UV Equipment Procurement and Bid Document Preparation

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ABSTRACT

UV disinfection systems for drinking water are offered by many different manufacturers in a variety of configurations. While variety provides benefit to customers allowing them to choose a more optimized system, this same variety creates challenges for UV equipment procurement and bid document preparation, which are critical steps in the overall success of a UV disinfection system project. Equipment procurement options are discussed in this article and a procurement method called the "Evaluated Bid Approach" is presented. Also discussed is the UV Cost Analysis Tool, or UVCAT, developed by Carollo Engineers, P.C., as part of a New York State Energy Research and Development (NYSERDA) project, and development of UV disinfection system specifications.

Keywords: procurement, specifications, selection, cost analysis, equipment

INTRODUCTION

UV disinfection technology has been evolving in the US from strictly wastewater applications to more frequent drinking water applications. There are many different UV disinfection systems currently available, and most are unique, requiring very specific design for proper application. The overall success of a UV project can be impacted negatively if the equipment installed is significantly different from the equipment on which the design was based. This problem can be avoided early on in the project through the equipment procurement procedure. Carollo Engineers (Carollo) uses an alternative equipment procurement approach referred to as an *evaluated bid*, and has developed a UV Cost Analysis Tool (UVCAT) and our UV equipment specification to facilitate this approach. The *evaluated bid* approach to UV equipment procurement, the UVCAT tool, and guidelines for UV system specifications will be presented in this article. The 'traditional design/procurement approach', illustrated in Figure 1, may not be the best approach for UV system design because commercial UV disinfection systems have important differences, as listed in Table 1, that can significantly impact that design.

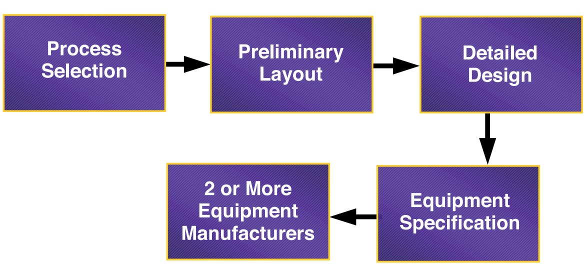

Figure 1. *Traditional Design Approach*

These differences make it difficult to carry out a detailed design that is open to all commercial UV reactor product lines. Even when narrowing the field to two or three manufacturers, there can be substantial differences among the equipment.

Table 1. *UV System Features that Impact Design*

Feature	Impact
Lamp Type	Power Supply
Headloss	Location, Pumping
Reactor Validation	Inlet/Outlet Piping
Footprint	Location, Building Size
Cleaning System	Water Quality, O&M

UV EQUIPMENT PROCUREMENT

Four of the more common equipment procurement options are:

- Design/bid (traditional)
- Sole source
- Base bid
- Pre-purchase

A fifth equipment procurement option called the *evaluated bid* approach can be used. This approach allows UV systems to be evaluated competitively before detailed design begins. With this approach, one UV system is selected from the proposed systems to serve as the Basis of Design.

Key benefits to an *evaluated bid* procurement process include:

- Competitive bids result in a fair price
- Cost comparison is based on total life cycle costs
- Additional metrics such as validation testing, installation history, and performance can be evaluated
- Single UV manufacturer selected early in design phase

The *evaluated bid* process is illustrated in Figure 2. The Design Proposal Request sent to UV manufacturers includes the following requests for information:

- Equipment specification
- Preliminary layout
- Evaluation criteria/analysis description
- Request for UV system information

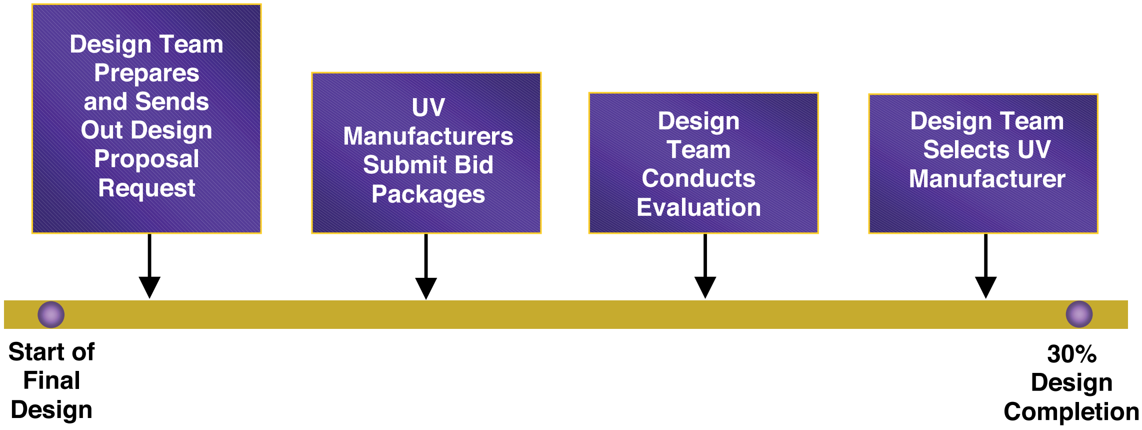

Figure 2. *Evaluated Bid Approach to UV System Procurement*

General and site-specific UV system performance and design criteria are given to the manufacturers. An example of the criteria sent to manufacturers for a Carollo UV disinfection system project in Tracy, CA is presented in Table 2.

Table 2. *Example UV System Peformance Criteria*

Criteria	Tracy UV System
UV Dose, mJ/cm^2	40
UV Transmittance, %	90
System Flow, mgd	
Maximum	30
Average	17
Minimum	7
Lamp Aging Factor	0.7
Quartz Sleeve Fouling Factor	0.85
System Configuration (No. of Reactors)	2 at nominal 15 mgd each

In the Design Proposal Request, the manufacturers are told on what the basis their proposals will be scored. The scoring system used for the Tracy UV system is presented in Table 3. In this example, if a manufacturer scores above zero in both of the Part 1 categories of the evaluation, then their proposal is evaluated further and scored for net present value in Part 2. Part 1 represents non-monetary factors and Part 2 represents monetary factors.

Table 3. *Scoring System Used for Tracy UV System*

Criteria	Maximum Possible Score
Part 1	
Reactor Validation	2
Installation Operational Experience	2
Part 2	
Net Present Value	4
Total Score	**8**

Manufacturers evaluated in Part 2 of the evaluation are then compared on an overall net present value basis. One manufacturer is then selected, typically with the highest overall score. The results of the Tracy UV evaluation are presented in Table 4. The Basis of Design for the UV system is then developed based on the selected manufacturer's equipment, as presented in Table 5.

Table 4. *Results of Tracy UV Evaluation*

	Manufacturer Evaluation Score		
Criteria	**A**	**B**	**C**
Validation Experience	1.0	2.0	2.0
Operation/Installation	0.9	0.9	0.8
Net Present Value	4.0	3.6	4.0
Total Overall Score	**5.9**	**6.5**	**6.8**
	System Cost		
Net Present Value, $M	**2.8**	**3.1**	**2.8**

Table 5. *Tracy UV Design Criteria*

Description	Criteria
Type of Units	LPHO
Number & Capacity per Unit (duty)	2 units (15 mgd each)
Number of Lamps per Unit	96
Total Operating Load at Peak Flow, kW	76
Headloss through Unit, inches	16

UV COST/BENEFIT ANALYSIS AND UVCAT

The importance of life cycle cost analysis is illustrated by Figure 3. Referring to Figure 3, low-pressure high-output (LPHO) and medium-pressure (MP) UV systems were under consideration for an application. In this example, the MP footprint allows a reduction in UV building size with a corresponding reduction in capital cost. However, the LPHO power requirements are typically less, and thus the LPHO operational costs are less. Considering this operational cost savings, the LPHO system could potentially save more money over the life cycle of the equipment, even though the MP system is less expensive to construct (Note: This is only an example. LPHO life cycle costs are not always lower than MP life cycle costs. Construction issues can favor MP systems, and some MP systems have very efficient UV dose-pacing control philosophies allowing the MP system to compete with LPHO on power to the point where other factors besides power may drive system selection).

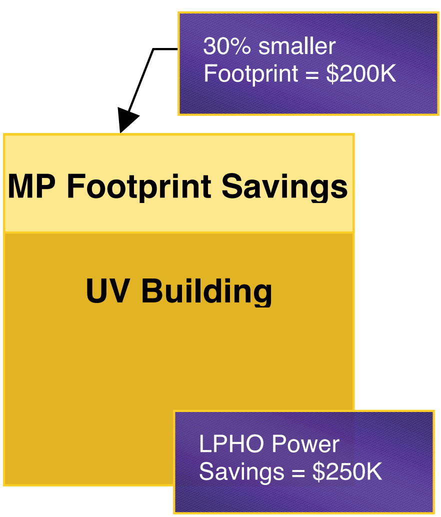

Figure 3. *Importance of Life Cycle Cost*

Typically, cost analysis includes capital costs, such as the UV reactor, associated piping and valves, the building, power supply and backup power, instrumentation and control, and engineering, and operation and maintenance (O&M) costs such as power, lamp and other component replacement, UV sensor calibration, and labor.

Often O&M costs are estimated assuming UV dose pacing only responds to flow. That is, the power costs, lamp and component replacement costs, and labor cost are calculated assuming the UV system on average operates with "x" lamps on:

$$x = \text{No. of Duty Lamps x } \frac{\text{Average Flow}}{\text{Design Flow}}$$

This approach does not account for the impact of UVT, lamp aging, fouling, the efficiency of UV dose monitoring and control, and the validated range on UV system operation.

Often factors, such as the efficiency of UV dose monitoring and control, turndown limitations, and the risk of off-spec performance, are treated as non-monetary factors that are qualitatively ranked (e.g., on a scale of 1 to 5). Such ranking systems are arbitrary and subjective. A better approach would be to quantify the impact of these factors on UV system costs.

The UV Cost Analysis Tool, or UVCAT, was developed by Carollo for the New York State Energy Research and Development Authority (NYSERDA) project entitled "Optimization of UV Disinfection." UVCAT was developed to provide a more realistic and comprehensive model for UV system performance that would allow one to better evaluate UV systems proposed for a given application.

UVCAT Input

Inputs to the UVCAT model include:

- Flow, UVT, power quality, and pathogen concentration data over time for the Water Treatment Plant
- UV system configuration (number of reactors, banks of lamps, etc)
- Performance and cost data for the UV system components
- Lamp aging and fouling profiles
- The UV system's UV dose monitoring and control algorithm

A screen shot of the UVCAT worksheet containing a library of dose monitoring algorithms for commercial UV reactors is presented in Figure 4. The UVCAT user references these dose algorithms when they analyze the performance of a given commercial UV system. These algorithms are obtained from the validation reports submitted by UV vendors when they propose on a design job. The example shown in Figure 4 includes algorithms for many of the commercial reactors by WEDECO, Calgon, Trojan, and IDI. Because this data is highly proprietary to the UV vendors, the final version of UVCAT given to NYSERDA will not have these specific algorithms entered. Carollo has password protected this information and controls distribution of the software so that this information stays confidential. Instead, each UVCAT user will need to develop their own library of UV dose monitoring algorithms based on data provided by the UV vendors.

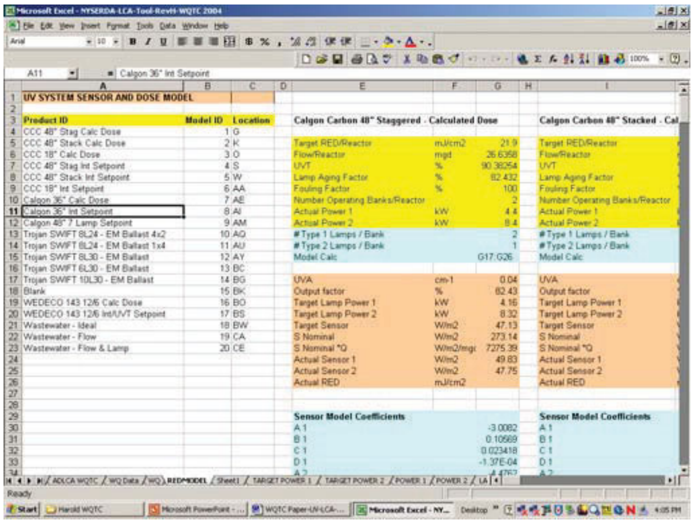

Figure 4. *UVCAT Reactor Model Data*

An example of flow and UVT data that was entered into UVCAT for a Carollo UV study carried out for one of our clients is presented in Figure 5. The data entered was obtained from a twenty-year simulation of flow and UVT values, based on historic and projected future flows and four years of historic UVT data. The example data chart shows strong seasonal and year-to-year trending that will impact UV system performance over time.

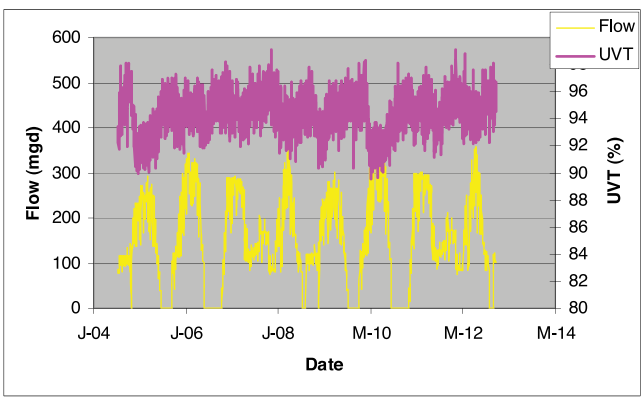

Figure 5. *Flow and UV Data Input into UVCAT*

A screenshot of the UVCAT worksheet used to input data on UV system configurations and performance and costs of UV system components like lamps, sleeves, ballasts, and UV sensors is presented in Figure 6. Each column in the worksheet represents a UV system that can be analyzed. This format is convenient because multiple proposals for a given UV application can easily be analyzed.

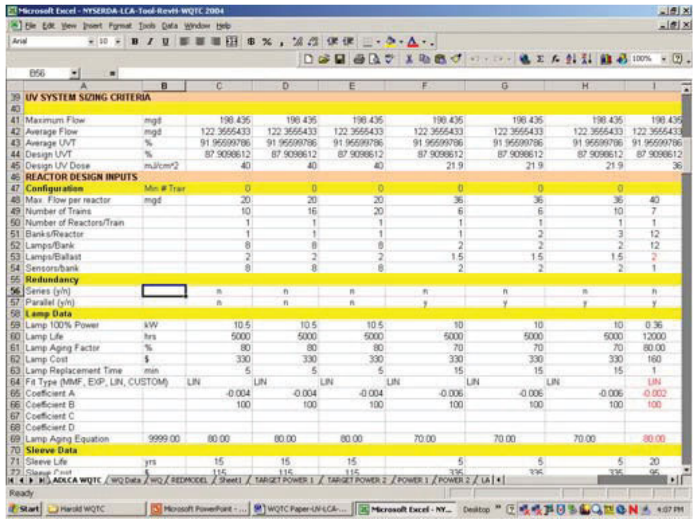

Figure 6. *UVCAT Input Fields*

UVCAT Output

Outputs from UVCAT include predictions of:

- Reactors and lamps required to deliver the target UV dose
- Power consumption
- UV dose and pathogen log inactivation
- Off-spec performance
- Integrated O&M costs
- Capital and life cycle costs

An example of power consumption over time predicted by UVCAT is presented in Figure 7. The software provides the actual power consumed given the turndown of the lamps used by the UV system and the power that would be consumed if the UV system was not limited by turndown. In Figure 7, when the ideal power is greater than the actual power, the UV system cannot deliver the design UV dose and is undersized. When the ideal power is less than the actual power, the UV system is limited by turndown of the lamps and is overdosing. This type of data allows one to understand if the UV system is under-sized or over-sized for a given application and it allows one to understand the efficiency of UV dose pacing.

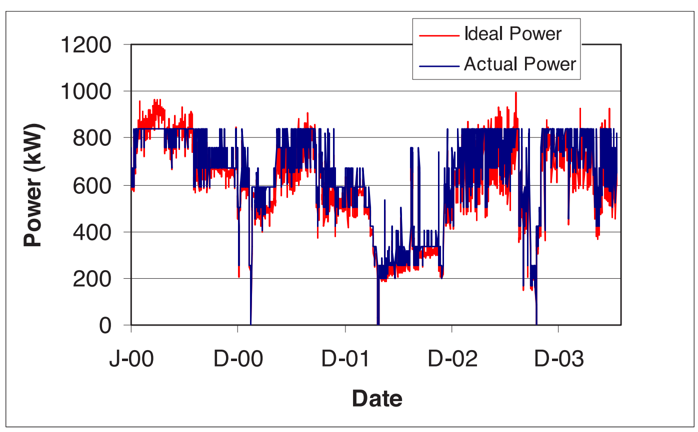

Figure 7. *Power Consumption Predicted by UVCAT*

An example of off-spec performance of the UV system caused by flow, UVT, lamp aging, and fouling is presented in Figure 8. The off-spec performance is calculated as a monthly off-spec volume and a monthly off-spec time. These data are valuable because it lets the user size UV systems to achieve an off-spec goal, instead of sizing UV systems for worse case flow, UVT, lamp aging, and fouling.

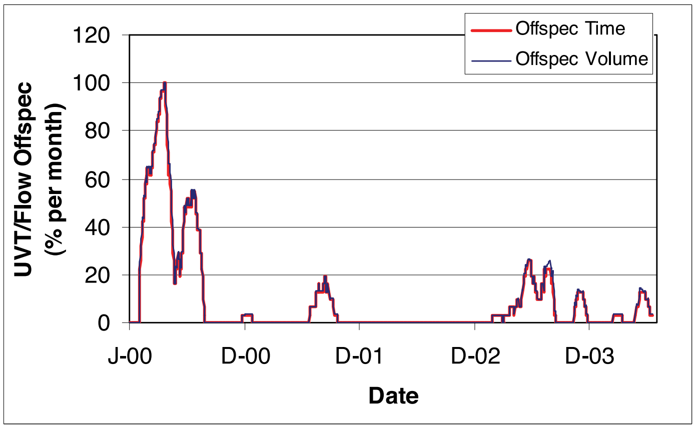

Figure 8. *Off-Spec Performance Predicted by UVCAT*

An example of daily and accumulated power costs over time predicted by UVCAT for a given UV system is presented in Figure 9. Such data provides engineers and utilities a much more accurate estimate of UV system O&M costs compared to current rule of thumb approaches used because it includes the impact of factors such as the UV output efficiency of the lamp and ballast, turndown limitations of the UV system, hydraulic limitations of each reactor, the discrete operation of the UV system (e.g. a UV system may have four ballast power settings), and off-spec limitations of validation data. UVCAT integrates accumulated power and component replacements costs to estimate annualized and present worth costs.

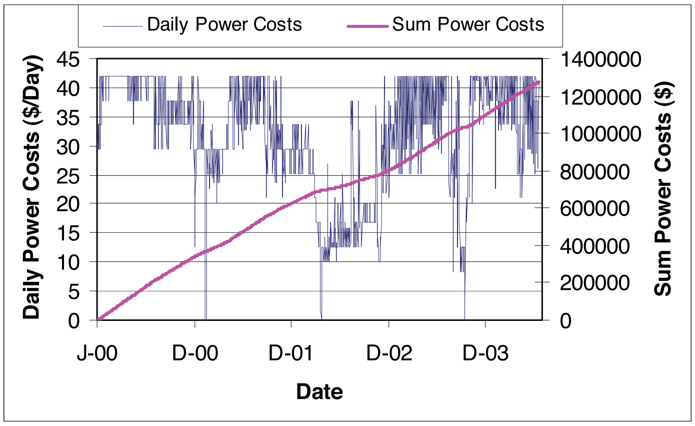

Figure 9. *Power Costs Predicted by UVCAT*

A screenshot of the UVCAT worksheet used to output UV system cost data is presented in Figure 10. The data provides side-by-side comparisons of UV system alternatives for a given UV application, lending a greater level of accuracy to the Evaluated Bid Approach of equipment procurement.

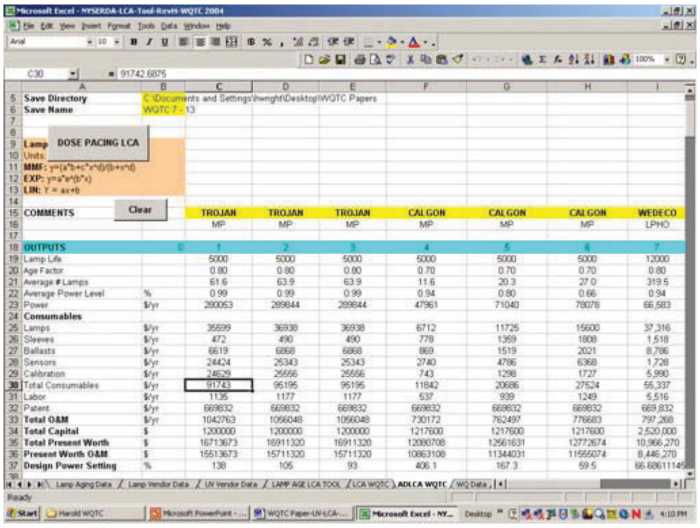

Figure 10. *UVCAT Summary Table*

UVCAT provides a more accurate assessment of O&M and life cycle costs compared to standard approaches used by the industry because it better accounts for the true performance of the UV system. Overall, the software provides a new approach optimizing UV capital and O&M costs and should provide better selection of UV systems for a given UV application.

UV SYSTEM SPECIFICATIONS

UV disinfection is a well-established technology in the US for wastewater applications. The use of UV disinfection in drinking water applications is much newer to the US market and has experienced considerable change in recent years. Application of UV disinfection in drinking water involves a number of issues that either do not occur with, or have greater emphasis than UV disinfection of wastewater, such as:

- UV Dose monitoring and UV sensors
- Ultraviolet Disinfection Guidance Manual (UVDGM) validation and equipment factor calculations
- Off-spec performance targets
- Alarms and responses
- Startup testing and verification

The nature of UV disinfection of drinking water is such that the equipment specification is all the more critical as compared to specifications for wastewater applications of UV disinfection. An outline of the main sections included in the "Ultraviolet Disinfection System for Drinking Water Application" specification developed by Carollo is presented in Table 6.

Table 6 *Example UV System Specification Outlines*

PART 1 — GENERAL

1.1 SUMMARY
1.2 RELATED DOCUMENTS
1.3 REFERENCES, CODES, STANDARDS, AND RECOMMENDED PRACTICES
1.4 DEFINITIONS
1.5 UV SYSTEM DESIGN CRITERIA
1.6 SUBMITTALS
1.7 SPARE PARTS
1.8 GUARANTEES AND WARRANTIES

PART 2 — PRODUCTS

2.1 SCOPE OF SUPPLIES
2.2 MANUFACTURERS
2.3 GENERAL PRODUCT REQUIREMENTS
2.4 MATERIALS
2.5 UV REACTOR CHAMBER
2.6 UV LAMPS
2.7 QUARTZ SLEEVES
2.8 CLEANING SYSTEM
2.9 UV SENSORS
2.10 UV TRANSMITTANCE MONITOR
2.11 OTHER SENSORS
2.12 ELECTRICAL
2.13 CONTROL AND INSTRUMENTATION
2.14 SAFETY EQUIPMENT

PART 3 — EXECUTION

3.1 GENERAL
3.2 PLANNING AND SCHEDULES
3.3 SPECIAL SERVICES
3.4 FACTORY TESTING
3.5 DELIVERY, STORAGE & HANDLING

1.5 UV SYSTEM DESIGN CRITERIA
- A. UV Installation
- B. Water Quality
- C. UV Reactor Sizing Criteria for UV Dose Deliver
- D. On-line UVT Monitor
- E. Hydraulic Criteria
- F. Average Conditions for Net Present Worth Evaluation described in Section 00305
  1. Flowrate: ______ mgd
  2. UVT: ______%
  3. Lamp aging factor: ______ %
  4. Fouling factor: _______ %
- G. UV Validation
- H. Electrical Criteria
- I. Controls Criteria
- J. Structural Design
- K. Equipment Mounting and Anchoring

1.6 SUBMITTALS
- A. Submittal Package No.1 shall include the following information:
  5. Dimensional and Cut-away Drawings
  6. UV System Parts Lists
  7. UV System Sizing
  8. Layout
  9. Structural
  10. UV Irradiation chamber
  11. UV Lamps
  12. Lamp Ballasts
  13. Quartz Sleeves
  14. Cleaning System
  15. Duty UV Sensors
  16. Reference UV Sensors
  17. UV Sensor Port
  18. Electrical
  19. Control and Instrumentation
  20. Dose Monitoring Algorithm
  21. UV System Control Philosophy
  22. Operating and Maintenance Costs
- B. Submittal Package No.2 shall include the following information:
  1. Operation and Maintenance (O&M) Manuals
  2. SUPPLIER's delivery instructions.
  3. SUPPLIER's installation instructions.
  4. Startup, testing, and training plan.
  5. Qualifications of SUPPLIER's field representative.
- C. Submittal Package No.3 shall include the following information:
  1. Manufacturer's Guarantee: Submit performance guarantee and guarantee bond.
  2. Manufacturer's Warranty: Submit UV equipment warranty.
  3. Certificate of Proper Installation.
  4. End of Warranty Report.
  5. Inspection, Functional Test, Operational Test, and Field Test Reports.
  6. Finalized O&M Manuals
  7. Record Documentation for all electrical schematics, wiring, diagrams, loop drawings, ladder logic, loop descriptions, and interconnection diagrams.

The point of Table 6 is detail, detail, detail; UV disinfection of drinking water is a very critical application requiring detailed and careful specification. One needs to specify exactly what is required in terms of UV dose monitoring and control, alarms and responses, validation, and system sizing because with UV disinfection of drinking water one cannot measure CT the way one does with chlorine disinfection, or measure coliforms the way one does with the UV disinfection of wastewater.

As shown in the example on UV system design criteria presented in Table 6, each section within the specification is also detailed. This level of detail is critical in the evaluated bid approach to UV equipment procurement. It is important to define the requirements for the UV equipment as completely as possible to ensure that the proposing manufacturer has a clear idea of the performance requirements and constraints for the UV system. For example, considering UV installation, what does the system look like, and where will it be installed? Considering water quality, what is the expected range of turbidity, temperature, pH, hardness, alkalinity, calcium, iron, manganese, and aluminum? How exactly is UV dose monitoring and control implemented? How will validation be done, or has it been done to prove UV dose monitoring and control? What is the validated range of the reactor? How does the UV system calculate off-spec performance?

Following suit, the submittal requirements are very detailed, and are also critical in the evaluated bid approach to equipment procurement. Submittals provide evidence that the installed UV system will meet the specification. The submittal requirements are also outlined in Table 6. Three submittal packages are required. Submittal Package No. 1 with validation report is to be submitted 90 days after Contractor Notice to Proceed. Submittal Package No. 2 is to be submitted 30 days before shipment. Submittal Package No. 3 is to be submitted before Final Completion. Submittals are checked for compliance with the UV equipment specification. Such checks prevent expensive change orders and retrofits after the UV system is installed.

SUMMARY

UV disinfection systems are offered in a variety of configurations, and design differences between UV equipment can be significant. The *evaluated bid* approach to UV equipment procurement allows UV systems to be competitively evaluated before the detailed design. One system is selected from the proposed systems to serve as the Basis of Design. The *evaluated bid* approach offers many benefits for UV design, including:

- Competitive bids
- Life cycle cost analysis
- Non-economic factors evaluated
- Single UV system design

The UV Cost Analysis Tool (UVCAT) developed by Carollo provides a more accurate assessment of O&M and life cycle costs compared to standard approaches used by the industry because it better accounts for the true performance of the UV system, rather than only looking at design conditions. Overall, the software provides a new approach optimizing UV capital and O&M costs and should provide better selection of UV systems for a given UV application. In this regard, UVCAT facilitates the evaluated bid approach to UV equipment procurement.

UV system specification development is a critical step in the overall success of a UV disinfection project. Sufficient detail must be provided to fully describe the application conditions, desired level of disinfection, and equipment features. Detail is particularly important when using the evaluated bid approach for UV equipment procurement.

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- UV Validation Centers: Portland, OR and DVGW, Germany

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