Liquid Filtration

4.1 Introduction:

The separation of solids from a suspension in a liquid by means of a porous medium or screen which retains the solids and allows the liquid to pass is termed filtration. The particle is a separate phase or cake and the passes as the clear filtrate. In general, the pores of the medium are **larger** than the particles which are to be removed, and the filter works efficiently only after an initial deposit has been trapped in the medium. Filtration is essentially a mechanical operation and is less demanding in energy than evaporation or drying where the high latent heat of the liquid, which is usually water, has to be provided.

Volumes of the suspensions to be handled vary from the extremely large quantities involved in water purification and ore handling in the mining industry to relatively small quantities, as in the fine chemical industry where the variety of solids is considerable. In most industrial applications it is the solids that are required and their physical size and properties are of paramount importance.

The valuable product may be the clear filtrate from the filtration or the solid cake. In some cases, complete removal of the solid particles is required and in other cases only partial removal.

Typical filtration operation is illustrated in Figure 1, which shows the filter medium, in this case a cloth, its support and the layer of solids, or filter cake, which has already formed. The cake gradually builds up on the medium and the resistance to flow progressively increases. During the initial period of flow, particles are deposited in the surface layers of the cloth to form the true filtering medium.

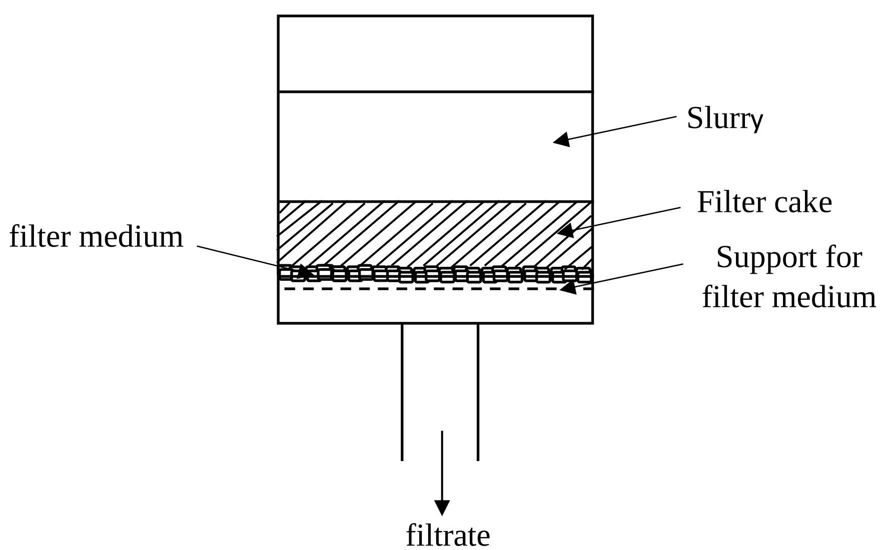

Figure 1: Principle of filtration

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The main factors to be considered when selecting equipment and operating conditions are:

(a) The properties of the fluid, particularly its viscosity, density and corrosive properties.
(b) The nature of the solid-its particle size and shape, size distribution, and packing characteristics.
(c) The concentration of solids in suspension.
(d) The quantity of material to be handled, and its value.
(e) Whether the valuable product is the solid, the fluid, or both.
(f) Whether it is necessary to wash the filtered solids.
(g) Whether very slight contamination caused by contact of the suspension or filtrate with the various components of the equipment is detrimental to the product.
(h) Whether the feed liquor may be heated.
(i) Whether any form of pretreatment might be helpful.

The most important factors on which the rate of filtration then depends will be:

(a) The drop in pressure from the feed to the far side of the filter medium.

(b) The area of the filtering surface.

(c) The viscosity of the filtrate.

(d) The resistance of the filter cake.

(e) The resistance of the filter medium and initial layers of cake.

***Two basic types of filtration processes* may be identified, although there are cases where the two types appear to merge.**

In the **first**, frequently referred to as ***cake filtration***, the particles from the suspension, which usually has a high proportion of solids, are deposited on the surface of a porous septum which should ideally offer only a small resistance to flow. As the solids build up on the septum, the initial layers form the effective filter medium, preventing the particles from embedding themselves in the filter cloth, and ensuring that a particle-free filtrate is obtained.

In the **second** type of filtration, ***depth or deep-bed filtration***, the particles penetrate into the pores of the filter medium, where impacts between the particles and the surface of the medium are largely responsible for their removal and retention. This configuration is commonly used for the removal of fine particles from very dilute suspensions, where the recovery of the particles is not of primary importance. Typical examples here include air and water filtration.

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4.2. Filter media and filter aids.

Filter media: The filter media for the industrial filtration must fulfill a number of requirements. First and foremost, it must remove the solids to be filtered from the slurry and give a clear filtrate. Also, the pores should not become plugged so that the rate of filtration becomes too slow. The filter medium must allow the filter cake to be removed easily and clearly. Obviously, it must have sufficient strength to not tear and must be chemically resistance to the solutions used. Some widely used filter media are twill or duck weave heavy cloth, woven heavy cloth, glass, paper and nylon cloth.

Filter aids: Certain filter aids may be used to aid filtration. Those are often incompressible diatomaceous earth or kieselguhr, which is composed primarily of silica. Also used are wood cellulose and other inert porous solids. These filter aids can be used in a number of ways. They can be used as a p-recoat before the slurry is filtered. This will prevent gelatinous type solids from plugging the filter medium and also give a clearer filtrate. They can also be added to the slurry before filtration. This increases the porosity of the cake and reduces resistance of the cake during filtration The use of filter aids is usually limited to cases where the cake is discarded or to cases where the precipitate can be separated chemically from the filter aid.

4.3. Filtration equipments:

The most suitable filter for any given operation is the one which will fulfill the requirements at minimum overall cost. Since the cost of the equipment is closely related to the filtering area, it is normally desirable to obtain a high overall rate of filtration. This involves the use of relatively high pressures although the maximum pressures are often limited by mechanical design considerations. Although a higher throughput from a given filtering surface is obtained from a continuous filter than from a batch operated filter, it may sometimes be necessary to use a batch filter, particularly if the filter cake has a high resistance, since most continuous filters operate under reduced pressure and the maximum filtration pressure is therefore limited. Other features which are desirable in a filter include ease of discharge of the filter cake in a convenient physical form, and a method of observing the quality of the filtrate obtained from each section of the plant. These factors are important in considering the types of equipment available. The most common types are filter presses, leaf filters, and continuous rotary filters. In addition, there are filters for special purposes, such as bag filters, and the disc type of filter which is used for the removal of small quantities of solids from a fluid. The most important factors in filter selection are the specific resistance of the filter cake, the quantity to be filtered, and the solids concentration.

For free-filtering materials, a rotary vacuum filter is generally the most satisfactory since it has a very high capacity for its size and does not require any significant manual attention. If the cake has to be washed, the rotary drum is to be preferred to the rotary leaf. If a high degree of washing is required, however, it is usually desirable to re-pulp the filter cake and to filter a second time. For large-scale filtration, there are three principal cases where a rotary vacuum filter will not be used. Firstly, if the specific resistance is high, a positive pressure filter will be required, and a filter press may well be suitable, particularly if the solid content is not so high that frequent dismantling of the press is necessary. Secondly, when efficient washing is required, a leaf filter is effective, because very thin cakes can be prepared and the risk of channeling during washing is reduced to a minimum. Finally, where only very small quantities of solids are present in the liquid, an edge filter may be employed.

4.4 Basic theory of filtration:

The calculation of the rate of flow of a fluid through a bed of granular material, and these are now applied to the flow of filtrate through a filter cake. Some differences in general behavior may be expected, however, because the cases so far considered relate to uniform fixed beds, whereas in filtration the bed is steadily growing in thickness. There are two quite different methods of operating filter, if the filtration pressure is constant; the rate of flow progressively diminishes whereas, if the flow rate is to be maintained constant, the pressure must be gradually increased. Because the particles forming the cake are small and the flow through the bed is slow, streamline conditions are almost invariably obtained, and, at any instant, the flow rate of the filtrate may be represented by the following form of equation:

$$u_c = \frac{1}{A}\frac{dV}{dt} = \frac{1}{5}\frac{e^3}{(1-e)^2}\frac{-\Delta P}{S^2 \mu l} \quad \text{.....................1}$$

Where ***V*** is the volume of filtrate which has passed in time ***t***, ***A*** is the total crosssectional area of the filter cake, u_c is the superficial velocity of the filtrate, ***l*** is the cake thickness, ***S*** is the specific surface of the particles, ***e*** is the voidage, ***μ*** is the viscosity of the filtrate, and ***P*** is the applied pressure difference.

In deriving this equation, it is assumed that the cake is uniform and that the voidage is constant throughout. In the deposition of a filter cake this is unlikely to be the case and the voidage, ***e*** will depend on the nature of the support, including its geometry and surface structure, and on the rate of deposition. The initial stages in the formation of the cake are therefore of special importance for the following reasons:

(a) For any filtration pressure, the rate of flow is greatest at the beginning of the process since the resistance is then a minimum.

(b) High initial rates of filtration may result in plugging of the pores of the filter cloth and cause a very high resistance to flow.

(c) The orientation of the particle in the initial layers may appreciably influence the structure of the whole filter cake.

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Filter cakes may be divided into two classes-incompressible cakes and compressible cakes. In the case of an incompressible cake, the resistance to flow of a given volume of cake is not appreciably affected either by the pressure difference across the cake or by the rate of deposition of material. On the other hand, with a compressible cake, increase of the pressure difference or of the rate of flow causes the formation of a denser cake with a higher resistance. For incompressible cakes ***e*** in equation (1) may be taken as constant and the quantity is then a property of the particles forming the cake and should be constant for a given material.

Thus: $$\frac{1}{A}\frac{dV}{dt} = \frac{-\Delta P}{\mathbf{r}\mu l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$e^3/[5(1-e)^2 S^2]$

Where: $$\mathbf{r} = \frac{5(1-e)^2 S^2}{e^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

It may be noted that, when there is a hydrostatic pressure component such as with a horizontal filter surface, this should be included in the calculation of **- Δ*P***. Equation (2) is the basic filtration equation and ***r*** is termed the specific resistance which is seen to depend on e and ***S***. For incompressible cakes, ***r*** is taken as constant, although it depends on rate of deposition, the nature of the particles, and on the forces between the particles.