MECHANICAL AND CYCLONIC COLLECTORS

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Contents

Summary

Mechanical forces in particle separation involve:

- Sedimentation or settling, in ducts, settling chambers, and the environment at large;
- Inertia, as in louvers and almost any type of equipment, e.g. boilers;
- Centrifugal forces, whether created by geometrical features, as in cyclones, or by rotary devices, such as wetted fans.

Interception and thermal diffusion (or Brownian movement) gain importance especially for small submicron particles, for which mechanical forces are ineffective.

In this chapter brief reference is made to the handling of solids and to atmospheric deposition.

1. Survey

In this chapter attention is paid to settling and centrifugal separators and to dry atmospheric deposition.

2. Settling Chambers

2.1. Description of Settling Chambers

Settling chambers may have a large variety of forms and shapes, e.g. cylindrical, box type, tubes, ducts with rectangular or oval section, etc. In traditional thermal or metallurgical plant the shape was non-optimal, since ill adapted to actual flow conditions. As a consequence, part of the volume was short-circuited by the gas flow and, in fact, useless.

Settling chambers separate particles by gravity, possibly with separation enhanced by inertial effects, created by changes in gas direction. Sometimes baffles are incorporated for this purpose, albeit at the cost of extra head losses.

Particles sink faster than they can be entrained by the gas flow, reaching the walls or bottom of the separator before the gas leaves the settling chamber.

Gravity forces are given by: *mass* (g) *.gravity acceleration* (9.81 m s^{-1}).

The limiting size d_k^* that can still be separated is given by:

$$d_k^* = \sqrt{\frac{18 \cdot \mu \cdot H \cdot w_p}{\rho_k \cdot g \cdot L}} \quad (1)$$

where

μ = Dynamic viscosity (Pa s)
H = Height of the settling chamber (m)
w_p = Horizontal gas velocity (m s^{-1})
ρ_k = Dust density (kg m^{-3})
g = Gravity acceleration (m s^{-2})
L = Length of the settling chamber (m)

The separating efficiency is low for all but the coarser particles and large, bulky settling chambers are quite expensive to build. Hence their use is severely limited, centering on applications such as:

- Separating entrained water droplets, in the vapor filled upper half of a boiler steam drum,
- The freeboard zone above a fluidized bed unit, settling entrained bed particles by lowering gas velocity,
- Protecting downstream equipment (turbines, fans, compressors) against damage by coarse particles or droplets.

In practice, settling is enhanced by providing a wider diameter to the duct, thus lowering the linear gas velocity to values below 3 m s^{-1}. Entrainment of part of the particulate or droplets is still almost impossible to prevent, because process gases often do not show a uniform velocity distribution in a cross section, and due to local velocity gradients and turbulence.

Settling chambers are very simple, since they have no moving parts. Their efficiency can considerably be improved by:

- Reducing the required settling height of the particles, by providing internal partitions, such as horizontal or inclined plates, onto which the dust deposits. The difficulty is to clean the plates by suitable means, e.g. sufficient inclination, periodic vibration, jets for periodic pneumatic cleaning, mechanical rabble arms, etc.
- Introducing baffles that curb the flow of the gas around this obstacle. This produces a downward vertical gas movement that helps in settling particles. The latter are also separated by gravity, or sometimes even by impinging upon the baffle wall.

There are many different arrangements to separate solid or liquid particles by inertia. Parallel plates, bended in a sick sack shape, are often used for collecting droplets. The droplets impinge on wetted surfaces and are collected easily, e.g. the Louver type.

As a conclusion, settling chambers are inefficient, bulky, and hence too expensive for dedicated dust collection. However, they provide an additional dust removal function for reactor or storage volume that was required anyway. The freeboard of a fluidized bed combustor, for example, not only serves to decant entrained solids, but more importantly also to complete combustion, or roasting of sulfide ores, or particle drying, or other essential chemical or physical processes that justifies the larger volume at hand.

The same reasoning holds for another major form of settling chambers, namely those incorporated into the transfer lines. Since settling of coarse dust is unavoidable provisions should be made anyway for extracting settled dust from such a line, a settling chamber, or any other dry collector indeed.

2.2. Handling of settled dust

Proper handling of settled dust is important. The techniques used are those from powder handling, and the same definitions, notions, and equipment also apply. Common problems in dust handling are: bridging over chutes, solidification, abrasion, erosion, and clogging.

Settled dust is normally collected in pyramidal or conical shaped hoppers, with sides steeper than the angle of repose of the particles to be collected. The hoppers are kept empty, to avoid re-entrainment of the dust collected in the hoppers. All discharge apertures remain carefully closed, since in-leaking air will turn the powder airborne. An airtight lock is provided between the hoppers on the one hand and the ducts, through which this collected dust is conveyed, on the other, using a screw conveyor, a chain or other type of drag conveyor, a belt conveyor, or a pneumatic system.

Since most filters operate at a negative pressure, relative to their surroundings, it is essential to avoid and monitor leaks. Dust extraction must have ample capacity to eliminate dust from the hoppers and still never be a source of parasitic air. Overfilled hoppers encourage re-entrainment, as well as other undesirable conversions or transformations. Hydraulic fly ash easily solidifies, activated carbon starts smoldering combustion!

To separate the dust collector from downstream handling equipment, the following mechanical parts are frequently used:

- Star or rotary valves, featuring five or six-legged stars,
- Locks formed by two or more slide valves, or hinged plates, opening under the weight of dust,
- Legs for fluidized subtraction, for free flowing powders. Often filter dust is much too fine, however, for fluidization!

3. Cyclone Separators

3.1. Operating Principle

The cyclone separator is a widely used type of particulate collector (see, *Pollution Control in Industrial Processes*), in which dust-laden gas enters tangentially into a cylindrical or conical chamber, follows a spiraling gas flow pattern and leaves through a central opening.

The vortex motion creates a strong centrifugal force field in which dust particles, separate from the carrier gas stream on the basis of centrifugal force, i.e. $mv^2\ r^{-1}$. Separated particles migrate along the cyclone walls, moved by both gas flow and gravity and report to a storage receiver, where they remain permanently separated from the gas flow.

3.2. Efficiency of Cyclone Separators

Although cyclones look deceptively simple, their operation and design is not, and relies much more on experimental testing than on modeling. Commercial units have a shape and form that has matured over many years of operation. The ability of a cyclone to collect particles depends on the particular cyclone design, in particular on the entrance design and velocity and on the pressure drop, the size distribution of the particles, the properties of the gas and the dust particles, and the amount of dust contained in the gas.

Most efficiency determinations are made during tests on a geometrically similar prototype of a specific cyclone design, in which all of the above variables are accurately known. When a particular design is chosen it is usually sufficiently accurate to estimate this cyclone's collection efficiency, based upon the manufacturer's efficiency curves for handling a similar dust and gas.

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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).