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Operation and Performance of the AquaDAF[®] Process System for Water Purification

Authored by:

Joseph M. Wong, P.E., BCEE

Chief Engineer

Brown and Caldwell

201 North Civic Drive, Walnut Creek, CA 94596, USA

Tel: (925) 210-2555; Email: jmwong@brwncald.com

Ryan J. Hess

Director of Advanced Separation

SUEZ Water Technologies and Solutions

8007 Discovery Drive, Richmond, VA 23229, USA

Email: ryan.hess@suez.com

Lawrence K. Wang, PhD, PE, BCEE

Retired Acting President and Professor

Lenox Institute of Water Technology

1 Dawn Drive, Latham, NY 12110, USA

Tel: (518) 785-4843; Text (518) 250-0012

Email: lenox.institute@yahoo.com; lenox.institute@gmail.com

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Joseph M. Wong

Brown and Caldwell
201 North Civid Drive
Walnut Creek, CA 94596, USA

Ryan J. Hess

Director of Advanced Separation
SUEZ Water Technologies and Solutions
8007 Discovery Drive
Richmond, VA 23229, USA

Lawrence K. Wang

Lenox Institute of Water Technology
1 Dawn Drive, Latham 12110, USA

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This chapter introduces the high-rate AquaDAF clarification system which was developed in the mid 1990s for water treatment. The process is much more compact than conventional clarification systems with surface loading rate as high as 20 gpm/ft². The presentation includes the history of process development, application, system description and design criteria, pilot and full-scale case studies, and marketing outlook. Since 2000 more than 55 full-scale AquaDAF plants have been installed worldwide with a total capacity of 1.4 billion gallons per day.

KEYWORDS

Dissolved air flotation,
Surface loading rate,
Mechanical Sludge Withdrawal
False Floor

Drinking water treatment,
Algae removal,
Hydraulic sludge withdrawal,
Membrane pretreatment,

Clarification,
Recycle rate,
Flocculation,
AquaDAF

NOMENCLATURE

MGD	Million gallons per day
UWNJ	United Water New Jersey
MG	Million gallons
DAF	Dissolved air flotation
SLR	Surface loading rate
Aqua-DAF [®]	Infilco Degrement Inc. dissolved air flotation
MF	Microfiltration
UF	Ultrafiltration
AWWA	American Water Works Association
PACL	Polyaluminum chloride
TOC	Total organic carbon
SSJID	South San Joaquin Irrigation District
WTP	Water treatment plant
NTU	Nephelometric turbidity unit
IDI	Infilco Degrement, Inc.
USEPA	US Environmental Protection Agency
WW	Wastewater
DW	Drinking water
WWTP	Wastewater treatment plant

Operation and Performance of the AquaDAF[®] Process System for Water Purification

1. INTRODUCTION

The AquaDAF process is a proprietary high-rate dissolved air flotation (DAF) process designed especially for treating waters laden with algae and moderate levels of suspended solids (up to 30 NTU in turbidity). The AquaDAF technology was developed by Oy Rictor (Finland) and licensed to Infilco Degrement, Inc. (IDI), now SUEZ, for worldwide use. The process uses conventional DAF principles but includes several enhanced components, including a unique effluent collection system, to achieve high-rate operation. The DAF surface loading rate of AquaDAF ranges from 10 to 20 gpm/ft²; thus, the process is much more compact than conventional sedimentation or DAF. The early conventional DAF process by Rictor was developed in the 1960s and was mostly installed in Finland and Europe for water and wastewater treatment. The high-rate DAF by Rictor was developed in the mid 1990s, and the first plant was a 19-MGD system installed in the Town of Tempere, Finland, in 2000. The Rictor DAF was branded the AquaDAF for the U.S. market with the first U.S. plant being installed in the State of New York in 2003. Since then, over 50 AquaDAF systems have been installed in North America, Europe and other parts of the world. Most of the applications are in drinking water clarification treatment. Several are used for membrane filtration pretreatment, tertiary wastewater, membrane backwash recovery, as well as seawater clarification in desalination plants.

2. HISTORY OF PROCESS DEVELOPMENT AND APPLICATIONS

DAF uses minute bubbles generated from dissolved air to attach and float flocculated particles (flocs) to the top of the clarification basin for removal. Chemically coagulated water goes through flocculation prior to meeting with a recycled stream which releases a large number of air bubbles for attachment to the flocs forming 'float' or sludge. The float is removed either by mechanical or hydraulic means upon thickening at the surface, and clarified effluent exits the DAF tank near the bottom. About 5-10 percent of the effluent is pumped and recycled through an air saturator tank to the front of the DAF tank. The recycled stream is pressurized to 60-90 psig by the recycle pump and saturated with air by a compressor. It is introduced to recycle dispersion zone through a distribution system of nozzles, valves, or orifices. When the recycled stream pressure is suddenly decreased to atmospheric pressure,

saturated air within the recycle stream is released in the form of micro bubbles with size range of 10-100 μm , and averaging around 40-50 μm .¹

There have been several advancements in the design of DAF system since the early designs of the 1920s. Early generations of DAF systems, developed out of Scandinavia, consisted of tanks that used a length-to-width ratio of approximately 3-5:1 and were rather shallow in depth (6 to 8 feet). Flotation velocities of these early systems were 1 to 2 gpm/ft^2 . The micro-bubble bed depth is rather shallow at less than 1 foot. The shallow, long, narrow design means clarified water flows mostly horizontal in the tank to the outlet, which limits its flotation rate.

The next advancements started surfacing in the 1960s and 1970s and originated primarily out of Sweden, Finland and the United Kingdom. Advancements included designing the tanks a bit more square, although still using tanks that were longer than they were wide. Tank depths were increased (9 to 10 feet). With shorter and deeper tanks, the direction of flow from inlet to outlet became a bit steeper. Consequently, the micro-bubble blanket now became much thicker and deeper at the first 25 percent of the flotation tank length, and thinned out toward the outlet. This improvement in hydraulics and bed depth allowed for increased loading rates to 2 to 4 gpm/ft^2 .

The latest advancements in DAF came out of Helsinki, Finland, and the Rictor Company in the mid 1990s. These process advancements further improved hydraulics and DAF geometry, even at turbulent flow conditions, and allow for design flotation rates from 25 to 40 m/hr (10-16 gpm/ft^2).² Tanks are being designed wider due to limited tank lengths. Tanks are designed from 10 to 14 feet deep. The bottom of the flotation tank incorporates a perforated plate with orifices spread in a patented, non-uniform pattern. The density and diameter of holes is higher toward the inlet of the DAF and less so at the outlet, which allows for uniform collection of water and a consistent micro-bubble bed over the entirety of the flotation tank.

Currently branded the AquaDAF in North America, this technology made its debut in the U.S. in 2000 in West Nyack, NY, a 20-MGD water treatment plant. There are now more than 1.7 billion gallons per day of high-rate, AquaDAF and Rictor systems installed around the world from the U.S. to Canada, France, Finland, Brazil, China, Spain, Russia, Romania, Portugal and the United Arab Emirates.

Table 1 shows the installation list of the AquaDAF systems and the predecessor DAF systems by Rictor. All of the installations since the Town of Tampere water treatment plant (WTP) in 2000 include the latest process enhancements of high-rate AquaDAF and Rictor systems. All installations preceding the Tampere system are conventional rate systems. The largest system AquaDAF system (208.3 MGD) was installed in the Haworth WTP in New Jersey in 2009, at a DAF loading rate of 16 gpm/ft². Most of the AquaDAF systems were installed for conventional drinking water pretreatment, several were for membrane filtration and desalination pretreatment, and two were for tertiary treatment of wastewater, including phosphorous removal.

Table 1. Installation List of AquaDAF® and Rictor DAF Systems (Courtesy of SUEZ)					
Plant	Country	State	Application	MGD	Start-up
Twin Oaks WTP	USA	California	Membrane Backwash	12.0	2020
Stony Brook WTP	USA	Connecticut	DW Clarification	4.4	2020
Haverhill	USA	Massachusetts	DW Clarification	16.1	2020
Paulding County	USA	Georgia	DW Clarification	18.0	2020
Williamstown WTP	USA	Kentucky	DW Clarification	4.0	2017
Carthage WTP	USA	North Carolina	DW Clarification	1.0	2017
Canmore WWTP	Canada	Alberta	Filter Backwash	1.0	2016
Broad Brook WFP	USA	Connecticut	DW Clarification	10.0	2014
Ebensburg WTP	USA	Pennsylvania	DW Clarification	1.1	2013
Roux-Canal WWTP	Belgium		Tertiary WW	4.6	2012
El Dorado	Brazil			50.8	2012
Grenoble	France			4.4	2012
La Houlme	France			1.3	2012
Evreux WWTP	France		Tertiary WW	3.8	2012
Canoe Brook WTP	USA	New Jersey	DW Clarification	15.0	2012
Al Dur	Bahrain		Desal Clarification	152.2	2011
Kokkola	Finland		Tertiary WW	7.9	2011
Amesbury WTP	USA	Massachusetts	Drinking Water (DW) Clarification	8.4	2011
Berea Municipal Utilities WTP	USA	Kentucky	DW Clarification	8.0	2009
Haworth WTP	USA	New Jersey	DW Clarification	208.3	2009
Claresholm WTP	Canada	Alberta	Membrane Pretreatment	3.0	2009
Hudson WWTP	USA	Massachusetts	Tertiary Phosphorous Removal	6.6	2009
Monistrol WTP	France		DW Clarification	4.4	2009
Wetaskwin WTP	Canada	Alberta	DW Clarification	4.5	2008
Barcelona WTP	Spain	NA	Desalination Clarification	126.8	2008
Hameenlinna WWTP	Finland	NA	Tertiary WW	16.0	2008
La Segarra WTP	Spain	NA	DW Clarification	6.3	2008
Scottsdale Water Campus	USA	Arizona	Membrane Pretreatment	25.0	2008
White Tanks Regional	USA	Arizona	DW Clarification	20.0	2008

WTP					
Seneca WTP (Phase II)	USA	South Carolina	DW Clarification	6.0	2008
Jekaterinburg WTP	Russia	NA	DW Clarification	44.5	2007
UAE WTP	United Arab Emirates		Desalination Clarification	70.0	2007
Qingzhen	China	NA	DW Clarification	27.9	2007
Brasov WTP	Romania	NA	DW Clarification	45.7	2006
Macao Coloane	China	NA	DW Clarification	8.3	2006
Ville de Contrecoeur WTP	Canada	Quebec	DW Clarification	3.2	2006
Lac Etchemin WTP	Canada	Quebec	DW Clarification	0.6	2006
Monte Novo WTP	Portugal	NA	DW Clarification	7.0	2006
Turku, Finland	Finland	NA	DW Clarification	20.4	2006
Minera Escondida	Chile	NA	Desalination Clarification	24.5	2006
Apremont WTP	France	NA	DW Clarification	22.8	2005
Macao MSR2 WTP	China	NA	DW Clarification	15.9	2005
Utti WTP	Finland	NA	DW Clarification	5.1	2005

Table 1 (continued). Installation List of AquaDAF and Rictor DAF Systems (Courtesy of SUEZ)					
Plant	Country	State	Application	MGD	Start-up
Seneca WTP (Phase I)	USA	South Carolina	DW Clarification	6.0	2005
Saint Brieuc WTP	France	NA	DW Clarification	6.5	2005
SSJID WTP	USA	California	Membrane Pretreatment	46.0	2004
Lake Deforest WTP	USA	New York	DW Clarification	20.0	2003
Manaus WTP	Brazil	NA	DW Clarification	75.0	2002
Town of Tampere WTP	Finland	NA	DW Clarification	19.0	2000
Joutseno WWTP	Finland	NA	NA	1.3	2000
Lappavesi Oy, Kuortane	Finland	NA	NA	1.0	1999
Butoniga WTP	Croatia	NA	NA	22.8	1999
Town of Vaasa WWTP	Finland	NA	NA	8.2	1997
United Paper Mills, Kajaani	Finland	NA	NA	3.6	1995
Cellulose and Paper Mill Veitsiluoto Oy, Kemi	Finland	NA	NA	6.4	1995
Tittesworth WTP	England	NA	NA	13.2	1994
Ogston WTP	England	NA	NA	11.9	1994
Town of Norrtälje, Sweden	Sweden	NA	NA	3.2	1992
Paper Mill, Veitsiluoto Oy, Oulu	Finland	NA	NA	6.5	1991
Voss Country WWTP	Norway	NA	NA	4.6	1990
Veitsiluoto Oy, Oulu	Finland	NA	NA	9.1	1990
Town of Tampere	Finland	NA	NA	9.5	1989
The commune of Sahalahti	Finland	NA	NA	1.0	1989
Kymmene Oy, Kaukas	Finland	NA	NA	3.2	1988
Svetogorsk, USSR	Russia	NA	NA	73.0	1988
Town of Vammala	Finland	NA	NA	1.5	1987
LSO Slaughter House, effluent	Finland	NA	NA	0.2	1985
Paper Mill Veitsiluoto Oy, Kemi	Finland	NA	NA	4.8	1984
Cellulose Mill Oy Metsä-Botnia Ab, Aaneoski	Finland	NA	NA	3.4	1984

Textile Mill Nanso Oy, Nokia	Finland	NA	NA	0.4	1983
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Table 1 (continued). Installation List of AquaDAF and Rictor DAF Systems (Courtesy of SUEZ)

Plant	Country	State	Application	MGD	Start-up
Sugar Factory Suomen Sokeri Oy, Kantvik	Finland	NA	NA	2.6	1983
Power Plant Pohjolan Voima Oy, Kristiinankaupunki	Finland	NA	NA	0.7	1983
Town of Iisalmi	Finland	NA	NA	1.7	1982
Paper Mill Tampella Oy, Inkeroinen	Finland	NA	NA	1.2	1982
Town of Rauma	Finland	NA	NA	5.7	1981
Veitsiluoto Paper Mill	Finland	NA	NA	0.4	1980
Yhtyneet Paperitehtaat, The United Paper Mill	Finland	NA	NA	1.9	1980
Rauma Repola Paper Mill	Finland	NA	NA	7.7	1980
Veitsiluoto Bleached Paper Mill	Finland	NA	NA	0.4	1978
Town of Pieksamaki	Finland	NA	NA	2.7	1978
Town of Kristiinankaupunki	Finland	NA	NA	0.1	1977
The rural commune of Jyväskylä	Finland	NA	NA	2.7	1977
Town of Uusikaupunki	Finland	NA	NA	1.9	1977
Town of Oulu	Finland	NA	NA	7.7	1976
Imatran Voima, Electric Steam Power Plant	Finland	NA	NA	1.6	1976
Town of Varkaus	Finland	NA	NA	2.5	1975
The Finnish State Railways	Finland	NA	NA	0.8	1975
Town of Pietarsaari	Finland	NA	NA	2.3	1974
Town of Vaasa	Finland	NA	NA	7.7	1973
Military Base Ylojarvi	Finland	NA	NA	0.3	1972
Varkaus co-operative dairy	Finland	NA	NA	0.1	1972
Town of Hamina	Finland	NA	NA	1.7	1971
Kymi Fine Paper Mill	Finland	NA	NA	1.9	1971
Town of Kristiinankaupunki	Finland	NA	NA	0.1	1971

Table 1 (continued). Installation List of AquaDAF and Rictor DAF Systems (Courtesy of SUEZ)					
Plant	Country	State	Application	MGD	Start-up
Town of Sienajoki	Finland	NA	NA	6.9	1971
Town of Lohja	Finland	NA	NA	2.5	1970
Town of Uusikaupunki	Finland	NA	NA	1.5	1970
Lohja Cement and Lime Mill	Finland	NA	NA	1.5	1970
Varkaus co-operative	Finland	NA	NA	0.1	1970
Town of Kuopio	Finland	NA	NA	5.3	1969
Town of Oulu	Finland	NA	NA	5.7	1969
Rinnekehti-foundation	Finland	NA	NA	0.5	1969
Municipality of Karhula	Finland	NA	NA	1.5	1969
Tervakoski Condensator Paper Mill	Finland	NA	NA	2.9	1968
Council of Kiuruvesi	Finland	NA	NA	0.4	1968
Town of Vaasa	Finland	NA	NA	5.3	1968
Town of Nokia	Finland	NA	NA	0.2	1968
Town of Kristiinankaupunki	Finland	NA	NA	0.1	1967
Town of Oulu	Finland	NA	NA	2.9	1967
Town of Kuusankoski	Finland	NA	NA	1.5	1967

Notes: Installations including the Town of Tampere WTP (2000) and thereafter are high-rate AquaDAF and Rictor systems; the rest are conventional DAFs by Rictor. NA: Not Available.

3. PROCESS DESCRIPTION

3.1 PROCESS OPERATIONS

The AquaDAF system is a proprietary treatment system. Figure 1 shows and describes how the process operates.³

Figure 1. AquaDAF System Operation (courtesy of SUEZ, Ref. 22)

1. **RAW WATER INLET:** Coagulated water from an in-line or vertical, mechanical rapid mixer enters a flow distribution channel prior to the flocculation zone. Coagulation is the destabilization of colloidal particles, which facilitates their aggregation and is achieved by the injection of a coagulant, such as alum, polyaluminum chloride (PACL) or ferric chloride.
2. **FLOCCULATION ZONE:** Coagulated water is equally split to each unit, with traditional 2-stage tapered energy flocculation with variable frequency mixers. In this step, the destabilized particles agglomerate and form larger floc particles. The DAF process requires only the formation of light, pinpoint particles, eliminating or significantly reducing the need for flocculant polymers. Additionally, the retention time employed in this stage is generally only between 6 to 10 minutes.
3. **AIR-WATER DISPERSION ZONE:** Flocculated water is then transitioned to the base of the flotation zone, where it passes through the injection of a saturated air-water recycle stream. This recycle stream is produced by recycling 8-12% of clarified or filtered water to a pressurized saturator vessel (70 to 90 psi). The recycle stream is then depressurized through a series of release nozzles, which are submerged and span the entire width of this transition zone. This depressurization creates thousands of micro bubbles, which disperse into the flotation zone.
4. **FLOTATION ZONE:** The principle behind the flotation process is the micro-bubbles which form a dense air blanket within the flotation zone. The flocculated particulate will agglomerate with the micro-bubbles, as they rise to the surface, subsequently clarifying the water.
5. **SLUDGE ACCUMULATION:** The floated solids accumulate on the surface of the AquaDAF® resulting in a thick sludge layer. The floatable sludge is removed hydraulically or mechanically to an integral sludge trough.
6. **COLLECTION:** Clarified water is collected uniformly across a perforated collection floor. This uniquely engineered system, in combination with other process enhancements, creates resistance over the flotation zone, resulting in uniform collection and efficient hydraulics throughout the basin. The result is the ability to handle high downward velocities and DAF loading rates significantly higher than conventional DAF processes.

3.2 ALTERNATIVES FOR FLOCCULATION

3.2.1 Hydraulic Flocculation

Hydraulic flocculation uses baffles in chambers to induce required hydraulic gradients for achieving floc formation. This method of flocculation is simple and requires no mechanical equipment; however, the process is not easily adjusted and is ineffective in the case of widely varying flow capacities. Hydraulic flocculation was used in earlier AquaDAF systems but is no longer used in new installations.

3.2.2 Mechanical Flocculation

Mechanical flocculation uses slow-speed mixers in two stages of tapered flocculation in AquaDAF. The first or primary stage employs four to six minutes of retention time at a mixing energy of 80-100 s^{-1} . The second stage also uses four to six minutes of retention time but at a mixing energy of 20-40 s^{-1} .

3.3 Alternatives for Sludge Withdrawal

3.3.1 Hydraulic Sludge Withdrawal

This alternative uses an automatic two-position or infinite position weir located at the outlet to the DAF system. The system raises the weir plate to a prescribed level on an operator-adjusted frequency and duration. Change in effluent weir elevation raises the hydraulics in the flotation zone and hydraulically evacuates the sludge into a sludge channel. Advantages are less maintenance and lower capital cost versus a scraper mechanism. Disadvantages are more dilute sludge at ~0.3 to 0.5 percent and water loss of ~1-2 percent. Figure 2 shows the schematic diagram of a system with hydraulic sludge withdrawal.

Figure 2. Schematic Diagram of AquaDAF with Hydraulic Sludge Withdrawal (courtesy of SUEZ)

3.3.2 Mechanical Sludge Withdrawal

This alternative uses an automatic, traveling bridge truss and single blade to scrape the sludge from the DAF flotation surface. The traveling bridge truss is initiated on an operator-adjusted frequency. The traveling bridge is designed to scrape 25 to 50 percent of the flotation surface at one time and will make multiple passes in one cycle to completely scrape the entire flotation surface. Advantages are thicker sludge at 2 to 4 percent and water loss of <0.5 percent. Disadvantages are higher capital costs and equipment maintenance. Figure 3 shows the schematic diagram of an AquaDAF system with mechanical sludge withdrawal system (scraper).

Figure 3. Schematic Diagram of AquaDAF with Mechanical Sludge Withdrawal (courtesy of SUEZ)

3.4 DESIGN CRITERIA

The main AquaDAF[®] system design criteria include that for flocculation, recycled water and air dispersion, and DAF surface loading rate. Table 2 shows the typical process design criteria for the AquaDAF[®] system. A sample specification for the AquaDAF[®] system is included in Appendix A.

Table 2. Typical Process Design Criteria for AquaDAF (courtesy of SUEZ)	
System	Criteria
<i>Flocculation system</i>	
No. of Stages	2
Primary stage retention time, minutes	3 to 5
Primary stage energy gradient	80-100 s ⁻¹
Secondary stage retention time, minutes	3-5
Secondary stage energy gradient	20-40 s ⁻¹
<i>Recycled Stream</i>	
Recycled flow, % of throughput	8-12
Operating pressure, psi	70-90
<i>DAF surface loading rate</i> , gpm/ft ²	12-20
<i>DAF chamber height</i> , ft	10-14
<i>DAF chamber effluent collection</i>	PVC lateral system with patented hole pattern

4. CASE STUDIES – OPERATIONS AND PERFORMANCE

4.1 PILOT TESTING

Since the introduction of AquaDAF to North America, many pilot testing studies have been conducted for different applications. Pilot testing is typically conducted prior to implementation to confirm operating criteria, especially at high surface-loading rate conditions. Specifically, owners are looking for efficient removal of solids (turbidity), total organic carbon (TOC), algae and color, with a consistent clarified effluent turbidity of less than 1 NTU. The pilot tests are usually conducted on-site by SUEZ personnel with a mobile pilot system. The mobile system includes all the operating AquaDAF components with automatic monitoring equipment and chemical feed systems. Figure 4 shows the outside and inside views of the AquaDAF pilot system in a tent.⁴

Figure 4. AquaDAF Pilot System Pictures

4.1.1 Pilot Testing Case Study: South San Joaquin Irrigation District Surface WTP, California, USA

The South San Joaquin Irrigation District (SSJID) in Central California entered into an agreement with the cities of Manteca, Escalon, Lathrop and Tracy to build a new 40-MGD surface water treatment plant to meet the project

future water demands of these cities. Source water is obtained through SSJID's Stanislaus River Water Rights from its Woodard Reservoir. The pre-selected filtration process for the treatment plant was the ZeeWeed 1000 (ZW-1000) ultrafiltration system. A pilot testing program was conducted to prove the proposed design criteria of the ZW-1000 with two options for pretreatment.⁴ An inclined lamella plate settler was used for the first-phase testing. The AquaDAF was used for testing the second and third phases. The third-phase testing involved optimization of the AquaDAF system. Coagulation with ferric chloride, followed by flocculation, preceded both the inclined plate settler and AquaDAF. The plate settler operated at a surface loading rate (SLR) of 0.65 gpm/ft² of projected plate area. The AquaDAF operated from 14-18 gpm/ft² over the DAF collection floor. The plate settler and the AquaDAF pilot systems were each tested for approximately 40 days sequentially as pretreatment to ZW-1000. Table 3 shows a comparison of average treatment performance between the plate settler and AquaDAF[®] at the pilot plant. The AquaDAF outperformed the plate settler in turbidity and TOC removal when a slightly lower ferric chloride dosage was used.

Table 3. Comparison of Average Treatment Performance of Plate Settler and AquaDAF		
Parameter	Plate Settler	AquaDAF
FeCl ₃ Dosage, mg/L	15	14
SLR, gpm/ft ²	0.65	14
Effluent Turbidity, NTU	1 to 2	0.5
TOC Removal, %	18	>30

As shown in Figure 5, during optimization testing of AquaDAF, the effluent turbidity remained essentially unchanged (0.5 NTU) between the surface loading rate (SLR) of 14 and 18 gpm/ft² with influent turbidity of 3 to 4 NTU. The use of alum in place of ferric chloride also produced similar effluent turbidity; however, as shown in Figure 6, the TOC removal efficiency decreased at a higher SLR (18 gpm/ft²) and also when alum was used as the coagulant (at 14 gpm/ft²). The influent TOC concentration ranged between 1.7 mg/L and 2.0 mg/L. During turbidity spiking testing, the raw water turbidity was increased to 14 NTU by adding bentonite clay solution, but the DAF effluent turbidity remained consistent at 0.6 NTU. ZW-1000 performance was not affected by the high raw water turbidity as a result of good pretreatment by the AquaDAF. The pilot testing results proved the robustness and reliability of the DAF system as pretreatment for ZW-1000, and it was selected for full-scale implementation.

Figure 5. AquaDAF Optimization Testing

Performance

Figure 6. AquaDAF TOC Removal P

4.2 FULL-SCALE PLANTS

Since the year 2000, more than 55 full-scale AquaDAF plants have been installed throughout the world. The following section presents several case studies of full-scale projects using AquaDAF®.

4.2.1 South San Joaquin Irrigation District Surface WTP, California, USA

The design of the full-scale plant was completed in early 2003, and construction started in June. Construction was completed in June 2005 and the plant was dedicated on July 14, 2005 as the Nick C. DeGroot Water Treatment Plant.⁵ The treatment process train included coagulation, flocculation and AquaDAF® as pretreatment for removing suspended solids and dissolved materials contributing to color, taste and odor; chemical stabilization with lime and

carbon dioxide; membrane filtration (ZW-1000) to remove microbial-size and larger particulates; and chlorination (hypochlorite) for disinfection. The design criteria of the full-scale DAF system are presented in Table 4.

Table 4. Design Criteria of Full-scale SSJID AquaDAF System

Description	Criteria
No. of DAF Units	4
Surface Loading Rate, gpm/ft ²	15
Design Treatment Capacity, each in mgd	11.5
Hydraulic Capacity, each in mgd	15
Basin Area, each in ft ²	926
Flocculation Time, min	15
Recycle Rate, %	10

The treatment performance of the full-scale DAF system has been similar to that of the pilot plant. The effluent turbidity is approximately 0.5-0.6 NTU with influent turbidity varying from 1.11-7.17 NTU. The TOC concentrations of the raw water have been higher than those during the pilot testing period and range between 2.0 and 3.1 mg/L. The average TOC removal efficiency of the full-scale AquaDAF has been about 34 percent, which compared well with pilot plant performance. At varying plant flow rates, the AquaDAF system has operated well within the SLR of 8-15 gpm/ft². This 40-MGD water treatment plant is the first membrane filtration plant using the high-rate DAF process as pretreatment, and it was also the largest membrane water treatment plant in California during the time of its commissioning. The process is very compact and provides excellent particulate removal without the use of polymer.

4.2.2. Lake DeForest Water Treatment Plant, New York, USA

The Lake DeForest Water Treatment Plant in West Nyack, New York, is the first water treatment plant in North America with a full-scale AquaDAF system for pretreatment. Owned and operated by United Water New York, the 20-MGD Lake DeForest Water Treatment Plant is fed by a 1,000-acre reservoir and provides 33 percent of Rockland County's drinking water. In 2001, United Water began seeking an upgrade of the plant's aeration and sedimentation basins to a higher-rate clarifier to improve overall water quality and taste, filter run times and plant efficiency. The AquaDAF was identified as the most cost-effective high-rate process, as algae removal was one of

the important criteria. A pilot study was conducted in mid-2002 to confirm proposed operating criteria. The pilot testing confirmed the AquaDAF performance at a high SLR of up to 16 gpm/ft². Even at such a high rate, low coagulant dosage was needed and sludge production was minimized. Based on the pilot success, a design-build team of IDI, United Water and Black & Veatch began full-scale design. The design, permitting and construction period took only seven months. With the re-rating of the existing mixed media filters from SLR of 2 gpm/ft² to 4 gpm/ft², the plant capacity was increased from 10 MGD to 20 MGD as the pretreatment was converted from conventional sedimentation to high-rate DAF. Filter runs have been increased from 24 to 80 hours, and algae removal efficiencies have been increased from 40 to 60 percent to 70 to 90 percent. Figures 7 and 8 show the original and converted schematic process flow diagrams of the Lake DeForest Water Treatment Plant.⁶ The DAF system has replaced the aerator system; the existing flocculation and sedimentation systems remain only as pass-through facilities. The permitted SLR for the AquaDAF[®] system was 15 gpm/ft². The design SLR is 12.5 gpm/ft².

Figure 7. Original Lake DeForest Water Treatment Plant Process Schematic

Figure 8. Lake DeForest Water Treatment Plant Process Schematic with AquaDAF®

4.2.3 Haworth Water Treatment Plant, New Jersey, USA

The 208-MGD Haworth Water Treatment Plant located in Haworth, New Jersey, has the largest AquaDAF® system in the U.S. as of 2019. The plant is owned and operated by SUEZ New Jersey (UWNJ) and in 1989 became one of the first large water treatment plants in the U.S. to use ozone for disinfection. In the mid-2000s, SUEZ conducted engineering studies to address a combination of regulatory and operational drivers that were impacting efficiency and finished water quality of the Haworth Water Treatment Plant, including:

- Deteriorating raw water quality (turbidity, algae and organics) combined with increasing finished water quality standards that challenged the existing plant, which resulted in poor plant efficiency (less than 15-hour filter runs) and risks of non-compliance

- A regulatory need to cease discharge of supernatant from the existing residuals handling process to Oradell Reservoir on or before October 1, 2009
- An existing ozone system that had reached the end of its useful life.⁷

Following a year-long pilot testing study in 2006-2007, the selected treatment process improvement was the addition of the AquaDAF system as pretreatment to existing dual-media gravity filters, as well as an upgrade of the ozone system and related improvements. The DAF process was favored because of its high SLR (16.5 gpm/ft²) and small footprint compared to traditional conventional flocculation/ sedimentation and its ability to effectively remove algae during the troublesome summer algae blooms. Installing the DAF as pretreatment has extended filtration runs and reduced the volume of filter backwash water significantly. The backwash water is treated and recycled to the head of the plant to eliminate discharge. The AquaDAF system required one-eighth the process tank volume needed for traditional sedimentation clarification, which conserved 12 acres of woodland and saving millions of dollars on infrastructure.⁸ Figures 9 and 10 show the algae removal performance and turbidity removal performance of the system, respectively, at the Hawthorn Water Treatment Plant in 2009.⁵ With an average raw water algae count of 4,200 counts/500 mL, the DAF[®] average algae removal efficiency was 95 percent. With an average raw water turbidity of 6 NTU, the average DAF effluent turbidity was 0.6 NTU, with SLR ranging from 8.5 to 16.5 gpm/ft².

Figure 9. AquaDAF Algae Removal Performance at Haworth WTP (courtesy of SUEZ)

Figure 10 AquaDAF® Turbidity Removal Performance at Haworth WTP (courtesy of SUEZ)

5. MARKETING OUTLOOK

Since the high-rate AquaDAF[®] process was invented in 2000 more than 55 full-scale plants have been installed worldwide, with capacities ranging from 0.6 MGD to 208 MGD. Most of the installations have been for drinking water clarification as pretreatment for granular media filtration, but several have been installed for membrane filtration. AquaDAF[®] is especially applicable for raw water with cold temperatures, high algae content, and high organics and color measurements. It is anticipated that AquaDAF[®] for membrane filtration pretreatment will be used more often for larger plants when organics removal would be required to meet disinfection by-product regulations. AquaDAF[®] advantages include a compact footprint and the lack of polymer needed for clarification, which avoids potential fouling of polymeric MF/UF membranes by polymers. Recently, membrane filtration has become the filtration method of choice for most new water treatment plants and even plant upgrade/retrofit projects.

There have been several AquaDAF[®] systems recently installed for seawater desalination pretreatment (24.5 MGD to 126.8 MGD). This market is also expected to grow as seawater desalination has recently become an important supplemental water resource in many worldwide coastal areas facing long-term water shortage issues, such as in the Middle East, Australia, Spain, China, Singapore, Mexico and Southern California. DAF has been identified as the effective pretreatment process for seawater desalination due to occasional occurrence of “red tide”, which is a phenomenon caused by algal bloom, especially in the coastal areas. Recently the scwd² Task Force, which oversees the collaborative seawater desalination program for the City of Santa Cruz and Soquel Creek Water District, approved the staff recommendation to employ DAF and pressurized MF/UF membrane filtration as pretreatment processes for the proposed 2.5-MGD seawater desalination plant.⁹ The DAF is needed to protect the MF/UF system from occasional “red tide” events.

Other applications of the AquaDAF process include tertiary treatment for reuse and phosphorous removal, and filter backwash water recovery. The advantage of the AquaDAF system in residuals and reuse applications is that the sludge solids concentration is relatively high when mechanical sludge withdrawal is incorporated. Further thickening prior to dewatering may not be necessary. Furthermore, as the US Environmental Protection Agency (USEPA) continues to issue more stringent discharge requirements for nutrients in wastewater, the AquaDAF is a viable alternative as a tertiary clarifier for removing phosphorous to levels less than 0.1-0.2 mg/L of total

phosphorous. The readers are referred to the literature (10-24) for additional technical information concerning the technologies and terminologies of dissolved air flotation, membrane pretreatment, desalination, rapid mixing, coagulation, flocculation, clarification, filtration, microfiltration, ultrafiltration, desalination, and water purification.

GLOSSARY

Coagulant: A chemical (alum or iron salts) added to water to destabilize particles, allowing subsequent floc formation and removal by clarification (flotation or sedimentation) and/or filtration.

Coagulation: A process of destabilizing charges of suspended and colloidal particles in water by adding chemicals (coagulants). In coagulation process, positively charged chemicals are added to neutralize or destabilize these negative charges and allow the neutralized particles to accumulate and be removed by clarification (flotation or sedimentation) and/or filtration.

Collector: A device or system designed to collect filter backwash water, or other treatment unit.

Dispersion: A uniform and maximum separation of extremely fine particles, often of colloidal size.

Dissolved air flotation (DAF): One of dissolved gas flotation (DGF) processes when air is used for generation of gas bubbles. See dissolved gas flotation (DGF).

Dissolved gas flotation (DGF): It is a process involving pressurization of gas at 25 to 95 psig for dissolving gas into water, and subsequent release of pressure (to one atm) under laminar flow hydraulic conditions for generating extremely fine gas bubbles (20-80 microns) which become attached to the impurities to be removed and rise to the water surface together. The impurities or pollutants to be removed are on the water surface are called float or scum which scooped off by sludge collection means. The clarified water is discharged from the flotation clarifier's bottom. The gas flow rate is about one percent of influent liquid flow rate. The attachment of gas bubbles to the impurities can be a result of physical entrapment, electrochemical attraction, surface adsorption, and/or gas stripping. The specific gravity of the bubble-impurity agglomerate is less than one, resulting in buoyancy or non-selective flotation (i.e. Save-All).

Floc: Collections of smaller particles that have agglomerated together into larger, more separable (floatable or settleable particles) as result of the coagulation process.

Flocculation: A water treatment unit process following coagulation that uses gentle stirring to bring suspended particles together so they will form larger, more separable (floatable or settleable) floc.

Flocculator: A process device to enhance the formation of floc in a water. Mixing energy can be provided by slow turning mechanical means or head loss.

Rapid mixing: A water treatment unit process of quickly mixing a chemical solution uniformly through the process water.

Velocity gradient (G): A measure of the mixing intensity (in units of per second) in a water treatment process. Very high velocity gradients (greater than 300 per second) are used for complete mixing and dissolution of chemicals in a coagulation process, whereas lower values (less than 75 per second) are used in flocculation to bring particles together and promote agglomeration.

REFERENCES

1. Wong, J., "Using High Rate Clarification Processes to Optimize Water Treatment," Water World, June 2005.
2. Edzwald, J.K., "Development of High Rate Dissolved Air Flotation for Drinking Water Treatment," Jour. of Water Supply: Research and Technology–AQUA Vol. 56, No. 6-7, pp 399-409 (2007).
3. Infilco Degremont Inc. Bulletin: Infilco – AquaDAF® High-Rate Clarifier, 2009, www.Degremont-Technologies.com
4. Wong, J. and Enson, J., "Pilot Testing for the Largest Membrane Water Treatment Plant in California," presented at the CA-NV AWWA Spring Conference, Industry Hills, California, April 4-8, 2005.
5. Wong, J, Hubkey, B., and Hartman, R., "Comparison of Pilot and Full-Scale Performances of the Largest Membrane Water Treatment Plant in California," proceedings of AWWA Membrane Technology Conference, Tampa, Florida, March 18-21, 2007.
6. Capuzzie, A. and Witko, J., "10 to 20 in 7: The First US High Rate DAF," poster presentation at 2005 AWWA ACE, San Francisco, California, June 12-16, 2005.
7. Infilco Degremont Inc. Infilco AquaDAF® Case Study: Haworth WTP, Haworth, NJ, 2010, www.Degremont-Technologies.com.
8. American Academy of Environmental Engineers, 2010 E3 Design Honor Award: Haworth Water Treatment Plant Upgrade, 2007 – 2010.
9. Wang, LK, Chen, JP, Hung, YT, and Shamma, NK (2011). Membrane and Desalination Technologies. Humana Press, Totowa, NJ, USA. 716 pages.
10. Krofta, M., and Wang, LK (1985). Application of dissolved air flotation to the Lenox, Massachusetts water supply: water purification by flotation, Journal of New England Water Works Association, 99(3), pp. 249-264.
11. Krofta, M., and Wang, LK (1985). Application of dissolved air flotation to the Lenox, Massachusetts water supply: sludge thickening by flotation and lagoon, Journal of New England Water Works Association, 99(3), pp. 265-284.
12. Forestell, W, and Wang, LK (1991). Air flotation and sand filtration : a success for innovation in Pittsfield, MA, Journal of New England Water Works Association, 105(3), pp. 223-243.

13. Wang, LK, Fahey, EM, and Wu, Z. (2005). Dissolved air flotation. In: Physicochemical Treatment Processes, (Wang, LK, Hung, YT, and Shamas, NK, editors), Humana Press, Totowa, NJ., USA, pp. 431-500.
14. Wang, LK, Shamas, NK, Aulenbach, DB, Selke, WA, and Guss, DB (2010). Pittsfield water treatment plant: once the world's largest flotation-filtration plant. In: Flotation Technology (Wang, LK, Shamas, NK, Selke, WA and Aulenbach, DB, editors), Humana Press, Totowa, NJ, USA, pp. 485-502.
15. Wang, LK (2018). Development and construction of the first two potable DAF-Filtration plant in Two America Continents. Journal of New England Water Works Association, pp.90-95, July 2018.
16. Wang, LK (2007). Emerging flotation technologies. In: Advanced Physicochemical Treatment Technologies (Wang, LK, Hung, YT, and Shamas, NK, editors), Humana Press, Totowa, NJ, USA, pp.449-484.
17. Wang, LK, Shamas, NK, Selke, WA, and Aulenbach, DB (2010). Flotation Technology. Humana Press, Totowa, NJ, USA. 680 pages.
18. Shamas, NK and Wang, LK (2016). Water Engineering: Hydraulics, Distribution and Treatment. John Wiley & Sons, Hoboken, NJ, USA. 806 pages.
19. Wang, LK, Hung, YT and Shamas, NK (2004) Physicochemical Treatment Processes. Humana Press, Totowa, NJ, USA. 723 pages.
20. Wang, MHS and Wang LK (2016). Glossary of land and energy resources engineering. In: Natural Resources and Control Processes. (Wang LK, Wang MHS, Hung YT, and Shamas NK , editors). Springer, New York, USA. 493-623.
21. Wang, MHS and Wang LK (2015). Environmental water engineering glossary. In: Advances in Water Resources Engineering. (Yang CT and Wang LK , editors). Springer, New York, USA. 471-556.
22. Wong, J (2013). Clarifying treatment: dissolved air flotation provides alternative for treating raw water with light particles. Water World, August 2013, pp. 41-45.

Appendix A: Sample Specifications for AquaDAF® System

SECTION 11260

DAF CLARIFIER

PART 1 - GENERAL

1.1 SCOPE

A. Description of Work

1. The Contractor shall furnish and install _____ (___) high-rate dissolved air flotation (DAF) clarifier(s) as described in these specifications and in strict compliance with the Contract Drawings.
2. The DAF clarifier shall be installed in a concrete basin and consist of flocculator mixers, saturator vessels, air dispersion headers, recycle pumps, air compressors, sludge removal devices, collection system, weirs and all necessary valves, instrumentation and controls.

B. System Description

Following rapid mixing and two stages of flocculation the water enters the dissolved air flotation section of the unit. In this zone, the previously formed floc particles attach to microbubbles and are entrained by the bubbles to the surface. The microbubbles are produced by the depressurization of a partially air saturated pressurized recycle stream. This recycle stream is a portion of the clarified water stream that is pressurized by a recycle pump and saturated in a specially designed saturator tank. Depressurization of the stream takes place through proprietary dispersion nozzles fixed on a header that is located at the entrance of the DAF section. The clarified water passes through a patented perforated floor and leaves the unit over a weir plate into an effluent channel.

As floated solids accumulate on the surface of the DAF unit, a thick sludge layer is formed. Periodic removal of the sludge layer is required and may be carried out by one of two methods. Either by hydraulic means, where by raising the water level in the unit causes the overflow of the sludge blanket into the sludge collection trough. This is accomplished by raising an automatic effluent weir plate on a prescribed frequency and duration. If highly concentrated sludge is desired, a mechanical scraper system may be implemented to scrape the accumulated sludge onto a sludge beach and into the sludge trough.

1.2 SUBMITTALS

A. [INSERT SUBMITTAL REQUIREMENTS]

1.3 PRODUCT HANDLING

- A. All materials and equipment shall be shipped, stored, handled and installed in such a manner as not to degrade quality, serviceability or appearance as specified herein.
- B. The equipment shall be stored in a clean, dry location, free from construction dust, precipitation and excess moisture. If stored for more than two weeks, the equipment shall receive all maintenance considerations required by the Manufacturer for proper storage of the equipment. At no time shall the treatment modules; including all associated equipment, media and appurtenances; be stored outdoors, uncovered and/or unprotected.

1.4 RESPONSIBILITY FOR EQUIPMENT

- A. The Contractor shall be responsible for furnishing, installing, testing, and placing in satisfactory operation all mechanical equipment, instruments, monitoring devices, appurtenant process equipment, piping, electric and manual operated valves, control instrumentation and equipment, and accessories.
- B. It shall be the responsibility of the Engineer to coordinate any signal pacing and chemical feed pump control interface with the instrumentation system supplier and/or chemical feed supplier.
- C. The complete clarification system shall be provided by a single supplier, who shall bear sole responsibility for the supplied equipment. The Contractor shall coordinate the work of the System Supplier's service personnel during construction, testing, startup, calibration and acceptance of the system, and operator training.
- D. The System Supplier shall have in his steady employ, during the entire project period, capable personnel for administration; detailed engineering and drafting; coordination; procurement and expediting; scheduling; construction inspection; testing, startup assistance; and final commissioning. The System Supplier shall also have available, for the duration of the specified warranty period, capable personnel for all necessary administration, engineering, and/or service.
- E. The system design shall provide for complete operation of all signals from point to point, and shall assure complete compatibility of all instrumentation and equipment. It shall be the Engineer's sole responsibility to resolve any and all interconnecting or interfacing problems, in order to ensure a complete and acceptable operating system.
- F. The System Supplier shall have available supervisory service during construction to review and advise the Contractor on the method of mounting, piping and wiring of each device, and advising protective measures, if needed for the equipment, prior to placing it into service.

1.5 EQUIPMENT WARRANTY

- A. The Manufacturer shall warrant the equipment being supplied, to the Owner, against all defects in workmanship and materials for a period of one (1) year from the date of startup or eighteen (18) months

from shipment, provided that the plant installation, startup and subsequent operations are performed in strict accordance with written and oral instructions provided by the Manufacturer.

- B. The Manufacturer shall replace any part or parts which are determined to be defective during the warranty period, provided that the defects are not a result of misuse or neglect.

1.6 SYSTEM AND EQUIPMENT PATENTS

The bid price shall include all royalty and license fees for use of patented devices or systems and shall protect the Owner and Engineer from patent infringement litigation thereon.

PART 2 – PRODUCTS

2.1 GENERAL

- A. This portion of the section covers the work necessary to detail, manufacture, deliver to the jobsite, and to startup and test, complete and ready for operation a dissolved air flotation system (DAF) including all equipment, appurtenances, and services as specified herein.
- B. The major components supplied by the DAF manufacturer shall consist of, but is not limited to, the following:
- DAF basin(s) in concrete (by installing Contractor)
 - Recycle pumps
 - Stainless steel air saturation vessels
 - Rotary screw air compressors
 - Automatic sludge removal mechanism
 - Collection system and supports
 - Dissolved air dispersion nozzles and piping
 - Flocculation mixers
 - DAF sludge spray headers
 - Associated valves & instrumentation
 - Local control panel

2.2 SYSTEM MANUFACTURER

- A. The DAF system shall be supplied by one system manufacturer to ensure compatibility between components.
- B. The DAF system to be installed shall be the high-rate AquaDAF[®] system, as manufactured by Infilco Degremont, Inc. (IDI).
- C. The DAF supplier shall have installed and designed at least ten (10) full-scale DAF systems at or above the design loading rates described herein, which all include a non-uniform collection system across the full length of the DAF cell.
- D. All costs associated with design, engineering and equipment modifications shall be borne by the DAF manufacturer and be pre-approved by the engineer at least 10 days prior to bid day.

2.3 SYSTEM DESIGN & PERFORMANCE REQUIREMENTS

- A. The DAF system shall continuously receive and clarify the chemically treated and flocculated water received from the flocculation basins. The water shall be clarified by continuously injected air saturated water into the head of each DAF basin. The clarified water shall discharge to the combined DAF effluent channel and the DAF float shall be mechanically removed into a sludge trough. The DAF system shall be able to operate continuously on demand and shall be suitable for clarifying water continuously for up to 24 hours per day, 7 days a week.
- B. The total DAF system shall be capable of producing a design flow of ____-MGD at a loading rate of ____ gpm/ft². Each unit shall be capable of producing a design unit of ____ gpm at a loading rate of ____ gpm/ft².

2.4 DAF EQUIPMENT AND MATERIALS

The Contractor will furnish and install ____ () AquaDAF[®] dissolved air flotation unit(s), as described in these specifications and in strict compliance with the Contract drawings.

A. RAPID MIXER

- 1. The DAF system shall include ____ () in-line static/mechanical mixer or vertical mount rapid mixer as specified under Section _____. The mixer shall be provided by Others.

B. FLOCCULATOR MIXERS

- 1. Primary & Secondary Stage Mixers
 - a. The DAF manufacturer shall provide a total of ____ () primary stage vertical mixer(s) and a total of ____ () secondary stage mixers. Each mixer shall be designed in accordance with the DAF supplier's recommendations. One (1) VFD shall be provided per ____ () mixers by Others and in accordance with Section _____.
 - b. Electric Motors: Cast iron vertical mounted motor, with cast iron fan cover and cast iron, diagonally split conduit box, drip cover, standard NEMA C-Frame 230/460 volt, 60 Hz, 3-Ph be of an enclosure for operation on electrical characteristics as specified. The motor insulation shall be class "F" and the motor shall have a 1.15 Service Factor. Motor bearings shall be grease lubricated. The connection between the motor output shaft and the reducer input shaft is to be made by a torsionally resilient flexible coupling which is Wood's Sureflex or equivalent, to reduce the effects of shock and vibration, and to minimize the effects of parallel, angular, and axial misalignment.
 - c. Speed Reducer: Each drive unit shall consist of a fine grain cast-iron heavy duty speed reducer. The speed reducer used shall be directly connected through a flexible coupling to the electric drive motor. The speed reducer shall be specifically designed for mixing service and shall be capable of 24 hr/day continuous operation in an outdoor environment. The mechanical rating of the speed reducer shall be at least 2.0 times the motor nameplate. The speed reducer shall bear an AGMA nameplate.

All drives shall be a vertical in-line double reduction helical gear combination to ensure maximum efficiency coupled with the convenience of mounting, maintenance, and installation. All gearing shall be AGMA Quality 10 as a minimum. Worm gears are not acceptable.

General maintenance, specifically including replacement of all anti-friction bearings, all oil seals, and lubricant maintenance shall not require removal of the speed reducer housing from its foundation. The speed reducer shall be provided with lifting lugs.

All reducer bearings shall be Timken taper roller anti-friction type, shall be oil lubricated and have a minimum L-10 bearing rating of 100,000 hours. All bearings shall be submerged in the lubricating oil to ensure positive lubrication. Oil pumps will not be allowed. A single oil drain shall be provided at the low point of the speed reducer to allow oil drainage and leave a maximum residual of oil of no more than ¼" in the drive housing. Oil changes following the initial run-in period shall not be required at less than one year intervals. Oil leakage down the low speed output shaft shall be prevented by means of a drywell. No oil seals shall be permitted below the operating oil level for rotating elements. The speed reducer breather shall be located above possible oil foam level.

All gears and bearings shall be protected from rusting during storage by the application of a shop-applied protective coating.

The thermal rating of the speed reducer shall exceed the design mechanical rating to eliminate the need for external cooling. External cooling devices are not allowed.

The mixer shaft shall be connected to the output shaft of the speed reducer by means of a removable coupling accessible from outside the tank and located above the mounting surface. The rigid coupling shall be designed to minimize runout to less than ¼" per 10' of shaft length.

- d. Shaft: The rotating speed of the shaft and turbine assembly shall not exceed 80% of the first critical speed of the shaft and impeller assembly when stabilizing devices are used. The shaft supporting the turbine shall be removable from the reducer without disturbing the internals of the speed reducer.
- e. Impellers: All mixing impellers shall be designed to operate under specified liquid level variations while maintaining dynamic and hydraulic stability. Impellers shall be high efficiency axial flow turbines. Impellers shall incorporate a constant pitch ratio blade design, producing a uniform, axial fluid velocity profile. Impeller hub is welded to the shaft; the removable impeller blades are bolted to the hub.
- f. Wetted Parts: All wetted parts shall be furnished of 316SS. Wetted parts are defined as those parts normally wetted by the process liquid. All mill scale, rust, and contaminants must be removed. Sharp corners or cuts of sheared edges shall be dulled by at least one pass of a power grinder or file.
- g. Non-Wetted Parts - Painted: Normally painted surfaces not subject to continuous wetting by the process liquid include electric motors, speed reducers, mounting bases, etc. These painted surfaces shall receive a protective coating capable of withstanding heat so that minimal discoloration of the paint takes place at temperatures below 250 deg F. The paint shall have a minimum salt spray resistance of 400 hours, and shall withstand most solvents if removed within five minutes. Specifically, the paint shall be modified styrenated alkyd enamel of the air-dry type. All painted components shall be of the mixer manufacturer's standard coating and color.
- h. Non-Wetted Parts - Unpainted: Surfaces normally left uncoated, such as flexible couplings, etc., will not require special coatings. However, these surfaces shall be protected prior to shipment by a sprayed or hand applied covering of rust preventative compound such as "Rust-Guard". This coating shall be easily removable with a solvent.
- i. Internal Coating & Shipment Preparation: Each drive unit shall be run with a polarizing rust-inhibiting oil before shipment, during the reducer test at the manufacturer's facility. Each unit shall receive a vapor phase inhibitor sprayed into the reducer housing interior at the factory to further guard against internal corrosion during field storage of the equipment.
For additional protection, a specially prepared paper treated with vapor phase inhibitor and covered with water repellent tape shall be applied over all external couplings and bearings that could be exposed to corrosion. All openings in the equipment shall be covered with the vapor phase inhibitor impregnated paper and water repellent tape. Water repellent tape and vapor phase inhibitor treated paper will be applied over any adaptor sleeves, locknuts, reducer dipsticks, breather assemblies, and other areas or openings requiring special protection.
- j. Guards: All rotating shafts above platform level shall be supplied with guards in accordance with OSHA Standards.

- k. The Contractor shall furnish and install each mixer complete with: (a) all supports; (b) all mechanical equipment required for proper operation, including complete drive units; (c) all steel, iron, and other materials of construction indicated on the drawings; (d) all electrical equipment, including starters, etc.; and (e) any additional materials of construction required by the manufacturer's design. Equipment shall be of U.S. manufacture.
- l. The Contractor shall provide the mixer support bridges or concrete pads.

C. AIR SATURATION SYSTEM

1. Saturator Vessel

- a. General: Each DAF basin shall have one (1) air saturator vessel per DAF unit, for a total of ____ (__) vessels. The air saturation vessel shall be sized and be suitable for operation of one DAF basin at peak flow conditions. The air saturation vessels shall be of the vertical and unpacked type.
- b. Each saturator shall be designed approximately as follows:
 - 1) Design Pressure: 150 psi
 - 2) Hydrostatic Test Pressure: 225 psi
- c. Each vessel shall be constructed as per the latest revision of Section VIII, Division 1 of the ASME code.
- d. One saturator vessel shall be supplied to feed one DAF train and be located directly above the injection headers. One saturator feeding multiple DAF basins shall not be allowed.
- e. Saturator Accessories: The saturator vessel shall include all components to ensure a completely operational vessel for the DAF system. These components include a safety relief valve, air inlet solenoid valves, air check valves, air inlet globe valve, magnetic level controller with level indication, injectors, flanges and gaskets.
- f. Materials: Each air saturation vessel shall be fabricated from 304 stainless steel materials. The finish shall be glass-beaded. Material thickness shall be governed by the ASME code. All internal water distribution components, mounting brackets and external flanges shall be 304 stainless steel. Vessels fabricated of painted carbon steel or galvanized steel shall not be allowed.

2. Dissolved Air Dispersion Piping and Nozzles

- a. General: Each DAF basin shall have ____ (__) set of air/water dispersion headers. The entire header shall be designed to handle approximately ____ gpm of recycle flow.
- b. The design of the headers shall allow only one flow rate at one pressure for simplicity of operation.
- c. The recycle injection nozzles shall be designed to provide the pressure drop required to disperse the bubble cloud. The nozzle spacing shall be determined and supplied to provide effective and efficient dispersion in the reaction zone.
- d. The DAF manufacturer shall design and supply the recycle piping and supports from the outlet of the saturator vessel to the nozzle. All piping shall be designed to handle the required design recycle flow at velocities not to exceed the manufacturer's limitations for efficient dispersion.
- e. Materials: The dispersion piping and header shall be fabricated from Sch10s, 304 stainless steel. Each nozzle shall be formed from a single piece of Sch 80 PVC with male threads. Nozzles have multiple connections and orifice plates shall not be allowed.

- f. Nozzles: Each nozzle shall be formed from a single piece of Sch 80 PVC with male threads. Nozzles that have multiple connections and orifice plates shall not be allowed. The air dispersion nozzles shall be designed according to the DAF System manufacturer's recommendations. The air dispersion nozzles shall be removable for cleaning purposes.

D. COLLECTION SYSTEM

1. Collection Floor

- a. General: The DAF Manufacturer shall provide a process collection floor within each DAF basin to ensure proper DAF performance. Each basin will be provided with the required 1/8" thick aluminum sheets or FRP plates to cover each flotation cell. Each sheet will come predrilled with a hole pattern for installation, in strict compliance with the submittal drawings, by the Contractor.
- b. Supports: Each basin will be provided with the required aluminum angle, support channel and structural tubing and necessary expansion anchor bolts to serve as support for the collection floor.

E. RECYCLE PUMP & COMPRESSOR SYSTEM

1. Recycle Pumps

- a. General: The recycle system shall be designed to provide an air/water recycle stream to the each DAF basin. Each recycle system shall be provided with ____ () pump(s). The pumps shall be of vertical turbine type each capable of producing a design flow of ____ gpm at an approximate TDH of ~250 feet.
- b. Motor: The motor shall be NEMA standard design B, Vertical Hollow Shaft high thrust, TEFC enclosure, 1775 RPM, squirrel cage induction full voltage type starting, powered by an electrical service rated at 460 volts, 60 hertz, 3 phase. Each motor shall be capable of driving the pump under all head conditions without exceeding the rated capacity of the motor. Motor shall have class B insulation, 1.15 service factor rated 90 6; rise at service factor load. Motor shall conform to AIEE and NEMA, standards. Motor design shall be premium efficiency style.

The motor thrust bearing shall be designed to carry the hydraulic thrust plus the weight of the shaft and the impellers. The thrust bearing life expectancy shall have a five year average rating based on 24 hours per day usage. The motor shall be capable of carrying up thrust equal to approximately 30% of the total down thrust. Bearings shall be oil or grease lubricated as per manufactures standard design.

Each motor shall be provided with a corrosion-resistant nameplate giving the name of the manufacturer, horsepower, voltage, frequency, speed, efficiency and current for unit at full load.

- c. Discharge Head Assembly: Discharge head shall be a cast iron surface discharge with 125 lb ANSI dimension discharge flange and shall support the motor, column, shafting and pump assembly. The discharge head shall be mounted on a fabricated steel, base-plate which shall be anchored to a concrete pad over the well or sump. The bottom surface of the head shall be machined smooth. A tapped drain line connection shall be provided for the removal of the excess water to a drain.

A cast iron stuffing box shall be provided with a bronze removable stuffing box bushing, galvanized split gland, T-bolts with stainless steel clips and brass nuts. Stuffing box shall utilize a minimum of five synthetic Garlock 8913 packing rings, compressed around the pump shaft and lubricated by the pumped water. A two piece top shaft shall be threaded and coupled just above the stuffing box.

- d. Column Assembly: Column pipe shall be furnished in interchangeable sections not over 10 feet in length and shall be connected with threaded sleeve type couplings. The friction loss in the column shall not exceed 5 feet per 100 feet of column, based on the rated capacity of the pump. The weight and size of the column shall be no less than required in AWWA spec E101-1. The line shafting shall be

AISI 416 stainless steel of ample size, minimum of 1" diameter, to operate the pump without distortion or vibration. The shaft shall be furnished in interchangeable sections not more than 10 feet in length and shall be coupled with AISI 410 stainless steel coupling. The column assembly shall have bronze bearing retainers retained by the butted pipe ends. Each bearing retainer shall contain a water-lubricated, cutless rubber bearing designed for vertical turbine pump service.

- e. Pump Bowl Assembly: The pump bowls shall be of close grained cast iron, having a minimum tensile strength of 30,000 pounds per square inch, free from blow holes, sand holes, and all other faults; accurately machined and fitted to close dimensions. Bowls are to be coated inside with a smooth vitreous enamel to reduce friction losses, corrosion and sand wear in the water passages and thus gives better efficiency. Each intermediate bowl is to be constructed by using a bronze bearing and a neoprene bearing to support the impeller shaft which gives the longest possible life, based on the widest range of pump conditions.

The bowl is to provide a side seal at the impeller skirt and in addition, a resilient neoprene ring, reinforced with an imbedded steel core, is to be installed in the bowl directly below the impeller skirt. This "lateral bowl ring" is to reduce the wear of the impeller skirt. Original capacities and efficiencies are to be maintained by adjustment of the top shaft nut at the top of the motor. The impellers shall be of _____ enclosed type only, accurately machined and finished, and balanced. They shall be securely fastened to the impeller shaft with a steel taper bushing. The impeller shaft shall be of stainless steel of not less than 12% chrome. The impeller shaft shall be supported by a combination of water lubricated, fluted rubber and bronze bearings. Discharge and suction cases shall both be fitted with steel sand collars. All bowl bolting shall be of stainless steel.

- f. Strainer: The bell suction shall be fitted with a clip-on type galvanized steel basket strainer. The openings in the strainer shall be of proper size to exclude anything large enough to clog the impeller. The open area of the strainer shall not be less than four times the impeller eye area.
- g. Coatings/Finish: The DAF recycle pump(s) shall be coating with manufacturers standard finish/color.
- h. Factor Assembly: Close coupled vertical pump(s) shall be factory assembled if the overall length does not exceed 20 feet from top of discharge head to bottom of suction casing. The motor(s) and motor shaft of the two-piece top shaft shall be shipped un-mounted for field installation by contractor.
- i. Variable frequency drives for the recycle pumps shall be provided by others and in accordance with Section _____.

2. Recycle Piping

- a. All recycle piping shall be sized by the DAF manufacturer. The flow velocity and headloss shall be designed to prevent any air from prematurely dispersing within the piping system. The Contractor shall provide the recycle piping and supports from the recycle pump outlet to the flanged inlet section of the saturator vessel.
- b. All recycle piping shall be schedule 10, 304 SS. No other materials of construction shall be allowed. All piping velocities shall be limited to the manufacturer's tolerances to prevent any unnecessary headloss.

3. Air Compressor

- a. General: Compressor shall be rotary screw type. There shall be provided a total of ____ (____) duty air compressors for the entire DAF system. Each compressor shall be a pressure lubricated oil filled rotary screw type. The compressors shall be mounted on an ASME designed air receiver tank(s). Each air compressor shall be designed for 100 percent duty to supply a minimum of ____ cfm at 125 psi.

- b. Motors: Each air compressor shall have a 460-volt, 3 phase, 60 hertz, TEFC motor. All motors shall be premium efficiency type. All motors shall have Class F insulation with a 1.15 service factor.
- c. Features:

Noise Level – <63 dB(A) at 1 meter

Integral refrigerant dryer (IFD) with Class 1 integrated filters (0.01 micron particle and 0.01 ppm oil).

Food grade oil

Automatic condensate drains on coolers and receiver tank

Integral control panels with OIT and keypad. Control panels shall allow duty/standby selection and automatic alternation via one of the panels acting as the master.

E. SLUDGE REMOVAL SYSTEM

1. Scraper Mechanism

- a. The DAF manufacturer shall provide a mechanical scraper, similar to a traveling bridge, for sludge removal. The scraper mechanism shall be designed and capable of removing sludge from the top of the DAF basin. The mechanism shall move along a guide rail at approximately 1/2 the length of the DAF basin. Each motor shall be 1/2 HP.
- b. Each scraper shall be supplied with one (1) 304SS sludge beach, spanning the width of each DAF cell.
- c. Materials: The scraper equipment shall be fabricated from painted carbon steel and structural materials. The scraper blade and all fastening hardware shall be 304 stainless steel.
- d. All interconnecting air piping shall be provided by the Contractor.

2. Sludge Wash Header & Sludge Trough Spray Header

- a. One (1) sludge trough spray header per unit shall be supplied with the use of mechanical sludge removal. The spray header shall be designed to discharge plant process water over top of each float sludge trough. Each spray header shall be provided with an automatic and manual isolation valve, spray nozzles and piping over the sludge trough.
- b. One (1) peripheral sludge wash header per unit shall be supplied. The spray header shall be designed to discharge plant process water around the periphery of the flotation area. Each spray header shall be provided with an automatic and manual isolation valve and piping around the periphery of each DAF cell.
- c. Materials: The spray header shall be fabricated from Sch 80 PVC. Each header shall be sized according to the design requirements. The spray nozzles shall be fabricated from 316 SS.
- d. Pressurized Water Supply: The Contractor shall supply and connect a pressurized water supply (40-50 psi) to both spray headers upstream to the control valve.

3. Effluent Weir (Fixed – Optional automatic weirs available)

- a. General: One (1) manual effluent weir plate shall be provided.
- b. Materials: The sludge weir shall be fabricated from 304SS, 1/4" thick.

4. DAF Sludge Trough

- a. General: The DAF sludge removal channel shall be sized by the DAF supplier and constructed of concrete to be installed by the Contractor.
- b. Each channel shall slope at least 10% grade and shall be sized according to the design requirements by the DAF manufacturer and as shown on the Contract drawings.

F. VALVES

1. General: The following valves for the DAF system shall be provided:

DAF VALVES					
DESCRIPTION	QTY	TAG	TYPE	SIZE	Actuator
DAF Recycle Pump Isolation		--	BFV	2"	Manual
Saturator Safety Relief		--	PRV		Spring type
Saturator Air Inlet (auto)		--	SOL		Electric
Saturator Air Inlet		--	CV		Swing type
Saturator Air Bleed		--	GV		Manual
Saturator Tank Drain		--	BV		Manual
Spray Wash Inlet		--	BV		Electric
Spray Wash Isolation		--	BV		Manual – True Union
Compressed Air (blade)		--	SOL		Electric
Compressed Air (blade)		--	BV		Manual
Compressed Air (blade)		--	PR		Manual
Air Dispersion Isolation #1*			BV		Full port ball valve
Air Dispersion Isolation #2*			BV		Full port ball valve

*Only required for multiple dispersion header arrangement.

2. Butterfly Valves for Water Service:

- a. General: Butterfly valves shall be the product of one company. Valves and operators shall conform to AWWA C504, Class B, except as specified herein. Minimum rated working pressure of 150 psig. The valves shall be of the flanged type with EPDM seats and Type 316 stainless steel shafts. Valve bodies shall be cast in one piece and be constructed of cast iron per ASTM A126, Class B. Valve discs shall be constructed of cast iron or ductile iron. Shaft seals shall be self compensating split V-type or O-ring packing made of BUNA-N. Valve wetted parts shall be NSF-61 approved.
- b. Manufacturer: Butterfly valves shall be manufactured by Dezurik or Henry Pratt Company.

3. Ball Valves

- a. General: Ball valves for saturator drain isolation and air dispersion shall be manually operated, reinforced TFE seats and seals, full port, ANSI Class 150 flanged. Valve bodies and trim shall be constructed of Type 316 stainless steel. Valves shall be rated to 250 psi.
- b. Process air line isolation ball valves shall be manually operated, bronze body, stainless steel inserts, Teflon seats, regular port, with threaded connections.

- c. Ball valves for miscellaneous drain service and isolation of pressure transmitters, pressure gauges, and air release valves shall be corporation stops for connections to piping 4-inches or larger, and for connections to piping smaller than 4-inches in diameter shall be constructed of stainless steel (body, ball and stem), Teflon seats, with NPT connections.
 - d. Proportional control ball valves for spray headers shall be PVC with solvent welded true union connections and manual handles, viton seals, and rated to 250 psi.
 - e. Electric operated ball valves for spray headers shall be PVC true union ball valves with viton seals and 115VAC electric actuator. Actuator shall have NEMA 4X enclosure and 25% duty cycle.
4. Check Valves
- a. Check valves for water service shall be wafer style silent check type. The valves shall be all cast iron body, bronze seat and plug, stainless steel spring, 150 psi working water pressure.
 - b. Check valves for air service shall be bronze, carbon steel disc, Teflon seats, swing type with threaded ends.
5. Pressure Relief Valve
- Pressure relief valves shall be all stainless steel construction. Pressure shall be adjustable over a range up to 140 psig.
6. Solenoid Valves
- Solenoid valves shall be forged brass or cast brass type, with Buna-N seats. Valves shall be normally closed, with NEMA 4X enclosures, and operate on 120 V, 60 Hz, single phase power supply. Solenoid valves shall be manufactured by ASCO Valve. All DAF solenoid valves to be powered from the DAF control panel.
7. Pressure Regulators
- Pressure regulators shall be backpressure type, rated 125 psig working pressure, with aluminum body, bonnet and bottom plug. Outlet pressure shall be field adjustable between a pressure range of 5 to 135 psig.
8. Air Release Valves
- ARV's shall be of the combination type with a small venting orifice to vent the accumulation of air and other gases with the line or system under pressure, a large orifice to vent large amounts of air upon pump start-up, and vacuum relief capability. ARV's shall incorporate an isolation valve to allow removal of the valve without shutting down the equipment. Valves shall be suitable for pressures up to 150 psi.
9. Globe Valve
- Globe valves shall be class 125, with a rising stem and screw in bonnet. The body and stem shall be constructed of bronze, the handwheel of malleable iron, the bonnet of either brass or bronze, and the packing shall be graphite.
10. Pressure Reducing Regulator Valve
- Pressure reducing regulator valves shall be 1/2-inch stainless steel with NPT connections. Valves shall be properly rated for inlet pressures of at least 150 psig and adjustable outlet pressures as necessary to meet a setpoint of 80 psig.

G. INSTRUMENTATION

1. General: The following instruments for the DAF system shall be provided:

DAF INSTRUMENTS				
Item Description	Qty	TAG	SIZE	Type/Actuator
Recycle Flowmeter		---		Magmeter
Recycle Pressure Transmitter		---		
Pressure Gauges (recycle pump)		---		Ashcroft
Pressure Switch (recycle pump)		---		Solenoid - Electric
Start-up Strainer (recycle line)		---		Conical Type
Liquid Low Level (recycle pump well)		---		Float Switch
Saturator Level Controller		---		Magnetic Type

2. Pressure Gauges shall be constructed from type 316 stainless steel. Gauges shall be fluid filled with adjustable pointer, with ranges as indicated in the Contract Drawings. Pressure gauges shall be manufactured by Ashcroft.
3. Pressure Transmitters shall have a Coplanar platform design, NEMA 4X enclosure, and 4 – 20 mA signal with a range of 0 to 200 psi. Pressure transmitters shall be model 3051 by Rosemount or Endress-Hauser
4. The level indicator for the air saturator level indication and control shall be a magnetically coupled type with an ANSI pressure class of 150. The chamber shall be 2-inch diameter and constructed of 304L stainless steel. Level indication shall be in inches. Process connections shall be 1-inch flanged side connections, with a dome cap and bottom blind flange. The level indicator shall have three integral electro-magnetic switches for level control. The level indicator shall be the Atlas model and the level switches the stainless steel NEMA 4X rated OES-100 model, both manufactured by Magnetrol.
5. Each DAF saturator system shall have a spool-piece magnetic flow meter. Flow meters shall be of the inductive type. The measuring tube shall be manufactured from type 304L stainless steel with Teflon liner and Class 150 stainless steel flanges. Flowmeter and transmitter shall have NEMA 4X rated enclosures. Flowmeters shall be manufactured by Rosemount or Endress-Hauser and shall be outfitted with a remote transmitter with 15 feet of cable.
6. Pressure switches shall be adjustable deadband type with NEMA 4 enclosure with operating range of 5 - 200 psig and consist of a switch unit and transducer unit.

H. DAF CONTROL PANEL

A total of ____ (__) main DAF control panel housed in a NEMA 4X FRP enclosure will be provided. The control panel will include an Allen-Bradley CompactLogix PLC, Panelview 600 HMI and required control devices to provide automatic and manual control of the DAF equipment. All motor starters and VFD's shall be provided by Others and located in the MCC.

I. SPARE PARTS

1. General: Provide the following spare parts for the DAF system:
 - a. Solenoid valves (1 of each size/type)
 - b. Air dispersion nozzles - ____ (__)
 - c. One flocculator mixer fix kit: including set of bearings, shims and seals for each size of gear reducer.

J. PROTECTIVE COATINGS

All fabricated steel parts, excluding stainless steel, shall be factory finish painted with a polyamide epoxy coating system in accordance with the Equipment Manufacturer's standard painting specifications. Appropriate measures shall be taken where material incompatibility exists.

PART 3 EXECUTION

3.1 INSTALLATION BY THE CONTRACTOR

A. Contractor Performance:

1. All materials and equipment shall be installed in a neat, workmanlike manner.
2. All wiring of the equipment shall be as specified under the electrical section of these specifications and shall terminate at diagram connection points for devices and panels.
3. All equipment specified herein shall be installed in accordance with the Manufacturer's recommendations and the contract drawings.
4. Where anchor bolts and other parts in concrete are required, such parts shall be furnished by Contractor. Such installation shall be performed in accordance with Division 3 Concrete.
5. The Contractor shall not energize the instrumentation/control system prior to receipt of a certified statement of approval from the Engineer with his authorization for energizing the system (if required to be supplied by the Manufacturer).
6. Prior to startup and field testing, all foreign matter shall be removed from the equipment, inside the control panel (if required), and interconnecting piping. Spillage of lubricants used in servicing the equipment shall be cleaned from pumps, piping, and concrete surfaces.

3.2 MANUFACTURER'S SERVICES

A. Installation and Startup Assistance

1. The Manufacturer shall provide supervision services for inspection, start-up, and training. All costs for services furnished by the water treatment system Manufacturer shall be included in the total price, with no additional compensation provided. Services shall be provided for ____ () days. Service for performance testing (if required) shall be provided at an additional cost to the Owner.
2. The service times specified shall be considered as full eight (8) hour working days and do not include travel time. A unit price per day shall be included in the proposal, should the Owner request additional time.

3.3 MANUFACTURER'S INSTRUCTIONS

Must be in compliance with Manufacturer's product data; including product technical bulletins, installation instructions, assembly drawings and product container instructions for installation.

-END OF SECTION-