

Lessons Learned During the Design, Construction, Start-Up, and Validation Testing of a 20 MGD LP-HI UV Disinfection System

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ABSTRACT

As part of a \$65 million expansion and regulatory compliance program, the City of Manteca (City) replaced the existing chlorine contact tank at the 10 mgd Wastewater Quality Control Facility (WQCF) with tertiary filtration and UV disinfection. Design, construction, start-up, and validation of the UV system represented a unique challenge considering the on-going evolution of state/local design and approval requirements while meeting a compliance/construction schedule in the midst of a major plant renovation. Lessons learned by the City-designer team are presented in this paper with an eye toward streamlining the project delivery process, avoiding costly delays during construction, and fast-tracking regulatory approvals.

KEYWORDS: UV disinfection, regulatory approvals, validation protocol

INTRODUCTION

The use of UV disinfection is becoming more common in California, particularly at treatment plants that discharge to surface waters or are part of an urban reclamation program. UV disinfection systems vary considerably from vendor to vendor and because of their uniqueness force an owner/engineer to select a specific manufacturer early in the design process. Pre-selection of the UV system supplier, however, creates an opportunity for plant operational staff, design engineer, and equipment supplier to partner through the procurement, installation, testing, commissioning, and approval steps. The development of this partnership becomes critical when construction contractors and water quality regulator demands are superimposed as part of the project delivery process. For the City of Manteca (City), project delivery extended over a five-year period, concluding ultimately with the successful start-up, commissioning, and validation of a 20 mgd Wedeco TAK-55HP, low pressure-high intensity system.

BACKGROUND

The City discharges tertiary effluent to the San Joaquin River near Stockton in Northern California. The WQCF is a 10 mgd activated sludge-biofilter plant that has been recently upgraded to full nitrification and tertiary filtration. Chlorination and dechlorination of secondary effluent had been accomplished historically with chlorine and sulfur dioxide gas utilizing a converted sedimentation basin as a chlorine contact tank. Because of poor hydraulics and a nitrified effluent, satisfying NPDES coliform requirements consistently with conventional chlorination practices had proven difficult. As part of the \$65 million Phase III expansion and

upgrade of the Manteca WQCF, the City replaced the existing chlorine contact basin with tertiary filtration and UV disinfection. Following completion of the Phase III Project, tertiary effluent from the plant is suitable for unrestricted reuse in accordance with California Title 22 reclamation criteria and meets the requirements of a new NPDES permit. A process flow diagram of the Manteca WQCF is presented in Figure 1.

DESIGN/CONSTRUCTION CONSIDERATIONS

The design phase for the UV disinfection system focused upon equipment selection, development of a facility consistent with operational staff objectives, and designer-vendor activities to minimize potential field construction issues. Superimposed on these design activities was the requirement that the system be compliant with National Water Research Institute (NWRI) guidelines for ultraviolet disinfection. Each activity is discussed below.

Equipment Selection

While there are a number of UV disinfection systems that comply with NWRI guidelines for a series of specific water quality parameters, the owner/engineer faces the challenge of selecting the superior alternative for the desired conditions and then designing the appropriate infrastructure.

Early selection of the specific UV disinfection system in design is recommended because reactor configurations, electrical requirements, footprint for ancillary facilities, and control options vary widely between suppliers. If a selection is not made during preliminary design, then the engineer is required to prepare multiple construction documents to reflect differences in manufacturers and appurtenant equipment. Without the appropriate level of design detail for each alternative, the engineer then relies upon a prospective general contractor to sort out the nuances between suppliers along with the differences in supporting infrastructure during the bidding phase. Unfortunately, many contractors are either unwilling or unable to invest the required level of effort and will instead prepare a bid based on the “apparent” lowest price negotiated with a supplier. While acquisition of the desired UV disinfection system can certainly occur in this fashion, considering the likely significant capital investment and engineering resources associated with the design of this key plant facility, every effort should be made to acquire the owner/engineer selected alternative rather than the prospective contractor’s choice.

To ensure procurement of the preferred UV disinfection system for the City, selection of the equipment supplier occurred during the preliminary design phase. Selection was part of a formal prequalification process that considered a number of factors, including:

1. Site visits to similarly sized operating facilities
2. Historical performance data
3. Pilot study results or side by side comparisons
4. Status of conditional approvals from health department agencies including the California Department of Health Services (DHS), now known as the California Department of Public Health (CDPH).
5. Desk top evaluations of alternative supplier design proposals

6. Layout drawings depicting equipment components, elevations, and structural elements
7. Budgetary costs

Three vendors participated in the prequalification process and submitted comprehensive proposals for a system designed to treat a peak flow of 20 mgd. Following review of the proposals by the City-designer team, Wedeco was selected as the preferred supplier.

Facility Design

Although the NWRI guidelines provide a template for system design, site specific criteria were developed by the design team. The suitability of a UV disinfection achieving water quality goals with a specific wastewater was established through a combination of collimated beam testing and pilot studies. At Manteca, particle size analysis of filtered wastewater was conducted to ensure that downstream disinfection practices were not compromised by particle shielding.

Transmittance levels were also monitored for an extended period to confirm long-term values consistent with the NWRI guidelines and to provide sufficient information to Wedeco for actual system sizing and selection.

In parallel with development of design criteria, the design team consulted extensively with Wedeco regarding reactor configuration. Only reactor configurations and equipment features that had previously passed CDPH scrutiny were considered. Validation reports submitted to the then DHS by Wedeco to obtain “conditional approval” were reviewed to verify applicability for specific design conditions. System sizing then fell within the scale-up criteria in the validation report including all hydraulic loading or velocity ranges. Ultimately, the development of design criteria was a multi-step process that included:

1. Collimated beam tests conducted by the University of California-Davis to determine required UV dose;
2. Three week pilot study to collect data on wastewater transmittance and to determine the feasibility of UV disinfection;
3. Site visits to full-scale operational facilities in California and the United Kingdom;
4. Particle-size distribution analysis as part of six-week filterability study of secondary effluent; and,
5. Review of validation reports for specific UV reactor designs submitted by Wedeco.

The results of these activities are presented in Table 1 as the design criteria for the UV disinfection system constructed at the Manteca WQCF.

Table 1. Design Criteria for Ultraviolet Light Disinfection System at Manteca WQCF.

Item	Units	Value
Average flow	Mgd	9.87
Peak flow	Mgd	19.15
Total coliform limit, 7-day median	MPN/100 mL	2.2
UV transmittance	%	55
Minimum dose	mJ/cm ²	100
Channels	ea	2
Banks, per channel	ea	5
Lamps, total	ea	2,340
Output, per lamp	W	150
Power consumption, peak flow	kW	646

Operator input was also critical to facility design. By visiting full-scale facilities and cataloging desired features, a laundry list of “musts” and “maybes” were created. This information served as an agenda for subsequent face-to-face workshops between Wedeco technical support staff and the design team to “work-out” specific features and site adaptations. The interactive process resulted in a number of “add-ons” to the standard product offering and satisfied operator requests for:

1. Convenient removal of lamp modules
2. Easier access to individual banks of lamps
3. Fewer potential safety hazards due to routing of power/instrumentation cabling
4. Greater compatibility of vendor-supplied PLCs with plant-wide systems
5. More robust data logging to facilitate regulatory reporting
6. Increased flexibility in the shunting of water during normal and emergency events

By engaging operational staff directly with the systems supplier during design, augmented through site visits to full-scale facilities, not only were City objectives met effectively, but owner-requested changes were minimized during construction.

Designer-Vendor Team Activities

Because of the magnitude and complexity of the UV disinfection system, designer-vendor coordination extended beyond the traditional roles. Following selection of Wedeco, the design team worked closely with the manufacturer to determine detailed infrastructure requirements particularly related to power, instrumentation, and control. This iterative process included development and review of preliminary shop drawings, equipment specifications, and control

strategies. A specific scope of supply and firm fixed price were negotiated and folded into the final construction documents clearly delineating manufacturer/contractor responsibilities. By negotiating the scope of supply and then identifying contractor work elements in design, surprises in the field during construction were minimized and a relatively seamless transition between manufacturer and contractor was achieved.

To further expedite or fast-track the procurement process, the City-design team retained Wedeco to prepare shop drawings under a separate contract in advance of the construction contract. To ensure that the manufacturing staff was engaged, pre-submittal meetings were conducted at the factory with the design team. This resulted in a more complete shop-drawing submittal and expedited subsequent design team review. Because the fabrication and delivery of UV equipment typically represented a long lead time item, by jump-starting the process, the overall procurement timeline could be shortened by allowing for shop drawing submittal/review and early release of an equipment order. The timing of equipment deliveries was then better coordinated with the installation contractor and potential delays were avoided. Use of this two step procurement process also had the advantage to the engineer of confirming actual system details through the shop drawing review process prior to execution of the final construction documents.

REGULATORY AGENCY ACCEPTANCE PROCESS

In California, before a UV disinfection system may become operational, a series of approvals are necessary from the CDPH. Specific equipment parameters are accepted by CDPH following a rigorous testing and validation process. Field testing and commissioning of full-scale systems are then required to demonstrate equivalence to previously validated equipment. A discussion of the regulatory acceptance process for the Manteca UV disinfection system is presented below, along with the associated schedule constraints.

Critical Construction Milestone - Cutover From Chlorination to UV Disinfection

Construction of the UV disinfection system was part of a larger treatment plant upgrade project that extended over a two year period at the Manteca WQCF. The UV disinfection system was intended to replace the existing chlorination-dechlorination system that was required for discharge to the San Joaquin River. Replacement of the system was also tied to a compliance schedule within a new discharge permit for the plant. CDPH required that the UV system undergo performance testing including validation and field commissioning before allowing the discontinuation of the practice of chlorination-dechlorination at the plant. This superimposed an additional constraint within the construction contract and created the potential for contractor delay should testing and commissioning experience any hiccups from an approval perspective. The window for accomplishing testing and commissioning was also narrow because of other operational constraints that limited where plant effluent could be routed on a seasonal basis. Because these schedule constraints were recognized early on in project development, outreach to the regulatory community was initiated well in advance of the mandatory milestones.

Summary of Coordination Activities

Extensive outreach to the CDPH occurred during both design and construction of the UV disinfection system. Coordination with CDPH during design focused on monitoring staff review and approval of the validation studies submitted by Wedeco for the TAK-55HP unit. While the

supplier took the lead in obtaining CDPH acceptance of hydraulic loading rates and dosing requirements, the design team observed the full-scale field testing used to establish the hydraulic limits of the TAK-55HP reactor configuration, reviewed the application of the NWRI guidelines with the vendor validation team, and confirmed with CDPH staff that the design of the Manteca system was consistent with draft and final NWRI guidelines.

Following acceptance of the validation and full-scale field testing studies of the TAK-55HP by CDPH at the state level, coordination activities shifted to the district level CDPH office. As envisioned in the new discharge permit for the plant, final operational approval of the disinfection system rested with district CDPH staff. Recognizing that the Manteca UV disinfection system would be the first site accepted formally by the local district staff, a long-term, incremental step approach was implemented. As summarized in Table 2, outreach was initiated 18 months in advance of the desired final outcome.

Table 2. Summary of Coordination Activities/Project Milestones with California Department of Public Health.

Date	Action	Objective
November 2005	Submit draft Field Testing Plan	Confirm framework for field testing
December 2005	Submit final Engineering Report for Production, Distribution, and Use of Reclaimed Water (Title 22 Report)	Demonstrate consistency with Title 22 regulations and NWRI guidelines
January 2006	Submit final Field Testing Plan	Continue process of engaging CDPH staff
March 2006	Respond to CDPH comments regarding Title 22 Report and Field Testing Plan	Vet potential concerns from CDPH staff
August 2006	Meet with CDPH staff to discuss the response to comments	Respond to concerns and set context for subsequent submittals
April 2007	Submit draft Check-Point Bioassay Protocol	Obtain approval for validation procedures
June 2007	Submit final Check-Point Bioassay Protocol	Incorporate CDPH staff input
August 2, 2007	Submit Summary of Results of Check-Point Bioassay	Demonstrate that equipment performance is consistent with previously validated system
August 9, 2007	Submit Field Commissioning Report	Demonstrate system reliability
August 10, 2007	Meet with CDPH staff to discuss the Field Commissioning Report and cutover from chlorination facilities	Vet any final staff concerns and identify additional information requirements
August 16, 2007	CDPH staff formally concur with plan to discontinue use of chlorination facilities and rely upon the UV disinfection system	Cutover to UV system

Because local CDPH staff did not have extensive experience with UV disinfection systems, the design team approach to obtaining approvals emphasized the following:

1. Clearly demonstrating that the design of the system was consistent with all NWRI guidelines particularly provisions for reliability and redundancy
2. Carefully documenting that the design of the system was within the range of accepted values from previous validation studies
3. Crafting a protocol for field validation based on successful performance testing accomplished at other plants
4. Recognizing that the CDPH staff viewed their acceptance of the system as a two-step process: confirmation that equipment performed within the approved validation range and operational experience demonstrating reliability

PERFORMANCE TESTING AND COMMISSIONING

Lessons learned during performance testing and commissioning of the UV disinfection system are summarized below.

Check-Point Bioassay

The performance of the UV disinfection system was verified in a check-point bioassay. For reference, a checkpoint bioassay is an abbreviated version of the biological validation procedure presented in the NWRI Guidelines. The check-point bioassay approach was selected versus a velocity profile study for the following reasons: 1) a check-point bioassay provides actual inactivation data for an installed UV disinfection system that can be compared to inactivation data collected during previous off-site validation studies; 2) uniform hydraulic conditions do not necessarily indicate that adequate disinfection is achieved, and hydraulic irregularities do not necessarily lead to sub-par disinfection; 3) laboratory staff with advanced training in microbiology were available at the Manteca WQCF; 4) regulatory agency staff seemed to prefer and be comfortable with the check-point bioassay approach for confirming the performance of installed UV disinfection systems.

A protocol for the check-point bioassay was prepared in accordance with applicable sections of the NWRI Guidelines as modified in previous UV system performance testing and submitted to CDPH staff. CDPH staff reviewed and accepted the protocol, and testing occurred in July 2007. In general, testing followed the accepted protocol. Several procedural modifications (involving flow rates, additional tests, and analysis of collimated-beam results) were made prior to the check-point bioassay and during the check-point bioassay.

Considering the importance of the test and the limited window for the schedule, opportunities were provided for operators, laboratory personnel, and engineering support staff to practice achieving and maintaining test conditions. The practice sessions were held approximately one week before testing began. All test conditions and procedures were simulated. Test flow rates

were produced and maintained, the target UVT of 55 percent was attained, UV disinfection systems were operating, samples were collected, and instruments and laboratory equipment were used.

Numerous communication, transportation, and coordination issues were encountered and resolved during the practice sessions. Many were associated with the size and layout of the WQCF. Personnel involved in achieving and monitoring the operational conditions were: 1) in the laboratory, 2) on the deck above the cloth disk filters, 3) near the UV disinfection equipment, 4) in the control room, and 5) moving between these locations. Test results, especially UVT results from a benchtop spectrophotometer, were communicated to team members as they became available. Radios and cellular devices were used extensively. A small vehicle (golf cart) was needed for transporting samples and people during the tests. The lessons learned during the practice sessions were instrumental in the subsequent successful testing.

Each channel within the UV disinfection system was tested at the minimum, average, and maximum design flow rates. Testing conditions are summarized in Table 3. In addition, two tests (Test I and Test J) were performed at an alternative minimum flow rate. A quality control test was also conducted.

Table 3. Manteca WQCF - UV Disinfection System Check-Point Bioassay Summary of Testing Conditions^a.

Test ID	Channels Tested	Target Flow per Channel, gpm
QC	No. 1	6,652
A	No. 1	1,875
B	No. 1	3,431
C	No. 1	6,652
D	No. 2	1,875
E	No. 2	3,431
F	No. 2	6,652
G	No. 1 and No. 2	3,431
H	No. 1 and No. 2	6,652
I	No. 1	2,486
J	No. 2	2,486

^a Single-channel tests using an alternative minimum flow rate were added while the check-point bioassay was in progress. The alternate minimum flow rate was equivalent to approximately 11.1 gpm/lamp.

During all of the tests, the target UVT was 55 percent, the target influent MS-2 bacteriophage concentration was $10^5 - 10^6$ pfu/mL, and the power setting for operating banks was 100 percent. The quality control test was conducted with no operating banks. Instant coffee was used for UVT

adjustment. The MS-2 bacteriophage seed stock was prepared by Biovir Laboratories, Inc. (Biovir).

Several steps were taken to ensure that conditions would be stable during the tests. All of the tertiary filters were backwashed prior to each test. During the tests, all of the tertiary filters were operating simultaneously. In accordance with the NWRI Guidelines, a mixing and stabilization period of at least five empty-bed contact times was allowed to elapse prior to sampling. Information regarding the mixing and stabilization periods is provided in Table 4.

Table 4. Manteca WQCF UV Disinfection System Check-Point Bioassay Required Mixing and Stabilization Periods.

Hydraulic Condition	Total FSE Flow Rate, gpm	UV Disinfection System Flow Rate, gpm per channel	Estimated Empty-Bed Contact Time^a, min	Required Mixing and Stabilization Period^b, min
Min. flow, one UV channel	1,875	1,875	13.5	67.5
Alternative min. flow, one UV channel ^c	2,486	2,486	10.2	51.0
Ave. flow, one UV channel	3,431	3,431	7.4	35.0
Ave. flow, two UV channels	6,862	3,431	6.2	37.0
Max. flow, one UV channel	6,652	6,652	3.8	19.0
Max. flow, two UV channels	13,304	6,652	3.2	16.0

^a Theoretical residence time in the pipeline from filters to UV disinfection system plus theoretical residence time in the UV disinfection system with lamp assemblies removed.

^b The required mixing and stabilization time is equal to five empty-bed contact times.

^c Single-channel tests using an alternative minimum flow rate were added while the check-point bioassay was in progress. The alternate minimum flow rate is equivalent to approximately 11.1 gpm/lamp.

The following system parameters were monitored during the check-point bioassay: flow rate, UVT, UV intensity, turbidity, chlorine concentration, temperature, and water level. Data were collected using bench-top instruments and on-line analyzers.

In one sample of UV influent collected during the check-point bioassay, total chlorine was detected at a concentration of 0.14 mg/L. A free chlorine analysis was not performed on this sample. However, all available information (including operational logs, operational procedures, operational configuration of the WQCF, quality control test results, results of free chlorine concentration analyses, and all other check-point bioassay data) suggested that chlorination was not occurring at the WQCF and the UV influent contained no free chlorine. Total chlorine was not detected in any other samples collected during the check-point bioassay.

Two UV influent samples were collected and delivered to Biovir for collimated-beam analysis. The samples were divided, and a collimated-beam apparatus was used to apply UV doses ranging from zero to 100 mJ/cm². The observed MS-2 bacteriophage dose-response was within applicable USEPA bounds. Check-point bioassays performed at other facilities prior to November 2006 used bounds from the NWRI Guidelines for checking and validating MS-2 bacteriophage dose-response. Because the USEPA bounds were published more recently and include references for the data upon which the bounds are based, they were utilized in the Manteca WQCF check-point bioassay. A linear regression of the collimated-beam results yielded the following dose-response equation:

$$\text{Inactivation} = 0.045 \times \text{UV Dose} + 0.032 \quad (R^2 = 0.989)$$

Average delivered UV doses were calculated for each test using influent and effluent MS-2 bacteriophage data and the dose-response equation above. All tests were performed with one bank of lamps operating in each UV channel, and each UV channel is equipped with five banks of lamps.

Samples were chilled immediately to 4°C and analyzed within 24 hours by technicians in the laboratory at the Manteca WQCF. As discussed in the NWRI Guidelines, USEPA Method 1602 was used to enumerate MS-2 bacteriophage in the influent and effluent samples. Use of an on-site laboratory had numerous benefits, including: 1) prompt analysis; 2) short chains of custody; 3) minimal transport of samples; and, 4) rapid reporting of results.

After completing the check-point bioassay tests, the average UV dose results from the check-point bioassay were compared to UV dose results from the 2003 validation study. A performance equation (based upon a multiple linear regression of data from the 2003 validation study) was utilized to accomplish this comparison. UV doses calculated using the performance equation deviated from the actual average UV doses observed during the 2003 validation study, and the range of deviations was -17 percent to +28 percent. For each condition tested during the Manteca WQCF check-point bioassay, a UV dose was predicted using the performance equation. The difference between the predicted UV dose and the actual average UV dose observed at the WQCF was computed and compared to the range of deviations observed during the 2003 validation study.

Test A and Test D were conducted at the design minimum flow rate and yielded average UV dose results that were not sufficiently similar to UV dose results from the 2003 validation study. The flow rate used in Test I and Test J was greater than the design minimum flow rate and was chosen during the check-point bioassay in an attempt to identify a flow that is 1) less than the average flow and 2) yields average UV dose results that do not deviate excessively from validation-predicted UV doses. UV dose results from Test I and Test J were sufficiently similar to the validation-predicted UV doses. Based upon the results of the check-point bioassay, performance of the UV disinfection system was deemed consistent with validation performance at flow rates ranging from 3.58 mgd to 19.15 mgd.

Commissioning Tests and Results

The check-point bioassay was part of a larger formal commissioning process that began on June 19, 2007, after completion of pre-operational check-out and start-up activities. During commissioning, all components of the UV disinfection system were operated over a wide-range of hydraulic conditions. The focus of the commissioning period was to test systems to the maximum extent, vet potential operating issues, and de-bug controls and alarms. A description of the commissioning period and the results of performance testing are provided below.

From June 19 to August 1, 2007, the UV disinfection system was in operation and treating filtered effluent for more than 870 hours. Operational data collected during the period are presented in Table 5. The system was in operation 23 or more hours per day, seven days per week, for the last two weeks of the period. Channels in service and flow rates were varied by operations staff throughout the period. The maximum and minimum flow rates were approximately 2.7 mgd and 19.8 mgd. While check-point bioassay tests were being performed (June 19 and July 3, 5, 6, and 24), UVT was adjusted to approximately 55%. The average unadjusted UVT during the commissioning period was approximately 81%.

Water levels within the channels were automatically controlled by effluent weir gates and continuously monitored using ultrasonic level sensors. Gate control systems and water level sensors performed as designed, maintaining necessary lamp submergence and (when two channels were in use) evenly distributing flow between channels. Based on signals from ultrasonic level sensors, flow rate differences between Channel 1 and Channel 2 were insignificant when both of the channels were in use.

Table 5. Operational Data Collected During Commissioning June 19 - August 1, 2007.

Date	Channels in Service	Hours of Operation	Flow, mgd		Transmittance, %			Minimum Water Level, inches
			Ave	Max	Min	Ave	Max	
6/19/2007	1,2	18	4.04	10.08	58	73	100	36.4
6/21/2007	1,2	15	4.04	6.02	75	77	98	36.0
6/22/2007	1,2	23	4.04	19.80	74	77	78	35.9
6/25/2007	1,2	15	7.51	16.61	79	84	100	36.0
6/26/2007	1,2	7	11.78	18.67	78	89	100	36.1
6/27/2007	1,2	10	5.40	18.81	80	81	100	35.4
6/28/2007	1	24	4.04	5.06	78	80	81	36.6
6/29/2007	1	24	4.19	6.23	63	80	84	36.5
6/30/2007	1	24	2.65	2.97	78	81	83	36.6
7/1/2007	1,2	23	2.88	3.39	80	82	85	36.7
7/2/2007	2	20	3.74	6.18	82	83	100	35.9
7/3/2007	1,2	15	5.30	11.05	64	83	100	36.2
7/5/2007	1,2	15	5.02	18.33	52	87	100	35.0
7/6/2007	1,2	24	5.19	17.21	56	82	100	35.7
7/7/2007	2	24	3.80	3.98	84	85	86	36.6
7/8/2007	2	24	3.80	3.99	85	85	86	36.6
7/9/2007	2	24	3.85	6.26	85	85	100	35.7
7/10/2007	1,2	24	3.88	10.06	85	85	100	36.0
7/11/2007	2	22	6.62	6.19	74	82	100	36.1
7/12/2007	1, 2	24	3.70	6.36	74	75	87	36.5
7/13/2007	1, 2	24	4.15	6.19	66	77	97	36.0
7/14/2007	1	24	4.05	4.21	72	76	81	36.6
7/15/2007	1	24	3.14	4.22	68	81	83	36.6
7/16/2007	1	24	4.44	8.69	75	78	98	36.1
7/17/2007	1	23	6.01	6.22	75	76	97	35.9
7/18/2007	1, 2	24	4.13	6.17	73	76	98	35.7
7/19/2007	1, 2	24	2.55	2.74	74	77	81	36.4
7/20/2007	2	24	2.88	3.25	77	78	79	36.6
7/21/2007	2	23	3.35	3.72	78	78	79	36.6

Table 5 (continued). Operational Data Collected During Commissioning June 19 - August 1, 2007.

Date	Channels in Service	Hours of Operation	Flow, mgd		Transmittance, %			Minimum Water Level, inches
			Ave	Max	Min	Ave	Max	
7/22/2007	2	24	2.79	2.98	78	79	80	36.6
7/23/2007	2	23	3.67	4.24	78	79	80	36.6
7/24/2007	1,2	24	3.94	5.27	17	77	95	35.8
7/25/2007	1,2	23	4.29	4.84	79	81	100	35.8
7/26/2007	2	23	4.53	4.76	80	81	85	36.1
7/27/2007	2	24	4.53	4.76	82	83	87	36.1
7/28/2007	2	24	4.25	4.71	83	84	85	36.4
7/29/2007	1,2	24	3.69	4.23	80	85	96	35.9
7/30/2007	1	24	3.67	4.21	82	85	95	36.4
7/31/2007	1,2	23	4.04	4.27	82	84	100	35.8
8/1/2007	2	23	3.98	4.24	84	85	87	36.4
Total		872						

The UV disinfection system incorporated a number of alarms that provided useful information to operational staff. These alarms triggered either an automatic sequence or necessitated manual activities. A summary of alarms, categorized as either “high priority,” “low priority,” or “other” is presented in Table 6.

Table 6. Alarm Conditions Monitored in UV Disinfection System.

	High Priority Alarms	
Adj. Lamp Fail	Low Level	Multi Lamp Fail
Dose Fail	Low UV	Total Lamp Fail
High Level		
	Low Priority Alarms	
Lamp Fail	Low Level Warning	UV Transmittance Low
Low Dose	UV Low Dose	
	Other Alarms	
24VDC Fail	Outlet Gate FtO	UV Influent Flow Out of Range
Ballast High Temp	Outlet Gate Fully Closed	UV Meter Fail
Cabinet High Temp	Outlet Gate Not in Remote	UV Power Fail
Comms Fail	Phase Loss	UV System Flow Less Than Design
Module Lifted	Surge Suppressor Fail	UV System Off
Module Not Connected	UV 24VDC Fail	Wiper Not at End
Outlet Gate FtC	UV Compressor Low Pressure	Wiper Not at Rest

An extensive de-bugging process was undertaken during commissioning. Based on internal and external inputs to the system, alarms were triggered to trouble-shoot specific components. An emphasis was placed initially on adjusting mechanical system components, particularly wiper systems, lamp module supports, inlet/outlet gates, compressors, and hydraulic elements. As problems with these components were corrected during Weeks 1-3, the focus then shifted to electrical, instrumentation, and data acquisition issues. The balance of instrumentation and control de-bugging occurred during Weeks 4-6 and was timed to occur with other plant-wide start-up activities, particularly emergency power systems. A numerical summary of discrete alarms is included in Table 7 and reflects the level of system testing accomplished during the shake-down period.

Table 7. Discrete Alarm Records by Week During UV Commissioning.

Week	High Priority	Low Priority	Other	Total
6/19/07-6/23/07	22	33	227	282
6/24/07-6/37/07	52	72	38	162
7/01/07-7/07/07	40	104	88	232
7/08/07-7/14/07	24	72	200	296
7/15/07-7/21/07	60	75	111	246
7/22/07-7/28/07	58	39	266	363
7/29/07-8/07/07	72	39	432	543
Totals	328	434	1,362	2,124

All instruments associated with the UV disinfection system were calibrated before commissioning began including: the electromagnetic UV influent flow meter, the on-line UVT analyzer, the UV intensity sensors, and the ultrasonic water level sensors. Calibrations occurred prior to installation and during pre-operational checkout. During preliminary testing, calibrations were verified.

During commissioning, differences were observed between UVT values from the on-line UVT analyzer and UVT values from the bench-top spectrophotometer located in the WQCF laboratory. The on-line UVT analyzer was re-calibrated in accordance with manufacturer instructions.

UV disinfection system influent and effluent water quality data are presented in Table 8 and Table 9, respectively. The following influent parameters were monitored: UVT, suspended solids, BOD, ammonia, turbidity, temperature, and chlorine concentration. Effluent samples were analyzed for coliform bacteria. All of the data in Table 8 and Table 9 are from analyses of grab samples.

The results in Table 8 and Table 9 and the operational data presented in Table 5 indicate that the UV disinfection system was challenged throughout the commissioning period and performed well. Transmittance and flow were adjusted to their respective design limits. The system was in operation for extended periods with Channel 1 only, Channel 2 only, and Channel 1 and Channel 2 simultaneously. Coliform bacteria results for effluent samples did not exceed applicable current and future limits set forth in the NPDES permit for the WQCF. For 13 of the 14 effluent samples analyzed for coliform bacteria during the commissioning period, the result (MPN) was >2/100mL. The coliform bacteria result was 4/100mL for one sample.

Table 8. UV Influent Water Quality Data Collected During System Commissioning.

Sample Date	Sample Time	Channel No.	Transmittance, %	SS, mg/L	BOD, mg/L	Ammonia, mg/L	Turbidity, NTU	Sample Temp, °C	Chlorine, mg/L	
									Total	Free
6/19/2007	1427	1	56.6	1.4		0.4	2.27	26.7	ND	--
6/19/2007	1700	1	56.9						--	--
6/19/2007	1820	1	56.8						--	--
6/25/2007	1400	2		1.4	ND	0.03	0.847	26.2	ND	--
6/26/2007	1315	1	79.9	0.6	ND	0.03	0.625	27	ND	--
6/28/2007	1125	1	78.6	1.2	ND	0.02	1.23	26.9	ND	--
6/29/2007	1255	1	70.8	0.8	ND	0.03	1.08	27.1	ND	--
7/2/2007	1430	2	74	1	ND	0.04	0.626	27.2	ND	--
7/3/2007									0.14	--
7/5/2007	1228	2	55.8					29.1	ND	--
7/5/2007	1437	1	57.7					29.1	ND	--
7/5/2007	1527	1,2	55.9					27.6	--	--
7/5/2007	1540	2	73.1	0.6	ND	0.02	0.446	27.2	ND	--
7/6/2007	1000	1	56.6					28.1	ND	--
7/6/2007	1100	2	57.2					28.5	ND	--
7/6/2007	1335	1,2	56.2					28	--	--
7/6/2007	1545	1	76.1	0.8	ND	0.01	0.442	27.4	ND	--
7/9/2007	1105	2	75.2	0.8	ND	0.03	0.484	27.4	ND	--
7/10/2007	1357	1	74.4	0.4	ND	0.02	0.613	27.6	ND	--
7/11/2007	1425	2	76.8	1.4	ND	0.02	0.738	27	ND	--
7/12/2007	1135	2	75.2	0.6	ND	0.02	0.701	27.1	ND	--
7/13/2007	1110	1	71.2	0.8	ND	0.04	0.779	27	ND	--
7/24/2007	948	1	58.8					26.1	ND	ND
7/24/2007	1100	2	58.2					26.3	ND	ND

Table 9. Results of Coliform Testing During UV Commissioning.

Sample Date	Sample Time	Channel No.	Coliform Concentration, MPN/100 ML
6/19/2007 ^a	1427	1	>1600
6/25/2007	1400	1,2	<2
6/26/2007	1315	1	<2
6/28/2007	1125	1	<2
6/29/2007	1255	1	<2
7/2/2007	1430	2	<2
7/6/2007	1545	1,2	<2
7/9/2007	1108	2	<2
7/10/2007	1351	1,2	<2
7/11/2007	1425	2	<2
7/12/2007	1135	1,2	4
7/13/2007	1110	1,2	<2
7/18/2007	1046	2	<2
7/19/2007	1138	2	<2
7/20/2007	930	2	<2

^aNo UV banks on.

CONCLUSIONS

Design, construction, start-up, and validation testing of the UV disinfection system at the Manteca WQCF presented a variety of opportunities and challenges. Major lessons learned by the City-designer team included the following:

1. A UV disinfection system vendor/manufacture should be selected and engaged during preliminary design. Obtaining UV equipment shop drawings during final design helps to prevent delays and coordination issues during construction.
2. A strong designer-vendor team should be formed and maintained from the design phase through the commissioning phase.
3. Laboratory and pilot-scale tests should be conducted to support the development of design criteria and ensure that selected UV equipment is compatible with upstream treatment processes.

4. Operator input and involvement should be encouraged. Specifically, operator participation in vendor meetings and full-scale facility visits is beneficial and helps to identify preferred features.
5. Effective communication and coordination with regulatory agency staff is critical and should occur in every stage of the project. Development of an overall testing plan and vetting test procedures/specifications with agency staff helps to eliminate surprises.
6. Biological and hydraulic approaches for verifying system performance should be considered carefully. A check-point bioassay has several advantages over velocity profile testing and can be helpful in finalizing operational limits. Careful examination of full-scale system performance at low flow rates is warranted.
7. At a larger wastewater treatment facility, performance testing procedures present many practical challenges. Completing one or more trial runs helps to resolve communication and transportation issues prior to testing.