

There are methods that can be used to optimize clarifier and filter press efficiency. By optimizing settling performance, solids loading and sludge withdrawal rates, the equipment can be fine-tuned to optimize its fullest potential. The ability to dewater sludge, however, is usually another limiting factor. Simple tests that are easily performed may be used to determine these factors, and optimize the efficiency of the system.

The clarifier itself is not usually the bottleneck in a solids/water separation system. Many parallel plate clarifiers can be run at their rated capacity, or even a little higher, when separating metal hydroxide solids. The highest possible efficiency must be obtained from the equipment so that capacity can be increased, without investing more capital in additional equipment. The clarification flow rate can be maximized by:

- Improving settling rates
- Determining solids loading
- Optimizing sludge withdrawal

There are five major factors that affect the performance of parallel plate clarifiers, commonly called lamella settlers:

- Maintenance
- Flow rate
- Solids loading
- Sludge withdrawal
- Settling rate

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Maintenance is very important if performance is to be optimized. The clarifier should be pumped down below the plates at least once a week. If possible, the plates should be pulled out and cleaned to remove scale and restore the smooth, slippery surface. Clarifiers with a plate pack that must be removed as a "unit" should be cleaned with a high-pressure spray washer. Acid washing with inhibited hydrochloric (muriatic) acid is also an option.¹ The scale usually does not dissolve, however, and the acid may damage the clarifier. Also, the plates or plate pack unit should be removed at least once a year to clean the sludge hopper. This will help prevent "channeling" where one side of the clarifier is favored. Be sure to check for tools that may have been dropped into the clarifier and block the sludge withdrawal ports. Special consideration should be given to the ceiling height above the clarifier. Removing the plates can be very difficult when there is not enough clearance.

Flow rates for optimum conditions are set by the manufacturer. For example, a 200 gal/min clarifier can easily handle a hydraulic load of 200+ gal/min without overflowing. It is also easy to separate sand and water at high flow rates. Separating metal hydroxide "floc" with a specific gravity only slightly heavier than water, however, will be more challenging. Fortunately, high flow rates can usually be achieved if the settling rate, solids loading and sludge withdrawal rate are all optimized.

Settling Rate

Perhaps the most important factor affecting clarifier efficiency is how fast the solids or "floc" will settle. The density of the precipitate, coagulant and polymer being used determines the settling rate. Clarifier Usually "jar parallel tests" are conplates ducted in the lab to optimize the coagulation and flocculation processes. These tests should be done on a regular basis for control

Fig 1.—When the water is withdrawn too fast, a phenomenon called "coning" may result. purposes, and to test new coagulants and polymers. There is a quick and easy method to check the settling rate. Complete the coagulation and flocculation steps and pour the solution into an Imhoff settling cone and record the time required for the floc to settle from 1,000 mL to 800 mL. This distance is usually about $1^{1/4}$ in. (31 mm) on most cones. Then, measure the distance between the parallel plates in the clarifier. Typical spacing is between 1 and $1^{1/2}$ in. A wastewater with good settling properties should drop one inch during five minutes or less. Maximum flow rates are only possible with a fast-settling floc.

Solids Loading

Equipment manufacturers specify the maximum load of solids that may be applied to the clarifier. Typical loading range is from 500 to 2,000 mg/L. Another important specification is the ft² of settling area. This factor increases in direct proportion to the flow rate.

The solids loading may be calculated in the laboratory by filtering a 1,000 mL sample of the flocculated solution through a filter paper of known weight. The sample is then dried and weighed. The dry weight minus the weight of the filter paper is

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the mg/L of influent solids. Unfortunately, this test is time consuming and the solids loading may fluctuate.

There is a quick and easy test that may be used as a guide however. Fill an Imhoff cone with flocculated solution to the 1,000 mL level and start a stopwatch. Check the clarifier specifications for the volume or capacity in gallons. Divide this figure by the desired flow rate to get the retention time. For example, if the clarifier will hold 3,000 gal of solution and the desired flow rate is 200 gal/ min, then the retention time may be computed using the following formula:

$\frac{3,000 \text{ gal of solution}}{200 \text{ gal/min}} = 15 \text{ min}$

This means that at a 200 gal/min flow rate, the solids will have 15 min to "drop out" in the clarifier. By noting the solids level in the Imhoff cone after 15 min of settling, an estimation of the solids loading can be made. One can expect the solids level to be in the range of 100 mL to 500 mL. This range is for metal hydroxide precipitates, and not for heavy solids from burnishing or tumbling operations. Solids loading above 500 mL may result in floc being carried out of the clarifier. On the other hand, low solids of 200 mL or less may contribute to "pin floc." Pinpoint floc is a very small particle of floc that does not settle rapidly and is easily carried out in the effluent. Since pin floc contains metal hydroxides, permit limitations may be exceeded. A minimum solids loading of 200 mL will help minimize pin floc by trapping the small particles and filtering them out as they travel up through the sludge blanket in the clarifier.

Underflow

The last factor that must be controlled is the underflow, more commonly known as the sludge withdrawal rate. This is important because clarifier manufacturers specify an optimum level for the sludge blanket. If the blanket is too high, then the floc will be carried out in the effluent. When the blanket is too low, pin floc will not be filtered out of solution.

Optimum conditions exist when the sludge blanket is at the ideal level and the solids removed (underflow) are equal to the solids added (influent). This is difficult to obtain in practice, however, because of a phenomenon known as coning. When the sludge is withdrawn too rapidly from the bottom of the clarifier, a funnelshaped cone may develop.² This will cause water instead of solids to be pumped out. The phenomenon is illustrated in Fig. 1.

This problem may be minimized by using an interval timer to cycle the pump on and off. The cone will fill up with sludge again during the off cycle.

Unfortunately, cycling the sludge withdrawal pump makes it more difficult to equalize the influent and underflow rates. Usually the sludge is pumped from the clarifier to a conical bottom tank for thickening. In order to optimize the sludge withdrawal rate, the volume pumped out must be measured accurately. In addition, the underflow must be inspected to make certain that sludge, not water, is pumped out at the end of the cycle. This may be easily accomplished by installing a "T" fitting with a valve and hose on the discharge pipe from the sludge withdrawal pump. The hose and fittings must be the same size as the discharge plumbing, and head pressure is not taken into consideration. Measure the amount of time that is required to fill a 55-gal drum with the underflow. Then calculate the flow rate by using this formula:



A good underflow that is not diluted with water will show little settling (100 mL or less) in a five-min settling test. Now it is possible to balance the influent and underflow solids. The influent solids will be equal to the percent of settled solids from the solid loading test multiplied by the flow in gal/min.³ For example, if the 250 mL of solids settled during the 15 min settling test and the flow rate is 200 gal/min, then the influent solids are calculated as follows:

Influent Solids = % Settleable Solids x Flow/gal/min = .25 x 200 = 50 gal/min

A 55-gal drum of sludge would almost have to be emptied every minute to balance the influent solids loading. This presents another challenge—what to do with 3,000 gal of sludge per hour! Additional jar testing is required. Fill an Imhoff



cone with underflow sludge and note the sludge level after 60, 120 and 180 min intervals of settling. Typical metal hydroxide sludge will reduce by 50 to 75 percent in volume after one to two hours of additional settling. A large capacity, well-designed sludge thickening tank may be required.

Sludge Thickening

Thickening and dewatering the sludge is usually the limiting factor in maximizing clarifier flow rates. A large tank with a minimum of two hours' retention time is needed. Moreover, the tank should be designed to promote fast settling and produce a clear, high-quality supernatant. Sludge thickeners usually are tall, cylindrical tanks with conical bottoms and are constructed much like municipal clarifiers.⁴ The solids enter a large 10 to 12 in. diameter tube at the top of the tank and flow by gravity to the exit inside the tank about 24 in. above the bottom of the cone. This minimizes disturbances to the sludge blanket when solids are pumped in. The clear supernatant gently overflows into a weir around the circumference of the top of the tank. This concept is illustrated in Fig. 2.

The effluent may require polishing in a sand filter to remove small suspended solids if very low permit limits must be met.

Thickened sludge, approximately one to two percent solids, is withdrawn from the bottom of the cone and dewatered in a filter press. Again, a proper balance must be achieved between the capacity to thicken solids and the ability of the filterpress to dewater the slurry.

Sludge Dewatering

The filter press should be operated at maximum efficiency to keep up with the sludge production. Selecting a press with a large enough capacity to do the job requires evaluating these factors:

- Volume of sludge to dewater
- Average cycle time
- Down-time for cleaning

The capacity of the filter press is difficult to estimate and usually too small of a press is purchased. Selecting the proper size can be made easier by renting a small portable unit (0.5to 1.0 ft³) for pilot testing. Based on the techniques presented in this paper, one should be able to estimate the average volume of thickened solids produced during a typical working day. Then, pilot tests should be run to optimize the production of filtercake in the shortest possible time. Experiments should be conducted using a diatomaceous precoat to protect the filter cloths from blinding. Precoating usually decreases the cycle time and produces a clear filtrate immediately.

The press is not usually cleaned until the filter feed pump slows to 20-30 sec between strokes. Because the goal is to dewater the largest volume of sludge in the shortest period of time, try this experiment. Start the feed pump at 25 psi after precoating the filter cloths. Measure the filtrate volume (in gal/min), and try to keep a constant volume of flow by slowly increasing the air pressure to the pump. Some filter press manufacturers have equipment that will do this automatically. Once the air pressure is raised to 100 psi (maximum), wait for the filtrate flow to decrease to less than 50 percent of the original volume. This is usually the point of diminishing returns. The flow through the press decreases dramatically as the filtercake becomes thicker. Blow the press down with air for a few minutes until very little water is draining from the filtrate discharge pipe. Open the press and examine the filtercake to determine if it is dry enough to landfill. To qualify for landfilling, the filtercake must pass the "paint filter" test. The filtercake should be placed in a paint filter and no free liquid is allowed to drip-out within a five-min period.

Properly sizing the filter press to keep up with sludge production can be accomplished through pilot testing. For example, if a one ft³ press will maintain an average flow rate of two gal/min over a six-hr filtration cycle, then a 10 ft³ press should flow 20 gal/ min. Therefore, a large press (25 ft³) would be required to dewater the 25 gal/min of thickened sludge generated from clarifying a 200 gal/min influent.

Conclusion

The complete solids/water separation system must be evaluated to maximize clarifier flow rates. More often than not, the ability to dewater sludge will be the limiting factor in the process. Settling rates can usually be improved and the solids loading determined accurately. The sludge withdrawal rate can also be optimized. Equipment to thicken solids and dewater the sludge, however, must be properly designed and be large enough in capacity to keep up with solids removed by the clarifier.**P**&SF

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