High Rate Pulsed Sludge Blanket Clarifier Performance on Rivers and Reservoirs with Widely Different Raw Water Characteristics in Texas and United States

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Introduction

There are many different types of sludge blanket clarifiers and it is important to note that the pulsed sludge blanket clarifier is completely different. The pulsed sludge clarifier is known in the water treatment industry as the Pulsator® Clarifier or Superpulsator® Clarifier by Infilco Degremont Inc. The Pulsator® Clarifier is the first generation pulsed sludge blanket clarifier. Listed below are the generations of pulsed sludge blanket technology in the order of development:

1. Pulsator® Clarifier
2. Pulsatube® Clarifier
3. Superpulsator® Clarifier.
4. Superpulsator® Type U Clarifier.

The original Pulsator® Clarifier was developed in the early 1950's. The Pulsator® Clarifier was developed to combine flocculation and clarification within the same area and treat raw waters with low and high turbidity and color, 1-1000 NTU and 1-400 PCU, respectively. The Pulsator® Clarifier was also designed to be easy to operate with minimal maintenance. The pulsed sludge blanket clarifier installations vary in size from 0.5 to 440 MGD.

Worldwide, there are over 600 installations of the pulsed sludge blanket technology. In the United States, the Superpulsator® Clarifier is the most common as shown below:

1. Pulsator® and Pulsatube® Clarifiers >25
2. Superpulsator® and Superpulsator® Type U Clarifiers >73

The different versions of pulsed sludge blanket clarifiers by Infilco Degremont Inc. are capable of operating at rise rate of 0.5 to 5.0 gpm/sq. ft.

For the purpose of this paper, the information will be presented on the Superpulsator® Clarifier and Superpulsator® Type U Clarifier. The difference between the two versions is the fact that the Superpulsator® Type Clarifier has lamellar tubes above the settling plates.

Pulsed Sludge Blanket Clarifier Process Description

The Superpulsator® Clarifier design is based on the following principles:

1. Plug flow.
2. Combined flocculation/clarification in one vessel.
3. Pulsed flow through the vessel.
4. Internal sludge concentration and automatic sludge removal.
5. No submerged moving parts.
7. Simple treatment chemistry and effective usage of chemicals.
The Superpulsator® Clarifier consists of five main components (See Figure 1):

1. Raw water distribution.
2. Lamellar Plates and/or Tubes.
3. Effluent collection.
4. Sludge collection, concentration and discharge.
5. Vacuum chamber equipment.

Before entering the Superpulsator® Clarifier, the raw water and chemicals are added and mixed via inline mixer or rapid mix. The coagulated water is then split between the individual treatment units via flow splitter boxes, which then transfers the water to the vacuum chamber via a transfer pipe. The vacuum system creates low pressure within the chamber, causing the water to rise to a predetermined level. The vacuum time is adjustable by the control system which allows height and frequency of the rise (water level) to be adjustable. The amount of vacuum on the chamber is controlled by an air bleed valve on the vacuum line. This also helps fine-tune the height and pulsing action within the Superpulsator® Clarifier.

When the water reaches a maximum adjustable level (equal to the vacuum time) in the vacuum chamber, the vent valve opens releasing the vacuum on the chamber. The hydraulic head within the chamber causes a surge of water into the bottom distribution system. Orifices in the distribution pipes create uniform distribution across the entire clarifier tank displaying a plug flow characteristic.

The coagulated water, as it is distributed across the bottom of the flocculation/clarification zone, creates the pulsing energy. This energy is converted into gently stirring turbulence. The gently stirring turbulence helps flocculate the coagulated water into a settable floc. Within the flocculation/clarification zone, newly flocculated floc is mixed with previously flocculated sludge. The contacting of the newly formed floc with previously formed floc helps create larger and more settable floc.

When the hydraulic head water level in the vacuum chamber reaches a low level (equal to vent time) and the energy has been dissipated, the surge of flow slows and the sludge blanket begins to settle. At the low water level, the vent valve closes and the vacuum is applied again to the vacuum chamber. The incoming raw water rises in the vacuum chamber and repeats the cycle described above. A complete pulsation cycle is usually 40 to 60 seconds. This action helps create a uniform sludge blanket. The rhythmic and controlled surging or pulsing is the trademark by which the Pulsator® is known and named.

The vacuum chamber/sludge blanket relationship can be described as follows:

For every action in the vacuum chamber, the opposite action is occurring in the sludge blanket. As the water level in the vacuum chamber rises, the blanket contracts to its original position. As the water level drops in the vacuum chamber, the sludge blanket expands.

The pulsation affects the hydraulic flow through the clarifier as described in the following example:

The theoretical design flow through the unit is 1000 gpm. During the vacuum time step, the flow to the distribution channel is only 900 gpm because the vacuum on the vacuum chamber is creating a column of water with the missing 100 gpm from the design flow. The vent valve is opened and the vacuum is released. This creates an instantaneously high flow of 1400 gpm for the 10 seconds while the vent valve is open.
As water enters the sludge blanket and passes upward through it, the sludge blanket performs a double task. First it agglomerates newly formed floc, then it helps the suspended matter and colloidal particles adhere to the floc. The sludge blanket acts as a "flocculation-filter" in which these tasks are accomplished.

The clarified water separates from the sludge blanket at the concentrator weir (fixed) and is collected near the surface with a submerged orifice lateral collection system. Within the sludge blanket, there are specially designed plates that extend just above the concentrator edge. Above the plates, there are lamellar tubes, which settle light floc that is not removed by the sludge blanket. The collection system uniformly covers the tank for even collection of the clarified water. The lamellar plates and tubes allow the Superpulsator® Clarifier to operate at rise rates between 0.5 to 5.0 gpm/sq. ft.

Automatic sludge removal in the Superpulsator® Clarifier is achieved by blowdown collection piping, a valve, and a concentrator (collection area). First, the excess sludge flows from the sludge blanket into the concentrator. The excess sludge is removed by the pulsation cycles. The sludge is allowed to concentrate within the concentrator, and is then blown down periodically once the concentrator is almost full. The blowdown frequency and duration are dependent upon the flow, raw water characteristics, and chemicals.

Sludge enters the concentrator over the top edge of the concentrator only. This establishes the depth of the sludge blanket. The depth of the sludge blanket remains constant regardless of the flow conditions. The concentrator design provides protection against the sludge blanket being lost if extended blowdown occurs. Other systems may lose the sludge blanket because the sludge is blown down from the bottom of the blanket.

**Water Clarification -- Superpulsator® Clarifiers**

Suspended matter can be removed from water by agglomerating it into particles large enough to settle by gravity. Coagulants are added to the raw water for the coalescing of small particles into larger particles. After introduction of coagulating chemicals, small, slow settling floc is formed. A polymer is then added to help flocculate and form large settable floc. In addition, the water and flocculating material are gently agitated, so contact between the particles increases the size and settling characteristics of the floc. In the Superpulsator® Clarifier, the flocculation occurs in the presence of previously formed floc particles. Newly formed floc particles deposit on the surface of those already present so that they grow in size at a much higher rate, producing a heavier, faster settling floc.

The sludge blanket in the Superpulsator® Clarifier utilizes the phenomena described above. In other clarifiers, mechanical agitation mixes and flocculates the chemicals and water which is then followed by upward percolation through a suspension of previously formed solids known as a "sludge blanket." Successful operation depends upon a relatively static suspension of the particles in equilibrium with an upward flow. Such a suspension is inherently stratified and non-homogeneous and irregularities in bed density exist. The rising water naturally tends to flow through the irregularities where the sludge is less concentrated and, by doing so, it displaces the sludge still further from that particular zone. Consequently, the sludge blanket gradually settles into a compact mass through which the rising water has made a localized passageway. Effective contact between the water and the sludge mass has been lost in that area.

A different action results when water flows upward through the sludge blanket intermittently -- in a cycling or pulsating flow. During surging flow, the bed expands uniformly, as it would in a liquid at rest. As a result of pulsating flow, the blanket remains homogeneous throughout, with no stratification, maintaining continuous effective contact between water and sludge.

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The pulsed sludge blanket technology is based on the fact that as the sludge blanket concentration increases, the settling rate also increases to certain value. Each type of sludge has a maximum settling speed and rise rate.

A pulsating sludge blanket may be described as a coiled spring. It is compressed by the force of gravity but will be extended by the counter force of the friction of the water on particles constituting this spring. The spring extends more and more as the upward velocity increases to the point of breaking if overstressed. Overstressing a sludge blanket must be avoided by establishing an optimum vertical velocity. Moreover, the resistance of the spring may be improved by developing a heavier floc, with the use of flocculant aids, such as polyelectrolytes. Sludge characteristics vary with the water being treated, the chemicals used, the dosages, and the operation.

The Superpulsator® Clarifier utilizes powdered activated carbon (PAC) more effectively than any other treatment system. The PAC is fed into the sludge blanket where it is retained and absorbs organic material. The PAC can be retained within the sludge blanket between 12 hours and 3 days. This allows the PAC to continuously be in contact with new water entering the clarifier. This allows the complete absorbent capacity of the PAC to be completely used. In addition, the dosages are dramatically reduced when compared to other systems. At typical dosage of PAC in a Superpulsator® Type U Clarifier is between 2 to 5 ppm. Other systems typically use between 10 and 40 ppm. The reduced dosage is a big cost saving when compared to other systems.

**Superpulsator® Clarifier Operating Performance by Raw Source Waters**

**Delaware River**

One of the most recent installations is the Delaware River plant which utilizes pre-ozone, Superpulsator Clarifiers, and GAC filters. The Superpulsator Clarifiers are designed for a 4 gpm/sq. ft. rise rate with a hydraulic capacity of 5 gpm/sq. ft. The plant treatment chemistry uses ozone, KMnO₄, ferric chloride and anionic polymer.

Since the plant has been operating, the Superpulsator Clarifier clarified effluent has rarely exceeded 2 NTU. Figure 2 show the average typical clarified and filtered turbidity results versus raw turbidity:
Figure 3 show the plant’s process effectively removed about 40% of the TOC on a low TOC water:

![TOC Removal](image)

**Intracoastal Waterway**

The Intracoastal Waterway installation has a 30 mgd capacity. The raw water characteristics are impacted by flow from the Little Pee Dee River, the source waters of which are very swampy. The raw water is low in alkalinity and high in color, which makes it very difficult to treat. The Superpulsator Clarifiers are designed at a rise rate of 3.0 gpm/sq. ft. The treatment chemistry is alum and anionic polymer.

Statistically, it is important to note that the settled turbidity never exceeded 2 NTU on any occasion between July 1996 and June 1997. In addition, the average raw color was 108 PCU versus a finished color of 3 PCU between July 1996 and June 1997.

Figure 4 shows comparison of flow versus turbidity.

![Flow vs. Turbidity](image)
Figure 5 shows the removal of true color at the installation:

![Color Removal Graph](image)

Figure 6 shows the TOC removal achieved:

![TOC Removal Graph](image)

**Monogahela River**

The Monogahela River installation is the largest Superpulsator Clarifier installation in the United States. The clarifier treatment design rise rate is 3.0 gpm/sq. ft. using a treatment chemistry of ferric chloride and anionic polymer.

The plant operating data shows that the average daily settled turbidity has rarely or if ever exceeded 2 NTU. This installation frequently experiences widely changing raw water conditions. The raw turbidity typically is as low as 3 NTU with spikes at high as 300 NTU with the clarified effluent quality showing very little to no affect on performance. Figure 7 shows the typical turbidity characteristics achieved by the Superpulsator® Clarifier and this installation.
Lake Cumberland

The Lake Cumberland installation is influenced by the Cumberland River which is the primary source water for the lake. The plant experiences very low turbidity conditions most of the year. But during storm events, the plant experiences high turbidities for two or three days after the event. The treatment plant uses alum and anionic polymer for the treatment chemistry. Also, this installation operates a conventional flocculation and sedimentation system and Superpulsator Clarifiers.

Figure 8 shows a comparison between the 6 MGD conventional flocculation and sedimentation (tube settlers) system and the 4 MGD Superpulsator Clarifiers. As can be seen, the Superpulsator® Clarifier works equally as well at approximately 9 times, the rise rate.
Figure 9 shows the performance of the Superpulsator® Clarifiers with varying raw water turbidity levels:

**Ohio River**

The Ohio River installation is an excellent example of Superpulsator Clarifier performance under very high raw water turbidity conditions. During in flooding in March 1997, the plant experienced very high turbidity. The March turbidity data shows the Superpulsator performance under difficult and changing water conditions. The plant uses alum and a high molecular weight, low charge density flocculant cationic polymer for turbidity removal.

Figure 10 shows how the Superpulsator Clarifier performs under very high turbidity conditions. During the March flooding the high turbidity measured 1,400 NTU resulting in a one day average of 769 NTU.
Lake Verner

The Lake Verner installation is located in Georgia on a reservoir, which is fed by a creek. This raw water source is typically a low turbidity raw water between 1.5 and 12 NTU. The clarifiers are the Superpulsator® Type U type which incorporates lamellar tubes. The clarifiers are permitted at 2.6 gpm/sq. ft which is 3.5 mgd per clarifier. The installation utilizes an treatment chemistry of potassium permanganate, alum and anionic polymer.

Figure 11 shows performance of the clarifier on two-hour intervals:

Lake Moultrie

The Lake Moultrie installation consists of four Superpulsator® Clarifiers which were initially designed for a rise rate of 2.0 gpm/sq. ft. The plant wanted to increase the capacity, so a full-scale pilot study was conducted in March 1996, September 1996 and February 1997. The pilot study operated one (1) clarifier at 3.0 gpm/sq. ft. and another at 2.0 gpm/sq. ft. This installation utilizes alum and anionic polymer treatment chemistry. During the study, settled turbidities and TOC removal was evaluated.
Figure 12 shows the turbidity performance of the clarifiers during the study:

![Pilot Performance Graph]

Figure 13 shows the TOC performance of the installation during the study. The average TOC removal is approximately 50%.

![TOC Removal Graph]

Beaumont, Texas

The City of Beaumont operates the original Pulsator Clarifier. Figure 14 shows typical clarifier performance of a Pulsator Clarifier operating between 0.75 and 1.5 gpm/sq. ft.
Neches River

This installation is a Superpulsator Clarifier, which is presently under construction. A pilot study was conducted in 1994 to determine the viability of the Superpulsator for this application. The raw water characteristics consists of moderately high turbidity (40-60 NTU) and highly colored (>100 PCU) water. Figure 15 compares raw turbidity versus clarified turbidity during the pilot study.

**Raw vs. Clarified Turbidity**

Figure 16 shows the TOC removal in the utilizing an alum chemistry with a dosage of 50 to 100 ppm and anionic polymer.
Figure 17 shows the color removal achieved through the clarifier only. Typically the color was reduced to less <10 PCU through the Superpulsator Clarifier.

**Large Creeks in Central Pennsylvania**

This installation raw water source is two large creeks in the central Pennsylvania area. These creeks have constantly changing raw water characteristics. The plant utilizes an alum and anionic polymer treatment chemistry. Figure 18 shows the performance of the Superpulsator Clarifiers under typical four conditions.
Conclusion

The Pulsator®, Superpulsator® and Superpulsator® Type U Clarifier have been demonstrated in many different applications across the Carolina's and the United States. The applications shown in this paper are only several of the 75 installations in the United States and 600 installations worldwide. The pulsed sludge blanket technology allows owner and engineers an alternative to conventional flocculation and sedimentation. The pulsed sludge blanket technology provide benefits such as easy operation, very little to no maintenance and no submerged moving parts in the clarifier. Lastly, all submerged components are corrosion resistant.