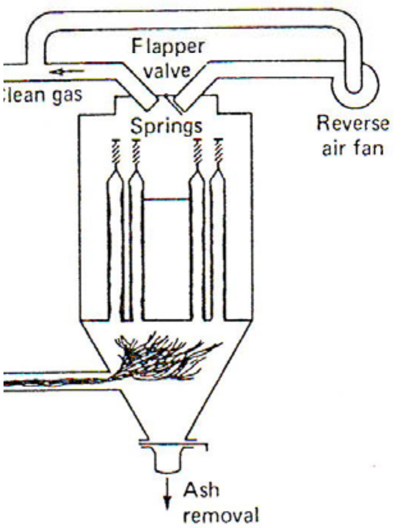
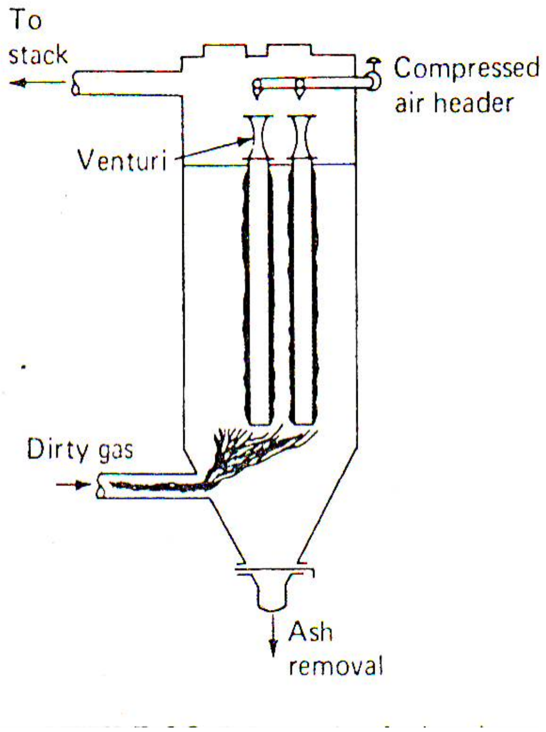


FIGURE 23.2 Reverse air cleaning.



Pulse jet cleaning



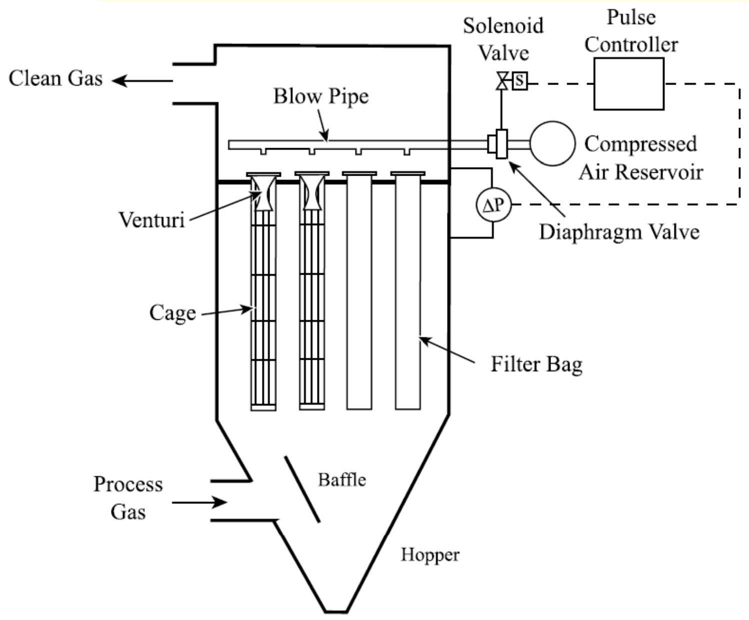
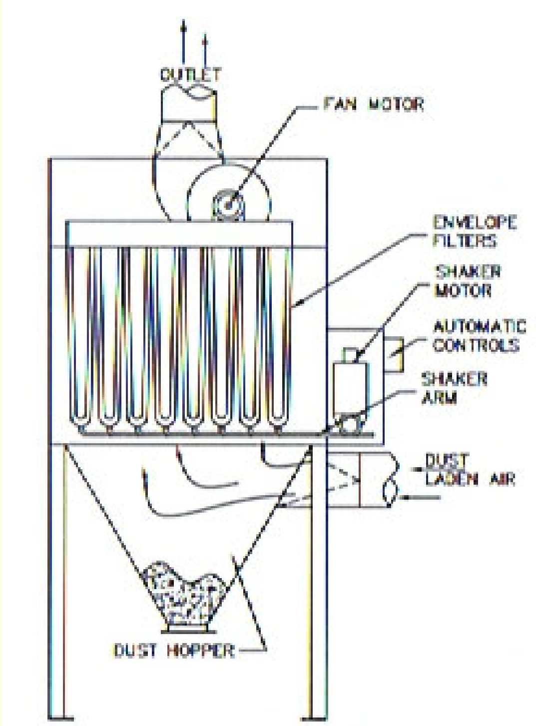


FIGURE 23.4 Schematic of pulse-jet baghouse.

Mechanical cleaning



Sonic horn

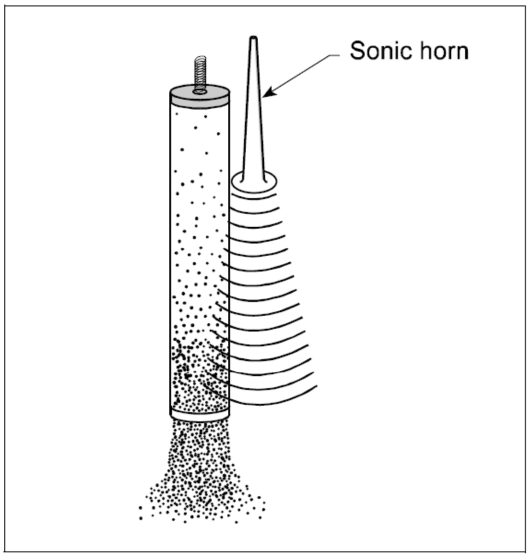
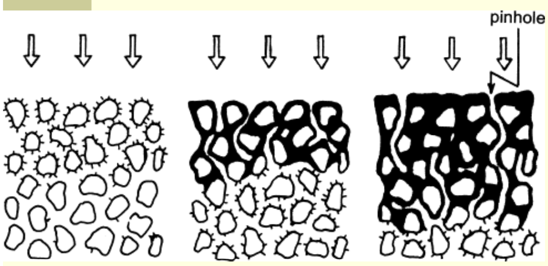
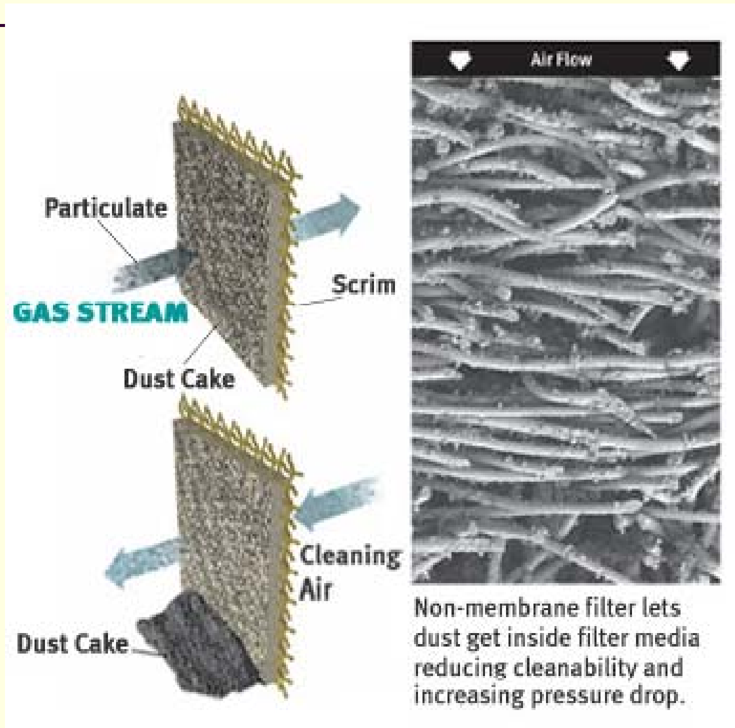


Figure 2-14. Sonic vibrations, usually used along with another bag cleaning mechanism

Pressure Drop during Operation





Pressure Drop during Operation

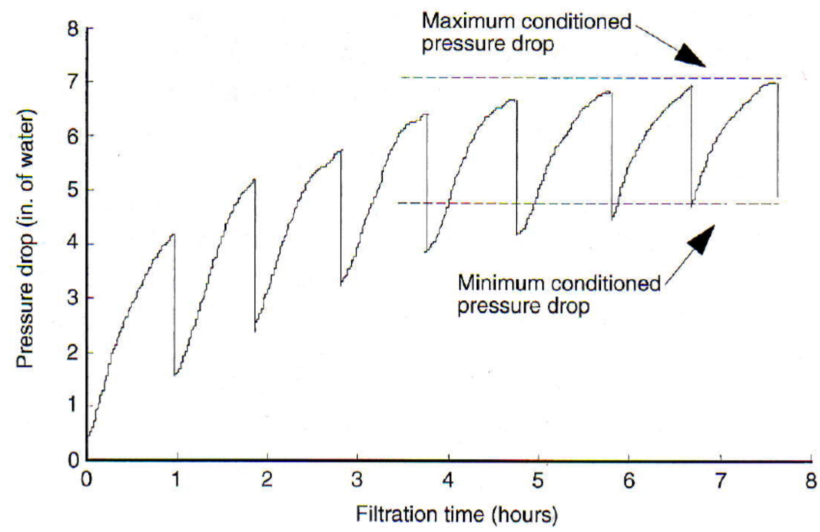


FIGURE 5-30 Pressure drop as a function of time showing the conditioning process for a filter with a 1-hour filtration cycle.

Design of Bag Filters

- **Mechanical Design:**
  - The only objective of a bag filter design is to determine the <u>required filter surface area</u>.
  - Then, determine the operation time period and cleaning frequency

- **Efficiency Determination:**
- Efficiency modelling for bag filters has no applicable theoretical background. But rather, experimental data are used which depend upon the material of filter media.

Mechanical Design

- Design Procedure::
  - Select an appropriate filter material depending upon the physical and chemical properties of dusts and carrying gas stream.
  - If gas cooling is necessary, choose an appropriate cooling method, apply this method and re-calculate the gas flow rate that will enter into bag filter.
  - Calculate the necessary filter surface area which is suitable to the air-to-cloth ratio (filtration velocity) of the selected filter material.
  - Select the appropriate cleaning mechanism and suitable bag dimensions.
  - Calculate the number of bags and arrange in a suitable array
  - Construct the filter unit.
  - Operate the filter unit and set the cleaning time frequency.
  - Determine the overall removal efficiency experimentally.