FABRIC FILTERS

WASTE GASES: PARTICULATE REMOVAL

Particulate is removed to:

- recover valuable material
- protect downstream DUCTS/APCDs, or to maintain APCDs high efficiencies (e.g. SCR, Granular Activated Carbon – GAC – Filters)
- clean the waste gas before emission to the atmosphere (ELVs; BAT-AELs; permitted emission limits, …)
- improve removal efficiency of many pollutants (e.g. heavy metals, micro-pollutants). Fine particles often (perhaps, always!) contain high concentrations of inorganic/organic micro-pollutants!

Fabric filters (baghouses) are generally used for waste gas filtration (Electrostatic precipitators are sometimes used for flue gases).

ELVs and BAT-AELs only refer to the total mass of particulate, mg/Nm^3 (not to PM$_{10}$ or PM$_{2,5}$)

WASTE GASES AND FLUE GASES FILTRATION: ROLE OF TEMPERATURE IN FILTRATION

Filtration efficiency is lower at higher temperatures, because of "normalization" of gas flow and downstream condensation:

- ❑ If a waste gas at 20 °C is filtered through a FF, the dust content is typically reduced to around 0.5 mg/m^3. The calculated concentration at n.c. remains substantially unchanged. i.e. 0.5 mg/Nm^3.
- ❑ If a FF operates at 200 °C, the effective emission value after temperature correction in the cleaned gas becomes: 0.5 x 573/293 = 0.98 mg/Nm^3, that is the double!
- ❑ In addition, the cooling of hot filtered streams, for instance from 200 °C to 100 °C, can produce solid fine dust due to condensation (→ *ammonium salts, semi-volatile metal compounds, organic micro-pollutants, etc. can condensate because of reduction of their vapor pressure)*.

FABRIC FILTERS: $T_{WORK.} > T_{DEW}$

Particulate Control: Baghouse Filter

FABRIC FILTERS - FF

(BAGHOUSES - BH, BAG FILTERS)

(FILTRI A MANICA o A CALZE, MANICHE FILTRANTI)

Similar to conventional home vacuum-cleaners

Don't use a Fabric Filter in case of:

1. High concentrations of combustible and/or explosive dust
2. High concentrations of potentially explosive CO, VOC, or other gases
3. Entrained droplets / too wet air systems
4. High concentrations of "sticky" particulate
5. Very high particulate concentration *(install a pre-cleaner!)*
6. High temperatures (> 250 °C; …new ceramic materials show promise for higher temperature applications) *(Lower Temp. are better!; also install a quencher or a false-air intake, upstream, when T is difficult to control ,or fire is possible!)*
7. Corrosive gases

Fabric filter

Factors negatively affecting efficiency:

1. Filter media
   - Abrasion
   - High temperature
   - Chemical attack
2. High gas filtration velocity, v_g!
3. Broken, or worn bags
4. Fabric blinding (humidity, sticky particulate)
5. Micro- / submicro-particles size
6. Leaks
7. Re-entrainment (→ interstitial (can) velocity, v_c!)
8. Malfunction of discharge equipment
9. Corrosion

Sizing filters with big bags (*long, and/or large***) must take in account their weight (0.3÷0.9 kg/m²);**
Fabric Area = (π D) x H *[side surface, also filtration area!]*
e.g*. H=3 m; D = 15 cm* → ***A = 1.4 m²***

❑ ***Weight of each bag****:* ***up-to 1.3 kg of fabric + weight of the cage!)***

Baghouses: advantages and disadvantages

Advantages

- They have extremely high collection efficiencies even for very small particles
- They can operate on a wide variety of dust types
- They are modular in design, and modules can be preassembled at the factory. They can operate over an extremely wide range of volumetric flow rates
- They require reasonably low preassure drops
- Can collect acid gases (with the addition of powdered lime)
- Can collect mercury (with the addition of powddered activated carbon)

BAG FILTERS HAVE A KEY ROLE IN THE <u>DRY</u> GAS CLEANING

Disadvantages

- They require large floor areas
- Fabrics can be harmed by high temperatures or corrosive chemicals
- They cannot operate in most environments
- They have potential for fire or explosion
- Not well suited for very high dust loads
- Require a lot of maintenance

Fabric filter: primary design factors

Primary **design factors** for *fabric filters* are:

A. the typology of fabric filter
B. the air-to-filter (*A/F*) ratio or filtration velocity
C. the can velocity
D. the pressure drop
E. the materials
F. the auxiliary units: dust hopper and discharge
G. the costs

Design approach

- ❑ With an high collection efficiency **as a «given»,** baghouse design involves optimizing the filtering velocity to balance capital costs (baghouse size) versus operating costs (pressure drops)

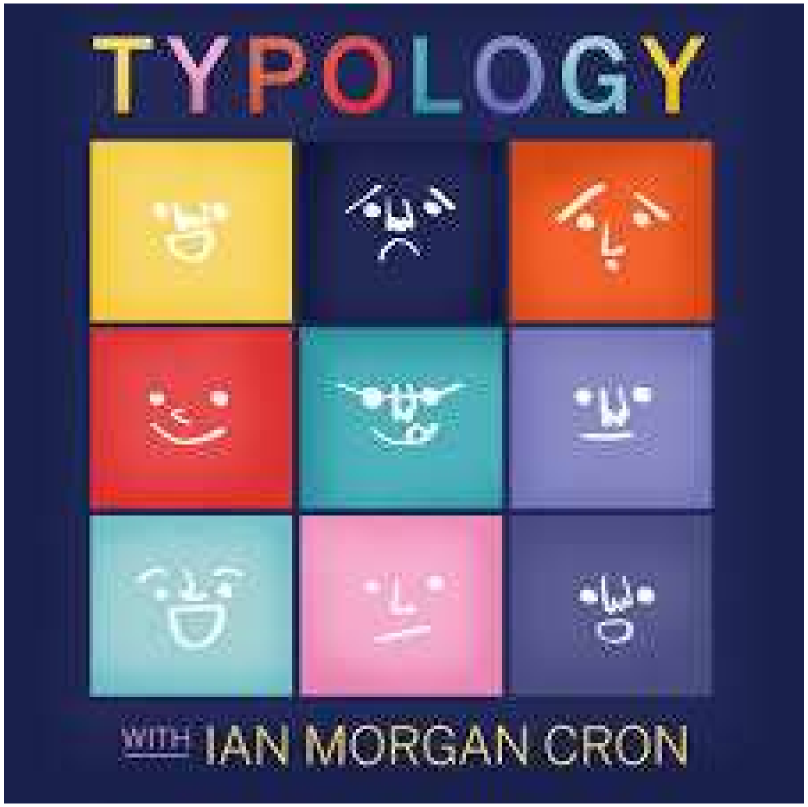
- ❑ Filter media selection
  - gas conditioning for T correction (if needed)
  - cold air mixing: Q increase → higher filtration area
  - heat exchanger: no Q variations, capital cost
  - water spraying: Q increase, moisture increase → higher filtration area, dew point increase (acid corrosion, water condensation on dust panel)

- ❑ Theoretical cloth surface A_N calculation
  - $A_N = Q/v$ where v= filtration velocity

- ❑ Design cloth surface A_L calculation. Correction for compartments and cleaning system effects
  - $A_L = n(1+m)/m\ A_N$
  - m = number of compartments
  - m ≥2 for mechanical/reverse air cleaning (this is not necessary for pulse jet Baghouse)
  - n = cleaning system correction factor

    n =1.33: mechanical system
    n = 1.25: reverse air
    n = 1: pulse jet

A.
FABRIC FILTER TYPOLOGY



Design consideration and types

With a high collection efficiency as a «given», baghouse design involves optimizing the filtering velocity to balance capital costs (baghouse size) versus operating costs (pressure drops)

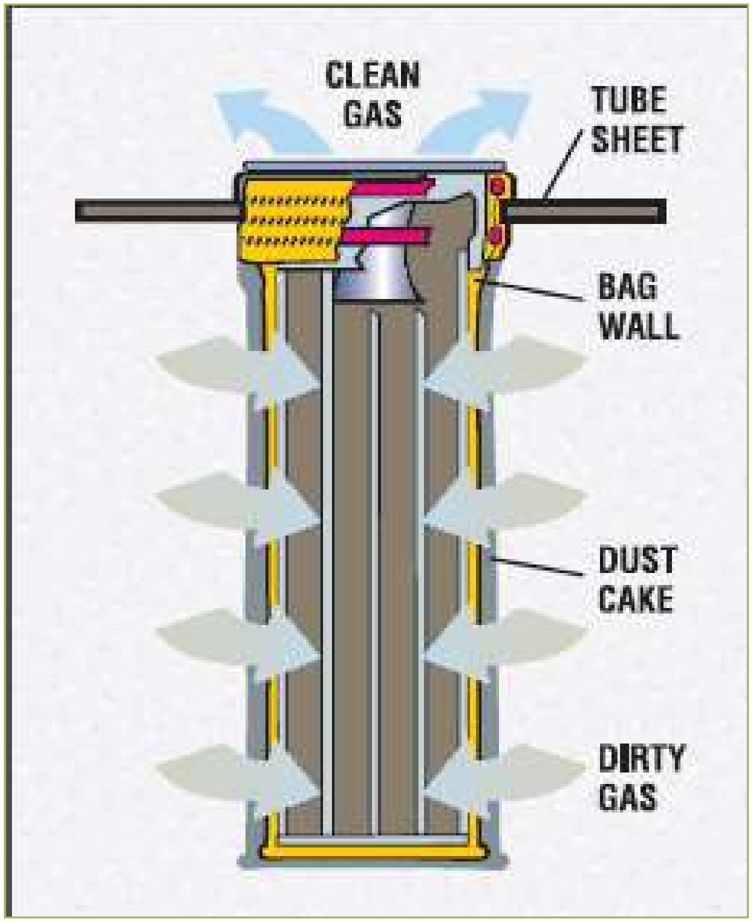
A) Jet-Pulse (exterior filtration)

B) Shaker (interior filtration) – not discussed

C) Reverse Air (interior filtration) – not discussed

Different methods for cleaning the dusts

Fabric Filters: pulse jet system



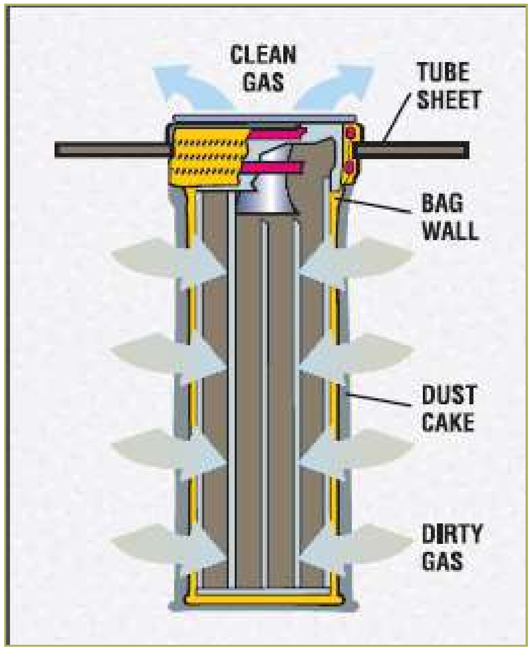
The exhaust stream enters the bags through their felt walls.

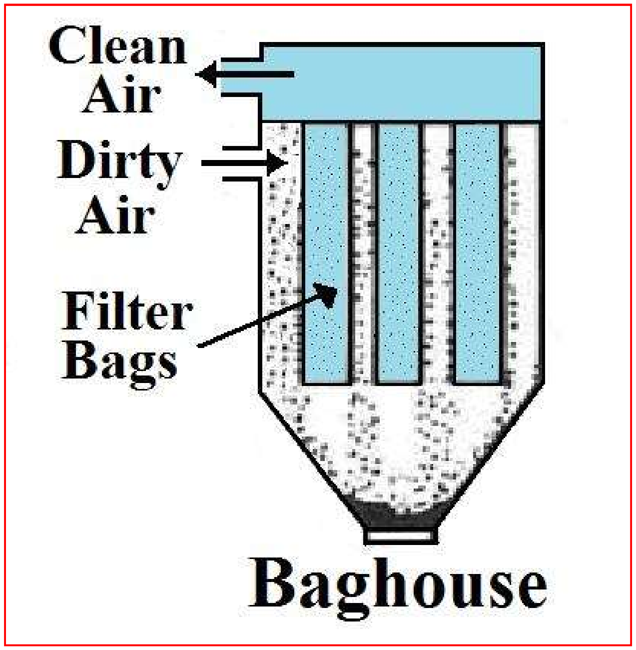
Dust does not pass through the felt walls and accumulates on the **outside** of the bags. As the dust accumulation increases, periodic cleaning of the bags becomes necessary.

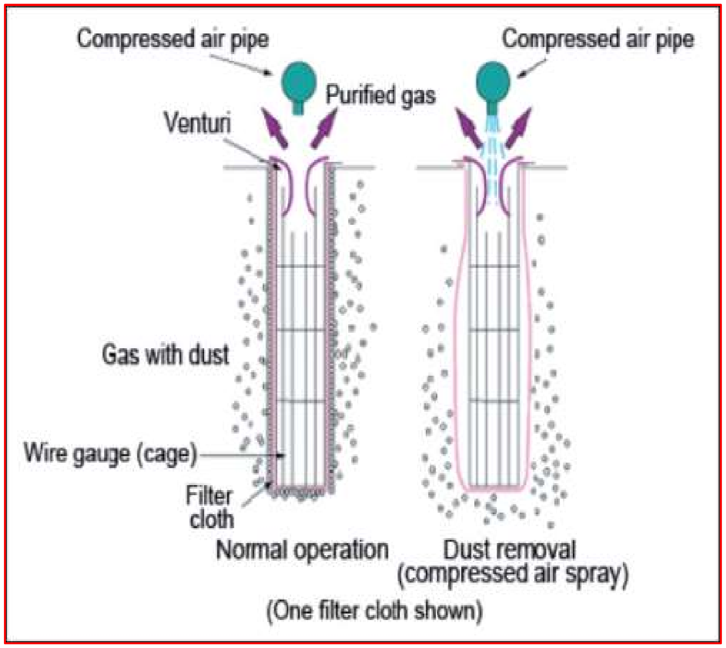
(Although there are several types of cleaning systems, **the pulse jet system is most common in the industry.**)

Baghouse application and operation: *Jet-pulse configuration*

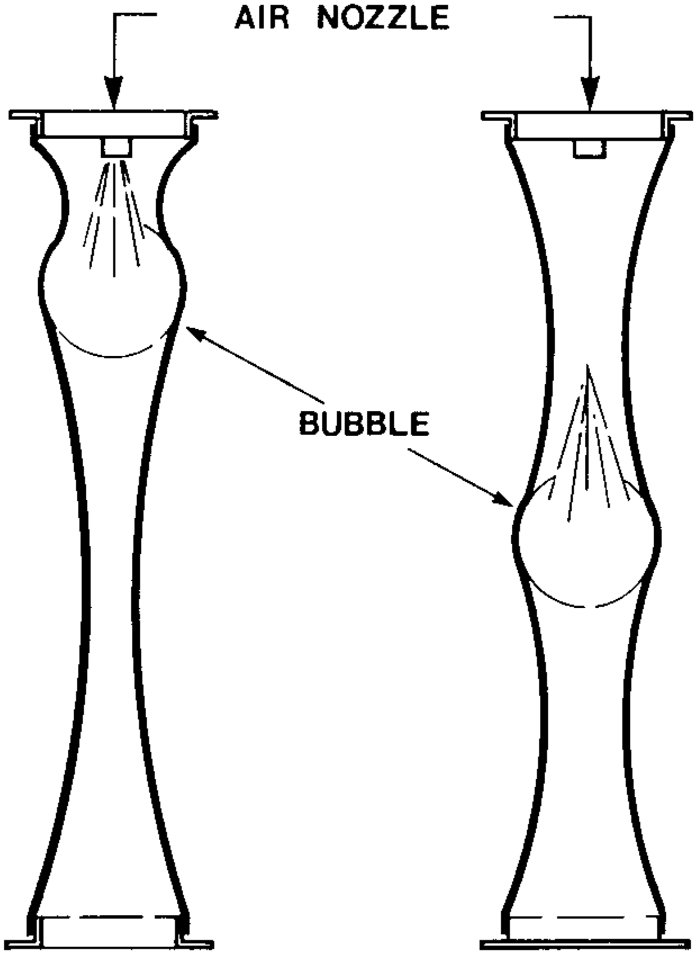
- **OPERATION: Particulate Matter collected by many filters (bags)**
  - Dusty air enters and crosses the fabric at low velocity (**ext. → int.**)
  - PM falls to bottom, during filter cleaning
  - Under suction, cleaned air exits







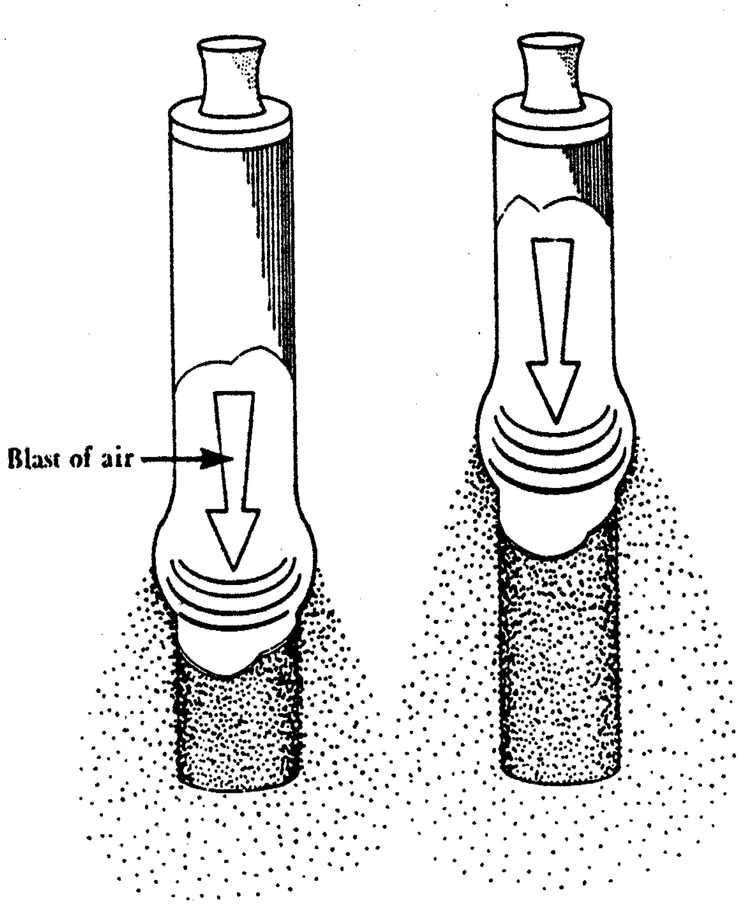
Pulse-jet cleaning mechanism

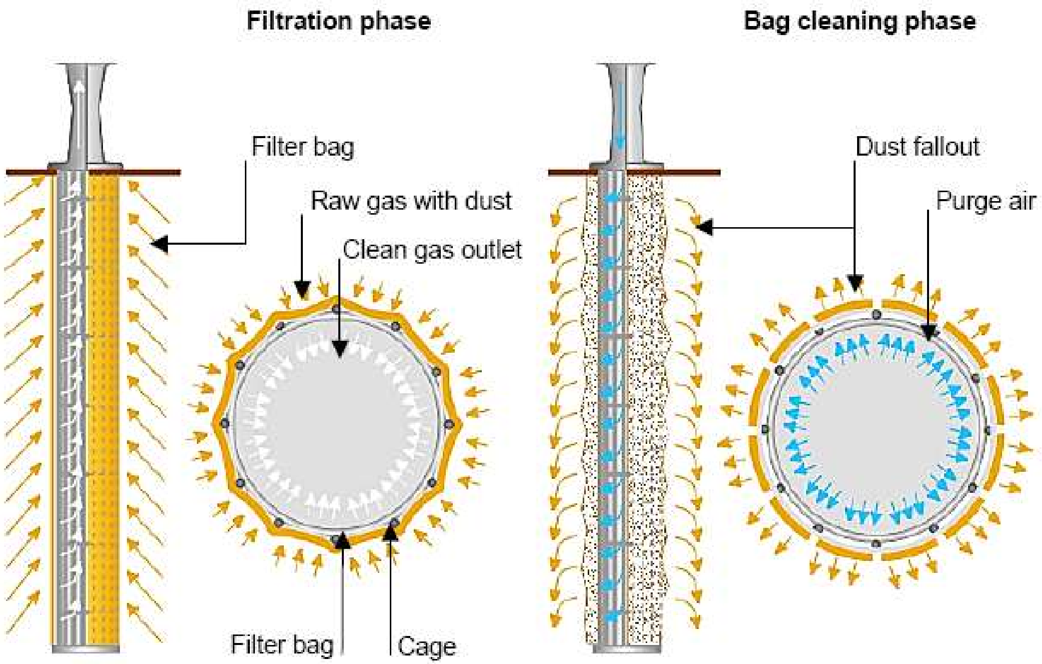


*During pulse-jet cleaning, a short burst, **0.03 to 0.1** seconds in duration, of high pressure [**4 to 8 bar**] air is injected into the bags.*
*The cleaning cycle is regulated either by a **remote timer** connected to a solenoid valve, or cleaned-on-demand (The process of cleaning the bags based on **differential pressure** as opposed to a timer).*

*The burst of air is controlled by the solenoid valve and is released into **blow pipes** that have nozzles located above the bags. The bags are usually cleaned row by row, in the same compartment.*

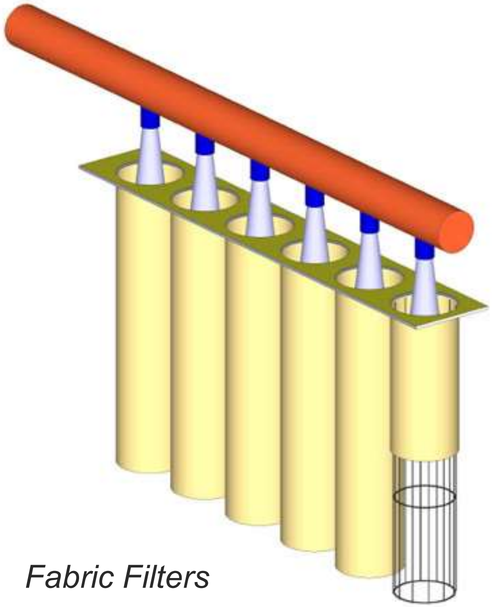
Pulse-jet cleaning mechanism





Baghouse application and operation:
Jet-pulse configuration

CYLINDRICAL WIRE CAGE



Manifold pipes (blow pipes) provide short pulses of compressed air (4 to 8 bar) with equal cleaning force to each filter bag for good cleaning efficiency and long bag life.

Manifold pipes simultaneously clean entire rows of bags.

Baghouse application and operation:
Jet-pulse bags size

DIAM.: pulse-jet baghouses use 10 to 15 cm diameters bags (4 *to 6 in., more often 5" and 6").*
LENGTH: usually about 3 m (10 to 12 ft, but can be as long as 20 ft (6.1 m);
standard lengths (feet): 8, 10, 12, 14, 16, and 20.

Baghouse application and operation: *Designs*

Exterior filtration

In exterior filtration systems, dust is collected on the outside of the bags.

The waste gas crosses the bag and the clean gas exits from the inside of the bag, as shown in figure.

Rigid bag supports are necessary.

Bags are attached at the top to a **tube sheet** and are closed at the bottom by an end cap.

WIRE CAGE

Exterior filtration: wire cages and bags

Cages are available in **6, 10, 12, 16, 18, 20 & 24 vertical wire designs**, which can be constructed from bright wire, galvanized wire and **stainless steel**. **Also, recently, painted and enamelled wires!**

Filter Bags and cages

Each filter bag **incorporates a stainless steel snap ring** sewn into the top of the bag which, when fitted, locates securely in the tube sheet effecting a seal.

To support the fabric of the bag a mild steel wire (or stainless steel) cage is provided.

The cage is designed to support the fabric evenly and restrict flexing and abrasion of the filter bag whilst allowing optimum dust release at the time of cleaning. The cage will be without joints as standard, but can be offered with a split joint if required.

Each cage consists of 10 or 16 vertical wires (seldom 6), depending of the choice of the fabric, evenly spaced about its' circumference which are, in turn, attached to horizontal bracing rings placed at appropriate intervals along its' length.

Baghouse application and operation:
Empty Tubesheet

TUBE SHEET = metal plate *(reinforced with iron beams)*

Separation between the dusty stream (<u>below</u>) and the cleaned stream (<u>above</u>).

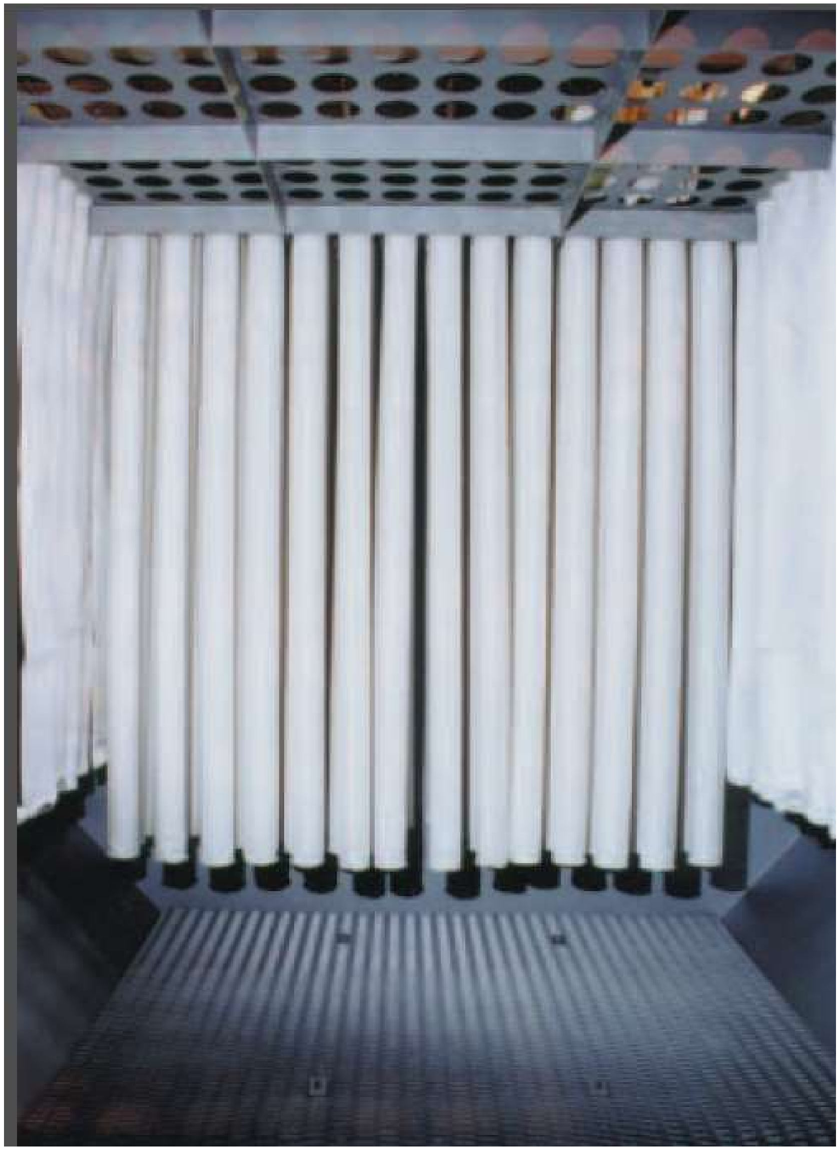
Tube sheets hold heavy weights: WIRE CAGES + BAGS!

Pulse-jet baghouse (Filtration OUT and IN)

Photo of snap ring and a diagram of a snap ring and tube sheet

Baghouse application and operation: cylindrical wire (bag)cages

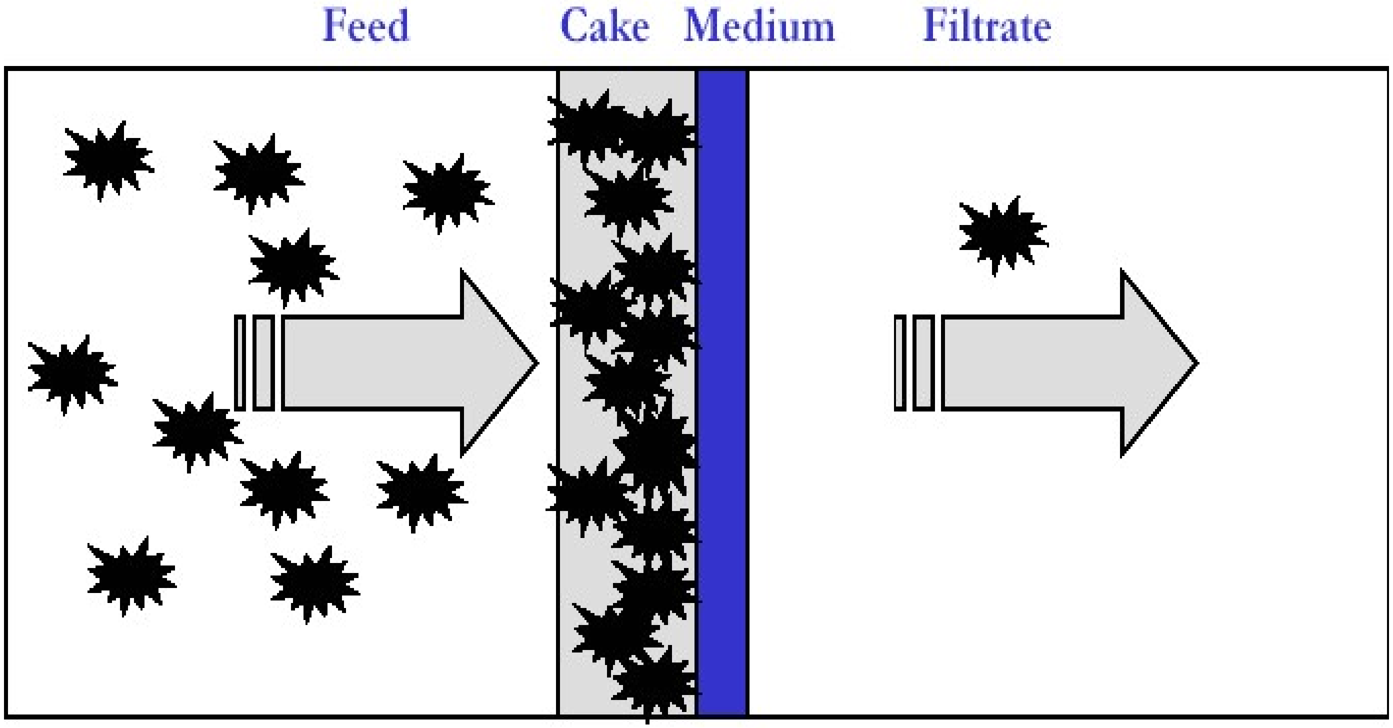
Inside of Baghouse



Baghouse particular

Bag, cage and venturi assembly is easily removed and replaced.

Fabric filter

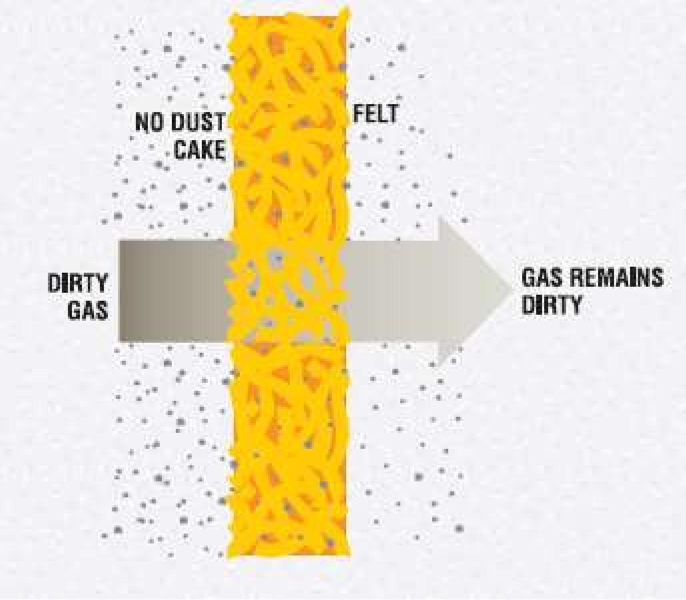


$$P_{\mathrm{INLET}} > P_{\mathrm{OUTLET}}$$

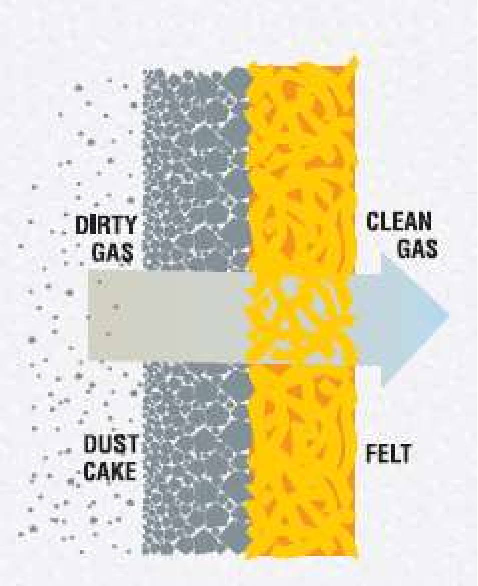
ΔP *Pressure drop*

ΔP = an important parameter in <u>all</u> gas cleaning sections, continuously measured (*and recorded*); sudden drop in case of damage. Too high ΔP values must be avoided→ possible damages, higher running costs, …)

The dust cake



FELT WITHOUT A DUST CAKE FILTERS POORLY



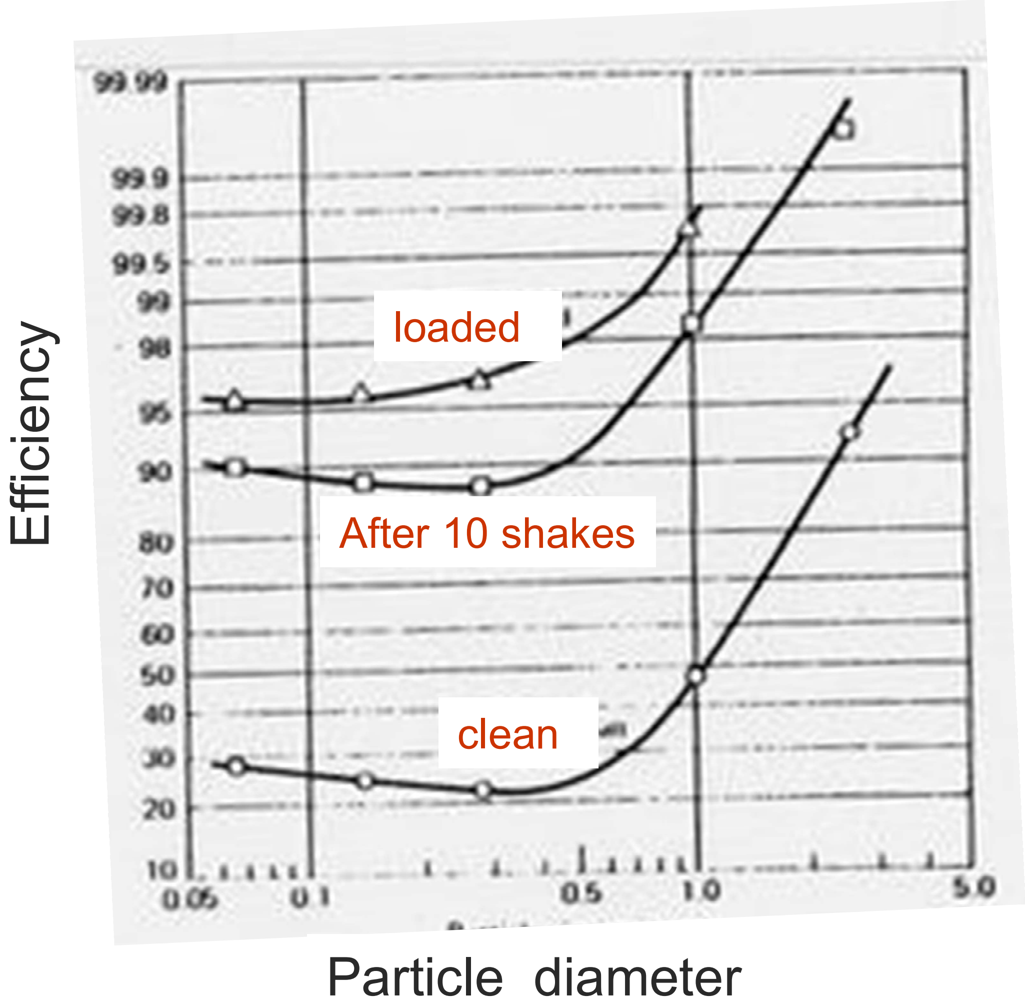
FILTERING FUNCTION OF DUST CAKE

The dust accumulation on the bags is referred to as the “**dust cake**” and it is of critical importance in the performance of the baghouse**.**

The dust cake is actually the working filter: without a dust cake the system can only collect relatively large particles.

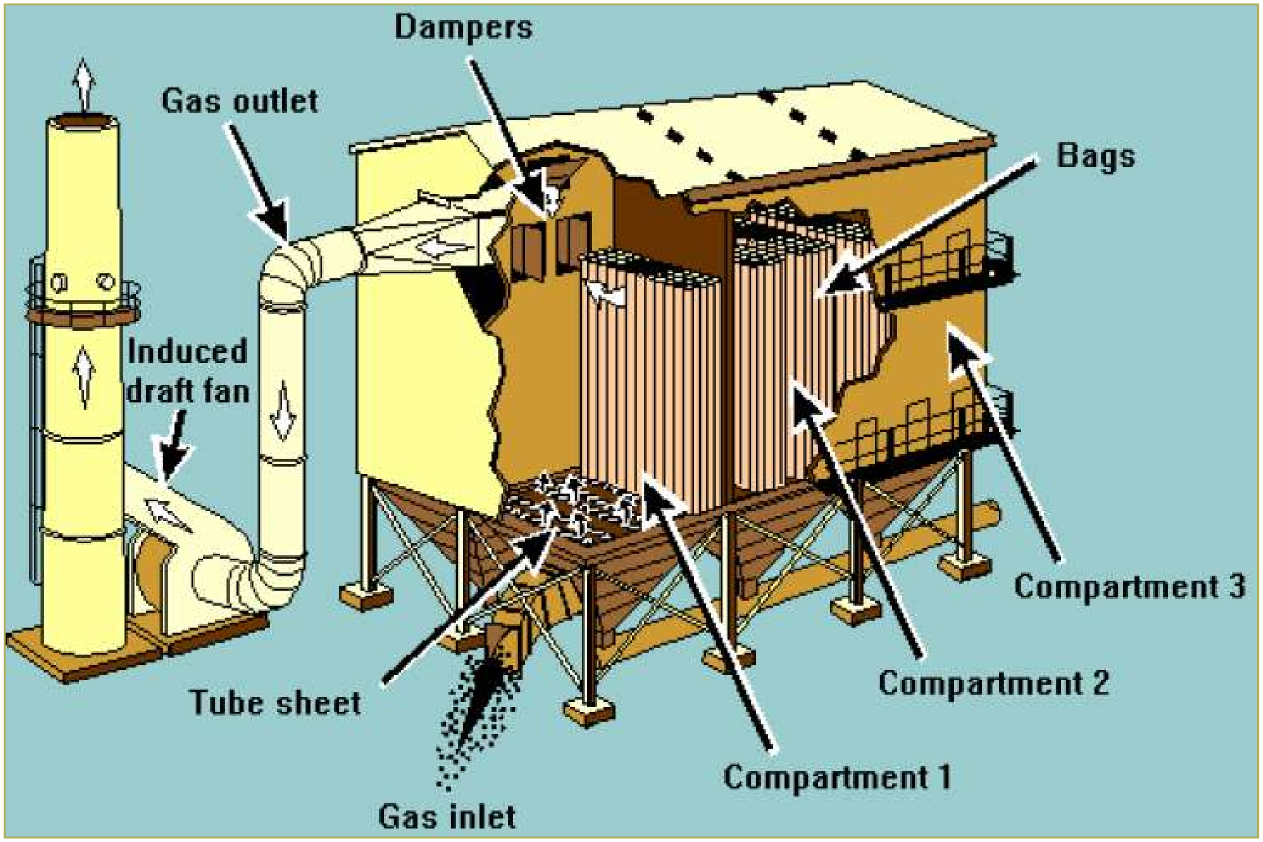
A baghouse with a good dust cake can collect particles as small as 1.0 micron, **with 99.99% overall efficiency** and can even collect some submicron particles.

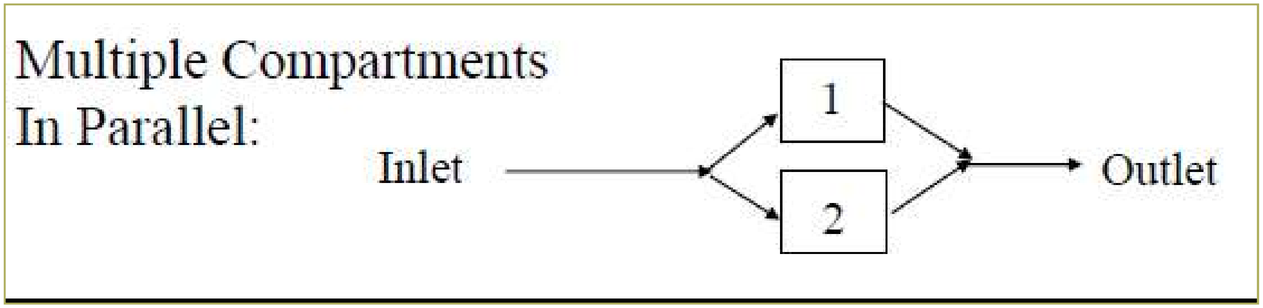
Baghouse efficiency



Shakes, or jet pulse cleaning cycles.

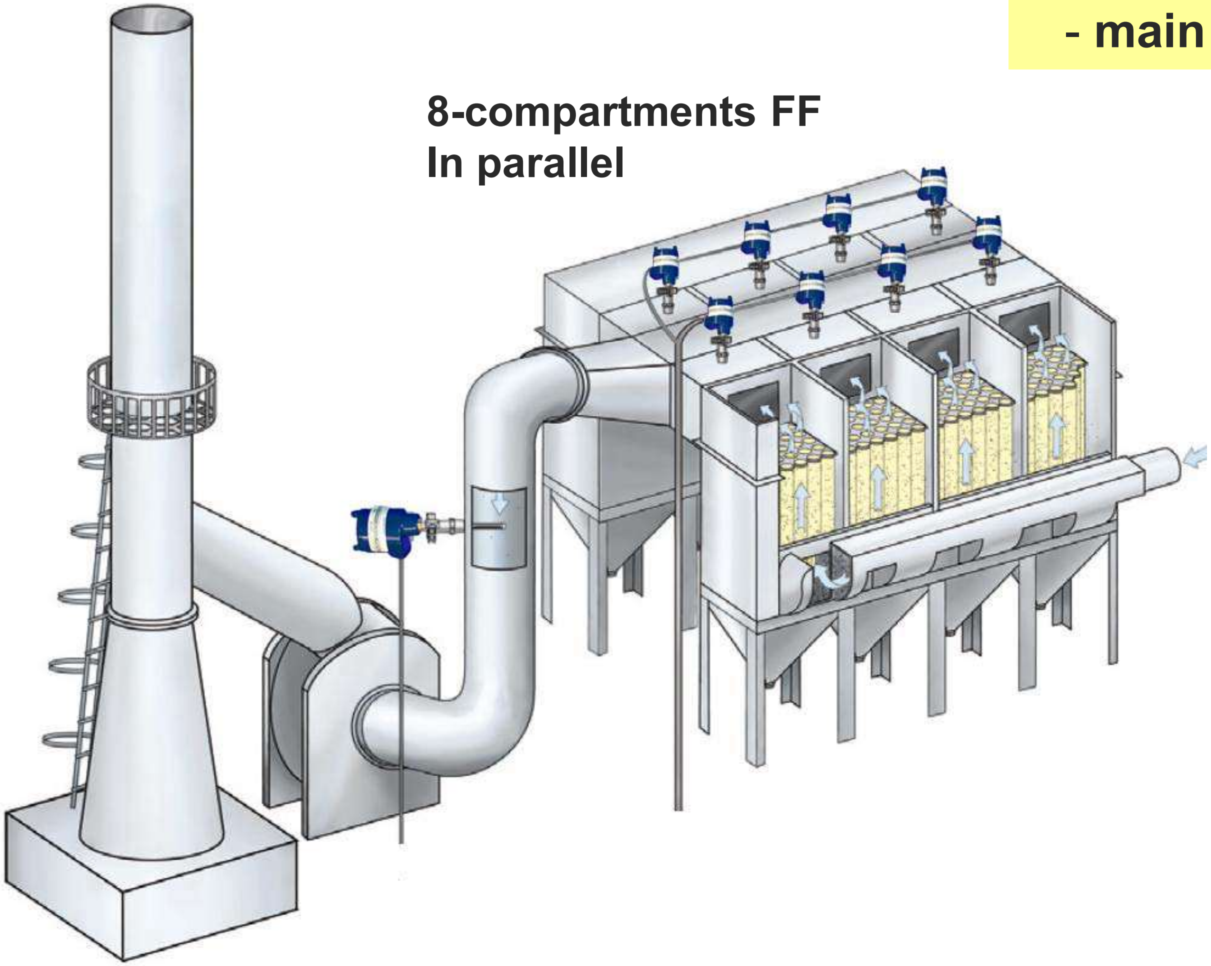
Bags and Compartments




Multiple Compartments In Parallel:

Baghouse Configuration: sometimes with few compartments

Dust monitoring systems in:
- each compartment duct
- main duct (EXIT)



8-compartments FF
In parallel

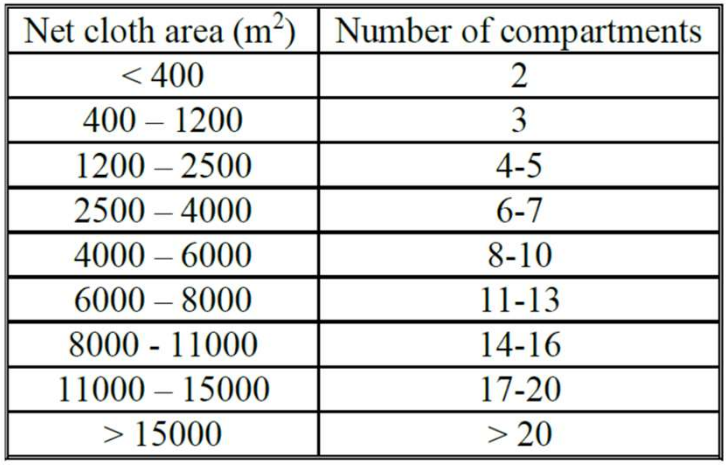
Wastegas Inlet

A large baghouse

Remember that some compartments are off-line for cleaning (no for pulse inject design)

A 20-compartment baghouse at a cement processing plant.

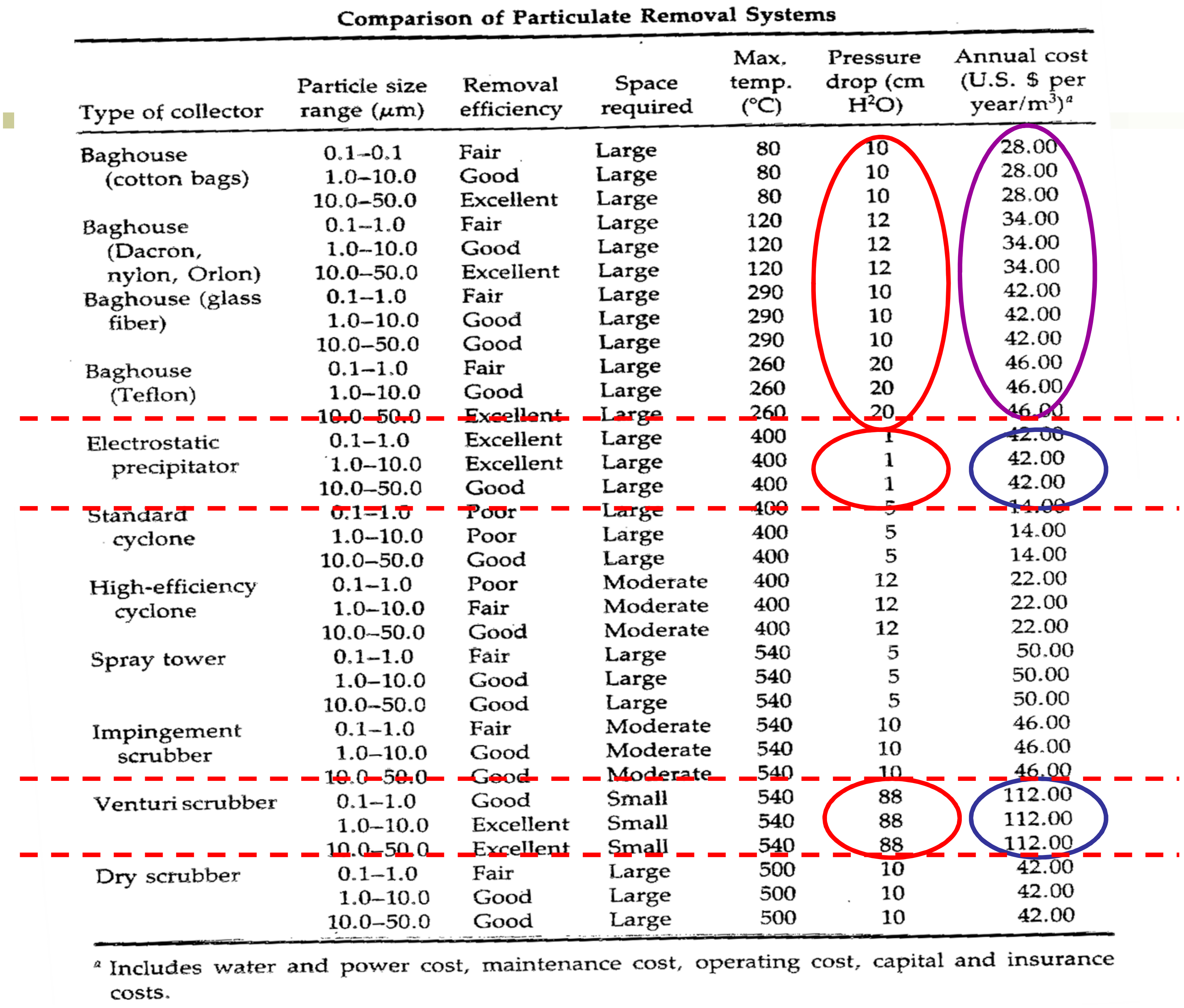
Compartments



Net cloth area (m^2)	Number of compartments
< 400	2
400 – 1200	3
1200 – 2500	4-5
2500 – 4000	6-7
4000 – 6000	8-10
6000 – 8000	11-13
8000 - 11000	14-16
11000 – 15000	17-20
> 15000	> 20

As general guide, the table presents information on the number of compartments typically used as a function of the **net cloth** (the fabric area that is left on-line while one compartment is being clean)

A major advantages of the pulse-jet method is that it allows the cleaning of some of the bags while dusty air continues to flow through the baghouse. There are no compartments and thus no extra bags, which reduces the size and the cost. However, it should be noted that when designing a pulse-jet fabric filter fo a large plant (ex. Coal-fired power), the baghouse is so large that is designed with separate compartments.



Comparison of Particulate Removal Systems

Type of collector	Particle size range (μm)	Removal efficiency	Space required	Max. temp. (°C)	Pressure drop (cm H^2O)	Annual cost (U.S. $ per year/m^3)[a]
Baghouse (cotton bags)	0.1–0.1	Fair	Large	80	10	28.00
	1.0–10.0	Good	Large	80	10	28.00
	10.0–50.0	Excellent	Large	80	10	28.00
Baghouse (Dacron, nylon, Orlon)	0.1–1.0	Fair	Large	120	12	34.00
	1.0–10.0	Good	Large	120	12	34.00
	10.0–50.0	Excellent	Large	120	12	34.00
Baghouse (glass fiber)	0.1–1.0	Fair	Large	290	10	42.00
	1.0–10.0	Good	Large	290	10	42.00
	10.0–50.0	Good	Large	290	10	42.00
Baghouse (Teflon)	0.1–1.0	Fair	Large	260	20	46.00
	1.0–10.0	Good	Large	260	20	46.00
	10.0–50.0	Excellent	Large	260	20	46.00
Electrostatic precipitator	0.1–1.0	Excellent	Large	400	1	42.00
	1.0–10.0	Excellent	Large	400	1	42.00
	10.0–50.0	Good	Large	400	1	42.00
Standard cyclone	0.1–1.0	Poor	Large	400	5	14.00
	1.0–10.0	Poor	Large	400	5	14.00
	10.0–50.0	Good	Large	400	5	14.00
High-efficiency cyclone	0.1–1.0	Poor	Moderate	400	12	22.00
	1.0–10.0	Fair	Moderate	400	12	22.00
	10.0–50.0	Good	Moderate	400	12	22.00
Spray tower	0.1–1.0	Fair	Large	540	5	50.00
	1.0–10.0	Good	Large	540	5	50.00
	10.0–50.0	Good	Large	540	5	50.00
Impingement scrubber	0.1–1.0	Fair	Moderate	540	10	46.00
	1.0–10.0	Good	Moderate	540	10	46.00
	10.0–50.0	Good	Moderate	540	10	46.00
Venturi scrubber	0.1–1.0	Good	Small	540	88	112.00
	1.0–10.0	Excellent	Small	540	88	112.00
	10.0–50.0	Excellent	Small	540	88	112.00
Dry scrubber	0.1–1.0	Fair	Large	500	10	42.00
	1.0–10.0	Good	Large	500	10	42.00
	10.0–50.0	Good	Large	500	10	42.00

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[a] Includes water and power cost, maintenance cost, operating cost, capital and insurance costs.

B.

FILTRATION VELOCITY (AIR-TO-CLOTH RATIO)

Filtration velocity

Filtration velocity (different from can velocity, as reported in the next slide) is commonly referred to as the **air-to-cloth ratio (A/C)**, **face velocity (v_F)**, or **superficial velocity (v_s)**.

It is equal to the volumetric gas flow rate divided by the cloth area:

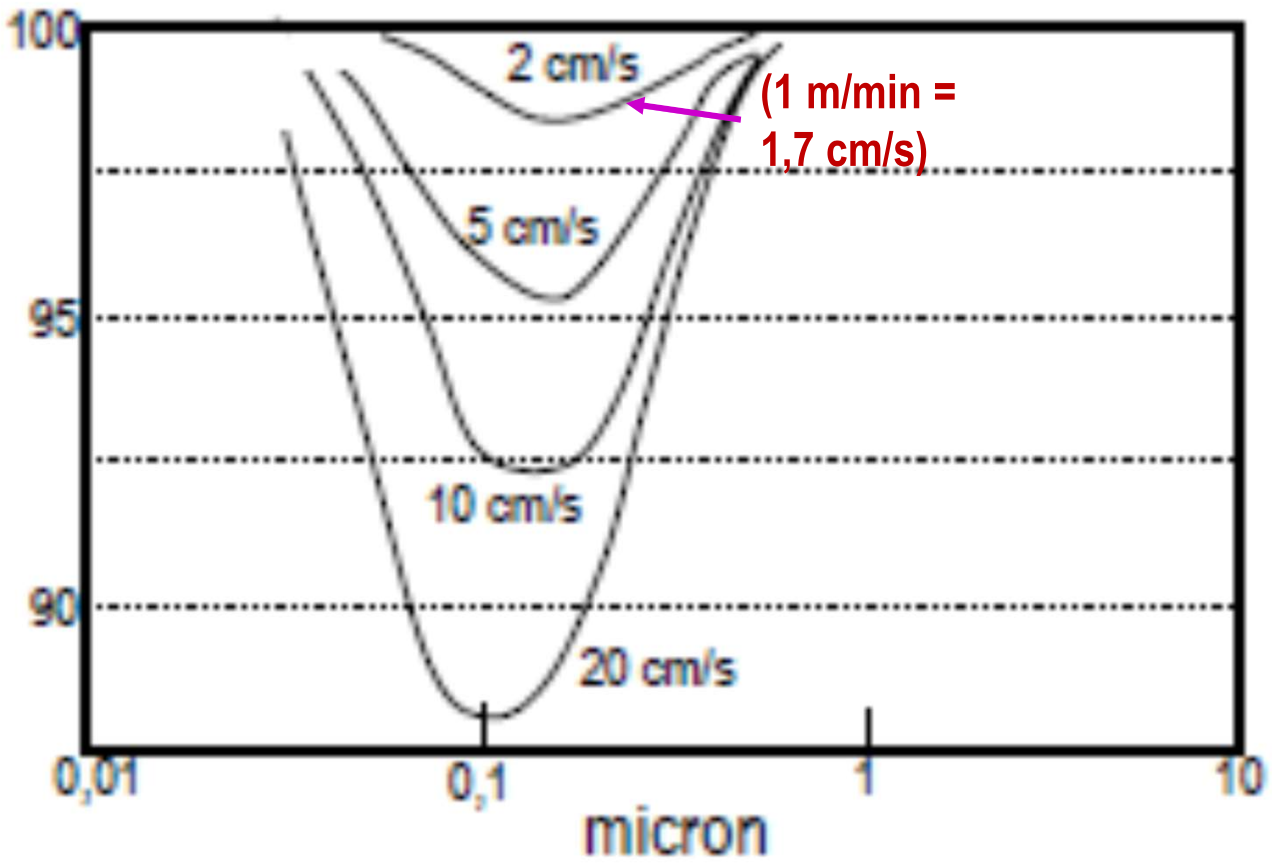
$$v_S = \frac{Q}{A}$$ *[m/min]*

Where:

- Q = volumetric gas flow rate (m^3/min)
- A = cloth area (m^2)

Table	**Typical air-to-cloth ratio (filtration velocity)**	
Cleaning mechanisms	**Air-to-cloth ratio ($(m^3/min)/m^2$)**	**Filtration velocity (m/min)**
Pulse-jet	**0.5 to 2:1**	**0.5 to 2:1**

Total collection efficiency as a function of dp for different face velocities

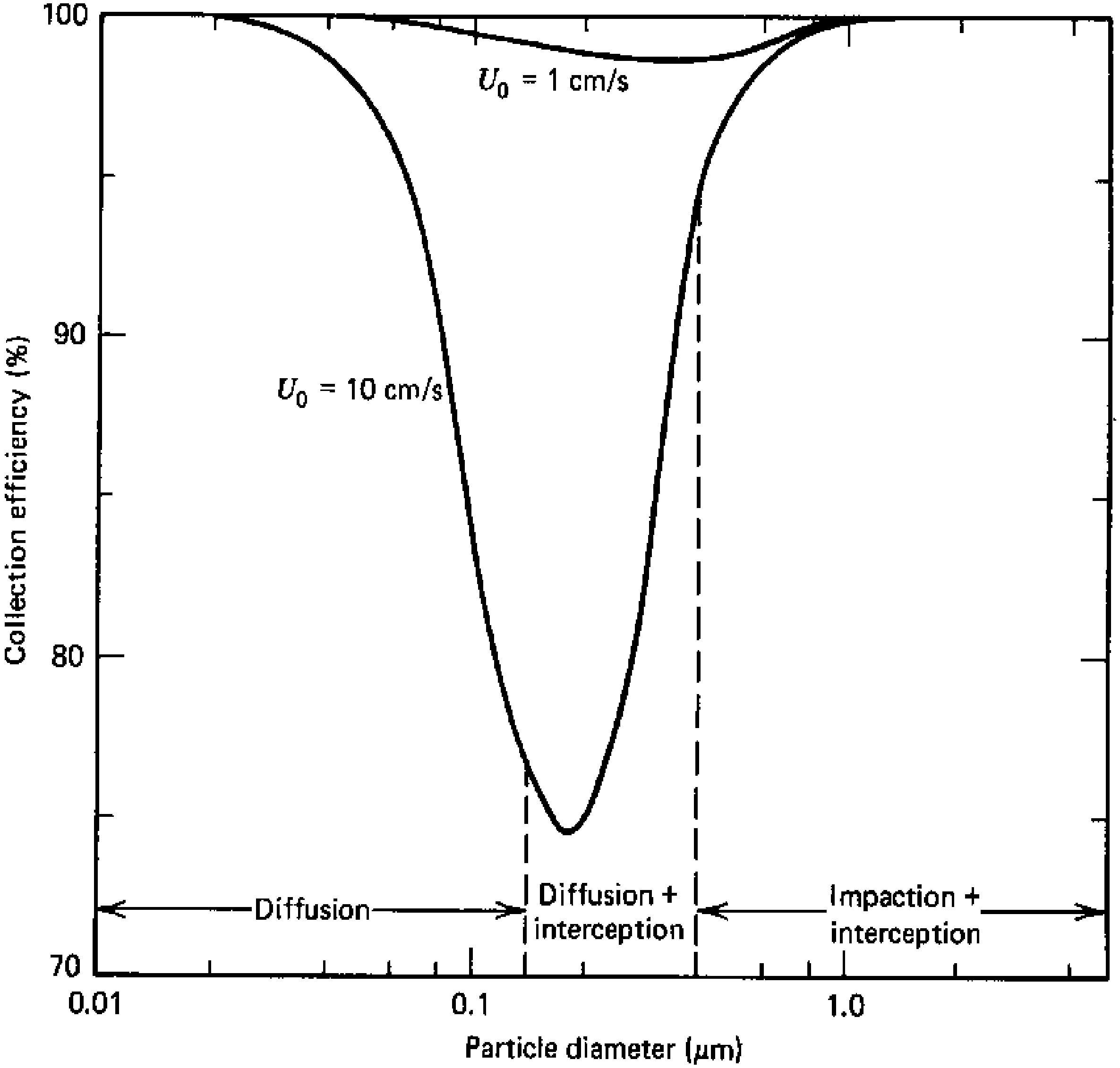


(1 m/min = 1,7 cm/s)

Total collection efficiency as a function of dp for different face velocities

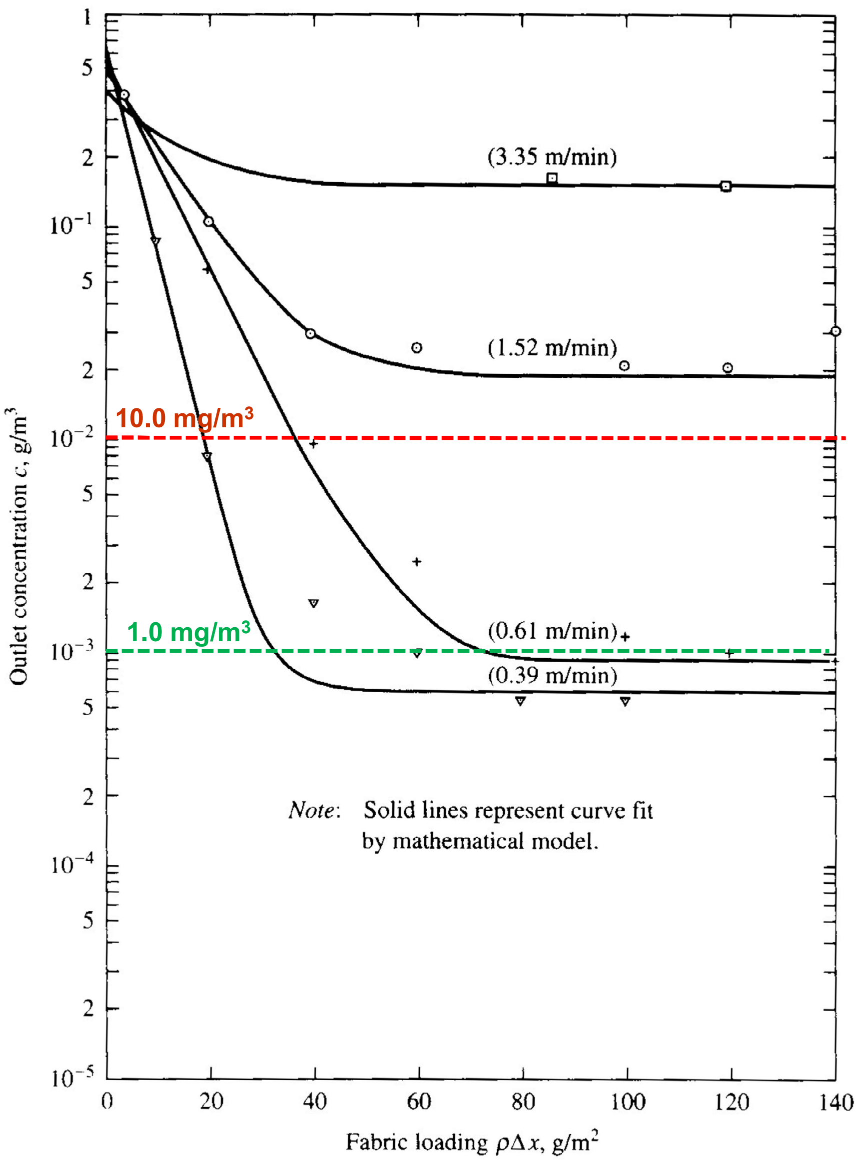
Different names for it:

- Filtration velocity v
  or
- air-to-cloth ratio (A/C),
  or
- face velocity (v_F; u_0),
  or
- superficial velocity (v_s).



Total collection efficiency as a function of d_p for different face velocities

Filtration efficiency



Note: Solid lines represent curve fit by mathematical model.

FILTRATION EFFICIENCY *vs.*

1. filtration velocity;
2. fabric loading g/m²

If the superficial velocity increases, the efficiency falls!

If v_g = 3.35 m/min the outlet concentration is about 20 (0,2g/m3) percent of the inlet concentration → *η = 80%.*

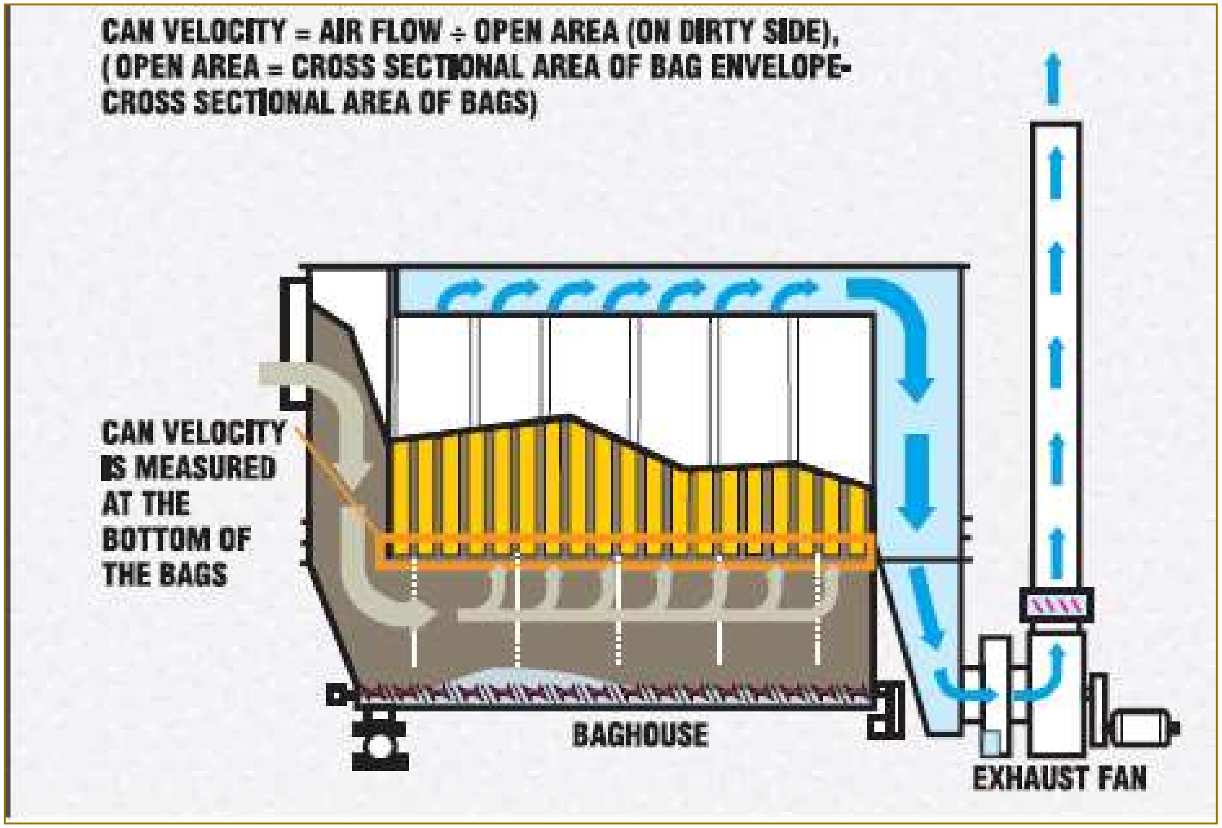
$$v_S = \frac{Q}{A} \quad [m/min]$$

Effect of fabric loading (mass of collected participles per unit area) and face velocity on filtration efficiency concentration. For all the tests, the inlet concentration was about **0,8 g/m3**)

C.

CAN VELOCITY

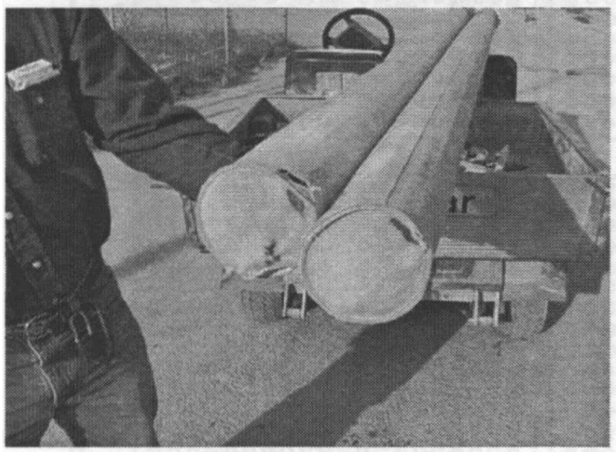
Can velocity



CAN VELOCITY = AIR FLOW ÷ OPEN AREA (ON DIRTY SIDE), (OPEN AREA = CROSS SECTIONAL AREA OF BAG ENVELOPE- CROSS SECTIONAL AREA OF BAGS)

Bags failure

Too high upward gas velocity → **abrasion**



BHs should be designed for <u>can velocities</u> between 80 m/min and 90 m/min.

Can velocities in that range will result in good performance even when difficult situations are encountered: ***max can vel. 120 m/min (=2 m/s)***

Can velocity

Can velocity is the airflow’s upward velocity between the bag filters. It is calculated by dividing the flow of dust-laden air entering the baghouse chamber by the **net flow area** available in the airflow’s direction.

$\mathbf{v_{can} = Q/(A\text{-}B)}$ *m/s*
where
Q = actual gas flow (m^3/s)
A = Area of the tubesheet:
  rectangular base width x length (m^2)
  circular: π x $(diam)^2/4]$ (m^2)
B = Area of the bottom of the bags: (n° of bags) x [π x $(out\ diam)^2/4$] (m^2)

The net flow area (**A-B**) is determined by subtracting the total axial cross-sectional area of the bag filters from the cross-sectional area of baghouse chamber.

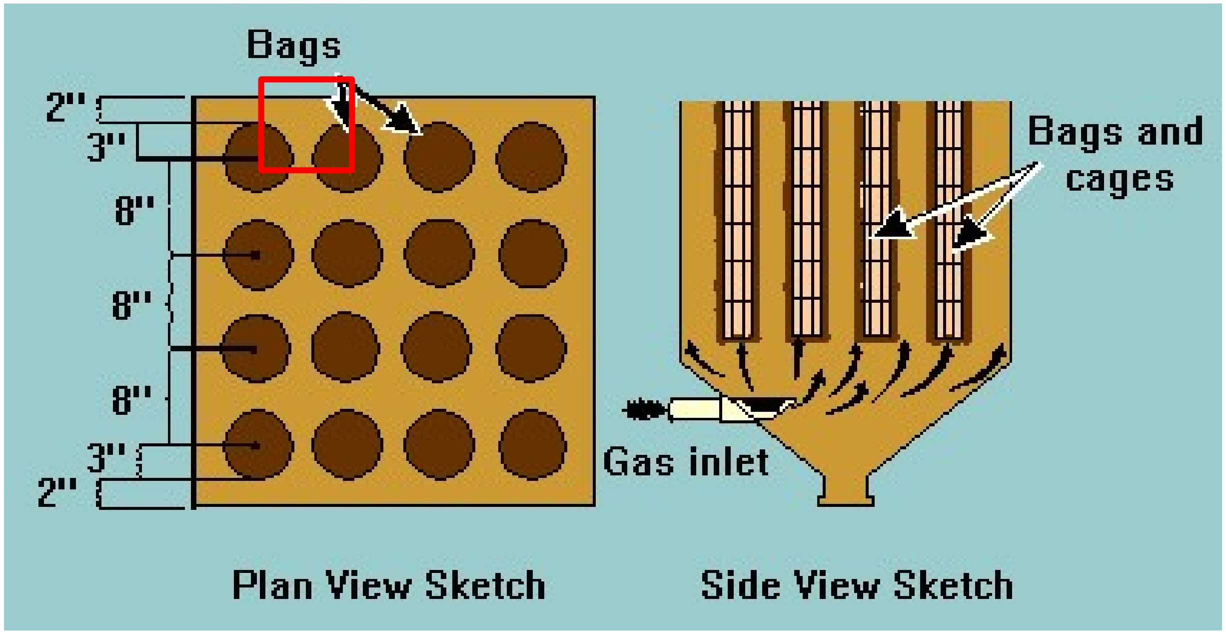
Recommended maximum can velocities V_{can}: 1 – 2 m/s

- Most BHs used in the industry can be handled adequately with interstitial velocities about **2.0 m/s**. **However, can velocity must be lower in case of many sub-micron and/or low density particles!**
- When can velocity is too high for the particular dust, the plant’s capacity will be limited by baghouse pressure drop due to the inability of the baghouse cleaning system to clean properly: dust discharged from the bags is impeded in its fall into the hopper by the force of the upward flow of exhaust gases. Ideally, velocity between the bags should be not **higher than 1.0 m/s**.
- **High can velocities** are obtained when the bags are too close or too long, or the gas flow is too high.

Can velocity

MANY BAGS IN A SINGLE FF
Vertical (tall) bags in a single vessel and small bags diameter to get high filtration area in a small vessel.

Example:



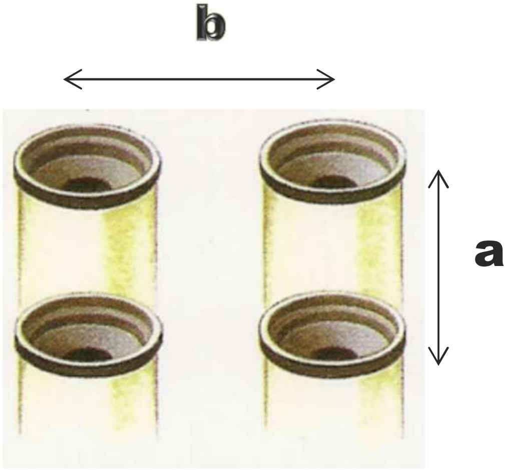
Bag diameter: 6” (= 15 cm)
Distance between bag centers: 8” (= 20 cm)
“Bag spacing”: 8-3-3=2” (= 5 cm)

<u>Note.</u> Nr.1 bag in 8” x 8” area = 20 x 20 = 400 cm^2

Free bag area = total plan area containing Nr.1 bag – cross-section of Nr. 1 bag =
=400 cm^2 - 3,14(15x15)/4 cm^2 = 400 – 177 = 223 cm^2

% Free area = 223/400 = 56%

Can velocity



a = b

Can velocity (or ***interstitial***, *or, approach velocity*)

To prevent excessive dust loading, a pulse Bag House must provide sufficient filtration area and an adequate dropout area.

The dropout area is the interstitial area.

Can velocity: abrasion failure

Bottom of filter bags located directly in line with inlet gas stream (*from the bottom*)

Excessive movement of filters causing bag to bag abrasion: bags can swing, because they are suspended, and their base have not a fixed position.

Bag-to-bag abrasion depends also on their distance.

Can velocity: bag spacing

Bag spacing is very important for good operation and ease of maintenance. Bag spacing affects the velocity at which the flue gas moves through the baghouse compartment. If bags are spaced too close together, the gas velocity would be high because there is very little area between the bags for the gas stream to pass through. Settling of dust particles during bag cleaning would become difficult at high velocities. Therefore, it is preferable to space bags far enough apart to minimize this potential problem but not so far apart as to increase the size of the baghouse shell and associated costs.

For pulse-jet baghouses, bag spacing is important to prevent bag abrasion. Bag-to-bag abrasion can occur at the bottom of the bags because the bags are attached to the tube sheet only at their tops which allows them to hang freely. Slight bows in the bag support cages or a slight warping in the tube sheet can cause bag-to-bag contact at the bottom of the bags.

1. **Bag spacing of three inches (7.62 cm) between bags is the widest in the industry**.
2. **In a generic baghouse, the typical bag spacing is 1" (2,54 cm) between the diameters of the bags** (this means 5 ½" between the centers of the bags for typical 4 ½" diameter bags).
3. **Many commercial baghouses provide 2 inches (5 cm) spacing between bags.**

D.
DROP PRESSURE

Drop pressure

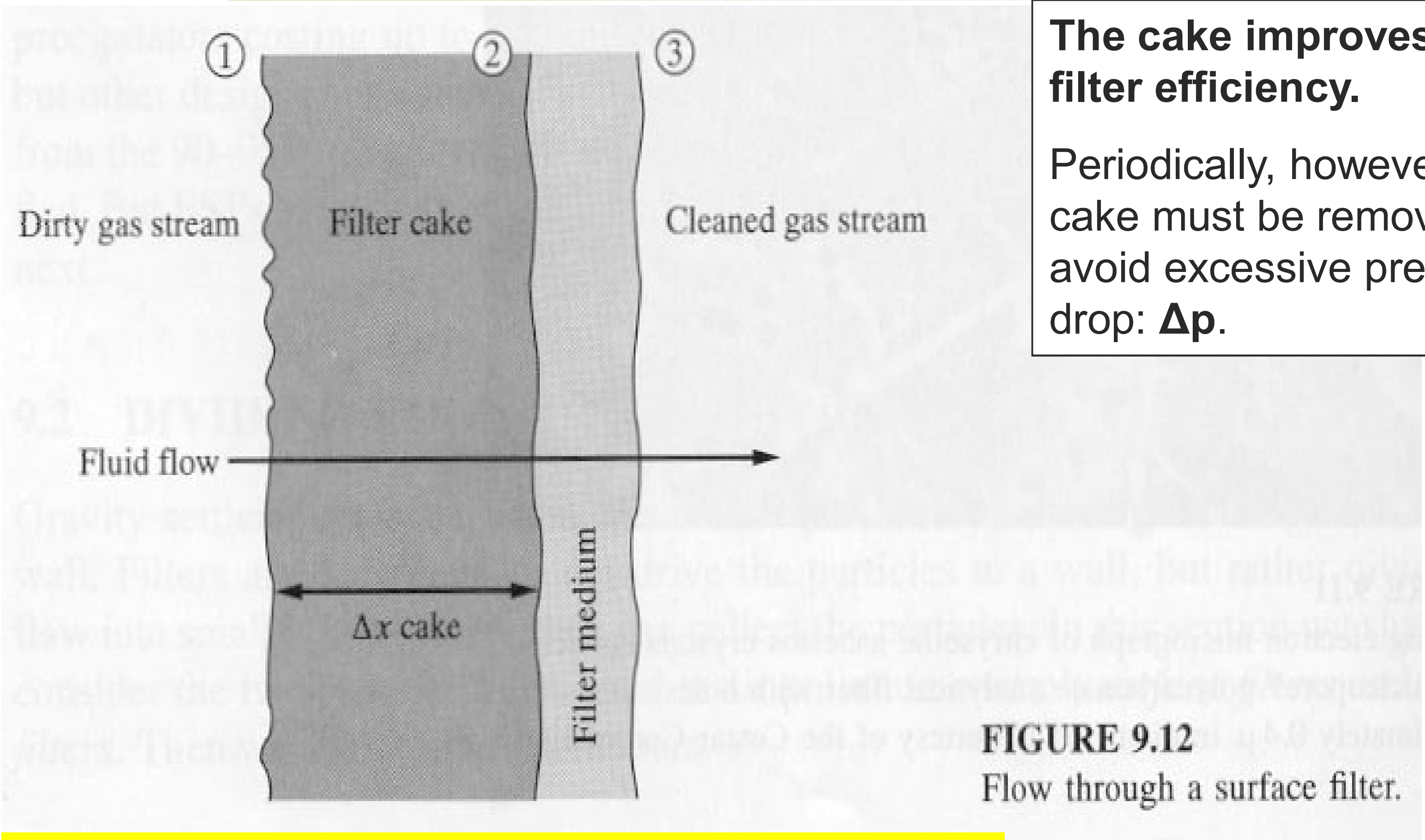


FIGURE 9.12
Flow through a surface filter.

The cake improves the filter efficiency.

Periodically, however, the cake must be removed to avoid excessive pressure drop: **Δp**.

$$\Delta P_{\text{total}} = \Delta P_{\text{filter}} + \Delta P_{\text{cake}} \underbrace{+ \Delta P_{\text{baghouse structure}}}_{\text{small}}$$

de Nevers

ΔP concerns all the equipments, not only the FF!

Baghouse application and operation: *pressure drop monitoring*

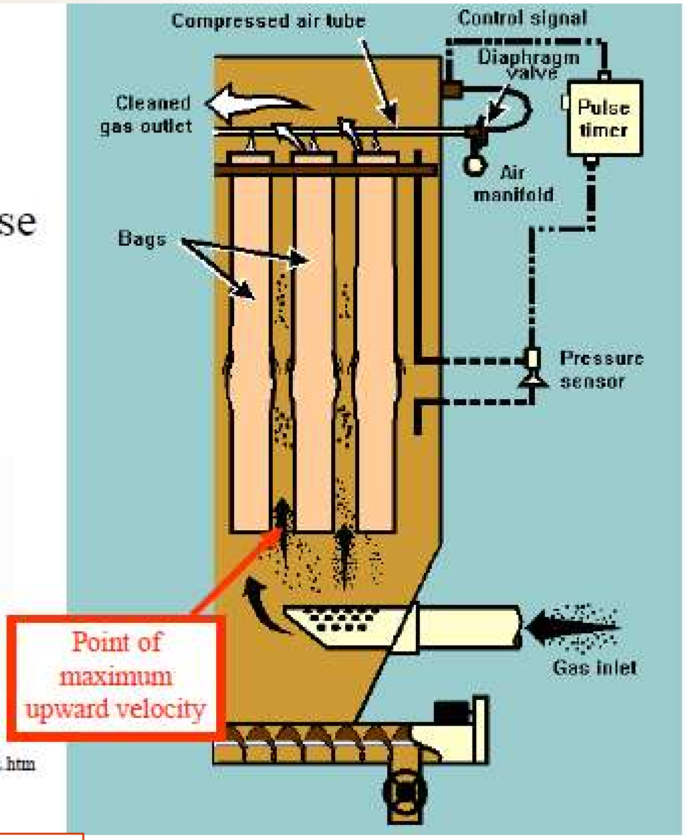
Extract from U.S. Code of Federal Regulations

".. (ii) You must install, maintain, and operate a pressure drop monitoring device to measure the differential pressure drop across the fabric filter during all times when the process is operating. The pressure drop shall be recorded at least once per day (note: I recommend that the pressure difference ΔP across the fabric filter should be continuously measured and recorded!!). If a pressure drop is observed outside of the normal operational ranges, you must record the incident and take immediate corrective actions. You must also record the corrective actions taken. You must submit a monitoring system performance report in accordance with § 63.10(e)(3).

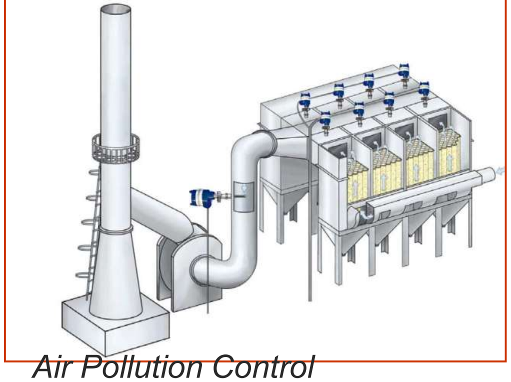
(iii) You must conduct a visible emissions observation at least once per day to verify that no visible emissions are occurring at the discharge point to the atmosphere from any emissions source ….".

Pulse-Jet Baghouse
(newer technology)

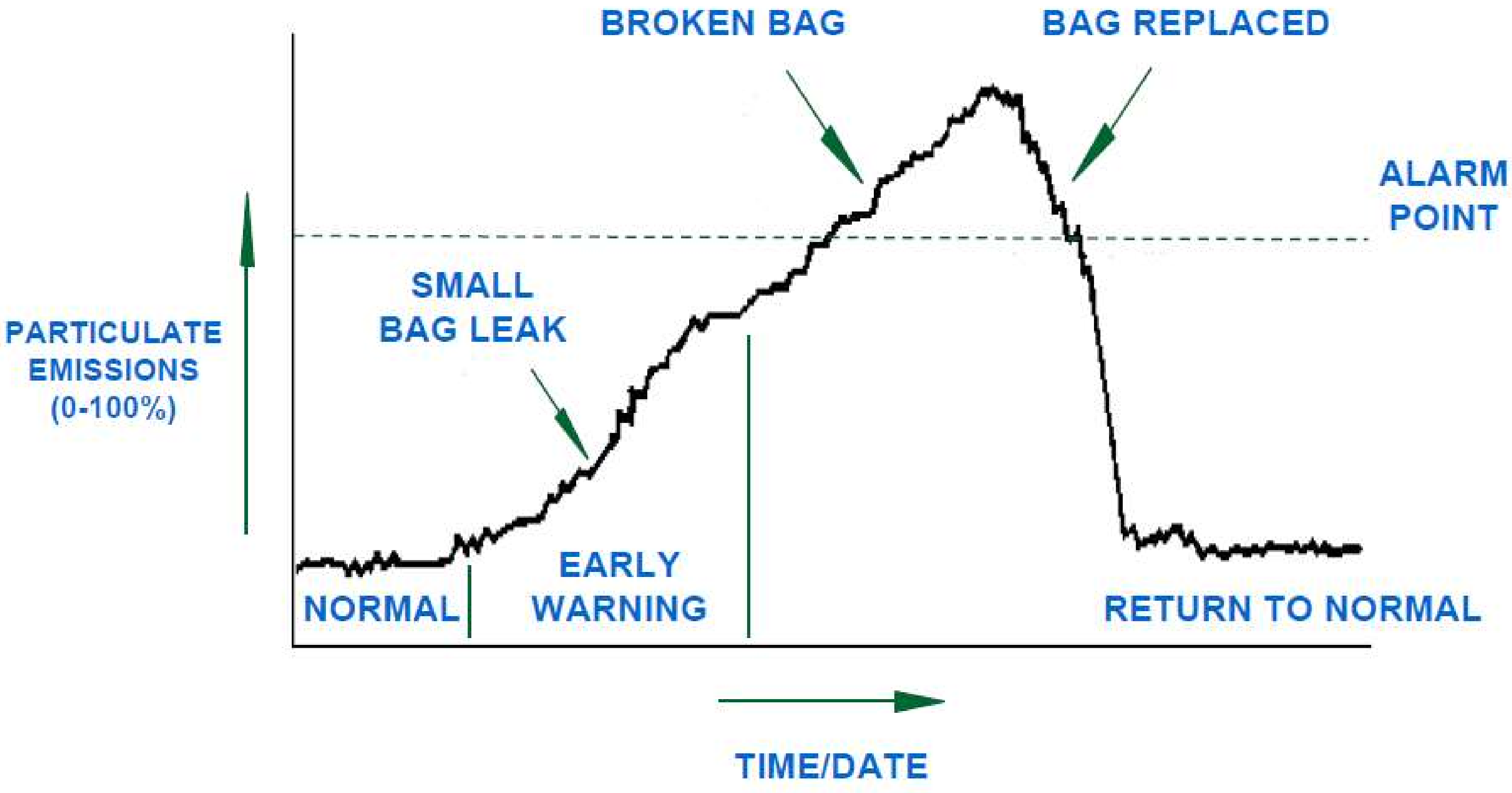
Photo at: http://members.aol.com/apcutk/index.htm



Upward velocity = interstitial (or can) velocity

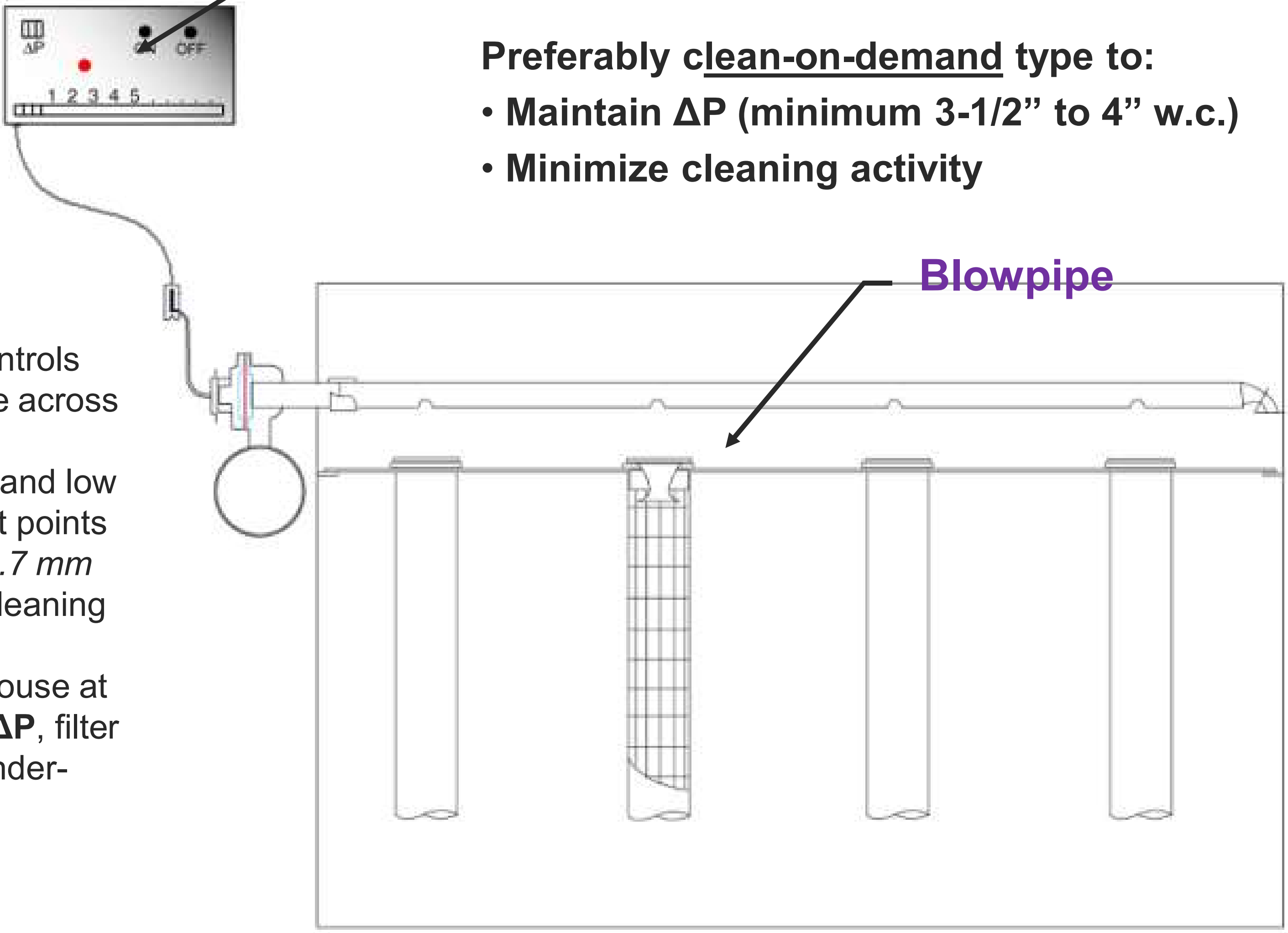


Typical Baghouse Activity



Basic Cleaning System Configuration

Blow pipe: compressed air pipe for bag cleaning;



Controller:

Preferably clean-on-demand type to:

- **Maintain ΔP (minimum 3-1/2” to 4” w.c.)**
- **Minimize cleaning activity**

Blowpipe

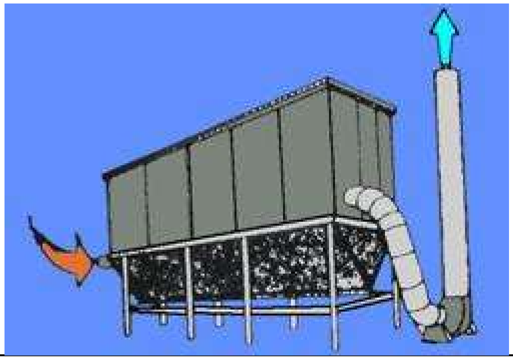
Clean-On-Demand controls the differential pressure across the filter bags.
The user sets the high and low differential pressure set points *(generally 1/2” w.c. (12.7 mm w.c.) apart),* whereby cleaning will start and stop.
By operating the bag house at a stable and optimum **ΔP**, filter bags are not over-or under-cleaning.

Baghouse Fan Location (Positive and Negative Pressure)

Particle-laden gas is either pushed or pulled through the baghouse by a fan.

When the dirty gas is **pushed** through the baghouse the collector is called a forced draft or a positive pressure baghouse.

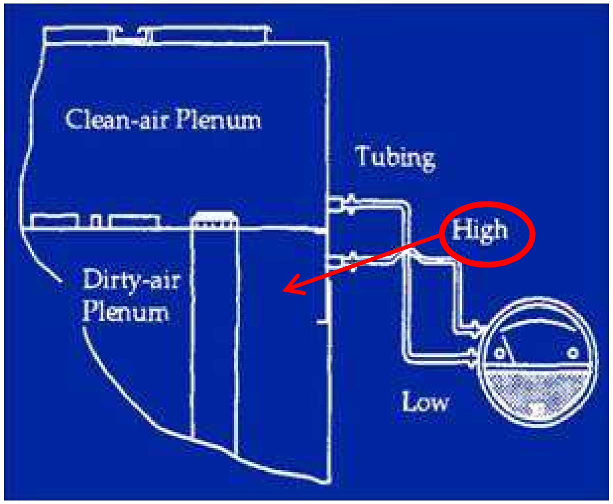
When the fan is on the downstream side of the baghouse, the dirty gas is **pulled** through the baghouse and the collector is called an induced draft or negative pressure baghouse. Comparisons are shown in table.

Fan Type		Pros	Cons
FORCED		Smaller motor Less expensive Leaks easy to identify	Fan blade erosion
INDUCED		Fan on clean side	Larger motor More expensive Harder to identify leaks

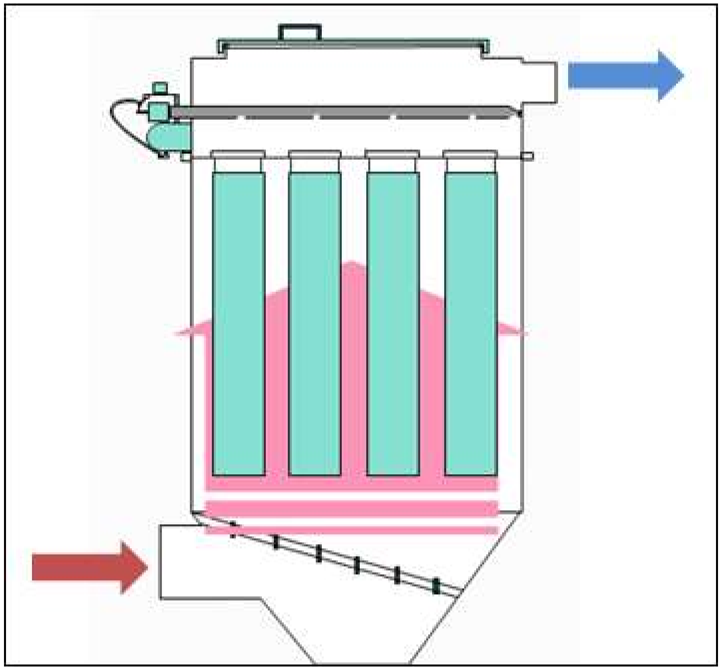
Pressure drop, ΔP

Bag Filter

Differential pressure

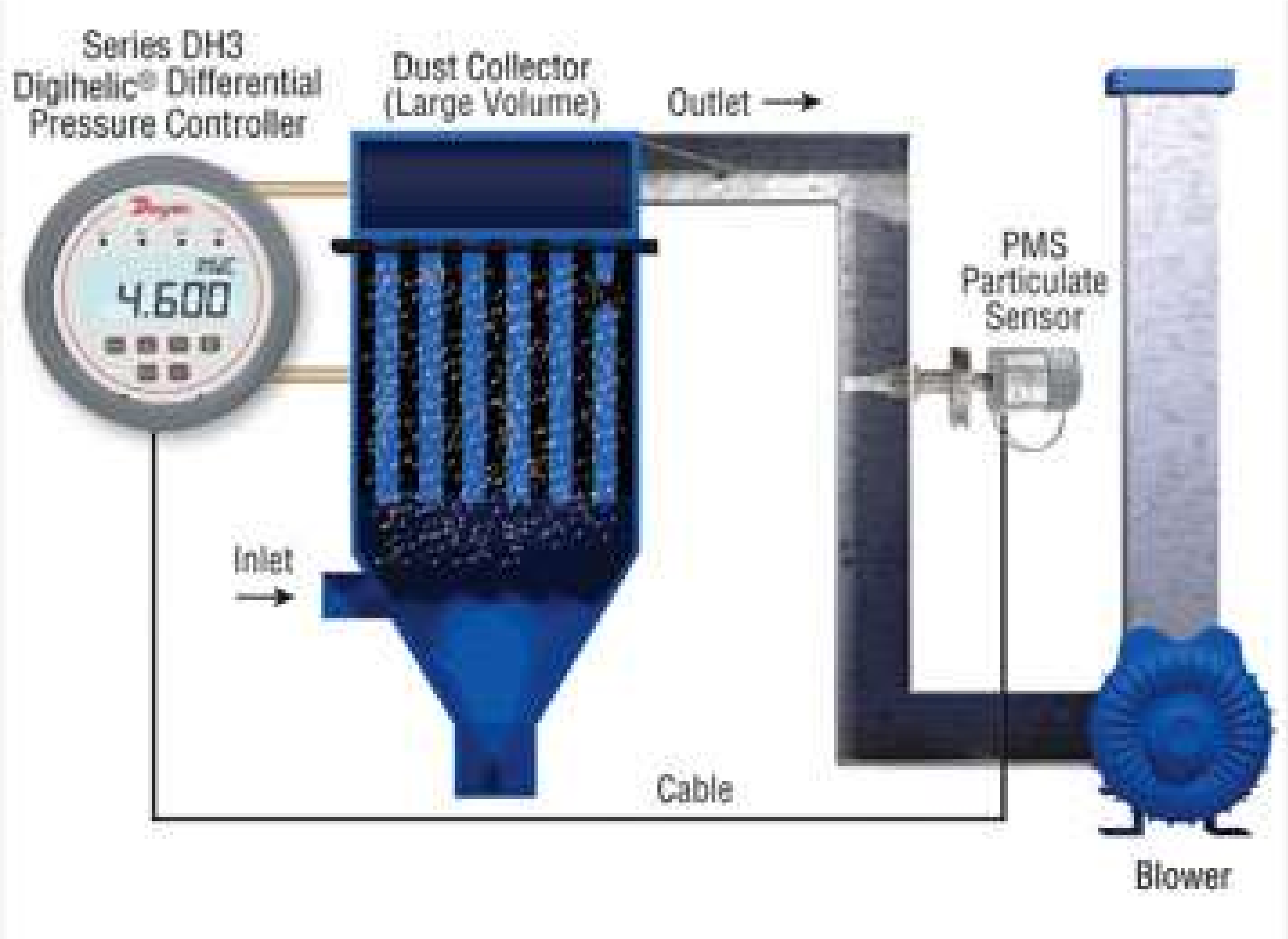


Under suction

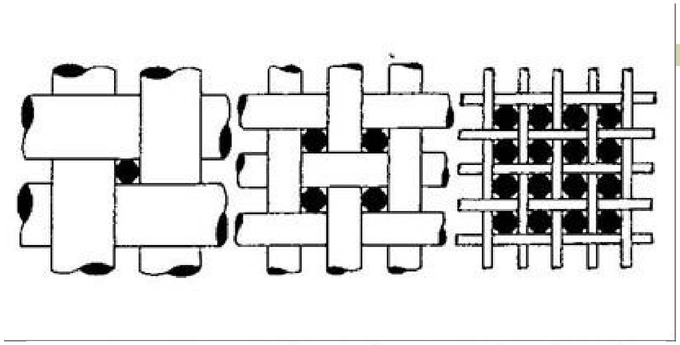


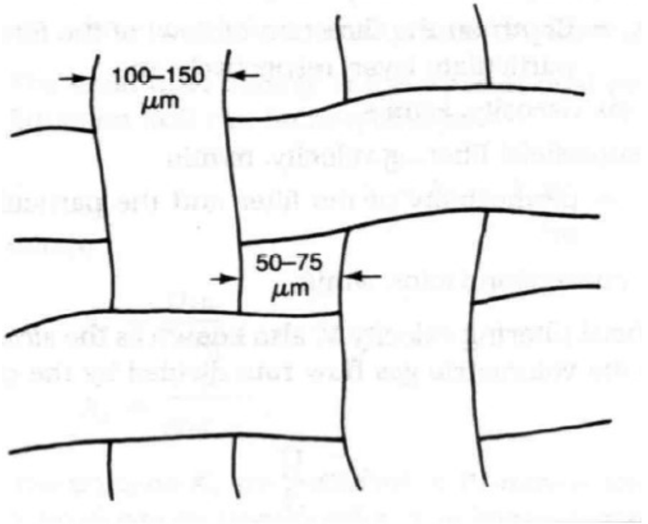
Filtering the solid particles dispersed in a process carrier gas leads to surface deposition and clogging of the porous filter media and is accompanied by an increase in pressure drop of the process.
Therefore, the filter bags must be periodically regenerated, by a pulse-jet cleaning system. During cleaning, high-pressure, short-duration air injections in the reverse direction blow the dust layer partially off the bag surface, which is collected in the dust hopper located at the bottom of the filter housing.

Pressure drop, ΔP



Pressure drop, ΔP - Theory





- We will start considering a brand-new woven filter cloth, with fibers of about 100-150 microns in diameter and open spaces between the fibers as large as 50-75 microns.
- The spaces are occupied by tiny, randomly oriented fibrils.

- As discussed previously, the collection efficiency is initially low because a large portion of the dust will pass directly through the cloth.
- During time, due to impaction, interception and diffusion phoenomena, dust particles will build up on the fibrils and bridge across the gaps. AS MIGHT BE EXPECTED, This will results in A INCREASED RESISTENCE TO GAS FLOW.

ASSUMPTIONS:

The PRESSURE DROP through a baghouse at a given flow rate will be calculated as:

$$\Delta P\text{total} = \Delta P\text{filter} + \Delta P\text{particulate layer} + \Delta P\text{baghouse structure}$$

$$\Delta P = \Delta P_f + \Delta P_p + \Delta P_s$$

ΔP due to baghouse structure is usually low and can be ignored

Pressure drop, ΔP - Theory

Darcy law

$$Q = \frac{-K \cdot A \cdot \Delta P}{\mu \cdot L}$$

Where:

Q= flow [m^3/s];

K = coefficient of permeability [m^2];

A = cross sectional area of flow [m^2];

ΔP =pressure drop [N/m^2];

μ = fluid viscosity [kg/m/s];

L= length of medium [m];

Pressure drop, ΔP - Theory

$$\Delta P = \Delta P_f + \Delta P_p$$

Both terms can be expressed using the Darcy's equation for fluid flow through porous media:

$$\Delta P_f = \frac{D_f \mu v}{60 K_f} \qquad \Delta P_p = \frac{D_p \mu v}{60 K_p}$$

Where:

ΔP_f =pressure drop in the filter [N/m^2];
ΔP_p=pressure drop in the particulate layer [N/m^2];
D_f = depth of the filter (in the direction of flow) [m];
D_p = depth of the particulate layer (in the direction of flow) [m];
μ = gas viscosity [kg/m/s];
v = superficial filtering velocity (**Filtration Velocity**) [m/min];
K_f = permeability of the filter [m^2];
K_p = permeability of the particulate layer [m^2];
60= conversion factor [s/min].

Pressure drop is thus proportional to the superficial filtering velocity v.

Pressure drop, ΔP - Theory

$$\Delta P = \Delta P_f + \Delta P_p$$

During filter operation, the depth of the dust layer increases. For a constant filtering velocity and a constant mass concentration of dust (=dust loading), it should increase linearly with time.

$$D_p = \frac{Lvt}{\rho_L}$$

Where:

L =dust loading [g/m^3];
v= superficial filtering velocity [m/min];
t=time of operation [min];
ρ_L= bulk density of the particulate layer [g/m^3].

Substituting D_p into the previous expressions we obtain:

$$\Delta P = \frac{D_f \mu}{60K_f} v + \frac{\mu}{60K_p \rho_L}(Lvt)v$$

Now we define the:

FILTER DRAG (S)

$$S = \frac{\Delta P}{v}$$

Pressure drop per unit filtration velocity
S [N min/m^3] or [Pa min/m];

AREAL DUST DENSITY (W)

$$W = Lvt$$

Mass of dust per unit area of fabric
W [g/m^2]

$$S = \frac{\Delta P}{v} = \frac{D_f \mu}{60K_f} + \frac{\mu}{60K_p \rho_L}(Lvt)$$

$$S = \frac{D_f \mu}{60K_f} + \frac{\mu}{60K_p \rho_L} W$$

Pressure drop, ΔP - Theory

$$S = \frac{D_f \mu}{60K_f} + \frac{\mu}{60K_p \rho_L} W$$

Now we indicate the groups at the second member in the following way:

$$K_1 = \frac{D_f \mu}{60K_f}$$

expressed as [N min/m^3] or [Pa min/m]

$$K_2 = \frac{\mu}{60K_p \rho_L}$$

expressed as [N min/(kg m)] or [Pa min m/kg]

➡ $$\boxed{S = K_1 + K_2 W}$$

This **linear model** is called **FILTER DRAG MODEL**
K_1 and K_2 are the Filter drag model coefficients

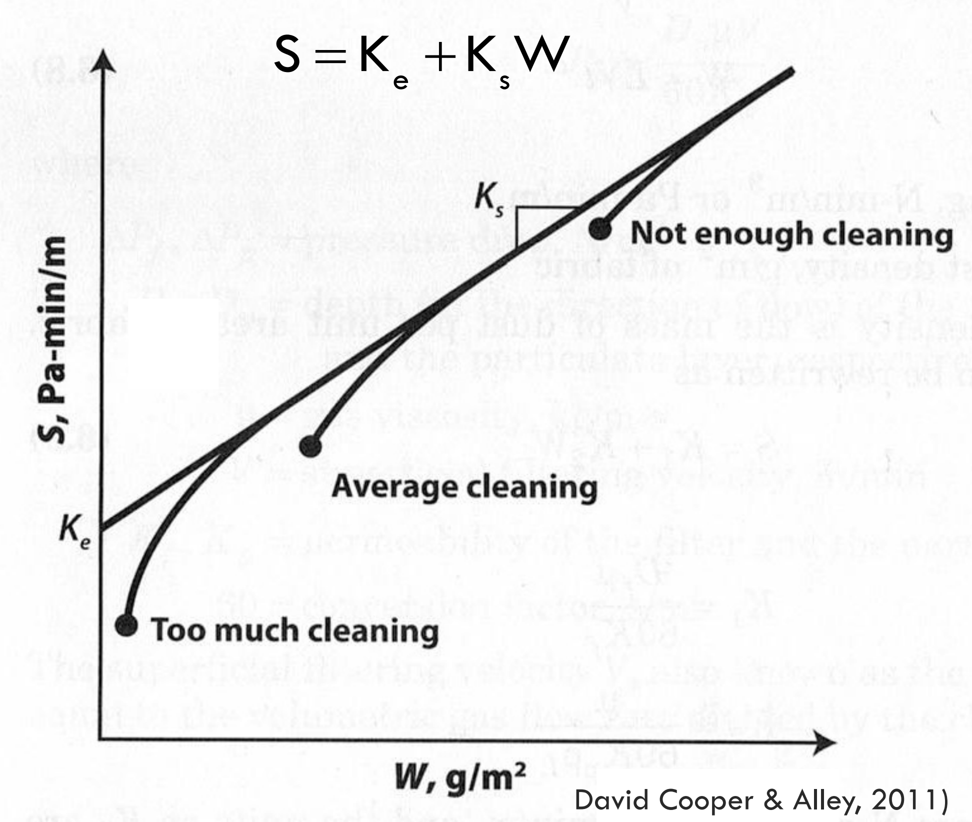
- The evaluation of K_1 for clean fabric is appropriate just for the first run, whilst it becomes inaccurate after a cleaning cycle (see explanation afterwards)
- The evaluation of K_2 from its defining parameters is inconvenient.
- It is more convenient to determine the coefficients empirically from pilot test on a dusty gas similar to the one of which the design is being made.
- The previous expressions are thus rewritten as:

$$S = K_e + K_s W$$

K_e=extrapolated clean cloth filter drag $\frac{N{*}min}{m^3}$

K_s=slope constant for the particulate dust, gas and fabric involved $\left[\frac{N\ min}{kg\ m}\right]$ or $\left[\frac{1}{min}\right]$

Pressure drop, ΔP - Theory



$$S = K_e + K_s W$$

David Cooper & Alley, 2011)

This is a typical plot of the Filter Drag (**S**) as a function of aeral dust density (**W**).

Remark that the real path differs from the linear model:

✓ Curves usually do not start from W=0;
✓ Curves have a initial non linear portion.

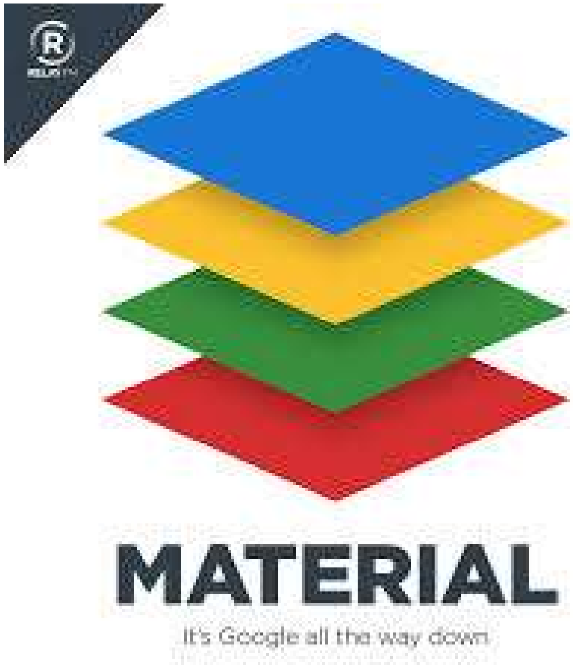
The represented curves relate to different levels of cleaning attained on the filter.

➔If the cleaning is not accurate, at the beginning of the new cycle a residual dust mass will be present on the filter ➔the plot will not start at W=0.
The less accurate the cleaning, the higher the curve starting point.

➔The curves are initially non linear because, since the previous cleaning cycle generally remove the dust cake in irregular chunks (the bag will have some parts very clean and other still quite dusty), the flow through the fabric is not uniform.

➔This is the reason why we cannot use the K_1 coefficient, valid only for the filter at its first use. Constants are thus determined empirically.

E.
MATERIAL



Baghouse filter media: materials

FIBRA SINTETICA	T° MAX CONTINUA/PUNTE	RESISTENZA ALLA IDROLISI	RESISTENZA AGLI ACIDI	RESISTENZA AGLI ALCALI	RESISTENZA ALLA OSSIDAZIONE
Polipropilene	90/100	Ottima	Ottima	Ottima	Cattiva
Poliolefina per alta T	125/130	Ottima	Ottima	Ottima	Cattiva
Poliammide	110/115	Cattiva	Moderata	Buona	Moderata
Poliacrilonitrile cop.	110/115	Buona	Moderata	Moderata	Buona
Poliacrilonitrile omo.	125/140	Buona	Buona	Moderata	Buona
Poliestere	140/150	Cattiva	Moderata	Cattiva	Buona
M-aramide	180/220	Moderata	Moderata	Moderata	Buona
Polifenilensolfuro	190/200	Ottima	Ottima	Ottima	Buona
Poliimide	240/260	Buona	Buona	Moderata	Buona
Politetrafluoroetilene	250/280	Ottima	Ottima	Ottima	Ottima

FIBRA NATURALE	T° MAX CONTINUA/PUNTE	RESISTENZA ALLA IDROLISI	RESISTENZA AGLI ACIDI	RESISTENZA AGLI ALCALI	RESISTENZA ALLA OSSIDAZIONE
Cotone	86/105	Moderata	Cattiva	Cattiva	Cattiva
Lana	95/120	Moderata	Moderata	Cattiva	Cattiva

Baghouse filter media: materials

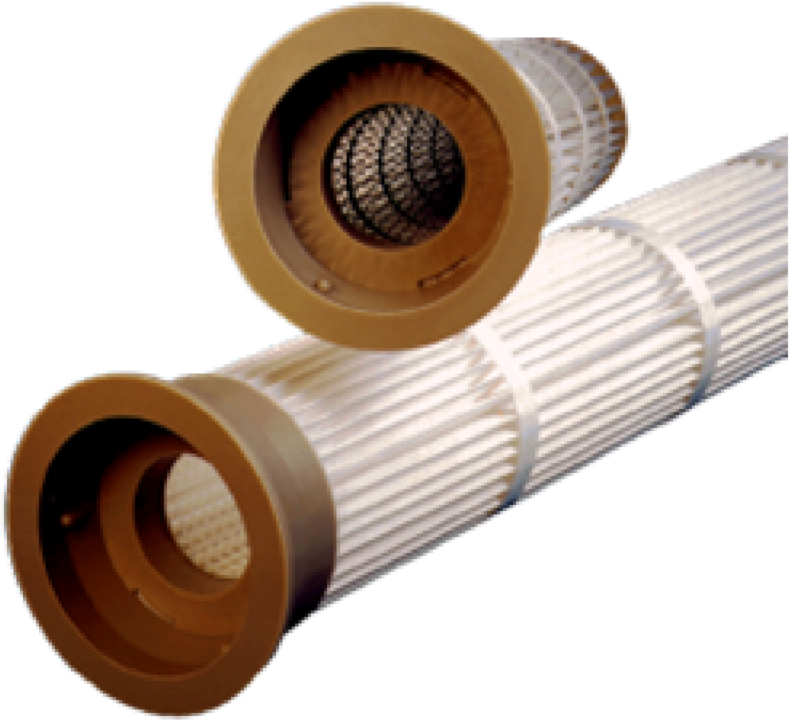
Oper. Vari.	Polyester	Acrylic	Fiberglass	Aramid	PPS	P84
Max. Oper. Temperature	275°F (134°C)	265°F (130°C)	500°F (259°C)	400°F (204°C)	375°F (190°C)	500°F (259°C)
Abrasion	Excellent	Good	Fair	Excellent	Good	Fair
Filtration Properties	Excellent	Good	Fair	Excellent	Very Good	Excellent
Moist Heat	Poor	Excellent	Excellent	Good	Excellent	Good
Alkalines	Fair	Fair	Fair	Good	Excellent	Fair
Mineral Acids	Fair	Good	Poor**	Fair	Excellent	Good
Oxygen(15%+)	Excellent	Excellent	Excellent	Excellent	Poor	Excellent
Relative Cost	X	XX	XXX	XXXX	XXXXXX	XXXXXXX

Jet Pulse-Pleated Filter

Cartridge filters

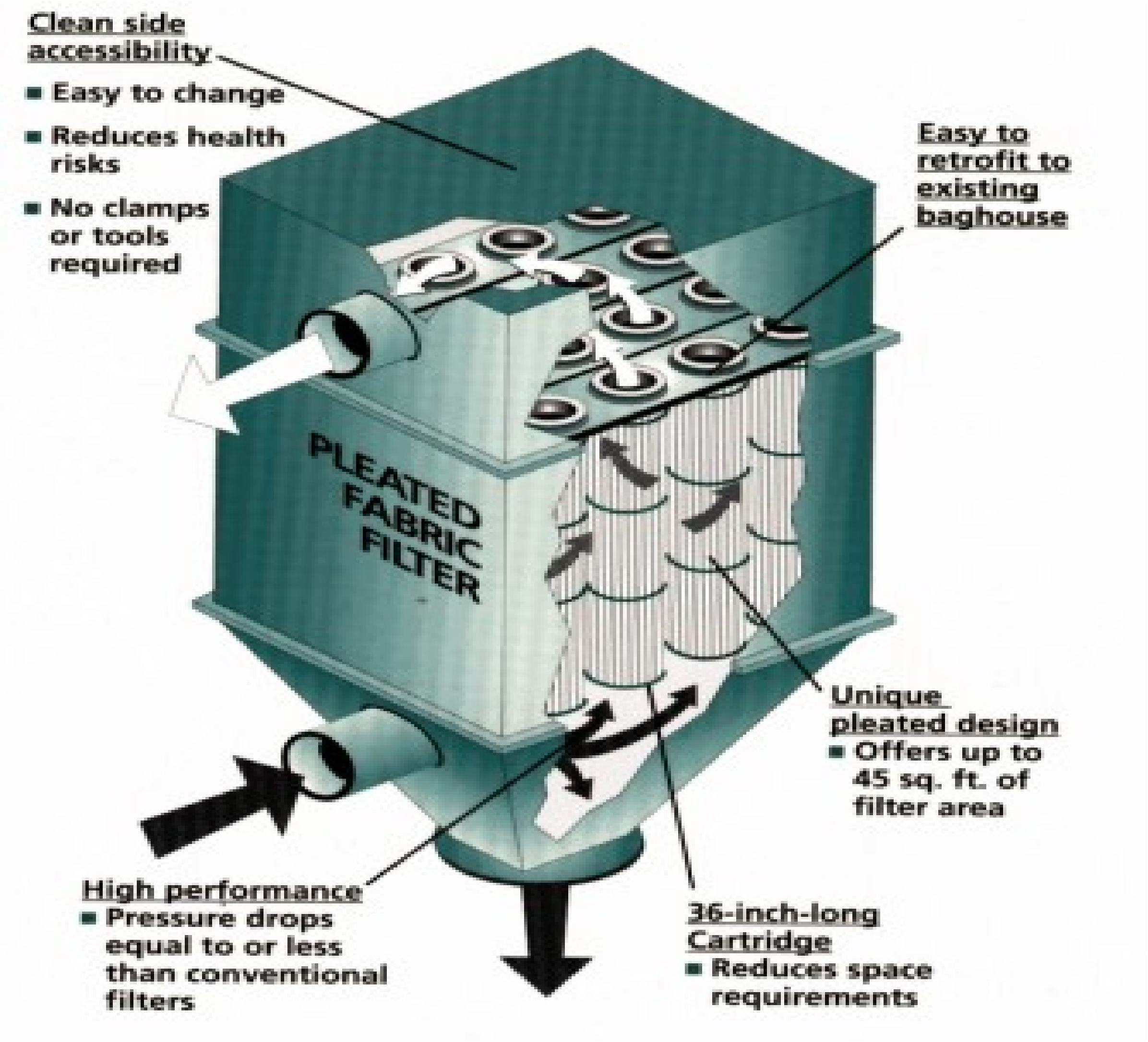
A way to further increase filtration area in small volumes

Filter surface area: 2-3 times larger than bag filter



- Can operate up to 240 °C, but not a wide choice of materials is available; therefore temperature can represents a limit factor
- Filter length: max. 2 m
- Jet cleaning more difficult
- Effective filtration area ≈ x 2 respect to common bag filters.

Pleated Fabric Filters

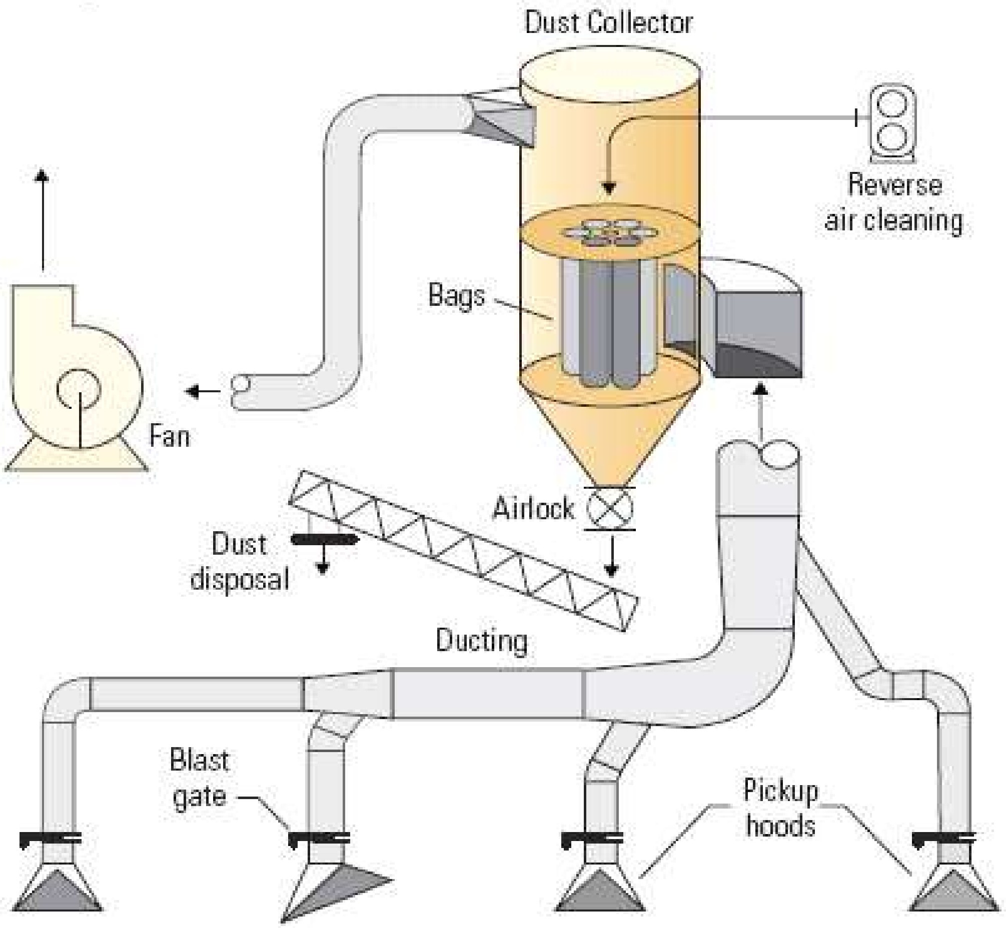


Top Load Pulse Pleat Filter

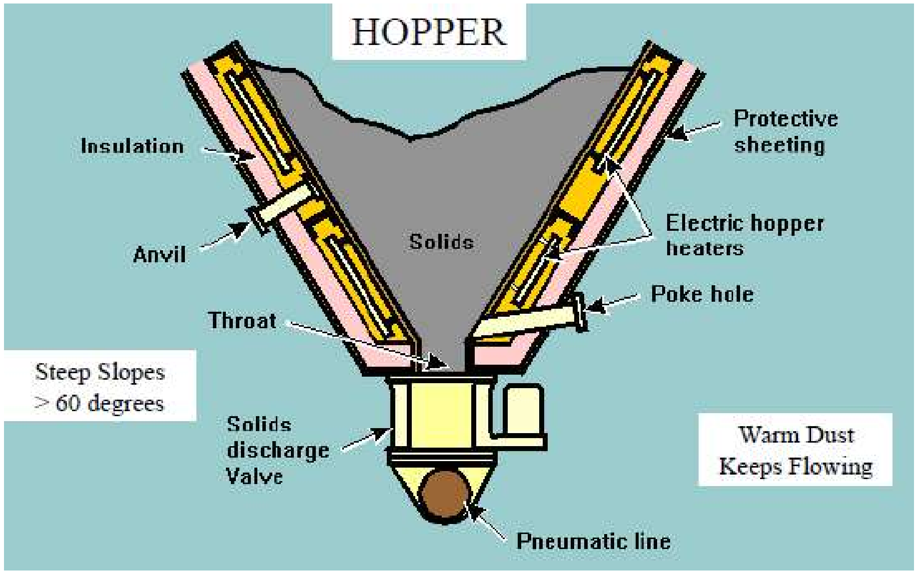
F.
AUXILIARY UNITS:
Dust hopper and discharge

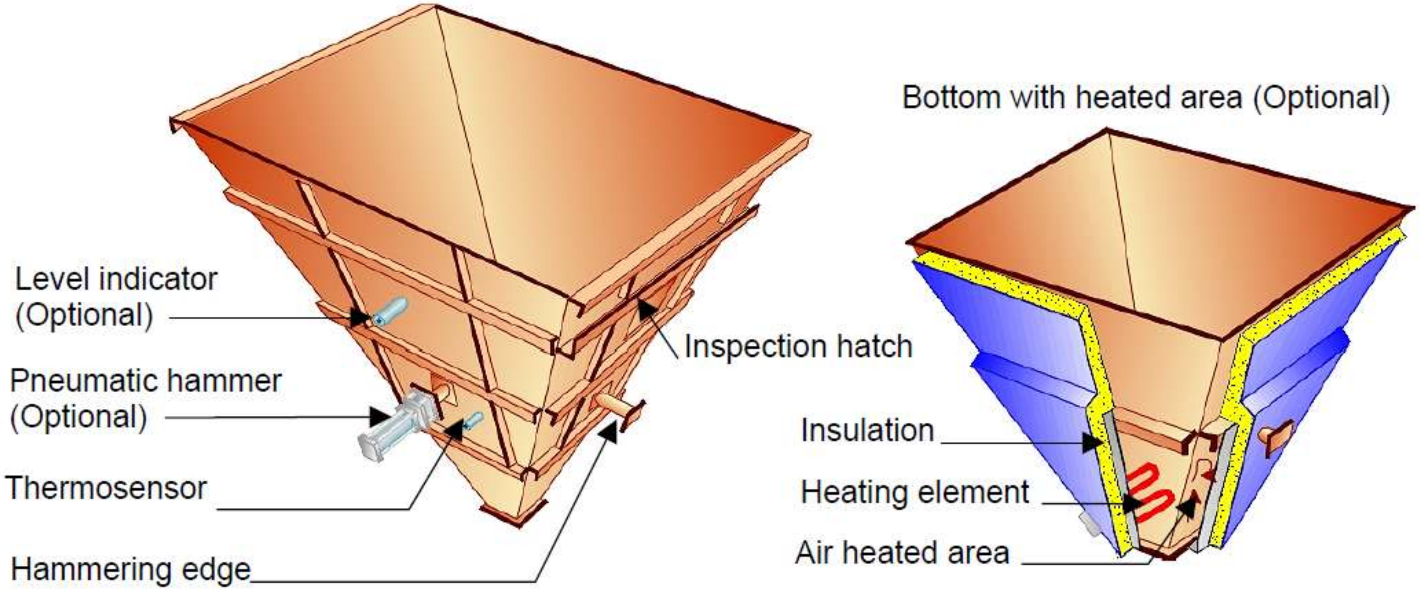
Baghouse Dust Collector – General Scheme

- **Exterior Filtration: OUT → IN;**
- **Induced Draft (Negative Pressure);**
- **Reverse air jet-pulse cleaning.**

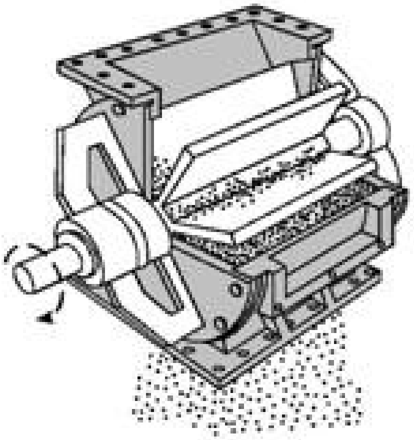


Hopper

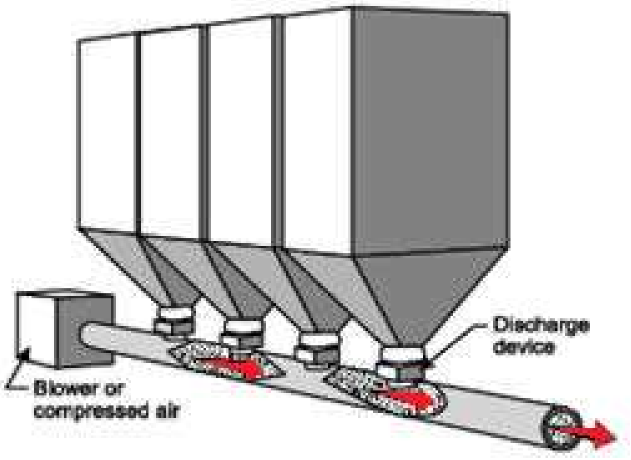

HOPPER
Insulation
Anvil
Throat
Solids
Protective sheeting
Electric hopper heaters
Poke hole
Steep Slopes > 60 degrees
Solids discharge Valve
Warm Dust Keeps Flowing
Pneumatic line


Level indicator (Optional)
Pneumatic hammer (Optional)
Thermosensor
Hammering edge
Inspection hatch
Bottom with heated area (Optional)
Insulation
Heating element
Air heated area

Automatic Dust Discharge Devices



Example of a
rotary airlock



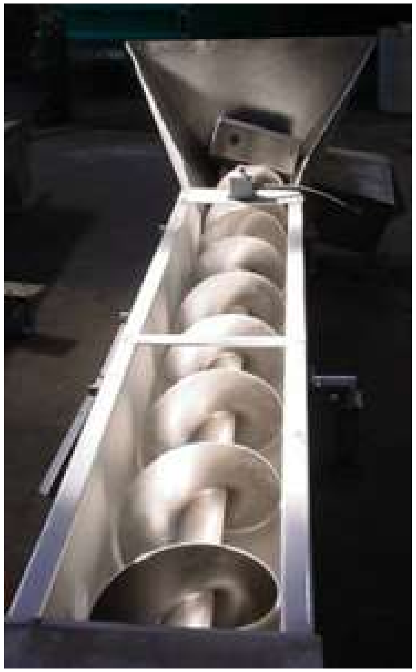
Pneumatic conveyor

Dilute phase transport
< 1% volume solid/volume of air

Dense phase transport
> 1% volume solid/volume of air

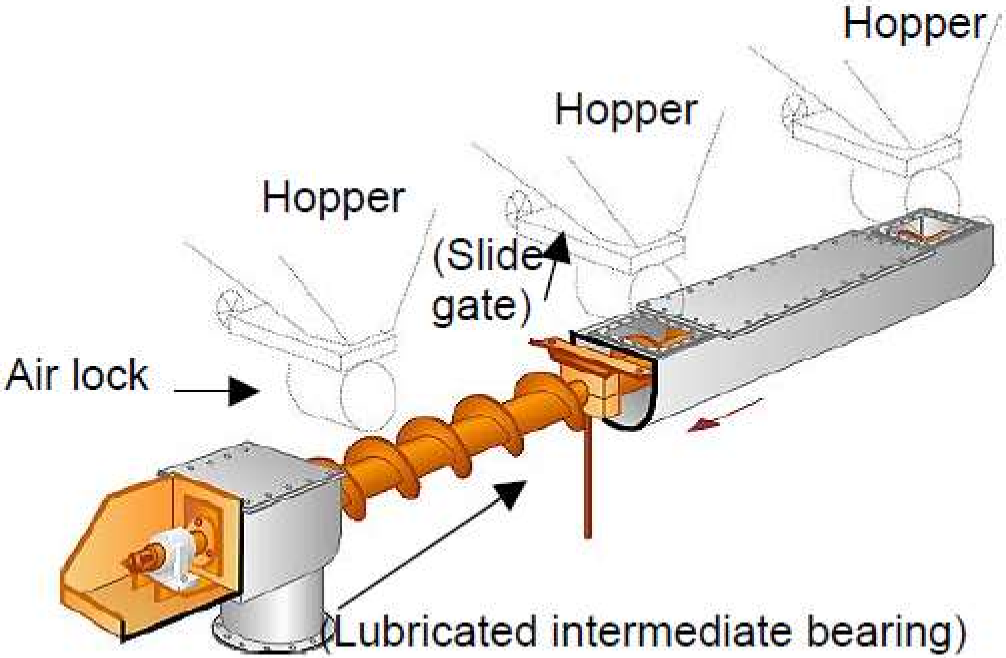
We use dense pneumatic system to remove dusts from FF or EF

Screw conveyor



Screw conveyor hopper discharge

When screw conveyors are applied, dust from the individual hoppers are often fed into the screw conveyor via rotary air lock.



G.
COSTS

Baghouse costs

Case	Q (m^3/s)	Bag material	L_B (years)	C_B ($/$m^2$)
Reference	200	Ryton felt	3	32
#1	200	Teflon felt	5	110
#2	200	Glassfiber	2	16

C_0	*Bag cost (\$/m^2)*
L	*Life (years)*
Q	*Gas flow rate (m^3/s)*