GAS FILTRATION

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Contents

Summary

Traditionally bag house filters have been used in the food and fodder industry, but their role in environmental applications rapidly assumes more importance. The operation of a bag house filter is much more complex than generally understood, not only in the mechanisms responsible for retention, but also in the selection of a membrane and developing adequate strategies for operating and cleaning the filter. In this chapter the filter construction, cost and operating factors, design, operation, and maintenance are discussed.

1. Survey

The problem of gas filtration is a basic consideration in numerous industrial processes (see, *Dust Collection* , *Pollution Control in Industrial Processes*, *Control of Pollution in Power Generation*, *Control of Pollution in Power Generation*, *Control of Pollution in the Chemical Industry*, *Control of Pollution in the Petroleum Industry*, *Control of Pollution in the Iron and Steel Industry*, *Control of Pollution in the Non-ferrous Metals Industry*, and *Control of Pollution in the Pulp and Paper Industry*).In fabric filters the flow of gas to be cleaned is directed through a needle felt or (rarely) a woven fabric, so that particles are retained and the gas purified. In this operation fabric filters act as a combination of (1) a permeable membrane, the fabric, providing physical support to (2) a deposited layer of filter cake, responsible for filtration in the depth of its layer, i.e. deep bed filtration. Particles are retained inside a layer of others, separated earlier. Pressure drop hence gradually increases during filtration, so that after a certain period the filter has to be cleaned. Cleaning involves detaching most, but preferably not all of the filter cake, and usually proceeded by shaking, collapsing of the bag, or rapping of the support frame. Today it is almost general by briefly reversing the gas flow and detaching part or all of the filter cake by a periodic blast of external, clean compressed air. Cleaning is either triggered by controlling the pressure drop over the cake, or by a timer. The life expectancy of the fabric, as well as the quality of the clean gas, is markedly influenced by method and frequency of cleaning. The efficiency drops to a low value, when a bag gets punctured or torn. Such punctures can be detected off-line using fluorescent powder as a tracer or using a tribo-electric sensor.

2. Absolute Filters

Absolute filters are used in specific applications such as clean rooms, operating theatres, research facilities, the electronic, nuclear and pharmaceutical industries, and for protecting high-speed turbines.

The filtration medium is provided by micro-fine glass fibers formed into a paper-like surface, supplied in various grades depending upon filtration efficiency required. The filter paper is formed into a close pleated package to provide a larger surface area. Corrugated spacers of either Kraft paper or aluminum are inserted between pleats to provide support and also ensure that the entire surface of the filtering medium is used.

The collection efficiency ranges from 95 % to 99.99995 %. The first corresponds to 350 000 particles per m^3 greater than 0.5 µm, 2000 larger than 5 µm, the last to 350 particles per m^3 greater than 0.5 µm, none larger than 5 µm.

Filter capacity of commercial units typically varies from 200 to 4000 $m^3 h^{-1}$

3. Filter Characteristics

3.1. Filter Construction, Cost and Operating Factors

A simple way of building a large, but compact filtration area is to suspend long cylindrical sleeves or bags, which explains the name “bag house” filter. It consists of two main compartments:

- The raw gas compartment, in which the raw gas enters and is distributed
- The cleaned gas compartment, usually on top of the former, and delivering the clean gas.

The separating plate is punched with holes; each hole supports a cylindrical bag. Cylindrical cages from steel wire, resistant to the pressure difference between the dirty and the clean gas side (which is also the pressure drop over cake and fabric) support and stretch each sleeve.

Gases pass usually from the outside to the inside of bags, which communicates with the clean compartment. The dust is collected on the outside of bags, and is bound to fall down into the hopper bottom of the dirty compartment. Dust is continuously extracted from the hopper that has to be kept empty for a better dust settlement, for avoiding re-entrainment, solidification, smoldering fires, etc.

Investment cost is distributed as follows:

- 75 percent for the steel casing,
- 15 percent for the sleeves,
- The balance for various auxiliaries.

This means that the available space is better well filled with sleeves. However, gas distribution and the linear gas velocity with which the gas flows to the sleeves and sedimentation inside the filter housing are also to be considered.

3.1.1. Mechanism of Filtration

Filtration initially is based on physical impaction or interception of particles by the ‘membrane’, a permeable fabric surface, and after a while a cake of particles previously separated and involving a ‘deep bed’ type of filtration takes over.

Although this process seems relatively straightforward in reality it is not and various electrostatic, interception and adhesion forces supplementing direct screening are still poorly understood. Hence, the study and practice of filtration largely retained an empirical character and the same holds for predicting the filtering results and lifetime of filter sleeves in any particular application. Moreover, in all applications the filter material (membrane) proper only serves as support and actual filtration largely takes place inside the dust cake, deposited onto the filter membrane, mainly its freshest parts. Hence, the best filtration efficiency is obtained from a dust cake made of a wide particle size distribution, leading to a mix of small and large pores, together offering a good overall porosity. For example, too much fines in the dust may cause a rapid increase of the pressure drop over the filter cake, requiring much more frequent filter cleaning. In bag house filtration it may be advantageous to recycle coarse dust and thus assist in building a sufficiently porous filter mass.

A common emission rate for a bag filter is about one mg per Nm^3 (mg per normal cubic meter) dust concentration, far below current regulation requirements.

Much of the efficiency hence depends on structure, porosity and other properties of the layer, formed by the collected particles, a factor that is rather unpredictable and impervious to study or characterization. Ideally, such a granular medium is formed with a fairly uniform structure, which requires an even dust load over all of the sleeve surface but with also a wide range of particle sizes, and easily accommodating newly collected particles of variable shape and size. Gradual extension and clogging of the cake leads to a steady rise in pressure drop as described by the Law of Darcy for flow through granular media. In practice it is difficult to predict the pressure evolution with time, since clogging may also be a consequence of collecting very fine particles only too well or of operating below dew point. Moreover, there are many sleeves in a bag house, and their exposure to dust often varies with location and with vertical position on the sleeve in a way, which is unpredictable.

When the pressure drop rises over a certain threshold the original flow rate can no longer be sustained and the flow is either directed towards other sleeves, or declines. The filter then has to be cleaned, generally pneumatically, by reversing the flow locally (one series of elements by one) or wholly (all filter elements together) and applying a local overpressure. In older plants cleaning was often mechanical, e.g. by shaking the support structure, or loosening, then stretching the sleeve.

Cleaning the filter is of paramount importance for optimal filtration results and developing appropriate strategies requires a patient observation of the results and probably a comparison of alternate cleaning strategies. Several methods can be tested, varying the method (isolated groups of sleeves, or on-line), pressure drop triggering cleaning, pressure of the cleaning blast, etc. A naked sleeve may filter quite poorly.

Another type of cleaning consideration regards to lifetime expected from sleeves.

3.1.2. Filter Cleaning

The pressure drop over the filter layer may be controlled between two set point values by means of the bag cleaning control system. Cleaning starts automatically, either through the filter pressure drop controlling monitor, from a given set point, or after fixed intervals of time.

Filter cleaning normally proceeds by blowing in airflow counter-currently:

- By means of a dedicated fan,
- Aspired by the negative gauge pressure inside the bag house filter, or,
- as short pulses of compressed dry air, from the clean to the dirty side.

The third system is now the most often used. A bag filter can be divided into separate cells with individual isolation dampers:

- Either for maintenance only, in order to change worn or punctured bags in one isolated cell and at any time, while other cells remain in operation, or
- for the purpose of off-line cleaning.

Off-line cleaning of bags requires isolation dampers, at the outlet of each cell individually.

Halting for a while the gas flow through the cell also allows the dust to fall down and settle, without gas flow or re-entrainment. This highly efficient mode of cleaning is sometimes required for very fine dust, or for low-density material. But there are also a few drawbacks to this subtle method:

- The dust cake is completely removed in the cleaned cell, destroying filtration capacity of a significant part of the bag filter,
- Taking one cell of N cells in total out of service during the time required for cleaning, increases the gas filtration rate in a ratio ranging from $N/(N-1)$ up to $(N+1)/(N-1)$, as the countercurrent cleaning flow is almost the same as the feed to one cell and adds to the gas flow passing through the remaining (N-1) cells. The remedy is obviously to oversize the filtration area by one cell, somewhat increasing the investment cost.

On-line cleaning routinely is conducted during filtration, without any cell isolation. Only one row of bags is cleaned at a time, and each pulsing time takes only a fraction of a second. After each pulse, the dust just detached is soon aspired again, partly to the same bag, and partly to the surrounding bags. Thus, this cleaning system never completely removes the cake, preserving the filtration capacity of each of the sleeves, and usually very low emission levels such as 1 mg per Nm^3 can be reached.

Because of the small fraction of filtration area cleaned at a time, the cake thickness remains nearly constant, and the filter pressure drop is maintained closer to the set point. This improves filtration efficiency, as well as gaseous pollutant neutralization through the cake (see semi-wet and dry flue gas cleaning, from HCl and SO_2), and also maintains a more stable operating pressure into the gas circuits.

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Bibliography

[1] Bank M. (2000). *Basiswissen Umwelttechnik : Wasser, Luft, Abfall, Lärm und Umweltrecht – 4., komplett neue, bearbeitete Auflage*, Wurzburg: Germany: Vogel, ISBN 3-8023-1797-1. [Comprehensive treatise of all environmental sciences, including air pollution]

[2] http://www.airclean.co.uk/PDF/aac51.pdf. *Airclean – Your Air Filter Manufacturer*. [Commercial site exemplifying user needs and vendors data]

[3] Löffler F. (Ed.), Dietrich H. and Flatt W. (1988). *Dust Collection with Bag Filters and Envelope Filters*, Germany, Braunschweig: Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, ISBN 3-528-08933-4. [Monography referring to both the technical and practical aspects of baghouse operation]

[4] Van den Heuvel, H. (2000). Remedia™ DF Catalytic Filter System: Updated Experiences in Waste Incinerator Plants, In: *Proceedings of a Conference on Air Pollution*, VUB – ULB, Brussels, Belgium, November 14, 2000. [Conference contribution on the W. L. Gore & Associates, Inc. Catalytic Filter System]. See also their website for more details: http://www.gore.com/en_xx/products/filtration/catalytic/

Biographical Sketch

Alfons Buekens was born in Aalst, Belgium; he obtained his M.Sc. (1964) and his Ph.D (1967) at Ghent University (RUG) and received the K.V.I.V.-Award (1965), the Robert De Keyser Award (Belgian Shell Co., 1968), the Körber Foundation Award (1988) and the Coca Cola Foundation Award (1989). Dr. Buekens was full professor at the Vrije Universiteit Brussel (VUB), since 2002 emeritus. He lectured in Ankara, Cochabamba, Delft, Essen, Sofia, Surabaya, and was in 2002 and 2003 Invited Professor at the Tohoku University of Sendai.

Since 1976 he acted as an Environmental Consultant for the European Union, for UNIDO and WHO and as an Advisor to Forschungszentrum Karlsruhe, T.N.O. and VITO. For 25 years, he advised the major industrial Belgian Bank and conducted more than 600 audits of enterprise.

Main activities are in thermal and catalytic processes, waste management, and flue gas cleaning, with emphasis on heavy metals, dioxins, and other semi-volatiles. He coordinated diverse national and international research projects (Acronyms Cycleplast, Upcycle, and Minidip). Dr. Buekens is author of one book, edited several books and a Technical Encyclopedia and authored more than 90 scientific publications in refereed journals and more than 150 presentations at international congresses. He is a member of Editorial Boards for different journals and book series.

He played a role in the foundation of the Flemish Waste Management Authority O.V.A.M., of a hazardous waste enterprise INDAVER, and the Environmental Protection Agency B.I.M./I.B.G.E. He was principal ministerial advisor in Brussels for matters regarding Environment, Housing, and Classified Enterprise (1989). Since 1970 he has been a Member of the Board of the Belgian Consumer Association and of Conseur, grouping more than a million members in Belgium, Italy, Portugal, and Spain.

He is licensed expert for conducting Environmental Impact Assessments (Air, Water, Soil) and Safety Studies regarding large accidents (Seveso Directive).