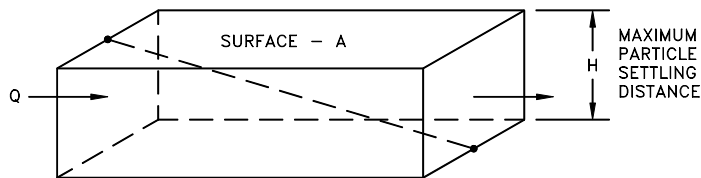


Plate Separation - Budding Conventional Technology?

8036

Gravity separators come in different forms and those variants built around stacks of parallel plates offer the treatment plant owner and designer a number of distinct performance advantages.

By C.G. Steiner Reprinted from the March 1986 issue of *Water Engineering & Management* magazine



Simple Rectangular Clarifier
Figure 1

First developed in 1904 by a scientist named Hazen, plate separators have become an accepted technology for a wide variety of water and wastewater treatment applications relatively recently. The traditional clarifier, except in a number of special cases, may not be so commonly used as a particle separation device in the future. The explanation is simple: separators generally cost less to purchase, take up less space and perform better than clarifiers.

Notwithstanding this growing acceptance, separators are still a technological mystery to many engineers and plant owners contemplating their use. However, they can certainly be considered in many new treatment applications. Throughout the 1970's, separators were effectively utilized for the removal of oil from water to achieve compliance with the more stringent EPA treatment requirements. These units, called oil/water separators, did an excellent job of removing the oil - - but a poor job of extracting suspended solids, and important secondary treatment objective. During the same period, solids separators incorporating a stack of parallel inclined plates were also introduced to remove settleable particles from a variety of streams found in the chemical, food, mining, metal finishing, electronics, and power industries as well as in municipal treatment plant influents. These separators usually accomplish a splendid job of removing settleable solids but permit rising particles, or scum, if present, to pass through and out with the treated effluent.

During the last ten years, separation devices have been greatly improved and their treatment capabilities expanded. Up-flow and down-flow separators both suffer from particle reentrainment. Particle reentrainment always occurs when the removal direction of the separated particle is countercurrent, or opposite to, the direction of the flow stream through the unit. The introduction of the cross-flow separator has permitted the simultaneous removal of both rising and settling particles without favoring one kind of particle over another while eliminating particle reentrainment. Also, plate flocculators, dissolved air flota-

tion capabilities, and multiple stage treatment have been added to the basic separator equipment designs to offer separation of virtually any particle, or mixture of particles, without reservations or exception.

Consider the general theory dealing with the differential gravity separation of particles. Gravity clarification permits removal of particles which exhibit densities different from their carrier fluid. Separation is accomplished by detaining the flow stream for a sufficient time to permit particles to separate out. In water and wastewater treatment practice, particles which rise to the surface of a liquid are said to possess rise rates while particles which settle to the bottom exhibit settling rates. Both types obey Stoke's Law which establishes the theoretical terminal velocities of the rising and/or settling particles. Stoke's Law states:

$$V_p = \frac{G}{18\mu} (B - A) D^2$$

where V_p = Rising or settling velocity of discrete particle

G = Gravity constant

A = Density of particle

B = Density of carrier fluid

D = Diameter of discrete particle

μ = Viscosity of carrier fluid

A negative velocity is described as a rise rate. Oil, scum, fats, greases, waxes, and other such particles which float to the surface of a liquid are said to possess rise rates. A positive velocity is referred to as a settling rate. All particles which settle to the bottom of a carrier fluid are said to possess settling rates. More often than not, both rising and settling particles are present in the same fluid stream. Traditional separation equipment frequently consists of circular and rectangular unit (Fig. 1) of height "H", surface area "A", and hydraulic capacity, or flow through, of "Q", the residence time "T_r" of the liquid can be determined according the following equation:

$$T_r = \frac{A \times H}{Q}$$

Now assume that a discrete particle with a positive settling velocity is suspended at the inlet top of the clarifier at point "⊕". The time it takes, designated as "T_p", for this particle to reach the bottom can be found by dividing the height of the clarifier by the particle settling velocity, or

$$T_p = \frac{H}{V_p}$$

Particle “ \oplus ” will reach the bottom of the clarifier (and thereby become separated from its carrier fluid) if the residence time is at least equal to the settling time of the particle. This condition may be expressed as:

$$T_r = T_p$$

In substituting for T_r and T_p , we have

$$\frac{A \times H}{Q} = \frac{H}{V_p}$$

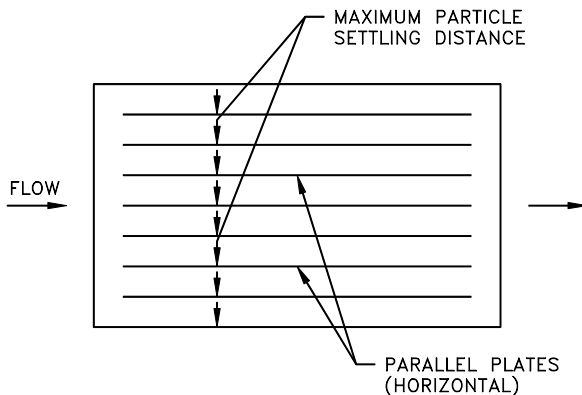
which reduces to:

$$V_p = \frac{Q}{A} \text{ (Equation 1)}$$

The ratio Q/A is designated as the “overflow rate” of the “surface loading” of the clarifier and is expressed in GPM/sq ft or GPD/sq ft. The overflow rate then, is but a shorthand method of expressing the separation velocity V_p of the particle which the clarifier will remove.

The equation above defines an extremely significant relationship in separator technology. It proves that neither the height of the clarifier nor the residence time influences particle removal efficiency. The relationship, rather between flow and surface area (or settling area) is controlling.

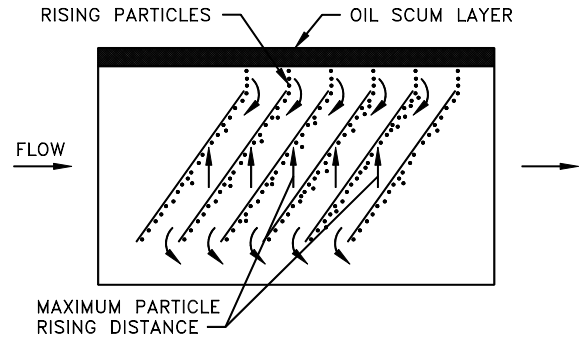
A number of separator designs have been developed as we have seen. In an ordinary *clarifier*, a particle must traverse the full height of the vessel to separate out. This is shown at the right hand side of Figure 1.



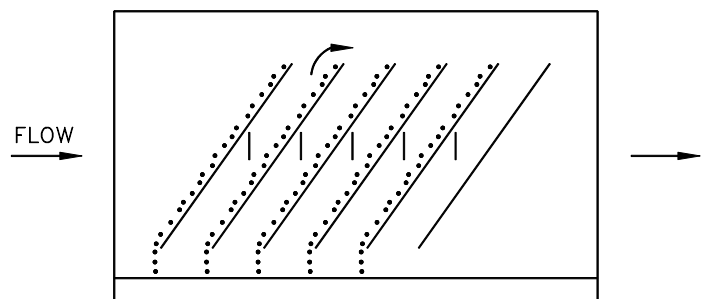
**Clarifier with Parallel Plates
Figure 2**

In 1904 Hazen introduced the *horizontal plate separator*. Note the short vertical distance through which the settling particle falls during separation (Fig. 2). In the initial settling phase, the horizontal plate system works very well. As separated particles begin to build up on the collector plates, the flow path of the liquid becomes partially restricted. Eventually, laminar flow conditions gradually disappear because of induced turbulence. This condition then causes reentrainment of some once-separated particles - - and a degradation of effluent quality. At this time,

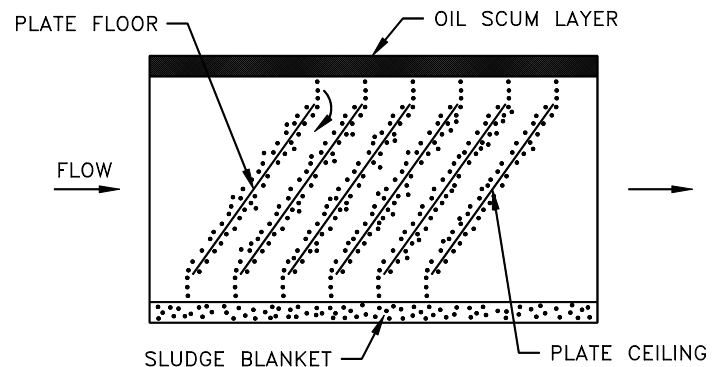
the Hazen separator has to be cleaned to restore its initial efficiency.



**Down Flow Separator
Figure 3**



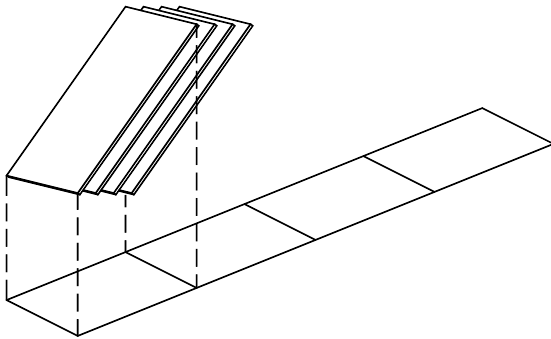
**Up Flow Separator
Figure 4**



**Cross Flow Separator
Figure 5**

The horizontal plate separator was improved by inclining the plates in excess of the **angle of repose** (otherwise known as the slide away angle) exhibited by the specific separated particles. This plate inclination improvement permitted both rising and settling particles to be removed without shutdown of the device for periodic cleaning. A down-flow separator is commonly used for oil/water separation and other liquid/liquid applications (Fig. 3). Up-flow separators can be applied to solids/liquid separation tasks (Fig. 4). In a cross-flow unit, both rising and settling particles are removed simultaneously (Fig. 5). By adding inclined plates to a separator, the new capacity is reflected by the summation of the horizontal projection areas of each individual plate. Recalling that the capacity of any clarifier is determined by its settling area, you will see that

the effective settling area of a plate separator as illustrated in Figure 6 is substantially larger than obtained with the horizontal plate variant.



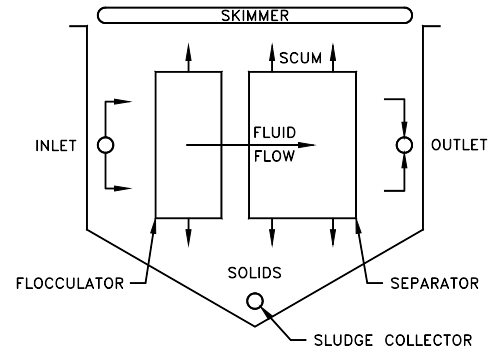
Inclined Plate Separator
Figure 6

Separator technology involves intricate and sometimes sensitive process conditions. For example, the use of corrugated rather than flat plates can cause particle coalescence to occur. When two particles of equal size coalesce together, the rate of separation of the combined particle is four times greater than either individual particle (refer again to Stoke's Law). Coalescence is illustrated in Figure 7. Plate spacing, Reynolds numbers, internal hydraulics, particle loadings, and pressure drops are additional considerations which affect separator performance. A full discussion of each of these is, however, beyond the scope of this article.

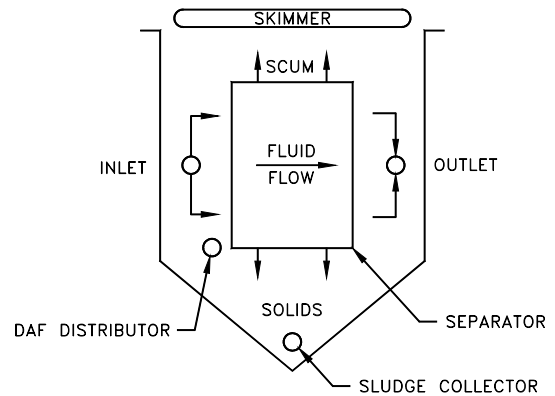


Corrugated Plate Separator
Figure 7

A plate flocculator accomplishes flocculation in much the same manner as a static mixer accomplishes flash mixing. Both are static devices which are becoming more cost effective and better performing than the mechanical flocculators and mixers they replace in certain applications. Plate flocculators in conjunction with a chemical feed may be used in a separation process to form agglomerated particles which exhibit either rising or settling rates. This type of two-stage treatment is illustrated in Figure 8. Dissolved air flotation (DAF) is another process system which may be adapted to the separator (Fig. 9).



Combination Flocculator Separator
Figure 8



Typical DAF Separator
Figure 9

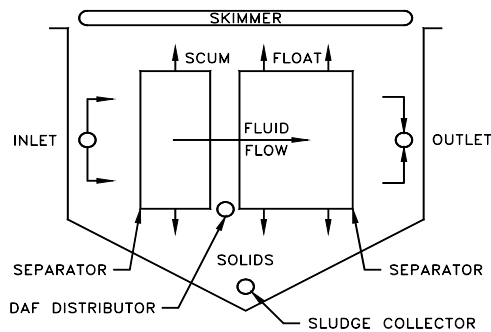
In general, separators are used to remove large quantities of small particles. By large quantities is meant concentrations of suspended solids up to say, 50% but generally in the 0.5 to 5% range. By small particles is meant particles down to about 15 microns in size. If smaller sized particles are present in only low quantities, then media filtration might be considered as the appropriate technology.

To use separators cost-effectively, the raw water or influent characteristics and the treatment objectives must be clearly defined. Also, the limitations of plate separation must be understood so that the treatment desired is achieved. Some examples indicate the importance of this knowledge.

In the metal finishing industry, the usual practice is to form the hydroxide of the metal to be removed and separate it out by precipitation as a settleable solid. In some cases, the metal hydroxide exhibits extremely poor settling characteristics and escapes from the separator. The reasons for slow separation velocities may include chemical feed characteristics, production levels, or the presence of other contaminants. For this application, DAF is an appropriate process since particles of a somewhat neutral gravity are easily raised to the surface with this system. Stoke's Law establishes the terminal settling velocity of a discrete particle in a carrier fluid. The term **discrete** should not be overlooked. If the carrier fluid contains a high concentration of suspended particles, then the discrete character of each particle is lost. Settling which occurs in a highly concentrated carrier fluid is described as **hindered settling**.

This type proceeds more slowly than the discrete variety. Whether hindered settling occurs is determined by the concentration of particles, their sizes, and their specific gravities. To be kept in mind is the fact that theoretical efficiencies of particle separation are only achieved when discrete particles are to be removed. In this example, the appropriate technology consists of a two-stage separator with the first stage accomplishing gross particle removal and the second achieving theoretically achievable particle removal.

Throughout industry, there has been a widespread application of the dissolved air flotation process without regard to the characteristics and concentrations of the particles present. For example, if a raw water flow contains both neutral gravity particles (thus easy to remove by DAF) and settleable solids, the use of DAF may indeed accomplish removal of the neutral gravity particles. At the same time, however, it could also cause the settleable particles to acquire a neutral gravity state due to air particle attachment. These would then escape the separation process and go on to contaminate the effluent. The appropriate technology in this case would consist of a first stage separator to remove the easily settleable solids followed by a DAF separator for the neutral gravity material (Fig. 10).



Combination Separator DAF Separator
Figure 10

A typical application of the above type of wastewater treatment was exhibited at a lamb kill facility in Iowa where the discharge required pretreatment to eliminate municipal surcharges for excessive suspended solids and BOD. The first stage separator indeed removed those particles which exhibited either rising or settling characteristics. A following DAF separator removed the remainder of the particles, namely those exhibiting neutral gravity characteristics.

At a coal-fired utility in Nebraska, a pretreatment requirement was to remove coal fines from a pond that collected coal pile runoff water. The one condition imposed by the utility on the process scheme was the ability to remove the fines without using any chemicals. Normally, chemicals are added in this type of application to coagulate the fines and thus achieve more rapid separation rates. In that chemicals were eliminated as a process aid, a method had

to be devised to separate the particles as they existed. The solution was simple. Since the heavier coal fine particles have already settled out in the collection pond, only the fines require removal. By treating in a first stage DAF separator, particles down to about 15 microns in size are easily removed. By following this with fine media filtration, the purification of the black pond water to a turbidity of NTU equal to 1 is achieved. This approach can be taken in the cleaning up of other common industrial discharges such as fly ash pond supernatant, mining tailing pond supernatant, lumber mill recirculation ponds, etc. - - all without the use of costly chemicals.

Until now most separator installations of the types described have been in the industrial area. The use of these devices in municipal purification applications is now beginning to occur. For example, a large separator was used as a secondary clarifier following a two-stage rotating disc biological treatment system in North Bergen, New Jersey. Since its installation four years ago, no operational problems have been traceable to the system. Separators may one day also be installed at municipal treatment plants as primary clarifiers following gross solids removal. For many years, separators have been used in package treatment plants for potable water supply. Their use in large municipal water treatment facilities has yet to be adopted even though surface water source supplies are identical to package plant sources. This additional application is sure to follow.

Since gravity separation can occur in a pressurized vessel, the use of separators in this mode may be considered without reservation. A pressurized vessel is often preferred over a gravity vessel. In the chemical processing industries, there are many liquid/liquid separation applications currently carried out in traditional clarifiers. Virtually any liquid/liquid separation can be accomplished in a separator provided there exists a sufficient specific gravity differential between the two liquids.

If a separator is used under hydraulic conditions which impose turbulent flow conditions (Reynolds numbers in excess of 500), it is then possible to separate particles which exhibit significantly different separation rates. When applied in this manner, a separator may be used as a classification device to separate two types of particles. By accomplishing particle classification in a dynamic rather than a static mode, significant quantities of transport, dilution, or elutriation water may be saved.

There is no doubt that plate separators represent a splendid addition to the designer's inventory of processes that can achieve cost-effective treatment. The technology is now better understood and better applied. Separator designs offer several treatment options as well as unlimited flow capabilities in either shop-built packaged steel or site-constructed concrete materials of construction.

