



STATE OF ARKANSAS  
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

DATE 04/07/08 SHEET      of       
BY MJ  
PROJECT GERBER

GERBER - NPDES ARO001511

OUTFALL 002 - PROCESS + NON CONTACT COOLING WATER  
HOWEVER, NO PROCESS WASTEWATER DISCHARGED AT  
THIS TIME,

PROCESS WASTEWATER → CITY OF FT. SMITH  
ONLY NCCW DISCHARGED THROUGH 002

EXISTING TREATMENT SYSTEM :

NCCW ; NONE

PROCESS : SCREENING, ACTIVATED SLUDGE, AERATED  
LAGOON, FINAL CLARIFIER)

PROPOSED :

SEPERATION OF WASTESTREAMS (NEW OUTFALL 003)

OUTFALL 002 : PROCESS WASTEWATER ONLY

TREATMENT SYSTEM : SCREENING → GREASE TRAP →  
EQUALIZATION TANK → DAF UNIT → AEROBIC  
PROCESS → TERTIARY (FILTRATION) → 002

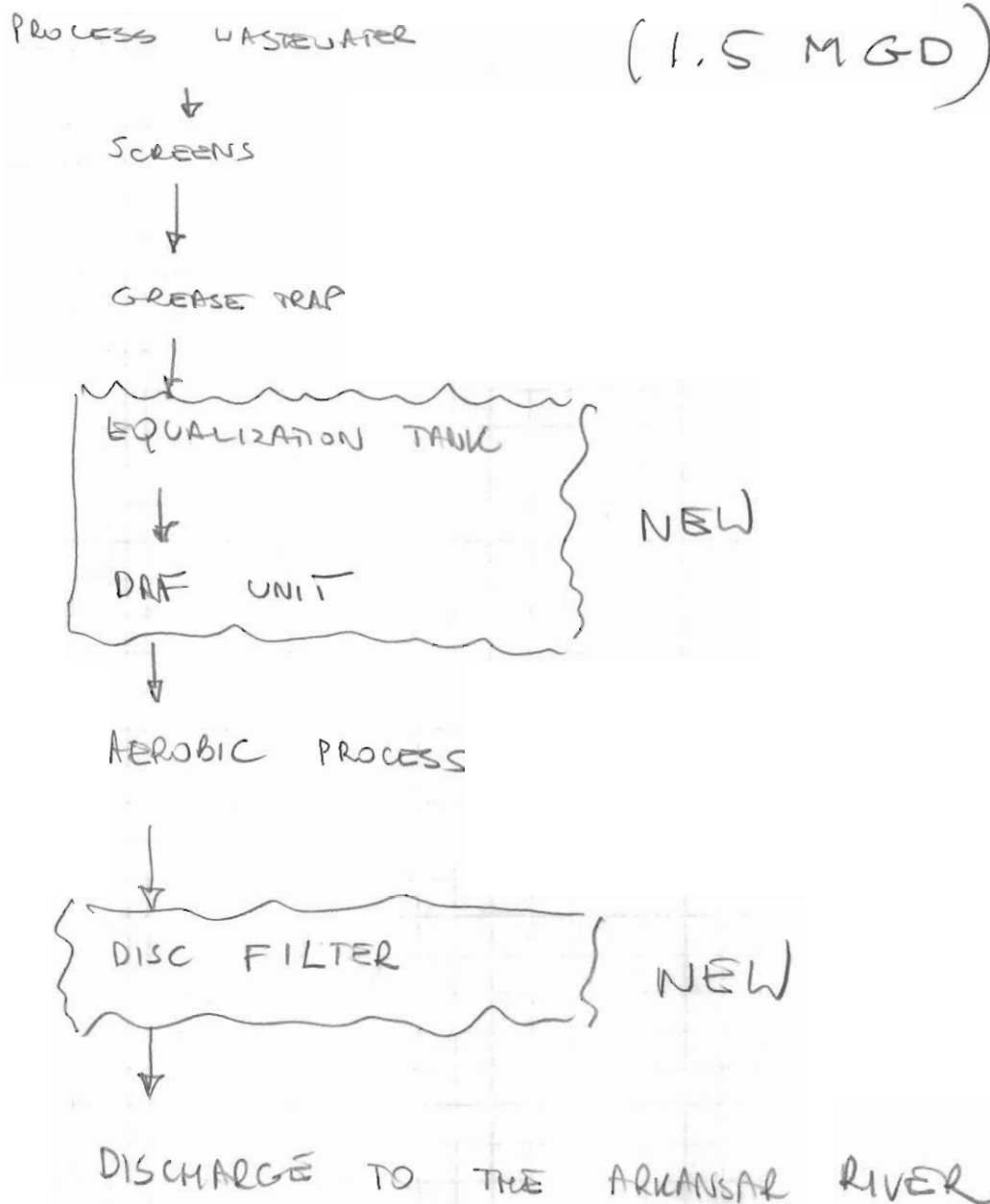
OUTFALL 003 : NON CONTACT COOLING WATER  
NO TREATMENT



STATE OF ARKANSAS  
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

SHEET 1 of       
DATE 04/08/08 BY NJ  
PROJECT GOEBER

DESIGN CALCULATIONS :





STATE OF ARKANSAS  
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

DATE 04/09/08 SHEET 2 of      
BY      
PROJECT WEBER

EQUALIZATION TANK

65 DIAMETER, 32 FT TANK

7 FT LOW LEVEL SHUTOFF  
2 FT FREEBOARD

$$\rightarrow (32 - 9) \text{ FT} = 23 \text{ FT}$$

STORAGE CAPACITY 344,350 GAL

DAF UNIT (SEARCHED NET, FOUND)

BASED ON ATTACHED ARTICLE (SEE YELLOW TAB)

THERE ARE NO CONSISTENT GENERALLY ACCEPTABLE  
DESIGN CRITERIA FOR DAF UNITS OUTSIDE  
HYDRAULIC LOADING OF 1.0 - 2.0 GPM/FT<sup>2</sup>

ACCORDING TO SUBMITTED INFORMATION

EFFECTIVE PLATE AREA 1,405 SQ. FT

$$1,500,000 \text{ GPD} = 1,041 \text{ GPM}$$

$$\text{HYDRAULIC LOADING} = \frac{1,041 \text{ GPM}}{1,405 \text{ SQ. FT}} = 0.74 \text{ GPM/} \text{sq. FT}$$

$$< 1.0 - 2.0 \text{ GPM/FT}^2$$

## **RETHINKING DISSOLVED AIR FLOTATION (DAF) DESIGN FOR INDUSTRIAL PRETREATMENT**

Charles C. Ross, P.E.  
Brandon M. Smith, E.I.T.  
G.E. Valentine, Jr.  
Environmental Treatment Systems, Inc.  
P.O. Box 94005  
Atlanta, Georgia 30377

### **ABSTRACT**

Dissolved air flotation (DAF) has been used with increasing frequency in recent decades for the treatment of industrial wastewater. Advances in the technology have expanded the range of applications for DAF; however, engineers and designers frequently use outdated and insufficient design data to design and specify DAF systems for industrial pretreatment. Discussions of advances in DAF design are discussed, including recycle pressurization, improved whitewater systems, enhanced chemical programs, and expansion of manufacturers' base of experience in industrial applications. The need for treatability testing is also emphasized. A case study illustrating these advances is presented, describing the application of DAF at a poultry rendering facility.

### **KEYWORDS**

Dissolved air flotation, DAF, industrial wastewater, industrial pretreatment, poultry rendering

### **INTRODUCTION**

Dissolved air flotation (DAF) has gained widespread usage over the last forty years for the removal of suspended solids (TSS), oils and greases (O&G), and biochemical oxygen demand (BOD) from wastewater and other industrial process streams. DAF systems are frequently used to provide wastewater pretreatment, product recovery, and thickening of biological solids in industries ranging from food processing to pulp and paper to petrochemicals.

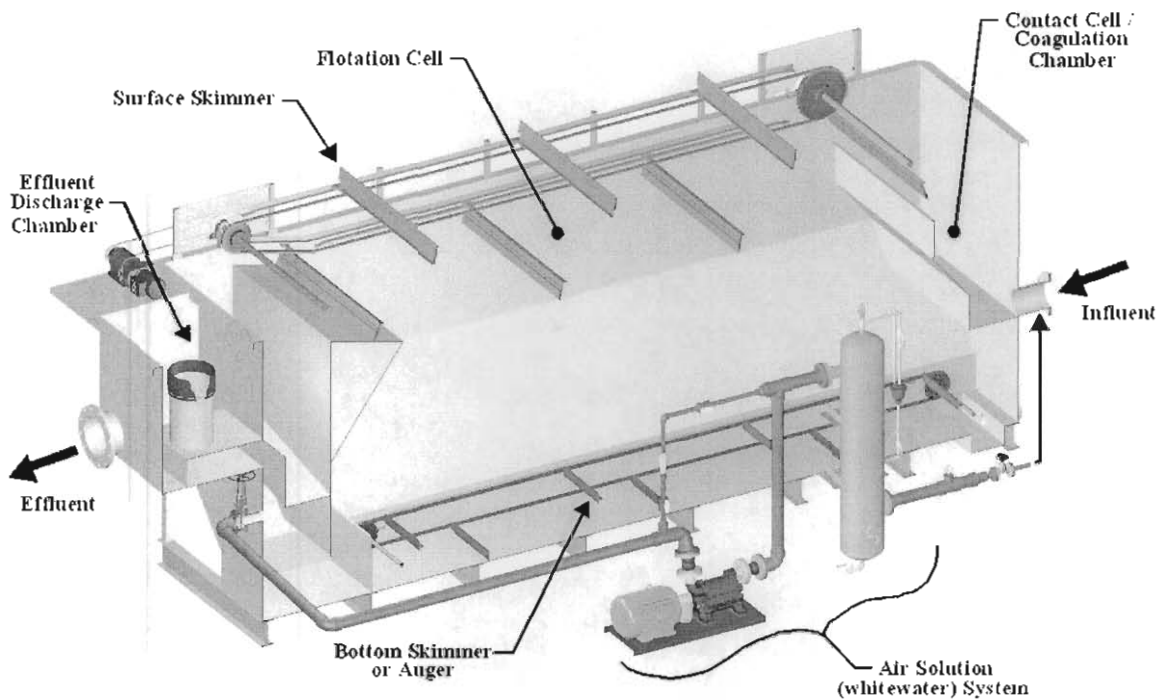
Years of experience in specifying DAF systems for industrial applications has shown that many engineers, designers, and end users have come to rely on DAF design information from common reference materials, such as engineering handbooks. Such reference materials base specification of DAF systems on parameters such as recycle rate and pressure, air-solids ratio, hydraulic loading, and surface loading. However, the values provided in common references for these parameters tend to be outdated or inadequate when compared to data from actual operating systems.

In other words, the reliability and performance of DAF systems have improved with increased use of this technology, but there has not been a corresponding change in the standard design criteria for these systems. Moreover, DAF systems have evolved to a point where some of these

parameters are not as critical to the design and are frequently not used for design purposes. This paper will address these issues and provide suggestions for improving the design and specification of DAF-based treatment systems for industrial wastewater.

## DAF OVERVIEW

While DAF units come in many forms, the systems most commonly produced today are rectangular-shaped units using recycle pressurization to provide dissolved air to encourage flotation. As illustrated in Figure 1, a DAF system consists of the following primary components:



**Figure 1. Typical DAF Unit**

1. Contact cell or coagulation chamber. Provides for the mixing of dissolved air with flocculated particles in the influent to allow for attachment of bubbles to particles. Also provides even distribution of flow across the width of the unit.
2. Flotation cell. Provides surface area for the flotation of air and flocculated particles (float). Some systems employ the use of inclined plates to augment the separation of

solids in wastewaters with certain characteristics.

3. Surface skimmer. Provides the means for removal of float from the flotation cell for transfer to dewatering or other handling. The most commonly-used system involves a series of flights pulled by a chain drive system with variable-speed, timer-operated drives.
4. Bottoms skimmer or auger. Provides for the removal of settled solids in the bottom of the unit.
5. Effluent discharge baffle and chamber. Provides for physical separation of clarified water from flocculated particles and bottoms prior to discharge from the unit through weirs or similar structures.
6. Air saturation (whitewater) system. Provides the required amount air in the proper form (bubble sizes in the range of 10-100  $\mu\text{m}$ ), ideally using minimum recycle flow. The whitewater system uses pump pressurization to force air into solution with either the influent stream or a clarified effluent recycle stream. The air-water solution is then injected into the incoming wastewater stream to encourage bubble-solid contact and flotation.

While the DAF unit is the centerpiece of a DAF-based system design, there are several other supporting systems important to optimal DAF operation. Some of these systems are shown in Figure 2, a typical DAF process design:

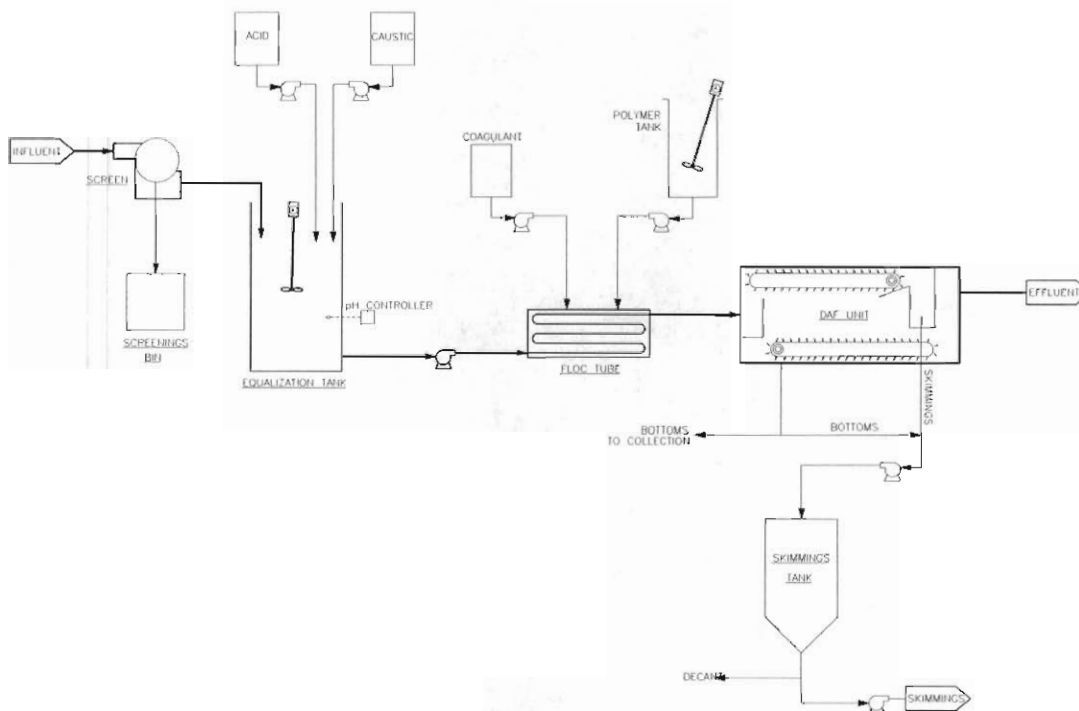


Figure 2. Typical DAF Process Diagram

1. Screening. Although occasionally overlooked by designers, proper screening of large solids (e.g., product solids, trash) from an industrial wastewater reduces the solids loading on a DAF, can improve chemical conditioning downstream, and reduces maintenance requirements due to clogged valves, pumps, and piping.
2. Equalization. Proper equalization of an industrial effluent can provide a more constant and homogeneous flow to the DAF unit. This can improve the effectiveness of the chemical program used for coagulation and flocculation prior to the DAF unit. In addition, equalization reduces hydraulic surging which can be detrimental to system performance. In some cases, equalization tanks can be sized to allow operation of the DAF unit during specific time periods (e.g., a single plant shift), thus reducing operator labor costs.
3. Chemical addition. Most chemical addition systems utilize either flocculation (floc) tubes or flash/floc tanks to introduce chemicals into the process flow. These systems must be designed to provide the proper amount of time and mixing energy for the chemical program employed. In addition, precise pH control will typically improve the performance of most chemical programs.
4. Float handling. The pH adjustment chemicals, coagulants, and polymers used in a chemical program will impact the available methods of disposal and/or utilization of the float generated by a DAF system. The moisture content and volume of material recovered by a system will vary and must be considered when sizing transfer pumps, storage tanks, and dewatering systems.

## ADVANCES IN DAF DESIGN

Numerous advances in DAF design over the last 20 years have contributed to the increased efficiency and use of the technology for industrial pretreatment applications. Discussion of shape (i.e., circular vs. rectangular) and other physical design characteristics are the subject of ongoing debate and will not be addressed here. However, there are a number of advances that are common to many of the designs currently marketed for pretreatment applications:

### Recycle Pressurization

Over the years, most DAF manufacturers have made a transition from full-flow pressurization to recycle-flow pressurization for the creation of whitewater to induce flotation. Most of the full-flow pressurization systems, which involve pressurizing the total influent to the flotation cell, operate at lower pressures (<50 psig), which limits the amount of air going into solution. Furthermore, in cases where flocculating chemicals are used upstream, full-flow pressurization exposes the floc to high shear forces and turbulence from the pressurization pump, pressurization tank, and pressure control valve prior to entering the flotation cell. This tends to destroy the floc formed prior to pressurization, thereby limiting the effectiveness of the system. In contrast, recycle pressurization involves pressurization of a sidestream of clarified effluent for return to

the flotation cell. Systems which feature recycle pressurization can operate at higher pressures and minimize the destruction of floc formed in the process flow. Generally, the benefits of higher air saturation and undisturbed floc formation outweigh the increased total hydraulic loading that a recycle pressurization system imparts on the flotation system.

#### Air Saturation (Whitewater) Systems

In addition to the transition from full-flow to recycle-flow pressurization systems, significant advances have also been made in methods for dissolving air into water. These advances have come primarily from injecting air into pumps capable of handling water with entrained air. These pumps operate at higher pressures than standard centrifugal process pumps, increasing both air saturation and volumetric efficiencies. The combined effects of recycle pressurization and improved pumping systems allow the introduction of the same amount of dissolved air into the flotation cell of a DAF using 50 to 70% less recycle flow than earlier whitewater system designs. Additional discussion of whitewater system improvements is provided below.

#### Chemical Programs

Over the last 20 years, there has been a dramatic increase in the number chemical programs developed for the coagulation and flocculation of contaminants in industrial wastewaters. Industrial pretreatment applications typically rely on chemical programs to improve the destabilization of emulsions, precipitation of proteins, and the destabilization of suspended solids through pH control and the addition of coagulants such as metal salts. Flocculation of the resulting coagulated solids is typically accomplished through the addition of cationic and/or anionic polymers. The resulting floc from these chemical programs can be easier to float than that from many municipal applications, thus requiring less dissolved air. This allows many industrial DAF systems to operate with much lower air:solids ratios and higher solids loading rates than are typically used in municipal applications.

Significant advancements have been made in the development of polymers with a wide variety of molecular weights and charges (cationic, anionic, and nonionic) and applying them to specific industrial contaminants. This has resulted in the development of single- and multiple-polymer programs that reduce or eliminate the need of some of the more common metal salt coagulants. In many cases, the use of these advanced polymers promotes stronger floc formation, lower float volumes, and lower float moisture content.

Improvements have also been made in the blending of these chemicals into the process flow. While traditional flocculation tanks are still used for this purpose, the use of flocculation tubes has increased in many applications where sequential addition of chemicals is desired and shorter retention times are acceptable.

#### Application Experience

The most significant advancements in DAF design have come from actual experience in industrial pretreatment. Over the last 40 years, DAF has been tested or implemented in wastewater applications for practically every major industrial category. In fact, it is one of the most common form of pretreatment in the food processing industry. For example, of 30 poultry processing plants in Georgia, 29 use dissolved air flotation as a pretreatment process (Valentine

et al., 1993).

As a result of this experience, DAF manufacturers have developed a considerable knowledge base of appropriate sizing and application of DAF technology for most industrial effluents. When coupled with treatability testing programs, this base of experience allows most manufacturers to design a system for a specific industrial effluent and treatment goal. Unfortunately, much of this design information has not been transferred to many of the engineering design texts for wastewater treatment.

## WHITEWATER SYSTEM IMPROVEMENTS

Improvements in whitewater systems have had perhaps the most dramatic effect on the design and specification of DAF systems over the past few decades. As described above, most of the early DAF designs used centrifugal process pumps to force flow into a pressurization tank at a design pressure of less than 50 psig. Compressed air at pressures 10 to 20 psi greater than the recycle pressure was then injected into the recycle stream somewhere between the pump discharge and the pressurization tank. The combined pressure and retention time of the tank forced the air into solution.

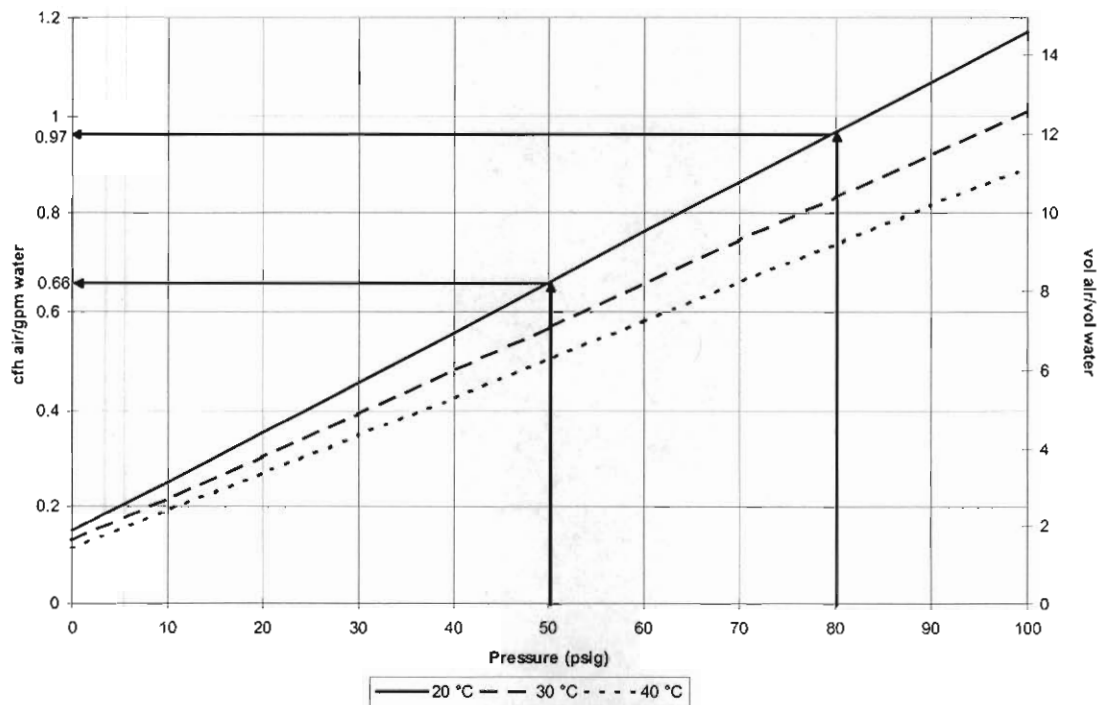


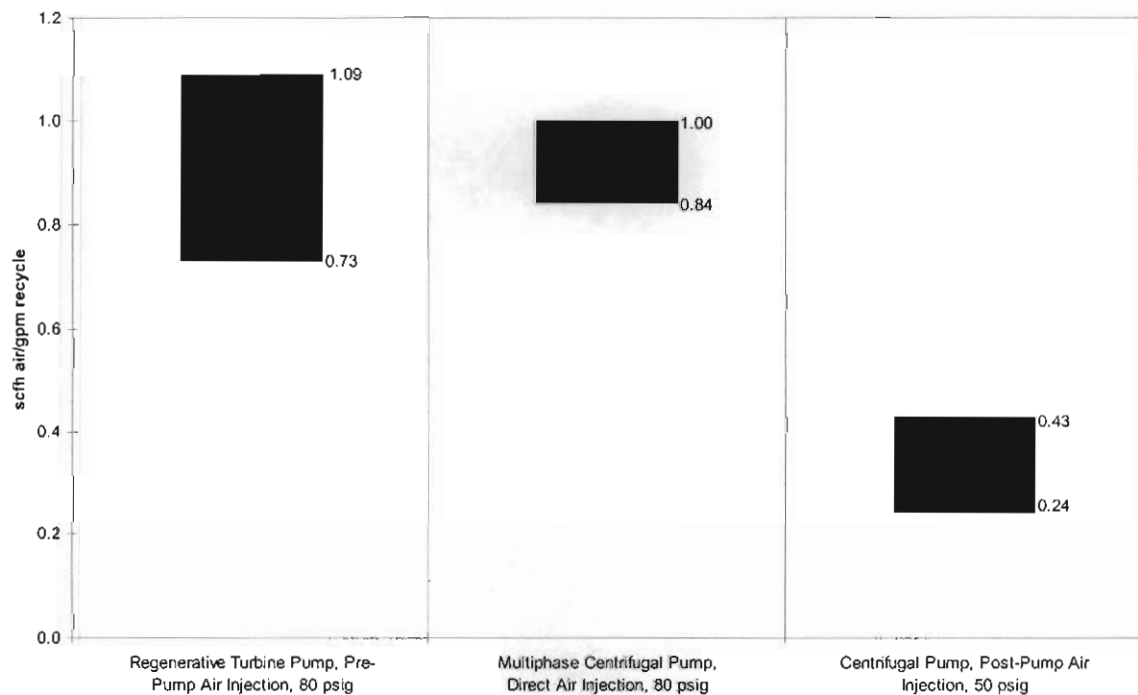
Figure 3. Air Solubility in Water vs. Pressure

Although not noted in most published design criteria, this post-pump air injection system has

given way in recent years to the use of air-handling recycle pumps that can pressurize water with entrained air without causing cavitation or vapor lock. These air-handling pumps include regenerative turbine and special multi-phase centrifugal pumps which can handle limited air injection (10-20% v/v).

These pumps have a number of advantages over the traditional centrifugal pump design:

- **Pressure.** Air-handling pumps can typically operate at pressures of 80 to 120 psig, versus 50 psig for traditional centrifugal pumps. This higher pressure significantly increases the amount of air that can go into solution, as illustrated in Figure 3. For example, at 20°C, the maximum amount of air that can be saturated in water at 80 psig is 46% greater than the amount at 50 psig.
- **Saturation efficiency.** Whitewater systems based on air-handling pumps draw air into the suction or volute of the pump, subjecting the mixture to the high shear forces of the pump impeller(s) to force air into solution more rapidly and efficiently. In addition, studies on various DAF saturator configurations by Valentine et al. (1993) have indicated that mixing at higher pressures (>50 psi) significantly increases saturation efficiency over systems without mixing at lower pressures.



**Figure 4. Comparison of Saturator Efficiencies for Different Types of DAF Recycle Pumps**

- Volumetric efficiency. Since air-handling pumps operate at higher pressures and achieve higher saturation efficiencies, they provide a higher mass of air per unit volume of recycle flow. This is illustrated in the bar graphs in Figure 4 for data collected from three different types of recycle pump systems. Regenerative turbine and multi-phase centrifugal pumps operating at 80 psig provided over 230% more dissolved air per unit volume of recycle (scfh air/gpm recycle) than a standard centrifugal pump operating at 50 psig. In some cases, the upper saturation efficiencies for the vapor pumps exceeded the theoretical air solubility at a given temperature and pressure. These air injection rates that exceed theoretical saturation rates can be attributed to the mechanical energy of the pump producing small undissolved air bubbles in the pressurized solution, in addition to the air that is actually in solution.
- Pressurization tank size. In contrast to a traditional whitewater system which requires a pressurization tank detention time of at least one minute for good saturation efficiency, an air-handling pump negates or minimizes the need for a pressure tank, except as a means for venting excess air to the atmosphere. Therefore, the size of the pressurization tank can be greatly reduced over that needed with a traditional centrifugal pump.
- Air supply. Because the location of air injection on air-handling pump systems is under low pressure or vacuum conditions found in the pump suction or volute, air can be supplied by low-pressure compressors or drawn from the ambient air without the need for an air compressor. This contrasts with a traditional centrifugal pump design, where compressed air must be supplied at 10 to 20 psi greater than the pump operating pressure (60 psig or greater).

However, in spite of their many advantages, whitewater systems based on air-handling pumps have a number of disadvantages which should be considered by the engineer or system designer:

- Greater horsepower requirements. Operation at higher pressures requires higher horsepower motors, although this effect is partially offset by the reduced recycle flow that is required.
- Closer tolerances. Regenerative turbine pumps have closer tolerances than typical centrifugal pumps. Wear caused by solids in the clarified effluent can reduce pump effectiveness over time.
- Excess air. Since air-handling pumps can draw air in excess of what can be dissolved in the recycle stream, excess air can result in large, disruptive bubbles in the flotation cell if not vented from the system.

After considering both these advantages and disadvantages, many DAF manufacturers have opted to include in their designs whitewater systems based on air-handling pumps.

## IMPACTS ON DAF DESIGN CRITERIA

Although DAF has been in use for over 40 years, the design criteria available to engineers and system designers for industrial applications is limited in the more popular design manuals. As illustrated in Table 1, criteria provided in these references has either gaps or wide ranges, some of an order of magnitude or greater (e.g., air/solids ratio). Much of the early design criteria were developed using municipal wastewater or waste activated sludge (WAS) thickening data. As shown in Table 1, even the more recently-published criteria appear to focus on municipal applications with little data input from industrial applications and do not reflect the advances in DAF technology over the last 20 years.

### Recycle Pressure

The typical recycle pressure shown in Table 1 of 15 to 75 psig for a DAF whitewater system is based on a post-pump air injection system with a standard centrifugal pump providing pressurized flow. Higher-pressure air-handling pump systems are more prevalent today. As discussed above, these systems typically operate at 80 to 120 psig, resulting in much higher volumetric efficiencies (scfh air/gpm recycle flow).

### Saturation Efficiency

While design saturation efficiencies of 50 to 90% are suggested in Table 1, most of the traditional centrifugal pump based systems operate in the range of 45 to 65% (Valentine et al., 1993). Recycle systems based on air-handling pumps have demonstrated saturation efficiencies up to 100% due to the mechanical mixing of air within the pump.

### Recycle Percentage

DAF recycle rate as a percentage of throughput through the system is considered by many in the industry as an outdated parameter to use when sizing a system. With volumetric efficiencies ranging from 0.24 to 1.09 scfh air/gpm of recycle flow (Figure 4), the actual percentage of recycle is inconsequential.

### Pressurization Tank Detention

While Table 1 suggests pressurization tank detention times of 0.5 to 3.0 minutes, Valentine et al. (1993) noted that with traditional centrifugal pump designs, the detention time was less important than the physical configuration of the tank. Most whitewater systems based on air-handling pumps do not require significant detention time for air saturation and as a result use either small tanks or none at all.

### Hydraulic Loading Rate

DAF hydraulic loading rate (HLR) is typically the primary design parameter for most industrial applications. As indicated in Table 1, published suggested values range from 0.2 to 5.5 gpm/ft<sup>2</sup>; however, most references do not indicate whether or not this includes the recycle rate in addition to the influent wastewater stream. Given that some DAF systems use the post-pump air injection system with high recycle rates, it is important make this distinction since high recycle flows can significantly increase the hydraulic loading of a DAF system. Generally, a HLR of 2.0 gpm/ft<sup>2</sup>, without recycle, is considered a good starting point in a design. Other factors, including

chemical programs, the nature of the contaminants being removed, and prior treatment experience, will have an effect on the final design value.

#### Solids Loading Rate

The solids loading rate (SLR) is determined by dividing the mass flow rate of solids and/or O&G by the available surface area in the flotation cell. As illustrated in Table 1, only two of the five references include this parameter, with a range of 0.80 to 2.8 lb/ft<sup>2</sup>-hr. As with the HLR, the optimum SLR is dependent on a number of other operating conditions. The fact that these published ranges apply only to a small range of primarily municipal applications raises questions of whether they can be applied to industrial applications at all.

**Table 1. Comparison of Published DAF Design Parameters**

|                                             | <b>WPCF<br/>MOP-8<br/>(1977)</b> | <b>Metcalf &amp;<br/>Eddy<br/>(1991)</b> | <b>WEF<br/>MOP-8<br/>(1992)</b> | <b>WEF<br/>MOP-FD-3<br/>(1994)</b> | <b>Corbitt<br/>(1999)</b> |
|---------------------------------------------|----------------------------------|------------------------------------------|---------------------------------|------------------------------------|---------------------------|
| Reference treatment category                | Wastewater                       | Sludge                                   | Sludge thickening               | <b>Industrial</b>                  | Wastewater                |
| Recycle pressure, psig                      | 15-45                            | 40-75                                    | 75                              | 15-45                              | 25-70                     |
| Saturation efficiency, %                    |                                  | 50-95                                    | 50-90                           | 80                                 |                           |
| Recycle, %                                  |                                  | 15-120                                   | 100                             |                                    | 5-120                     |
| Pressurization tank detention, min          |                                  |                                          |                                 | 3.0                                | 0.5-3.0                   |
| Hydraulic loading rate, gpm/ft <sup>2</sup> |                                  | 0.20-4.00                                | 0.50-2.00                       | 1.0-2.00                           | 0.35-5.50                 |
| Solids loading rate, lb/ft <sup>2</sup> -hr | 1.0-2.8                          |                                          | 0.80-2.00                       |                                    |                           |
| Air-solids ratio, lb air/lb solids          | 0.010-0.200                      | 0.005-0.060                              | 0.020-0.060                     | 0.006-0.070                        | 0.010-0.200               |

#### Air-to-Solids Ratio

The air-to-solids (A:S) ratio is the ratio of the mass of dissolved air delivered by the whitewater system to the mass of solids in the influent entering the flotation system (lb air/lb solids). The values provided in Table 1 range from 0.005 to 0.200 lb air/lb solids, representing a range greater than an order of magnitude. As one would expect, it would be difficult to specify an A:S ratio with such a range to choose from. Choosing a high A:S ratio can lead to large recycle systems which will in turn affect the HLR and overall size of the DAF system. Typically, systems are sized initially with A:S ratios in the lower range (0.005 to 0.010), especially when influent TSS concentrations are less than 2,000 mg/L and the HLR is the predominant design criteria. Higher

solids loading may or may not require an increase in the amount of air supplied to maintain the design A:S ratio. This will depend greatly on the characteristics of the contaminants and the chemical program used to coagulate and flocculate. The use of bench- and pilot-scale treatability testing would be very beneficial under these conditions.

In general, the design criteria for DAF design provided by the most common environmental engineering design manuals are short in specifics and represent data that do not correspond with most industrial applications. While DAF treatment programs are well-established for some industries, data are limited for many industrial effluents. Moreover, variability in wastewater characteristics and the introduction of new chemical programs can make it difficult to optimize the sizing of a DAF system.

This stresses the need for treatability testing prior to sizing DAF systems for many industrial applications. Testing can range from simple jar testing to bench-scale batch tests to on-site pilot tests. Pilot testing is particularly effective for determining the optimum size of a full-scale DAF system so that under-sizing (unrealized performance) and over-sizing (increased capital cost) can be avoided.

## CASE STUDY- RENDERING PLANT

In 1998, Environmental Treatment Systems, Inc. conducted a series of pilot-scale treatability tests on the screened effluent from a poultry rendering plant prior to biological treatment. The testing was deemed necessary due to the very high levels of TSS and O&G in the wastewater (approximately 35,000 and 25,000 mg/L, respectively) and the need to determine the most economical chemical program for coagulation and flocculation.

Prior to the pilot test, jar testing showed that the most effective chemical program was pH adjustment to pH 4.5-5.5 to precipitate proteins, followed by flocculation using a cationic polymer dosed at 15 to 20 ppm. For the pilot test, a side-stream of screened and equalized wastewater was neutralized to the target pH using PID-based pH control and sulfuric acid in a small equalization tank. The conditioned wastewater was then pumped through a flocculation tube, where cationic polymer was added and blended in prior to entry into the pilot DAF system.

A summary of the pilot test operating conditions and performance results is provided in Table 2. The pilot DAF unit had 15 ft<sup>2</sup> of surface area and was nominally loaded at 25 gpm, or a HLR of 1.7 gpm/ft<sup>2</sup> not including recycle. Air was supplied to the whitewater system by a regenerative turbine pump using pre-pump air injection at an average rate of 10 scfh, with a recycle flow of 10 gpm at 80 psig (1.0 scfh/gpm). As illustrated in Table 2, TSS, O&G, and COD removals were 98.6, 99.2, and 89.3%, respectively, during the test.

The design criteria drawn from the pilot test was used to design a full-scale DAF system, as shown in Table 2. The rectangular DAF system was sized at 1.8 gpm/ft<sup>2</sup> to treat a flow of 330 gpm with a whitewater recycle rate of 90 gpm at 80 psig and an air injection rate of 65 scfh (0.72 scfh/gpm). The system was installed in 1998 and has operated as shown in Table 2. Although initial influent COD and TSS concentrations were higher than those observed during the pilot

test, the system provided TSS, O&G, and COD removals of 99.4, 99.6, and 91.7%, respectively.

**Table 2. Operating Parameters and Performance - Rendering Plant Case Study**

|                                                           | Pilot DAF | Full-Scale DAF | Published Ranges |
|-----------------------------------------------------------|-----------|----------------|------------------|
| <b>Operating Parameters</b>                               |           |                |                  |
| DAF surface area, ft <sup>2</sup>                         | 15        | 180            |                  |
| Influent flow, gpm                                        | 30        | 330            |                  |
| Recycle rate, gpm                                         | 12        | 90             |                  |
| Recycle pressure, psig                                    | 80        | 80             |                  |
| Air injection rate, SCFH                                  | 10        | 65             |                  |
| Air solution rate, SCFH/gpm                               | 1.0       | 0.72           |                  |
| Influent TSS, mg/L                                        | 34,975    | 43,706         |                  |
| Influent COD, mg/L                                        | 63,446    | 113,864        |                  |
| Influent O&G, mg/L                                        | 25,219    | 18,568         |                  |
| Hydraulic loading rate, feed only, gpm/ft <sup>2</sup>    | 2.0       | 1.8            |                  |
| Hydraulic loading rate, incl recycle, gpm/ft <sup>2</sup> | 2.8       | 2.5            | 0.2-5.5          |
| Solids loading rate, lb/ft <sup>2</sup> -hr               | 35.0      | 40.1           | 0.8-2.8          |
| Air-solids ratio, lb air/lb solids                        | 0.0015    | 0.0006         | 0.005-0.200      |
| <b>Performance Data</b>                                   |           |                |                  |
| Effluent TSS, mg/L                                        | 505       | 263            |                  |
| TSS removal, %                                            | 98.6      | 99.4           |                  |
| Effluent COD, mg/L                                        | 6,765     | 9,400          |                  |
| COD removal, %                                            | 89.3      | 91.7           |                  |
| Effluent O&G, mg/L                                        | 191       | 72             |                  |
| O&G removal, %                                            | 99.2      | 99.6           |                  |

Most notable of the operating parameters for both the pilot-scale and full-scale systems was the SLR, which was significantly higher than the published values. The full-scale DAF operating SLR of 40.1 lb/ft<sup>2</sup>-hr was roughly 13 times greater than the maximum published value of 2.8 lb/ft<sup>2</sup>-hr. More importantly, the DAF A:S ratio of 0.0006 lb air/lb solids was roughly one-tenth the minimum value found in Table 1, indicating that the flocculated solids in this waste stream could be effectively removed with this type of DAF system at a much lower A:S ratio than that suggested in the design literature.

If either of the less-stringent values for SLR or A:S ratio in Table 1 had been used in sizing the unit based on the wastewater characteristics alone, the DAF system would have been much larger than it actually needed to be. If the maximum allowable SLR in Table 1 had been used as the primary design criterion, instead of the 180 ft<sup>2</sup> of surface area provided, the DAF unit(s) would have needed greater than 1,800 ft<sup>2</sup> of surface area. In addition, using the minimum A:S ratio in Table 1 would have resulted in a recycle flow of at least 900 to as much as 1,800 gpm instead of the 90 gpm used.

The capital cost using these published design values would have been \$1.5 to \$2.0 million higher, and the operating and maintenance costs would have been proportionally higher. The pilot testing and resulting installation confirms the need to conduct treatability testing on industrial wastewater prior to selecting design criteria. It also calls into question the wisdom in using some of the published design data reflected in Table 1.

## CONCLUSIONS

1. The increased use of recycle pressurization, advances in whitewater systems and chemical programs, and expansion of DAF manufacturers' base of experience in industrial applications has not been accompanied by a corresponding change in standard published design data commonly used by engineers and designers.
2. Many design references commonly used by engineers and designers provide wide ranges in data, or no data at all, for many common design parameters. While it may not be the intention of the authors of these references for these ranges to be used in actual designs, it has become fairly common practice to use such references as sources of firm design data. This practice can result in sizing systems incorrectly, which can also lead to false elimination of DAF as an economically feasible treatment alternative. Since DAF is still used in municipal wastewater treatment and sludge thickening, these design references should still include data for these applications. However, these references should also emphasize that the data they supply should be used with caution and restraint and stress the need for further investigation when treating industrial wastewaters.
3. Treatability testing, both on a bench scale and pilot scale, is often overlooked as a step in design of DAF-based wastewater treatment systems. Experience has shown that such testing can markedly improve the economic feasibility of a treatment project. While it may complicate the traditional design-bid-build process, testing should be included in any industrial treatment system design where the engineer, designer, or equipment supplier

does not have substantial experience in the particular industry.

## REFERENCES

American Society of Civil Engineers and Water Environment Federation (1992) *Design of Municipal Wastewater Treatment Plants, Volume II*. ASCE Manual and Report on Engineering Practice No. 76/WEF Manual of Practice No. 8, New York/Alexandria, Va.

American Society of Civil Engineers and Water Pollution Control Federation (1977) *Wastewater Treatment Plant Design*. ASCE Manual on Engineering Practice No. 36/WPCF Manual of Practice No. 8, New York/Washington, D.C.

Corbitt, Robert A. (1999) *Standard Handbook of Environmental Engineering*. 2<sup>nd</sup> Ed., McGraw-Hill, New York

Metcalf & Eddy, Inc. (1991) *Wastewater Engineering: Treatment, Disposal, and Reuse*. 3<sup>rd</sup> Ed., McGraw-Hill, New York.

Water Environment Federation (1994) *Pretreatment of Industrial Wastes*. Manual of Practice No. FD-3, Alexandria, Va.

Valentine, G. Edward; Ray, B. Russell; and Shadburn, Tim (1993) Dissolved -Air Flotation Pilot Scale Research: Investigating Air Solubility. Project N-3200-160 and N-3200-260, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta.



STATE OF ARKANSAS  
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

SHEET 3 of       
DATE 04/09/08 BY HN  
PROJECT GERBER

DISC FILTER

AQUA DISC

DESIGN FLOW 1.5 MGD  
MAX FLOW 2.0 MGD

8 DISKS (1 UNIT)

430.4 FT<sup>2</sup> FILTER AREA PROVIDED

VERTICALLY MOUNTED CLOTH MEDIA DISKS WITH  
AUTOMATICALLY OPERATED VACUUM BACKWASH.

HOPPER BOTTOM & SOLIDS REMOVAL MANIFOLD SYSTEM

AVG. HYDRAULIC LOADING:

$$1041.6 \text{ GPM} / 430.4 \text{ FT}^2 \\ = 2.42 \text{ GPM} / \text{FT}^2$$

MAX HYDRAULIC LOADING:  $1,388.9 \text{ GPM} / 430.4 \text{ FT}^2$

$$= 3.2 \text{ GPM} / \text{FT}^2$$

ACCORDING TO MANUFACTURER  
MAX LOADING RATE:  $3.25 \text{ GPM} / \text{FT}^2$

SEE "EVALUATION AND DESIGN OF A CLOTH DISK  
FILTER TO MEET TITLE 22 REUSE CRITERIA

SEE YELLOW TAB

HIGHER HYDRAULIC RATES WERE USED

SEARCHED  
NET.  
FOUND

# **EVALUATION AND DESIGN OF A CLOTH DISK FILTER TO MEET TITLE 22 REUSE CRITERIA**

By: Alison Furuya

## **ABSTRACT**

The City of Manteca (City) Regional Wastewater Quality Control Facility (WQCF) is adding filtration and UV disinfection facilities to meet California Title 22 wastewater reuse criteria. The cloth disk filter (CDF), manufactured by Aqua-Aerobic Systems, Inc. (AAS) was evaluated and selected as the technology for use at the WQCF. The evaluation process included a pilot filter study, researching historical operating performance of the filter, site visits to existing reclamation plants, and contact with facilities in the process of constructing or starting-up the CDF.

Results from the pilot filter study indicated that the CDF was a feasible filtration technology for the WQCF which would meet Title 22 effluent requirements and provide adequate particle removal for effective downstream UV disinfection. References from existing CDF plants confirmed the operational reliability and low-maintenance requirements for the CDF. Final selection of the CDF was implemented after City personnel and design engineers visited several operational CDF facilities. A second site visit at additional CDF facilities aided in determining design features for the 20 mgd filtration process at the WQCF and in identifying potential start-up issues.

## **INTRODUCTION**

The City of Manteca (City) Regional Wastewater Quality Control Facility (WQCF) is adding filtration and UV disinfection facilities to meet California Title 22 (Title 22) wastewater reuse criteria. The WQCF is a combined biofilter-activated sludge plant that has been upgraded recently to full nitrification, with future addition of denitrification scheduled in the year 2005/2006. A variety of technologies exist for the filtration of secondary effluent to meet Title 22 requirements. The cloth disk filter (CDF), manufactured by Aqua-Aerobic Systems, Inc. (AAS) was evaluated and selected as the technology for use in the expansion and upgrade of the WQCF.

## **PURPOSE AND OBJECTIVES**

The principal objective of the filtration design was to provide the City with a reliable, cost effective, and easily maintained filtration system for secondary effluent, with specific reference to Title 22 wastewater reuse criteria. This objective was attained through a multi-step process for evaluating the selected filtration technology which included: 1) a pilot filter study at the WQCF, 2) researching historical operating performance, 3) site visits to existing facilities, and 4) contacts with plants under construction or in the process of starting-up with filters. The information collected during these steps was then incorporated into the design of the CDF for the City.

## **DESCRIPTION OF CLOTH DISK FILTER (CDF)**

The CDF involves the use of a cloth membrane as the filter medium. The cloth membrane is a simple random weave fabric that is used to separate the particles from the fluid to be filtered.

The density and thickness of the filter cloth is selected according to the characteristics of the influent wastewater and desired effluent quality. Disks covered by the cloth membrane are mounted vertically to a common hollow tube. The number of disks mounted on the tube can be varied depending on the filtration area required. Wastewater passes through the cloth membrane by gravity, and enters inside the filter disks. Filtered effluent is conveyed through the hollow tube. The filter is quiescent during the filtration operation, which allows larger particles to settle to the bottom of the tank. The sedimentation of larger size particles within the filter basin decreases the amount of solids to be filtered. An individual full scale filter disk is divided into six equal segments with a total surface area of approximately 54 ft<sup>2</sup>.

The pressure loss across the membrane increases as more particles are accumulated and a mat is formed on the surface of the membrane. The backwash operation is started when the terminal headloss (usually 12 inches of water) or a certain run time is reached. Accumulated particles are removed from the surface of the cloth membrane by liquid suction applied to each side of the disk. Disks rotate slowly (approximately one revolution per minute) allowing each segment to be cleaned. A backwash vacuum shoe is mounted on each side of the filter disk. The accumulated solids are vacuumed from the media as the disk rotates past the shoes. Filtration occurs through the remainder of the filter disk resulting in continuous filtration operation. The vacuuming effect is created through the use of a backwash pump. Filtered water is used for backwash, therefore a separate clean water tank is not required as part of the backwash system. Disks are usually backwashed in multiples of two. Large particles which have settled in the filter basin are removed through sludge assembly piping connected to the backwash pumps. The backwash system typically consists of one to two backwash pumps (depending on the number of disks within the filter basin), sludge assembly piping, motorized valves, and associated piping. The backwash system is often located to the side of a filter basin in a pump gallery at the same elevation as the filter disks.

The CDF is offered as a package system, which includes metal tanks for the filter, or can be installed within a concrete basin. The CDF has been in operation since 1994. The filter is typically chosen for its small footprint, minimal maintenance and backwash requirements, and low initial capital cost.

## **PILOT FILTER STUDY AT MANTECA WQCF**

A pilot filter study with a CDF was conducted from December 9, 2003 through January 16, 2004 at the Manteca WQCF. Two filtration rates and chemical addition using several different chemicals and doses were evaluated for varying influent total suspended solids concentrations. Filter runs ranged from approximately three hours to one week (with multiple backwash cycles within a single filter run) depending on the conditions tested.

### **Objectives of Pilot Filter Studies**

The principal objective of the filtration studies was to evaluate the performance of the CDF with WQCF secondary effluent with specific reference to Title 22 wastewater reuse criteria. Supporting objectives included: (1) the quantification of CDF operating characteristics, (2) evaluation of the filter reliability and performance as affected by variations in filter influent quality and filtration rate, (3) determination of the backwash water requirements, and (4) assessment of the effect of the filter performance on disinfection efficiency. Effluent quality was the major criterion to assess the filter performance.

### **Description of Pilot Filter**

AAS provided a trailer mounted AquaDisk™ pilot test system. The pilot facilities consisted of a submersible pump to provide the required flow to the system, chemical addition system, a one-disk cloth media filter with 12 square feet of effective filter area (with two segments), magnetic flow meters, effluent, overflow, backwash, and drain lines from the unit. The pilot unit employed a PA-13 pile cloth as the filtering medium which has a nominal pore size of 10 microns.

A two stage chemical feed and flocculation system was used in experiments with chemical addition. The chemical addition system included a coagulant feed pump, a flash mixer, a polymer feed pump, and two mixing tanks in series (each equipped with a variable speed mixer).

The system was furnished with continuous turbidity and particle size sampling equipment and a data logging system. Influent and effluent sampling ports were used for grab samples to be analyzed in the WQCF laboratory. Pilot filter characteristics are listed in Table 1.

**Table 1 – Aqua Disk Pilot Filter Characteristics**

| Filter Surface Area, ft <sup>2</sup><br>(Submerged) | Filter Dimensions<br>(WxLxH), ft | Normal Hydraulic Loading Rate |                                      | Maximum Hydraulic Loading Rate |                                      | Filter Medium                 |                       |
|-----------------------------------------------------|----------------------------------|-------------------------------|--------------------------------------|--------------------------------|--------------------------------------|-------------------------------|-----------------------|
|                                                     |                                  | Flow, gpm                     | Filtration rate, gpm/ft <sup>2</sup> | Flow, gpm                      | Filtration rate, gpm/ft <sup>2</sup> | Type                          | Nominal pore size, µm |
| 12                                                  | 9x45x13.5                        | 39                            | 3.25                                 | 78                             | 6.5                                  | PA-13 pile cloth <sup>a</sup> | 10                    |

<sup>a</sup> Filter medium involving the use of nylon fiber material

The influent for the pilot test system was delivered by a submersible, 3-HP pump to supply flow up to 78 gpm. The submersible pump was placed in the secondary effluent collection box. Backwash reject water was returned to the head of the plant.

### Filter Performance Data

Field parameters that were monitored to assess the performance of the filter included: (1) turbidity, (2) total suspended solids (TSS), (3) particle size distribution (PSD), and (4) transmittance. Parameters were monitored for both filter influent and effluent. The backwash and influent flow rate were also measured to monitor operational parameters such as backwash ratio and effective filtration rate. The influent flow was monitored using a Krohne IFC020D magnetic flow meter. The backwash flow was monitored using an ABB Model 10D1475 magnetic flow meter.

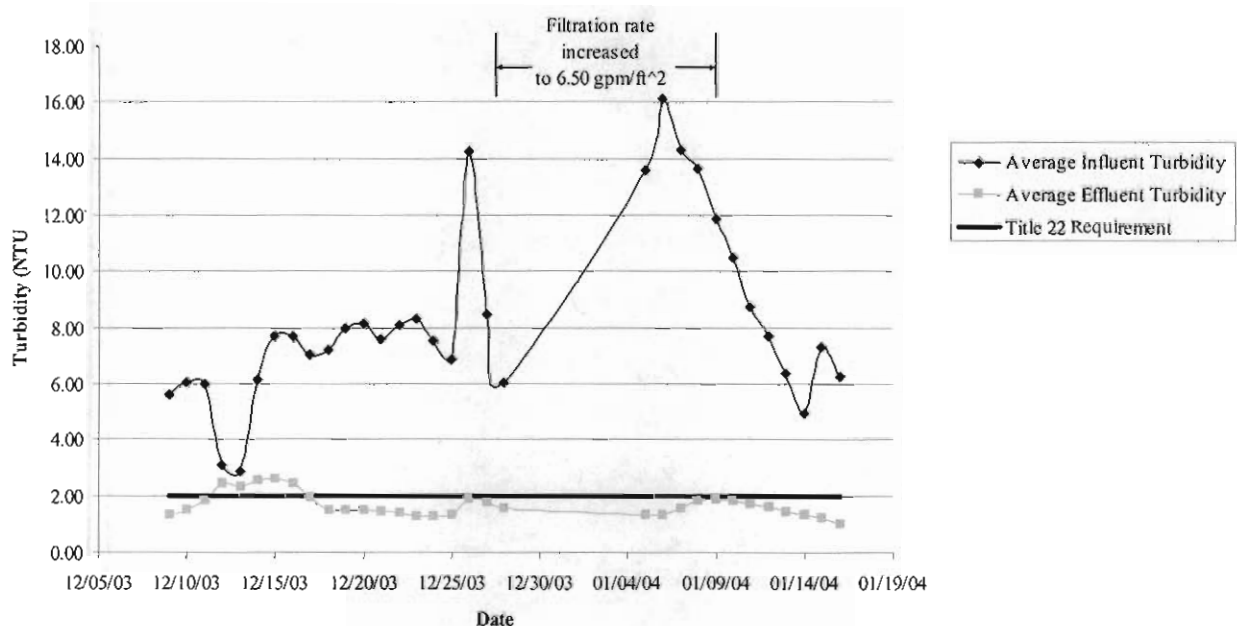
### Turbidity

Influent turbidity and effluent turbidity were monitored continuously with two Hach Model 1720 D low range process turbidimeters. The monitored results were recorded every 30 seconds using the data logging system. Filter effluent turbidity values were compared with the Title 22 turbidity requirements to determine if Title 22 approval would be achieved using the CDF with WQCF secondary effluent.

Daily average influent and effluent turbidity values observed during the entire period of the testing program are shown in Figure 1. The filter was left unattended between December 29, 2003 and January 4, 2004 due to the holidays. Results obtained during this period were not

included in the evaluation because of the questionable influent turbidity data.

**Figure 1 – Manteca WQCF Pilot Filter Study – Average Daily Influent and Effluent Turbidity**



**Filter runs without chemical addition:** The daily average effluent turbidity was observed to be below 2 NTU (Title 22 requirement), between 1.29 NTU and 1.90 NTU, for 23 days. Daily average influent turbidity values were between 5.64 NTU and 14.27 NTU for these 23 days. Daily average effluent turbidity exceeded 2 NTU for 7 days (between 2.17 and 2.61) for the daily average influent turbidity values between 2.86 NTU and 15.13 NTU.

**Filter runs with chemical addition:** Coagulant and polymer addition was evaluated at concentrations ranging from 2.5 – 15 mg/L and 0.05-0.20 mg/L, respectively. Turbidity results were evaluated for filter runs conducted with chemical addition for 10 days. The daily average effluent turbidity was observed to be below 2 NTU for nine of these runs (between 0.99 NTU and 1.93 NTU) for daily average influent turbidity values between 6.45 NTU and 18.44 NTU. The daily average effluent turbidity was 2.05 NTU on January 8, 2004 for a daily average influent turbidity value of 14.15 NTU. Polymer was not added on that day and the only coagulant was applied at a low concentration of 2.5 mg/L.

**Filter runs to simulate upset conditions:** Filter runs were conducted on January 14, 2004 and January 15, 2004 to evaluate the performance of the CDF without chemical addition subject to upstream process upsets. Plumbing modifications were made to mix return activated sludge with the secondary effluent before the pilot filter. The daily average influent turbidity was 34.08 NTU on January 14, 2004. Average daily and maximum effluent turbidity values were observed to be 6.06 NTU and 8.49 NTU, respectively. The daily average influent turbidity was 44.84 NTU on January 15, 2004. Average daily and maximum effluent turbidity values were observed to be 4.51 NTU and 8.64 NTU, respectively.

**Filter runs at higher filtration rate:** Filter performance was also evaluated at a higher filtration rate (twice the design filtration rate for average plant flows) from December 26, 2003 through January 6, 2004, and from January 12-13, 2004. All of the runs at higher filtration rate were performed without chemical addition. The daily average effluent turbidity was observed to be below the Title 22 turbidity requirement (2 NTU) for these runs (between 1.34 - 1.87 NTU) for daily average influent turbidity values between 5.94 NTU and 14.27 NTU.

#### Total Suspended Solids (TSS)

Influent and effluent TSS values were measured for grab samples collected three times a day from December 12, 2003 through December 21, 2003 and from January 5-16, 2004. TSS measurements were performed at the WQCF laboratory in accordance with the guidelines in *Standard Methods for the Examination of Water and Wastewater*, 20<sup>th</sup> Edition.

The average effluent TSS for all the grab samples collected during the pilot study was 2.8 mg/L (for an average influent TSS value of 13.7 mg/L). The average daily effluent TSS concentrations ranged from 0.47 mg/L to 7.23 mg/L for average daily influent TSS concentrations from 6.93 mg/L to 25.60 mg/L.

6.93 → 0.47  
25.60 → 7.23

**Filter runs to simulate upset conditions:** The influent TSS concentration was observed at 147 mg/L for a sample collected on January 14, 2004 during the filter run to simulate upstream plant upset conditions. The effluent TSS was 11 mg/L for this period.

147 → 11

**Filter runs at higher filtration rate:** The performance of the filter was evaluated at a higher filtration rate (6.50 gpm/ft<sup>2</sup>). Average influent and effluent TSS values (for samples collected during higher filtration rate runs) were 18 and 1.8 mg/L, respectively for January 5-6, 2004. The effluent TSS value was 2.4 mg/L for an influent TSS value of 15 mg/L on January 6, 2004.

#### Particle Size Distribution (PSD)

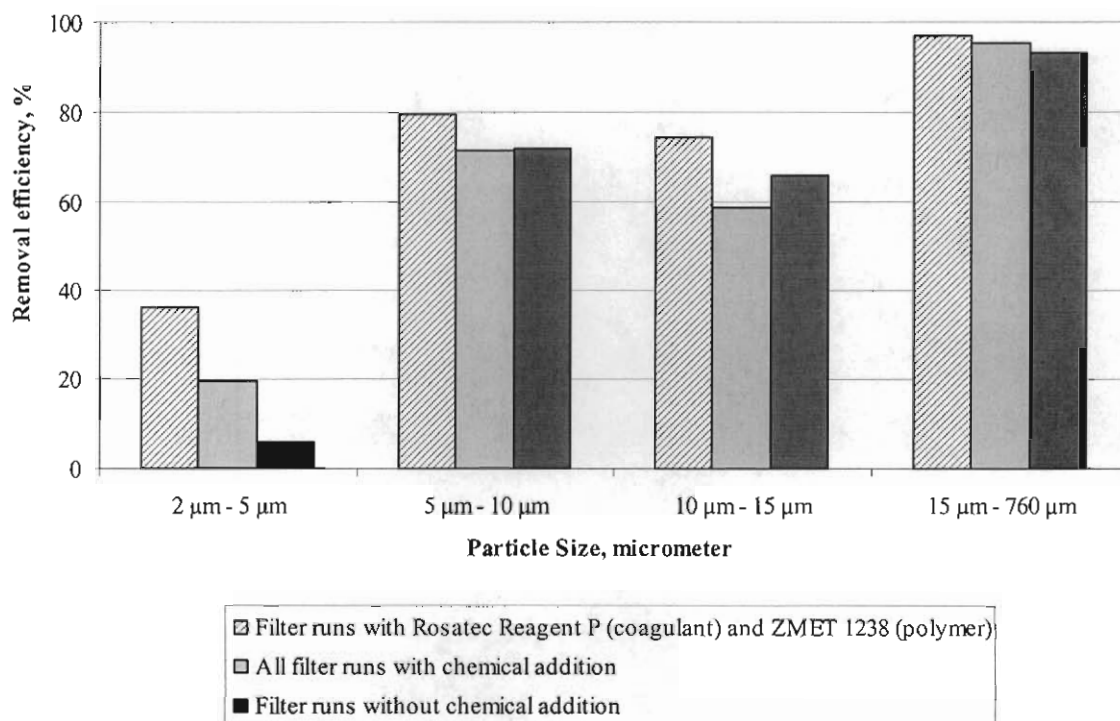
UV disinfection efficiency is greatly affected by the performance of the upstream filtration process in terms of turbidity, TSS removal, and PSD of the filtered effluent. Large particles provide better shading and shielding effects than smaller particles. Particles larger than 20 µm in size can easily be removed by almost all wastewater filtration technologies. The efficiency of filtration technologies vary significantly for the removal of particles smaller than 20 µm in size. Particles between 5 to 10 µm and 20 µm still provide significant shading and shielding effects for pathogens during the disinfection process. Therefore, poor disinfection efficiencies can still be expected if the filter effluent contains a considerable amount of suspended particles between 5 to 10 µm and 20 µm even if the filtered effluent turbidity is less than 2 NTU. Particles smaller than 5 µm to 10 µm in size are not as problematic for disinfection purposes.

Influent PSD and effluent PSD were monitored continuously with two Hach 2200 PCX particle counter units and recorded every 30 seconds using the data logging system. Installation and adjustment of the particle size equipment to obtain the desired data were completed on December 18, 2004. Clogging of the influent particle size sampling lines due to large size particles required frequent cleaning of the influent sampling lines and equipment. A screen was installed in the particle size influent sampling line on December 19 to help prolong particle meter run times.

The performance of the CDF was evaluated for the following four particle size ranges: (1) between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ , (2) between 5  $\mu\text{m}$  and 10  $\mu\text{m}$ , (3) between 10  $\mu\text{m}$  and 15  $\mu\text{m}$ , and (4) between 15  $\mu\text{m}$  and 760  $\mu\text{m}$ . Removal efficiencies for the particles between 5  $\mu\text{m}$  and 10  $\mu\text{m}$  and between 10  $\mu\text{m}$  and 15  $\mu\text{m}$  were used as the major criteria to evaluate the effect on downstream UV efficiency for the reasons mentioned above.

As expected, removal efficiency was quite high for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  in size and was very low for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ . The average removal efficiencies were 93 percent and six percent for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  and for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ , respectively for filter runs conducted without chemical addition (see Figure 2). The average removal efficiencies were 72 percent and 66 percent for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$  and for particles between 5  $\mu\text{m}$  and 15  $\mu\text{m}$ , respectively as shown in Figure 2.

**Figure 2 – Manteca WQCF Pilot Filter Study Average Removal Efficiency for Various Particle Sizes**



The effect of chemical addition on removal efficiency was observed to be greater for smaller particles. Chemical addition increased the average removal efficiency from 6 percent to 20 percent for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ . The increase in the removal efficiency for particles between 15  $\mu\text{m}$  and 760  $\mu\text{m}$  was less than five percent as seen in Figure 2. Another key conclusion from Figure 2 is the importance of chemical selection to increase the filtration efficiency. Higher removal rates were achieved with the use of a polymer type, ZMET 1238, when compared to results for the other three polymers tested. The removal efficiencies for particles between 2  $\mu\text{m}$  and 5  $\mu\text{m}$  and for particles between 5  $\mu\text{m}$  and 10  $\mu\text{m}$  had increased to 36 percent and 80 percent with polymer type ZMET 1238.

### Transmittance

Another important criterion for UV effectiveness is transmittance. UV efficiency increases as the transmittance (254 nm transmittance) increases and filtration generally increases transmittance. The performance of the CDF in terms of transmittance was evaluated to determine if the UV transmittance design criteria objective of 55 percent would be achieved.

Influent and effluent transmittance values were measured for grab samples collected three times a day from December 12, 2003 through December 16, 2003 and from January 5, 2004 through January 16, 2004. Secondary effluent transmittance values ranged from 37.5 percent to 67.7 percent with an average value of 58.9 percent. Filtered effluent transmittance values ranged from 54.8 percent to 70.5 percent with an average value of 62.6 percent.

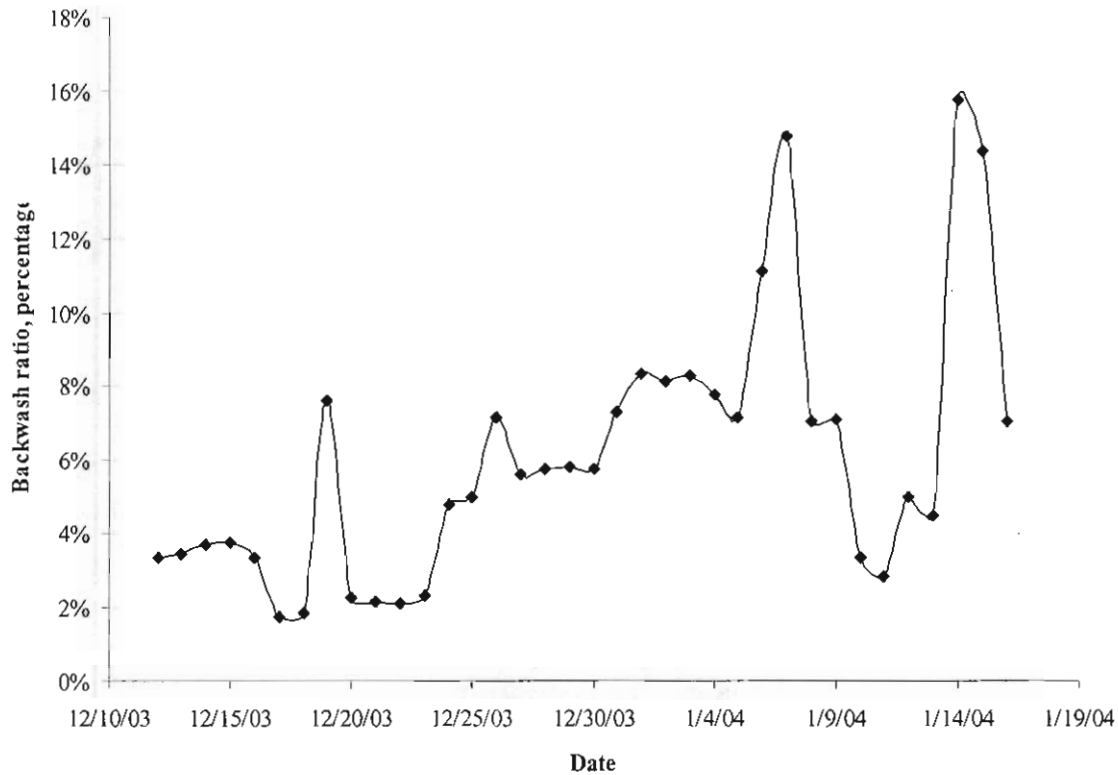
### Backwash Ratio

The following operational parameters were monitored to calculate the net water production rate and the backwash ratio:

1. Filtration rate (in gpm)
2. Backwash flow rate (in gpm)
3. Length of filtration period (in minutes)
4. Length of backwash cycle (in minutes)

The daily average backwash ratio ranged from 1.7 percent to 16 percent with an average value of 6 percent as seen in Figure 3. As expected high backwash ratios (from approximately 14 percent to 16 percent) were observed on January 13, 2004 and January 14, 2004 as a result of high solids loading conditions tested on these days. High backwash ratios from approximately 11 percent to 15 percent were also observed on January 6, 2004 and January 7, 2004. Influent turbidity values were unusually high (from approximately 14 NTU to 16 NTU) during these days due to cleaning of the secondary clarifier weirs.

**Figure 3 – Manteca WQCF Filter Pilot Study Average Daily Backwash Ratio**



### **Pilot Study Conclusions**

Conclusions drawn from the pilot study conducted at the WQCF are summarized below:

1. At a filtration rate of 3.25 gpm/ft<sup>2</sup> Title 22 turbidity requirements are expected to be achieved with the CDF for daily average influent turbidities up to 9 - 10 NTU without chemical addition. With chemical addition the Title 22 turbidity requirements were satisfied up to a daily average influent turbidity of 18 NTU.
2. Based on filter runs conducted at 6.5 gpm/ft<sup>2</sup>, TSS and turbidity removal performance of the filter did not appear to decrease with the increase in the filtration rate.
3. Based on tests conducted to simulate plant upset conditions, filter effluent turbidity was between 5 NTU and 10 NTU for influent turbidities between 20 NTU and 80 NTU.
4. The average effluent TSS was less than 10 mg/L during normal plant operating conditions (filter influent TSS less than 30 mg/L).

5. The CDF produced an effluent with TSS between 20 mg/L to 30 mg/L for plant upset conditions (with filter influent TSS values between 100 - 150 mg/L).
6. Based on PSD results, filtration of secondary effluent using CDF would enhance the efficiency of the downstream UV disinfection process by removing the residual particles (from 66 percent to 93 percent depending on the particle size range) that are disinfection barriers.
7. The UV transmittance design criteria objective of 55 percent was achieved with the CDF.
8. The average backwash water ratio was observed to be approximately 6 percent during the pilot study.

## **HISTORICAL OPERATING EXPERIENCE**

The pilot filter study demonstrated the feasibility of the CDF for use at the WQCF. Additionally, eight wastewater treatment plants with the CDF were surveyed to evaluate the operational history of the CDF. The treatment plants contacted were selected based on the number of years the CDF has been in operation, size of the treatment facility, facility location, and production of recycled water. Most of the existing CDF installations are at small treatment plants with influent flows less than 2 mgd. There are over 250 installations worldwide with approximately thirty in the United States. At the time of the survey, less than five operational CDF installations existed in California.

Fifty percent of the CDF facilities contacted had an upstream sequencing batch reactor. The other fifty percent of the treatment facilities had activated sludge and secondary clarifiers prior to the filters. Operators reported that the filter required minimal operator attention, had no major maintenance problems, and operated with a typical backwash ratio of less than 5 percent. Most of the facilities did not use chemical addition prior to the filters. The greatest limitation associated with the CDF was the low removal rates for particles smaller than the cloth size. Overall, the references recommended this type of filter for treatment plants. All of the references indicated that the CDF was able to handle high turbidity influent and process upsets well, but with a resulting increase in backwash rate. Two references mentioned that the cloth filter does not remove color well, which can be encountered when algae is present or with certain industrial processes. Three of the treatment plants contacted used UV disinfection downstream of the CDF. None of the three treatment plants had problems meeting their waste discharge requirements for coliform.

## **SITE VISITS**

Two site visits to operational CDF facilities were conducted. During the first site visit, design engineers and City personnel visited CDF facilities as well as membrane disk filter facilities (a similar type of filtration technology). Based on the layout of the filtration facilities, operational data, and interviews with operators, the CDF was selected as the future filtration technology at the WQCF.

A second site visit with design engineers and representatives from AAS was conducted prior to beginning design. This site visit was useful for visualizing various CDF design layouts, conferring with operators as to useful design features, and requesting information from AAS. Two facilities in Arizona were visited. Both facilities had retrofitted existing filter basins with the CDF. Several observations resulted from the site visit including the need to:

1. Locate all of the backwash pumps in a separate building area.
2. Provide a catwalk within the filter basin.
3. Customize PLC panels and programming to match existing technology used at the facility.
4. Install a removable sunshade cover to allow crane access to the filters if needed.
5. Provide adequate space and accessibility to the filter basins and pump galleries.

### **ADDITIONAL FEEDBACK FROM FACILITIES WITH RECENT CDF INSTALLATIONS**

The California Department of Health Services (DHS) approved the CDF for use in the production of recycled water in 2002. Since DHS acceptance of the CDF for Title 22, several large facilities in California have selected the CDF for installation. Three facilities in particular, two of which were in the vicinity of the City, were contacted. The following useful information was gathered with regard to the design of the CDF facilities:

1. Provide additional space within the filter basins and pump galleries than typically suggested.
2. Turbidimeters on the effluent of each individual filter would be useful.
3. Provide easy access to the pump galleries.
4. Provide a canopy or roof over the filters to make it easier to see the control panel screens and limit algae growth within the filter basins.
5. Use steel or ductile iron piping for the backwash system.

The following start-up operational information was also gathered from these facilities:

1. Expect a two to four week "seasoning" period for the filters during initial start-up. The effluent turbidity will improve and eventually stabilize over this time period. Ideally the filters should run continuously during this period.
2. Do not have more than one backwash cycle operate at a time if there are multiple filtration units. After a backwash, the effluent turbidity will increase slightly.
3. Do not change the fabric for more than one filter unit at a time to avoid an unexpected increase in effluent turbidity due to the "seasoning" period.

### **CONCLUSIONS**

The CDF is a recent filtration technology which has typically been selected for its small footprint, minimal maintenance and backwash requirements, and low initial capital cost. A pilot filter study with the CDF indicated that the CDF was a feasible filtration technology for the Manteca WQCF which would meet Title 22 effluent requirements and provide adequate particle removal for effective UV disinfection. References from existing facilities with the CDF

confirmed the operational reliability and low-maintenance requirements claimed by the manufacturer. Final selection of the CDF was decided after site visits to operational CDF facilities by City personnel and design engineers. A second site visit and follow-up with more recent CDF facilities aided in determining design features for the filtration facilities at the WQCF and identifying potential start-up issues.

## **ACKNOWLEDGMENTS**

The authors would like to thank the City of Manteca Department of Public Works for their assistance and support throughout the selection and design process and the wastewater treatment facilities contacted and visited during the project for their valuable information.

## **REFERENCES**

Nolte Associates, Inc. (2004) *City of Manteca Wastewater Quality Control Facility Phase III Expansion Project Schedule D – Effluent Filtration and UV Disinfection Assessment of Aqua Aerobic Systems Cloth Disk Filter for the Filtration of Secondary Effluent*; Manteca, CA.