A Unique Integrated Membrane Makeup and Zero Liquid Discharge System for a Combined Cycle Power Plant

GERALD ALEXANDER
Siemens Industries, Inc.
La Canada, CA

STANLEY KARRS
Siemens Industries, Inc.
Warrendale, PA

KEYWORDS: Zero liquid discharge, tubular microfiltration, reverse osmosis, evaporation ponds, cross flow microfiltration, softening/clarification, silica reduction, reverse osmosis concentrate

ABSTRACT: The growing trend to limit the use of fresh water while minimizing, if not totally eliminating, the discharge of wastewater in the Power Industry has made the need to provide an integrated approach a critical factor. This case study describes how the combination of off-site service with a wastewater plant design that incorporates precipitation with micro-filtration was the solution for the Harry Allen Gas Turbine Combined Cycle power plant. The virtually all membrane design operates at an overall recovery of greater than 95% while discharging a stream of wastewater to evaporation ponds and trucking solids off-site. The feedwater to the plant is variable originating from three different wells while the wastewater is a combination of reverse osmosis concentrate, steam generator blowdown, evaporative cooler blowdown, wet surface air cooler blowdown, multimedia backwash water, oil/water separator wastes, and other service water wastes. This design overcomes many of the shortcomings of a conventional approach or a thermal design which would have much higher capital and operating costs.

Background

The Harry Allen Generating Station is a natural gas fueled power plant located in Southern Nevada approximately 25 miles northeast of Las Vegas. The Plant was originally built in 1995 as a simple cycle plant with a 72-megawatt combustion turbine. A second similar sized combustion turbine was installed in 2006 doubling the plant capacity to 144-megawatts. The final build-out of the Plant was completed in 2011 with the addition of two heat recovery steam generators that capture waste heat from the combustion turbines which then drive a single steam turbine generator to produce an additional capacity of 484 mega-watts raising the total Plant capacity to 628 mega-watts. This modification resulted in the transformation of the Plant from a peaker to a base loaded combined cycle Plant.

One of the design objectives of the Plant was to minimize the quantity of water required while eliminating any water discharge off-site. The Plant consumes a mere 32 gallons of water for each mega-watt of power produced whereas a conventional plant would use more than 600 gallons per megawatt of energy produced. The reduction in water demand was principally addressed by the use of air-cooled condenser cells and evaporative coolers.

The combined wastewater from the Plant is discharged to a pair of refurbished 2.5 acre geo-textile, riprap-lined evaporation ponds. The solids produced from the wastewater are recovered by a filter press and sent off-site for disposal to a sanitary landfill. In essence the objective of the Plant's water and wastewater treatment systems was to achieve zero liquid discharge (ZLD). The selection of a wastewater treatment system that was capable of meeting this objective is the heart of this paper.

Design Requirements

The water and wastewater requirements of the Plant can be summarized as follows:

- Potable Water Treatment System (PWTS)
- Make-up Water Treatment System (MWTS)
- Wastewater Treatment System (WWTS)

The source of raw water for the Plant is from the Harvey well with alternate supplies from the Chuck Lenzie Station Wells #1 and #2. The system design is based upon the worst possible blend of any of the three wells. The synthetic design well water analysis use for the Plant design is given in Attachment A. This water quality was used for the design of both the potable water and the makeup water treatment systems.

PWTS

The potable water system treats the well water and has a design capacity of 3 gpm continuous net to storage. Due to the insignificant capacity of this system in relation to the makeup and wastewater, its design will not be a topic discussion in this paper. For information purposes, the system consisted of two (2) 100% trains, each consisting of multimedia filters, granular activated carbon, brine regenerated strong acid cation units (softeners), reverse osmosis and sodium hypochlorite addition.

MWTS

The makeup water treatment system consists of three (3) 50% trains. The system is divided into a roughing treatment system followed by a polishing system. The roughing system is capable of treating 300 GPM of well water with the flexibility to also treat a portion of the recovered wastewater. The treated water from this roughing system is channeled to a blend storage tank that also has the ability to store recovered water from the wastewater treatment system. This partially treated and blended water is used for various plant demands including fire protection. The balance of this stored water is fed to a polishing makeup demineralizer system. The multimedia filter backwash/rinse and reverse osmosis concentrate is sent to the wastewater treatment plant. The polishing system consists of three (3) 50% 40 GPM feed second pass reverse osmosis trains and off-site regenerated mixed bed ion exchange polishers. The polished water is stored demineralized water storage tank. The second pass RO concentrate is returned to the filtered/blend water storage tank so the polishing system does not produce any wastewater during normal operation.

WWTS

The wastewater treatment system is designed to treat the Heat Recovery Steam Generator (HRSG) blowdown, the MWTS multi-media filter backwash water, the MWTS first pass RO concentrate, the Combustion Turbine Generator (CTG) evaporative cooler blowdown, the Wet Surface Air Cooler (WSAC) blowdown, the existing service water wastes, the discharge from the oil/water separator, and recycle water from the WWTS after these streams are collected in a wastewater equalization tank. The design capacity of the WWTS is 300 GPM. The water processed by this system is either sent to the evaporation ponds or returned to the makeup treatment system for further processing and recovery. The solids produced are dewatered and hauled off-site.

Makeup Water Treatment System

The raw water source being well water makes the design of the pretreatment system very straight forward. The well water analysis reports suspended solids in the range of 3 mg/l dictating the need for filtration to reduce the silt density index (SDI) to an acceptable value for RO feed. The alternatives for filtration were either multi-media filtration (MMF) or ultra-filtration (UF). While the UF would provide a more positive barrier and produce a superior filtrate water quality, it does have some drawbacks given the fact its wastewaters would require recovery to minimize the volume of waste that would have to be sent to the wastewater treatment system. The backwash water for the MMF is less than one percent (1%) whereas the UF would require a backwash water volume of approximately five percent (5%). In addition, the MMF does not require periodic chemical cleanings that would further complicate the wastewater recovery system.

The well water is dosed with sodium hypochlorite to ensure the complete oxidation of any soluble iron. The filtrate from the multimedia filters is stored in a filtered water/blend water storage tank. In addition to the filtered water, this tank will receive concentrate from the downstream makeup second pass RO, permeate from the wastewater recovery RO, and potentially some of the wastewater recovery RO concentrate.

The filtered water is dosed with an anti-scalant, sodium bisulfite and then processed through five (5) micron (nominal) safety cartridge filters before being sent to the first pass roughing reverse osmosis trains. The selection of a two pass RO was chosen to minimize the loading on the downstream polishing demineralizer. While the pH of the well water would indicate the minimal presence of carbon dioxide, provisions are included to eliminate the presence of any carbon dioxide by the addition of inter-stage sodium hydroxide.

An inter-pass permeate storage tank is included to collect and blend the first pass RO permeate and the reclaimed wastewater RO permeate. A portion of the permeate stored in this tank is used for various plant uses including first pass RO flushing and firewater. The balance of the permeate is treated by the second pass RO and then the off-site regenerated mixed bed polishers to produce demineralized makeup water.

The concentrate from the first pass RO is sent to the wastewater treatment plant for treatment. This pass operates at a comfortable recovery of approximately 75%. The relatively low recovery ensures simple, reliable, and trouble free operation without producing excessive wastewater while its concentrate stream will be recovered by the wastewater treatment system. The second pass operates at a recovery of approximately 85% with its concentrate being sent to the filtered water/blend tank. This second pass concentrate will be blended with the filtrate from the multi-media filters and permeate from the wastewater RO.

The second pass RO permeate could have been polished by either electro-deionization (EDI) or conventional mixed bed ion exchange (MBIX). The EDI would have the advantage of eliminating any waste stream, other than the possibility of periodic cleaning. Its concentrate stream could be returned to one of the upstream RO permeate storage tank or the filtrate/blend storage tank. The ion exchange approach would require off-site regeneration to avoid the production of spent regenerant wastewater. The off-site regeneration also shifts the capital investment and the operation and maintenance costs to the service provider. Finally, the mixed bed ion exchange simplifies the recycling of the stored demineralized water to ensure the highest possible water quality is always available. The final decision was to use a mixed bed ion exchange solution with off-site regeneration in lieu of the EDI.

Refer to Attachment B for a block Process Flow Diagram of the system.

Wastewater Treatment System

The wastewater that must be treated comes from a multitude of sources which increases the complexity of any wastewater treatment process that would be used to reduce the volume of wastes and its discharge to the evaporation ponds. The first option for treatment would have been a thermal process, or evaporator. This process has been used in many plants throughout the western United States but it is a given fact they are very expensive to not only purchase but operate as well. The second option was a design based upon the use of reverse osmosis membrane technology to concentrate the wastewater into an acceptable stream that could be sent to the evaporation ponds. The key to the membrane approach is to manage the water chemistry and avoid exceeding the solubility of any inorganic contaminants that could be possible. In addition, it is necessary to reduce particulates, remove undesirable organic constituents, and manage the bio-fouling that can result in excessive membrane fouling. Finally it is important to minimize the cleaning frequency of the RO that would place an unacceptable burden on the Plant’s operators. It should be noted although a full clean-in-place (CIP) membrane cleaning system was provided, the current plant operation utilizes off-site membrane cleaning. The reverse osmosis membrane approach was selected for this Plant as the most cost effective design and one that could be operated and maintained without placing a burden on the operating personnel.

As with all reverse osmosis membrane plants, their performance is a function of the pretreatment system's ability to minimize membrane fouling. The variety and the variability of the wastewaters for this application would have been a challenge for any pretreatment system. Two options were evaluated for the reverse osmosis pretreatment system. The first option consisted of a conventional solids contact clarifier for the reduction in sparingly soluble salts followed by media filtration. The use of a solids contact clarifier is commonly employed in power plants as a standalone cooling tower blowdown minimization system or in combination with media filters. It can also be used as pretreatment in a thermal zero liquid discharge (ZLD) system to reduce the size of the evaporator. The second option involved chemical precipitation in combination with a cross-flow tubular micro-filtration system. As with a solids contact clarifier, this design uses chemical precipitation to reduce the salts and concentration of chemical species that can limit the recovery of the wastewater RO. The unique feature of this approach is the use of a cross-flow tubular MF to enhance the reduction in the unwanted salts while providing a physical barrier to reduce the level of suspended solids that cannot be achieved with a media filter. In essence, the slurry cross flow tubular microfiltration system replaces the function of a typical precipitator/clarifier/filter system into a single unit operation. The chemically pretreated wastewater flows through the tubular modules at a high cross flow velocity sufficient to maintain turbulent flow. This design is a pressure driven process with typical operating pressures in the range of 40 – 60 psi. The fluid is forced through the membrane with a pore size in the range of 0.1 – 0.3 microns that is cast onto the inside of a tubular porous material. The turbulent flow prevents the buildup of particles on the inner surface of the modules while the filtrate is forced through the pores of the membrane. The design incorporates a periodic back-pulse with air to prevent solids accumulation on the surface of the membrane and extend the service cycle before a chemical clean in place is required. This turbulent cross-flow and tubular design also eliminates the need for pre-filtration with the ability to handle solids levels up to five percent (5%) by weight.

Experience indicates this type of design is particularly beneficial when treating a mixture of waters. Chemical dispersants/soaps routinely found in cooling water interfere with critical coagulation, flocculation and settling processes in a conventional precipitator/clarifier. Consistency of both the precipitation and solids removal processes is more effective when both processes occur within the micro-filtration process.

Perhaps the key issue in the decision to select the cross-flow tubular MF over a clarifier was its ability to deal with the variability of the wastewater that was to be treated. While some of the streams to the WWTP are relatively constant in flow and contaminants and an equalization tank is used to moderate the variability, it would be impossible to maintain a constant flow and feedwater analysis. One of the traits of a solids contact clarifier is the fact it is a constant rate process. Variations in temperature, flow rate, and salinity can result in an upset in the sludge blanket and the settling velocity of the solids unless the changes are gradual and controlled which in this instance was not possible. In addition, there can be carry over of polymers that are normally used to enhance the performance of the clarifier. Most polymers will result in severe membrane fouling of either low pressure filtration or high pressure reverse osmosis membranes. Operation of the cross-flow MF however does not require the use of a polymer. The use of an equalization tank attempts to level out such variations in operating parameters but it is not possible to provide a tank sized large enough to minimize the impact upon the performance of a clarifier. Such variations will result in excessive solids carryover from the solids contact clarifier as the suspended matter will not be able to settle. This carryover can produce excessive loading on the downstream filtration system and the resultant short service runs. Variations in the raw water analysis require corresponding modifications in chemical addition to ensure the required precipitation of the undesirable salts. This includes salts that are not only precipitated but those that are adsorbed on precipitated material, such as silica. With the elimination of sparingly insoluble salts from the process, the limiting factor of the downstream reverse osmosis system becomes the level of TDS in the concentrate stream. The use of seawater membranes in the RO system will permit a reduction in the wastewater volume corresponding to the limitation of the osmotic pressure, which would be a concentrate steam that contains a TDS in the range of approximately 80,000 mg/l. This would equate to an overall recovery of about 98-99% assuming a feedwater TDS of approximately 1,000 mg/l.

The wastewater treatment system begins with an equalization tank that blends the multi-media filter backwash water, the first pass RO reject from the makeup water treatment system, the raw water, and the various plant waste streams. The effluent from the equalization tank is pumped to the two (2) stage reaction tanks where the chemical addition is performed. The chemical addition is specific to the precipitation/adsorption that must be accomplished. This process relies upon hardness reduction by precipitation and silica reduction by the adsorption of silica on magnesium hydroxide precipitate. While the design feedwater contained ample magnesium for this purpose, the decision was made to incorporate the ability to add a magnesium salt to ensure the required silica reduction could be produced.

Sodium hypochlorite and hydrochloric acid are added to the first reaction tank for pH control and to oxidize any incoming organic matter to prevent potential membrane fouling. Provisions are also included to feed ferric chloride to act as a coagulant which can often be helpful in minimizing the frequency of membrane cleaning. The adjusted water flows to the second stage reaction tank where soda ash and caustic soda are added to precipitate calcium carbonate and magnesium as magnesium hydroxide.

The effluent from the two stage reaction tanks flows by gravity to a MF feed/concentration tank. This tank acts as a pump suction tank, a level control device, a slurry recirculation tank for the downstream MF. By increasing the slurry of the precipitated materials, it enhances the reduction of the silica by increasing the concentrations of the solids that are used to remove certain species such as silica. The concentration of this slurry is in the range of 2 – 5 percent solids. Excess sludge is intermittently bled from the system by pumping some of the sludge from the concentrate tank to a thickener.

Each cross-flow tubular MF train consists of a feed/recirculation pump, membrane modules, a cleaning pump, and a chemical cleaning tank and water rinse tanks. The flow is controlled to each module by the level in the concentrate tank. If this level drops below a given set-point, the flow to the first stage reaction tank is increased. When the flow to an MF train drops below the design rate that was established to process all the wastewater, the train is removed from service and cleaned. There are a total of four (4) – 33% MF trains. The trains utilize ten (10) tubular PVDF membranes with a pore size in the range of 0.1 micron (nominal). Each module is approximately one (1) inch dia. and 72 inches long and there are a total of four (4) modules per housing. There are a total of thirty six (36) eight (6) inch dia. by ten (10) foot long PVC housings housing per train. The MF membranes are typically rated to operate at a flux of approximately 300 GFD for this application. The actual operating flux will be dependent upon the nature of the precipitated materials, the particulates, and other impurities combined with the effectiveness of the cleaning regime.

A redundant MF train is provided to ensure the design flow rate is maintained when a train is taken off-line for module cleaning. The automated design cleaning frequency for each MF train is approximately three (3) days. When the MF is cleaned, the feed/recirculation pump is shut down and the MF is flushed to displace the slurry back to the feed tank. For this application, cleaning is conducted with hydrochloric acid and occasionally sodium hypochlorite. This is accomplished by recirculating the cleaning solution back to the cleaning tank for about 30-60 minutes. After the cleaning cycle is completed, the cleaning chemicals will be reclaimed by feeding them back to the concentrate feed tank. The solids that are sent to the sludge thickener are processed by a filter press that produce a cake of approximately 50% solids. The filtrate from the press along with the overflow from the thickener is returned to the first reaction tank for reprocessing.

The filtrate from the MF is be pH adjusted with hydrochloric acid in a pH adjustment tank for optimum pH for the downstream RO and then flow by gravity to a MF filtrate tank. The filtrate from this tank is pumped to the reverse osmosis units. Chemical addition ahead of the RO consists of sodium bisulfite for the removal of any residual free chlorine that could be present in the filtrate as a result of the feed to the reaction tanks or the MF cleaning process. A non-oxidizing biocide can also be added to retard biological activity. It should be noted an anti-scalant is not required or included as the sparingly insoluble salts are all kept well below their saturation levels by the upstream process.

The reverse osmosis concentrate system consists of five (5) - 25% three (3) stage trains designed to treat a feedwater capacity of 300 gpm. The system is design to operate at an overall recovery of 90% with 270 gpm of permeate being reclaimed by returning this stream to the makeup treatment system to either the filtrate tank for further reprocessing or to the first pass permeate storage tank for plant use including the Wet Surface Air Cooler. As noted, the design recovery of the RO is 90%. However, due to the fact a portion of the concentrate stream can be returned upstream to either the reaction tanks or the pH correction tanks for reprocessing, it is possible to operate the RO at a very comfortable recovery of 75% producing a total concentrate flow rate of 75 GPM while still maintaining the overall system recovery at a minimum of 90%. The 75 GPM of concentrate is routed to a RO reject holding tank where it can be split into three streams. The RO concentrate is either directed to the evaporation ponds, the first stage reaction tank, and/or the pH adjustment tank. The exact ratios depend upon the actual concentrate water quality. There are conditions under which the RO reject's water quality is such that a majority of the reject can be recycled to the makeup plant increasing the recovery above the 90% value. To date a recovery of up to 98% has been achieved under certain operating conditions.

Operation and Performance

A well trained and competent operator is critical to the reliable and efficient performance of any water or wastewater treatment system. This is especially true when a wastewater stream varies in composition, temperature, and flow rate as in the case for this system. While the various unit operations are primarily pressure driven membrane processes, the correct chemistry must be maintained to ensure the necessary operating parameters are maintained and that the required membrane cleanings are performed when required. Based upon the design data presented, the key constituents that must be monitored and controlled to permit the required RO recovery at a minimum of 90% are total hardness and silica. The MF systems primary function is to reduce these impurities and any others constituents that could limit recovery if they are concentrated in the RO and permitted to result in scaling. Naturally, the MF must also ensure the silt density index (SDI) of the RO feed water is below 3.0. To ensure the system is in chemical balance, the operators monitor the following key parameters of the MF filtrate to determine if any adjustments to the chemical addition are required:

- Silica
- Total Hardness
- Alkalinity
- pH

Since the raw water can contain a wide variety of contaminants due to the various wastewater streams that are fed to the equalization tank, provisions were incorporated into the design to utilize a wide variety of chemicals to precipitate the hardness, silica and any other constituents prior to the MF. It has not been necessary however, to feed each of the available chemicals at all times. The filtrate is then pH adjusted and dosed with a biocide to further condition the filtrate for feed to the RO. The chemicals required for the MF system include:

- Sodium hypochlorite
- Hydrochloric acid
- Sodium hydroxide
- Magnesium sulfate
- Sodium carbonate
- Ferric chloride
- Calcium chloride

In addition to the above, the following additional chemicals are used for operation of the MF and RO. It should be noted the RO elements are cleaned off-site in a service center while a portion of the MF cleaning chemicals are sent to the evaporation ponds for final disposal:

- Sodium hypochlorite
- sodium biusulfite
- Anti-scalant
- Biocide

Based upon the composition of the wastewater that has been treated to date, the chemical utilization has been primarily sodium hydroxide for hardness reduction and hydrochloric acid for pH adjustment. Given this operating condition, the actual operating flux of the membrane is substantially higher than the design flux permitting fewer on-line units during normal operation and extending the period of time between MF membrane cleanings. A summary of the chemical consumption for one month of operation is given in Attachment D.

The operator has a great deal of flexibility in determining the timing for the MF cleaning. Unlike other membrane processes that rely upon trans-membrane pressure loss or flux decline to initiate a cleaning, the cleaning of the MF is based upon the ability of the MF to process a specific wastewater flow rate. If the level in the equalization tank begins to rise to an unacceptable level due to a limit in the downstream MF processing capacity, an MF is taken off-line and replaced with a standby MF thereby increasing the wastewater treatment processing rate. Since the maximum operating flux for easy to treat wastewaters can be in the range of 600 gallons per square foot per day (GFD), the operator has a greater flexibility in deciding when to perform a cleaning of an MF. For example although each of the MF trains were designed to operate at a capacity of 100 GPM, the trains have been operated at flow rates up to approximately 250 GPM. The operator may also find it convenient to schedule MF cleanings based upon the total production capacity or use the calendar for initiation. Attachment D illustrates some performance data for the MF over a period of time. To date, an acid cleaning using hydrochloric acid has be very effective in returning the membrane to its required flux which accounts for the higher than anticipated flow rates.

As is the case for all RO systems, the performance of the wastewater RO concentrator is a function of the quality of the feedwater produced by the pretreatment system, which in this case is the MF. Since being placed into operation on about February 2011, the wastewater RO has been cleaned only one time. The RO is the unit process that determines if the required overall recovery of 90 percent can be achieved. The system has consistently exceeded this objective by returning a portion of its concentrate/reject stream to the first stage reaction tank. As indicated in Attachment D, after the initial commissioning of the system the average recovery of the system has been approximately 98%. The high system recovery has been possible by the use of seawater RO membranes in the wastewater RO which operate at pressures up to approximately 500 psig. The wastewater RO produces a permeate water quality with a total dissolved solids content in the range of 50 micro-siemens per centimeter, or 25 mg/l of total dissolved solids. Since this relatively low TDS water quality is returned to the makeup demineralizer system and further polished by the makeup RO as illustrated in Attachment C, the loading on the service ion exchange demineralizers has extended their service cycle. Currently the replacement frequency for the ion exchange units is in the range of six (6) to eight (8) weeks. This also reduces the raw water demand on the well water that supports the overall Plant.

Conclusions

The integrated water and wastewater system has been operating for over one year. After a normal commissioning and start-up period, the required objective of producing the required makeup water and treating a variety of wastewaters, the plant is continuously exceeding the primary goal of minimizing the wastewater discharge to the evaporation ponds by a maximum of 90% for design. In fact, the discharge over the past approximately six months has been consistently in the range of 5% of design. While it can be said the wastewater that the system has had to treat is less demanding than the original design analysis, it should also be recognized the demands on the system from a start-stop operation perspective and the variations in feedwater create a difficult operating environment. This would be especially true if the system had included conventional softener/clarifier and filtration process in lieu of the existing slurry cross-flow tubular micro-filtration system. The guaranteed performance has been validated not only by the minimal discharge to the evaporation ponds but the trouble free performance of the reverse osmosis wastewater concentrator.

The successful performance of this integrated membrane makeup and zero liquid discharge system is based upon the following considerations:

- A complete profile of the various raw water and wastewater streams that must be treated. This information must not only include the design basis for the system but also the actual water quality variations that can occur during the Plant's operation.
- An understanding of the water and wastewater treatment chemistries required to produce the desired results. The overall recovery of the system is ultimately based upon the control of the solubility of the potential compounds that can be produced within the system.
- An understanding of the basic unit processes required to achieve the specified objectives. The system should be flexible enough to deal with reasonable changes in the design criteria which will occur in all water and wastewater treatment plants.
- A trained operating staff committed to operate and maintain the system. Their success will ultimately be a function of the data collection, analysis, and ability to implement periodic changes in the operation of the system. This also includes their ability to address periodic performance shortcomings as a result in unanticipated changes.

REFERENCES

1) Krzesowski, L. (1999) Recovery of Reverse Osmosis Brine at GM Mexico Ramos Arizpe Complex. International Water Conference, 34, 259 to 266

2) Patrick, G. (2001)Microfiltration for Second-Stage Softening Provides Many Benefits to an Automotive Assembly Plant in Mexico. WEFTEC Latin America, pp 193 to 207

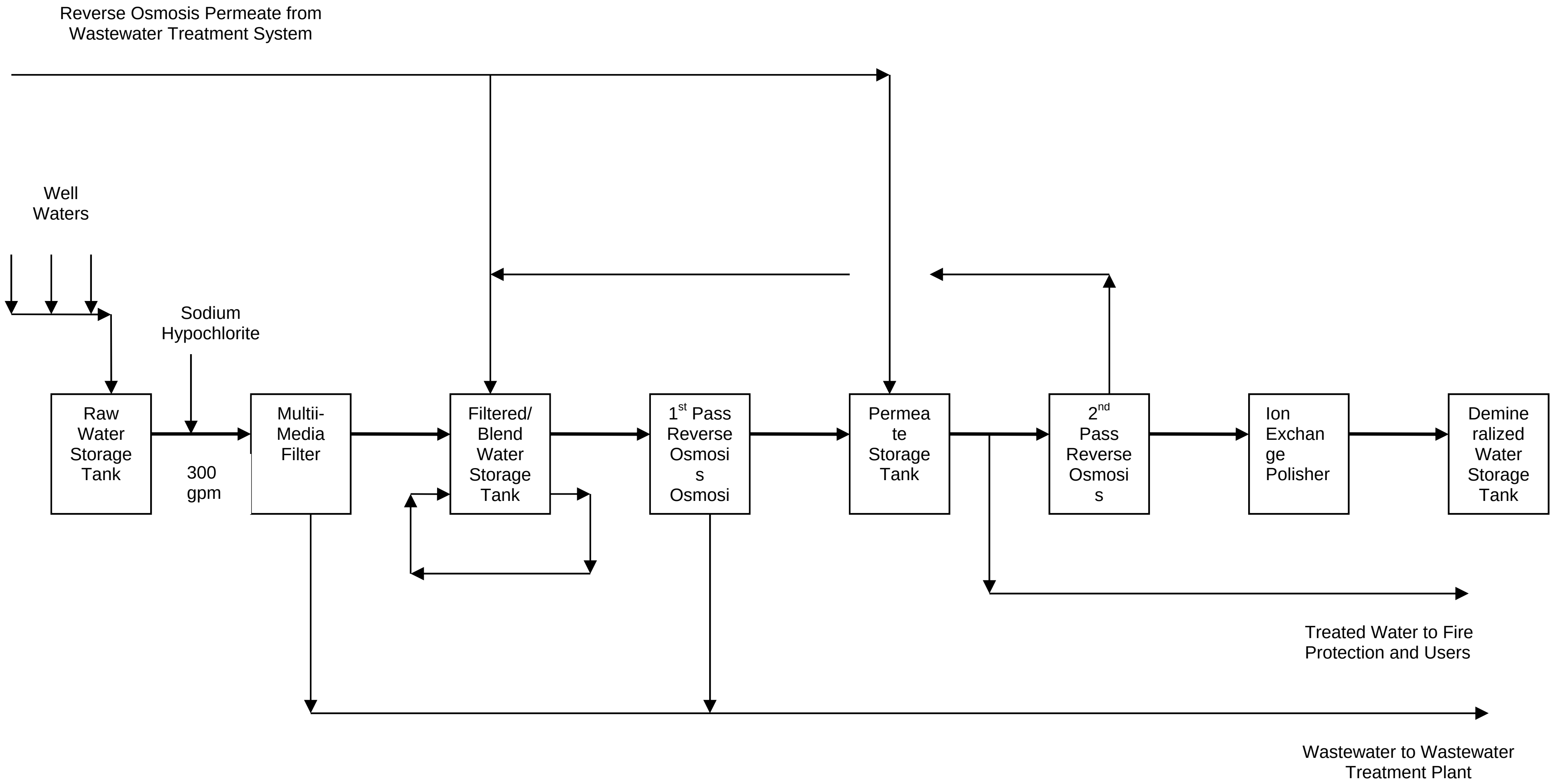
ACKNOWLEDGEMENTS

The authors wish to thank all the people and organizations that contributed to the engineering, implementation, start-up and ongoing operation of the facilities described in this paper including:

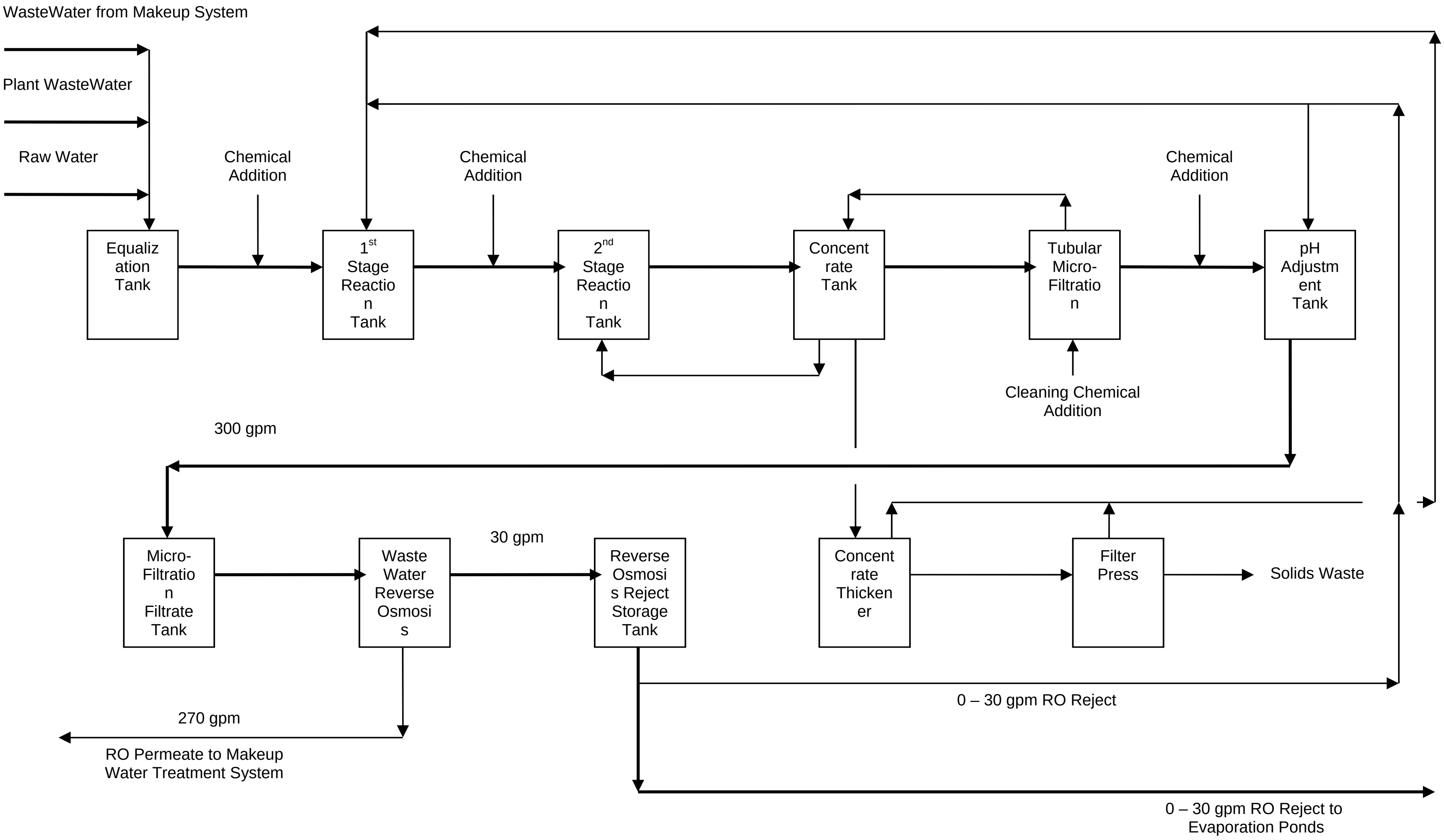
NVEnergy
Siemens Customer Service
Siemens Industries, Inc.

ATTACHMENT A

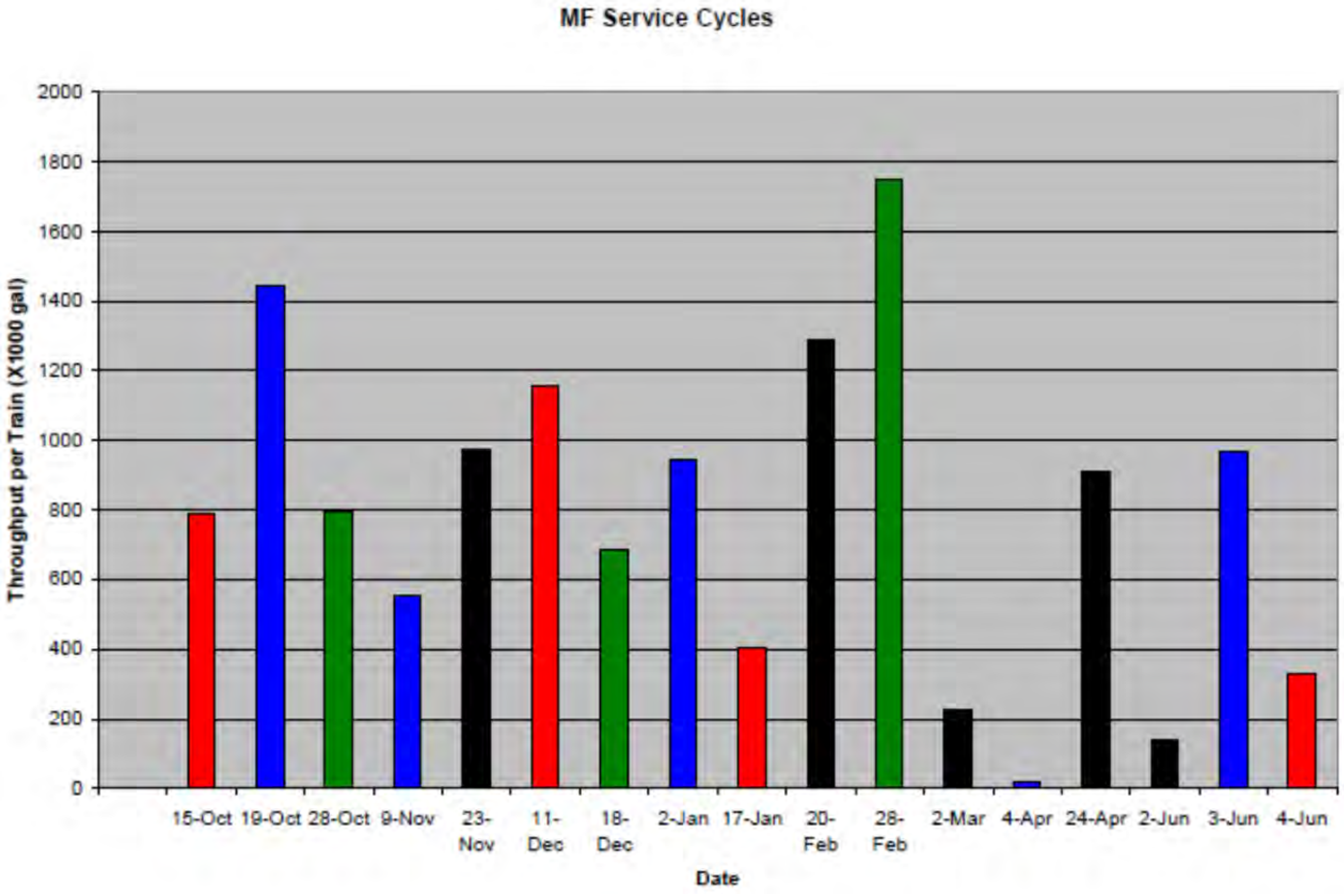
Parameter	Design Well Water Composite	Design Wastewater Influent	Guaranteed Wastewater Effluent	Actual WasteWater Effluent
Cations/Metals	<0.1			
Aluminum (Al), mg/l	<0.05			
Barium (Ba), mg/l	0.3	<0.05		
Boron (B), mg/l	<0.05	0.18		
Cadnium (Cd), mg/l	100 - 120			
Calcium (Ca), mg/l	<0.05	178		
Chromium (Cr), mg/l	<0.05			
Copper (Cu), mg/l	<0.05			
Iron (Fe) – Soluble, mg/l	0.12 – 0.75			
Iron (Fe) – Total, mg/l				
Lead (Pb), mg/l	<0.1			
Lithium (Li), mg/l	0.14 – 0.23	0.27		
Magnesium (Mg), mg/l	49 – 57	62.6		
Manganese (Mn), mg/l	<0.05			
Molybdenum (Mo), mg/l	<0.1			
Nickel (Ni), mg/l	<0.05			
Phosphorus (P), mg/l	<0.1			
Phosphorus (PO_4), mg/l	<0.3			
Potassium (K), mg/l	15	33		
Silica (SiO_2), mg/l	21.0	36.4		
Sodium (Na), mg/l	130	266	<130	
Strontium (Sr), mg/l	3.60	5.69		
Vanadium (V), mg/l	<0.05			
Zinc (Zn), mg/l	<0.05			
Anions				
Bromide (Br), mg/l	<2.0			
Chloride (Cl), mg/l	160 – 180	582.4	<160	
Nitrate (NO_3), mg/l	<2.0 – 6.7	<2.0		
Nitrite (NO_2), mg/l				
Phosphate (PO_4), - Total	<0.2			
Phosphate (PO_4), - Ortho	<0.10		<300	
Sulfate (SO_4), mg/l	300 – 350	307		
Alkalinity				
Bicarbonate ($CaCO_3$), mg/l	170 – 180	222		
Methyl Orange ($CaCO_3$), mg/l	170 – 180			
Phenolphthalein, ($CaCO_3$), mg/l	<10			
Others				
pH, standard units	8.2	6.0 – 8.3		
Sum of Ions	998 – 1,097	1,656		
Carbon Dioxide (CO_2), mg/l	2.0	67		
Conductivity, *u*S/cm	1,400 – 1,600	2,939	<1,400	
Organic Carbon (C) - Total, mg/l	<2.0			
Ammonia (NH_3), mg/l	<0.04			
Ammonia ($CaCO_3$), mg/l	<0.12			
Suspended Solids(Total at 105^O C)	<3.1			
Benzoltriazole Background, %	TBD			
Temperature, deg. F	55-65	60 - 100		



MAKEUP WATER TREATMENT SYSTEM



WASTEWATER TREATMENT SYSTEM


MF Service Cycles
Throughput per Train (X1000 gal)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
15-Oct
19-Oct
28-Oct
9-Nov
23-Nov
11-Dec
18-Dec
2-Jan
17-Jan
20-Feb
28-Feb
2-Mar
4-Apr
24-Apr
2-Jun
3-Jun
4-Jun
Date

IWC 12-14

SIEMENS

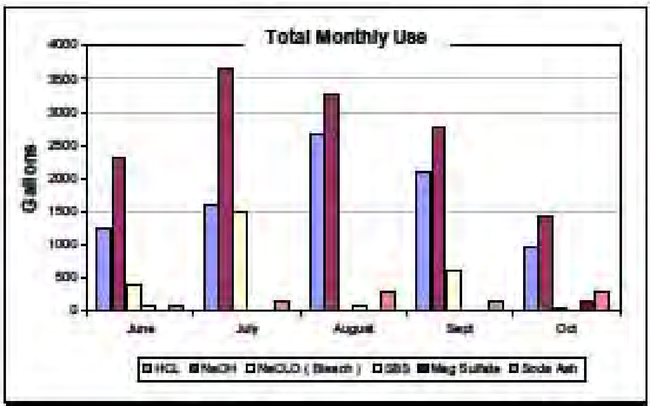
HARRY ALLEN Chemical Inventory - Monthly Usage Report

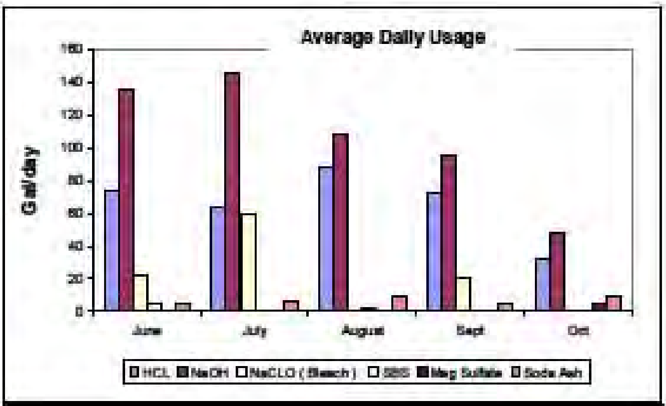
NVEnergy

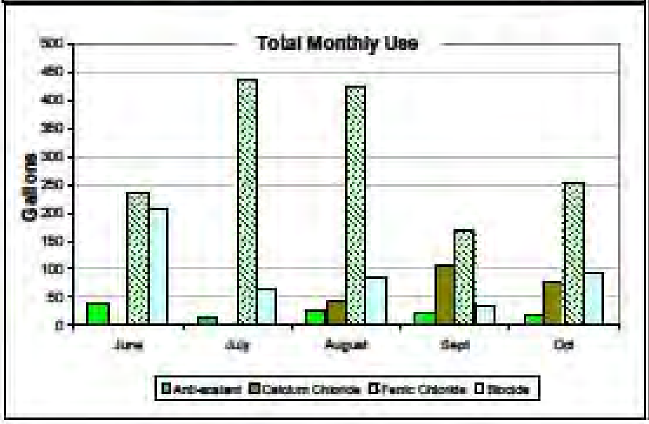
Month: October, 2011

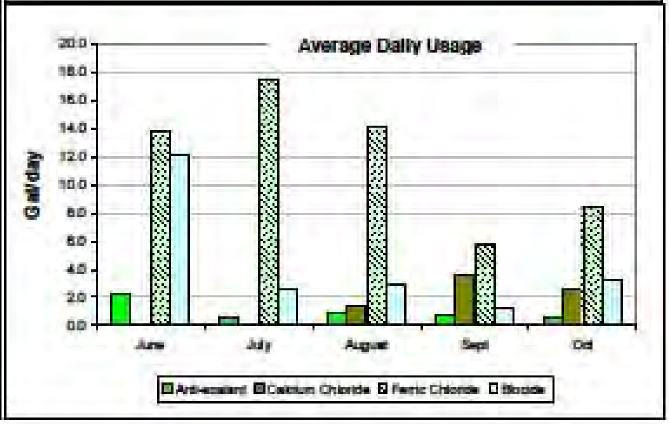
Chemical Tank/Tote Levels	Beginning Inventory	Gallons	End Inventory	Gallons	Total Gallons Delivered	Total Gallons Used	Average Daily Usage
Date	10/1/2011		10/31/2011				30
HCL	63%	5962	53%	5012	0	950	31.7
NaOH	35%	4839	53%	7355	3940	1425	47.5
NaCLO (Bleach)	24%	1127	88%	4110	3004	21	0.7
SBS	0%	0	78%	566	566	0	0.0
Mag Sulfate	89%	4690	86%	4555	0	135	4.5
Soda Ash	45%	6222	43%	5955	0	267	8.9

	Beginning Inventory	End Inventory	Gallons Delivered	Gallons Used	Average Daily Usage
Chemical Tote Levels	Gallons	Gallons			Gallons
Anti-scalant	236	217	0	19	0.6
Calcium Chloride	69	229	236	77	2.6
Ferric Chloride	272	85	67	253	8.4
Biocide	213	213	95	96	3.2









Comments:

- Chemical usage is stable.