Conversion of Orange County Water Supply Facilities From Chlorine Gas to Sodium Hypochlorite Disinfection

Chuck DiGerlando, Pat DiVecchio, Rob Teegarden, Kim Kunihiro, Stan Keely, Chris Gayner, and Jacqueline W. Torbert

Orange County Utilities Water Division (OCUWD) is a water-supply utility with over 100,000 service connections. In response to growing concerns regarding security and to improve plant and neighborhood safety, OCUWD evaluated the use of alternative methods of disinfection to provide a safer means of disinfecting at its water facilities.

Chlorine gas has long been considered a safe, cost-effective means to produce active free hypochlorite for the disinfection of drinking water. Although history has shown relatively few catastrophic accidents related to the handling of this chemical, the potential exists. Also, these supplies are difficult to secure, considering the possibility of tampering during the transportation of the product and at the point of use. Using current detection systems, these chemicals produce undesirable emergency responses to the most routine of incidents, and the safety requirements now imposed for handling the product are time consuming, cumbersome, and costly.

The evaluation report's conclusions showed that maintaining the status quo using chlorine gas was the most cost-effective method of disinfection. The study also showed that the next most economical method of disinfection was the use of on-site bulk sodium hypochlorite feed systems (BFS). As a result, two separate projects were developed: first, to convert 11 of the subregional facilities by October 2003, and second, to convert the two regional facilities by the fall of 2004.

The purpose of these projects is to convert the existing gas chlorination systems to BFS without interrupting water-supply service to OCUWD customers. This process was selected in order to improve local neighborhood safety and operator safety and also to improve water quality.

The design team assembled the design criteria based on input from all members of the project team, including consulting engineers (WCG/Neel-Schaffer, Inc.), OCUWD engineers, and water-treatment plant personnel. The county water-supply facilities consist of Floridan well-water supply and ground storage. Most facilities tray aerate for H_2S removal and use sodium hydroxide for pH stabilization. The following qualitative design criteria were developed:

1. Pre- and post-tank chlorination.
2. Standardized skid-mounted feed systems
   a. Two self-contained skids provided for pre- and post-chlorination.
   b. Each skid has two prominent pumps, one working and one standby.
   c. Overpressure relief.
   d. Pulsation dampening.
   e. Combination calibration tube/Degas port to prevent buildup of carbonate off-gas.
3. Two Depolox 3+ analyzers–dual channel pre side chlorine residual/fluoride post side chlorine residual/pH.
4. Standardized high-density polyethylene (HDPE) tanks–substituted for cross-linked polyethylene after awarding construction contract.
5. Easily replaceable half-inch poly tubing hypochlorite injection lines piped through a two-inch conduit chase for ease of replacement.
6. Above-ground piping all UV-resistant PVC.
7. Drop point pre-injection point into the tank to reduce contact with water and eliminate the need for scale cleaning.
8. Suction line post injection point, to provide mixing in the pump and adequate chlorine control.
9. Dual contained tanks to speed up construction.
10. Mixing pump to suspend any settled solids within the tanks.
11. Chemical feed panels – Modicon Quantum PLCs connected to main PLC via fiber optic interface.
12. Stand-alone chemical buildings for facilities where tanks and pumps do not fit in existing chlorine facilities.
13. Temporary chlorine facilities for systems requiring demolition of existing chlorination facilities.
14. Tank design was based on 14 days of storage during the maximum-month flows. Metering pumps were sized based upon chlorine-to-hypochlorite dosage conversion and pacing with well and/or high-service pumps.

A modular approach to design was taken to improve the constructability of these systems and minimize down time at any single facility. This design also allows for uniformity between plants and interchangeable parts for repairs, thus reducing inventory.

Chuck DiGerlando, P.E., is a senior engineer for Orange County Utilities. Pat DiVecchio is a water production section manager for Orange County Utilities. Rob Teegarden, P.E., is a chief engineer for Orange County Utilities. Kim Kunihiro is a water quality manager for Orange County Utilities. Stan Keely, P.E., is a vice president with the consulting engineering firm WCG/Neel-Schaffer Inc. Chris Gayner E.I., is a project manager with Wharton-Smith Inc. Jacqueline W. Torbert is a water division manager for Orange County Utilities.

Other considerations were to reduce and simplify the maintenance of these facilities; such as drop-point chlorination and chlorine-tubing carrier pipe with pull boxes, for quick and inexpensive tubing replacement. Also, fiber-optic connections were selected to increase the speed and reliability with which existing plant-control PLCs communicate with the chemical-control PLCs.

The sodium hypochlorite feed pumps were sized using a qualitative analysis of past chlorine usage, coupled with jar testing. This data was valuable in determining the approximate size of feed pumps, even though it differed from actual dose rates observed in the field. One possible reason is that the jar-test chlorine demand samples taken at the pretreatment side of the facility had time to react with oxygen in the water prior to demand testing in the lab.

Facilities with significant raw-water sulfide concentrations historically exhibited higher chlorine demands on the pre-chlorination side of the reaction than were observed in the bench tests. Evidence supports the fact that oxygen takes five to 15 minutes to completely react with sulfide. Bench scale tests were conducted well beyond this period of time, differing from field conditions, where chlorine contact occurs almost immediately following aeration; therefore, field-observed chlorine demand at the pre-chlorination point typically required more chlorine than was predicted in the bench scale tests.

Control schemes were set to provide well-flow-paced chlorine addition at the pre-chlorination point. All points are assumed from historical well-flow data, not from digital input from a flow meter. A chlorination point is checked but is currently not used to do feedback control on the pre-chlorination point. The post-chlorination point is controlled based on flow-meter input and adjusted in increments of 0.1 units, based on input from the post-chlorine analyzer.

Lag times were adjusted to allow for complete mixing

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A number of modifications were made during construction that improved the overall value of the facilities both operationally and technically. The county evaluated the option of single-containment facilities with a constructed secondary-containment wall. Some of the retrofit facilities did not have sufficient room for the single tank plus constructed secondary containment; therefore, the county decided that all tanks would have built-in secondary containment for consistency.

Manufacturers of chemical tanks have standard sizes, but very few have common dimensions. It was found at a couple of facilities that the tanks could not fit in the proposed locations because dimensions different from the engineer's proposed tank. Thus, the tanks were downsized to fit the designated areas.

Metering pump skids were set up for both the pre and post ground storage tank. The pumps were designed to start with and match well or service-pump flows where appropriate, using an assumed dosage. For consistency and redundancy, the largest pump required, either pre or post, was selected for both skids. Unfortunately, this selection meant in some instances that the chemical feed pumps were greatly oversized, resulting in high turndowns during normal operation; therefore, it became necessary to downsize some of the pumps to use them in a more normal turndown range.

Specifically, the second post-side pump was replaced with a smaller pump. This allowed for adequate turndown during low flows. The larger pump was set to activate in the event of high flows. Although this did not provide the redundancy originally planned, it was decided that there was sufficient redundancy present in the dual point feed.

To measure storage-tank volume, a pressure transducer was installed on the pump outlet. During metering operation, some of the transducers provided erratic measurements. The county is in the process of changing the system to an ultrasonic depth measurement system in the tank to alleviate the variation.

All 11 BSF facilities were substantially complete by October 8, 2003. The systems were started in groups of three, with the first facilities in successful operation for over six months. The original contract was $2,577,000 with a final amount of approximately $2,552,000.

Based on the experience gained in this hypochlorite implementation project, the following specific design and operational recommendations will be considered for future hypochlorite facilities:

1. Dosage rates were found to vary from gas chlorine and batch tests. It is recommended that pump platforms be designed to allow the metering pumps to be exchanged once the system is operational. Pump selection can then be accomplished by either installing a temporary operation or establishing an exchange with the supplier after the permanent system is stabilized.
2. Gas bubbles within the hypochlorite product found areas to collect. Particularly, fittings on the suction side of the metering pumps collected gas pockets that air-locked the pumps. Operationally, the calibration tube was left open, allowing gas to escape from the suction piping. Also, a suction-side cross fitting caused significant gas build-up. That fitting was tapped to allow gas to vent. It is important to minimize fittings between tanks and metering pumps. In addition, the piping should be sloped sufficiently to allow gas to migrate back to the tank once pumping is shut down. To help facilitate the release of the gas, the control scheme was modified to open the vent solenoid valves each time the pumps were given a pacing signal.
3. The PLC control system for the BFS system provides a flexible operation as well as ease

Table 1.1
Comparison of Water Quality Parameters Before and After Hypochlorite Conversion at Point of Entry and At Distribution Locations

Parameter	Concentration Before Hypochlorite Conversion at Point of Entry	Concentration After Hypochlorite Conversion at Point of Entry	Increase/ Decrease At Point of Entry	Concentration Before Hypochlorite Conversion in Distribution System	Concentration After Hypochlorite Conversion in Distribution System	Increase/ Decrease in Distribution System
Total Dissolved Solids (mg/L)	209.0	277.0	68.0	207.8	209.6	1.8
Conductivity (uhmos/cm)	341.7	435.7	94.0	338.9	331.9	-7.0
pH (SU)	7.70	8.15	0.45	7.80	8.00	0.2
Chloride (mg/L)	16.6	25.7	9.1	17.0	20.0	3.0
Sulfate (mg/L)	28.0	29.1	1.1	14.1	17.1	3.0
Total Alkalinity (mg/L as $CaCO_3$)	133.3	176.0	42.7	145.0	140.1	-4.9
Calcium (mg/L)	49.0	57.4	8.4	48.9	44.7	-4.2
Sodium (mg/L)	11.7	20.0	8.3	12.5	16.1	3.6
Total Haloacetic Acids (ug/L)	19.0	13.0	-6.0	30.5	34.4	3.9
Total Trihalomethanes (ug/L)	13.0	29.1	16.1	34.8	37.2	2.4

This represents average data from 11 point-of-entry locations and 44 distribution locations.

of SCADA operation; however, the operating software must make certain assumptions on dosage and hypochlorite strength. During start-up, the dosage assumptions were continuously modified.

4. Chlorine analyzer control loop logic was not effective on the pre side due to the detention time in the GSTs. Thus, it was used primarily as an indication. Residual control on the post side was more effective, as responses to changes were almost immediate.
5. Metal contact with hypochlorite resulted in some corrosion issues. In particular, the flexible coupling between the storage tank and secondary containment utilized hastelloy bolts. They almost immediately began to dissolve when coming into contact with the hypochlorite. These bolts were changed to titanium, which is resistant to hypochlorite.
6. The tank storage transducers also had a stainless steel face, which began to corrode. A rubber membrane was installed that protected the metal seat from the hypochlorite. Eventually, these transducers will be replaced with the ultrasonic depth-measurement system mentioned earlier.
7. The strength of the hypochlorite is maintained by scheduling deliveries of fresh product every three to four weeks.

Pre- and post-hypochlorite sampling was conducted at the point of entry and in the distribution system for all plants. Eighty-five different parameters were analyzed for each location. The testing included primary and secondary drinking-water standards, disinfection byproducts, total organic carbon, and volatile organics. Most of the data was unchanged after the hypochlorite conversion; however, **Table 1.1** represents a summary of the selected parameters that changed.

Some initial water-quality changes were apparent after the addition of hypochlorite. The most obvious change was the elimination of caustic feed at the plants. The higher pH of the hypochlorite is sufficient to increase the finished-water pH to the county's target for corrosion control.

Total trihalomethane (TTHM) formation was also a consideration when selecting this process. A desired benefit was a reduction in TTHMs using sodium hypochlorite. Testing to date in the distribution system has not shown a significant reduction in TTHMs. In addition, potential strategies are being evaluated to reduce contact time through the tank, which may effectively reduce TTHM formation overall in the system.

Water-quality results have been above expectations, and not having to store and feed caustic is an unforeseen benefit. Operation and maintenance personnel are enthused about the conversion because they no longer have to deal with gaseous chlorine and now have one less chemical (NaOH) to handle. Nuisance alarms that cost time and money, both for OCUWD personnel and the fire departments who must respond, have been eliminated.

This project has been a complete success. Communication and coordination by operations, engineering, consultants, equipment suppliers, and the construction contractor throughout the project resulted in implementation on time and below budget.