Item No. 6

CITY OF RIVIERA BEACH DISTRICT BOARD
AGENDA ITEM SUMMARY

MEETING DATE: September 21, 2011

AGENDA ITEM SUMMARY NO. J11-092-6

[ ] AWARDS / PRESENTATIONS / PETITIONS
[ ] CONSENT
[ ] PUBLIC HEARING
[ ] ORDINANCE ON SECOND READING
[ ] ORDINANCE ON FIRST HEARING

[X] REGULAR
[X] RESOLUTIONS
[X] DISCUSSION & DELIBERATION
[ ] BOARD APPOINTMENT
[ ] WORKSHOP

TITLE / SUBJECT: Approval of Sodium Hypochlorite (bleach) as the Water Disinfectant for the Utility District Water Treatment Plant.

MOTION: Approve Sodium Hypochlorite (bleach) as Water Disinfectant for the Utility District Water Treatment Plant.

DEPARTMENTAL APPROVAL REVIEW & DATE

♦City Manager	Library
♦District Attorney PHR 9/16/11	Marina
♦District Clerk	Police
Community Development	Public Works
♦Interim District Finance Director	♦Purchasing
Fire	Recreation & Parks
Human Resources	♦Utility Special District
Information Systems	Other

APPROVED BY EXECUTIVE DIRECTOR: DATE: SEP 06 2011

Originator:
UTILITY SPECIAL DISTRICT

User:
UTILITY SPECIAL DISTRICT

Advertised:
Date:
Paper:
[X] Not Required

Affected Parties
[ ]Notified [X]Not Required

Costs: $ None at this time

Current FY: 2011-2012

Funding Source:

[X] Capital Improvement
[ ] Operating
[ ] Other

Budget Account Number:

District Board Actions:
[ ] Approved
[ ] Approved w/conditions
[ ] Denied
[ ] Tabled to
[ ] Referred to Staff

Attachments:
1. Resolution
2. WTP Disinfection Alternatives Evaluation Report by Chen & Assoc. & C-Solutions, Inc., dated 09/3/2010
3. Copy of Powerpoint presentation

BACKGROUND/SUMMARY: A motion was made at the August 17, 2011 Utility Special District Meeting to: "bring back a sodium hypochlorite as the water disinfectant and proceed with a pilot study".

The City of Riviera Beach Utility District was created in June 2004. An Engineer's Report was prepared in September 2004 by R.C.T. Engineering, Inc. in association with Kimley-Horn and Associates, Inc. This report outlined a number of future capital improvements (including a Chlorine System Enclosure and Gas Scrubber).

At the Utility District Board Meeting of September 15, 2010, the Board received a presentation from Chen & Associates entitled "Water Treatment Plant Disinfection Alternatives Evaluation". This presentation discussed the advantages, disadvantages and estimated costs of improvements to water disinfection using chlorine gas or a sodium hypochlorite solution. Utility District Staff selected "the upgrade of the existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber".

Upon review of the previous information, subsequent analyses and discussion of the disinfection process with Utility District Water Treatment Plant Operators, it is my professional opinion that the City of Riviera Beach Utility District maintains chlorine gas as the Water Treatment Plant disinfectant, and further, plan and design a "state of the art" disinfection facility to contain a new chlorine gas system and a neutralizing chlorine scrubber. However, the agenda item presented at the August 17, 2011 Utility Special District Meeting died for lack of second to the motion to approve.

Subsequently, a motion was made at the August 17, 2011 Utility Special District Meeting to: "bring back sodium hypochlorite as the water disinfectant and proceed with a pilot study". The motion was seconded and unanimously approved by the District Board. The Utility District staff has brought back this agenda item as requested by the District Board and will discuss this item with the District Board. The District Board will render a final decision on the Water Treatment Plant disinfectant and the Utility District Staff will immediately proceed with implementation of the final decision.

II. FISCAL IMPACT ANALYSIS

A. Five Year Summary of Fiscal Impact:

Fiscal Years	2011	2012	2013	2014	2015
Capital Expenditures	$ NONE	0	0	0	0
Operating Costs	0	0	0	0	
External Revenues	0	0	0	0	0
Program Income (City)	0	0	0	0	0
In-Kind Match (City)	0	0	0	0	0
NET FISCAL IMPACT	$ 0	0	0	0	0
NO. ADDITIONAL FTE POSITIONS (Cumulative)	0				

Is Item Included In Current Budget? Yes X No______

Budget Account No.: Fund ___ Dept/Division ____ Org. ____ Object ______

Reporting Category:

B. Recommended Sources of Funds/Summary of Fiscal Impact:

FY 2011-2012 BUDGET

C. District Fiscal Review: ________________________
Mr. Louis C. Aurigemma, P.E., Executive Director

III. REVIEW COMMENTS

A. Finance Department and/or Purchasing/Intergovernmental Relations/Grant Comments:

Finance Department

Purchasing and Grants

B. Other Department Review:

RESOLUTION NO. ___________

A RESOLUTION OF THE BOARD OF DIRECTORS OF THE CITY OF RIVIERA BEACH UTILITY SPECIAL DISTRICT, PALM BEACH COUNTY, FLORIDA, APPROVING SODIUM HYPOCHORITE (BLEACH) AS THE WATER DISINFECTANT FOR THE UTILITY DISTRICT WATER TREATMENT PLANT; AND PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, an Engineer's Report was prepared in 2004 by R.C.T. Engineering, Inc. This report outlined a number of future capital improvements (including a Chlorine System Enclosure and Gas Scrubber); and

WHEREAS, the Utility Special District Board of Directors received a presentation from Chen & Associate entitled "Water Treatment Plant Disinfection Alternatives Evaluation" on September 15, 2010; and

WHEREAS, presentations discussed the advantages, disadvantages and estimated costs of improvements to water disinfection using chlorine gas or a sodium hypochlorite solution. The Utility Special District Staff selected "the upgrade of the existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber," in conjunction with the recommendation from Chen & Associates Consulting Engineering Firm.

NOW, THEREFORE, BE IT RESOLVED BY THE BOARD OF DIRECTORS OF THE CITY OF RIVIERA BEACH UTILITY SPECIAL DISTRICT, PALM BEACH COUNTY, FLORIDA, AS FOLLOWS:

SECTION 1: That the Utility Special District Board of Directors hereby authorizes the utilization of Sodium Hypochlorite (bleach) as the Water Disinfectant for the Utility District Water Treatment Plant.

SECTION 2: This Resolution shall take effect upon its passage and approval by the District Board.

PASSED AND APPROVED this 21th day of September, 2011.

RESOLUTION NO. ___________
PAGE 2

UTILITY SPECIAL DISTRICT

APPROVED:

____
JUDY L. DAVIS
CHAIRPERSON

ATTEST:

____
CARRIE E. WARD
MASTER MUNICIPAL CLERK
UTILITY SPECIAL DISTRICT CLERK

____
BILLIE E. BROOKS
VICE CHAIRPERSON

____
CEDRICK A. THOMAS
BOARD MEMBER

____
DAWN S. PARDO
BOARD MEMBER

____
SHELBY L. LOWE
BOARD MEMBER

MOTIONED BY: _______________

SECONDED BY: _______________

J. DAVIS _______

B. BROOKS _______

C. THOMAS _______

D. PARDO _______

S. LOWE _______

REVIEWED AS TO LEGAL SUFFICIENCY

____
PAMALA HANNA RYAN, CITY ATTORNEY

DATE: _______________

City of Riviera Beach

Water Treatment Plant Disinfection Alternatives Evaluation

September 6, 2010

CHEN & ASSOCIATES
Civil and Environmental Engineers

C Solutions Inc.

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Section 5 Selected Disinfection Alternative

Appendices

Section 1
Introduction

1.1 Background

The City of Riviera Beach (City) owns and operates a lime softening water treatment plant (WTP) with a permitted capacity of 14.5 MGD. The City's WTP is located adjacent to Blue Heron Boulevard in the City of Riviera Beach as shown in Figure 1-1.

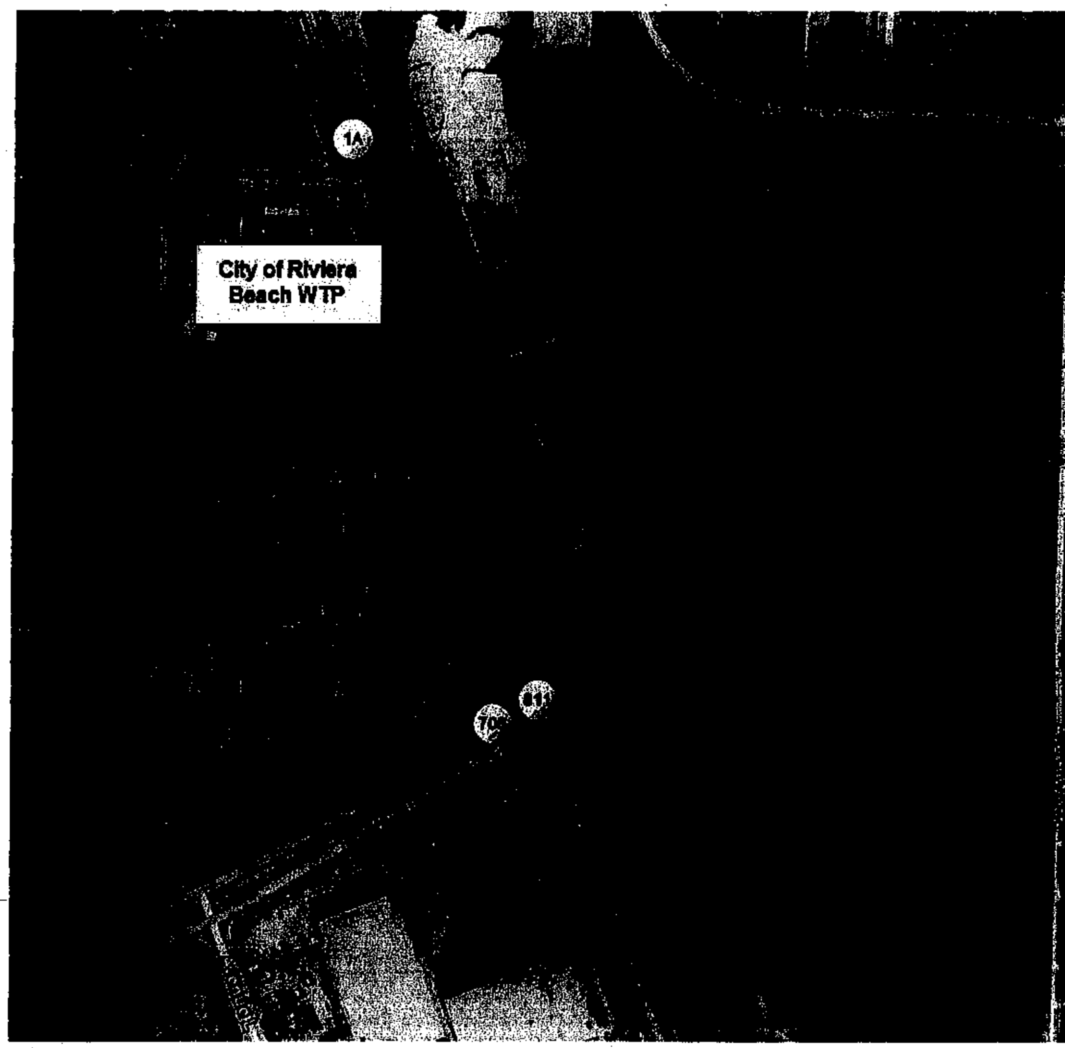


Figure 1-1 Water Treatment Plant (WTP) Location

The City has decided to consider alternative disinfection systems compared with an updated replacement of the gaseous chlorination system in order to reduce the hazards associated with storage and handling of chlorine gas. The City has requested an evaluation of the following four alternatives to the current gas chlorination system:

1. Bulk delivered sodium hypochlorite (12.5%) feed system

2. 0.8% sodium hypochlorite on-site generation (OSG) feed system using the ClorTec system by Severn Trent Services

3. 12.5% sodium hypochlorite OSG feed system using the Klorigen system by Electrolytic Technologies Corporation

4. Upgrade of existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber

Section 2
Existing System

The City's existing WTP is a traditional lime softening facility, consisting of softening, filtration and disinfection.

2.1 Existing WTP Description

The WTP has a permitted capacity of 14.5 MGD. Based on recent monthly operating reports (MORs), average day flow is approximately 8 MGD and maximum daily flow is 12 MGD. The WTP consists of four (4) packed towers, three (3) lime softening clarifiers (Accelators), sixteen (16) filters divided into two filter banks, two (2) interconnected clear wells, two (2) vertical turbine backwash/transfer pumps, and seven (7) vertical turbine high service pumps.

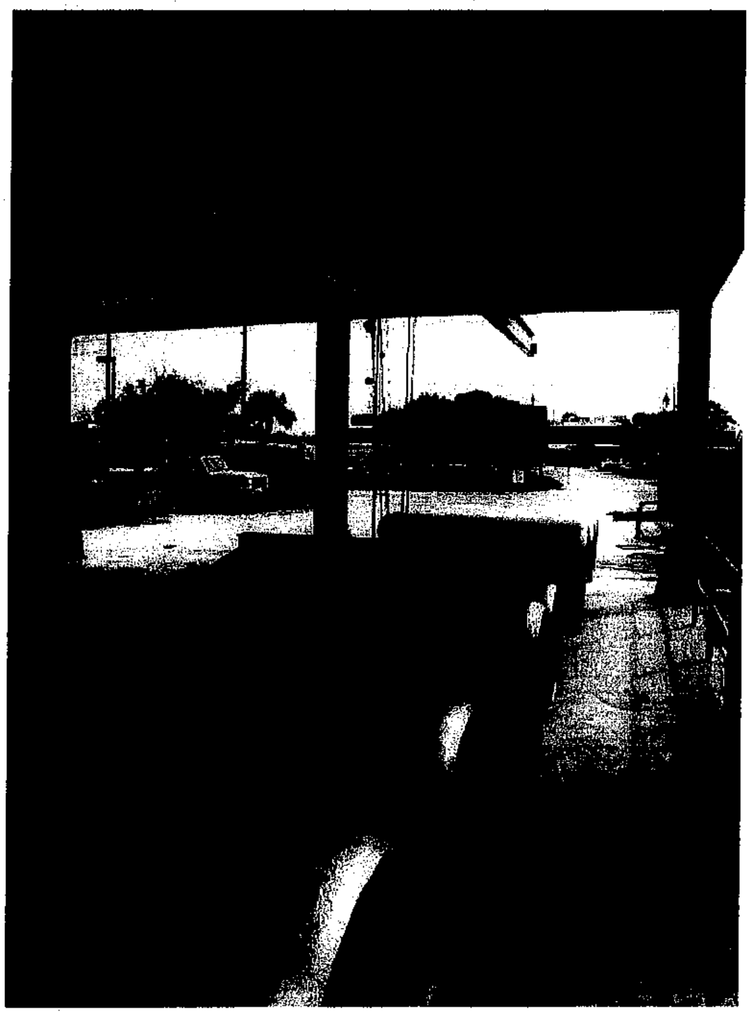
Raw water is pumped from the Biscayne Aquifer via twenty-seven (27) raw water wells into the packed tower scrubbers, which are used primarily for the removal of possible VOCs. Six vertical turbine pumps then transfer water into one of two (2) tray aeration basins[1] where alum is introduced to assist in coagulation. Ammonia and chlorine are injected into the influent line to the aeration basins. Water then flows by gravity into the clarifiers where chlorine and lime are introduced. Water then flows by gravity into the filters. After filtration, the water flows into interconnected clearwells located beneath each filter bank (south and north) where there is an additional chlorine application point. Finished water is then pumped from the clearwell to the distribution system and three (3) remote ground storage tanks[2] via the vertical turbine high service pumps.

Water from the clearwell is also used for backwash or transferred to a 1 MG ground storage tank located adjacent to the WTP via two backwash/transfer vertical turbine pumps[2]. Filter backwash water and overflow from the softeners is transferred to the Save All Basins[3] for decanting and settling. Settled solids from the sludge blowdown of the clarifiers are pumped from the sludge blowdown pits to the Save All Basins where lime sludge has historically been removed for sale to area contractors.

[1] The aerator trays were removed after the installation of the packed tower scrubbers but the influent pipes and basin still exist. The South aeration basin feeds two clarifiers and the north aeration basin feeds the northern-most clarifier.
[2] This ground storage tank is used for additional storage for the high service pumps and interconnected to the clear well. Water is thus pumped out of this tank by the high service pumps drawing water from the clear well.
[3] The Save All Basins are large ponds that are on the adjacent property north of the WTP. These ponds are primarily used as lime sludge settling and drying basins.

2.2 Existing Gas Chlorination System

Water is currently disinfected using chloramines. Free chlorine is provided by a gaseous chlorination system and mixed with free ammonia provided from an anhydrous ammonia system at the influent line to the aeration basins.

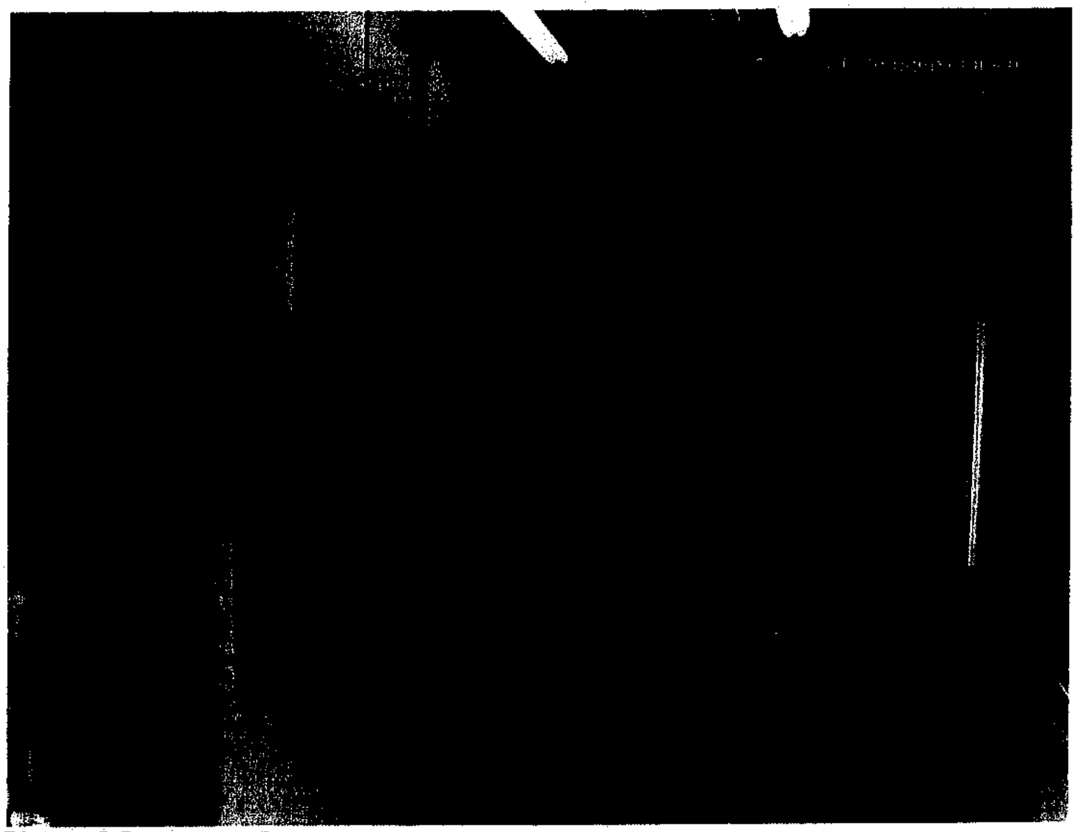


Picture 2-1 Chlorine Storage Area

The existing gas chlorination system is a traditional "open to the atmosphere" type of configuration. The system consists of one-ton chlorine cylinders, weigh scales, cylinder-mounted vacuum regulators, automatic switchover, gas detectors[4], free standing Wallace and Tiernan chlorinators, and chemical injectors. Chlorine gas cylinders are delivered by truck and unloaded into the storage area by a monorail hoist crane as shown in Picture 2-1. Cylinders are then moved onto scales and the vacuum regulators attached for use. Out of the four chlorine cylinders ready for use at any one time, only two chlorine cylinders are actually utilized at once. Gas flows under vacuum to one of three chlorinators, with the fourth chlorinator used as backup. From the chlorinators, gas is pulled by vacuum into three injectors creating a chlorine solution. The chlorine solution then flows into an application point manifold where each injector's solution is divided into one of seven application points (currently only six are in use). The chlorinators, injectors, and chlorine solution application point

[4] Two gas detectors are located in the chlorine cylinder storage bay while one gas detector is located in the chlorinator room.

manifold are located in the Chlorinator room on the second floor of the North Chemical Building as shown in Picture 2-2.



Picture 2-2 Chlorinator Room

The following application points are currently installed:

Pre Chlorination

- Influent line to South Aerator basin
- Influent line to North Aerator basin
- Each of the Accelators (3 in total)

Post Chlorination

- Clearwell (North)
- Clearwell (South) (this application point is unused, since clearwells are interconnected)

2.3 Existing Electrical System

The existing electrical services at the water treatment plant (WTP) have limited connectivity and are very old. Only small loads may be added to these systems. Large load additions, like onsite chlorine generation systems, will require a new power service. The existing WTP electrical services are from a single Florida Power and Light (FPL) vault. The WTP has two backup generators and two electrical rooms. The main backup generator (Generator No. 1) is 1000kW and is located in the South Chemical building. The second backup generator (Generator No. 2) is 250kW and is located in Electrical Room No. 2. The main electrical room (Electrical Room No. 1) is located adjacent to the filters and houses three automatic transfer switches, three electrical services and motor control centers (MCCs). Electrical Room No. 1 receives backup power from Generator No. 1. The second electrical room (Electrical Room No. 2) has a separate service from the single FPL vault and is located adjacent to the VOC air stripper towers. Electrical Room No. 2 is dedicated for service to the VOC air stripper towers and houses one automatic transfer switch, one electrical service, MCCs, and various electrical equipment for the air strippers. Electrical Room No. 2 receives backup power from Generator No. 2. The second floor of the North Chemical Building contains a MCC that is provided with power service from Electrical Room No. 1. This is a prospective source that will be used to supply power for small loads of approximately less than 50kW. Regardless of the alternative selected, this MCC should be the source of power to critical equipment (i.e. chemical metering pumps or chlorinators) since it has backup power supplied by Generator No. 1.

Section 3
Disinfection Alternatives

The water treatment plant (WTP) has a permitted capacity of 14.5 MGD. Historical data, provided by the City's monthly operating reports (MOR) for the past five years, shows the WTP operating at maximum day flows ranging between 6 and 10 mgd.

Essential information required to design a disinfection system is the proper determination of the WTP's design average and maximum day flows. Maximum day flow used for design is usually selected to be between the projected maximum day demand and the peak hour demand of a distribution system's service area (at the extremity with no storage). Typically, for an existing WTP, the design maximum day flow would be considered to correspond to the permitted capacity of the WTP, since remote storage accounts for peak hour demand fluctuations.

The City reports that sufficient finished water storage capacity exists to account for peak hour and fire flows in the distribution system. Currently, the City is in negotiations with the South Florida Water Management District (SFWMD) for renewal of their consumptive use permit. It appears that permitted withdrawals from the Biscayne aquifer may be reduced. Thus, it is likely that the current permitted capacity (maximum day) of 14.5 mgd will not be fully utilized.

Considering the current demands in the City, negotiations with SFWMD, and estimated growth projections, it was determined by the City that the design maximum day flow, for the purpose of this evaluation, shall be 11 MGD.[5] It is imperative that design flows and chlorination procedures be closely reviewed and the future WTP design flows established in the preliminary design report for any of the disinfection alternatives selected.[6] Table 3-1 provides suggested design parameters used for sizing chemical feed and storage facilities.

Design Parameter	Dosage Condition	Plant Flow Rate
Maximum Feeder Capacity	Peak Hour	Peak Hour
Minimum Feeder Capacity	Minimum Hour	Minimum Hour
On-site storage	Maximum Month	Maximum Month
Day tank volume	Maximum Day	Maximum Day

Table 3-1 Suggested Chemical Feed and Storage Design Parameters [7]

[5] In the determination of the design maximum day flow by the City, it was observed that no maximum day flow in the past five years has exceeded 10mgd. Additionally, recorded maximum day flows in 2010 have not exceeded 8mgd. This selection also allows chlorine consumption to be below 1,500 lbs/day which gives more reasonable future cost comparison of the alternatives in this evaluation.
[6] FAC 62-555.320 (6) states that "The Department shall not specify a permitted plant operating capacity greater than the design capacity of the plant's treatment facilities as established by the applicant."
[7] Water Treatment Plant Design Fourth Edition Table 15.1

Average daily flow used in this evaluation was derived using the percentage difference between historical maximum day and average day flows recorded in the MORs (approximately 20%). Table 3-2 summarizes the design flows and chlorine consumption used in the preliminary sizing of each alternative. Historical MOR data is presented in Appendix A.

Criteria	Design Value
Average Day Flow (mgd)	9
Maximum Day Flow (mgd)	11
Average Day Chlorine Use (lbs/day)	1,193
Maximum Day Chlorine Usage (lbs/day)	1,459

Table 3-2 Design Flows and Chlorine Use

In determining chlorine usage, a constant dosage condition of 14.9 mg/L (pre chlorination) and 1 mg/L (post chlorination) was used.

This report will evaluate four alternatives to the current gas chlorination system used for pre and post chlorination as stated below.

1. Bulk delivered sodium hypochlorite (12.5%) feed system
2. 0.8% sodium hypochlorite on-site generation (OSG) feed system using the ClorTec system by Severn Trent Services
3. 12.5% sodium hypochlorite OSG feed system using the Klorigen system by Electrolytic Technologies Corporation
4. Upgrade of existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber

These technologies provide either chlorine gas (Cl_2) or liquid sodium hypochlorite (NaOCl) for disinfection. This section provides a general overview of each chemical used for disinfection as well as the technologies listed above.

3.1 Disinfection Chemical Overview

Both chlorine gas (Cl_2) and sodium hypochlorite (NaOCl) produce the same disinfectant, hypochlorous acid (HOCl), when added to water as shown by the following two reactions:

$$Cl_2 + H_2O \leftrightarrow HOCl + HCl \qquad (3\text{-}1)$$

$$NaOCl + H_2O \leftrightarrow HOCl + NaOH \qquad (3\text{-}2)$$

Once added to the receiving water, the resulting disinfecting residuals (initially HOCl) are indistinguishable. The difference is that the use of sodium hypochlorite slightly increases pH (adds alkalinity) while chlorine gas decreases pH (consumes alkalinity). These differences are not significant but should be considered when using high chlorine dosages in poorly buffered waters. Once formed, HOCl instantaneously establishes equilibrium as shown in the following equation and governed by the pH of the receiving water:

$$HOCl \leftrightarrow H^+ + OCl^- \qquad (3\text{-}3)$$

As the pH of the receiving water rises above 7.5, an increasing percentage of free chlorine is in the form of the hypochlorite ion (OCl^-). At pH below 7.5, a greater percentage of free chlorine is in the form of HOCl. The combined concentration of HOCl and OCl^- is known as free chlorine residual. These two molecules react very differently. HOCl is a much stronger and effective disinfectant, stronger oxidant, and more reactive than OCl^-. HOCl will disinfect one hundred times faster than OCl^-, but be consumed much faster. In effect, the free chlorine residual re-equilibrates based on the pH of the receiving water; OCl^- acts as a disinfectant buffer adding HOCl as it is being consumed. Thus the pH of the receiving water plays a large role in the effectiveness of disinfection.

3.1.1 Gaseous Chlorine

In the gaseous state, chlorine is greenish-yellow in color and has a pungent odor. Chorine only exists as a two-atom molecule (Cl_2). It is neither explosive nor flammable, although, as a strong oxidant, it supports combustion and reacts violently with many substances. As such, it should be handled and stored away from other compressed gases and flammable materials. Pure chlorine does not exist naturally because of its reactivity and is commercially produced by the electrolysis of sodium chloride brine as shown in the following reaction:

$$2NaCl + 2H_2O + \text{electric current} \rightarrow 2NaOH + Cl_2 + H_2 \qquad (3\text{-}4)$$

Chlorine is stored and shipped as a liquefied gas under pressure. The compressed liquid is amber in color and approximately 1.5 times heavier than water. If liquid chlorine is unconfined, it rapidly vaporizes to gas. Because chlorine in a container may exist in gas, liquid, or both forms, any consideration of liquid chlorine considers that of gas. Chlorine gas is approximately 2.5 times as heavy as air; therefore, released gas will initially settle to the lowest point in the container until mixed with the surrounding air. When mixed with water, chlorine will hydrolyze to form a corrosive mixture of acids and strong oxidants as shown in the following reaction:

$$Cl_2 + H_2O \leftrightarrow HOCl + HCl \quad (3\text{-}5)$$

The addition of chlorine gas to water slightly decreases the pH, forming hydrochloric acid (HCl).

3.1.2 Sodium Hypochlorite

Sodium hypochlorite (liquid bleach) is formed by combining a chlorine solution and sodium hydroxide as shown in the following reaction:

$$Cl_2 + NaOH \rightarrow NaOCl + NaCl + heat \quad (3\text{-}6)$$

The addition of sodium hypochlorite to water slightly increases the pH by the formation of sodium hydroxide (NaOH) as shown in the following equation.

$$NaOCl + H_2O \rightarrow HOCl + NaOH \quad (3\text{-}7)$$

In the commercial trade, the concentration of sodium hypochlorite solution is usually expressed as a percentage (trade percentage) that is a measure of weight per unit volume. Sodium hypochlorite for municipal use is usually delivered at a concentration between 12 and 17 percent. In South Florida, the typical delivered trade percentage for sodium hypochlorite is 12.5%. Unlike elemental chlorine, sodium hypochlorite is subject to decomposition (degradation) during storage. The rate of degradation is increased by the following:

- high hypochlorite concentrations
- high temperature
- the presence of light (UV radiation)
- low pH
- presence of metallic impurities such as iron, copper, nickel, and cobalt

Sodium hypochlorite continually degrades to salt and oxygen as shown by the following reaction:

$$2NaOCl \rightarrow 2NaCl + O_2 \quad (3\text{-}8)$$

Because of the generation of diatomic oxygen (O_2), sodium hypochlorite continually effervesces. This off-gassing generates concerns that must be addressed during design of any system using sodium hypochlorite.

3.2 Alternative 1 - Bulk Sodium Hypochlorite System

3.2.1 Process Description

Bulk delivered sodium hypochlorite disinfection systems generally include bulk storage tanks, day tanks and a chemical feed system as shown in Figure 3-1. Sodium hypochlorite (generally 12.5% concentration) is delivered by tanker truck to the bulk storage tanks which are typically located outside. In most systems, transfer pumps then convey the NaOCl to day tanks.

NaOCl can be delivered to the application point by means of gravity or educators. However, chemical metering pumps with mechanically actuated diaphragms are typically used for new installations.

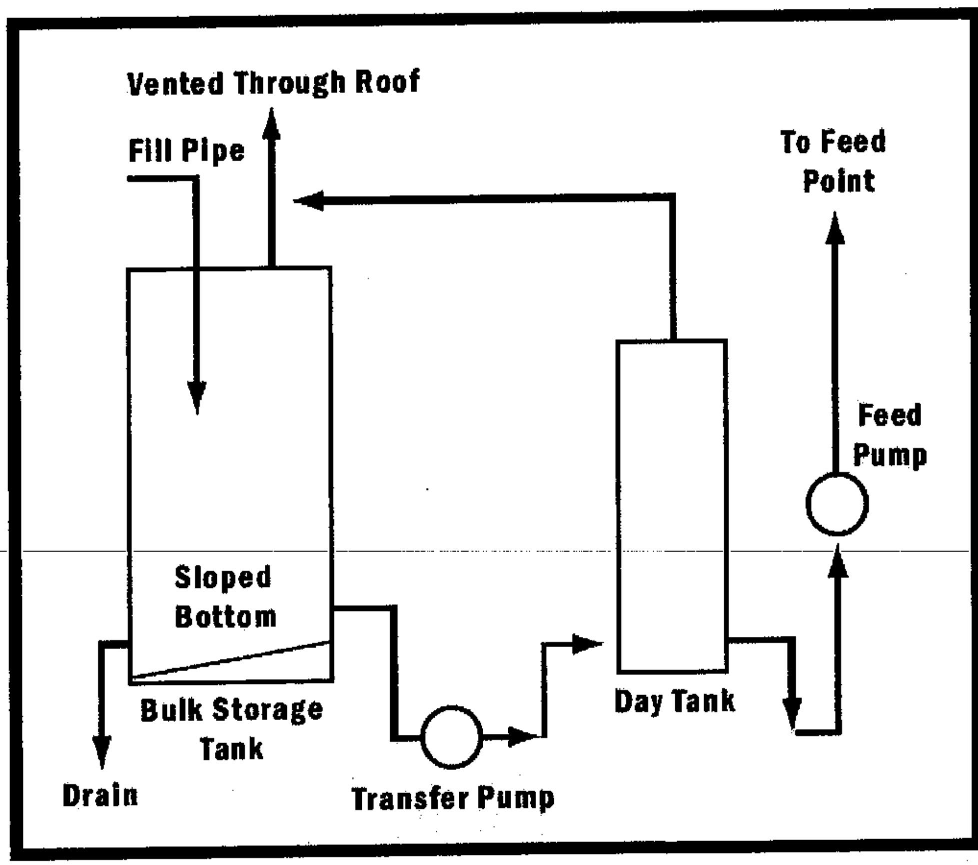


Figure 3-1 Sodium Hypochlorite Process Diagram

3.2.2 Conceptual Design Criteria

Some key design factors that need to be taken into consideration in the design of a bulk delivered system are:

- Sodium hypochlorite degradation
- Off gassing of sodium hypochlorite
- Storage, piping and valve material selection

Aside from chemical material compatibility, most design concerns relate to the degradation of sodium hypochlorite (available concentrations and off gassing). Establishing minimum specifications for the delivered sodium hypochlorite can greatly help to minimize degradation. A minimum specification should establish the following:

- A pH between 12 – 13
- Heavy metal contaminate concentrations (Ni^2 and Cu^2) < 0.1 mg/L
- A maximum chlorate concentration
- A maximum solution temperature (< 77°F (25°C))
- A delivered concentration between 12.5% and 14%

Since the bulk storage tanks will be located outdoors, they should be coated or be constructed with a type of UV resistant resin and painted a light color to help reflect heat. Consideration should also be given to providing covering for tanks to further reduce heat buildup. Multiple tanks are provided to accommodate a situation where one tank needs to be taken out of service. The tanks can be made of linear high-density polyethylene (HDLPE), high density cross-linked polyethylene (HDXLPE) or fiberglass reinforced plastic (FRP), and will be designed to sit within an appropriately sized spill containment area (110% of the largest tank volume). A properly specified and constructed FRP tank will provide the potential for the greatest lifespan.

It should be noted that when sodium hypochlorite degrades, it creates gas bubbles. Since the chemical is viscous and the bubbles are small, they tend to remain in suspension. The bubbles then often get trapped in piping, valve cavities, and pumps causing possible pipe or valve failure, inconsistent feed, and in some cases a "vapor lock" of diaphragm pumps.

To help alleviate the potential for a vapor lock condition when feeding 12.5% sodium hypochlorite, anti-gas/vapor lock pump protection should be installed, the suction lines should be kept short, and the pump should be located below the day tank. Valve selection, valve location, and chemical piping layout to the injection points to minimize possibilities of entrapped gas also need to be considered during design.

The preliminary chemical storage calculations for this alternative are presented below:

Alternative 1 - Bulk Sodium Hypochlorite System Requirements	
Bulk Storage	
Average Day Chlorine Usage (lbs/day)	1,193
Receiving Bulk Concentration (%)	12.5
Bulk Hypochlorite Solution Consumed (gpd) [(a)]	1,300
Required Storage Time (days)	14
Volume Required for Bulk Storage (gal)[(b)]	20,023
Selected Receiving Tank Size (gal)	10,147
Receiving Tank Quantity	2
Receiving Tank Dimensions	12'Wx12'H
Day Tank	
Maximum Day Chlorine Usage (lbs/day)	1,459
Receiving Bulk Concentration (%)	10-12.5
Max Daily Hypochlorite Solution Consumed (gpd)[(b)]	1,748
Selected Day Tank Size (gal)	1,700
Day Tank Quantity	1
Day Tank Dimensions	6'Ø x9'H

(a) Accounts for decay to 11% strength
(b) Accounts for decay to 10% strength

In addition to the storage requirements detailed above, the system will also include the following components:

- two (2) chemical transfer pumps
- nine (9) positive displacement metering pumps
- associated piping and controls

A preliminary layout of the system is provided in Figure 3-2.

3.2.3 Electrical Modifications

The bulk sodium hypochlorite alternative does not have a large additional electrical demand. Power will be supplied from an existing motor control center (MCC) located on the second floor of the North Chemical Building. This power feeder will be extended from the MCC to the new power distribution panel located in a new electrical / control room. The new electrical room will require the following electrical components to accommodate this alternative:

- Programmable logic controller (PLC)
- 480 volt power distribution panelboard

- step down transformer
- 120 volt panelboard
- Power and control conduit and wire

3.2.4 Operation and Maintenance

The operation and maintenance for a sodium hypochlorite disinfection system generally entails the chemical feed system. Sodium hypochlorite can build up deposits on valves, chemical injectors and pump diaphragms that require cleaning (typically water washing or acid cleaning) or replacement. Pump re-calibration might also be required and can be performed quickly by an operator with a properly designed pump (a pump with a permanently installed calibration system).

The strength of the sodium hypochlorite should also be tested on a regular basis to monitor degradation which can lead to insufficient disinfection and the formation of by-products such as chlorate and oxygen gas.

The storage tanks typically last in the range of 10-15 years depending on the original tank construction and how well they are maintained.

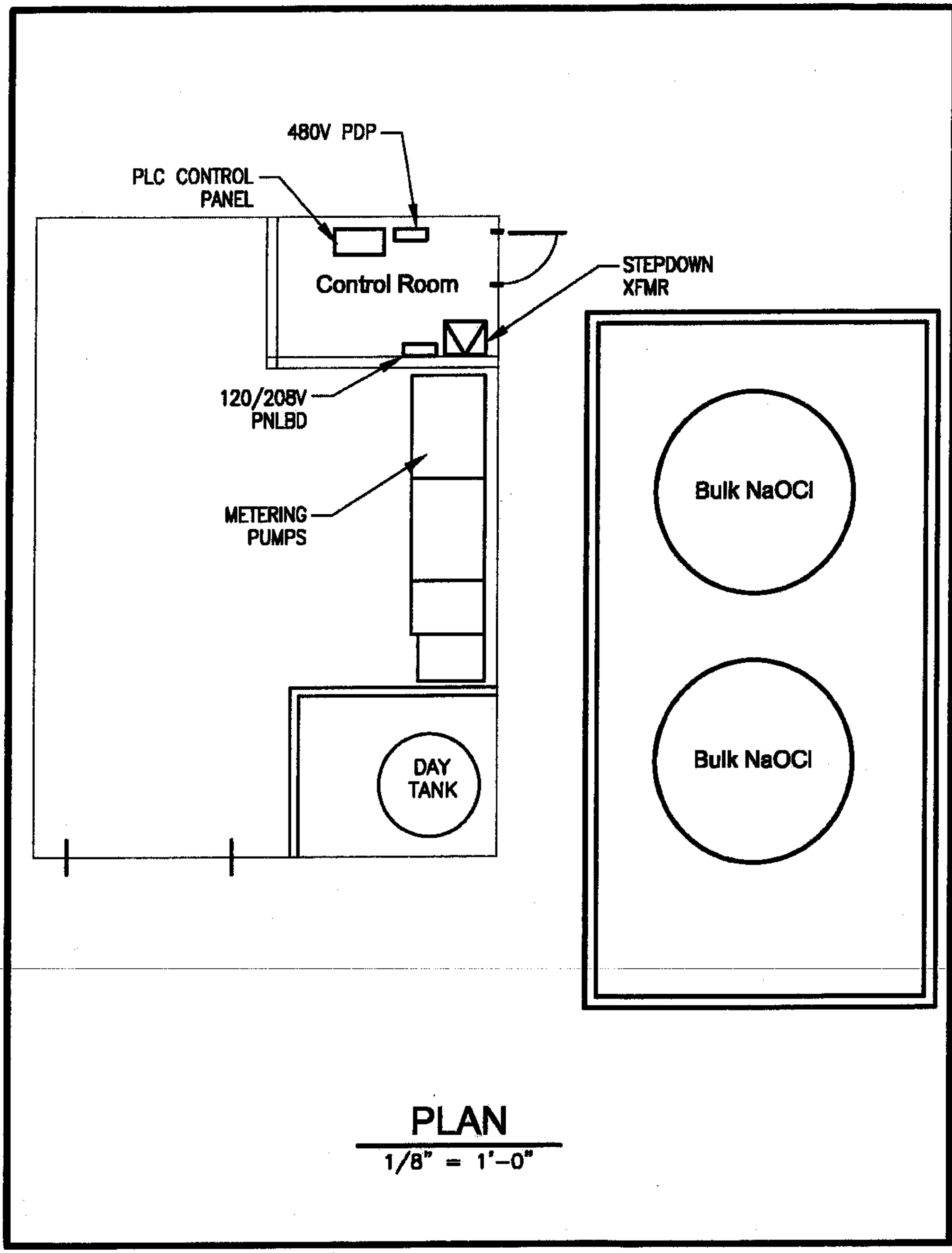


Figure No. 3-2
Alternative 1
Bulk Sodium Hypochlorite System Layout

3.3 Alternative 2 - ClorTec On-site Generation System

3.3.1 Process Description

The ClorTec System generates 0.8% sodium hypochlorite solution using salt, softened water and electricity as shown in Figure 3-3.

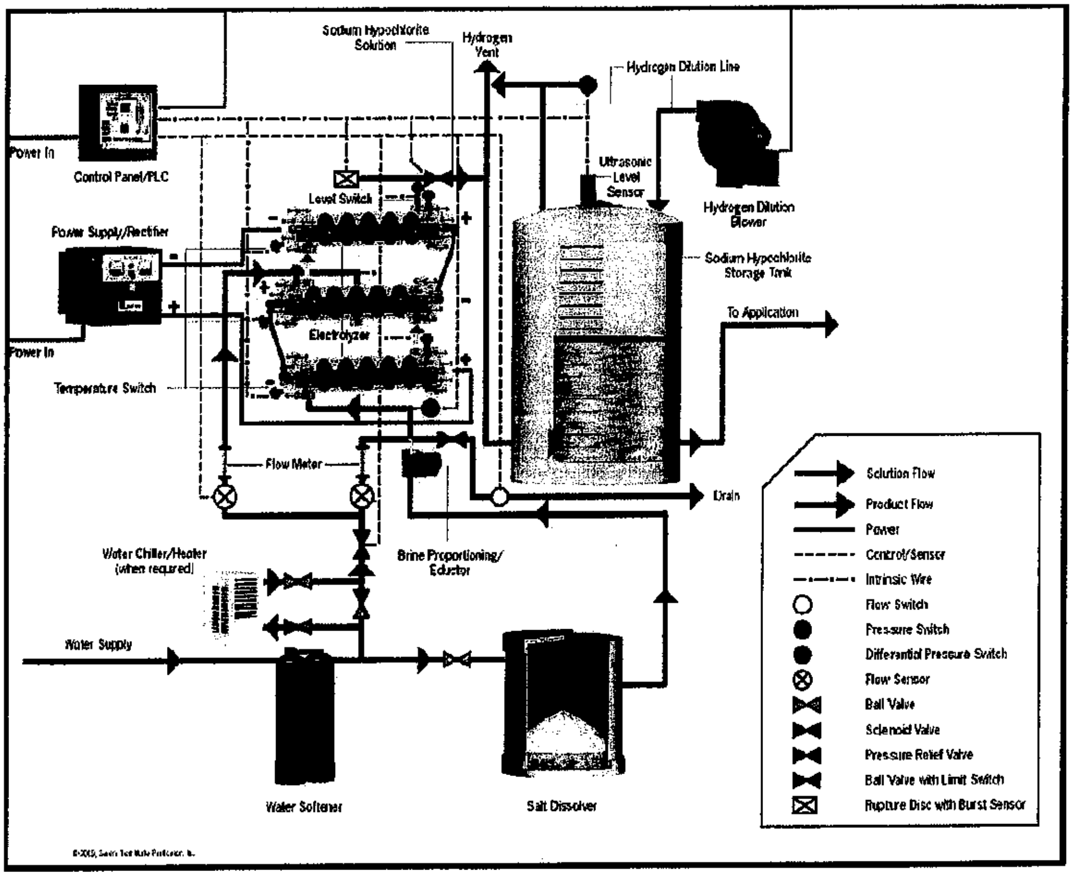


Figure 3-3 ClorTec On-site NaOCl Generation System Flow Diagram

The system requires a water softener, bulk storage tanks for the NaOCl solution, a brine saturator, an electrolytic cell, and an electric rectifier. In the standard process, 3.5 lb of salt, 2.3 KWh of electricity, and 15 gallons of softened water produce 1 lb of available chlorine in a 0.8% sodium hypochlorite solution.

The process works as follows:

1. Salt is dissolved in softened water to form a 30% concentrated brine solution.

2. The brine solution is reduced in concentration to 3% by a brine proportioning eductor for supply to the electroytic cell.

3. The 3% brine solution is pumped through an electrolytic cell and electrolyzed into a 0.8% sodium hypochlorite solution as shown in the following equation:

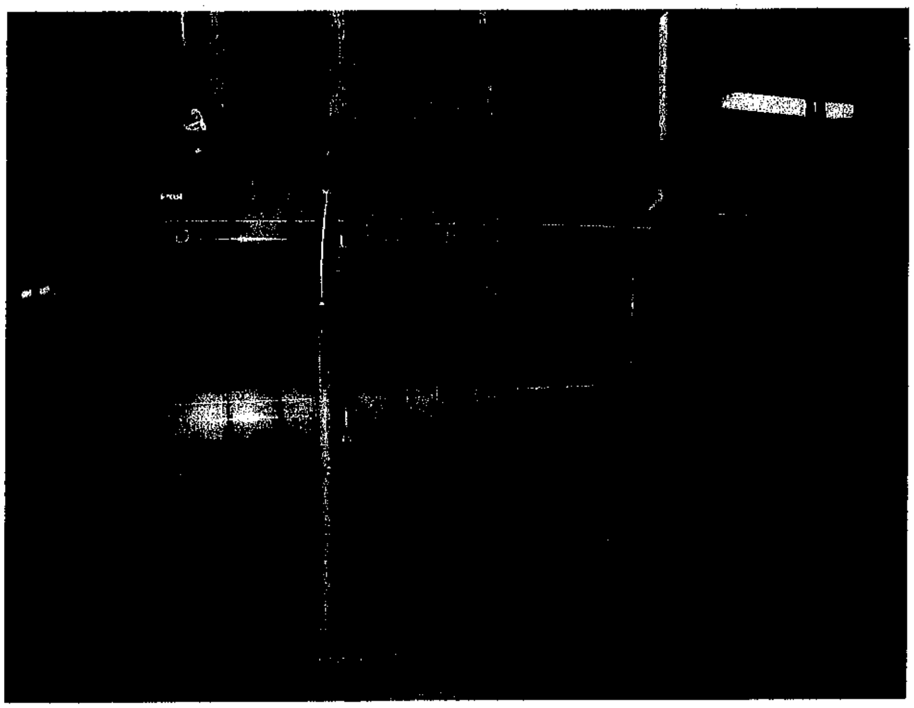
$$NaCl + H_2O + 2e \rightarrow NaOCl + H_2 \quad (3\text{-}9)$$

   Power is supplied by a rectifier that converts 3 phase AC power to DC and controls how much power is sent to the cells. This controls how much NaOCl is generated.

4. The 0.8% NaOCl solution flows into the storage tank.

5. Chemical metering pumps deliver the disinfectant (NaOCl) to the injection points.

The byproduct of this process is diatomic hydrogen (H_2) that must be properly disposed of. Hydrogen is extremely explosive, so vapor spaces must be purged with air to keep the concentration of hydrogen below the lower explosive limit (LEL). There have been a few instances of failures (explosions) of ClorTec on-site generation systems in South Florida. Much of the hydrogen is captured as it is produced, at the electrolyzer tube. It is piped out of the building separately from solution to a vent stack where blowers force the hydrogen to vent to atmosphere. Some hydrogen remains in solution until it is delivered to the vent stack and vented off. If a valve or blockage occurs in the line, the gas will build up presenting a potential failure of the generation unit. ClorTec has improved safety features of their units in recent years, as with the example of providing separate piping to vent the hydrogen gas separately. In addition to new piping configurations allowing the removal of hydrogen gas from solution earlier on in the process, the units now also include better designed end-caps (reducing stress on the acrylic cell), better instrumentation and lock-outs which prevent system start-up should a valve be in the incorrect position, and blow off valves which trigger an alarm and shut down the system, but allow the gas to escape the unit. In addition, protective shields can be built around the unit as an added safety measure.



Picture 3-1 ClorTec Generation Skid

3.3.2 Conceptual Design Criteria

Some key design factors that need to be taken into consideration in the design of a ClorTec sodium hypochlorite generation system are:

- Use of high purity salt that contains low levels of impurities in the production of concentrated brine is not required but will reduce fouling of the electrolyzers
- Use of softened water (< 2 mg/L as $CaCO_3$) to remove hardness contained in potable water for production of concentrated brine
- Placement of rectifiers in well ventilated areas
- Provision of sufficient storage with 0.8% NaOCl solution
- Dilution of hydrogen gas with air to prevent concentrations that exceed the low explosion limit (LEL)

Many of the same design considerations discussed for bulk sodium hypochlorite delivery are applicable for the ClorTec on-site generation system as far as the requirements of the bulk storage tanks (materials, spill containment, etc.). However, the sodium hypochlorite generated from this process is at a concentration significantly less than the bulk delivery concentration (0.8% versus 12.5%). Therefore, the volume of 0.8% sodium hypochlorite solution storage will be approximately 15 times greater than storage for 12.5% sodium hypochlorite but, practically, will not be susceptible to degradation.

Storage for 0.8% generated sodium hypochlorite is typically sized for only 2-3 days. The Palm Beach County Environmental Control Rule II calls for seven days of sodium hypochlorite solution on reserve. The ClorTec system provides for the ability to utilize one of the two bulk storage tanks to receive sodium hypochlorite bulk delivery during emergency situations. The Palm Beach County Health Department has issued permits to other utilities based on the ability to secure bulk delivered sodium hypochlorite fairly quickly in these situations.

Positive displacement diaphragm pumps cannot handle the larger flows required for a 0.8% application. Instead, peristaltic (hose) pumps or rotary lobe pumps will be required; typically peristaltic (hose) pumps are used. Hose pumps will require hose replacement on a fairly regular basis. The potential for scaling in the chemical feed system will be greatly reduced since the concentrations of sodium hypochlorite are highly diluted. Additionally, off-gassing of the solution will not be prevalent since the degradation of 0.8% sodium hypochlorite is negligible.

Using the design information provided in Table 3-1, the ClorTec on-site generation system will include:

Alternative 2 – ClorTec On-site Generation System Requirements	
Chlorine Demand	
Maximum Day Usage (lb/d)	1,459
Average Day Usage (lb/d)	1,193
Raw Product	
Salt Usage (lb/d) [(a)]	3,580
Storage Days	30
Total Salt Storage Capacity (tons)	63
Briner Quantity and Capacity (ton)	80
Briner Dimensions	12'Ø x 22'H
Hypochlorite 0.8 % Solution Storage	
Solution Usage (gal/d)	21,851
Storage Days (Max Day)	2
Total Storage Capacity (gal of soln)	43,701
Tank Size (gal)	32,000
Number of Storage Tanks	2
Storage Tank Dimensions (Horizontal)	12'Øx36'L

Hypochlorite Generators	
Hypochlorite Generator Capacity (lbs/d)	1,500
Quantity	2
Power Usage (kwh/lb Cl_2)	2.0

(a) 3.0 lbs salt/lb Chlorine

In addition to the requirements listed above, the system will also include:

- three (3) water softening units
- four (4) air blowers
- seven (7) hose pumps
- two (2) positive displacement metering pumps
- one (1) bulk sodium hypochlorite dilution make-down panel
- associated piping and controls

A preliminary layout of the system is provided in Figure 3-4.

3.3.3 Electrical Modifications

The ClorTec on-site generation alternative has a large additional electrical demand. A new service from the FPL vault will be required. Power will also be supplied from an existing motor control center (MCC) located on the second floor of the North Chemical Building. This power feeder will be extended from the MCC to the new power distribution panel located in a new electrical / control room and service critical chemical feed equipment (i.e. chemical metering pumps). Although the new service could easily power the critical chemical equipment, a new backup generator is not envisioned in this evaluation. In emergency situations, the onsite generation equipment would not function and rely solely on the backup bulk sodium hypochlorite feed system. Thus, the existing generator (Generator No. 1) would need to supply backup power for the critical chemical feed equipment on a separate electrical service from that used to power the onsite generation equipment. The new electrical room will require the following electrical components to accommodate this alternative:

- Programmable logic controller (PLC)
- 480 volt power distribution panelboard
- Step down transformer
- 120 volt panelboard
- Power and control conduit and wire
- Power and control raceway to the various equipment

A new power service from the vault will be required. The size will be approximately 800 amp.

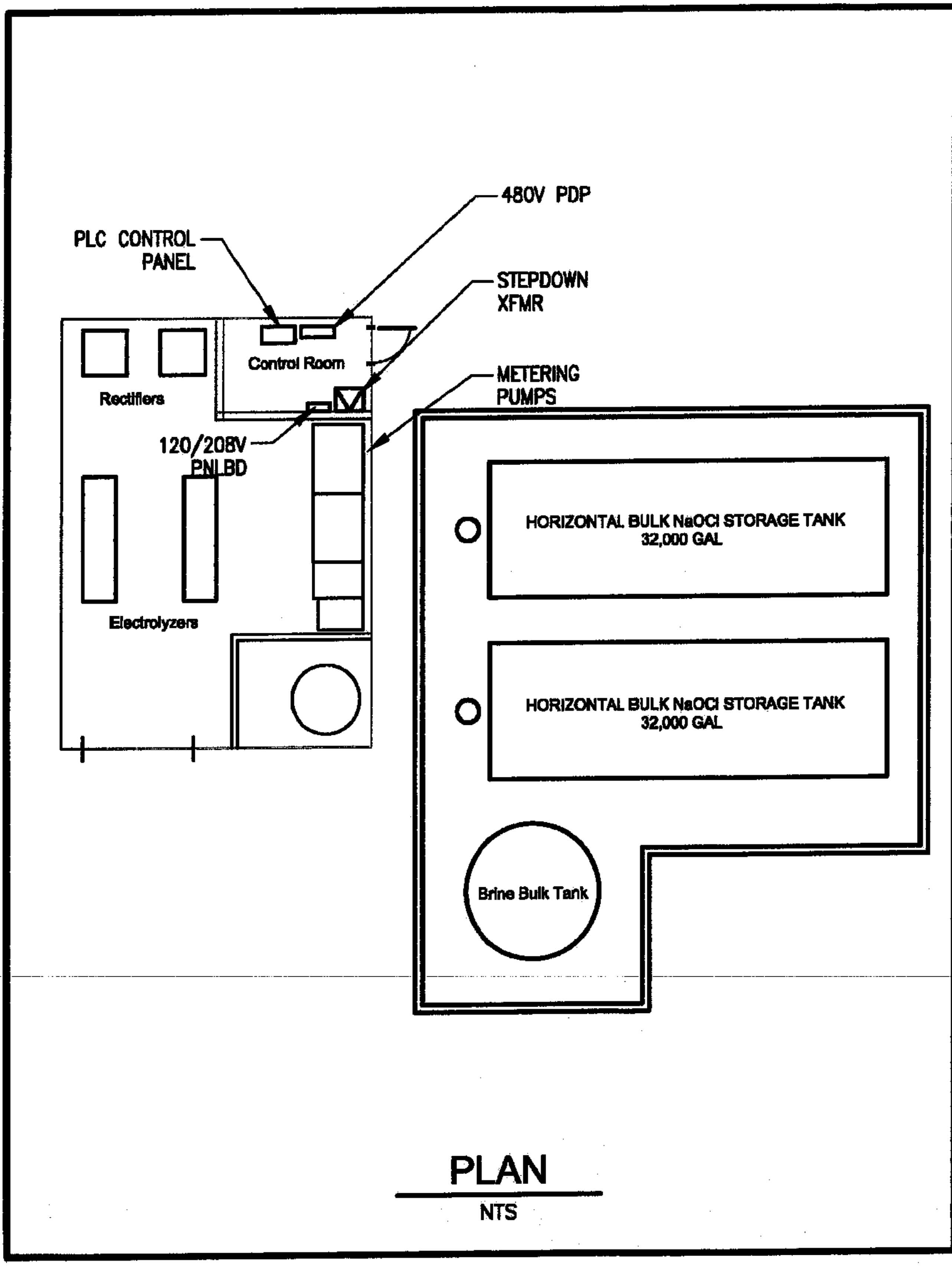


Figure No. 3-4
Alternative 2
ClorTec On-Site Generation System Layout

3.3.4 Operation and Maintenance

The typical maintenance concerns are associated with the potential for heavy metal precipitation on the electrolyzers and hose replacement on the chemical feed pumps. Typically, the electrolyzers require acid washing of the tubes on a monthly basis. A thorough cleaning, where the anodes and cathodes are pulled from the tubes and physically cleaned and inspected, is reportedly required on a yearly basis. To minimize calcium and magnesium precipitates within the electrolyzers, the salt and water should be as free of hardness as possible. The use of high purity salt will likely be economically unattractive as opposed to the increased maintenance issues caused by the presence of precipitates in salt. Supply water for preparation of the brine solution should be softened and should not exceed 2 mg/L as $CaCO_3$. The softeners are self regenerating and only require monitoring for the occasional replacement of salt. Also, the room where the hypochlorite generators are located will require a hydrogen monitoring system which will need to be calibrated on a regular basis.

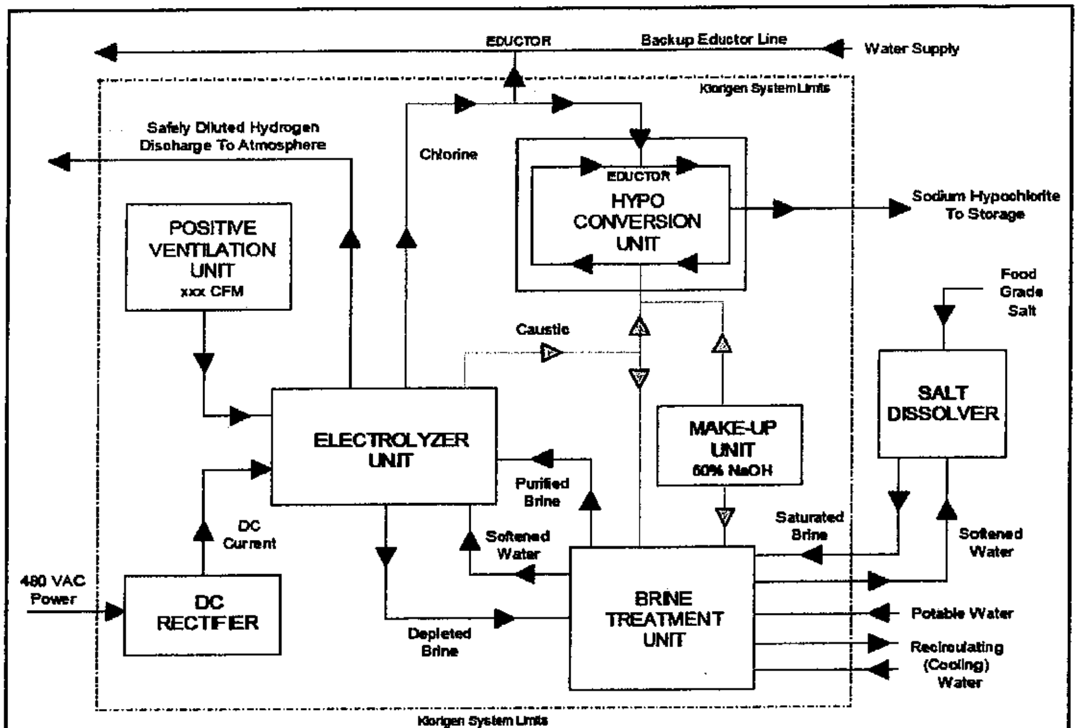
Hoses in the peristaltic chemical feed pumps will have to be replaced on a fairly regular basis (usually monthly). When replacement of a tube element is required, it is done where the pump sits, without the need for special tools. However, it is a messy job with internal liquids spilling on the floor.

South Florida municipalities have also reported greatly shortened life of the rectifiers if they are located in areas that are not well ventilated or isolated from particulate matter in the air. Those utilities are finding that rectifiers are in need of replacement every 2-4 years.

3.4 Alternative 3 - Klorigen On-site Generation System

3.4.1 Process Description

The Klorigen system resembles the process utilized by major bulk sodium hypochlorite manufacturers. The system generates 12.5% sodium hypochlorite solution using high purity salt, softened water, and electricity as shown in Figure 3-5. However, the use of other chemicals (caustic, sodium bisulfate, and hydrochloric acid) is also required in the treatment of saturated and depleted brine solutions. The system uses an ion-exchange membrane located between the electrodes that initially separate chlorine gas and sodium hydroxide (NaOH) which can be subsequently combined to produce a 12.5% sodium hypochlorite solution depending on the user's design requirements.



PROCESS FLOW DIAGRAM

Figure 3-5 Klorigen Process Flow Diagram

In the standard process, 1.65 lbs of high purity salt, 1.75 KWh of electricity, and 0.95 gallons of softened water produce 1 lb of chlorine in a gaseous form with 15% sodium hydroxide (NaOH). The chlorine gas can then be combined with the sodium hydroxide to form a 12.5% sodium hypochlorite solution (NaOCl). The process as shown in Figure 3-3 works as follows:

1. High purity salt is dissolved in softened water to form a concentrated brine solution.

2. Brine is softened in a brine treatment unit to remove impurities, namely alkaline earth metal ions, to a 20 ppb of Ca hardness equivalent or less.

3. The purified brine solution is pumped to a finished brine storage tank.

4. The purified brine solution is pumped from the storage tank through an electrolytic cell where DC power is provided to form sodium hydroxide (NaOH), chlorine gas (Cl_2), and Hydrogen gas (H_2). An ion-exchange membrane is located between the electrodes that separate the anode reaction (chlorine gas (Cl_2)) and the cathode reaction (sodium hydroxide (NaOH) and hydrogen (H_2)). A more detailed discussion of the electrolyzer module is provided below.

5. Depleted brine is dechlorinated in an air-stripping column, pH adjusted, treated with sodium bisulfate to remove residual chlorine, and returned to the salt dissolver for resaturation.

6. The hydrogen gas is diluted with air and vented to atmosphere.

7. The chlorine gas (Cl_2) and sodium hydroxide (NaOH) are combined in the *Hypo Conversion Unit* to form 12.5% sodium hypochlorite (NaOCl).

8. The 12.5% NaOCl solution is pumped into the storage tank.

9. Chemical metering pumps deliver the disinfectant (NaOCl) to the injection points

Each electrolyzer module has an anolyte and catholyte tank. The anolyte tank uses a titanium heat exchanger and cooling water to keep the circulated finished brine solution at the optimum temperature. Chlorine is educted under negative pressure from the anolyte tank. The catholyte tank collects 18% NaOH produced from the electrolyzers.

The following reactions occur on the anode side of the membrane:

(1) The major reaction is the two-electron transfer of the chloride ion shown in equation 3-10.

$$2Cl^- \rightarrow Cl_2(g) + 2e^- \qquad (3\text{-}10)$$

(2) The major competing anolyte reaction is the electrolysis of water, forming oxygen gas and hydrogen ions as shown in equation 3-11.

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \qquad (3\text{-}11)$$

(3) An inefficiency reaction caused by the back migration of NaOH through the membrane is the formation of chlorate ($NaClO_3$) as shown in equation 3-12 that must be purged from the brine loop. Optionally, it can be destroyed by reacting with a side stream of HCl, reducing the $NaClO_3$ back to Cl_2.

$$3Cl_2 + 6NaOH \leftrightarrow 2NaClO_3 + 5NaCl + 3H_2O \qquad (3\text{-}12)$$

(4) Finally, chlorine hydrolyzes to form hypochlorous acid (HOCl) and hydrochloric acid (HCl) as shown in equation 3-13. The solubility is dependent on the anolyte solution temperature that is controlled with a heat exchanger. The pH of the anolyte solution is between 3 and 5 that achieves an equilibrium between the HOCl and chlorine gas.

$$2Cl_2 + H_2O \leftrightarrow HOCl + HCl \qquad (3\text{-}13)$$

The following reaction occurs on the cathode side of the membrane:

(1) The reaction at the cell cathode is the reduction of water, producing hydrogen gas (H_2) and hydroxide ions (OH^-) as shown in equation 3-14

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \qquad (3\text{-}14)$$

(2) Sodium migrating across the ion exchange membrane then combines with the hydroxide (OH^-) ions to form sodium hydroxide (caustic) as shown in equation 3-15.

$$Na^+ + OH^- \rightarrow NaOH \qquad (3\text{-}15)$$

The diatomic hydrogen (H_2) gas produced in the cathode side of the membrane is separated from the sodium hydroxide in the caustic head tank and is diluted with air to below the lower explosive limit (LEL).

Hydrochloric acid (HCl) and sodium bisulfate are required in the dechlorination of the depleted brine from the anolyte tank of the electrolyzers. 32% HCl is used to adjust the pH of the depleted brine to about 2. The acidified solution is circulated with a pump in the packed air stripper tower while blowers circulate air to strip the chlorine. The air stream, containing chlorine gas, is passed to the hypochlorite tower where it reacts with NaOH to form 12.5% NaOCl. The stripped solution is pumped to the depleted brine storage tank, located on hypochlorite conversion module, where it is pH adjusted to about 10 with the used of NaOH (caustic). Sodium bisulfate is added to destroy any residual chlorine in solution before the depleted brine is recycled to the salt dissolver tank. A portion of the depleted brine is purged to waste to control the sodium chlorate ($NaClO_3$) to below 30 gm/L.

The end product, 12.5% NaOCl requires the same storage and chemical metering pumps as the bulk sodium hypochlorite delivery system.

3.4.2 Conceptual Design Criteria

Some key design factors that need to be taken into consideration in the design of a Klorigen sodium hypochlorite generation system are:

- Use of high purity salt that contains low levels of impurities in the production of concentrated brine is required unless the addition of a chemical precipitation treatment step is added

- Use of softened water (< 2 mg/L as $CaCO_3$) to remove hardness contained in potable water for production of concentrated brine is required
- Required treatment of concentrated brine to remove any impurities before transfer to the electrolyzer units
- Required dechlorination of depleted brine solution for recycling to the salt dissolver
- Dilution of hydrogen gas with air to prevent concentrations that exceed the low explosion limit (LEL)

Using the design information provided in Table 3-2, the Klorigen on-site generation system will include the following:

Alternative 3 – Klorigen On-site Generation System Requirements	
Chlorine Demand	
Maximum Day Usage (lb/d)	1,459
Average Day Usage (lb/d)	1,193
Raw Product	
Salt Usage (lb/d) [a]	1,969
Storage Days	30
Total Salt Storage Capacity (tons)	30
Salt Storage Capacity (ton)	72
Salt Tank Quantity	2
Salt Tank Dimensions	
Hypochlorite Solution Storage	
Solution Strength (%)	12.5
Solution Usage (gal/d)	1,144
Storage Days (Max Day)	14
Total Storage Capacity (gal of soln)[a]	20,023
Tank Size (gal)	10,147
Number of Storage Tanks	2
Storage Tank Dimensions	12'Øx12'H

Day Tank	
Maximum Day Chlorine Usage (lbs/day)	1,459
Receiving Bulk Concentration (%)	10-12.5
Max Daily Hypochlorite Solution Consumed (gpd)[(a)]	1,748
Selected Day Tank Size (gal)	1,700
Day Tank Quantity	1
Day Tank Dimensions	6'Ø x9'H
Hypochlorite Generators	
Hypochlorite Generator Capacity (lbs/d)	1,920
Quantity	1
Power Usage (kwh/lb Cl_2)	1.75

(a) Accounts for decay to 10% strength

In addition to the above requirements, the system will also contain the following:

- two (2) water softening units
- one (1) 1,000 gal finished brine tank
- one (1) 400 gal HCl tank and two (2) HCl metering pumps
- one (1) 400 gal Sodium Bisulfate tank and two (2) Sodium Bisulfate metering pumps
- one (1) 400 gal caustic storage tanks
- one brine treatment unit
- one (1) hypo conversion and chlorine stripper units
- two (2) air blowers
- two (2) brine maker pumps
- two (2) cooling tower pumps
- two (2) finished brine transfer pumps
- two (2) NaOCl transfer pumps
- nine (9) positive displacement metering pumps
- associated piping and controls

A preliminary layout of the system is provided in Figure 3-6.

3.4.3 Electrical Modifications

The Klorigen on-site generation alternative has a large additional electrical demand. A new service from the FPL vault will be required. Power will also be supplied from an existing motor control center (MCC) located on the second floor of the North Chemical Building. This power feeder will be extended from the MCC to the new power distribution panel located in a new electrical / control room and service critical chemical feed equipment (i.e. chemical metering pumps). Although the new service could easily power the critical chemical equipment, a new backup generator is not envisioned in this evaluation. In emergency situations the on-site generation equipment would not function and rely on the backup bulk sodium hypochlorite feed system. Thus, the existing generator (Generator No. 1) would need to supply backup power for the critical chemical feed equipment on a separate electrical service from that used to power the onsite generation equipment. The new electrical room will require the following electrical components to accommodate this alternative:

- Programmable logic controller (PLC)
- 480 volt power distribution panelboard
- Step down transformer
- 120 volt panelboard
- Power and control conduit and wire
- Power and control raceway to the various equipment
- A new power service from the vault will be required. The size will be approximately 800 amps

3.4.4 Operation and Maintenance

The Klorigen system has more equipment and uses more chemicals than any other alternative which adds to the operational complexity of the system. The same maintenance concerns discussed for bulk sodium hypochlorite will have to be addressed with the Klorigen system in regards to scaling and off-gassing of the sodium hypochlorite. The list of equipment for the Klorigen system above highlights the maintenance of more equipment. However, the extra treatment of the brine solution greatly reduces scaling and theoretically should provide longer lives for the electrolyzers and chemical feed equipment.

Additionally, the operators have to handle additional chemicals used for pH adjustment (HCl and NaOH), dechlorination (sodium bisulfate), and NaOCl production (makeup NaOH) when the Klorigen unit is above 90% of rated capacity. For the Klorigen unit sized in this evaluation, makeup NaOH should not be required.

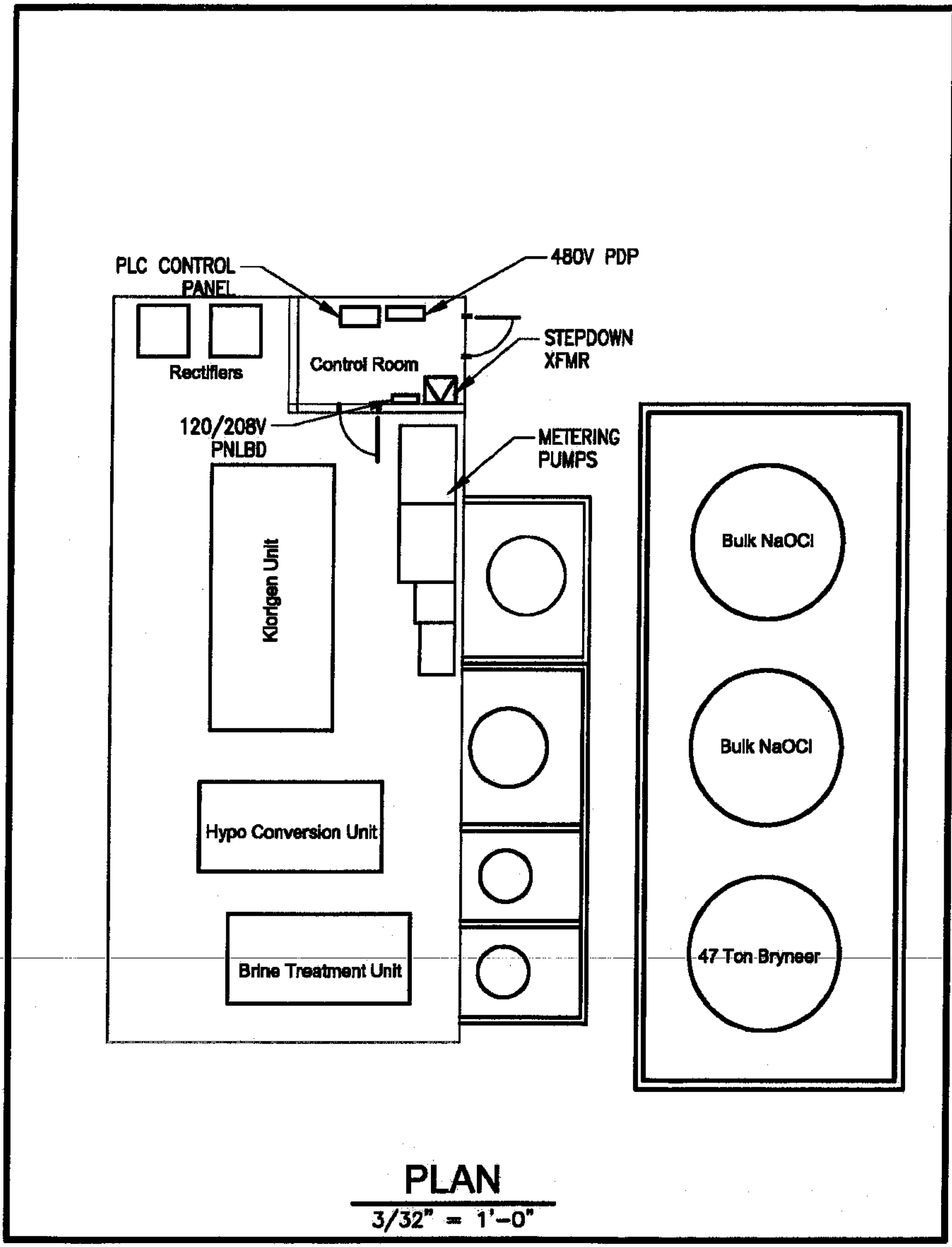


Figure No. 3-6
Alternative 3
Klorigen On-site Generation System

3.5 Alternative 4 - Gas Chlorination System (Scrubber)

The existing chlorinators, injectors, and chlorine solution application point manifold are located in the chlorinator room on the second floor of the North Chemical Building. The ton containers are located on ground level in a typical "open to the atmosphere" configuration as previously shown in Picture 2-1. This alternative would provide for new gas chlorination equipment on ground level, as required by regulations, as well as housing the ton container cylinders in an enclosed facility equipped with a chlorine scrubber.

3.5.1 Process Description

As discussed in detail in Section 2.2, the existing gas chlorination system consists of one-ton chlorine cylinders, weigh scales, cylinder-mounted vacuum regulators, automatic switchover, gas detectors, chlorinators, and chemical injectors. Although new chlorination equipment would be provided in this alternative, the chlorination process would be similar to the existing process with a couple of upgrades. Chlorine gas cylinders are delivered by truck and unloaded into the storage area by a monorail hoist and bridge crane system. Cylinders are then moved onto scales and the vacuum regulators attached for use. Gas flows under vacuum through the automatic switchover to chlorinators. From the chlorinators, gas is pulled by vacuum into injectors that provide a chlorine solution for the various application points. Motive water for the injectors is provided by booster pumps depending on the pressures required.

New chlorine gas systems require an emergency chlorine scrubber system to protect the public's safety in the event of a chlorine leak or spill. In South Florida, wet scrubber systems are typically used to neutralize chlorine. Wet scrubbers use sodium hydroxide (caustic) to neutralize the chlorine. The caustic reacts with the chlorine gas to produce sodium chloride, sodium hypochlorite, water and heat. This evaluation will consider the use of a wet scrubber system.

3.5.2 Conceptual Design Criteria

Some key design considerations for gas chlorination feed systems are as follows:

- Temperature maintenance is suggested where in-shade temperatures are high or freezing temperatures are possible.

- Chlorine storage cylinders should be located in a separate contained room from the chlorinators

- A chlorine treatment system to mitigate accidental release of chlorine gas and liquid from the largest storage container being used. Maximum atmospheric chlorine concentration of 5 ppm before release to atmosphere is required

The 2006 Uniform Fire Code (UFC) requires that a neutralizing system (scrubber) be able to handle the full contents of the largest single storage container should a leak occur. Although the UFC is not necessarily adopted in every jurisdiction, this regulation is usually the basis for most system designs. This regulation requires the system to limit the discharge concentration of the chlorine vapor to one half of the immediately dangerous to life and health (IDLH) condition at point of discharge of 10 ppm. A packaged scrubber system capable of neutralizing gas from a 1 ton cylinder container would generally consist of a scrubber absorber, caustic storage tank, caustic recirculation pump and all electrical panels. The system is required to be rated at handling 3,000 cfm. This configuration would take approximately 30 minutes to neutralize 2,400 lb of chlorine. The spent caustic solution can be disposed of by metering small quantities over a long period of time to a wastewater treatment system or can be handled by the caustic supplier or a professional disposal contractor.

It should be noted that caustic solutions absorb carbon dioxide from the air when in storage and when testing the scrubber system, which may cause the caustic to lose strength over time. Therefore, it is important to test the concentration to verify strength, as a weakened solution may be inadequate to neutralize the entire contents of the one ton cylinder.

In the evaluation of this alternative, the gas withdrawal from the one ton cylinders is assumed to be limited to a continuous rate of 1,500 lbs/day. Switching from gas withdrawal to liquid withdrawal and utilizing an evaporator should be considered at continuous chlorination rates greater than 1,500 lbs/day.

Considering the continuous chlorination rate of 1,500 lbs/day, the gas chlorination system will include the following:

- sixteen (16) one-ton cylinder storage trunnions in a room contained and connected to the scrubber
- four (4) weigh scales with 2 channel electronic indicator
- eight (8) cylinder-mounted vacuum regulators
- one (1) automatic switchover
- three (3) gas detectors
- seven (7) 2,000 lb/day chlorinators
- six (6) chemical injectors
- associated piping and controls

The packaged scrubber system would include:

- one (1) scrubber absorber and integral caustic storage tank
- two (2) caustic recirculation pumps
- an air handling system
- chlorine monitoring analyzers on air discharge and in the storage room

- all electrical panels

A preliminary layout of the system is provided in Figure 3-7.

3.5.3 Electrical Modifications

The gas chlorine alternative does not have a large additional electrical demand. Power will be supplied from an existing motor control center (MCC) located on the second floor of the North Chemical Building. This power feeder will be extended from the MCC to the new power distribution panel located in a new electrical room. Unlike other alternatives, the electrical room will be separate from the chlorinator control room to lessen the possibility of corrosion of the electrical equipment by chlorine gas[8] and provide separation between the climate-controlled electrical room and the well ventilated chlorinator room. The new electrical room will require the following electrical components to accommodate this alternative:

- PLC
- 480 volt power distribution panelboard
- step down transformer
- 120 volt panelboard
- Power and control conduit and wire

3.5.4 Operation and Maintenance

Proper maintenance can prevent many problems experienced with a gas chlorination system. In a system where the vacuum regulator is attached directly to the one-ton container, the only potential pressurized leak location is at the connection of the ton container adapter valve to the containers. Stiff container valves may also be an issue and if one is encountered and cannot be operated at all, the container should be set aside and the supplier notified.

A chlorine detector is the most reliable way to find chlorine leaks, and is sensitive to leaks as small as 1 ppm chlorine in air. Visual inspections can also be undertaken – checking for discoloration on tubing and fittings or water droplets under fittings. To prevent leaks, it is recommended that an operator install a new gasket every time a container is changed, clean the threads of a fitting with a wire brush each time a fitting is opened and replace all chlorine supply line valves annually.

The specific packaged scrubber manufacturer will have recommended guidelines for maintenance of the system. In general, the system will need to be tested on a fairly regular basis, as well as inspecting the packing, pumps and mist eliminator. The caustic strength as well as level will also need to be monitored. Other municipalities have recommended heat tracing for the caustic since the viscosity of the solution increases rapidly as the temperature drops to 65 degrees Fahrenheit and below.

[8] Small amounts of chlorine gas can be present during maintenance of the chlorinator equipment.

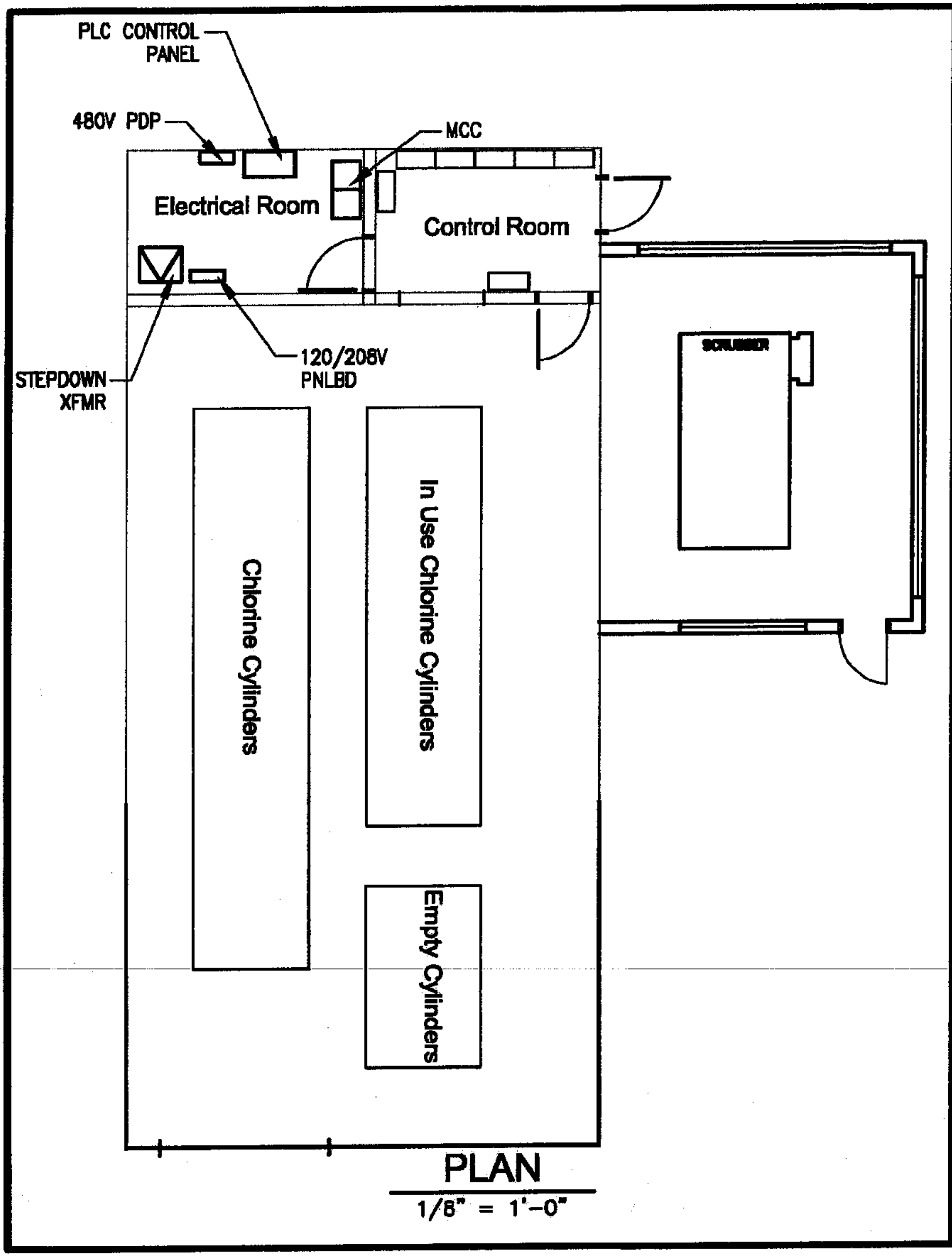


Figure No. 3-7
Alternative 4
Gas Chlorination System Layout

Section 4
Disinfection Alternatives Evaluation

This section provides the evaluation of each the four disinfection system alternatives described in Section 3 and listed below:

1. Bulk delivered sodium hypochlorite (12.5%) feed system
2. 0.8% sodium hypochlorite on-site generation (OSG) feed system using the ClorTec system by Severn Trent Services
3. 12.5% sodium hypochlorite OSG feed system using the Klorigen system by Electrolytic Technologies Corporation
4. Upgrade of existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber

For comparative evaluation of the alternatives, each alternative required a preliminary sizing of the equipment and storage facilities as provided in Section 3. Capital and operation and maintenance costs were estimated based on the design flows and chlorine consumption summarized in Table 4-1.

Criteria	*Design Value*
Average Day Flow (mgd)	9
Maximum Day Flow (mgd)	11
Average Day Chlorine Use (lbs/day)	1,193
Maximum Day Chlorine Usage (lbs/day)	1,459

Table 4-1 Design Flows and Chlorine Use

4.1 Economic Evaluation

The economic evaluation of the disinfection alternatives was based on life cycle cost using a 20-year present worth basis. The present worth analysis and a summary of combined capital and O&M cost for all alternatives is provided at the end of this subsection in Table 4-8. The following sections present the capital, operation and maintenance and net present worth costs developed for each alternative.

4.1.1 Conceptual Project Cost

A conceptual cost estimating methodology was employed to develop capital project costs for the alternatives considered and should not be equated to the engineer's opinion of probable cost generated at the design stage. Equipment costs for the alternatives were provided by various equipment vendors. Equipment installation was estimated to be 20 percent of the equipment cost. Electrical equipment costs were estimated based on the past experience of the engineer. Building additions and modifications are given on a cost per square foot basis and were determined assuming CBS construction. Certain items such as site work are given as a percentage. Bonds and contingency are given as a percentage of the total cost. A 30% contingency was provided for each alternative. Finally, engineering, legal, and administration costs are not included in this analysis. Typically these costs can be up to 20% of the total project cost. Table 4-2 presents a summary of the capital costs for the four alternatives. A more detailed cost breakdown for each alternative is presented in Appendix B.

	Capital Cost ($)
Alternative 1 - Bulk NaOCl	$833,790
Alternative 2 - OSG - 0.8%	$3,099,341
Alternative 3 - OSG - 12.5%	$3,401,844
Alternative 4 - Chlorine Gas	$1,066,589

Table 4-2 Summary of Capital Costs

4.1.2 Conceptual Operation and Maintenance Cost

Estimates of operations and maintenance (O&M) costs were determined for each alternative. O&M costs are dependent on the hours of operation of the disinfection system and the flow being treated. The O&M costs for this evaluation assumed the average day flows and chlorine usage stated in Table 4-1 with the plant in continuous operation. Table 4-3 presents the unit costs used for the development of daily operating costs and Table 4-4 summarizes the operating costs for each alternative to meet the estimated chlorine demand. For this evaluation, maintenance costs were assumed to include estimated yearly labor hours at a loaded rate of $35 per man-hour. Additionally, the on-site generation and chlorine scrubber equipment assumed inclusion of the manufacturer's maintenance plan. Table 4-5 presents the yearly maintenance contract cost and estimated labor cost used for the development of yearly maintenance cost. Finally, the development of O&M costs needs to consider the repair and replacement of equipment. For this evaluation, only the replacement of major equipment is considered[9]. Repair costs are difficult to define and are not considered to be a significant cost factor in the evaluation. Table 4-6 indentifies the assumed major equipment replacement schedule for all alternatives over a 20-year time frame. Table 4-7 presents the summary of O&M costs specific to each alternative.

[9] Installation costs are not assumed in the consideration of major equipment replacement cost.

Onsite-Generation		
Power	0.065	\$/kwh
NaCl (Rock Salt)	0.05	\$/lb
NaCl (Food Grade Salt)	0.15	\$/lb
Potable Water	0.004	\$/gal
NaOH (50%)	4.03	\$/gal
38-40% Sodium Bisulfate ($NaHSO_3$)	1.96	\$/gal
32% HCl (Hydrochloric Acid)	1.733	\$/gal
Bulk Sodium Hypochlorite		
NaOCl (12.5%)	0.7	\$/gal
Gas Chlorination		
Chlorine one-ton Gas Cylinders	0.325	\$/lb[1]

[1] Based on current price of \$650 per ton cylinder

Table 4-3 Operational Unit Costs

	Daily Operating Cost (\$/day)	Yearly Operating Cost (\$/year)	Cost per lb of Cl_2 (\$/lb Cl_2)
Alternative 1 - Bulk NaOCl	\$910.14	\$332,201	\$0.76
Alternative 2 - OSG - 0.8%	\$414.73	\$151,375	\$0.35
Alternative 3 - OSG – 12.5%	\$585.57	\$213,735	\$0.49
Alternative 4 - Chlorine Gas	\$387.87	\$141,573	\$0.33

Table 4-4 Operating Costs

For bulk sodium hypochlorite (NaOCl) the operating cost varies significantly based on the solution strength used to satisfy the chlorine demand.[10] As the solution strength diminishes more gallons of solution are required to satisfy the chlorine demand. The estimate of gallons of sodium hypochlorite consumed daily is based on an average solution strength of 11%. This estimation accounts for the decay of solution in storage. The ClorTec system produces an extremely dilute NaOCl solution that is not subject to significant degradation. The NaOCl solution produced by the Klorigen system is ultra pure and thus less subject to degradation compared to bulk delivered NaOCl. Additionally, the Klorigen system can provide chlorine gas or pace production to deliver continuous 12.5% NaOCl solution, thus avoiding concerns of solution degradation for normal operating conditions. For these reasons, decay was not factored into the operating cost of chlorine production for the Klorigen system.

[10] One gallon of 12% NaOCl solution equates to one pound of available chlorine (Cl_2). Thus the cost per pound of chlorine varies from \$0.84 at 10% NaOCl to \$0.67 at 12.5% NaOCl when the unit cost of delivered NaOCl is \$0.70 per gallon.

	Yearly Maintenance Cost			
	Maintenance Contracts ($/yr)	Estimated Labor (hrs)	Labor Cost ($/yr)	TOTAL Cost ($/yr)
Alternative 1 - Bulk NaOCl		96	$3,360	$3,360
Alternative 2 - OSG - 0.8%	$15,000	96	$3,360	$18,360
Alternative 3 - OSG – 12.5%		288	$10,080	$10,080
Alternative 4 - Chlorine Gas	$6,000	192	$6,720	$12,720

Table 4-5 – Yearly Maintenance Cost

	Replacement	*Schedule*	*Replacement Cost*
Alternative 1 – Bulk NaOCl			
	Metering Pumps[1]	Every 10 years	$56,000
	Day Tank	Every 7 years	$11,500
Alternative 2 – OSG 0.8%			
	Rectifiers[2]	Every 8 years	$116,000
	Electrolyzers [3]	Every 10 years	$220,000
	Metering Pumps[4]	Every 10 years	$112,000
Alternative 3 – OSG 12.5%			
	Rectifiers[5]	Every 8 years	$50,000
	Electrolyzers [6]	Every 5 years	$24,600
	Metering Pumps[1]	Every 10 years	$56,000
	Day Tank	Every 7 years	$11,500
Alternative 4 – Gas Chlorine			
	Scrubber Media/NaOH	Every 5 years	$35,000
	Gas Chlorine Equipment[7]	Every 15 years	$124,872

[1] *Assumes the replacement of 7 positive displacement metering pumps at unit cost of $8,000*
[2] *Assumes the replacement of 2 rectifiers at unit cost of $58,000*
[3] *Assumes the replacement of 4 - 750lb/day cells at unit cost of $55,000*
[4] *Assumes the replacement of 7 hose pumps at unit cost of $16,000*
[5] *Assumes the replacement of 2 rectifiers at unit cost of $25,000*
[6] *Assumes the replacement of 6 – 8 cell electrolyzers (40lb/day/cell) at unit cost of $4,100 (refurbished)*
[7] *Assumes the replacement of all gas chlorine equipment (chlorinators, weigh scales, etc)*

Table 4-6 Replacement Schedule and Cost

	Yearly Operating Cost ($/year)	Yearly Maintenance Cost ($/yr)	TOTAL Yearly O&M[1] Cost ($/yr)
Alternative 1 - Bulk NaOCl	$332,201	$3,360	$335,561
Alternative 2 - OSG - 0.8%	$151,375	$18,360	$169,735
Alternative 3 - OSG - 12.5%	$213,735	$10,080	$223,815
Alternative 4 - Chlorine Gas	$141,573	$12,720	$154,293

[1] *This O&M cost summary does not include the major equipment costs as specified in Table 4-6*

Table 4-7 Yearly Operation and Maintenance Cost Summary

4.1.3 Conceptual Net Present Worth Cost

Present worth provides the City with an idea of how much capital is required at the beginning of the project in order to provide enough investment to cover construction, operation and maintenance of the facility throughout the design life of the equipment. The net present worth value for each alternative was determined by adding the present worth capital costs (Section 4.1.1) and O&M costs (Section 4.1.2) and then subtracting any remaining value of the equipment at the end of the design life. A 20-year design life and 5% interest rate was used in the analysis. Table 4-8 presents the net present worth cost for each of the alternatives evaluated.

	Net Present Value ($)[1]
Alternative 1 - Bulk NaOCl	$5,025,775
Alternative 2 - OSG - 0.8%	$5,371,290
Alternative 3 - OSG - 12.5%	$6,174,320
Alternative 4 - Chlorine Gas	$3,029,429

[1] *The above represents 2010 dollars ($)*

Table 4-8 Net Present Value of Alternatives

4.2 Non-Economic Factors

In addition to the economic considerations discussed in the previous section, there are certain qualitative non-economic factors that must also be taken into consideration in the final evaluation of alternatives. Safety, operations and maintenance, site availability, public perception and flexibility were taken into consideration in determining the best alternative for the City.

4.2.1 Safety

Safety is possibly the most important non-economic factor to be compared between alternatives. Chlorine is classified by the US Department of Transportation (USDOT) as a poisonous and corrosive gas. It is extremely hazardous and poses a serious safety concern should a major leak occur. Exposure to chlorine causes irritation to the eyes, skin, mucous membranes, and the respiratory system. The health impact is dependent both on the concentration and time of exposure. Table 4-9 identifies the reported health effects to various chlorine gas exposure thresholds.

Exposure Thresholds (ppm)	Reported Responses to Exposure
0.2 – 0.4	Odor threshold (decrease in odor perception occurs over time)
1 - 3	Mild mucous membrane irritation, tolerated up to 1 hour
5 - 15	Moderate irritation of the respiratory tract. The gas is very irritating, and it is unlikely that any person would remain in such an exposure for more than a very brief time unless the person is trapped or unconscious
30	Immediate chest pain, vomiting, dyspnea, cough
40 - 60	Toxic pneumonitis and pulmonary edema
430	Lethal over 30 minutes
1000	Fatal within a few minutes

Table 4-9 Health Effects of Chlorine Exposure[11]

As previously discussed, unconfined liquid chlorine rapidly vaporizes and will tend to remain close to the ground since it is 2.5 times heavier than air. One pound of liquid chlorine will vaporize to yield approximately 5.4 cubic feet of 100 percent chlorine gas at 70°F and atmospheric pressure. Therefore the leak of a full one-ton cylinder would completely fill a 30ft x 30ft x 12ft room with 100 percent chlorine gas.

Sodium hypochlorite is classified by the USDOT as corrosive. It is a strong oxidizer and solutions can burn skin and cause eye damage, particularly at concentrated forms. At the 0.8% diluted concentration generated by the ClorTec system, little environmental or health hazard is expected. The biggest potential danger with sodium hypochlorite is the incompatibility with acids. Any mixing of sodium hypochlorite with acids will cause a release of moist chlorine gas. Proper design should incorporate safety measures to prevent this from happening. Safety issues for workers are related to the off-gassing of the sodium hypochlorite as it degrades. Trapped gas (i.e. between closed valves on long lengths of pipe) can build up to a level that causes the explosion of valves or failure of pipe. This is another safety concern that can be addressed with proper design.

[11] Chlorine Institute Pamphlet 1 Edition 7 October 2008

There is a difference in the safety of both the on-site generation processes. The main concern is that the hydrogen gas that is generated as a byproduct in both systems is highly explosive. The ClorTec process presents a potentially more hazardous condition than the Klorigen process, since the hydrogen gas is diluted with blowers at the vent stack near the bulk storage area rather than at the generation units as with the Klorigen system. Although ClorTec has recently incorporated more safety precautions on the generation unit, hydrogen gas is still contained in the greater portion of the system (piping between the generators and vent stack) than with the Klorigen system. Instrumentation and lock-outs have been added to the ClorTec system to lessen the possibilities of potential accidents occurring from closed valves or other situations under which the unit should not be operated.

In the proposed gas chlorination system, vacuum regulators are mounted directly to the one-ton cylinder adapter valves and designed to close, stopping the release of chlorine gas if vacuum is lost. This design can be a significant safety feature since the only potential pressurized leak location is at the connection of the ton container adapter valve to the containers, greatly reducing the risk of a serious leak, and any loss of vacuum, including a piping leak, will shut off the gas flow.

In summary, chlorine gas poses the largest safety risk. Proper design precautions for bulk sodium hypochlorite should eliminate the concern of mixing with incompatible chemicals and provide the safest option. The on-site generation systems pose safety concerns for operators with the formation of hydrogen gas and the need to dilute and vent the gas to atmosphere. The Klorigen process dilutes and vents the hydrogen sooner in the process and thus posses less of a safety concern than does the ClorTec system, but needs to be properly designed so that there is no potential mixing with the acid utilized in the process.

4.2.2 Operations/Maintenance

Typically, operations requirements increase with increasing process complexity. The City's operators are already used to operation of a gas system, and will just need to familiarize themselves with the testing and operation of the scrubber. Additionally, the new design upgrades for the gas chlorine system should also simplify operation.

The implementation of a bulk sodium hypochlorite delivery system should be relatively simple to operators since the main components of the system - storage tanks, transfer pumps and metering pumps – should already be familiar from use of other plant chemical systems. Sodium hypochlorite at higher concentrations (i.e. 10-12%) will cause scaling on injectors and valves that will require additional maintenance, typically occasional cleaning. The operation of a hypochlorite generation system would be a change for the plant operators and would require extensive training. Initially, a hypochlorite system would be more complex depending on the level of experience of the operator until the operators become more familiar with the new system.

In summary, with the past experience of the operators, a gas chlorination system would seem to pose the least amount of operation and maintenance concerns followed closely by the bulk sodium hypochlorite system. The on-site generation systems would have a good deal more maintenance, with the complexity of the Klorigen system being greater than the other two.

4.2.3 Site Availability

Site Availability is one of the most objective non economic factors to be considered. The North Chemical Building used for the existing gas chlorination equipment will be utilized as the future location for the disinfection system for the purpose of alternative comparisons.[12] Each option has different space requirements with some requiring a building addition, areas for bulk chemical storage, or both. The chlorine gas option will require the expansion of the existing building but does not require bulk storage tanks. The gas chlorination system is by far the smallest footprint and has the smallest concerns with site availability. The bulk sodium hypochlorite system requires space for the bulk storage tanks and containment, but can easily house all equipment within the existing building footprint. The ClorTec on-site generation system can also house the required equipment in the existing building but requires a larger footprint for the bulk storage tanks and containment than any of the other options. The Klorigen system requires the same size chemical metering equipment and bulk storage tanks as the bulk sodium hypochlorite system; however, the Klorigen system also utilizes a bulk chemical storage tank for salt and has the most pieces of equipment requiring an expansion of the existing building.

In summary, the ClorTec on-site generation system has the greatest space requirements due to its need for larger bulk chemical storage and containment. The Klorigen system is requires the next largest footprint while the gas chlorine system requires the smallest footprint by far.

4.2.4 Public Perception

The general public's main concern primarily revolves around how exposed individuals are to a potential chemical hazard. There are residential communities located across from the plant on the west side of Dixie Highway, Suncoast High School to the north, as well as other public parks within close proximity.

Although the on-site generation systems (ClorTec and Klorigen) both may present a safety concern for operators at the plant site, a failure or malfunction in the generation units themselves should not extend beyond the limits of the plant. Therefore, these processes present minimal concern to the general public in the surrounding areas.

[12] As discussed in Section 5, a new chemical building located north of the existing North Chemical Building will be used for the selected disinfection system.

Bulk sodium hypochlorite delivery as well as a gas system equipped with a scrubber both present a potential hazard to operators but will not extend beyond the plant site under normal operation. A hypochlorite solution leak from the bulk tank will be collected in the spill containment area and properly disposed of. A chlorine ton container cylinder malfunction or leak (when the container is physically located inside the chlorine room) will activate the scrubber and the chemical will be removed from the air. However, both alternatives will require truckloads of chemical to be transported through the surrounding community to the plant on a regular basis. There is a risk for an accidental spill or release during transportation for these two alternatives.

Only an accidental spill of gas chlorine is likely to cause severe public safety concerns. Thus a gas chlorination system would likely illicit the poorest public perception with the on-site generation systems providing little concern.

4.2.5 Flexibility

There is an obvious advantage to a system which can be readily modified to meet changing conditions and, in particular, emergency conditions which cannot always be anticipated. The on-site generation of sodium hypochlorite has a distinct advantage in that it can be used as a bulk delivery system during emergency conditions. Should problems be experienced with a major component of generation equipment, the solution tanks are already available to serve as bulk tanks for the delivery of commercially purchased sodium hypochlorite.

However, there is a significant difference in the flexibility between both the ClorTec and Klorigen on-site generation systems. The ClorTec system only provides for two days of storage (under max day conditions, 3 days under average day) at any given time. Should the system shut down or another emergency occur, the City must arrange and actually receive a bulk delivery within a 24-48 hour time period before what is stored on site is consumed. The Klorigen system, however, continuously provides for 14 days of storage at any given time. Therefore, should the Klorigen system shut down, the City will have 14 days to arrange for a continual bulk delivery schedule until the equipment is repaired.

One option that can be considered should the ClorTec system be selected is the integration of bulk delivery used in conjunction with the on-site generation, whereby the bulk is diluted down to 0.8% and combined with the solution generated from the ClorTec unit. This, however, will add to the capital and operation and maintenance costs of this alternative, as well as increase the complexity of day to day operations of the system.

The proposed storage area for the gas chlorination system will provide enough space for 30 days worth of ton container storage, although only 14 days of reserved, on-site storage is required by the Palm Beach County Health Department. The limitation of the gas chlorination system is that it must be changed to a liquid withdrawal gas chlorination system if future changes in the City (higher water demands than anticipated) require chlorine demands in excess of 1,500 pounds per day. Given the small footprint of this option, such a change could be made in the future but would require further building additions.

In summary, the Klorigen system would provide the most flexibility followed by the ClorTec system. Considering the gas chlorination and bulk sodium hypochlorite systems, gas chlorination would likely be considered more flexible considering the anticipated future water demands of the City.

4.3 Matrix Evaluation

A numeric rating system was used to evaluate a combination of both economic and non-economic factors. Each factor was assigned a value of 1 though 5, with 5 being a maximum and 1 being the minimum. The cumulative point scoring of each alternative is based on the total points for each criteria multiplied by an associated weighting factor, then added together. The weighting factors totaling 1.00 provides a means of judging the relative value of each evaluation criteria factor. The combined weighting of the four non-economic factors is the equivalent to the assigned weighting of the total project capital costs factor. The results of this rating procedure are shown in the Table 4-10 below.

Factors	Weight	Alternative 1 Bulk Sodium Hypochlorite System	Alternative 2 ClorTec On-site Generation System	Alternative 3 Klorigen On-site Generation System	Alternative 4 Gas Chlorination System (scrubber)
Safety	0.20	3	3	4	2
Operations/Maintenance	0.10	4	3	2	3
Site Availability	0.05	4	3	3	4
Public Perception	0.05	2	4	5	1
Flexibility	0.10	2	4	5	2
Net Present Worth Costs	0.50	3	2	1	5
Weighted Totals	1.00	3.00	2.65	2.40	3.65

Table 4-10 Alternative Matrix Evaluation

Section 5
Selected Disinfection Alternative

Following the review of the various disinfection alternatives, the City staff assigned ranking values for each disinfection alternative using both economic and non-economic factors for selection criteria. These selection criteria were inputted in to a selection matrix (Table 4-10) to provide a ranking of each alternative. Based on the City's preferences, Alternative 4, the upgrade of existing gas chlorination system to include a new gas feed system and a neutralizing chlorine scrubber, was selected. This section will provide a description of this disinfection alternative, recommend a location for the equipment, provide a general equipment layout, provide a summary of the regulatory process design criteria, and discuss a preliminary implementation plan for the installation of the new system to offset operational disruptions to the water treatment plant.

All of the disinfection alternatives were originally evaluated with the intent to use the existing North Chemical Building. However, the development of implementation strategies for the selected alternative suggests that the construction of a new building will likely be a better option considering cost, risk, and future beneficial use of the existing North Chemical Building. The added cost associated with a new building is estimated to be about $180,000 and is accounted for in the amended net present values shown Table 5-1. However, the reduction in contractor risk and specialized construction would likely reduce this cost by a third. The addition of the new building does not affect the ranking of the alternatives since the selected alternative had a net present worth cost of approximately $2 million dollars less (Table 4-8) than the next cheapest alternative. Even the adjustment of the site availability ranking to the lowest possible score, which would not be consistent with the comparison to other alternatives, would still have a new gas chlorination system being the highest ranked option. Additionally, a new chlorination building would be better suited and customized to the intended use and have the additional benefit of enabling a cost effective installation of sludge dewatering facilities in the future. Thus, the proposed implementation of a new gas system considers the construction of a new building (Chlorine Building) located between the existing north chemical building and the maintenance facility as shown in Figure 5-1.

	Net Present Value ($)[1]
Alternative 1 - Bulk NaOCl	$5,025,775
Alternative 2 - OSG - 0.8%	$5,612,866
Alternative 3 - OSG - 12.5%	$6,174,320
Alternative 4 - Chlorine Gas	$3,209,429

[1] *The above represents 2010 dollars ($)*

Table 5-1 Amended Net Present Value of Alternatives

5.1 Proposed Disinfection System Description

The proposed disinfection system is described in Section 3.4 of this report. The system will provide up to 1,500 lbs/day of chlorine and include the following:

- sixteen (16) one-ton cylinder storage trunnions in a room contained and connected to the scrubber
- four (4) weigh scales with 2 channel electronic indicators
- eight (8) cylinder-mounted vacuum regulators
- one (1) automatic switchover
- three (3) gas detectors
- seven (7) 2,000 lb/day chlorinators
- six (6) chemical injectors
- associated piping and controls

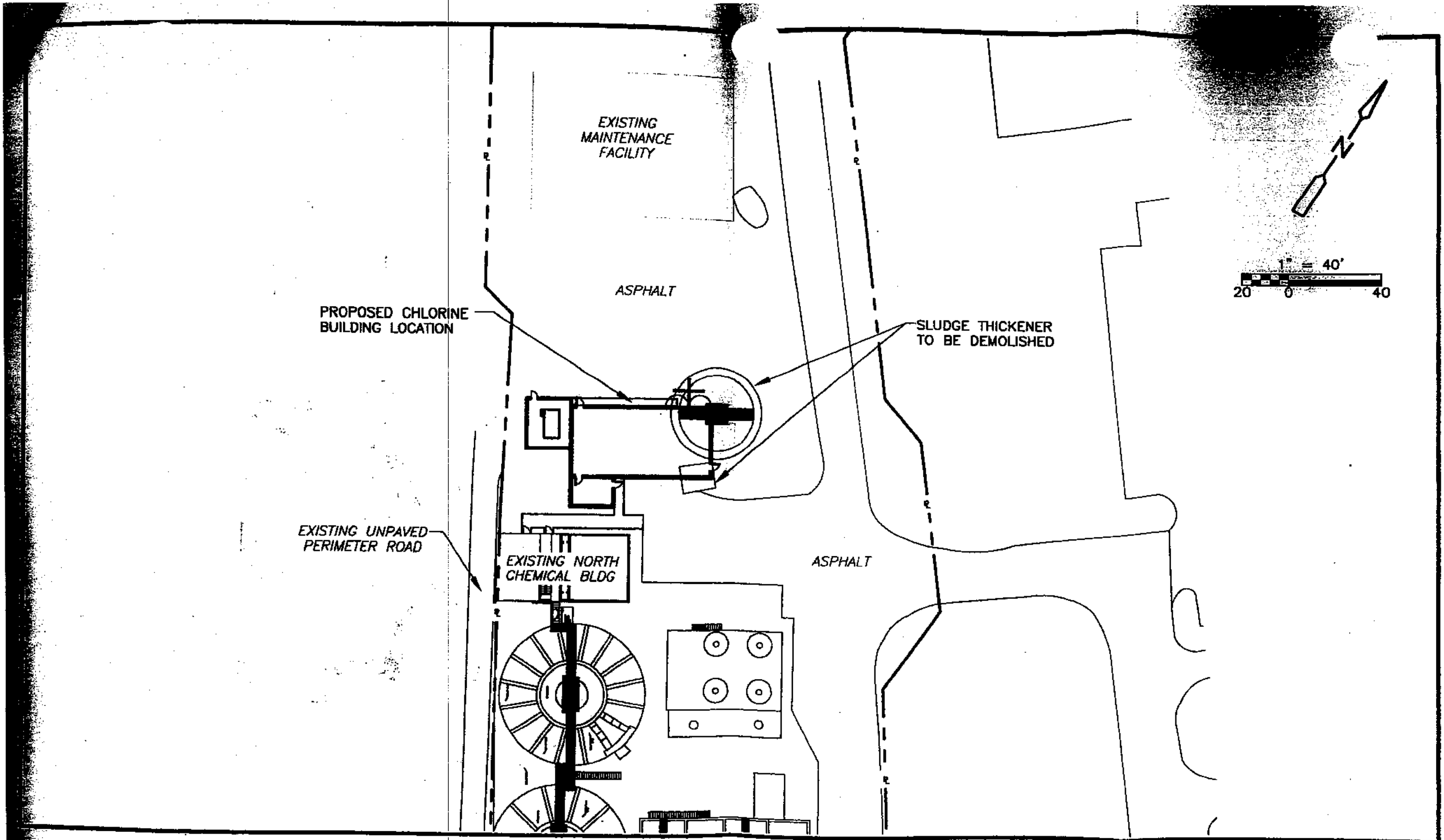
The packaged scrubber system would include:

- one (1) scrubber absorber and integral caustic storage tank
- two (2) caustic recirculation pumps
- an air handling system
- chlorine monitoring analyzers on air discharge and in the storage room
- all electrical panels

A preliminary layout of the proposed disinfection system is provided in Figure 5-2.

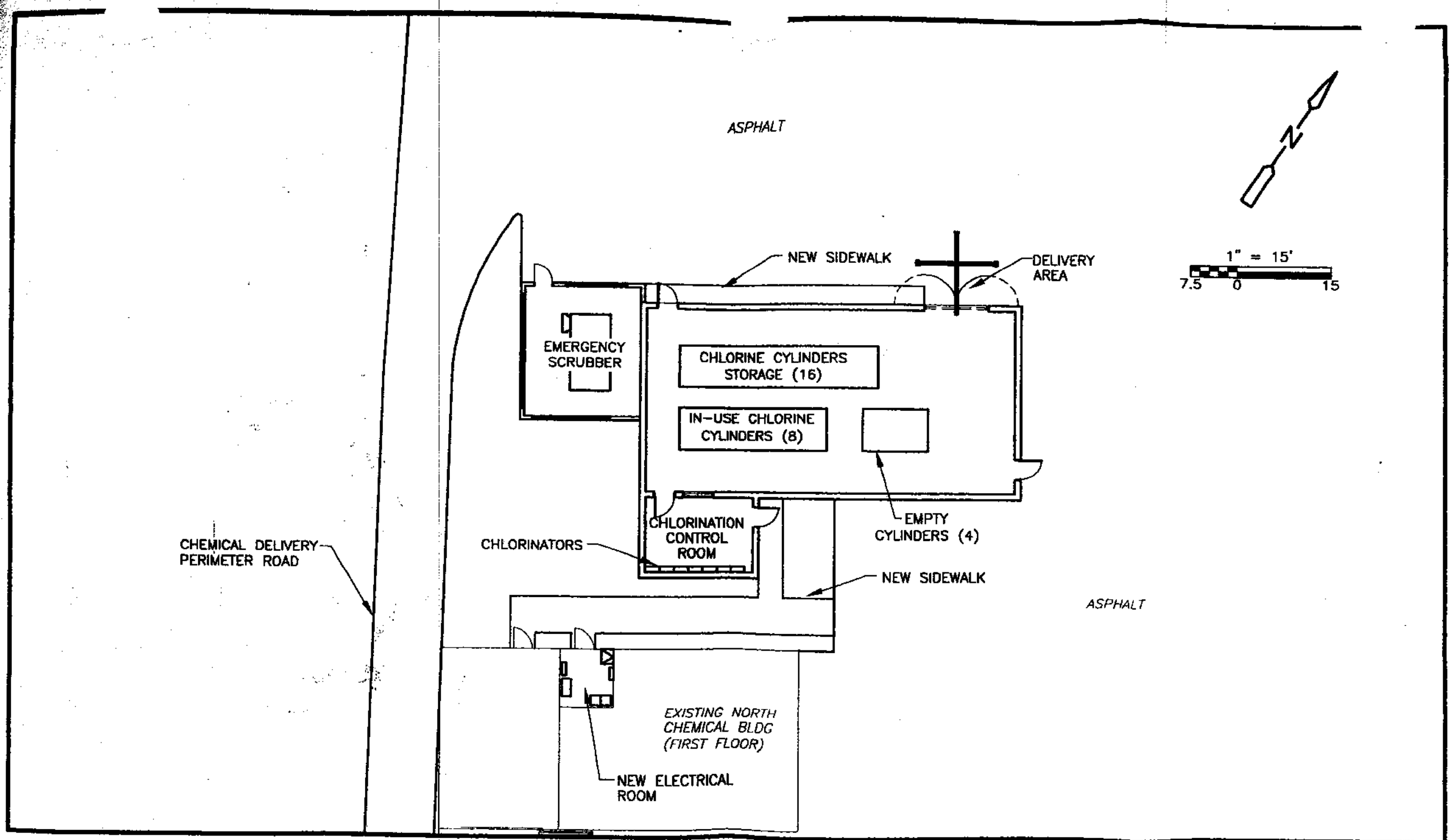
5.2 Regulatory Design Criteria

Design criteria are based on good design practice as stated by the Recommended Standards for Water Works 2007 (Ten State Standards) and the requirements for modifications to public access water systems as outlined in Chapter 62-550 and 62-555, Florida Administrative Code (F.A.C.). The Palm Beach County Health Department provides permit review on behalf of the Florida Department of Environmental Protection and follows Article 15, Chapter B – (Environmental Control Rule II) Drinking Water Supply Systems of the Palm Beach County (PBC) Unified Land Development Code. Design standards presented in this rule (Environmental Control Rule II) are stated as being in addition to the standards provided in FAC and as considered to be modern engineering practices. The Environmental Control Rule II states that if any differences in design criteria exist, the more stringent standard shall be used. For the most part, these standards do not differ and are governed by F.A.C. Any differences are addressed under the appropriate section below. Other conceptual design considerations for the selected alternative are discussed in Section 3.5.2 of this report.



Solutions Inc.

Figure No. 5-1
Proposed Disinfection System Location



CSolutions Inc.

Figure No. 5-2
Proposed Disinfection System Layout

5.2.1 Flow Rates

Chapter 62-555.320(6), F.A. C. requires that *the total capacity of all water source and treatment facilities connected to a water system shall at least equal the water system's design maximum-day water demand (including design fire-flow demand if fire protection is being provided).* As discussed in Section 3, the maximum-day water demand, for purposes of this analysis, has been set by the City as 11 mgd, less than the current design rating of the plant (14.5 mgd).

Chapter 62-555.320(13)(a), F.A. C. requires that chlorine be fed into drinking water proportional to flow.

5.2.2 Water Quality

Municipal water systems are required to disinfect water that is distributed to the public. An understanding of the raw water quality coming into the water treatment plant is critical to the proper design of any disinfection system. Sampling and analysis of raw water quality should be performed in the design phases of this project. Primary and secondary water quality standards are defined in Chapter 62-550 F.A.C. Disinfection criteria are discussed in Section 5.2.3.

5.2.3 Disinfection

Chapter 62-555.320(12) F.A.C. provides the requirements for disinfection of drinking water and states that suppliers of water shall provide continuous disinfection of the drinking water they distribute and that necessary equipment and tanks shall be designed to comply with the applicable requirements in Chapter 62-555.320(12) F.A.C and subsections 62-555.350(5) and (6), F.A.C. The following requirements apply to the City's existing treatment process:

- Chapter 62-555.320(12)(b) F.A.C requires that *suppliers of water using ground water that is not under the direct influence of surface water but that is exposed during treatment to the open atmosphere and possible microbial contamination shall provide treatment that reliably achieves at least four-log inactivation or removal of viruses before or at the first customer at all flow rates.*
- Chapter 62-555.320(12)(d) F.A.C requires the maintenance of a minimum combined chlorine residual of 0.6 mg/L throughout the water distribution system at all times.
- Chapter 62-550.310 F.A.C requires a maximum residual disinfectant goal (MRDLG) for chlorine or chloramine of 4 mg/L.

5.2.4 Gas Chlorination Equipment

Chapter 62-555.320(13)(a), F.A.C. and the Ten State Standards sets the following requirements for gas chlorination equipment.

- New chlorinators shall be the vacuum-operated, solution-feed type.
- Chlorinators must have the capacity to feed enough disinfectant to maintain any applicable minimum CT value and the minimum combined chlorine residual when maximum chlorine demand coincides with the maximum flow rate at the point of chlorine application.
- The supplier of water shall provide installed or uninstalled standby gas chlorination equipment (i.e., a standby chlorinator, including a standby vacuum regulator and a standby eductor, which is also referred to as an injector or ejector; a standby booster pump where booster pumps are used) of sufficient capacity to replace the largest equipment.
- Devices for automatic switch-over of chlorine cylinders or containers shall be provided.
- Scales shall be provided to accurately weigh chlorine cylinders or containers in use.
- An audio-visual alarm system that is activated by high- and low-vacuum switches, a continuous chlorine residual analyzer, or a continuous oxidation-reduction potential meter to indicate loss of chlorination capability or chlorine residual shall be provided.
- Chlorine shall be fed into drinking water proportional to flow.
- Chlorine shall be controlled to be fed into drinking water to match the chlorine demand.

The requirements for feed rate control are discussed in further detail below.

Chapter 62.555-320(13)(a)5., F.A.C. requires that chlorine be fed into drinking water proportional to flow and also states that "*Automatic flow proportioning control of chlorinators shall be provided where the flow rate fluctuates significantly*". The flow rate data provided by the CITY shows that the flow fluctuates significantly, thus flow proportioning would be required. Furthermore, Chapter 62.555-320(13)(a)5., F.A.C. states that "*automatic residual control of chlorinators shall be provided where the chlorine demand fluctuates significantly, and automatic compound-loop control of chlorinators shall be provided where both the flow and the chlorine demand fluctuate significantly.*" Historical MOR data suggest that chlorine demand fluctuates significantly. However, this should be confirmed during design.

5.2.5 Chlorine Storage

Chapter 62-555.320(13)(a), F.A.C. references the Ten State Standards for chemical storage requirements. Ten States Standards specifies that at least 30 days of chemical supply should be provided. This is in sharp contrast to the PBC Environmental Control Rule II that specifies 14 days of storage.[13] Space has been provided in the equipment and building preliminary sizing to provide for 30 days storage at 11 mgd. This will enable to City to purchase and store additional cylinders in preparation of an emergency, such as a hurricane, when deliveries may take a bit longer to resume afterwards.

- Chlorine gas and feed facilities shall be located in a room or area separate from other operating areas.

5.2.6 Chlorine Application Point

Chapter 62-555.320(13)(a), F.A. C. sets the following requirements that pertain to the injector mechanism at the application point.

- Chlorine shall be rapidly and thoroughly mixed with the drinking water being treated.

5.2.7 Housing

Chapter 62-555.320(13)(a)(8), F.A. C. and the Recommended Standards for Water Works (2007) sets the following requirements that pertain to housing.

- Chlorine storage and feed facilities shall be located in a room or area separate from other operating areas. If chlorine storage or feed facilities are enclosed in a room, the room shall be located at ground level and shall be provided with floor-level ventilation.
- The housing of chlorine gas shall comply with the Ten State Standards section 5.4.1.
- Chapter 62-555.320(4), F.A.C. specifies requirements for flood protection and states that structures for community water systems need to be protected from physical flood damage by the 100 year flood and should remain fully operational and accessible during the 25-year flood.

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[13] The consumption in the PBC Environmental Control Rule II is based, as a minimum on 50 percent design capacity. This is in additional sharp contrast to F.A.C. and Ten State Standards that base all consumption on maximum flow rate at maximum chlorine demand. Although Ten State Standards is the more stringent, Palm Beach County has permitted disinfection storage much less than that specified in the Ten State Standards.

5.2.8 Operator Safety

Chapter 62-555.320(13)(a)(10), F.A. C. sets the following requirements that pertain to operator safety.

- Protective equipment should be provided at the site as required by the reviewing authority.
- A self-contained breathing apparatus (SCBA) meeting the requirements of the National Institute for Occupational Safety and Health shall be provided in a convenient location, outside of any room where chlorine is stored or handled.
- Protective equipment in accordance with Table 15.5 in Water Treatment Plant Design shall be provided, except that the supplier of water shall provide a self-contained breathing apparatus in Chapter 62-555.320(13)(a)(10) (listed above) instead of providing a gas mask in accordance with this sub-subparagraph and Table 15.5.
- Continuous chlorine leak detection equipment that is connected to an alarm system shall be provided. The alarm system shall include an audio-visual alarm at the plant, and if the plant is not staffed 24 hours per day and seven days per week, the alarm also shall be telemetered to a place staffed 24 hours per day and seven days per week, or shall trigger an automatic telephone dialing or paging device, to enable notification of an authorized representative of the supplier of water.
- An emergency chlorine leak repair kit meeting the requirements of the Chlorine Institute shall be provided.

5.2.9 Operation and Maintenance

Chapter 62-555.350 F.A. C. sets the following requirements for the Operation and Maintenance of the City's public water system.

Suppliers of water who are using ground water not under the direct influence of surface water and who are required to provide treatment to reliably achieve at least four-log inactivation or removal of viruses in accordance with paragraph 62-555.320(12)(b), F.A.C., shall monitor, record, and maintain the effectiveness and reliability of disinfection treatment as follows:

- Continuously monitor the residual disinfectant concentration (C) before or at the first customer and shall record the lowest C measured before or at the first customer during peak flow, the corresponding disinfectant contact time (T) at the C monitoring point during peak flow, and the resulting lowest CT provided before or at the first customer during peak flow. In addition, at least once for each day, the supplier of water shall measure and record the temperature of the water at the point where C is monitored; shall measure and record the pH of the water at the point where C is monitored if free chlorine is being used for virus inactivation; and with this temperature and pH information, shall determine and record the minimum CT required to comply with paragraph 62-555.320(12)(b), F.A.C.

- Once per day, the supplier of water shall monitor the residual disinfectant concentration (C) before or at the first customer by taking at least one grab sample during peak flow and shall record the lowest C measured before or at the first customer during peak flow, the corresponding disinfectant contact time (T) at the C monitoring point during peak flow, and the resulting CT provided before or at the first customer during peak flow. In addition, at least once for each day the supplier of water serves water to the public from the plant, the supplier of water shall measure and record the temperature of the water at the point where C is monitored; shall measure and record the pH of the water at the point where C is monitored if free chlorine is being used for virus inactivation; and with this temperature and pH information, shall determine and record the minimum CT required to comply with paragraph 62-555.320(12)(b), F.A.C.

5.3 Implementation Plan

The installation of the new gas chlorination system cannot interrupt water treatment plant operations or the ability to continuously provide disinfection. The processes potentially affected by the construction of a new gas chlorination system at the existing north chemical building will be the existing gas chlorination system and possibly the delivery of lime.

The construction of the new chemical disinfection building will require the demolition of the unused gravity thickener. The construction implementation plan is broken into four sequential construction phases as detailed below. Construction Phases II and III occur simultaneously.

Construction Phase I - Demolition and Site Work

1. Demolish the existing sludge thickener and remove equipment

   Demolish and remove vacuum filter and associated piping on second floor of north chemical building

2. Prepare Site - Paving, Grading, and Drainage. This includes paving and grading of perimeter WTP road

Construction Phase II - Construct Chlorine Building

1. Construct building foundations
2. Construct slab, pipe trenches and install required sub-slab electrical conduits and piping
3. Construct slab for new wet scrubber containment area

4. Construct walls and roof (include all mechanical louvers, duct, and piping penetrations)
5. Construct new bridge crane

Construction Phase III- Yard Piping and miscellaneous (concurrent with phase II)

1. Install flow meters and chemical analyzers on existing raw water mains
2. Install new chemical yard piping
3. Refinish interior of the new electrical room (14'x9' utility closet in existing North Chemical Building first floor)
4. Install required conduit and install equipment in electrical room
5. Install conduit to required locations in new Chlorine Building

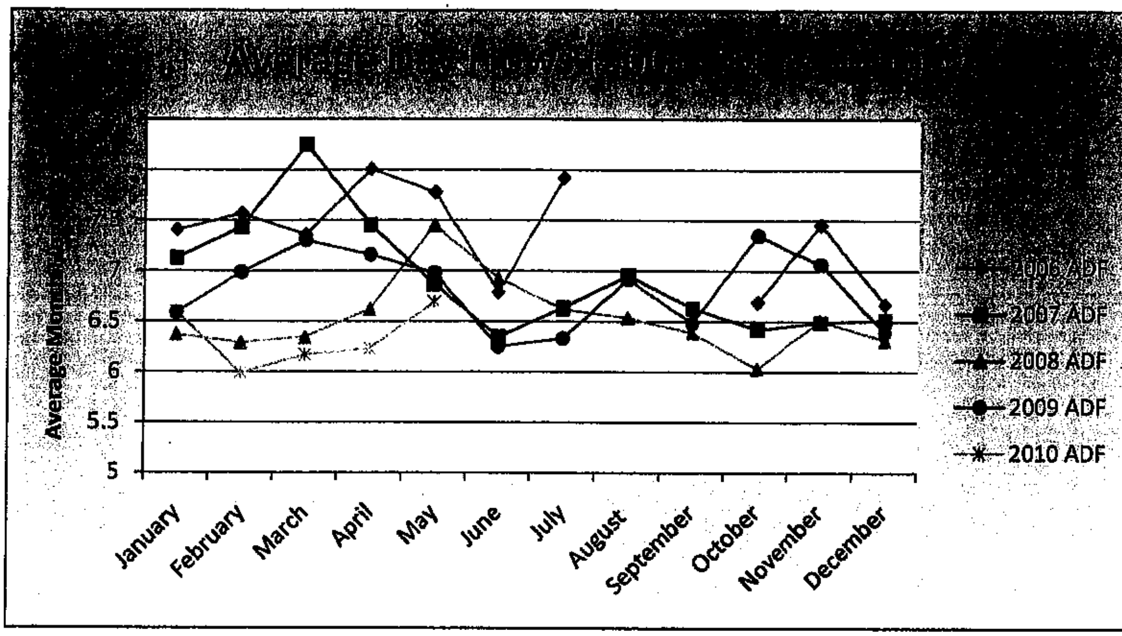
Construction Phase IV

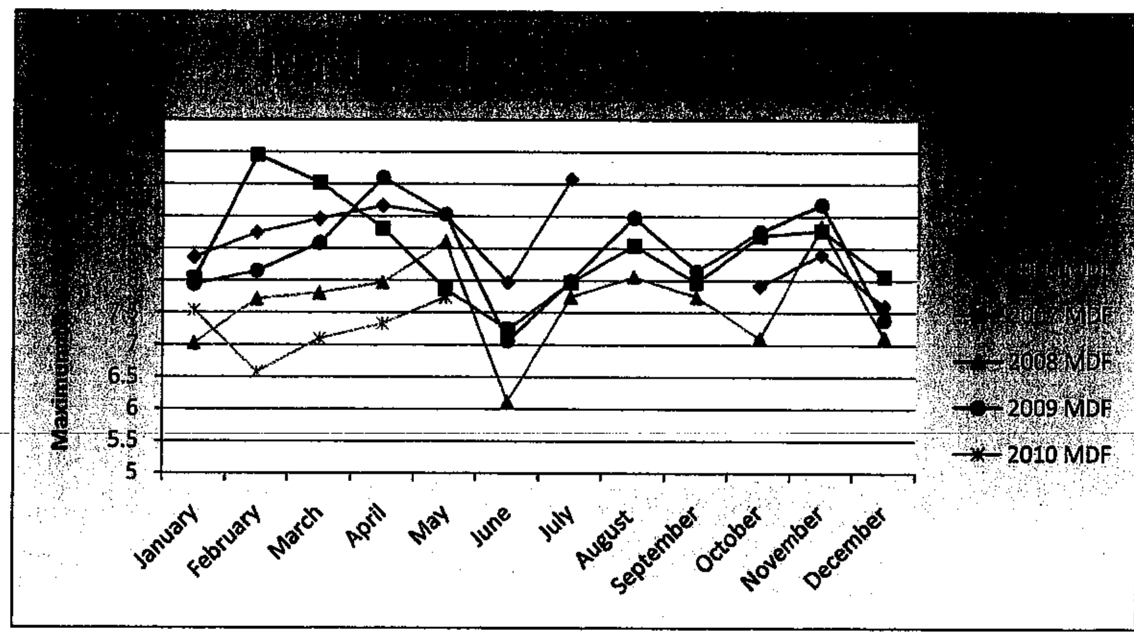
1. Install chlorination equipment (chlorinators, vacuum regulators, scales, controls, booster pumps, trunnions, etc.)
2. Connect chlorination system to new chemical yard piping
3. Take delivery of one-ton chlorine cylinders
4. Startup and test new chlorination system
5. Demolish existing chlorination system once new system is tested and fully operational

Appendix A

Appendix A - 1

RIVIERA BEACH RAW WATER FLOWS (2006 - 2010)



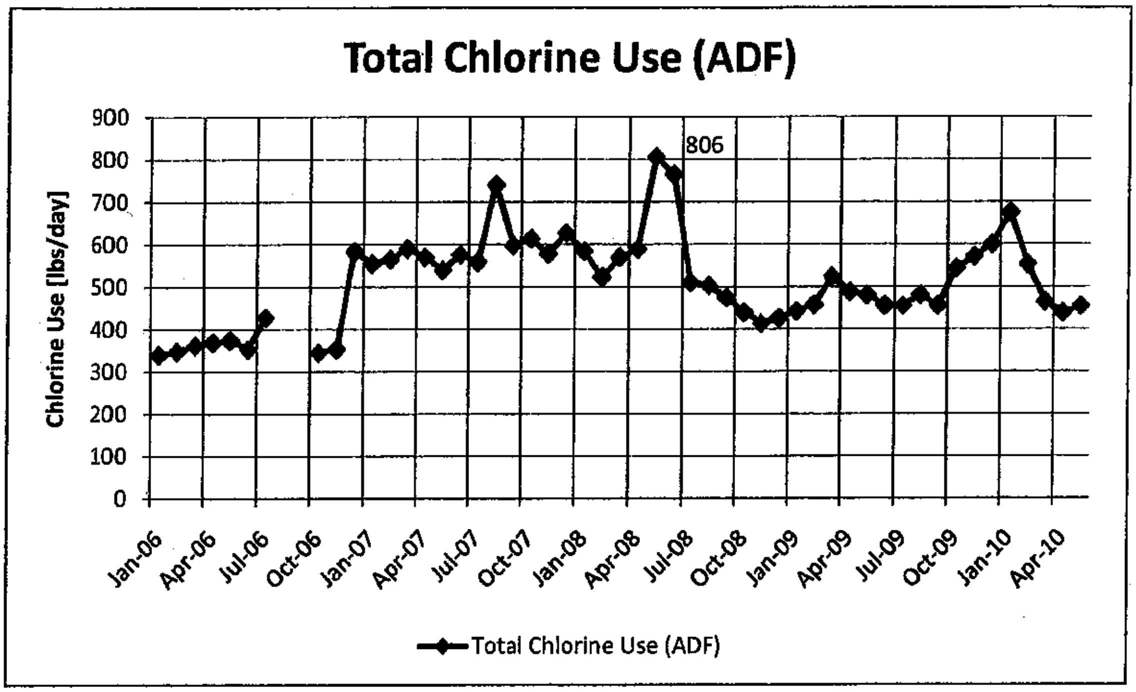


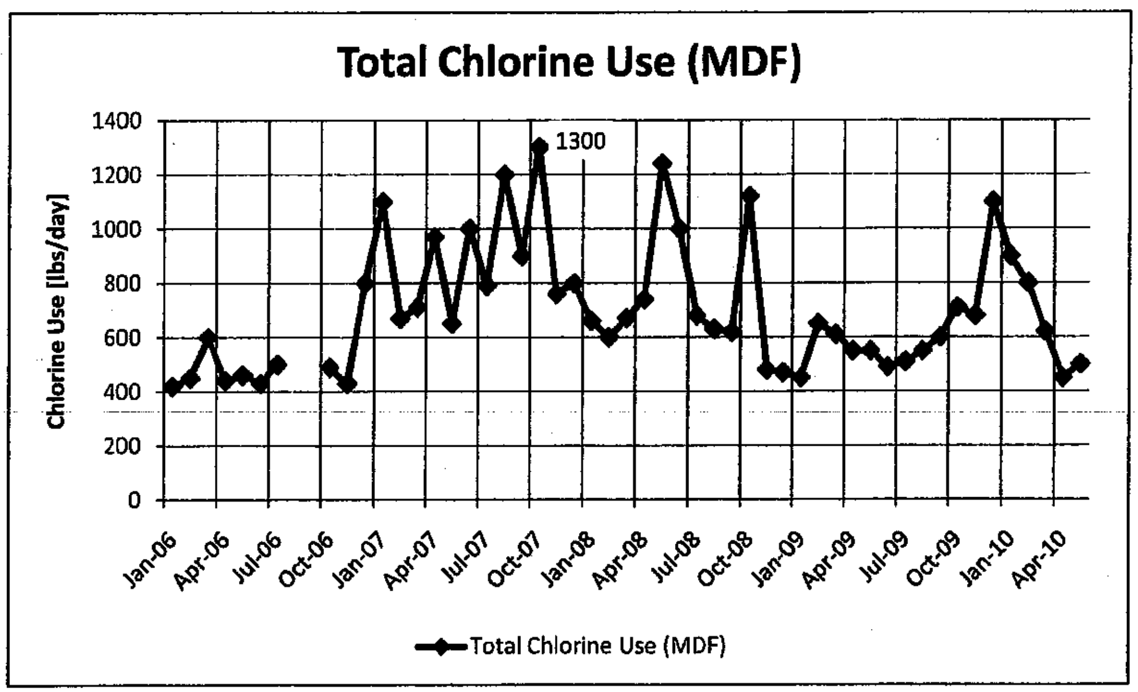
Note:

The data provided in the charts above are obtained from the official Monthly Operating Reports (MORs)

Appendix A - 2

RIVIERA BEACH Chlorine Use [lbs/day] (2006 - 2010)



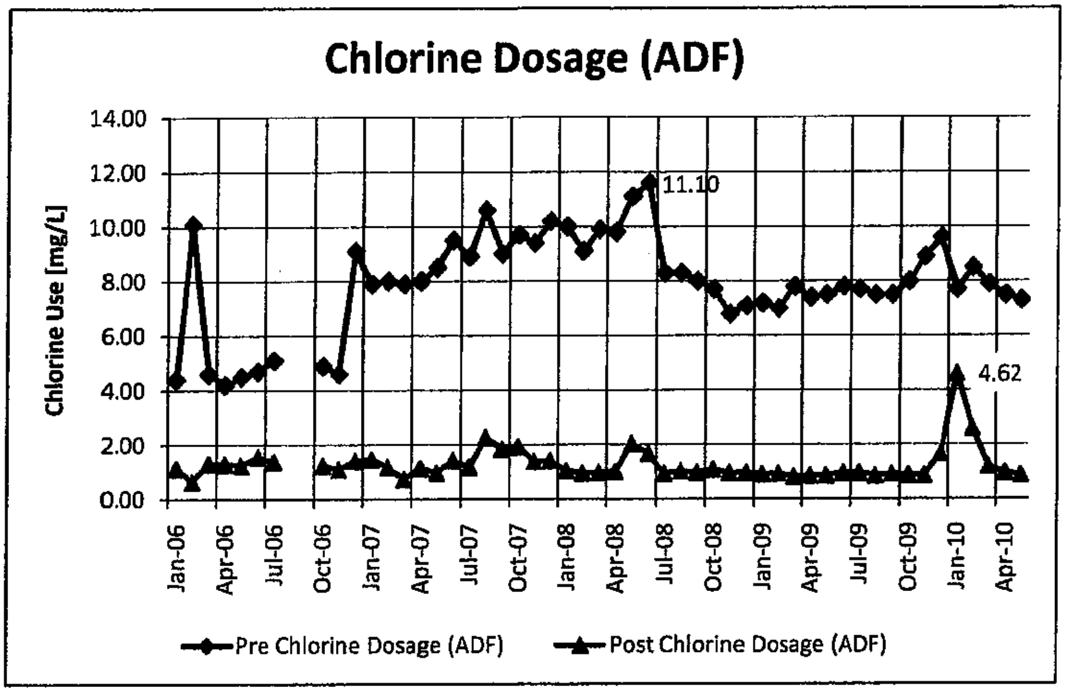


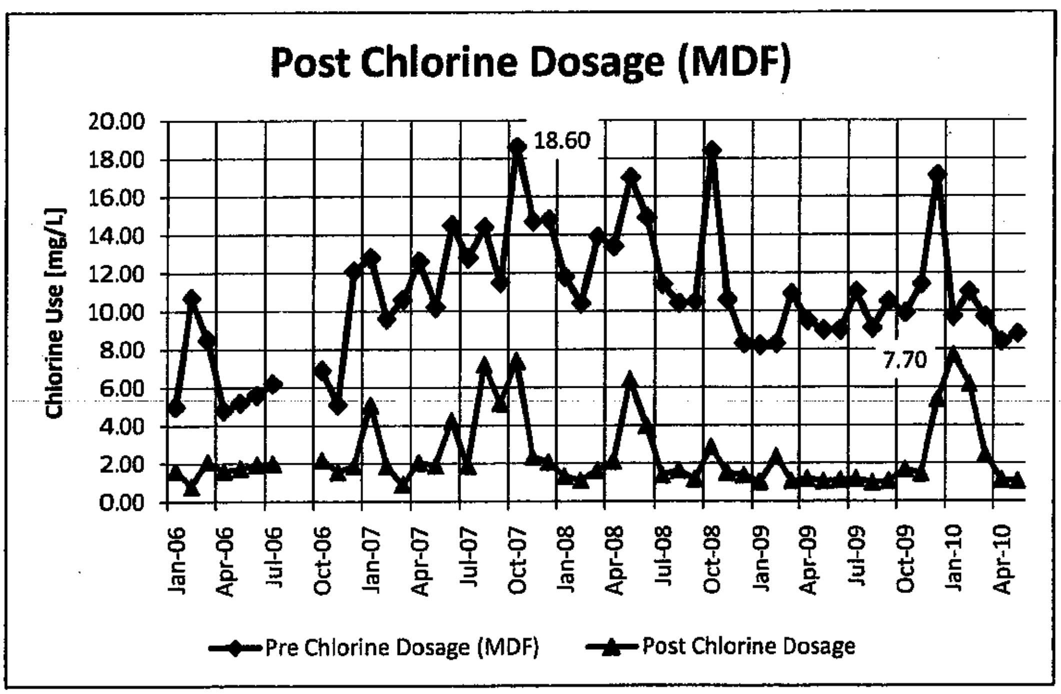
Note:

The data provided in the charts above are obtained from the official Monthly Operating Reports (MORs)

Appendix A - 3

RIVIERA BEACH Chlorine Dosage [mg/L] (2006 - 2010)





Note:

The data provided in the charts above are obtained from the official Monthly Operating Reports (MORs)

Appendix B

Table B-1
Summary of Equipment Costs

Item	Unit Cost	Installation	Total Unit Cost	
Klorigen System	$1,267,442	20%	$1,520,930	(a)
ClorTec System	$1,007,000	20%	$1,208,400	(a)
32,000 gal storage tanks (ea)	$106,000	20%	$127,200	(a)
Hose Pumps/VFDs	$24,986	20%	$29,983	(a)
20,038 gal FRP tank (ea)	$56,000	$10,000	$66,000	
10,147 gal FRP tank (ea)	$34,000	$10,000	$44,000	
1700 gal day tank (ea)	$11,500	20%	$13,800	
60 ton Bryneer	$45,000	$10,000	$55,000	
80 ton Bryneer	$52,000	$10,000	$62,000	
chemical transfer pump (ea)	$8,000	20%	$9,600	
chemical metering pumps (ea)	$8,000	20%	$9,600	
V2000 Wall mounted chlorinator (ea)	$8,245	20%	$9,894	
W&T 510M vacuum regulators	$2,100	20%	$2,520	
W&T 55-400 automatic switchover	$2,450	20%	$2,940	
2-inch injectors	$3,000	20%	$3,600	
Chlorine leak detector	$1,500	20%	$1,800	
Scale (ea)	$4,905	20%	$5,886	
Electronic indicator	$2,150	20%	$2,580	
Storage trunnions	$365	20%	$438	
1 ton overhead bridge crane	$25,000	20%	$30,000	
1 ton RJ 2000 scrubber	$105,000	20%	$126,000	
2-in yard piping (to injection points) (lf)	$20	incl	$20	
<u>bulk containment</u>				
slab (per yd3)	$650	incl	$650	
walls (per yd3)	$1,000	incl	1000	
<u>building modifications</u>				
existing (per ft2)	$100	incl	$100	
new (per ft2)	$180	incl	$180	

(a) includes 6% tax on equipment price obtained

Table B-2
Alternative 1 - Bulk Sodium Hypochlorite System
Capital Costs

Item	Quantity	Unit Cost	Total Cost
10,147 gal FRP vertical bulk storage tank and accessories	2	$44,000	$88,000
1,700 gal day tank and accessories	1	$13,800	$13,800
Chemical transfer pumps and accessories	2	$9,600	$19,200
Positive displacement chemical metering pumps and accessories	9	$9,600	$86,400
Bulk Storage Tank Containment Area			$61,333
Yard piping and appurtenances			$29,952
Electrical and Instrumentation			$216,000
Subtotal			**$514,685**
Sitework (20%)			$102,937
Subtotal			**$617,622**
Bonds (5%)			$30,881
Contingency (30%)			$185,287
Total Capital Cost 12.5% Bulk Delivered NaOCl*			**$833,790**

*Engineering and Administrative Allowances are not included and are typically in the range of 20%

Table B-3
Alternative 2 - ClorTec On-Site Generation System
Capital Costs

Item	Quantity	Unit Cost	Total Cost
ClorTec System (including two 1,500 ppd generators, rectifiers, 80 ton salt tank, controls, piping and accessories)	1	$1,208,400	$1,208,400
32,000 gal FRP horiontal storage tank and accessories	2	$127,200	$254,400
Peristaltic chemical feed pumps, vfds, piping and accessories	7	$29,983	$209,880
Storage Tank Containment			$120,852
Yard piping and appurtenances			$29,952
Electrical and Instrumentation			$363,000
Subtotal			**$2,186,484**
Sitework (5%)			$109,324
Subtotal			**$2,295,808**
Bonds (5%)			$114,790
Contingency (30%)			$688,742
Total Capital Cost ClorTec (0.8%)*			**$3,099,341**

*Engineering and Administrative Allowances are not included and are typically in the range of 20%

Table B-4
Alternative 3 - Klorigen On-Site Generation System
Capital Costs

Item	Quantity	Unit Cost	Total Cost
Klorigen System (including one 1,950 ppd generator, 2 rectifiers, 72 ton salt tank, 1,000 gal finished brine storage tank, 400 gal hydrochloric acid tank, 400 gal sodium bisulfate tank, 400 gal caustic storage tank, controls, piping and accessories)	1	$1,520,930	$1,520,930
10,147 gal vertical FRP storage tanks and accessories	2	$44,000	$88,000
1,700 gal day tank and accessories	1	$13,800	$13,800
Chemical transfer pumps and accessories	2	$9,600	$19,200
Positive Displacement Chemical Metering Pumps and Accessories	9	$9,600	$86,400
Yard piping and appurtenances			$29,952
Storage Tank Containment			$71,407
Building Modifications			$207,200
Electrical and Instrumentation			$363,000
Subtotal			**$2,399,890**
Sitework (5%)			$119,994
Subtotal			**$2,519,884**
Bonds (5%)			$125,994
Contingency (30%)			$755,965
Total Capital Cost Klorigen (12.5%)*			**$3,401,844**

*Engineering and Administrative Allowances are not included and are typically in the range of 20%

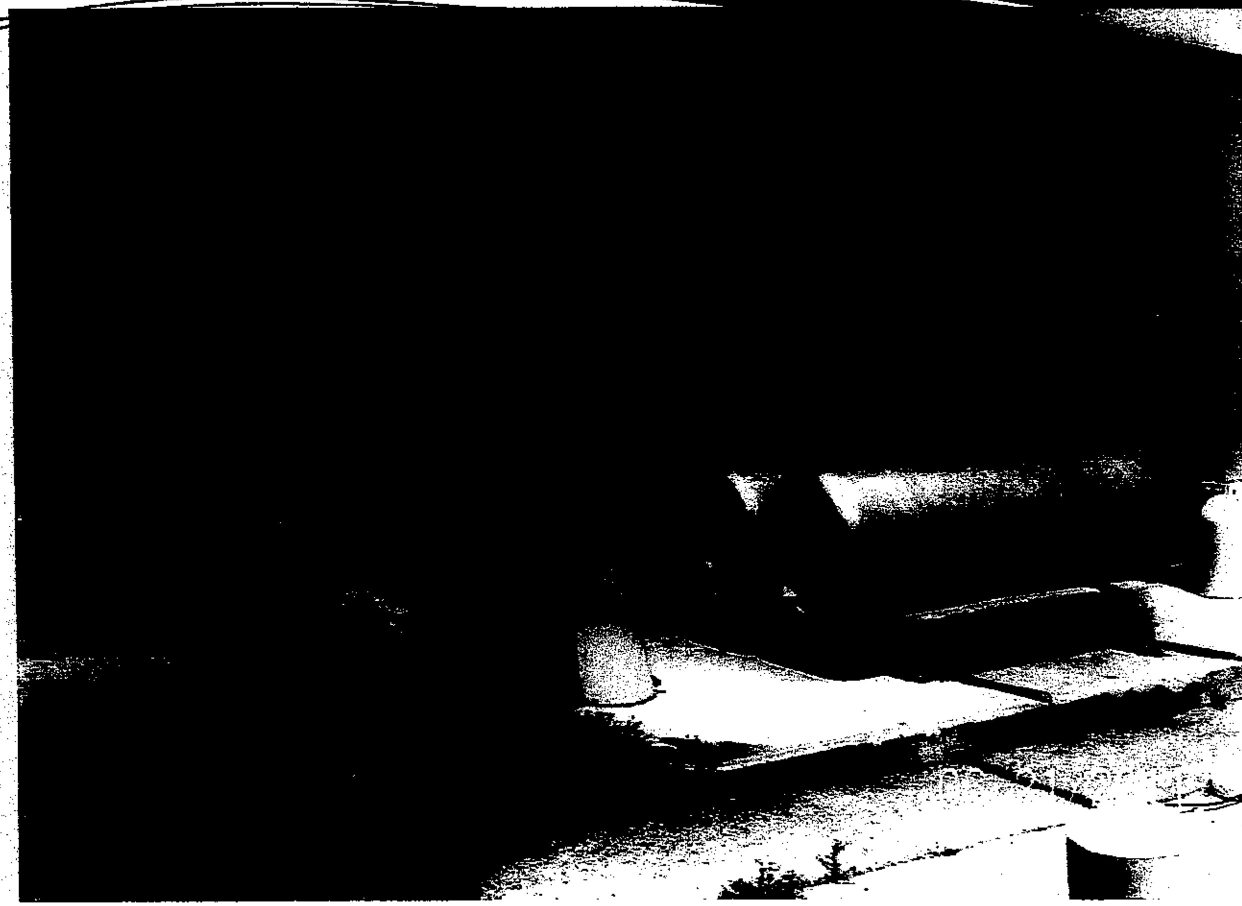
Table B-5
Alternative 4 - Gas Chlorination System (Scrubber)
Capital Costs

Item	Quantity	Unit Cost	Total Cost
2,000 ppd chlorinator and accessories	7	$9,894	$69,258
Vacuum regulators	8	$2,520	$20,160
Automatic Switchover	1	$2,940	$2,940
Injectors	7	$3,600	$25,200
Chlorine leak detector (single point)	3	$1,800	$5,400
Scale	4	$5,886	$23,544
Electronic indicator	1	$2,580	$2,580
Storage trunnions	16	$438	$7,008
One ton scrubber system and accessories	1	$126,000	$126,000
2 ton overhead bridge crane	1	$30,000	$30,000
Yard piping and appurtenances			$29,952
Building Modifications			$207,200
Electrical and Instrumentation			$169,000
Subtotal			**$718,242**
Sitework (10%)			$71,824
Subtotal			**$790,066**
Bonds (5%)			$39,503
Contingency (30%)			$237,020
Total Capital Cost Gas Feed System*			**$1,066,589**

*Engineering and Administrative Allowances are not included and are typically in the range of 20%

City of Riviera Beach Utility District

Disinfection Alternatives



Existing Chlorine gas system is <u>not</u> acceptable

"The majority of utilities in the United States use chlorine gas during treatment, but approximately one third of all US drinking water treatment plants use bulk hypochlorite for disinfection, and around 8% use onsite hypochlorite generators or onsite generators (OSGs) during treatment."

– Dr. Benjamin D. Stanford

(Source – American Water Works Association Journal, June 2011 Volume 103 Number 6)

Engineering Design and Construction of

a

<u>**"State of the Art"**</u>

enclosed disinfection facility is required

In this controlled environment,

the risk to public safety is <u>**minimized**</u>

Risk shifts to <u>our</u> employees, the **Water Treatment Plant Operators**

- Chlorine gas is familiar to Utility District staff
- On-site generation of Sodium hypochlorite has had documented "problems" in Palm Beach County

Disinfection Alternatives 20-year Cost Overview (Net Present Value)

- Chlorine Gas w/scrubber building — $3,209,429
- Bulk Delivery -Sodium Hypochlorite — $5,025,775
- On-site Generation of Sodium Hypochlorite (0.8% ClorTec) — $5,371,290
- On-site Generation of Sodium Hypochlorite (12.5% Klorigen) — $6,174,320

Taste

(Coke v. Pepsi analogy)

Disinfection Alternatives Comparison

Advantages of Chlorine Gas

- Familiar to UD operation staff
- Significantly lower operational cost
- Operation and maintenance is simpler
- System is scalable to provide for higher chlorine demands

Disadvantages of Chlorine Gas

- Gas poses a greater public safety concern than liquid bleach

Disinfection Alternatives Comparison

<u>Advantages of Sodium Hypochlorite (liquid bleach)</u>

- Liquid bleach poses less public safety concerns than gas
- Public perception of safety
- Flexibility in storage/supply

<u>Disadvantages of Sodium Hypochlorite (liquid bleach)</u>

- Higher capital cost to construct systems
- Higher operation and maintenance cost compared to gas
- Hydrogen gas is generated as a byproduct and is highly explosive
- Higher complexity of operation for staff

Utility District Staff previously recommended the Chlorine Gas with scrubber system.

In my Professional opinion, I concur with Staff recommendation that a "State of the Art" Chlorine gas facility is a safe and most cost effective disinfection system for the WTP

Board Actions Required Today

<u>Disinfection Selection by Board</u>

- Approval of this agenda item would mean that the Utility District Board agrees with staff recommendation to utilize Chlorine Gas as the water disinfectant.

- A denial of this agenda item would mean that the Utility District Board desires to pursue Sodium Hypochlorite (liquid bleach) as the water disinfectant.

Questions ???