Appendix E. Available Conditional Acceptance Letters Referenced in the ATTR

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A. Free Chlorine Disinfection

State Water Resources Control Board
Division of Drinking Water

November 2, 2017

Mr. Casey Wichert
City of Brentwood
Wastewater Operations Manager
Public Works/Operations
2251 Elkins Way
Brentwood, CA 94513-7344

Subject: Conditional Acceptance of Free Chlorine Disinfection at City of Brentwood to comply with California Water Recycling Criteria (0790005-704)

Dear Mr. Wichert,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed the City of Brentwood's (City) final report "Demonstration of Tertiary Free Chlorine Disinfection at the City of Brentwood Wastewater Treatment Plant", dated August 2017 from Trussell Technologies, Inc. to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. The report outlines findings from a study conducted at the City using a pilot scale chlorine contactor with tertiary filter effluent from the City's wastewater treatment plant (WWTP) as the feed to the pilot system.

Demonstration studies conducted using free chlorine at the City have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at the City subject to the following conditions:

1. The City must deliver a minimum free chlorine residual contact time (FCRCT) of 9 mg-min/Lat all times in order to receive 5-log virus inactivation credit.

2. The City must meet a minimum free chlorine residual (FCR) at the compliance point of 1.0 mg/L at all times.

3. The City must maintain a minimum free chlorine modal contact time of four (4.0) minutes at all times.

4. The City must continuously monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

5. If free chlorine CT is used as the sole disinfection process to produce tertiary recycled water, the Title 22, Section 60301.230(b) requirements for total coliform must also be achieved.

6. The City WWTP must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in a new or updated Title 22 Engineering Report for the City and included in the operations plan.

7. The FCRCT equation must be used as part of the automatic chlorination control system for calculating CT, and should be specified as a permit provision.

8. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

9. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzers must be recalibrated by a procedure recommended by the manufacturer.

10. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

11. The City WWTP should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick- reference plant- operations data sheet should be posted at the treatment plant and include a least the following information:

    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

12. The City should maintain records of compliance with these conditions, made available to the Division or the RWQCB upon request. In addition, the City should report a summary of compliance with an approved operations plant as part of its annual reporting to the RWQCB.

13. These conditions shall be incorporated into the RWQCB permit for the City.

Conditional acceptance is specific to the free chlorine disinfection process at the City only, as detailed in the report dated August 2017 described above. The Division must review in advance any future proposed changes made in the design or operation of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at the City is provided through the Regional Water Quality Control Board's water reclamation permitting process. Prior to the City being permitted by the RWQCB, a Title 22 Engineering Report for changes to the City wastewater treatment plant is required. The engineering report shall include how the City meets the requirements of Title 22 and this letter.

If you have any questions regarding this letter please me at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, PE
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Marco Pacheco, San Francisco District Engineer, SWRCB-DDW (via email)

San Francisco RWQCB, Region 2 (via email)

Brian Pecson, Trussell Technologies, Inc. (Brainp@trusseltech.com)

State Water Resources Control Board
Division of Drinking Water

May 4, 2015

Michael Phelps
Water Quality Manager
Camrosa Water District
7385 Santa Rosa Rd.
Camarillo, CA 93012

Subject: Conditional Acceptance of Free Chlorine Disinfection at Camrosa Water District to Comply with California Water Recycling Criteria (5690011-702)

Dear Mr. Phelps:

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated October 29, 2014, from MWH Global, to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a draft report entitled, "Camrosa Water Reclamation Facility: Chlorine Disinfection Study. Bioassay Testing Results and Proposed Contactor Rerating", dated October 2014. The final report has also been received by the Division and is dated April 2015.

The final report outlines findings from a study conducted at the Camrosa Water Reclamation Facility (Camrosa) located in Camarillo, CA. The purpose of the study is to show Camrosa can use free chlorine disinfection to meet Title 22, thus allowing a shorter contact time in its chlorine contact chambers. This will allow Camrosa to increase its flow rate from 1.5 MGD to 3.24 MGD peak flow without a facility expansion.

The definition of disinfected tertiary recycled water in Title 22, Section 60301.230 is based on the Pomona Virus Study, which requires a 450 mg-min/L of total chlorine CT with a 90 minute modal contact time; or a disinfection process that has been demonstrated to inactivate and/or remove five logs of virus. Camrosa has proposed to meet the Title 22 requirement by demonstrating that free chlorine disinfection can achieve a five log inactivation of virus.

Demonstration studies conducted using free chlorine at Camrosa have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection, subject to the following conditions:

1. As documented in the final report, Camrosa must deliver a minimum free chlorine residual contact time (FCRCT) of 59 mg-min/L at all times, and a minimum free chlorine residual (FCR) at the contact chamber outlet of 1.0 mg/L at all times.

2. As documented in the final report, Camrosa must maintain a minimum free chlorine modal contact time of 59-minutes.

3. The free chlorine disinfection process must meet Title 22, Section 60301.230(b) requirements for total coliform.

4. Camrosa must be operated with a built-in automatic reliability feature that must be triggered when the FCRCT or the minimum FCR is below the target.

5. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection.

6. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

7. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

8. Camrosa should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

9. These conditions shall be incorporated into the final permit for Camrosa.

Conditional acceptance is specific to free chlorine disinfection at Camrosa only, as detailed in the report dated April 2015 described above. The Division must review in advance any future proposed changes made in the physical attributes or characteristics of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at Camrosa is provided through the Regional Water Quality Control Board's Water Reclamation permitting process. The Division's local district office may also review the free chlorine disinfection process at Camrosa to confirm full compliance with all applicable treatment and reliability features required by Title 22.

If you have any questions regarding this letter, please contact Randy Barnard at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Recycled Water Committee

Joan Oppenheimer, BCES
Vice President, Principal Scientist
300 North Lake Ave, Suite 400
Pasadena, CA 91101

State Water Resources Control Board
Division of Drinking Water

October 10, 2017

Greg Lowe, CFM
Executive Director Facilities
Chumash Casino Resort
Santa Ynez, CA 93460

Dear Mr. Lowe,

Subject: Conditional Acceptance of the Chumash Casino Resort Free Chlorine Study to comply with California Water Recycling Criteria (4290005-702)

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated September 28, 2017, from Pacific Advanced Civil Engineering, Inc. (PACE) to consider free chlorine as an alternative filtration technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a report entitled, "Chumash Water Reclamation Facility Free Chlorine CT Study Report", dated September 26, 2017. The report outlines findings from a study conducted at the Chumash Water Reclamation Facility (Chumash) located in Santa Ynez, CA. The purpose of the study is to show Chumash can use free chlorine disinfection to meet Title 22 requirements, thus allowing a shorter contact time in their chlorine contact basin. This will allow Chumash to increase their plant flow rate from 72,000 GPD average flow to 0.32 MGD peak flow.

The definition of disinfected tertiary recycled water in Title 22, Section 60301 .230 is based on the Pomona Virus Study, which requires a 450 mg-min/L of total chlorine CT with a 90 minute modal contact time; or a disinfection process that has been demonstrated to inactivate and/or remove five logs of virus. Chumash has proposed to meet the Title 22 requirement by demonstrating that free chlorine disinfection can achieve a five log inactivation of virus.

Demonstration studies conducted using free chlorine at Chumash have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at Chumash, subject to the following conditions:

1. Chumash must modify the weir in the first contactor tank as described in the September 26, 2017 Title 22 engineering report prior to being permitted by the RWQCB.

2. Chumash must deliver a minimum free chlorine residual contact time (FCRCT) of 120 mg-min/L at all times to meet both the virus and total coliform reduction requirements of Title 22, section 60301.230.

3. Chumash must meet a minimum free chlorine residual (FCR) at the contact basin outlet of 2.3 mg/L at all times.

4. Chumash must maintain a minimum free chlorine modal contact time of 17-minutes.

5. Chumash must monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

6. The free chlorine disinfection process must meet Title 22, Section 60301.230(b) requirements for total coliform.

7. Chumash must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in an updated Title 22 Engineering Report for Chumash.

8. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

9. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

10. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

11. Chumash should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information :
    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

12. Chumash should maintain records of compliance with these conditions, made available to DDW or the RWQCB upon request. In addition, Chumash should report a summary of compliance with an approved operations plant as part of its annual reporting to the RWQCB.

13. These conditions shall be incorporated into the final permit for Chumash.

Conditional acceptance is specific to the free chlorine disinfection process at Chumash only, as detailed in the report dated September 2017 described above. The Division must review in advance any future proposed changes made in the design or operation of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at Chumash is provided through the Regional Water Quality Control Board's Water Reclamation permitting process. Prior to Chumash being permitted by the RWQCB, a Title 22 Engineering Report for the expansion project is required. The engineering report shall include how Chumash meets the requirements of Title 22 and this letter. The Division's local district offices will also review the free chlorine disinfection process at Chumash to confirm full compliance with all applicable treatment and reliability features required by Title 22.

If you have any questions regarding this letter, please contact me at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Central Coast RWQCB

Jeff Densmore, PE, DDW Santa Barbara DE

Andy Komor, MS, PE,
Pacific Advanced Civil Engineering, Inc.
17520 Newhope Street, Suite 200
Fountain Valley, CA 92708

August 17, 2021

Sylvie Lee
Manager of Strategic Planning & Resources
Inland Empire Utilities Agency
6075 Kimball Ave
Chino, California 91708

CONDITIONAL ACCEPTANCE OF THE FREE CHLORINE DISINFECTION FOR THE INLAND EMPIRE UTILITIES AGENCY AT RP-1 AND RP-4 WWTP TO COMPLY WITH TITLE 22 REQUIREMENTS (3690001-744)

Dear Ms. Lee,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated January 2021, from Inland Empire Utilities Agency (IEUA) to consider free chlorine disinfection as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60301.230(a)(2). Accompanying the request were reports prepared by Trussell Technologies, Inc. titled, "*Inland Empire Utilities Agency Regional Water Recycling Plant No. 4 Free Chlorine Disinfection Validation Report*" and "*Inland Empire Utilities Agency Regional Water Recycling Plant No. 1 Free Chlorine Disinfection Validation Report*" (Reports) dated July 2021. The reports contained an assessment of the disinfection process at the IEUA's Regional Water Recycling Plant No. 4 and Agency Regional Water Recycling Plant No. 1 (Treatment Plants). Treatment Plant based on the Chlorine Disinfection WaterVal Validation Protocol (2017) to validate virus inactivation by free chlorine. Tracer study conducted at the two treatment plants are also included in the Reports. IEUA should coordinate with the Santa Ana Regional Water Quality Control Boards (Regional Boards) to incorporate these conditions into the permits for the Chino Basin Recycled Water Groundwater Recharge Program, RP-1, and RP-4. In addition, IEUA should coordinate with the Division to host an on-site inspection for the demonstration of alarms and corresponding corrective actions under normal full-scale conditions for both treatment plants.

Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at IEUA's Water Recycling Plant No. 1 (RP-1) and Water Recycling Plant No. 4 (RP-4) subject to the following conditions:

1. RP-1 and RP-4 treatment plants must use the following tiered contact time approach (Tier 1 or Tier 2) for the disinfection process. For the purpose of indirect potable reuse application, IEUA must follow Tier 1 requirements at RP-1, RP-4, or both treatment plants. For the purpose of non-potable reuse application, IEUA must follow Tier 1 or Tier 2 requirements, at RP-1, RP-4, or both treatment plants.
    a. Tier 1: RP-1 and RP-4 treatment plants must deliver a minimum free chlorine

residual contact time (FCRCT) of 41 min-mg/l based on a 15-minute running average using a baffling factor of 0.5 to obtain 6-log virus reduction pursuant with Title 22, Section 60320.108. For non-potable reuse application only, if Tier 1 requirements are unable to be met, then Tier 2 requirements must be followed.

b. Tier 2: RP-1 and RP-4 treatment plants must deliver a minimum total chlorine residual contact time (TCRCT) of 450 min-mg/l at all times with a modal contact time of at least 90 minutes, based on peak dry weather design flow

2. For Tier 1, RP-1 and RP-4 treatment plants must meet a minimum free chlorine residual (FCR) of 1.0 mg/l based on a 15-minute running average as measured at each Chlorine Contact basin (CCB) effluent.

3. For Tier 1, RP-1 and RP-4 treatment plants must be operated with a built-in automatic reliability feature that must be triggered when the FCRCT or the FCR are below 41 min-mg/l, and 1.0 mg/l respectively pursuant with Title 22, Section 60341.

4. RP-1 and RP-4 treatment plants must not exceed the peak wet weather flowrate (PWWF) for any CCB.

5. RP-1 and RP-4 treatment plant effluents must meet the Title 22, Section 60301.230(b) requirements for total coliform, and the monitoring requirements of Title 22, Section 60321.

6. The combined filter effluent turbidity must not exceed the following requirements (a-b) pursuant to Title 22, Section 60301.320. Individual filter effluent may be monitored in lieu of combined filter effluent for the following requirements (a-b). Turbidity monitoring must be upstream of the disinfection process. Exceedance(s) must trigger automatic reliability feature in accordance with Title 22, Section 60341.

    a. Average of 2 NTU within a 24-hour period; and

    b. 5 NTU at any time.

7. Ammonia must be monitored in the upstream secondary treatment process to optimize nitrification and control ammonia breakthrough. Ammonia analyzers must be inspected and checked against a reference unit routinely to determine accuracy. If an online analyzer reading varies from the reference unit, the online analyzer must be recalibrated by a procedure recommended by the manufacturer.

8. Online turbidity analyzers, free chlorine analyzers, total chlorine analyzers and flow meters must be installed and properly calibrated based on manufacturer recommendations to ensure proper disinfection at all times. Turbidity, total chlorine, and free chlorine analyzers must be inspected and checked against a reference unit routinely to determine accuracy. If an online analyzer reading varies from the reference unit reading, the online analyzer must be recalibrated by a procedure recommended by the manufacturer. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

9. IEUA must update the Operations Plan for RP-1 and RP-4 treatment plants and submit a copy to Division for review and approval, based on this letter and the approved Reports,

by December 31, 2021. A copy of the approved Operations Plan should be regularly updated and be readily available to operators and regulatory agencies (if requested). In addition, a quick reference plant operations data sheet must be posted at the RP-1 and RP-4 treatment plants control center and include the following information:

a. The alarm set points as described in the Reports and this letter that trigger corrective actions other than automatic diversion, suspension, or retreatment. Minimum alarms include FCRCT (low) as calculated by SCADA, TCRCT (low) as calculated by SCADA, FCR (low) as measured at each CCB effluent, hydraulic detention time (low) as calculated by SCADA, Turbidity (high) as measured upstream of disinfection process, and Ammonia (high) as measured upstream of CCBs.

b. The alarm set points as described in the Reports and this letter that trigger automatic diversion, suspension, or retreatment (critical alarms). Minimum alarms include FCRCT (low-low) calculated by SCADA, TCRCT (low-low) calculated by SCADA, FCR (low-low) as measured at each CCB effluent, Turbidity (high-high) as measured upstream of disinfection process, and hydraulic detention time (low-low) as calculated by SCADA.

c. The required frequency of calibration for critical online instruments.

10. IEUA must submit monthly reports to Division and the Regional Boards electronically by the 10th day of the following month. The City must report “Yes” or “No” for each day as to whether the total required pathogenic microorganism log reductions (12-logs virus, 10-logs Giardia cyst, and 10-logs *Cryptosporidium* oocyst) has been achieved based on the overall disinfection and underground retention time. An overall LRV must be provided daily unless the disinfection at RP-1, or RP-4 or both are offline for a 24-hour period. The monthly reports must include the following for RP-1 and RP-4 treatment plants:

    a. Daily minimum log reduction achieved,

    b. Daily minimum FCRCT achieved based on 15-minute average in a 24-hour period,

    c. Daily minimum FCR based on 15-minute average in a 24-hour period,

    d. Daily minimum TCRCT based on 15-minute average in a 24-hour period,

    e. Monthly minimum temperature and maximum pH,

    f. Based on the calculations of log reductions achieved daily by the entire treatment system and underground retention time, IEUA must report the total log reductions achieved per pathogen and whether the necessary log reductions (12-log enteric virus, 10-log *Giardia* cyst, and 10-log *Cryptosporidium* oocyst) have been achieved.

11. IEUA must notify the Division if additional disinfection segment (i.e. CCBs) are added, or if the disinfection segment geometry is modified. If necessary, IEUA must reevaluate the T_{10} by conducting a new tracer study in consultation with the Division.

The Division will coordinate with the Regional Boards to incorporate these conditions into the appropriate permit(s). If you have any questions regarding this letter, please contact Faraz Asad at (714) 558-4708 or via email at faraz.asad@waterboards.ca.gov or me via email at Ginachi.Amah@waterboards.ca.gov.

Sincerely,

Ginachi Amah Water Boards
Digitally signed by Ginachi Amah
Date: 2021.08.17 16:15:20 -07'00'

Ginachi Amah, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
500 North Central Ave, Suite 500
Glendale, CA 91203

cc: Brian Bernados, DDW (via email)
Randy Barnard, DDW (via email)
Oliver Pacifico, DDW (via email)
Sean McCarthy, DDW (via email)
Kurt Souza, DDW (via email)
Amin Najah, RWQCB (via email)
Julio Lara, RWQCB (via email)
Bonita Fan, IEUA (via email at bfan@ieua.org)
Sylvie Lee, IEUA (via email at slee@ieua.org)

State Water Resources Control Board
Division of Drinking Water

May 13, 2016

Mr. Gregory W. Gibson
City of Lathrop
Public Works Department
390 Towne Centre Drive
Lathrop, CA 95330

Subject: Conditional Acceptance of Free Chlorine Disinfection at City of Lathrop to comply with California Water Recycling Criteria (3990015-705)

Dear Mr. Gibson,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated February 17, 2016, from Pacific Advanced Civil Engineering, Inc. to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a draft report entitled, "City of Lathrop Phase 2 Expansion of the Lathrop Consolidated Treatment Facility", dated February 2016. The final report has also been received by the Division and is dated May 2016. The final report outlines findings from a study conducted at the Lathrop Consolidated Treatment Facility (Lathrop) located in San Joaquin County, CA using Lathrop's full scale chlorine contact basin. The purpose of the study is to show Lathrop can use free chlorine disinfection to meet Title 22 requirements, thus allowing a shorter contact time in their chlorine contact basin. This will allow Lathrop to increase their plant flow rate from 1.6 MGD peak dry weather flow to 4 MGD peak dry weather flow without expanding the basin.

The definition of disinfected tertiary recycled water in Title 22, Section 60301 .230 is based on the Pomona Virus Study, which requires a 450 mg-min/L of total chlorine CT with a 90 minute modal contact time; or a disinfection process that has been demonstrated to inactivate and/or remove five logs of virus. Lathrop has proposed to meet the Title 22 requirement by demonstrating that free chlorine disinfection can achieve a five log inactivation of virus.

Demonstration studies conducted using free chlorine at Lathrop have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at Lathrop, subject to the following conditions:

1. Lathrop must deliver a minimum free chlorine residual contact time (FCRCT) of 60 mg-min/L at all times to meet both the virus and total coliform (limiting factor) reduction requirements of Title 22, section 60301.230.

2. Lathrop must meet a minimum free chlorine residual (FCR) at the contact basin outlet of 1.0 mg/L at all times.

3. Lathrop must maintain a minimum free chlorine modal contact time of 32-minutes.

4. Lathrop must monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

5. Prior to being permitted by the RWQCB, Lathrop must repair the chlorine contact basin baffles that contributed to short circuiting noted in the final report listed above.

6. The free chlorine disinfection process must meet Title 22, Section 60301.230(b) requirements for total coliform.

7. Lathrop must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in a new or updated Title 22 Engineering Report for Lathrop.

8. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

9. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

10. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

11. Lathrop should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

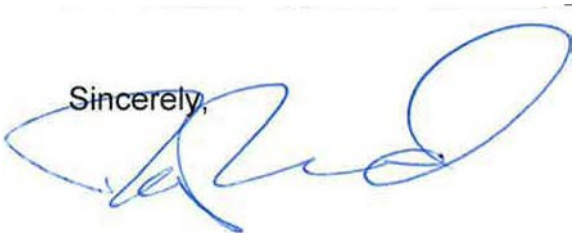
12. Lathrop should maintain records of compliance with these conditions, made available to DDW or the RWQCB upon request. In addition, Lathrop should report a summary of compliance with an approved operations plant as part of its annual reporting to the RWQCB.

13. These conditions shall be incorporated into the final permit for Lathrop.

Conditional acceptance is specific to the free chlorine disinfection process at Lathrop only, as detailed in the report dated May 2016 described above. The Division must review in advance any future proposed changes made in the design or operation of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at Lathrop is provided through the Regional Water Quality Control Board's Water Reclamation permitting process. Prior to Lathrop being permitted by the RWQCB, a Title 22 Engineering Report for the expansion project is required. The engineering report shall include how Lathrop meets the requirements of Title 22 and this letter. The Division's local district offices will also review the free chlorine disinfection process at Lathrop to confirm full compliance with all applicable treatment and reliability features required by Title 22.

If you have any questions regarding this letter, please contact Randy Barnard at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.



Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Recycled Water Committee

Bhupinder Sahota, Stockton District, SWRCB

Central Valley RWQCB, 5S Sacramento

Keisuke Ikehata, Pace, 17520 Newhope Street, Suite 200, Fountain Valley, CA 92708

March 7, 2017

Mr. Arne Sandvik
Padre Dam MWD
Senior Engineer
P.O. Box 719003
Santee, CA 92071

Subject: Conditional Acceptance of Free Chlorine Disinfection at Padre Dam MWD to comply with California Water Recycling Criteria (3790037-716)

Dear Mr. Sandvik,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed Padre Dam Municipal Water District's (Padre) "Final Report: Advanced Water Purification Demonstration Project", dated December 2016 from Trussell Technologies, Inc. to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. The report outlines findings from a study conducted at the demonstration plant at Padre's Water Recycling Facility (WRF) using a pilot scale chlorine contactor with secondary effluent from the Ray Stoyer WRF as the feed to the pilot system.

Padre currently provides recycled water for non-potable reuse. The purpose of the demonstration study was to evaluate a potential advanced treatment train for indirect potable reuse, either for groundwater recharge or surface water augmentation. The evaluated treatment train included the possibility of demonstrating up to 6-log virus inactivation through free chlorine disinfection. Free chlorine disinfection studies were completed on unfiltered secondary effluent, granular media filter (GMF) effluent, and ultrafiltration (UF) effluent.

Based on the results of the demonstration study, Padre is asking for the following virus inactivation credit when using free chlorine:

- 6-log when using UF filtrate and a CT of 2 mg/L-min; and;
- 5-log when using GMF effluent and a CT of 2 mg/L-min.

The Division will conditionally accept the following virus inactivation credit when using free chlorine:

- 6-log when using UF filtrate and a CT of 9 mg/L-min, and;
- 5-log when using GMF effluent and a CT of 9 mg/L-min.

The 9 mg/L-min is based on a minimum CT value of 3 mg/L-min multiplied by a safety factor of 3. The safety factor of 3 is the same factor the USEPA applies to their CT tables for drinking water. The Division's increase of the minimum CT value from 2 mg/L-min to 3 mg/L-min is based on review of Figure 4-24 of the Demonstration Report that shows that 5-log inactivation of GMF effluent and 6-log inactivation of UF filtrate is met at a CT range of 2 to 3 mg/L-min. As it is not clear at which CT between 2 and 3 mg/L-min that the requested CT is met, 3 mg/L-min is chosen.

Demonstration studies conducted using free chlorine at Padre have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at Padre subject to the following conditions:

1. Padre must deliver a minimum free chlorine residual contact time (FCRCT) of 9 mg-min/L at all times in order to receive 5-log virus inactivation credit using granular media filtration effluent or 6-log virus inactivation credit using ultrafiltration filtrate.

2. Padre must meet a minimum free chlorine residual (FCR) at the contact basin outlet of 1.0 mg/L at all times.

3. Padre must maintain a minimum free chlorine modal contact time of four (4.0) minutes.

4. Padre must monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

5. If free chlorine CT is used as the sole disinfection process to produce tertiary recycled water, the Title 22, Section 60301.230(b) requirements for total coliform must be achieved.

6. The Ray Stoyer WRF must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in a new or updated Title 22 Engineering Report for Padre.

7. The FCRCT equation must be used as part of the automatic chlorination control system for calculating CT, should be specified as a permit provision, and included in the Groundwater Replenishment Reuse Project's Operations Optimization Plan.

8. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

9. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

10. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

11. The Ray Stoyer WRF should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:

    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.

    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.

    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

12. Padre should maintain records of compliance with these conditions, made available to the Division or the RWQCB upon request. In addition, Padre should report a summary of compliance with an approved operations plan as part of its annual reporting to the RWQCB.

13. These conditions shall be incorporated into the RWQCB permit for Padre.

Conditional acceptance is specific to the free chlorine disinfection process at Padre only, as detailed in the report dated December 2016 described above. The Division must review in advance any future proposed changes made in the design or operation of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at Padre Dam MWD's Ray Stoyer WRF and/or future advanced water treatment plant is provided through the Regional Water Quality Control Board's water reclamation permitting process. Prior to Padre being permitted by the RWQCB, a Title 22 Engineering Report for changes to the Ray Stoyer WRF and/or the new advanced water treatment plant is required. The engineering report shall include how Padre meets the requirements of Title 22 and this letter.

If you have any questions regarding this letter, please contact Erica Wolski at (619) 525-4772 or Randy Barnard at (619) 525-4022 or via email at Erica.Wolski@waterboards.ca.gov or Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Recycled Water Committee

Sean Sterchi, San Diego District Engineer, SWRCB-DDW (via email)

San Diego RWQCB, Region 9 (via email)

Brian Pecson, Trussell Technologies, Inc. (via email)

State Water Resources Control Board
Division of Drinking Water

May 6, 2019

Edward Filadelfia
Technical and Compliance Manager
City of Riverside Public Works Department
3900 Main Street
Riverside, CA 92522

Subject: Conditional Acceptance of Free Chlorine Disinfection at City of Riverside to comply with California Water Recycling Criteria (3390031-729)

Dear Mr. Filadelfia,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated January 9, 2019, from Carollo Engineering to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a report entitled, "City of Riverside, Chlorine CT and Modal Contact Time Study, Contact Time Testing and CT Demonstration Results", dated November 2018. The report outlines findings from a study conducted at the Riverside Regional Water Quality Control Plant (Riverside) located in the City of Riverside, CA using Riverside's full-scale chlorine contact basin #2. The purpose of the study is to show Riverside can use free chlorine disinfection to meet Title 22 requirements, thus allowing a shorter contact time in their chlorine contact basin #2. This will allow Riverside to reduce disinfection byproducts and improve overall operational efficiency.

Demonstration studies conducted using free chlorine at Riverside have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at Riverside's chlorine contact basin #2 only, subject to the following conditions:

1. Riverside must deliver a minimum free chlorine residual contact time (FCRCT) of 30 mg- min/L at all times to meet both the virus and total coliform reduction requirements of Title 22, section 60301.230.

2. Riverside must meet a minimum free chlorine residual (FCR) of 1.0 mg/L at all times at the chlorine contact basin #2 sample point #2.

3. Riverside must maintain a minimum free chlorine modal contact time at the chlorine contact basin #2 sample point #2 of 29-minutes at all times, based on a peak flow of 46-mgd.

4. Riverside must monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

5. The free chlorine disinfection process must meet Title 22, Section 60301.230(b) requirements for total coliform.

6. Riverside must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in a new or updated Title 22 Engineering Report for Riverside.

7. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

8. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

9. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

10. Riverside should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

11. Riverside should maintain records of compliance with these conditions, made available to DDW or the Regional Water Quality Control Board (RWQCB) upon request. In addition, Riverside should report a summary of compliance with an approved operations plant as part of its annual reporting to the RWQCB.

12. These conditions shall be incorporated into the final permit for Riverside.

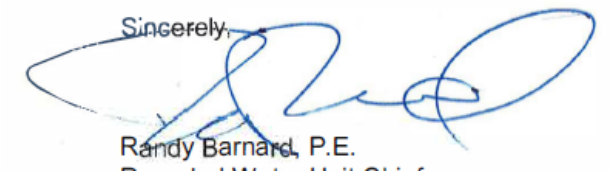
Conditional acceptance is specific to the free chlorine disinfection process at Riverside's chlorine contact basin #2 only, as detailed in the report dated November 2018 described above. The Division must review in advance any future proposed changes made in the design or

operation of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of free chlorine disinfection at Riverside is provided through the RWQCB's Water Reclamation permitting process. Prior to Riverside being permitted by the RWQCB, an approved Title 22 Engineering Report for the project is required. The engineering report shall include how Riverside meets the requirements of Title 22 and this letter. The Division's local district offices will also review the free chlorine disinfection process at Riverside to confirm full compliance with all applicable treatment and reliability features required by Title 22.

If you have any questions regarding this letter, please contact Randy Barnard at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,



Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control
Board 1350 Front St., Rm. 2050
San Diego, CA 92101

cc:

1. Hope Smythe, Executive Officer, RWQCB 8 (via email)
2. Steve Williams, P.E., District Engineer, DDW-District 20 (via email)
3. Robert Eland, City of Riverside, RWQCP, 5950 Acorn Street, Riverside, CA 92504

October 12, 2015

Christoph Dobson
Director of Policy and Planning
Regional SAN
8521 Laguna Station Road
Elk Grove, CA 95758-9550

Subject: Conditional Acceptance of Alternative Tertiary Treatment to comply with California Water Recycling Criteria (3490001-700)

Dear Mr. Dobson,

The Division of Drinking Water's (DDW) Recycled Water Unit has reviewed a request, dated June 29, 2015, from Sacramento Regional County Sanitation District (Regional San) to consider allowing increased filtration loading rates and free chlorine as alternative filtration and disinfection technologies for compliance with the California Water Recycling Criteria (Title 22). Accompanying the request was a report entitled, "Demonstration of a Conditionally Accepted Treatment Technology for Title 22, Tertiary Recycled Water, Equivalency at the Sacramento Regional Wastewater Treatment Plant", dated June 2015. The report outlines findings from a study conducted at the Sacramento Regional Wastewater Treatment Plant located in Elk Grove, CA using the Advanced Treatment Technology Pilot Project.

The Regional San report showed a full comparison between filter performances at 5 and 7.5 gpm/sf, which were conducted following DDW approved protocols similar to previous Filter Loading Rate Evaluation for Water Reuse (FLEWR) studies conducted in the past. The report showed no statistical difference in ability to disinfect (by measuring total coliform after the proposed free residual chlorine process), filtered effluent turbidity, or particle counts when operating at 5 or 7.5 gpm/sf.

The Regional San report also showed the equivalence of disinfection with free residual chlorine (FRC) to the requirements of Title 22, section 60301.230 by demonstrating their process can achieve a five log inactivation of virus. The disinfection demonstration was performed at the proposed higher (7.5 gpm/sf) filtration rate.

Based on a review of the materials submitted, DDW grants conditional acceptance for increased filtration loading rates and FRC disinfection only at the Regional San plant as alternative filtration and disinfection treatment technologies for recycled water subject to the following conditions:

1. The instantaneous filter rates should not exceed 7.5 gpm/sf. Regional San must continue to meet the disinfection requirements of Title 22 at the higher filter rates.

2. At loading rates above 5 gpm/sf, plant operation should be provided in the same manner (or optimized if this would produce better turbidity levels) as was practiced during the demonstration study to maintain the same range (or lower) of turbidity levels at the filter influent. This will require regular evaluation of secondary effluent water quality and filter influent turbidity.

3. Combined filter effluent turbidity should not exceed any of the following:
   An average of 1.5 NTU within a 24-hour period;
   2.5 NTU more than 5 percent of the time within a 24-hour period;
   and 5 NTU at any time.

4. Continuous effluent turbidity monitoring of each individual filter should be conducted.

5. Turbidity performance compliance should be determined using the levels of recorded turbidity taken at intervals of no more than 1.2 hours over a 24-hour period.

6. Regional San must deliver a minimum free residual chlorine contact time (FRC CT) of 162.5 mg-min/Lat all times to meet both the virus and total coliform (limiting factor) reduction requirements of Title 22, Section 60301.230.

7. Regional San must meet a minimum FRC of 1.3 mg/L at all times.

8. Regional San must maintain a minimum free chlorine modal contact time of thirty (30) minutes.

9. Regional San must be operated with a built-in automatic reliability feature that must be triggered when the free chlorination system is below the target FRC CT or FRC.

10. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection.

11. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

12. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

13. Regional San should be operated in accordance with an approved Standard Operating Procedure (SOP), which specifies clearly the operational limits and responses required for critical alarms while operating the free chlorination system and while at high loading rate filter operations. The SOP should list the conditions in this letter and provide instructions to ensure the conditions are met. A copy of the DDW approved SOP should be maintained at the treatment plant control room and should be readily available to operations personnel and regulatory agencies. In addition, control room operators should receive training on using the SOPs by the Chief Plant Operator. A quick-reference plant-operations data-sheet should be posted at the treatment plant control room and include at least the following information:
    a. The alarm set points for secondary and tertiary turbidity, high flow, low FRC, low contact time, and low FRC CT.

b. The values of high tertiary turbidity, high flow, low FRC, and low FRC CT when recycled water flow must be diverted.
c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

14. Regional San should maintain records of compliance with these conditions, made available to DDW or the Regional Water Quality Control Board (RWQCB) upon request. In addition, Regional San should report a summary of compliance with an approved SOP as part of its annual reporting to the RWQCB.

15. These conditions shall be incorporated into any permit or waiver for the Regional San.

Conditional acceptance is specific to Regional San detailed in the report dated June 2015 described above. DDW must review in advance any future proposed changes made in the physical attributes or characteristics of these treatment technologies to determine whether the modifications will require additional testing to ensure Title 22 equivalency. DDW recommends that the above conditions be included in any permit or waiver allowing increased filter loading rates or use of free chlorine at Regional San. Review and approval of all proposed water recycling projects using the technologies described in this letter are provided through the Regional Water Quality Control Board's Water Reclamation permitting process.

If you have any questions regarding this letter, please contact Randy Barnard at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: James Marshall
Senior Water Resources Control Engineer
CA RWQCB Central Valley Region
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670

Ali Rezvani, PE
Sacramento District Engineer
SWRCB, DDW, Sacramento District Office
1616 Capitol Avenue
PO Box 997377, MS 7407
Sacramento, CA 95899-7377

August 21, 2013

Philip L. Friess
Department Head Technical Services
County Sanitation Districts of Los Angeles County
P.O. Box 4998
Whittier, CA 90607-4998

Subject: Conditional Acceptance of Sequential Chlorination at San Jose Creek East WRP to comply with California Water Recycling Criteria (1990005-709)

Dear Mr. Friess:

The California Department of Public Health's (CDPH) Recycled Water Committee has reviewed a request, dated April 29, 2013, from the County Sanitation Districts of Los Angeles County (County San Districts) to consider sequential chlorination as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a report entitled, "Demonstration of Sequential Chlorination for Tertiary Recycled Water Disinfection at the San Jose Creek East Water Reclamation Plant", dated April 2013. The report outlines findings from a study conducted at the San Jose Creek East Water Reclamation Plant (San Jose East Plant) located in Whittier, CA using a pilot scale chlorine contact channel with unchlorinated filtered effluent from the San Jose Plant as the feed water to the pilot system.

The definition of disinfected tertiary recycled water in Title 22, Section 60301.230 is based on the Pomona Virus Study, which requires a 450 mg-min/L of total chlorine CT with a 90 minute modal contact time; or a disinfection process that has been demonstrated to inactivate and/or remove five logs of virus. The County San Districts have proposed to meet the Title 22 requirement at the San Jose East Plant by demonstrating that sequential chlorination disinfection can achieve a five log inactivation of virus.

The proposed San Jose East Plant sequential chlorination system is a two-step disinfection process developed by the County San Districts. In the first step, chlorine is added to fully nitrified filtered effluent at the inlet of the chlorine contact tank to achieve breakpoint chlorination and produce a measurable free chlorine residual (FCR). The FCR and contact time in the chlorine contact tank are used to calculate the free chlorine residual CT (FCRCT) needed to comply with the Title 22, Section 60301.230(a)(2) requirement of achieving greater than five log virus inactivation. In the second step, ammonia and additional chlorine, if needed, are added into the chlorine contact tank to form chloramines, which would ensure compliance with the Title 22, Section 60301.230(b) regarding total coliform.

Demonstration studies conducted using sequential chlorination at the San Jose East Plant have satisfactorily shown an equal degree of treatment and reliability as required in Title 22. Based on a review of the materials submitted, CDPH grants conditional acceptance for sequential chlorination only at the San Jose East Plant as an alternative disinfection treatment technology for recycled water subject to the following conditions:

1. As documented via pilot testing, the San Jose East Plant sequential chlorination system must deliver a minimum FCRCT of 9 mg-min/L at all times and a minimum FCR of 1.0 mg/L at all times.

2. As documented via pilot testing, the San Jose East Plant sequential chlorination system must maintain a minimum free chlorine modal contact time of four (4.0) minutes.

3. The sequential chlorination system must meet Title 22, Section 60301.230(b) requirements for total coliform.

4. The FCRCT equation must be used as part of the automatic sequential chlorination control system for calculating CT and should be specified as a permit provision.

5. The San Jose East Plant must be operated with a built-in automatic reliability feature that must be triggered when the sequential chlorination system is below the target FCRCT or FCR.

6. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection.

7. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

8. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

9. The San Jose East Plant should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operation plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:

    a. The alarm set points for secondary and tertiary turbidity, high flow, low

FCR, low contact time, and low FCRCT.

b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow to the reuse sites must be diverted to NPDES Discharge Serial No. 001.

c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

10. These conditions shall be incorporated into the final permit for the San Jose East Plant sequential chlorination system.

Conditional acceptance is specific to sequential chlorination at the San Jose East Plant only, as detailed in the report dated April 2013 described above. CDPH must review in advance any future proposed changes made in the physical attributes or characteristics of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of sequential chlorination at the San Jose East Plant is provided through the Regional Water Quality Control Board's Water Reclamation permitting process. The CDPH local district office will also review the sequential chlorination at the San Jose East Plant project to confirm full compliance with all applicable treatment and reliability features required by Title 22.

If you have any questions regarding this letter, please contact Randy Barnard at (619) 525-4022 or via email at Randy.Barnard@cdph.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Treatment Specialist
Technical Operations Section

cc: Recycled Water Committee

May 18, 2018

Michele Young
Program Manager
Environmental Services Department
South Bay Water Recycling
200 E. Santa Clara St. 7th floor
San Jose, CA 95121

Subject: Conditional Acceptance of Free Chlorine Disinfection at San Jose-Santa Clara Regional Wastewater Facility to comply with California Water Recycling Criteria (4390001-702)

Dear Ms. Young,

The Division of Drinking Water's (Division) Recycled Water Unit has reviewed a request, dated September 27, 2017, from Trussell Technologies to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60320.5. Accompanying the request was a report entitled, "Demonstration of Tertiary Free Chlorine Disinfection at the San Jose-Santa Clara Regional Wastewater Facility", dated September 2017. The report outlines findings from a study conducted at the San Jose-Santa Clara Regional Wastewater Facility (RWF) located in the City of San Jose (City) using a constructed 10-gpm pilot-scale disinfection plant with tertiary filtered effluent from the RWF.

Demonstration studies conducted using free chlorine at the RWF have satisfactorily shown an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, the Division grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection applications, subject to the following conditions:

1. The City must deliver a minimum free chlorine residual contact time (FCRCT) of 9 mg-min/L at all times in order to receive 5-log virus inactivation credit.

2. The City must meet a minimum free chlorine residual (FCR) at the compliance point of 1.0 mg/L at all times.

3. The City must maintain a minimum free chlorine modal contact time of four (4.0) minutes at all times.

4. The City must continuously monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

5. If free chlorine CT is used as the sole disinfection process to produce tertiary recycled water, the Title 22, Section 60301.230(b) requirements for total coliform must also be achieved.

6. The RWF must be operated with a built-in automatic reliability feature that must be triggered when the minimum FCRCT or FCR are below the targets. The reliability features shall be approved in a new or updated Title 22 Engineering Report for the City and included in the operations plan.

7. The FCRCT equation must be used as part of the automatic chlorination control system for calculating CT, and should be specified as a permit provision.

8. Ammonia analyzers, free chlorine analyzers, and flow meters must be installed and properly calibrated to ensure proper disinfection at all times.

9. Ammonia and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an on-line analyzer reading varies from the bench-top reading, the on-line analyzer must be recalibrated by a procedure recommended by the manufacturer.

10. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

11. The RWF should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick- reference plant- operations data sheet should be posted at the treatment plant and include a least the following information:

    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

12. The City should maintain records of compliance with these conditions, made available to the Division or the RWQCB upon request. In addition, the City should report a summary of compliance with an approved operations plant as part of its annual reporting to the RWQCB.

13. These conditions shall be incorporated into the RWQCB permit for the City.

Conditional acceptance is specific to the free chlorine treatment detailed in the report dated September 2017 described above. The Division must review in advance any future proposed changes made in the physical attributes or characteristics of this treatment technology to determine whether the modifications will require additional testing to ensure Title 22 equivalency.

Review and approval of all proposed water recycling projects using free chlorine are provided through the Regional Water Quality Control Board's Water Reclamation permitting process. The Division's local district offices will also review all proposed water recycling projects using free chlorine on a case-by-case basis to confirm full compliance with all applicable treatment and reliability features required by Title 22 for the specific treatment facilities.

If you have any questions regarding this letter, please contact me at (619) 525-4022 or via email at Randy.Barnard@waterboards.ca.gov.

Sincerely,

Randy Barnard, P.E.
Recycled Water Unit Chief
Recycled Water Unit
Division of Drinking Water
State Water Resources Control Board
1350 Front St., Rm. 2050
San Diego, CA 92101

cc: Brian Pecson, Ph.D., P.E.
Trussell Technologies, Inc.
1939 Harrison Street, Suite 600
Oakland, CA 94612

Eric Lacy, P.E., Santa Clara District Engineer, SWRCB-DDW (via email)

San Francisco Bay RWQCB, Region 2 (via email)

State Water Resources Control Board
Division of Drinking Water

Sent via email: llewis@wmwd.com

June 17, 2021

Lyndy Lewis
Principal Engineer – Regulatory Compliance
Western Municipal Water District
14205 Meridian Parkway
Riverside, CA 92518

Dear Ms. Lewis,

APPROVAL OF FREE CHLORINE DISINFECTION FOR WESTERN RIVERSIDE COUNTY REGIONAL WASTEWATER AUTHORITY (PROJECT NO. 339102-707)

The Division of Drinking Water's (DDW) Recycled Water Unit reviewed a request, dated December 18, 2020, from Western Riverside County Regional Wastewater Authority (WRCRWA) to consider free chlorine as an alternative disinfection technology for compliance with the California Water Recycling Criteria (Title 22), Section 60301.230 (a)(2) at their treatment plant. A technical memo prepared by Trussell Technologies accompanied the request. The memo contained an assessment of the disinfection process at the WRCRWA Treatment Plant based on the WaterVal Chlorine Disinfection Validation Protocol to validate virus inactivation by free chlorine. The WaterVal protocol provides tables showing the relationship between free chlorine residual contact time (FCRCT) and virus inactivation as a function of pH, turbidity, and temperature. These values are based on bench-scale study on free chlorine inactivation of coxsackie B5 virus (CB5) in an Australian secondary effluent conducted by Keegan et al. (2012). DDW has determined that the virus inactivation values from these tables can be used to demonstrate that a free chlorine disinfection process meets the alternative disinfection criteria of Section 60301.230 (a)(2):

> *A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999 percent of the plaque forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration.*

The WaterVal protocol tables show FCRCT values for up to 4-log of virus inactivation, which can be linearly extrapolated to find the required FCRCT for 5-log of virus

inactivation. The memo outlines this procedure and using conservative assumptions for pH, turbidity, and temperature finds that at a minimum FCRCT of 35 mg-min/L, 5-log virus inactivation is achieved.

The WaterVal protocol uses T_{10} to calculate FCRCT. DDW previously reviewed and accepted a WRCRWA tracer study finding a T_{10} Baffling Factor (BF) of 0.9. WRCRWA proposes the following operational criteria to achieve 5-log virus inactivation:

Parameter	**Criteria**
FCRCT	≥ 35 mg-min/L
FCR	≥ 1 mg/L
Turbidity	Instantaneous ≤ 5 NTU
	24-hr average ≤ 2 NTU
pH	≤ 9.0
Temperature	≥ 10 °C

The submitted memo also proposed operating at a minimum T_{10} of 4 minutes. While the proposed CT and adequate disinfection may be achieved at higher flow rates, DDW has determined that the Chlorine Contact Basins (CCBs) should not be operated at flows above the Peak Wet Weather Design Flow of 35 MGD. With one of the four CCBs offline, this becomes 11.7 MGD per CCB. With this exception, DDW accepts that operating per the proposed criteria will provide an equal degree of treatment and reliability as those technologies listed in Title 22. Based on a review of the materials submitted, DDW grants conditional acceptance of free chlorine as an alternative treatment technology for recycled water disinfection at the WRCRWA treatment plant, subject to the following conditions:

1. The WRCRWA treatment plant must deliver a minimum FCRCT of 35 mg-min/L at all times to meet both the virus reduction requirements of Title 22, section 60301.230. The FCRCT must be calculated using the tracer study determined BF of 0.9.

2. The WRCRWA treatment plant must meet a minimum free chlorine residual (FCR) of 1.0 mg/L at all times at the combined chlorine contact basin effluent sample point.

3. The flow rate through each CCB must not exceed the Peak Wet Weather Design Flow of 11.7 MGD.

4. The combined filter effluent turbidity prior to disinfection must not exceed the following:

    a. 5 NTU at any time
    b. 2 NTU 24-hour average

5. The WRCRWA treatment plant must monitor for ammonia prior to the free chlorine addition and optimize the secondary treatment system to prevent ammonia breakthrough.

6. The free chlorine disinfection process must meet Title 22, Section 60301.230(b) requirements for total coliform.

7. The WRCRWA treatment plant must be operated with an automatic reliability feature that must be triggered when the minimum FCRCT, FCR, or turbidity targets are not achieved.

8. Online ammonia analyzers, turbidity analyzers, free chlorine analyzers, total chlorine analyzers and flow meters must be installed and properly calibrated based on manufacturer recommendations to ensure proper disinfection at all times. Turbidity, ammonia, total chlorine, and free chlorine analyzers must be inspected and checked against a reference bench-top unit routinely to determine accuracy. If an online analyzer reading varies from the bench-top reading, the online analyzer must be recalibrated by a procedure recommended by the manufacturer. Flow meters must be inspected and checked against other flow determination methods routinely to determine accuracy.

9. The WRCRWA treatment plant must be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan must be submitted and approved prior to issuance of the permit. A copy of the approved operations plan must be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet must be posted at the treatment plant and include the following information:

    a. The alarm set points for tertiary turbidity, high flow, low FCR, low contact time, and low FCRCT.
    b. The values of high tertiary turbidity, high flow, low FCR, and low FCRCT when recycled water flow must be diverted.
    c. The required frequency of calibration for critical online instruments; such as online turbidity meters, ammonia analyzers, and chlorine analyzers.

10. The WRCRWA treatment plant must maintain records of compliance with these conditions, made available to DDW or the Regional Water Quality Control Board (RWQCB) upon request. In addition, WRCRWA must report a summary of compliance with an approved operations plan as part of its annual reporting to the RWQCB.

11. WRCRWA must coordinate with the Regional Boards to incorporate these conditions into the appropriate permit(s) for the WRCRWA treatment plant.

Review and approval of free chlorine disinfection at the WRCRWA treatment plant is provided through the RWQCB's permitting process. DDW's local district offices will also review the free chlorine disinfection process at the WRCRWA treatment plant to confirm full compliance with all applicable treatment and reliability features required by Title 22.

Thank you for the opportunity to review and comment. If you have any questions please contact Candida Granillo-Dodds at candida.granillo-dodds@waterboards.ca.gov or (619) 524-4042 or me at Ginachi.Amah@waterboards.ca.gov or (818) 551-2046.

Sincerely,

Ginachi Amah, P.E.
Recycled Water Unit Chief
Division of Drinking Water
State Water Resources Control Board
500 North Central Ave, Suite 500
Glendale, CA 91203

cc:

(1) Chun Huang, P.E., Riverside District Engineer, Division of Drinking Water, via email: Chun.Huang@Waterboards.ca.gov
(2) Kathleen Fong, Water Resources Control Engineer, Santa Ana Regional Water Quality Control Board, via email: Kathleen.Fong@waterboards.ca.gov
(3) Julio Lara P.E., Senior Water Resources Control Engineer, Santa Ana Regional Water Quality Control Board, via email: julio.lara@waterboards.ca.gov

B. Ozone and Ozone/Peroxide Disinfection

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

October 16, 2008

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

Dear Mr. Salveson,

CONDITIONAL ACCEPTANCE OF APPLIED PROCESS HIPOX OZONE/PEROXIDE REACTOR DISINFECTION SYSTEM, VALIDATION REPORT, MAY 2008

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the submittal entitled "Applied Process Performance Validation Of The HiPOx™ Disinfection Technology Using Ozone And Ozone/Peroxide For Reclaimed Water" (Carollo Engineers, May 2008)[1] and your letters dated August 6, 2008 and October 14, 2008, which contains the bioassay results of the testing in Dublin San Ramon Services District (DSRSD) Wastewater Treatment Plant in Dublin, California.

It is noted that one key study objective was to demonstrate the equivalent of 5-log inactivation of poliovirus and attainment of 2.2 MPN compliance using HiPOx (i.e., no filtration credit is factored into the 5-log target) as compared to other disinfection technologies which have typically targeted a 4-log objective. Also, the report demonstrates the relationship between log inactivation of poliovirus and MS2. An important point to note is that poliovirus is more resistant to ozone than MS-2 (unlike UV disinfection), i.e., 5-log reduction of poliovirus equates to 6.5-log reduction of MS-2.

The reduction of viruses via the HiPOx™ system is a function of the CT concept, which is the flow rate multiplied by the measured ozone residual. Although HiPOx has requested conditional acceptance at a CT of 0.20 mg-min/L, the Department can grant interim conditional acceptance (with continuous and proper monitoring of flow and ozone residual), at a **CT of 1.0 mg-min/L**, which would address total coliform as noted in the report and should be conservative enough while more work is done to address

[1] Agencies interested in this technology can obtain copies of the April 2008 Carollo Engineers report from Mr. Andrew Salveson, Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

miscellaneous issues in our prior draft comments and your response on October 14, 2008.

Full-scale HiPOx™ reactors must incorporate similar ozone dissolution (e.g., injection methods, mixing methods, injection/mixing configuration) conditions to the pilot-scale HiPOxTM reactor detailed in Appendix D of the 2008 report. The minimum contact time needed for CT compliance can be obtained through the use of downstream baffled tank contactors or pipeline contactors, but hydraulic efficiency of the downstream contactor should be taken into account when determining the CT value. For example, a pipeline contactor typically has a hydraulic efficiency closer to 1 while baffled tank contactors typically have a hydraulic efficiency closer to 0.75. Commissioning of full-scale systems must prove the hydraulic efficiency of the contactor.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the HiPOx™ Disinfection Systems to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an accepted filtration process.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. Conditional acceptance for the HiPOx™ reactors are acceptable under the following parameters:

    a. At this time, no peroxide shall be added[2]
    b. A minimum CT of 1.0 mg-min/L
    c. Determination of the necessary ozone dose to overcome ozone demand and maintain an adequate residual and contact time to meet the minimum CT
    d. The CT shall be calculated continuously by the control system
    e. Reliability features incorporated to ensure the minimum CT is met
    f. Continuous online monitoring of flow and ozone residual
    g. Establishment of a correlation between online ozone residual monitoring to approved grab (bench top) sample test method results

2. Any new proposal must evaluate site-specific water quality parameters (e.g., pH, alkalinity, ammonia, BOD, TOC, and nitrite) for determining their impact on ozone demand and operations of the HiPOx™ reactor. Water quality changes throughout the year must be considered.

[2] Peroxide addition may result in trace organic destruction and may reduce bromate formation. When practicing peroxide addition, the 2008 report showed increasing peroxide to ozone mass ratio correlates to decrease in disinfection potential. The optimal peroxide: ozone ratio will be dependent upon water quality (site-specific parameters), but, more importantly, the peroxide: ozone ratio will be dependent upon the type and degree of trace organic destruction along the need for bromate control and the amount of bromide in the water. Peroxide addition for virus inactivation and/or trace organic destruction and/or bromate control must to be assessed and demonstrated on a site-specific basis.

3. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2008 report from Carollo Engineers. The on-site bioassay or protocol must be approved by the Department. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

4. Conditional acceptance is predicated upon using calibrated continuous online monitoring of flow and ozone residual at all times. Detailed information related to the proper monitoring of ozone residual to be employed is presented in the 2008 report from Carollo Engineers.

5. The site specific engineering report must specify the frequency that calibration checks should be performed.

6. On-line monitoring of ozone residual must be calibrated against a standard bench top method (e.g. Indigo vs. DPD). Operators shall utilize the benchtop kit to develop an understanding of site-specific performance, and then correlate the bench results with the online monitoring. For example, Carollo recommends that the benchtop CT tests use the Hach DPD method to show compliance with the values from the 2008 report, correlating the values from the Hach method with those from the on-line method, and operating based upon this correlation.

7. The HiPOx™ system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target CT. If the measured CT goes below the minimum CT, the reactor in question must alarm and startup the next available reactor or automatically shutdown the plant.

8. Conditions that should shut a reactor down include: ozone sensor failure, reactor failure,

9. The 2008 report from Carollo Engineers contains additional information, including other information derived during the validation, which may be used to adequately design the HiPOx™ system. The following are notable excerpts,

    a. “Various water quality parameters can impact ozone demand, including alkalinity, ammonia, BOD, TOC, and nitrite. However, the use of the CT concept allows for effective system control independent of water quality parameters by measuring the ozone residual at various hydraulic detention times in the contactor to account for ozone demand and decay rates.”

    b. “pH appears to impact ozone residual by maintaining higher ozone residual at lower pH values. Similar to compounds that increase ozone

> demand, the CT concept of control allows effective operation under variable pH conditions."

Review and acceptance of individual systems will be handled on a case-by-case basis by the Department's individual District offices. Approval for the use of HiPOx™ Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

C. Ultraviolet (UV) Disinfection

State Water Resources Control Board
Division of Drinking Water

June 18, 2019

J Sergio Garcia, Sr Project Lead
AquaAzul
Sent via Email: Js.garcia@aquaazul.com

Dear Mr. Garcia,

CONDITIONAL ACCEPTANCE OF AQUAAZUL AZ-4,000 155-W UV DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Stantec Engineers November 2018 report entitled "AquaAzul UV Validation Report". The 2018 report presents the results of the 2018 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation [WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines). The AquaAzul AZ-4,000 UV system consists of four Low-Pressure High-Output (LPHO) UV lamps, in an open channel, utilizing Light Sources GHO64T5L/4P Special 155-Watt UV Lamps (LSI Spec # M1-1J-11, AquaAzul part # L-1-941-HO-N). There is no mechanical sleeve wiping system.

The reduction equivalent dose (RED) is a function of flow rate per lamp and UVT (minimum two banks online). Detailed testing was performed with a pilot unit of three banks with each bank consisting of four Light Sources GHO64T5L/4P Special 155-Watt UV lamps. Flow rates in the open channel ranged from 30 to 120 gpm (113 to 454 liters per minute) at UVTs from 55% to 65% (0.28 to 0.22 UVA).

The DDW finds that the validation testing and report have demonstrated the ability of the AquaAzul AZ-4,000 Open Channel LPHO Wastewater UV Disinfection System utilizing LSI GHO64T5L/4P Special 155-W UV Lamps to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The AquaAzul AZ-4,000 Open Channel (LPHO) Wastewater UV Disinfection System utilizing LSI GHO64T5L/4P Special 155-W UV Lamps must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. The UV system must be operated, with two-banks on-line as a minimum at all times.

3. Conditional acceptance of the AquaAzul AZ-4,000 Disinfection System utilizing GHO64T5L/44P Special 155-W UV Lamps is limited to the following parameter ranges:

    a. up to 114 **liters per minute per lamp**,
    b. UVTs at or above 55 percent,
    c. two-banks on-line as a minimum with 4 lamps per bank minimum

4. The equations below must be used for calculation of the AquaAzul AZ-4,000 UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

    log (Predicted UV Dose) = -1.946 + (-0.858 * **log** Q) + (2.864 * **log** UVT)

    RED_{calc} = LAF x FF x CR x (Predicted UV Dose)

    Where:

    RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2) per lamp
    LAF = lamp aging factor of 0.8 should be confirmed
    FF = fouling factor of 0.8 should be confirmed during commissioning
    CR = Confidence factor = 0.753
    UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent (e.g., 55), at or above 55 percent[1],
    Q = Flow rate per lamp, (liters per minute per lamp)

5. To verify performance on the site-specific recycled water upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the UV system using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site spot check bioassay protocol must be approved by the DDW and must be conducted over a range of flows and UVTs. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval prior to the production of recycled water.

6. The lamp aging factor for the Light Sources GHO64T5L/4P Special 155-Watt UV Lamps (LSI Spec # M1-1J-11, AquaAzul part # L-1-941-HO-N), is 0.8 at 16,000 hours of operation based upon the Lamp Data Sheet. Additional testing, in conformance with the 2012 UV Guidelines, is recommended to confirm the actual factor and corresponding hours of operation.

7. The AquaAzul AZ-4,000 UV Disinfection System does not have a mechanical sleeve-wiping system, which can be run daily. Therefore, the AquaAzul AZ-4,000 Disinfection System must be cleaned to reduce sleeve fouling by removing and cleaning them by hand on a regular operator maintenance frequency. The default fouling factor (FF) of 0.8 is assumed; however, it should be confirmed during commissioning, demonstrated via site specific testing and approved by DDW.

[1] At UVT values above 65 percent, the value (65 percent UVT, or A_{254} =0.22) should be used as the default value in the RED calculation.

8. On-line monitoring of flow, UVT, number of banks in operation, and UV lamp operation hours must be provided at all times.

9. The flow meters, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

11. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UV absorbance analyzer manufacturer.

12. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

13. The Aquaazul UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

14. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

15. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 55%,
    c. complete UV reactor failure, and
    d. flow exceeds the maximum flow of 450 liters per minute per lamp.

16. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:

    a. The alarm set points for flow, UV dose, and UVT.
    b. The values of flow, UV dose and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow and UVT.
    d. The required procedure and frequency of cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

17. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration and acceptance by DDW of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local DDW District offices. Approval for the use of Aquaazul AZ-4,000 Open Channel Low-Pressure High-Output (LPHO) Wastewater UV Disinfection System (utilizing GHO64T5L/4P Special 155-Watt UV Lamps) in any and all water recycling applications is granted through the local Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

cc: via email
Sundaram, Vijay <Vijay.Sundaram@stantec.com>
Recycled Water Committee

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

March 5, 2008

Robert Kelly, PhD
Director of Research, Development & Industrialization
Degremont North American R&D Center
PO Box 71390
Richmond, VA 23255-1390

Dear Dr. Kelly:

CONDITIONAL ACCEPTANCE OF Aquaray® 3X HO UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL DECEMBER 2007

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "Aquaray 3X HO UV Disinfection System Bioassay Validation Report" (HydroQual, Inc. December 2007)[1] which contains the bioassay results of the testing in Johnstown, NY. The Aquaray® 3X HO UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation (NWRI). This system has a 65.5-cm chamber and thirty-six 160-W low-pressure high-output (LPHO) lamps in a staggered six by six array oriented vertical to the flow in an open channel. An air scrub sleeve cleaning system is typically provided.

The Aquaray® 3X UV intensity sensor (Part # PW-254-420-SST) was developed in accordance with the reference sensor requirements as outlined in the 2003 NWRI guidelines. The Aquaray® 3X UV intensity sensor was developed to serve both as a duty and reference sensor. An additional PW-254-420-SST sensor is provided with all Aquaray® 3X installations for use as a reference sensor.

The reduction equivalent dose (RED) for the Aquaray® 3X HO UV system is a function of flow rate (Q) and Effective Output (EO). The EO is a function of the temperature of the wastewater (T) and lamp current in amps.

Detailed testing was performed to determine the flow-specific performance of the Aquaray® 3X HO reactor for flow rates ranging from two to twelve MGD at UVTs

[1] Agencies interested in this technology can obtain copies of the December 2007 HydroQual, Inc. report from Robert Kelly, PhD, Degremont North American R&D Center, PO Box 71390, Richmond, VA 23255-1390.

ranging from 55 to 75 percent, lamp current ranging from 2.8 to 4.5 amps, and Effective Output (EO) ranging from 0.42 to 1.00. Testing was performed using both granular media and membrane-filtered effluent. Two similar operating equations were developed with different constants for granular media filtration or membrane filtration.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the Aquaray® 3X HO UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an accepted filtration process.

The acceptance of the validation report is conditioned on the following: The following criteria must be met and/or demonstrated.

1. Aquaray® 3X HO UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Aquaray® 3X HO reactor is limited to the following parameter ranges:

    a. from 2 to 12 MGD
    b. UVTs at or above 55 percent for granular media filtration,
    c. UVTs at or above 65 percent for membrane filtration,
    d. lamp current ranging from 2.8 to 4.5 amps (20.49 to 31.42 kW),
    e. Effective Output (EO) ranging from 0.42 to 1.00,

3. The UV system must convey at worst-case conditions the minimum UV dose of 100 mJ/cm^2 for granular media filtration or 80 mJ/cm^2 for membrane filtration.

4. At least two reactors per channel must be simultaneously on-line.

5. Standby UV equipment must be provided via one of two options:
    a. A standby reactor per channel
    b. A standby channel of the same size

6. Dimensions of the reactor channel shall match the validation testing and manufacturer recommendations.

7. Different empirical equations were developed for granular media filtration and for membrane filtration, based on the performance data collected during the validation test and they must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

A linear regression analysis of the experimental dataset was conducted and a dose algorithm was developed by Ozonia to correlate the validation RED with the corresponding flow rate and EO values The regression equation used is as follows,

$$RED = 10^{(A+B\cdot Log(Q_{train})+C\cdot Log(EO)-\frac{t\cdot S_e}{\sqrt{n}})}$$

Where:

A, B and C are regression constants,

n is the number of bioassay runs,

t is the Student-t factor (for n-1 samples) for the 75 percent confidence interval (CI), and

S_e is the standard deviation of the sample population.

Table -1 presents these values determined for the granular media filtration and membrane filtration applications

Table -1. Ozonia Dose Algorithm Regression Constants

	To use for granular media filtration			**To use for membrane filtration**		
	value	**p-stat**	**R^2**	**value**	**p-stat**	**R^2**
A	2.156762836	8.52E-38	0.9854	2.254252972	4.48E-37	0.9784
B	-0.653390063	8.44E-23		-0.624881876	1.09E-20	
C	1.036441609	6.33E-20		1.139836869	1.67E-19	
T	1.173864190			1.173064871		
Se	0.031073279			0.037412002		
N	29			30		

8. Effective Output (EO) is defined as the product of the

- lamp-aging factor (F_p),
- the quartz sleeve fouling factor (F_t), and
- the lamp output dimming factor (D_i).
- For wastewater reuse applications the TF_{20} factor is added to the EO equation.

$$EO = F_P \cdot F_t \cdot D_i \cdot TF_{20}$$

With $0.42 < EO < 1.00$

According to the HydroQual, Inc. December 2007 report, the typical EO for wastewater reuse applications is 0.68 with F_P=0.85, F_t=0.80, Di=1.00 (4.5A) and TF_{20}=1.00 at a wastewater temperature of 20°C. However, alternate EO values can be used for sizing as long as the new EO remains within the range that was validated (0.42 to 1.00).

9. The lamp output dim level D_i corresponds to the ratio of sensor readings obtained under conditions of reduced lamp current to the sensor readings collected with lamps operating at full output (4.5A lamp current). Testing was conducted to generate data that would support determination of power (current) adjustments to simulate attenuation of the lamp output. D_i can be calculated from the lamp current I_{DR} by the following polynomial expression

$$D_i = A \times I_{DR}^2 + B \times I_{DR} + C$$

Where,

A, B, C = fitting constants as follows.

A	-0.1191891800
B	1.0934227200
C	-1.5073054300

I_{DR} = lamp current (A)

D_i = Dim level, ratio of the sensor output at actual current, I_{DR}, to the intensity at 4.5A

10. Temperature Factor (*TF*) must be adjusted to the temperature of the wastewater being disinfected at the plant site. Bioassaytesting was performed at a wastewater reference temperature of 20°C. For wastewater reuse applications the impact of wastewater temperature should be included into the plant design

according to the customer specifications. Ozonia applies a temperature correction factor (TF_{20}) to simulate the impact of wastewater temperature, T, on the lamp UVC output as follows:

$$TF_{20} = \left(\frac{T}{20}\right)^{0.22512}$$

With $5^{o}C < T < 30^{o}C$

11. Since perforated baffle plate diffusers were used during the validation testing and the velocity profiles measured at the validation testing exceeded the NWRI recommended limit of a 20% variance from the theoretical average velocity, on-site commissioning of the UV system after construction should include

    a. Velocity profile measurements to compare with the conditions experienced during the validation testing;

    b. an on-site check-point bioassay as described below.

12. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, on-site check-point bioassays must be performed on the reactor using seeded MS2 coliphage in a method similar to that in the 2003 NWRI / AwwaRF Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse. The on-site bioassay protocol must be approved by the Department and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

13. The number of tests required for the on-site check-point bioassay will need to be determined for each site on a case-by-case basis. Determination will depend upon whether velocity profile tests are conducted, how well the on-site velocity profiles match the velocity profiles measured at the validation testing, the use of perforated baffle plate diffusers, and any other possible factors that could influence performance.

14. The Aquaray® 3X UV intensity sensor (Part # PW-254-420-SST) was developed in accordance with the reference sensor requirements as outlined in the 2003 NWRI / AwwaRF Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse. Additionally, the Aquaray® 3X UV intensity sensor shall comply with the following properties for a reactor duty sensor, as specified in the November 2006 version of the USEPA UVDGM:

    a. A spectral response that peaks between 250 and 280 nm.

b. Less than 10% of the sensor total measurement is due to light >300 nm when mounted on the UV reactor and viewing the lamps through the water to be treated.

15. The Aquaray® 3X UV intensity sensor was developed to serve both as a duty and reference sensor. An additional PW-254-420-SST sensor shall be provided with all Aquaray® 3X reactors for use as a reference sensor.

16. Currently, the end-of-lamp-life (EOLL) factor (0.85) for the Aquaray® 3X LP amalgam lamp (PN # X0016.H10) is based on independent data collected from testing conducted by UV Technik, the lamp manufacturer. To date, EOLL data is based on 10,000 hours of lamp operation in air.

17. The EOLL test data for the Aquaray® 3X HO UV lamps should be submitted and approved by CDPH for the end of lamp life (EOLL) factor. Until accepted, the NWRI guidance recommends the use of an EOLL factor of 0.5.

18. On-line monitoring of flow, temperature, lamp current, UVT, and intensity must be provided at all times.

19. The accuracy and repeatability of the flow-meters, thermometers, lamp current monitors, UVT monitors, and on-line UV sensors must be demonstrated to the Department. The site specific engineering report must specify the frequency that calibration checks should be performed.

20. The UV disinfection cleaning system must deal effectively with site-specific water quality effects that can foul the sleeves. The engineering report assumes that the fouling factor shall be no worse than 80%. The effect of fouling on the intensity should be measured by the intensity monitor and the dose control should compensate for the fouling as well as the UVT. If fouling becomes too much, an additional reactor or row of bulbs must be brought online.

21. The Aquaray® 3X HO UV system shall provide a built-in automatic reliability feature that triggers more power or rows of lamps in use, when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and increase the number of rows of lamps and/or power setting. Further conditions that should trigger an immediate response include: temperature monitor failure, lamp current monitor failure, intensity monitor failure, UVT monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

22. The low-intensity alarm should be triggered if the actual UV intensity is lower than the minimum sensor reading for the specific combination of UVT and lamp current during the actual disinfection practice. Based on such a data set, an

equation was developed by Ozonia to predict the minimum sensor readings as a function of water transmittance and lamp current. This equation will be used for the system PLC to generate low-low UV Intensity alarm.

$$SR_A(mW/cm^2) = A' \cdot UVT^B \cdot (C + D \cdot I_{DR}^2 + E \cdot I_{DR})$$

A’	0.000000000065242
B	5.999999999999760
C	-1.507502880000210
D	-0.119207540003375
E	1.093555379999170

23. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms.

24. Recent on-site check-point bioassays from other studies have demonstrated poor performance due to hydraulics and short-circuiting, when the water level was 0.25 inches too high. The proposed operational water level of the Aquaray® 3X HO reactor is 66 inches, with a maximum 69 inches and a minimum of 63 inches. The tolerance should be clarified and the site commissioning of the UV system should demonstrate adequate control of the water level between 63-69 inches, within an allowable tolerance.

Review and acceptance of individual UV systems at a particular plant will be handled on a case-by-case basis by the Department’s individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board’s Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist
Cc Water Recycling Committee

HydroQual, Inc.
1200 MacArthur Blvd.
Mahwah, NJ 07430

January 10, 2019

Bruno Ferran
R&D Manager, Purification & Disinfection Systems, SUEZ Treatment Solutions Inc.
600 Willow Tree Rd.
Leonia, NJ 07605

CONDITIONAL ACCEPTANCE OF Aquaray® HiCAP UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL June 2016

The Division of Drinking Water (DDW) Recycled Water Unit (RWU) has reviewed the submittal letter dated August 19, 2016 and the revised submittal entitled "Aquaray HiCAP UV Disinfection System Validation Report" (HDR/HydroQual, Inc. June 2016)[1] which contains the bioassay results of the testing in Johnstown, NY. The Aquaray® HiCAP UV disinfection system was tested and the results analyzed in accordance with the August 2012 National Water Research Institute (NWRI)/Water Research Foundation *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 NWRI Guidelines).

The Aquaray® HiCAP is equipped with lamps rated at 1,000 Watts for a maximum arc current of 7.0 Amps (Part Number X0016.H16). The Aquaray® HiCAP lamps can be dimmed down to 40% of full arc current or 2.8 Amps. Rack mounted power centers power 12 lamps at once. The ideal water level for the Aquaray® HiCAP is 79 inches (201 cm), controlled at approximately 12 inches (30 cm) upstream of the lead bank. The minimum acceptable water level is 74 inches (188 cm).

The Aquaray® HiCAP comprises three different module sizes as illustrated in the HDR, Inc., June 2016 report, Figure 1-1, *3D Rendering of the Aquaray® HiCAP Modules*. The modules have twelve, twenty-four, or thirty-six 1000-W low-pressure high-output (LPHO) Amalgam lamps in a staggered array oriented vertical to the flow in an open channel. A mechanical sleeve cleaning system is typically provided. During bioassay testing lamps were turned on and off in half-bank segments, with a half-bank consisting of 2x6-lamp rows across the channel width. Therefore, a bank of Aquaray HiCAP modules consists of 2 half-banks or 4 rows of lamps with 2 rows per half-bank. As shown in the validation report, Figure 1-2 *Various Lamps Groups for the Adjacent 12-lamp Modules Configuration* and Figure 1-3 *Various Lamps Groups for the Single 24-lamp Modules Configuration* illustrate how the lamps inside the test channel were grouped per banks, half-banks and rows for either the two adjacent 12-lamp modules or the single 24-lamp modules, respectively.

Each UV module is equipped with a single 360-degree UV intensity sensor placed inside a quartz sleeve located equidistant from three adjacent lamps. The water gap between the sensor sleeve and adjacent lamp sleeves is 45.4 mm (1.79 inches). The Aquaray® HiCAP UV intensity

[1] Agencies interested in this technology can obtain copies of the June 2016 HDR, Inc. report from Bruno Ferran R&D Manager Purification & Disinfection Systems, SUEZ Treatment Solutions Inc., 600 Willow Tree Rd., Leonia, NJ 07605.

sensor (Part Number X0017.H13) has a reading range of 0 to 27.7 mW/cm^2 designed for a UVT range of 44% to 85%. It was developed in accordance with the reference sensor requirements as outlined in the 2012 NWRI guidelines and the USEPA UV Disinfection Guidance Manual. The Aquaray® HiCAP UV intensity sensor was developed to serve both as a duty and reference sensor. An additional sensor is provided with all Aquaray® HiCAP installations for use as a reference sensor.

The reduction equivalent dose (RED) for the Aquaray® HiCAP UV system is a function of UVT, flow rate (Q) and Effective Output (EO). The EO is a function of the variable parameters temperature of the wastewater (T) and lamp current in amps. Detailed testing was performed to determine the flow-specific performance of the Aquaray® HiCAP reactor for flow rates ranging from 1.4 to 21 MGD at UVTs ranging from 35 to 80 percent, lamp current ranging from 2.8 to 7.0 amps, and Effective Output (EO) ranging from 0.40 to 1.00. The observed dose ranged from 3.9 to 97.7 mJ/cm^2 per half bank. The DDW RWU finds that the validation testing and report have demonstrated the ability of the Aquaray® HiCAP UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. Aquaray® HiCAP UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Aquaray® HiCAP reactor is limited to the following parameter ranges:
    a. from 0.24 to 3.48 gpm/lamp
    b. UVTs at or above 35 percent,
    c. lamp current ranging from 2.8 to 7.0 amps.

3. At least two banks in series must be simultaneously on-line in accordance with the reliability design criteria of the NWRI.

4. The equations in the “Aquaray HiCAP UV Disinfection System Validation Report” (HDR, Inc. June 2016) must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be required as a permit provision. The equations can be found in the validation report, *Section 1.2.3.2 Dose Calculation Algorithms for Reuse Applications*, specifically the regression coefficients in the following tables:
    a. Table 1-3. Ozonia HiCAP **Dimming Factor-Based** Dose Algorithm Regression Coefficients for Reuse Applications, or
    b. Table 1-4. Ozonia HiCAP **Sensor-Based** Dose Algorithm Regression Coefficients for Reuse Applications; and
    c. Table 1-5. Ozonia HiCAP **Sensor Algorithm** Regression Coefficients

5. Since perforated baffle (stilling) plate diffusers were used during the validation testing the hydraulic conditions experienced during the validation testing should be reproduced.

6. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows at worst case conditions. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval. A registered engineer in California, who is independent from the manufacturer and has experience or training in UV equipment testing, must witness the test program.

7. In addition to the on-site check-point bioassay commissioning must include the following:
    a. Verification that the control system is programmed with the proper equations
    b. A flow split analysis if more than one channel is constructed
    c. A minimum water level check - 74 inches (188 cm)
    d. Any other items specified as appropriate per the NWRI UV Guidelines

8. On-line monitoring of flow, UV intensity, UVT, temperature, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

11. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

12. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

13. The HiCAP UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

14. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

15. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 44%,
    c. complete UV reactor failure, and
    d. flow exceeds the maximum flow of 3.5 gpm/lamp.

16. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The

operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:

a. The alarm set points for flow, UV dose, UVT, and UV intensity.
b. The values of flow, UV dose, and UVT when effluent must be diverted to waste.
c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
e. The UV lamp tracking procedures and replacement intervals.

17. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local DDW District offices. Approval for the use of HiCAP UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

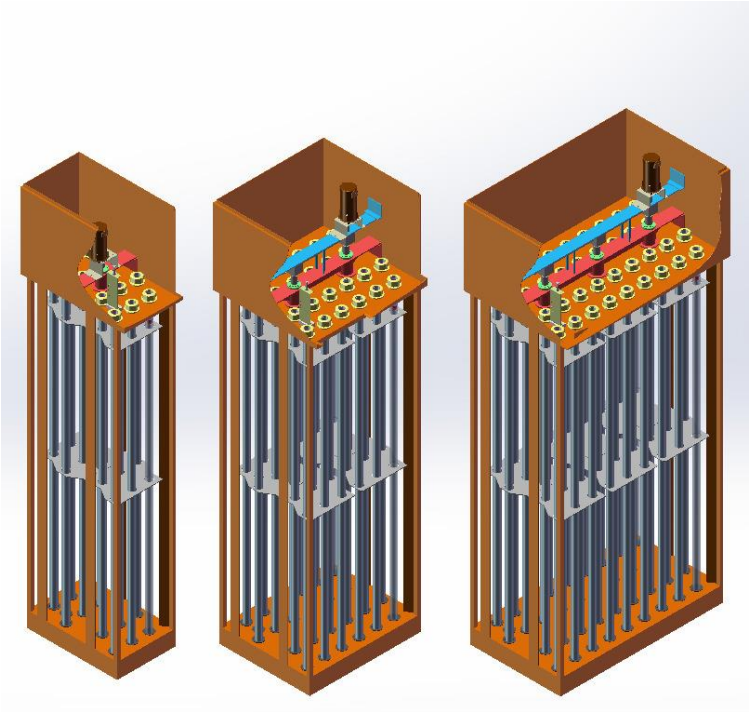
Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee



12-lamp 24-lamp 36 lamp

Figure 1-1. 3D Rendering of the Aquaray® HiCAP Modules

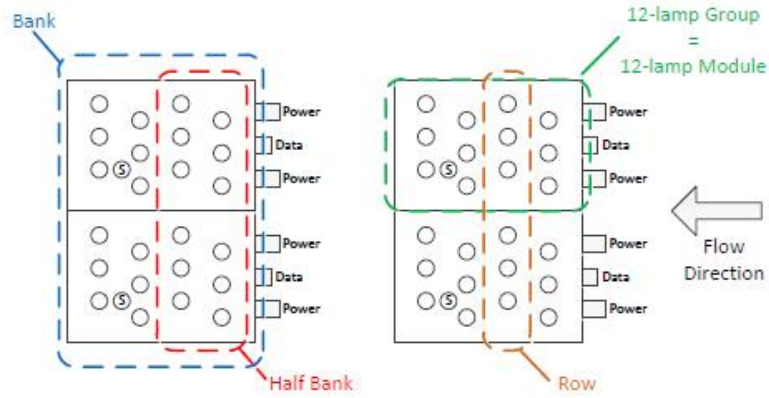


Figure 1-2. Various Lamps Groups for the Adjacent 12-lamp Modules Configuration

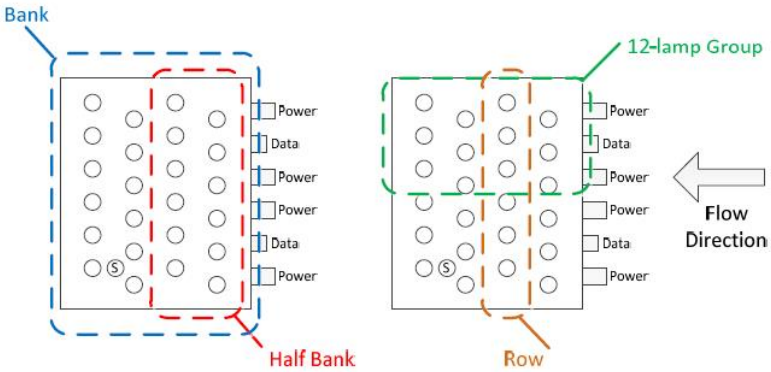


Figure 1-3. Various Lamps Groups for the Single 24-lamp Modules Configuration

State Water Resources Control Board
Division of Drinking Water

February 19, 2015

Mr. Paul Ropic
Aquionics Inc.
1455 Jamike Ave. Ste. 100
Erlanger, KY 41018

Dear Mr. Ropic,

CONDITIONAL ACCEPTANCE OF AQUIONICS INLINE 400+ UV DISINFECTION SYSTEM, 2012 NWRI ANALYSIS

The Division of Drinking Water (DDW) has reviewed the Carollo Engineers report entitled "Addendum – Inline+ UV Disinfection Systems Validation Report, 2012 NWRI Analysis Of The Inline 400+ Reactor Validation Data" (August 2014)[1] The 2014 Carollo report presents the results of the 2008 bioassay analyzed per the August 2012 National Water Research Institute (NWRI)/Water Research Foundation UV Guidelines (hereinafter referred to as 2012 NWRI Guidelines).

Comparison of the 2014 Carollo report to 2008 Carollo Report

The Recycled Water Unit (RWU) revises its previous conditional acceptance letter for the Aquionics Inline 400+ reactor and finds the following:

- The 2014 bioassay Reduction Equivalent Dose (RED) equation below, based upon an analysis per the 2012 NWRI Guidelines, is an appropriate dose equation to sufficiently demonstrate the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled water that has received treatment through an accepted filtration process.
- The equation developed for the predicted UV intensity sensor in the 2008 Carollo report must be replaced with the new predicted UV intensity sensor equation below from the 2014 Carollo report.
- The old RED equation in the 2008 Carollo report is more conservative than the new RED equation, when used in conjunction with the new predicted UV intensity sensor equation in the 2014 Carollo report.
- The old RED equation with the old predicted UV intensity sensor equation over estimates the dose delivered in some cases; therefore, this combination is no longer acceptable,

[1] Agencies interested in this technology can obtain copies of the August 2014 Carollo Engineers report from Mr. Andrew Salveson, Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

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unless appropriately modified, based upon on-site spot check bioassay results as determined by DDW.

The Aquionics Inline 400+ reactor system has a six-inch chamber and four medium-pressure high-output (MPHO) lamps oriented perpendicular to the flow, with an automated wiper system. It has a calibrated germicidal sensor that meets international standards and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the InLine 400+ UV system is a function of flow rate (Q), UV absorbance (A_{254}), and calibrated measured UV sensor value (S). Detailed testing was performed to determine the flow-specific performance of the InLine 400+ reactor for flow rates ranging from 0.115 to 0.824 MGD (80 to 572 gpm) at UVTs ranging from 41.8 to 77.3 percent, and sensor intensities ranging from 85 to 513 mW/cm^2.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The Inline 400+ Reactor UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the InLine 400+ reactors are limited to the following parameter ranges:

    a. from 0.115 to 0.824 MGD (80 to 572 gpm)
    b. UVTs at or above 41.8 percent,
    c. UV sensor intensities ranging from 85 to 513 mW/cm^2.

3. The following two empirical equations based on the 2014 Carollo report should be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{-3.4218} \times UVT^{2.9725} \times P^{1.5140}$$

Where:

S_{pred} = Predicted UV sensor value (mW/cm^2),
UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
P = Measured ballast power setting (kW/lamp), based on power settings at 1.43, 1.70, and 2.33 kW/lamp.

AND

$$RED_{calc} = CR \times 10^{2.9191} \times A_{254}^{-0.7737} \times [S/S_{pred}]^{0.5843} \times [1/Q]^{0.6795}$$

Where:

RED_{calc} = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
CR = Confidence Ratio, 0.935
A_{254} = UV absorbance at 254 nm, between 0.112 cm^{-1} and 0.379 cm^{-1})[2]
S = Measured UV intensity (mW/cm^2), between 85 and 513 mW/cm^2,
S_{pred} = Predicted UV intensity (mW/cm^2), at high lamp power setting (2.33 kW/lamp).

[2] At UVT values above 77.3 percent, the value (77.3 percent UVT, or A_{254} =0.112) shall be used as the default value in the RED calculation

Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site spot check bioassay must be performed on the reactor using seeded MS2 coliphage as described in 2012 NWRI UV Guidelines. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW Standard W294-3 version 12.2003) and is integral to the performance monitoring of the system. The duty sensor used in the validation testing was a IL Metronic Sensortechnik GmbH, ID# UV-technik SUV 20.2Y. Its calibration uncertainty is <±1% to the reference radiometer. DVGW determined its calibration is valid for 24 months.

6. Proper cleaning and lamp replacement must be maintained. The InLine 400+ system uses four ID B2020 lamps, which have an approximate variable power of between 1430 - 2330 Watts per lamp. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4]

7. During commissioning, the accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW. The predicted versus actual sensor readings was shown to yielded a slope of 0.99 with an R^2 of 0.97. This relationship should be confirmed during start-up testing of future UV systems. If the relationship is found to be in significant error, both the expression for “S” and the UV dose monitoring equation can be readily revised using the additional information accrued.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by

[3] At flow rates below 80 gpm, this value (80 gpm) should be used as the default value in the RED calculation

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The Inline 400+ UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 41.8%,
    c. UV intensity below the minimum validated of 85 mW/cm^2,
    d. complete UV reactor failure, and
    e. flow above the maximum flow validated of 572 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by the DDW's individual District offices. Approval for the use of Aquionics Inc. InLine 400+ UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

December 15, 2008

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

Dear Mr. Salveson,

CONDITIONAL ACCEPTANCE OF AQUIONICS INC. InLine 16000+ UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL APRIL 2008

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "Aquionics Inc. InLine+ UV Disinfection Systems Validation Report" (Carollo Engineers, April 2008)[1] which contains the bioassay results of the testing in Reno, NV. The Aquionics InLine UV system, InLine 16000+, closed-vessel UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation. This system has a twenty-inch chamber and twelve 6000 Volt-Amps variable intensity (power levels approximately 4 to 6 kW/lamp) medium-pressure high-output (MPHO) lamps oriented perpendicular to the flow, with an automated wiper system. It has a calibrated germicidal sensor that meets international standards (DVGW) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the InLine 16000+ UV system is a function of flow rate (Q) and measured UV sensor value (S). Detailed testing was performed to determine the flow-specific performance of the InLine 16000+ reactor for flow rates ranging from 0.835 to 5.962 MGD (580 to 4140 gpm) at UVTs ranging from 52 to 75 percent, and sensor intensities ranging from 215 to 739 mW/cm^2.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the InLine 16000+ UV Disinfection Systems to meet the minimum coliform and

[1] Agencies interested in this technology can obtain copies of the April 2008 Carollo Engineers report from Mr. Andrew Salveson, Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an accepted filtration process.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. Conditional acceptance for the InLine 16000+ reactors are limited to the following parameter ranges:

    a. from 0.835 to 5.962 MGD (580 to 4140 gpm)
    b. UVTs at or above 52 percent,
    c. UV sensor intensities ranging from 215 to 739 mW/cm^2.

2. One operational empirical equation was developed based on the performance data collected during the validation test and must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision.

$$RED_{calc} = 10^{\,[\,1.4766 - 0.7733 \times \log(Q) + 1.0571 \times \log(S)\,]}$$

    Where:

    S = Measured UV sensor value (mW/cm^2).
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    Q = Flow rate (gallons per minute [gpm]).

3. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2008 report from Carollo Engineers. The on-site bioassay protocol must be approved by the Department and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

4. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW Standard W294-3 version 12.2003) and is integral to the performance monitoring of the system. The duty sensor used in the validation testing was a IL Metronic Sensortechnik GmbH, ID# UV-technik SUV 20.2Y. Its calibration uncertainty is <±1% to the reference radiometer. DVGW determined its calibration is valid for 24 months. Detailed information related to the UV sensors to be employed is presented in Appendix A in the 2008 report from Carollo Engineers.

5. Proper cleaning and lamp replacement must be maintained. The InLine 16000+ system uses twelve ID B5050H lamps, which have an approximate variable power of between approximately 4 to 6 kW per lamp. The validation did not address the determination of lamp aging or lamp fouling factors. Instead, operation is based upon "sensor set-point" or "intensity pacing" methodology, relying on detailed and accurate sensor readings to maintain and confirm adequate dose in a reactor, similar to drinking water UV applications, thus ensuring that dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.

6. During commissioning, the accuracy and repeatability of the on-line UV sensors must be demonstrated to the Department. The predicted versus actual sensor readings was shown to yield a slope of 1.00 with an R^2 of 0.96. This relationship should be confirmed during start-up testing of future UV systems. If the relationship is found to be in significant error, both the expression for "S" and the UV dose monitoring equation can be readily revised using the additional information accrued.

7. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. Since only one duty sensor is used and it monitors the intensity of one lamp, that particular lamp should be representative of all of the other lamps in age and fouling condition.

9. On-line monitoring of flow and UV intensity must be provided at all times.

10. The InLine 16000+ UV systems must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and startup the next available reactor.

11. Conditions that should shut a reactor down include: intensity sensor failure, low UVT, reactor failure, multiple lamp failure, and ballast high temperature.

12. The 2008 report from Carollo Engineers contains additional information, including other equations derived during the validation, which may be used to adequately design the Aquionics InLine 16000+ UV system.

Review and acceptance of individual systems will be handled on a case-by-case basis by the Department's individual District offices. Approval for the use of Aquionics Inc. InLine+ UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

February 5, 2009

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

Dear Mr. Salveson,

CONDITIONAL ACCEPTANCE OF AQUIONICS INC. InLine 18000+ UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL APRIL 2008

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "Aquionics Inc. InLine+ UV Disinfection Systems Validation Report" (Carollo Engineers, April 2008)[1] which contains the bioassay results of the testing in Reno, NV. The Aquionics InLine UV system, InLine 18000+, closed-vessel UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation. This system has a twenty-inch chamber and eighteen 6000 Volt-Amps variable intensity (power levels approximately 4 to 6 kW/lamp) medium-pressure high-output (MPHO) lamps oriented perpendicular to the flow, with an automated wiper system. It has a calibrated germicidal sensor that meets international standards (DVGW) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the InLine 18000+ UV system is a function of flow rate (Q), UVT[2], and measured UV sensor value (S). Detailed testing was performed to determine the flow-specific performance of the InLine 18000+ reactor for flow rates ranging from 1.426 to 7.016 MGD (990 to 4872 gpm) at UVTs ranging from 52 to 75 percent, and sensor intensities ranging from 336 to 702 mW/cm^2.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the InLine 18000+ UV Disinfection Systems to meet the minimum coliform and

[1] Agencies interested in this technology can obtain copies of the April 2008 Carollo Engineers report from Mr. Andrew Salveson, Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598.

[2] The report states that the RED is a function of UVT for the 18000+, unlike the 16000+ and the 400+, which are only a function of Q and S.

virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an accepted filtration process.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. Conditional acceptance for the InLine 18000+ reactors are limited to the following parameter ranges:

    a. from 1.426 to 7.016 MGD (990 to 4872 gpm),
    b. UVTs at or above 52 percent,
    c. UV sensor intensities ranging from 336 to 702 mW/cm^2.

2. One operational empirical equation was developed based on the performance data collected during the validation test and must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision.

$$RED_{calc} = 10^{[\,-0.8533 + 1.3493 \times \log(UVT) + 0.7084 \times \log(S) - 0.4868 \times \log(Q)]}$$

    Where:

    UVT = % UV transmittance at 254 nm (%);
    S = Measured UV sensor value (mW/cm^2).
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    Q = Flow rate (gallons per minute [gpm]).

3. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2008 report from Carollo Engineers. The on-site bioassay protocol must be approved by the Department and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

4. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW Standard W294-3 version 12.2003) and is integral to the performance monitoring of the system. The duty sensor used in the validation testing was a IL Metronic Sensortechnik GmbH, ID# UV-technik SUV 20.2Y. Its calibration uncertainty is <±1% to the reference radiometer. DVGW determined its calibration is valid for 24 months. Detailed information related to the UV sensors to be employed is presented in Appendix A in the 2008 report from Carollo Engineers.

5. Proper cleaning and lamp replacement must be maintained. The InLine 18000+ system uses eighteen ID B5050[3] lamps, which have an approximate variable power of between approximately 4 to 6 kW per lamp. The validation did not address the determination of lamp aging or lamp fouling factors. Instead, operation is based upon "sensor set-point" or "intensity pacing" methodology, relying on detailed and accurate sensor readings to maintain and confirm adequate dose in a reactor, similar to drinking water UV applications, thus ensuring that dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.

6. During commissioning, the accuracy and repeatability of the on-line UV sensors must be demonstrated to the Department. The predicted versus actual sensor readings was shown to yield a slope of 1.00 with an R^2 of 0.94. This relationship should be confirmed during start-up testing of future UV systems. If the relationship is found to be in significant error, both the expression for "S" and the UV dose monitoring equation can be readily revised using the additional information accrued.

7. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. Since only one duty sensor is used and it monitors the intensity of one lamp, that particular lamp should be representative of all of the other lamps in age and fouling condition.

9. On-line monitoring of flow and UV intensity must be provided at all times.

10. The InLine 18000+ UV systems must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and startup the next available reactor.

11. Conditions that should shut a reactor down include: intensity sensor failure, low UVT, reactor failure, multiple lamp failure, and ballast high temperature.

12. The 2008 report from Carollo Engineers contains additional information, including other equations derived during the validation, which may be used to adequately design the Aquionics InLine 18000+ UV system.

Review and acceptance of individual systems will be handled on a case-by-case basis by the Department's individual District offices. Approval for the use of Aquionics Inc. InLine+ UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

[3] Lamp part number B5050 and B5050H are the same lamp according to Aquionics.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director

EDMUND G. BROWN JR.
Governor

February 13, 2012

John Platz
General Manager
UV Technologies Division
Calgon Carbon Corporation
2000 McClaren Woods Drive
Coraopolis, PA 15108

Dear Mr. Platz,

CONDITIONAL ACCEPTANCE OF CALGON C3 500D UV DISINFECTION REVISED, VALIDATION REPORT, FINAL JANUARY 2010

The California Department of Public Health (CDPH) Drinking Water Program's Recycled Water Committee (RWC) has reviewed the submittal entitled "Calgon Carbon C^3 500 Wastewater UV Reactor Validation Report" (Carollo Engineers, January 2010)[1] which contains the bioassay results of the testing in Stockton, CA. Calgon has recently informed CDPH that the tested reactor has been renamed 500D. The Calgon C^3 500D UV reactor UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation (NWRI). This system utilizes 574-W low-pressure high-output (LPHO) lamps (Light Sources Inc. W300110 part number). The lamps are mounted horizontally and parallel to the flow, with a spacing of six inches. It has a calibrated germicidal sensor that meets international standards (DVGW) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the Calgon C^3 500D UV reactor is a function of flow rate (Q), UVT, and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the Calgon C^3 500D UV reactor for flow rates ranging from 0.36 to 4.78 MGD (248 to 3,318 gpm) per bank, at UVTs from 35 to 74.5 percent (test runs at a UVT less than 55% have been disregarded), and sensor intensities ranging from 0.59 to 9.74 mW/cm^2 (test runs at UV intensities less than 1.6 mW/cm^2 have been disregarded).

[1] Agencies interested in this technology can obtain copies of the January 2010 Carollo Engineers report from Calgon Carbon Corporation, 2000 McClaren Woods Dr, Coraopolis, PA 15108.

The validation report test data has been re-analyzed and evaluated in detail. A misunderstanding regarding the sensor calculation at full power has been corrected, test runs at a UVT less than 55 percent have been eliminated because this is a rare condition for domestic wastewater, and this letter supersedes our previous correspondence. A comparison was made of the individual test results to the RED value calculated by the proposed equation in the validation report. Ratios can be used for comparison purposes using the actual bioassay test result and the RED value calculated by the proposed equation in the validation report. The minimum ratio was 0.82. The range of ratios includes:

minimum ratio was 0.82
the next lowest was 0.83
25 of 66 tests had a ratio < 1
7 had a ratio < 0.9
12 had a ratio <0.95

It is the experience of CDPH that in the commissioning of actual plants (25 plants in California), on-site check-point bioassay test results sometimes demonstrate underperformance in relation to the intent of Title 22, Section 60301.230. While a correction factor can be used and applied, the design capacity may be inadequate. Under-design potentially could compromise public health or limit the flow range of the recycled water treatment plant. This new approach of evaluating validations should prevent under-design. Some existing plants, which may have been under-designed based upon older validations or poor hydraulics, have been assigned a correction factor; therefore, these considerations should be taken into account during design.

In order to provide a consistent, reliable UV dose to meet Title 22, Section 60301.230, and to protect public health, the Calgon C^3 500D UV reactor RED equation must be modified by adding a multiplication factor of 0.93.

While the validation report contains tests performed at a range of 248 to 3,318 gpm per bank, the minimum flow per lamp tested was 19.1 gpm. Therefore, at flow rates below 19.1 gpm/lamp, this value (19.1 gpm/lamp) should be used as the default value in the RED calculation.

With the modified RED equation (see below), the RWC finds that the validation testing and report have demonstrated the ability of the Calgon C^3 500D UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by CDPH.

The acceptance of the validation report is conditioned on the following: The following criteria must be met and/or demonstrated.

1. The Calgon C^3 500D UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Calgon C[3] 500D UV reactor is limited to the following parameter ranges:

    a. from 0.36 to 4.78 MGD (248 to 3318 gpm) per BANK
        [from 8 to 16 lamps per BANK were tested]
        {minimum flow per lamp tested was 19.1 gpm}
    b. UVTs at or above 55 percent,
    c. UV sensor intensities ranging from 1.6 to 9.74 mW/cm^2.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S = 2.0508 \times 10^{-7} \times UVT^{4.2905} \times P^{1.2057}$$

$$RED_{calc} = 0.93 \times 10^{2.2302} \times A_{254}^{-1.2712} \times [S/So]^{0.4299} \times [1/Q]^{0.8107} \times B$$

    Where:

    UVTs at or above 55 percent[2],
    S = Measured UV sensor value (mW/cm^2).
    So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves (0.574 kW/lamp), typically expressed as a function of UVT (mW/cm^2).
    P = Measured ballast power setting, kW per lamp
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate per lamp, calculated as gpm divided by the number of lamps in one bank [3],
    B = Number of operating banks.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2010 report from Carollo Engineers. The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the CDPH for approval.

[2] At UVT values above 74.5 percent, the value (74.5 percent UVT, or A_{254}=0.128) should be used as the default value in the RED calculation.

[3] At flow rates below 19.1 gpm/lamp, this value (19.1 gpm/lamp) should be used as the default value in the RED calculation..

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW) and is integral to the performance monitoring of the system.

6. The Calgon C^3 500D UV reactor uses UV lamps by Light Sources Inc., Lamp Part No. W300110, which have a maximum power of 574 Watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in the 2010 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

9. On-line monitoring of flow, UVT, and intensity must be provided at all times.

10. The Calgon C^3 500D UV reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose or below the minimum UVT of 55%. If the measured UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available bank or reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the CDPH's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

October 6, 2017

Arijit Sarkar
Enaqua
2410 Birch Street
Vista, CA 92081

Dear Mr. Sarkar

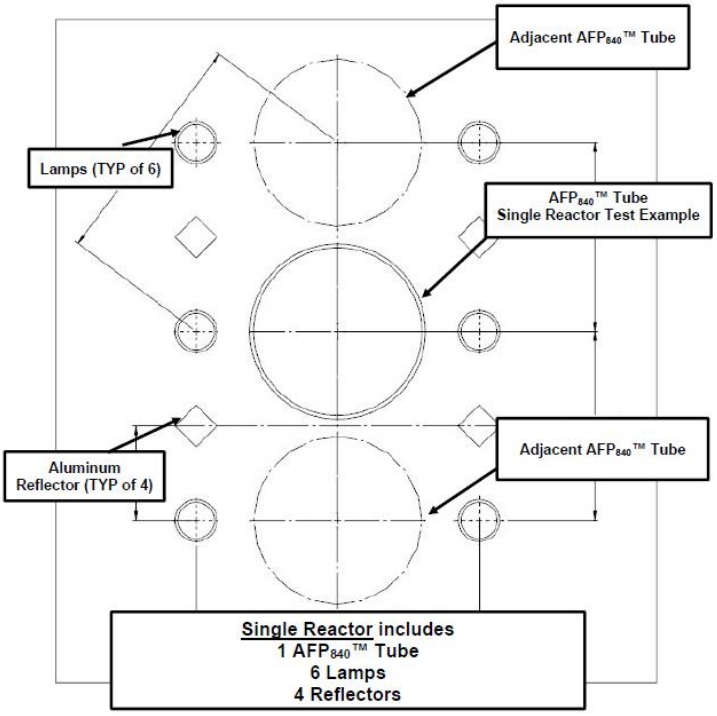
CONDITIONAL ACCEPTANCE OF ENAQUA ENLIGHT UV SYSTEM 60 MM TUBES

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Carollo Engineers January 2016 report entitled “Enaqua Enlight Non-Contact UV System NWRI Validation Report Final”. The 2016 Carollo report presents the results of the 2015 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation[WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines). The Enlight non-contact UV system consists of UV lamps, sensors, and electrical components outside of the water. Water flows through proprietary Activated Fluoropolymer (AFP_{840}™) plastic tubes that are uniformly surrounded by at least six UV lamps (Enlight lamp Model 001.0619055). The reactors are designed to operate under "closed pipe" hydraulics.

The figure on to the right illustrates what a single Enaqua Enlight UV reactor looks like, showing two adjacent AFP840™ tubes that are a portion of an adjacent single tube reactor.

A single reactor consists of one 60-millimeter (mm) (2.36 inches) internal diameter AFP_{840}™ tube surrounded by six low-pressure high-output UV lamps and four reflectors.

The reflectors are polished extruded aluminum that runs the entire length of the lamp.



The reduction equivalent dose (RED) is a function of flow rate per tube, UV absorbance at 254 nm, and number of banks in operation. Detailed testing was performed to determine the flow-specific performance of the Enaqua Enlight UV reactor for flow rates ranging from 20 to 90 gpm per tube at UVTs from 53.8% to 80.2% (0.2692 to 0.0958 UVA).

The DDW finds that the validation testing and report have demonstrated the ability of the Enaqua Enlight UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The Enaqua Enlight UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

    a. from 20 to 90 gpm per tube,
    b. UVTs at or above 53.8 percent

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

    $$RED_{calc} = LAF \times FF \times CR \times 10^{2.1828} \times Q^{-0.7252} \times UVA_{254}^{-0.6470} \times B^{0.9214}$$

    Where:

    RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
    LAF = lamp aging factor of 0.87
    FF = fouling factor of 0.8
    CR = Confidence factor = 0.939
    A_{254} = UV absorbance at 254 nm (cm^{-1}). At values below 0.0958, the value (0.0958) should be used as the default value in the RED calculation.
    Q = Flow rate per tube, (gpm per tube)
    B = Number of operating banks.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the UV system using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site spot check bioassay protocol must be approved by the DDW and must be conducted over a range of flows and UVTs. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval prior to the production of recycled water.

5. The lamp aging factor for the Enlight lamp (Model 001.0619055) is 0.87 at 15,812 hours of operation based upon the Carollo Engineers January 2016 report entitled "*Enlight Non-Contact UV System Lamp Age Factor Testing*".

6. The extent of fouling was evaluated in the Carollo Engineers January 2016 report entitled "*Enlight Non-Contact UV System Fouling Factor Testing*" 2015 fouling factor demonstration was inconclusive, with very different results for two tests. Therefore the default fouling factor should be 0.8, unless site specific testing demonstrates differently and is approved by DDW. Since the testing lasted for 73 days, tubes should be cleaned once every two months, via a bottle brush provided by Enaqua that does not scratch the tube.

7. On-line monitoring of flow per tube, UV absorbance, number of banks in operation, and UV lamp operation hours must be provided at all times.

8. The flow meters, and UV absorbance analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

9. The duty online UV absorbance analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

10. The on-line UV absorbance analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UV absorbance analyzer manufacturer.

11. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

12. The Enaqua Enlight UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

13. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

14. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 53.8%,
    c. complete UV reactor failure, and
    d. flow exceeds the maximum flow of 90 gpm per tube.

15. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, and UV absorbance.
    b. The values of flow, UV dose and UV absorbance when effluent must be diverted to waste.

c. The required frequency of calibration for all meters/analyzers measuring flow and UV absorbance.
d. The required frequency of cleaning and equipment inspection,
e. The UV lamp tracking procedures and replacement intervals.

16. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of Enaqua Enlight UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson and Mrs. Fontaine
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

July 15, 2014

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UV TECHNOLOGY UVLW-6800-10 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-6800-10 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UV Technology UVLW-6800-10 UV reactor disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes six 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 10-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UV Technology UVLW-6800-10 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the ETS/ATG UV Technology UVLW-6800-10 UV reactor for flow rates ranging from 49 to 1726 gpm (0.07 to 2.49 MGD), at UVTs from 55.5 to 68.1 percent, and sensor intensities ranging from 0.01 to 0.05 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-6800-10 UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UV Technology UVLW-6800-10 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UV Technology UVLW-6800-10 UV reactor is limited to the following parameter ranges:
    a. from 49 to 1,726 gpm (0.07 to 2.49 MGD) per reactor
    b. UVTs at or above 55 percent,
    c. UV sensor intensities ranging from 0.01 to 0.05 mW/cm^2,
    d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{-0.6018} \times UVT^{4.4268} \times P^{0.7190}$$

$$RED_{calc} = 0.828 \times 10^{2.7913} \times A_{254}^{-1.2695} \times [S/So]^{0.4032} \times [1/Q]^{0.7414}$$

    Where:
    S_{pred} = Predicted UV sensor value (mW/cm2),
    UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
    S = Measured UV sensor intensity value (mW/cm^2).
    S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
    P = Percent ballast power setting expressed as a decimal (100% = 1)
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate in gallons per minute (gpm)

4. At UVT values above 68.1 percent, the value (68.1 percent UVT, or A_{254} =0.167) shall be used as the default value in the RED calculation.

5. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

6. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

7. The ETS/ATG UV Technology UVLW-6800-10 UV reactor uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation

report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The ETS/ATG UV Technology UVLW-6800-10 reactor UV system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 55%,
    c. UV intensity below the minimum validated,
    d. complete UV reactor failure, and
    e. flow above the maximum flow validated.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

July 29, 2014

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UV TECHNOLOGY UVLW-6800-14 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-6800-14 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UV Technology UVLW-6800-14 UV reactor disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes six 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 14-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UV Technology UVLW-6800-14 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the ETS/ATG UV Technology UVLW-6800-14 UV reactor for flow rates ranging from 26 to 1547 gpm (0.04 to 2.228 MGD), at UVTs from 53.1 to 71.9 percent, and sensor intensities ranging from 0.01 to 0.04 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-6800-14 UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UV Technology UVLW-6800-14 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UV Technology UVLW-6800-14 UV reactor is limited to the following parameter ranges:
    a. from 26 to 1,547 gpm (0.04 to 2.228 MGD) per reactor
    b. UVTs at or above 53 percent,
    c. UV sensor intensities ranging from 0.01 to 0.04 mW/cm^2,
    d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{-0.8165} \times UVT^{3.9415} \times P^{0.2753}$$

$$RED_{calc} = 0.838 \times 10^{2.4395} \times A_{254}^{-1.4866} \times [S/So]^{1.0675} \times [1/Q]^{0.6992}$$

    Where:
    S_{pred} = Predicted UV sensor value (mW/cm2),
    UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
    S = Measured UV sensor intensity value (mW/cm^2).
    S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
    P = Percent ballast power setting expressed as a decimal (100% = 1)
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate in gallons per minute (gpm)

4. At UVT values above 71.9 percent, the value (71.9 percent UVT, or A_{254} =0.143) shall be used as the default value in the RED calculation.

5. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

6. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

7. The ETS/ATG UV Technology UVLW-6800-14 UV reactor uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation

report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The ETS/ATG UV Technology UVLW-6800-14 reactor UV system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 53%,
    c. UV intensity below the minimum validated,
    d. complete UV reactor failure, and
    e. flow above the maximum flow validated.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

September 16, 2014

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-8800-14 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-8800-14 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-8800-14 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes eight 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 14-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-8800-14 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-8800-14 UV reactor for flow rates ranging from 76 to 2,242 gpm (0.11 to 3.23 MGD), at UVTs from 53.3 to 72.6 percent, and sensor intensities ranging from 0.02 to 0.14 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-8800-14 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-8800-14 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-8800-14 UV disinfection system is limited to the following parameter ranges:
   a. up to 2,242 gpm (3.23 MGD) per reactor
   b. UVTs at or above 53.3 percent,
   c. UV sensor intensities ranging from 0.02 to 0.14 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{-0.1501} \times UVT^{5.1689} \times P^{0.5411}$$

$$RED_{calc} = 0.731 \times 10^{2.6909} \times A_{254}^{-1.2886} \times [S/So]^{1.0477} \times [1/Q]^{0.7093}$$

   Where:

   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   A_{254} = UV absorbance at 254 nm (cm^{-1})[2]
   Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-8800-14 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp

[2] At UVT values above 72.6 percent, the value (72.6 percent UVT, or A_{254} =0.139) shall be used as the default value in the RED calculation

[3] At flow rates below 76 gpm, this value (76 gpm) should be used as the default value in the RED calculation

aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-8800-14 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose,

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

b. UVT is below the minimum UVT of 53.3%,
c. UV intensity below the minimum validated of 0.02 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 2,242 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
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Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

May 24, 2016

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-16800-20 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW Series Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-16800-20 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes sixteen 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 20-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-16800-20 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-16800-20 UV reactor for flow rates ranging from 130 to 1,763 gpm (0.187 to 2.54 MGD), at UVTs from 53.9 to 70 percent, and sensor intensities ranging from 1.03 to 2.24 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-16800-20 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-16800-20 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-16800-20 UV disinfection system is limited to the following parameter ranges:
   a. up to 1,763 gpm (2.54 MGD) per reactor
   b. UVTs at or above 53.9 percent,
   c. UV sensor intensities ranging from 1.03 to 2.24 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.5693} \times UVT^{1.3875} \times P^{0.6083}$$

$$RED_{calc} = 0.878 \times 10^{3.0404} \times A_{254}^{-0.8818} \times [S/So]^{0.5796} \times [1/Q]^{0.6803}$$

   Where:
   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),[2]
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   A_{254}= UV absorbance at 254 nm (cm^{-1})[3]
   Q = Flow rate in gallons per minute (gpm)[4]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-16800-20 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV

[2] At UVT values above 70 percent, the value (70 percent UVT) shall be used as the default value in the RED calculation

[3] At UVT values above 70 percent, the value (70 percent UVT, or A_{254} =0.155) shall be used as the default value in the RED calculation

[4] At flow rates below 130 gpm, this value (130 gpm) should be used as the default value in the RED calculation

applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[5] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-16800-20 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:

[5] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

a. UV dose is below the minimum UV dose,
b. UVT is below the minimum UVT of 53.9%,
c. UV intensity below the minimum validated of 1.03 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 1,763 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

October 27, 2014

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
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Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-20800-20 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-20800-20 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-20800-20 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes twenty 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 20-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-20800-20 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-20800-24 UV reactor for flow rates ranging from 162 to 3,216 gpm (0.23 to 4.63 MGD), at UVTs from 53.9 to 68.8 percent, and sensor intensities ranging from 1.16 to 2.3 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-20800-24 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-20800-20 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-20800-20 UV disinfection system is limited to the following parameter ranges:
   a. up to 3,216 gpm (4.63 MGD) per reactor
   b. UVTs at or above 53.9 percent,
   c. UV sensor intensities ranging from 1.16 to 2.3 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.5221} \times UVT^{1.0182} \times P^{0.5964}$$

$$RED_{calc} = 0.878 \times 10^{3.1763} \times A_{254}^{-0.8818} \times [S/So]^{0.5397} \times [1/Q]^{0.6579}$$

   Where:
   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   A_{254} = UV absorbance at 254 nm (cm^{-1})[2]
   Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-20800-24 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp

[2] At UVT values above 68.8 percent, the value (68.8 percent UVT, or A_{254} =0.162) shall be used as the default value in the RED calculation

[3] At flow rates below 162 gpm, this value (162 gpm) should be used as the default value in the RED calculation

aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-20800-24 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose,

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

b. UVT is below the minimum UVT of 53.9%,
c. UV intensity below the minimum validated of 1.16 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 3,216 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

June 26, 2015

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-22800-24 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW Series Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-22800-24 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes twenty-two 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 24-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-22800-24 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-22800-24 UV reactor for flow rates ranging from 105 to 1,889 gpm (0.151 to 2.72 MGD), at UVTs from 52.4 to 71.4 percent, and sensor intensities ranging from 0.95 to 2.09 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-22800-24 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-22800-24 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-22800-24 UV disinfection system is limited to the following parameter ranges:
   a. up to 1,889 gpm (2.72 MGD) per reactor
   b. UVTs at or above 52.4 percent,
   c. UV sensor intensities ranging from 0.95 to 2.09 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.5213} \times UVT^{1.3655} \times P^{0.5698}$$

$$RED_{calc} = 0.816 \times 10^{3.2025} \times UVT^{0.5279} \times [S/So]^{0.48} \times [1/Q]^{0.4148}$$

   Where:
   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),[2]
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-22800-24 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp

[2] At UVT values above 71.4 percent, the value (71.4 percent UVT) shall be used as the default value in the RED calculation

[3] At flow rates below 105 gpm, this value (105 gpm) should be used as the default value in the RED calculation

aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-22800-24 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose,

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

b. UVT is below the minimum UVT of 52.4%,
c. UV intensity below the minimum validated of 0.95 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 1,889 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

October 24, 2014

Jon C McClean
President
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238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-30800-24 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-30800-24 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-30800-24 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes thirty 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 24-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-30800-24 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-30800-24 UV reactor for flow rates ranging from 388 to 6,713 gpm (0.56 to 9.67 MGD), at UVTs from 53.0 to 72.4 percent, and sensor intensities ranging from 0.92 to 2.26 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-30800-24 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-30800-24 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-30800-24 UV disinfection system is limited to the following parameter ranges:
   a. up to 6,713 gpm (9.67 MGD) per reactor
   b. UVTs at or above 53.0 percent,
   c. UV sensor intensities ranging from 0.92 to 2.26 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.5105} \times UVT^{0.9196} \times P^{0.6901}$$

$$RED_{calc} = 0.853 \times 10^{3.5451} \times A_{254}^{-0.5643} \times [S/So]^{0.5848} \times [1/Q]^{0.6397}$$

   Where:
   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   A_{254} = UV absorbance at 254 nm (cm^{-1})[2]
   Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-30800-24 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV

[2] At UVT values above 72.4 percent, the value (72.4 percent UVT, or A_{254} =0.14) shall be used as the default value in the RED calculation

[3] At flow rates below 388 gpm, this value (388 gpm) should be used as the default value in the RED calculation

applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-30800-24 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

a. UV dose is below the minimum UV dose,
b. UVT is below the minimum UVT of 53.0%,
c. UV intensity below the minimum validated of 0.92 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 6,713 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

May 27, 2015

Jon C McClean
President
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-30800-30 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW Series Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-30800-30 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes thirty 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 30-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-30800-30 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the ETS/ATG UV Technology UVLW-30800-30 UV reactor for flow rates ranging from 330 to 5,709 gpm (0.475 to 8.22 MGD), at UVTs from 52.9 to 72.9 percent, and sensor intensities ranging from 1.12 to 2.97 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-30800-30 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-30800-30 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-30800-30 UV disinfection system is limited to the following parameter ranges:
   a. up to 5,709 gpm (8.22 MGD) per reactor
   b. UVTs at or above 52.9 percent,
   c. UV sensor intensities ranging from 1.12 to 2.97 mW/cm^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.7001} \times UVT^{1.6929} \times P^{0.6152}$$

$$RED_{calc} = 0.854 \times 10^{3.2741} \times A_{254}^{-1.1055} \times [S/So]^{0.4412} \times [1/Q]^{0.6755}$$

   Where:
   S_{pred} = Predicted UV sensor value (mW/cm2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
   S = Measured UV sensor intensity value (mW/cm^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
   P = Percent ballast power setting expressed as a decimal (100% = 1)
   RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
   A_{254} = UV absorbance at 254 nm (cm^{-1})[2]
   Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The ETS/ATG UVLW-30800-30 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV

[2] At UVT values above 72.4 percent, the value (72.4 percent UVT, or A_{254} =0.14) shall be used as the default value in the RED calculation

[3] At flow rates below 330 gpm, this value (330 gpm) should be used as the default value in the RED calculation

applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The UVLW-30800-30 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert the UV system effluent to waste include the following:

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

a. UV dose is below the minimum UV dose,
b. UVT is below the minimum UVT of 52.9%,
c. UV intensity below the minimum validated of 1.12 mW/cm^2,
d. complete UV reactor failure, and
e. flow above the maximum flow validated of 5,709 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

August 14, 2014

Jon C McClean
Engineered Treatment Systems, LLC
238 Commercial Drive
P.O. Box 392
Beaver Dam, WI 53916

CONDITIONAL ACCEPTANCE OF ENGINEERED TREATMENT SYSTEMS/ATG UVLW-45800-30 CLOSED VESSEL UV REACTORS VALIDATION REPORT, FINAL APRIL 2013

Dear Mr. McClean

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Engineered Treatment Systems/ATG UV Technology UVLW-45800-30 Closed Vessel UV Reactors Validation Report" (Carollo Engineers, April 2013)[1] which contains the bioassay results of the testing in Pleasanton, CA. The Engineered Treatment Systems (ETS)/ATG UVLW-45800-30 UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes forty-five 800-W low-pressure high-output (LPHO) lamps (Phillips ATGW1001800 part number). The lamps are mounted horizontally and parallel to the flow, within a 30-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the ETS/ATG UVLW-45800-30 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the ETS/ATG UV Technology UVLW-45800-30 UV reactor for flow rates ranging from 340 to 7477 gpm (0.49 to 10.77 MGD), at UVTs from 52.8 to 74.8 percent, and sensor intensities ranging from 1.28 to 3.47 mW/cm^2. However, it is the experience of DDW in reviewing numerous validation reports, that when the flow range is extreme, performance suffers at the low end due to non-ideal hydraulics.

In order to evaluate the UVLW-45800-30 UV reactor performance at low flows, the validation report test data was re-analyzed in detail. A comparison was made of the individual test results to the RED value calculated by the proposed equation in the validation report. Ratios can be used for comparison purposes using the actual bioassay test result and the RED value calculated by the proposed equation in the validation report. The majority of ratios that were less than 1.0 occurred in the flows less than 700 gpm. In order to provide a consistent, reliable UV dose to meet Title 22, Section 60301.230, and to protect public health, the UV reactor RED equation must be modified by programming a minimum flow

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

setting. Therefore, while flow rates less than 700 gpm can be permitted, a value of 700 gpm should be used as the default value in the RED calculation.

The DDW finds that the validation testing and report have demonstrated the ability of the ETS/ATG UV Technology UVLW-45800-30 UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

1. The ETS/ATG UVLW-45800-30 UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the ETS/ATG UVLW-45800-30 UV disinfection system is limited to the following parameter ranges:
    a. up to 7,477 gpm (10.77 MGD) per reactor
    b. UVTs at or above 52.8 percent,
    c. UV sensor intensities ranging from 1.28 to 3.47 mW/cm^2,
    d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.7359} \times UVT^{1.6021} \times P^{0.6196}$$

$$RED_{calc} = 0.911 \times 10^{3.744} \times A_{254}^{-0.9176} \times [S/So]^{0.8422} \times [1/Q]^{0.7641}$$

    Where:
    S_{pred} = Predicted UV sensor value (mW/cm2),
    UVT= Percent UV transmittance expressed as a decimal (55% = 0.55),
    S = Measured UV sensor intensity value (mW/cm^2).
    S_o = Predicted UV intensity at full lamp power, corresponding to 800W for new lamps with clean sleeves (mW/cm^2).
    P = Percent ballast power setting expressed as a decimal (100% = 1)
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    A_{254} = UV absorbance at 254 nm (cm^{-1})[2]
    Q = Flow rate in gallons per minute (gpm)[3]

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

[2] At UVT values above 74.8 percent, the value (74.8 percent UVT, or A_{254} =0.126) shall be used as the default value in the RED calculation

[3] At flow rates below 700 gpm, this value (700 gpm) should be used as the default value in the RED calculation

6. The ETS/ATG UVLW-45800-30 disinfection system uses UV lamps by Philips, Lamp Part No. ATGW1001800, which have a maximum power of 800-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2013 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The ETS/ATG UV Technology UVLW-45800-30 UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup the redundant reactor include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 52.8%,
    c. UV intensity below the minimum validated of 1.28 mW/cm^2,
    d. complete UV reactor failure, and
    e. flow above the maximum flow validated of 7,477 gpm.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director

EDMUND G. BROWN JR.
Governor

December 30, 2013

Dr. Randy Cooper
Chief Technical Officer
NeoTech Aqua UV Solutions, Inc.
5893 Oberlin Dr., Suite 104
San Diego, CA 92121

Conditional Acceptance of the NeoTech Aqua D438™ UV System for Reverse Osmosis Permeate and for Advanced Oxidation Process (AOP) Applications

The California Department of Public Health (CDPH) Drinking Water Program's Recycled Water Committee (RWC) has reviewed and evaluated the submittal entitled *NeoTech Aqua D438™ UV System: Validation Testing Final Report* by Trussell Technologies, Inc. and Carollo Engineers. The testing was conducted with a focus on two criteria:

(1) NWRI/WaterRF *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (NWRI UV Guidelines, 2012) and
(2) Draft Groundwater Recharge Reuse Regulations (GRRR).

The D438™ UV System consists of a single reactor containing two low pressure, high output (LPHO) lamps each with a rated nominal input power of 111 W, Part No. 3000600. The pilot setup consisted of a tank and inline feed of RO permeate into the D438™ UV system, with static mixers located both upstream and downstream of the UV system.

Carollo Engineers and Trussell Technologies conducted bench and pilot-scale testing with MS2 in accordance with the 2012 NWRI UV Guidelines by spiking MS2 Coliphage into the feed water to the D438™ UV System treating RO permeate at West Basin Municipal Water District's Edward C. Little Water Recycling Facility (ECLWRF). Bench testing with a collimated beam apparatus was conducted at Trussell Technologies laboratory in Pasadena, CA. The testing was conducted by spiking MS2 Coliphage into the feed water at flows between 25 to 129 gpm. Based on the NWRI guidelines, the MS2 operational equation for the D438™ UV system was determined as a function of flow rate (Q), UVT (A_{254}), and normalized UV sensor value (S/S_0). The UV dose equation was developed using only 11 data points. Based upon an evaluation of the data, an uncertainty factor of 0.85 is reflected in the accepted equation; and a minimum UVT of 95% is required to reflect typical minimum UVT for RO permeate.

The MS2 results were also used to address compliance with the draft GRRR, which requires 12-log virus, 10-log Giardia, and 10-log Cryptosporidium removal, with no more than 6-log credit in a single treatment step. For potable reuse applications under the draft GRRR, the MS2 removal was determined based on the operational equation developed in accordance with the NWRI Guidelines, with the RED bias and pathogen removal estimated based on the EPA *UV Disinfection Guidance Manual* (UVDGM). For virus removal, the validation report recommended to use adenovirus as the target for virus removal, not MS2 or poliovirus.

Trussell Technologies conducted bench and pilot-scale testing for NDMA with the D438™ UV system. NDMA testing was conducted over a range of both flowrates (25-100 gpm) and UVT values (96.6-98.2%). These nine test runs were used to develop an operational equation, with flow rate the only variable.

Trussell Technologies conducted bench and pilot-scale testing to demonstrate a 0.5-log removal of 1,4-dioxane. Testing was conducted by spiking 1,4-dioxane at a single flow rate of 25 gpm, hydrogen peroxide doses between 3.8 to 11.9 ppm, and UVT values between 95.5 to 97.7%. These six test runs were used to develop an operational equation for 1,4-dioxane removal that accounts for variations in UVT and hydrogen peroxide dose, but not flow.

NON-POTABLE REUSE APPLICATIONS

The acceptance of the validation report is conditional based on the following criteria, which must be met and/or demonstrated:

1. All of the recycled water is treated with reverse osmosis (RO).

2. UVT is greater than or equal to 95%.

3. Flow is less than or equal to 129 gpm.

4. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.34757} \times A_{254}^{-0.4228}$$

$$RED_{calc} = 0.7 \times 10^{2.694} \times Q^{-0.517} \times A_{254}^{-0.239} \times [S/So]^{2.309}$$

Where:

S_{pred} = predicted sensor intensity
A_{254} = UV absorbance[1] at 254 nm.
S = Measured UV sensor value (mW/cm^2).

[1] A_{254} numbers lower than 0.0205 cm^{-1} represent a UVT above 95.4%, which was not validated by MS2 testing. At UVT values above 95.4%, the corresponding A_{254} value (0.0205 cm^{-1}) should be used as the default value in the RED calculation.

So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves (0.111 kW/lamp), typically expressed as a function of A_{254}.
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
Q = Flow rate in gpm,

5. Upon completion of construction and prior to distribution, an on-site check-point bioassay consisting of eight test runs must be performed on the reactor using seeded MS2 coliphage as described in Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (NWRI/Water Research Foundation, August 2012). The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to CDPH for approval.

6. A calibrated germicidal sensor must be used that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard, and is integral to the performance monitoring of the system.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. On-line monitoring of flow, UVT, and UV intensity must be provided at all times.

9. The D438™ UV system reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose or below the minimum UVT of 95%. If the measured UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, single lamp failure, and ballast high temperature.

10. The following information must be included in an Operation, Maintenance, and Monitoring Plan (OMMP):
    a. A description of how the D438™ UV system will respond to changes in system flowrate, UV transmittance, fouling, and lamp age.
    b. Lamp replacement criteria (i.e. hours in operation, %output, etc.)
    c. Alarm set points and corresponding actions, including conditions that call for the plant to shut down.
    d. The validation and calibration procedures and frequencies for on-line monitoring instruments such as flow meters, lamp intensity, and the UV transmittance monitor.

11. No equipment substitutions will be accepted without a demonstration of equivalent performance.

POTABLE REUSE APPLICATIONS

Pilot testing for NDMA was conducted across a range of flowrates to address the impact of hydraulics on UV reactor performance. The report demonstrated that the improved efficiency of the D438™ UV system reactor, compared to treatment performance data in the literature for other reactors in RO permeate, was likely due to the reflective surface of the D438™ UV system reactor. Past studies with reactors lacking the reflective surface demonstrated a decline in performance at lower flow rates associated with hydraulic conditions approaching laminar flow, as evidenced by higher electrical efficiency per log order reduction (EE/O) values at the lower flow rates. The tracer testing in this study demonstrated that the hydraulics approached plug flow as the flowrate was increased from 25 to 100 gpm, as evidenced by the greater spreading and tailing of the tracer profile at 25 gpm compared to 100 gpm.

Electrical Efficiency Per Log Order Reduction (EE/O)

The D438™ UV reactor pilot-scale system test results indicate EE/O values of 0.11 to 0.17 kWh/kgal EE/O for NDMA reduction across three different hydraulic conditions ranging from a Reynolds number (Re) of 13,000 at a flowrate of 25 gpm to Re near 50,000 at a flowrate of 100 gpm.. The test results indicate an EE/O typically observed at higher flow rates and higher Reynolds numbers indicative of a more highly turbulent flow regime than seen in other UV reactors. This observation is consistent with the proposition that increasing the reflective property of the reactor's walls can contribute to more uniform distribution of UV light at Reynolds numbers less than 100,000, thus improving performance. Furthermore, the D438™ UV pilot-scale system test results indicate EE/Os comparable to the potable reuse projects at Orange County Water District and West Basin Municipal Water District, which operate at approximately 0.2 kWh/kgal EE/O for NDMA at full-scale, respectively.

The test results indicate EE/O values for 1,4-dioxane varied depending on total chlorine and hydrogen peroxide concentrations, of 0.19 to 0.41 kWh/kgal EE/O. For comparison, full-scale demonstration testing at Orange County Water District demonstrated an EE/O of 0.46 kWh/kgal/log order reduction corresponding to 0.5-log 1,4-dioxane removal at a hydrogen peroxide dose of 3 mg/L

NDMA Collimated Beam Test Results

Collimated beam bench testing was conducted with the same water as the pilot testing. The test results show that bench-scale collimated beam (CB) NDMA testing with the D438™ UV system reactor produced results consistent with several past studies. The report demonstrated consistent levels of removal between collimated beam and pilot study data.

Chloramine as an Indicator

Previous experience has shown the potential of chloramine as an indicator of UV photolysis dose and, hence, for NDMA removal. In the validation report, Graph II-3 plots the log removal of NDMA and chloramines for a given UV dose and illustrates a

good correlation between the removal of NDMA and chloramines during collimated beam testing. The results indicate consistent levels of removal between CB and pilot study data. As such, a CB analysis on test water for NDMA and chloramine removal should be sufficient to use chloramine removal as an indicator for NDMA on that specific water sample. This information should be verified on any specific water source prior to using chloramines as an indicator for NDMA removal. These results suggest that monitoring chloramines before and after UV photolysis can be used as a means for continuously establishing performance.

Pathogen Inactivation

For virus removal, the validation report recommended to use adenovirus as the target for virus removal, not MS2 or poliovirus. When the D438™ UV system reactor is utilized in an AOP mode, the approximate equivalent MS2 UV dose will be many times greater than the dose required to achieve 6-log credits for microbiological pathogens. In AOP mode the UV dose is estimated to be between 300 to 1000 mJ/cm^2.

Potable Reuse Conditions

Based on the validation report, the D438™ UV system is acceptable for use in potable water reuse applications (i.e., AOP) if the following conditions are met and/or demonstrated:

1. All of the recycled water is treated with reverse osmosis (RO).

2. UVT is greater than or equal to 95%.

3. Flow is less than or equal to 129 gpm.

4. Upon completion of construction and prior to distribution, an on-site check-point bioassay consisting of eight test runs must be performed on the reactor using seeded MS2 coliphage as described in Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (NWRI/Water Research Foundation, August 2012). The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to CDPH for approval. In lieu of this any full-scale application must demonstrate a minimum dose of 300 mJ/cm^2 will be maintained at all times.

5. Additional testing should be performed to refine the equations for NDMA and 1,4-dioxane.
    a. The equation for NDMA does not include UVT as an independent variable. This should be confirmed via site specific demonstration testing. Previous research has proven that the efficiency of direct photolysis is dependent on the UVT of the process water.

   b. The equation for 1,4-dioxane does not include flow as an independent variable because only one flow rate was tested. This equation must be refined via site specific demonstration testing.

6. Any new proposal must evaluate site-specific water quality parameters for RO permeate in comparison to the water quality at the ECLWRF.

7. Hydrogen peroxide must be added to the influent of the UV reactor at all times for 1,4-dioxane credit, but is not required for disinfection or NDMA destruction. The peroxide dose must be determined via site specific demonstration testing.

8. A calibrated germicidal sensor must be used that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard, and is integral to the performance monitoring of the system.

9. The accuracy and repeatability of the on-line UV sensors must be demonstrated to CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

10. On-line monitoring of flow, UVT, and UV intensity must be provided at all times.

11. The D438™ UV system reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose or below the minimum UVT of 95%. If the measured UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, single lamp failure, and ballast high temperature.

12. The following information must be included in an Operation, Maintenance, and Monitoring Plan (OMMP):
    a. A description of how the D438™ UV system will respond to changes in system flowrate, UV transmittance, fouling, and lamp age.
    b. Lamp replacement criteria (i.e. hours in operation, %output, etc.)
    c. Alarm set points and corresponding actions, including conditions that call for the plant to shut down.
    d. The validation and calibration procedures and frequencies for on-line monitoring instruments such as flow meters, lamp intensity, and the UV transmittance monitor.

13. No equipment substitutions will be accepted without a demonstration of equivalent performance.

Based on the above evaluation, for the D438™ UV system to be conditionally accepted for a potable or non-potable reuse project, an engineering report demonstrating the above specified conditions must be submitted, reviewed, and accepted by CDPH. Review and acceptance of individual systems will be handled on a case-by-case basis by CDPH's individual District offices. Approval for the use of your technology in any and

all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Dr. R. Shane Trussell
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Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director

EDMUND G. BROWN JR.
Governor

September 30, 2013

Sunny Kim
Neotec UV Inc.
20280 S. Vermont Ave., Suite #200
Torrance, CA 90502

Dear Mr. Kim

CONDITIONAL ACCEPTANCE OF NEOTEC OPEN CHANNEL NOL-HM UV DISINFECTION VALIDATION REPORT, FINAL DECEMBER 2012

The California Department of Public Health (CDPH) Drinking Water Program's Recycled Water Committee (RWC) has reviewed the submittal entitled "Neotec Open Channel NOL-HM Wastewater UV Reactor Validation Report" (Carollo Engineers, December 2012)[1] which contains the bioassay results of the testing in Fresno, CA. The Neotec Open Channel NOL-HM UV reactor disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes 320-W low-pressure high-output (LPHO) lamps (Light Sources Inc. GPHHVA1554T6L part number). The lamps are mounted horizontally and parallel to the flow, with a spacing of ten centimeters. It has a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the performance monitoring of the system. The operating approach uses a "Dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the Neotec Open Channel NOL-HM UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the Neotec Open Channel NOL-HM UV reactor for flow rates ranging from 0.18 to 2.45 MGD (123 to 1,702 gpm), at UVTs from 52.7 to 75.9 percent, and sensor intensities ranging from 0.20 to 1.57 mW/cm^2.

While the validation report contains tests performed at a range of 123 to 1,702 gpm per bank, the minimum flow per lamp tested was 9 gpm. Therefore, at flow rates less than

[1] Agencies interested in this technology can obtain copies of the December 2012 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

9 gpm/lamp, this value (9 gpm/lamp) should be used as the default value in the RED calculation.

The RWC finds that the validation testing and report have demonstrated the ability of the Neotec Open Channel NOL-HM UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by CDPH.

The acceptance of the validation report is conditioned on the following:

1. The Neotec Open Channel NOL-HM UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Neotec Open Channel NOL-HM UV reactor is limited to the following parameter ranges:
    a. from 0.18 to 2.45 MGD (123 to 1,702 gpm) per BANK
        [16 lamps per BANK were tested]
        {flow per lamp tested was 9 to 106 gpm}
    b. UVTs at or above 53 percent,
    c. UV sensor intensities ranging from 0.20 to 1.57 mW/cm^2,
    d. Power range 70 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{0.8088} \times UVT^{5.1740} \times P^{0.5431}$$

$$RED_{calc} = 0.828 \times 10^{2.1457} \times A_{254}^{-1.1733} \times [S/So]^{0.5498} \times [1/Q]^{0.8589} \times B$$

Where:

S_{pred} = Predicted UV sensor value (mW/cm2),
UVT = Percent UV transmittance expressed as a decimal (55% = 0.55),
S = Measured UV sensor value (mW/cm^2).
S_o = Predicted UV intensity at full lamp power (new lamps) with clean sleeves (mW/cm^2).
P = Percent ballast power setting expressed as a decimal (100% = 1)
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
A_{254} = UV absorbance at 254 nm (cm^{-1}) .
Q = Flow rate per lamp, calculated as gpm divided by the number of lamps in one bank (gpm/bank),
B = Number of operating banks.

4. At UVT values above 75.9 percent, the value (75.9 percent UVT, or A_{254} =0.12) shall be used as the default value in the RED calculation.

5. At flow rates below 9 gpm/lamp, this value (9 gpm/lamp) shall be used as the default value in the RED calculation.

6. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (NWRI/Water Research Foundation, August 2012). The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to CDPH for approval.

7. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the performance monitoring of the system.

8. The Neotec Open Channel NOL-HM UV reactor uses UV lamps by Light Sources Inc., Lamp Part No. GPHHVA1554T6L, which have a maximum power of 320 Watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in the 2012 report from Carollo Engineers.

9. The accuracy and repeatability of the on-line UV sensors must be demonstrated to CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

10. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

11. On-line monitoring of flow, UVT, and intensity must be provided at all times.

12. The Neotec Open Channel NOL-HM UV reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose or below the minimum UVT of 53%. If the measured

UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available bank or reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by CDPH's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
Department of Health Services

California Department of Health Services

SANDRA SHEWRY
Director

ARNOLD SCHWARZENEGGER
Governor

June 8, 2007

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

Dear Mr. Salveson:

QUAY TECHNOLOGIES, LTD OCS 6000 MICROWAVE UV REPORT

The California Department of Health Services Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "Quay Technologies, Ltd. OCS 6000 Microwave UV Validation Report" (Carollo Engineers, September 2006) which contains the bioassay results using the OCS 6000 microwave based UV disinfection technology. The WRC finds that the validation testing and report are sufficient to meet the minimum recommendations to demonstrate the efficacy of the Quay UV technology following the testing protocol outline as set forth in the National Water Research Institute (NWRI)/American Water Works Association Research Foundation's (AWWARF) "UV Disinfection Guidelines Second Edition (2003)." The WRC recommends the following:

1. The design equation for the delivered dose should be:
   log dDose = -2.364606 - (0.636847 • log flow) + 2.633665 • log UVT)
   where flow is in gpm/bundle; a bundle is four lamps and the dDose is the delivered dose per rack in mJ/cm^2.

2. The equation is based on operation at 100% power.

3. The equation is based on UVT between 55 and 81%.

4. The flow range is 43.6 to 142.7 gpm/bundle.

5. A UV system cannot exceed 120 bundles per reactor.

6. Quay OCS 6000 UV system designs should follow all applicable design recommendations set forth in the NWRI/AWWARF "Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (December 2000)."

Drinking Water Technical Programs Branch, 850 Marina Bay Parkway, Bldg P, 2nd Floor, Richmond, CA, 94804-1011
(510) 620-3474 FAX (510) 620-3455
DHS Internet Address: www.dhs.ca.gov Program Internet Address: www.dhs.ca.gov/ps/ddwem

7. As noted in the report, the end of lamp life (EOLL) factor is not been documented or submitted to the Department for review and acceptance, hence, any design should be based on a default EOLL of 0.50.

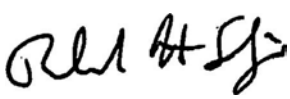
8. Because the actual testing conditions did not cover a minimum dose delivery of 100 mJ/cm^2, installations of the Quay OCS 60.00 should be commissioned using a checkpoint bioassay, using the operational surface defined by the equation in recommendation 1. All other design and operational factors will follow the NWRI/AWWARF UV Disinfection Guidelines unless variances are requested, justified, and accepted.

Any changes made to any component or design element of the Quay OCS 6000 UV system should be reported (in writing) to the Department in advance of making the changes to any production version of your UV system. Your written submittal will be reviewed by the Department's Water Recycling Committee (WRC) to determine if additional performance testing will be required. Should additional testing be required, the Department will ask you to provide a detailed study protocol, which will be reviewed by the WRC. The WRC must approve all study protocols as a condition of accepting the final report. The WRC will also review the final report and, if appropriate, approve any future changes to the design criteria.

Review and acceptance of individual systems will be handled on a case-by-case basis by the Drinking Water Program's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact Brian Bernados (bbernado@dhs.ca.gov; 619.525.4497) or Jeff Stone (jstone1@dhs.ca.gov; 805.566.9767).

Very truly yours,



Richard H. Sakaji, PhD, PE
Senior Sanitary Engineer

cc: WR Committee
chron

[Type here]

State Water Resources Control Board
Division of Drinking Water

August 2, 2017

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UVFitTM04AL20 DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Carollo Engineers September 2016 report entitled "Addendum – TrojanUVFit™ 04AL20 Validation Report 2012 NWRI Analysis of the TrojanUVFit™ 04AL20 Reactor Validation Data". This amends the UV dose equations in the 2010 Carollo validation report. The 2016 Carollo report presents the results of the October 2009 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation[WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines).

The TrojanUVFit™ 04AL20 UV disinfection system is a closed vessel reactor with four UV lamps per UV reactor that utilizes 0.25-kW low-pressure high-output (LPHO) lamps (Trojan part number 794447 manufactured by Heraeus Noblelight). The lamps are mounted horizontally and parallel to the flow, within a four-inch diameter closed vessel reactor. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVFit™ 04AL20 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ 04AL20 UV reactor for flow rates ranging from 0.014 to 0.969 MGD (9.90 to 673 gpm), at UVTs from 40.1% to 81.6% (0.088 to 0.397 UVA), and sensor intensities ranging from 0.84 to 7.55 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ 04AL20 UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

It should be noted that although the dose equation is theoretically valid up to 673 gpm, to achieve a UV dose of 80 mJ/cm^2, the UVT would need to be very high at 92.5% or above. Since the maximum UVT in the validation testing was 81.6%, the dose equation is valid for a single reactor up to 136 gpm for membrane filtration. For media filtration, where a UVT as high as 81.6% is not expected, and the UV guidance specifies a UV dose of 100 mJ/cm^2, the flow capacity is 103 gpm,

corresponding to a higher than normal (for media filtration) UVT of 81.6%. If there are two reactors in series, each operating at a dose of 40mJ/cm^2, the dose equation is theoretically valid up to 326 gpm.

To achieve a membrane filtered UV dose of 80 mJ/cm^2, the feasible flow capacity is approximately 100 gpm, at a UVT of 77% or higher. At flows greater than this, two reactors in series is recommended, unless the UVT is always very high. At the UV Guidelines lower UVT limit of 65% for membrane filtration, to achieve a UV dose of 80 mJ/cm^2, the flow capacity is 56 gpm. At the UV Guidelines lower UVT limit of 55% for media filtration, to achieve a UV dose of 100 mJ/cm^2, the flow capacity is 27 gpm.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ 04AL20 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

    a. from 0.014 to 0.47 MGD (9.9 to 326[1] gpm),
    b. UVTs at or above 40.1 percent,
    c. UV sensor intensities ranging from 0.84 to 7.55 mW/cm^2,
    d. Power range 60 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = ([2.9060 \times 10^{-5} \times BPL] - 8.4900 \times 10^{-4}) \times UVT^{1.8654}$$

$$RED_{calc} = CR \times UVA_{254}^{[-2.48258 - 10.8662 \times UVA]} \times [S/S_o/Q]^{0.79598 + -0.732 \times UVA^2} \times R$$

Where:

BPL = Ballast power level setting (percent)
UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 40.1 percent[2],
S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
S = Measured UV sensor value (mW/cm^2)
S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
CR = Confidence factor = 0.916
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate, (gallons per minute [GPM])
R = Number of operating reactors.

[1] For two reactors in series – for a single reactor 136 gpm

[2] At UVT values above 81.6 percent, the value (81.6 percent UVT, or A_{254} =0.089) should be used as the default value in the RED calculation.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (ÖNORM / DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit™ Model 04AL20 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated[3]. Detailed information related to the UV sensors to be employed under this project is presented in the 2016 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

[3] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 4 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVFit™ 04AL20 UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 40.1%,
    c. UV intensity below the minimum validated of 0.84 mW/cm^2
    d. complete UV reactor failure, and
    e. flow exceeds the maximum flow of 0.469 MGD (326 gpm).

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
    d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local DDW District offices. Approval for the use of TrojanUVFit™ 04AL20 UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

February 25, 2021

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

CONDITIONAL ACCEPTANCE OF TROJAN UVFitTM 8AL20 DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Carollo Engineers September 2016 report entitled "Addendum – TrojanUVFit™ 8AL20 Validation Report, 2012 NWRI Analysis of the TrojanUVFit™ 8AL20 Reactor Validation Data". This amends the UV dose equations in the July 2010 Carollo validation report. The 2016 Carollo report presents the results of the November 2008 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation[WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines).

The TrojanUVFit™ 8AL20 UV disinfection system is a single closed vessel reactor consisting of eight UV lamps that utilize 0.25-kW low-pressure high-output (LPHO) lamps (Trojan part number 794447 manufactured by Heraeus Noblelight). The lamps are mounted horizontally and parallel to the flow, within a 8-inch diameter closed vessel reactor. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVFit™ 8AL20 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ 8AL20 UV reactor for flow rates ranging from 18.7 to 671 gpm per reactor, at UVTs ranging from 40.5 to 81.5 percent (0.09 to 0.390 UVA), and sensor intensities ranging from 0.9 to 8.1 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ 8AL20 UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ 8AL20 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

a. from 18.7 to 671 gpm (0.03 to 0.97 MGD) per reactor,
b. UVTs at or above 40.5 percent,
c. UV sensor intensities ranging from 0.9 to 8.1 mW/cm^2,
d. Power range 60 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = ([1.813 \times 10^{-5} \times BPL] - 4.443 \times 10^{-4}) \times UVT^{1.9689}$$

$$RED_{calc} = CR \times 10^{5.05089} \times UVA^{11.9912 \times UVA} \times [S/S_o/Q]^{[1.00053 - 2.20213 + 3.87797 \times UVA \times UVA]}$$

Where:
BPL = Ballast power level setting (percent)
UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 40.5 percent[1],
S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
S = Measured UV sensor value (mW/cm^2)
S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
CR = Confidence factor = 0.886
UVA = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate, (gallons per minute [gpm])

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (ÖNORM / DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit™ Model 8AL20 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is

[1] At UVT values above 81.5 percent, the value (81.5 percent UVT, or A_{254}=0.09) should be used as the default value in the RED calculation.

delivered and the combined effects of lamp aging and sleeve fouling are incorporated[2]. Detailed information related to the UV sensors to be employed under this project is presented in the 2010 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor. Cleaning the sensor window should be performed during this sensor verification step.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVFit™ 8AL20 UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:

[2] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 8 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

a. UV dose is below the minimum UV dose,
b. UVT is below the minimum UVT of 40.5%,
c. UV intensity below the minimum validated of 0.9 mW/cm^2
d. complete UV reactor failure, and
e. flow exceeds the maximum flow of 671 gpm (0.97 MGD).

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
    d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of TrojanUVFit™ 8AL20 UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Brian Bernados

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

August 19, 2014

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UVFitTM18AL40 DISINFECTION SYSTEM

The Recycled Water Committee (RWC) has reviewed the Carollo Engineers August 2014 report entitled "Addendum – TrojanUVFit™ 18AL40 Validation Report 2012 NWRI Analysis of the TrojanUVFit™ 18AL40 Reactor Validation Data". This amends the UV dose equations in the 2009 Carollo validation report. The 2014 Carollo report presents the results of the December 2009 bioassays analyzed per the August 2012 National Water Research Institute (NWRI)/Water Research Foundation *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 NWRI Guidelines).

The TrojanUVFit™ 18AL40 UV disinfection system is a closed vessel reactor with 18 UV lamps per UV reactor that utilizes 0.25-kW low-pressure high-output (LPHO) lamps (Trojan part number 794447 manufactured by Heraeus Noblelight). The lamps are mounted horizontally and parallel to the flow, within a 16-inch diameter closed vessel reactor. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVFit™ 18AL40 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ 18AL40 UV reactor for flow rates ranging from 0.11 to 1.01 MGD (78.4 to 702.5 gpm), at UVTs from 39.8% to 80.7% (0.401 to 0.093 UVA), and sensor intensities ranging from 0.63 to 6.69 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ 18AL40 UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ 18AL40 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

    a. from 0.11 to 1.01 MGD (78.4 to 702.5 gpm),
    b. UVTs at or above 40 percent,
    c. UV sensor intensities ranging from 0.63 to 6.69 mW/cm^2,
    d. Power range 60 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = ([9.6858 \times 10^{-6} \times BPL] - 3.0248 \times 10^{-4}) \times UVT^{2.096}$$

$$RED_{calc} = CR \times UVA_{254}^{[-1.4033 - 5.1978 \times UVA]} \times [S/S_o]^{0.7796} \times Q^{-0.7307} \times R$$

    Where:

    BPL = Ballast power level setting (percent)
    UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 40 percent[1],
    S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
    S = Measured UV sensor value (mW/cm^2)
    S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
    RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
    CR = Confidence factor = 0.903
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate, (million gallons per day [MGD])
    R = Number of operating reactors.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (ÖNORM / DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit™ Model 18AL40 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is

[1] At UVT values above 81 percent, the value (81 percent UVT, or A_{254} =0.093) should be used as the default value in the RED calculation.

delivered and the combined effects of lamp aging and sleeve fouling are incorporated[2]. Detailed information related to the UV sensors to be employed under this project is presented in the 2009 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVFit™ 18AL40 UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 40%,
    c. UV intensity below the minimum validated of 0.63 mW/cm^2

[2] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 18 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

d. complete UV reactor failure, and
e. flow exceeds the maximum flow of 1.01 MGD (703 gpm).

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
    d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of TrojanUVFit™ 18AL40 UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director

EDMUND G. BROWN JR.
Governor

January 24, 2012

Mark Eyre
Market Regulatory Manager
Trojan Technologies
3020 Gore Road
London, Ontario, Canada N5V 4T7

Dear Mr. Eyre,

CONDITIONAL ACCEPTANCE OF TROJANUVFIT™ MODEL 32AL50 UV FOR RECYCLED WATER, MINOR REVISION, VALIDATION REPORT, SEPTEMBER 2009

The California Department of Public Health (CDPH) Drinking Water Program's Recycled Water Committee (RWC) has reviewed the submittal entitled "Trojan Technologies, TrojanUVFit™ 32AL50 Validation Report" (Carollo Engineers, September 2009)[1] which contains the bioassay results. The TrojanUVFit™ Model 32AL50 UV reactor UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation (NWRI). This reactor is a closed vessel UV system utilizing low-pressure high-output (LPHO) lamps (Heraeus Noblelight, Trojan part number 794447). The ballasts are adjustable from 60 to 100 percent of full power. Model 32AL50 has 32 lamps. The lamps are mounted horizontally and parallel to the flow, within a 20-inch diameter closed vessel reactor. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

The reduction equivalent dose (RED) for the TrojanUVFit™ Model 32AL50 UV reactor is a function of flow rate (Q), UVT, and normalized UV sensor value (S/S_0) or relative lamp output. Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ Model 32AL50 UV reactor for flow rates ranging from 0.10 to 6.0 MGD (69 to 4,230 gpm) per reactor, at UVTs ranging from 40 to 80.9 percent, and sensor intensities ranging from 1.10 to 15.11 mW/cm^2.

[1] Agencies interested in this technology can obtain copies of the September 2009 Carollo Engineers report from Mark Eyre, Trojan Technologies, 3020 Gore Road, London, Ontario, Canada N5V 4T7.

The validation report test data has been analyzed and evaluated in detail. A comparison was made of the individual test results to the RED value calculated by the proposed equation in the validation report. Ratios can be used for comparison purposes using the actual bioassay test result and the RED value calculated by the proposed equation in the validation report. The comparison shows a good fit. The range of ratios includes:

minimum ratio was 0.73
the next lowest was 0.83
the third lowest was 0.93
33 of 43 tests had a ratio > 1.000
3 of 43 tests had a ratio <0.96

The RWC finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ Model 32AL50 UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by CDPH.

The acceptance of the validation report is conditional based on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ Model 32AL50 UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the TrojanUVFit™ Model 32AL50 UV reactor is limited to the following parameter ranges:

    a. flow rates ranging from 0.10 to 6.0 MGD (69 to 4,230 gpm) per reactor
    b. UVTs at or above 40.1 percent,
    c. UV sensor intensities ranging from 1.10 to 15.11 mW/cm^2.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_0 = 2.3431 \text{ X } 10^{-4} \text{ x UVT}^{2.5167}$$

$$RED_{calc} = 10^{-0.9657} \text{ x } Q^{-0.7325} \text{ x UVT}^{1.5809} \text{ x } [S/So]^{0.7897}$$

Where:

UVTs at or above 40.1 percent [2],
S = Measured UV sensor value (mW/cm^2).
So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
Q = Flow rate, in million gallons per day in one reactor [3],

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2009 report from Carollo Engineers. The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the CDPH for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit^{TM} Model 32AL50 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in the 2009 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in

[2] At UVT values above 80.9 percent, the value (80.9 percent UVT) should be used as the default value in the RED calculation.
[3] At flow rates below 0.10 MGD, this value (0.10 MGD) should be used as the default value in the RED calculation..

its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

9. On-line monitoring of flow, UVT, and intensity must be provided at all times.

10. The TrojanUVFit™ Model 32AL50 UV reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the CDPH's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

December 5, 2017
Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UVFitTM 72AL75 DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Carollo Engineers August 2015 report entitled "Addendum – TrojanUVFit™ 72AL75 Validation Report 2012 NWRI Analysis of the TrojanUVFit™ 72AL75 Reactor Validation Data". This amends the UV dose equations in the November 2009 Carollo validation report. The 2015 Carollo report presents the results of the October 2008 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation[WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines).

The TrojanUVFit™ 72AL75 UV disinfection system is a single closed vessel reactor consisting of 72 UV lamps that utilize 0.25-kW low-pressure high-output (LPHO) lamps (Trojan part number 794447 manufactured by Heraeus Noblelight). The lamps are mounted horizontally and parallel to the flow, within a 30-inch diameter closed vessel reactor. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVFit™ 72AL75 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ 72AL75 UV reactor for flow rates ranging from 0.725 to 7.395 MGD (503 to 5128 gpm), at UVTs from 40.3% to 81.0% (0.0915 to 0.395 UVA), and sensor intensities ranging from 0.13 to 2.09 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ 72AL75 UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ 72AL75 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

a. from 0.725 to 7.4 MGD (503 to 5130 gpm),
b. UVTs at or above 40.3 percent,
c. UV sensor intensities ranging from 0.13 to 2.09 mW/cm^2,
d. Power range 60 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = ([1.5509 \times 10^{-7} \times BPL] - 4.973 \times 10^{-6}) \times UVT^{2.7691}$$

$$RED_{calc} = CR \times 10^{2.706} \times Q^{-0.8415} \times UVA_{254}^{[1.905 \times UVA + 9.3234 \times UVA\text{^}2]} \times [S/S_o]^{0.8234}$$

Where:

BPL = Ballast power level setting (percent)
UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 40.3 percent[1],
S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
S = Measured UV sensor value (mW/cm^2)
S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
CR = Confidence factor = 0.909
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate, (million gallons per day [MGD])

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (ÖNORM / DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit™ Model 72AL75 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated[2].

[1] At UVT values above 81.0 percent, the value (81.0 percent UVT, or A_{254} =0.0915) should be used as the default value in the RED calculation.

[2] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 72 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

Detailed information related to the UV sensors to be employed under this project is presented in the 2015 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVFit^{TM} 72AL75 UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 40.3%,
    c. UV intensity below the minimum validated of 0.13 mW/cm^2
    d. complete UV reactor failure, and
    e. flow exceeds the maximum flow of 7.4 MGD (5130 gpm).

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick

reference plant operations data sheet should be posted at the treatment plant and include the following information:

a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of TrojanUVFit™ 72AL75 UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

August 16, 2017

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UVFitTMD72AL75 DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Committee (RWC) has reviewed the Carollo Engineers August 2015 report entitled "Addendum – TrojanUVFit™ D72AL75 Validation Report 2012 NWRI Analysis of the TrojanUVFit™ D72AL75 Reactor Validation Data". This amends the UV dose equations in the 2009 Carollo validation report. The 2015 Carollo report presents the results of the September 2008 bioassays analyzed per the August 2012 National Water Research Institute [NWRI]/Water Research Foundation[WRF] *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 UV Guidelines).

The TrojanUVFit™ D72AL75 UV disinfection system is a closed vessel reactor, in a dual configuration consisting of two reactors within one chamber in a vessel. Each reactor has 72 UV lamps that utilize 0.25-kW low-pressure high-output (LPHO) lamps (Trojan part number 794447 manufactured by Heraeus Noblelight). The lamps are mounted horizontally and parallel to the flow, within a 30-inch diameter closed vessel reactor. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVFit™ D72AL75 UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVFit™ D72AL75 UV reactor for flow rates ranging from 1.05 to 7.30 MGD (729 to 5066 gpm), at UVTs from 41.4% to 80.8% (0.093 to 0.383 UVA), and sensor intensities ranging from 0.15 to 2.26 mW/cm^2.

The DDW finds that the validation testing and report have demonstrated the ability of the TrojanUVFit™ D72AL75 UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVFit™ D72AL75 Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

    a. from 1.05 to 7.3 MGD (729 to 5066 gpm),
    b. UVTs at or above 41.4 percent,
    c. UV sensor intensities ranging from 0.15 to 2.26 mW/cm^2,
    d. Power range 60 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = ([1.2907 \times 10^{-7} \times BPL] - 3.6596 \times 10^{-6}) \times UVT^{2.8198}$$

$$RED_{calc} = CR \times 10^{3.123} \times Q^{-0.7507} \times UVA_{254}^{[4.0230 \times UVA + 5.6658 \times UVA\text{^}2]} \times [S/S_o]^{0.7840} \times R$$

    Where:

    BPL = Ballast power level setting (percent)
    UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 41.4 percent[1],
    S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
    S = Measured UV sensor value (mW/cm^2)
    S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
    RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
    CR = Confidence factor = 0.951
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate, (million gallons per day [MGD])
    R = Number of operating reactors.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (ÖNORM / DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The TrojanUVFit™ Model D72AL75 UV reactor uses UV lamps by Heraeus Noblelight (Trojan part number 794447). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing

[1] At UVT values above 80.8 percent, the value (80.8 percent UVT, or A_{254} =0.093) should be used as the default value in the RED calculation.

methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated[2]. Detailed information related to the UV sensors to be employed under this project is presented in the 2015 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVFit™ D72AL75 UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,

[2] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 72 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

b. UVT is below the minimum UVT of 41.4%,
c. UV intensity below the minimum validated of 0.15 mW/cm^2
d. complete UV reactor failure, and
e. flow exceeds the maximum flow of 7.30 MGD (5066 gpm).

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
    d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of TrojanUVFit™ D72AL75 UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director

EDMUND G. BROWN JR
Governor

June 16, 2014

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UV3000PLUS DISINFECTION SYSTEM, 2012 NWRI ANALYSIS

The Recycled Water Committee (RWC) has reviewed the Carollo Engineers April 2014 report entitled “Addendum – UV 3000Plus (4” lamp spacing) Validation Report 2012 NWRI Analysis”. This replaces the reactor validation performed in 2005 and documented in “UV3000Plus Validation Report, Final” (Carollo Engineers, February 2006). The 2014 Carollo report presents the results of the 2005 bioassay analyzed per the August 2012 National Water Research Institute (NWRI)/Water Research Foundation UV Guidelines (hereinafter referred to as 2012 NWRI Guidelines).

Therefore, the RWC revises its previous conditional acceptance letters for the UV 3000Plus, finding that the 2014 bioassay equation, based upon an analysis per the 2012 NWRI Guidelines is a more appropriate dose equation to sufficiently demonstrate the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an accepted filtration process.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The Trojan UV3000Plus Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320. Conditional acceptance for the Trojan UV3000Plus reactors are limited to the following parameter ranges:

    a. from 6.2 to 126.5 gpm/lamp,
    b. UVTs at or above 55 percent,

2. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$Dose = (CR)*(FF)*(EOLL)*10^{-6.3439 - 0.8655 * \log Flow + 3.709 * \log UVT + 1.2909 * \log P}$$

Where:

Dose = Delivered UV dose per bank (mJ/cm^2);

CR = Confidence Ratio, 0.906

FF = Fouling Factor, as determined per the NWRI UV guidance

UVT = % UV transmittance at 254 nm (%);

Flow = Flow rate per lamp [gallons per minute (gpm)/lamp], with gpm/lamp calculated as gpm divided by the number of lamps in one bank;

EOLL = End of Lamp Life factor = 0.98 at 9000 hours for the Heraeus lamp

P = percent power

3. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the RWC and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the RWC for approval.

4. Proper cleaning and lamp replacement at 9000 hours must be maintained. The Trojan UV3000Plus system uses a 4-inch lamp spacing using the Heraeus lamp (Trojan part number 794447).

5. On-line monitoring of flow, UVT, and power must be provided at all times.

6. The flow meters and UVT monitors must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

7. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

8. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

9. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

10. The Trojan UV3000Plus UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

11. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:

    a. the UV dose goes below 105% of the minimum UV dose,

    b. failure of one bank of lamps,

    c. ballast failure and

    d. multiple lamp failure

12. Conditions that should divert effluent to waste include the following:

    a. UV dose is below the minimum UV dose,

    b. UVT is below the minimum UVT of 55%,

    c. complete UV reactor (channel) failure, and

    d. flow exceeds the maximum flow.

13. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:

    a. The alarm set points for flow, UV dose, UVT, UV lamp operation hours, and power.

b. The values of flow, UV dose, and UVT when effluent must be diverted to waste.

c. The required frequency of calibration for all meters/analyzers measuring turbidity, flow, UV transmittance, and power.

d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.

e. The UV lamp tracking procedures and replacement intervals.

14. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of Trojan UV3000Plus UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

State Water Resources Control Board
Division of Drinking Water

March 17, 2017

Steve McDermid
Validation and Research Services
Trojan UV
3020 Gore Road, London,
Canada N5V 4T7

Dear Mr. McDermid,

CONDITIONAL ACCEPTANCE OF TROJAN UVSIGNATM DISINFECTION SYSTEM

The Division of Drinking Water (DDW) Recycled Water Unit (RWU) has reviewed the Carollo Engineers January 2017 report entitled "TrojanUVSigna™ (2-Row) CA NWRI 2012 Validation Report Revision 1 Final". The Carollo report presents the results of the bioassays analyzed per the August 2012 National Water Research Institute (NWRI)/Water Research Foundation *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (hereinafter referred to as 2012 NWRI Guidelines).

The TrojanUVSigna™ (2-Row) is an open channel system that consists of 1,000 watt low-pressure, high-output (LPHO) amalgam lamps oriented at a 45-degree angle to the direction of flow. The test system was comprised of four banks in series with each bank having eight Trojan Lamps with two staggered rows of 4 lamps, for a total of 32 lamps. The TrojanUVSigna UV disinfection system utilizes 1000-W Trojan Solo Lamps (Trojan part number 908069-200) manufactured by Philips. Integral to the performance monitoring of the UV system is a calibrated germicidal sensor that meets the National Institute of Standards and Technology (NIST) traceable standard. The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings. The reduction equivalent dose (RED) for the TrojanUVSigna™ UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the TrojanUVSigna™ UV reactor for flow rates ranging from 99.4 to 1,211 gpm/lamp, at UVTs from 53.7% to 80% (0.27 to 0.097 UVA), and sensor intensities ranging from 1.11 to 10.46 mW/cm^2.

The DDW RWU finds that the validation testing and report have demonstrated the ability of the TrojanUVSigna™ UV reactor to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following criteria, which must be met and/or demonstrated:

1. The TrojanUVSigna™ Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance is limited to the following parameter ranges:

    a. from 99.4 to 1,211 gpm/lamp
    b. UVTs at or above 53.7 percent,
    c. UV sensor intensities ranging from 1.11 to 10.46 mW/cm^2,
    d. Power range 30 to 100 percent.

3. The equations below must be used for calculation of the UV dose value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose for the reactor and should be specified as a permit provision. They are:

$$S_{pred} = 10^{-4.16162} \times UVT^{1.91459} \times BPL^{0.76858}$$

$$RED_{calc} = CR \times 10^{[4.58043-1.65778 \times UVA]} \times UVA_{254}^{[2.54274 \times UVA]} \times [S/S_o]^{0.97312} \times Q^{-0.97312} \times B$$

Where:

BPL = Ballast power level setting (percent)
UVT = UV transmittance through 1 cm of water at 254 nm, expressed as percent, at or above 53.7 percent[1],
S_{pred} = Predicted UV sensor value (milliwatts per square centimeter [mW/cm^2])
S = Measured UV sensor value (mW/cm^2)
S_o = Calculated intensity from new lamp at full power (at same UVT) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
RED_{calc} = UV dose calculated with the UV dose-monitoring equation (mJ/cm^2)
CR = Confidence factor = 0.884
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate per lamp, calculated as gpm divided by the number of lamps in one bank (gpm/lamp)
B = Number of operating banks.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in August 2012 NWRI Guidelines. The on-site bioassay protocol must be approved by the DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets the National Institute of Standards and Technology (NIST) traceable standard.

6. The TrojanUVSigna™ UV reactor uses Trojan Solo Lamps made by Philips (Trojan part number 908069-200). This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is

[1] At UVT values above 80 percent, the value (80 percent UVT, or A_{254} =0.097) should be used as the default value in the RED calculation.

delivered and the combined effects of lamp aging and sleeve fouling are incorporated[2]. Detailed information related to the UV sensors to be employed under this project is presented in the 2016 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The TrojanUVSigna^{TM} UV systems must be designed with a built-in automatic reliability feature that must be triggered by critical alarm setpoints.

16. Conditions that should trigger an alarm and startup the redundant bank of lamps include the following:
    a. the UV dose goes below 105% of the minimum UV dose,
    b. ballast failure and
    c. multiple lamp failure

17. Conditions that should divert effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 53.7%,
    c. UV intensity below the minimum validated of 1.11 mW/cm^2

[2] This UV dose equation assumes that the intensity sensors would measure the decline as the lamps age. Since there is one UV Intensity sensor for 8 lamps, the lamps should be rotated once a quarter to detect any decline in intensity due to aging. The lamp with the lowest intensity value should be closest to the UV sensor. If all of the lamp ages vary by less than 20 percent, the oldest lamp should be placed in the position nearest the UV sensor.

d. complete UV reactor failure, and
e. flow exceeds the maximum flow of 1,211 gpm/lamp.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power
    b. The values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of calibration for all meters/analyzers measuring flow, UV transmittance, and UV intensity.
    d. The required frequency of mechanical cleaning, equipment inspection, and replacement of cleaning solution.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Equivalent or substitutions of equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by local District offices. Approval for the use of TrojanUVSigna™ UV Disinfection System in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Recycled Water Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

August 21, 2008

Oliver Lawal
Director of Engineering - Americas
ITT - Water & Wastewater
14125 South Bridge Circle
Charlotte, NC 28273

Dear Mr. Lawal,

CONDITIONAL ACCEPTANCE OF ITT, WEDECO LBX 90 UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL JULY 2008

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "LBX UV Disinfection Systems Validation Report" (Carollo Engineers, July 2008)[1] which contains the bioassay results of the testing in Portland. The Wedeco LBX 90 closed-vessel UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation. This system has a 20.8-cm chamber and four 330-W low-pressure high-output (LPHO) lamps oriented parallel to the flow. It has a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the LBX 90 UV system is a function of flow rate (Q), UVT, and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the LBX 90 reactor for flow rates ranging from 0.037 to 0.432 MGD (26 to 300 gpm) at UVTs ranging from 55.6 to 77 percent, and sensor intensities ranging from 2.1 to 8.0 mW/cm^2.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the LBX 90 UV Disinfection Systems to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for

[1] Agencies interested in this technology can obtain copies of the July 2008 Carollo Engineers report from Oliver Lawal, Director of Engineering – Americas, ITT - Water & Wastewater, 14125 South Bridge Circle, Charlotte, NC 28273.

recycled waters that have received treatment through an accepted membrane filtration process.

The acceptance of the validation report is conditioned on the following: The following criteria must be met and/or demonstrated.

1. Since this reactor was only tested using potable water, acceptance is limited to recycled water applications in which the filtration process is a membrane. LBX 90 UV Disinfection Systems must be preceded by membrane filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320 (b).

2. Conditional acceptance for the LBX 90 reactors are limited to the following parameter ranges:

    a. from 0.037 to 0.432 MGD (26 to 300 gpm)
    b. UVTs at or above 56 percent[2],
    c. UV sensor intensities ranging from 2.1 to 8.0 mW/cm^2.

3. Two empirical equations were developed based on the performance data collected during the validation test and they must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S = e^{-7.2354} \times e^{0.0367\,UVT} \times P^{1.1266}$$

$$RED_{calc} = 10^{0.5319} \times A_{254}^{-0.7104} \times [S/So]^{0.8879} \times [1/Q]^{0.8990}$$

Where:

S = Measured UV sensor value (mW/cm^2).
So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
P = Power setting, either 210 W, 270 W, or 330 W for the witnessed tests
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate (million gallons per day [mgd]).
B = Number of operating banks of lamps within the UV reactor (= 1 in this case).

4. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that

[2] At UVT values above 77 percent, the value (77 percent UVT, or A_{254} =0.114) should be used as the default value in the RED calculation.

demonstrated in the 2008 report from Carollo Engineers. The on-site bioassay protocol must be approved by the Department and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system. The duty sensor used in the validation testing was a Wedeco model SO 13599. The reference sensor was an IL Metronic MUV 23. Detailed information related to the UV sensors to be employed is presented in Appendix C in the 2008 report from Carollo Engineers.

6. The LBX 90 systems use Wedeco's XLR30 UV lamps, which have a maximum power of 330 Watts. These lamps have been tested and approved by CDPH for an end of lamp life (EOLL) factor of 0.88 over 10,074 hours of operation[3]. However, the validation report did not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the Department. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. Since only one duty sensor is used and it monitors the intensity of one lamp, that particular lamp should be representative of all of the other lamps in age and fouling condition.

9. The LBX 90 UV system provides the option of an automated mechanical wiping mechanism to reduce sleeve fouling. This is recommended; however, not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings.

10. On-line monitoring of flow, UVT, and intensity must be provided at all times.

11. The LBX 90 UV systems are designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and start the next available reactor. Further conditions that

[3] The lamp testing results are documented in "10,074-Hour Lamp Aging Report - SLR 32143 HP Lamp, Final, May 2005", by Carollo Engineers.

should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the Department's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

August 14, 2008

Oliver Lawal
Director of Engineering - Americas
ITT - Water & Wastewater
14125 South Bridge Circle
Charlotte, NC 28273

Dear Mr. Lawal,

CONDITIONAL ACCEPTANCE OF ITT, WEDECO LBX 400 UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL JULY 2008

The California Department of Public Health (CDPH) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "LBX UV Disinfection Systems Validation Report" (Carollo Engineers, July 2008)[1] which contains the bioassay results of the testing in Portland. The Wedeco LBX 400 closed-vessel UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation. This system has a 38.1-cm chamber and sixteen 330-W low-pressure high-output (LPHO) lamps oriented parallel to the flow. It has a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the LBX 400 UV system is a function of flow rate (Q), UVT, and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the LBX 400 reactor for flow rates ranging from 0.25 to 1.37 MGD (174 to 951 gpm) at UVTs ranging from 46 to 75 percent, and sensor intensities ranging from 2.8 to 9.2 mW/cm^2.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the LBX 400 UV Disinfection Systems to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for

[1] Agencies interested in this technology can obtain copies of the July 2008 Carollo Engineers report from Oliver Lawal, Director of Engineering – Americas, ITT - Water & Wastewater, 14125 South Bridge Circle, Charlotte, NC 28273.

recycled waters that have received treatment through an accepted membrane filtration process.

The acceptance of the validation report is conditioned on the following: The following criteria must be met and/or demonstrated.

1. Since this reactor was only tested using potable water, acceptance is limited to recycled water applications in which the filtration process is a membrane. LBX 400 UV Disinfection Systems must be preceded by membrane filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320 (b).

2. Conditional acceptance for the LBX 400 reactors are limited to the following parameter ranges:

    a. from 0.25 to 1.37 MGD (174 to 951 gpm)
    b. UVTs at or above 46 percent[2],
    c. UV sensor intensities ranging from 2.8 to 9.2 mW/cm^2.

3. Two empirical equations were developed based on the performance data collected during the validation test and they must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S = e^{-6.7705} \times e^{0.0312\,UVT} \times P^{1.1484}$$

$$RED_{calc} = 10^{0.9358} \times A_{254}^{-0.7267} \times [S/So]^{0.9535} \times [1/Q]^{0.6626}$$

Where:

S = Measured UV sensor value (mW/cm^2).
So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
P = Power setting, either 210 W, 270 W, or 330 W for the witnessed tests
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate (million gallons per day [mgd]).
B = Number of operating banks of lamps within the UV reactor (= 1 in this case).

4. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that

[2] At UVT values above 75 percent, the value (75 percent UVT, or A_{254} =0.125) should be used as the default value in the RED calculation.

demonstrated in the 2008 report from Carollo Engineers. The on-site bioassay protocol must be approved by the CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the CDPH for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system. The duty sensor used in the validation testing was a Wedeco model SO 13599. The reference sensor was an IL Metronic MUV 23. Detailed information related to the UV sensors to be employed is presented in Appendix C in the 2008 report from Carollo Engineers.

6. The LBX 400 systems use Wedeco's XLR30 UV lamps, which have a maximum power of 330 Watts. These lamps have been tested and approved by CDPH for an end of lamp life (EOLL) factor of 0.88 over 10,074 hours of operation[3]. However, the validation report did not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. Since only one duty sensor is used and it monitors the intensity of one lamp, that particular lamp should be representative of all of the other lamps in age and fouling condition.

9. The LBX 400 UV system provides the option of an automated mechanical wiping mechanism to reduce sleeve fouling. This is recommended; however, not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings.

10. On-line monitoring of flow, UVT, and intensity must be provided at all times.

11. The LBX 400 UV systems are designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and start the next available reactor. Further conditions that

[3] The lamp testing results are documented in "10,074-Hour Lamp Aging Report - SLR 32143 HP Lamp, Final, May 2005", by Carollo Engineers.

should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the CDPH's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

State Water Resources Control Board
Division of Drinking Water

February 8, 2016

Dr. Christian Bokermann
Xylem Services GmbH
Boschstrasse 4-14
32051 Herford, Germany

CONDITIONAL ACCEPTANCE OF XYLEM WATER SOLUTIONS WEDECO LBX 850E UV SYSTEM 2012 NWRI VALIDATION REPORT, FINAL REVISED OCTOBER 2015

Dear Mr. Bokermann,

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Xylem Water Solutions WEDECO LBX 850E UV System NWRI 2012 Validation Report" (Carollo Engineers, October 2015)[1] which contains the bioassay results of the testing in Portland, OR. The Xylem Water Solutions WEDECO LBX 850E UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. The LBX 850E UV disinfection system is a closed channel reactor with a horizontally aligned, stainless steel cylinder, 1966 mm in length and a 560-mm internal diameter. Lamps are configured parallel to flow. The system uses 32 amalgam low pressure gas discharge 320-W lamps (WEDECO ELR30-1 part number), arranged in three concentric circles with 5, 10, and 17 lamps progressively in each circle. A flow conditioner was used, consisting of three concentric stainless steel rings mounted inside the inlet portion of the reactor flush with the inlet flange. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. There is one intensity sensor per module (WEDECO Model SO 20101). The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

Besides MS2, test microorganisms included T1UV and T7 coliphages, and Bacillus pumilus spores. Only the MS2 data analyzed according to the 2012 UV Guidelines was included in the report. The analysis for the reduction equivalent dose (RED) equation was limited to testing performed at flow rates ranging from 0.26 – 9.56 MGD, at UVTs from 19.3 – 98.4 percent, and sensor intensities ranging from 7.12 – 347 W/m^2.

The reduction equivalent dose (RED) for the Xylem Water Solutions WEDECO LBX 850E UV reactor is a function of flow rate (Q), UV absorbance at 254 nm (UVA), percent ballast power (P_L) and normalized UV sensor value (S/ S_{pred}). Detailed testing was performed to determine the

[1]Agencies interested in this technology can obtain copies of the October 2015 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

validated flow-specific performance of the Xylem Water Solutions LBX 850E UV reactor for flow rates ranging from 0.26 to 9.56 MGD, at UVTs from 19.3 to 98.4 percent, and sensor intensities ranging from 7.12 to 347 W/m^2.

The DDW finds that the validation testing and report have demonstrated the ability of the Xylem Water Solutions WEDECO LBX 850E UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

1. The Xylem Water Solutions WEDECO LBX 850E UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Xylem Water Solutions LBX 850E UV disinfection system is limited to the following parameter ranges:
    a. Up to 9.56 MGD per reactor
    b. UVTs at or above 19.3 percent,
    c. UV sensor intensities ranging from 7.12 to 347 W/m^2,
    d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = (A \times B^{UVA} \times UVA^{C}) \times (D + E \times P_L + F \times P_L^2)$$

$$RED_{MS2} = 0.87 \times 10^{A+BxUVA} \times UVA^{C} \times [S / S_{pred,100\%} / Q]^{D+ExUVA^2}$$

Where:

S_{pred} = Predicted UV sensor value (W/m^2),

UVA= UV absorbance at 254 nm

S = Measured UV sensor intensity value (W/m^2).

$S_{pred,100\%}$ = Predicted UV intensity at full lamp power, corresponding to new lamps with clean sleeves (W/m^2).

P_L = Percent ballast power setting (100% = 100)

RED_{MS2} = UV dose per reactor (mJ/cm^2).

Q = Flow rate in MGD[2]

A - E = Empirical constants, whose values are listed in the validation report for each equation.

[2] At flow rates below 0.26 MGD, this value (0.26 MGD) should be used as the default value in the RED calculation

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The WEDECO LBX 850E disinfection system uses UV lamps by WEDECO, Lamp Part No. ELR30-1, which have a maximum power of 320-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[3] Detailed information related to the UV sensors to be employed under this project is presented in the 2015 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

[3] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each module (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The WEDECO LBX 850E UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant UV reactor include the following:
    a. The UV dose goes below 105% of the minimum UV dose
    b. Ballast failure
    c. Multiple lamp failure.

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose
    b. UVT is below the minimum UVT of 19%
    c. UV intensity below the minimum validated of 7.12 W/m^2
    d. Complete UV reactor failure
    e. Flow above the maximum flow validated of 9.56 MGD

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment, including lamps, should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Keel Robinson
Xylem Water Solutions USA
14125 South Bridge Circle
Charlotte, NC 28273

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State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

ARNOLD SCHWARZENEGGER
Governor

December 14, 2007

Oliver Lawal
Director of Engineering - Americas
ITT - Water & Wastewater
14125 South Bridge Circle
Charlotte, NC 28273

Dear Mr. Lawal,

CONDITIONAL ACCEPTANCE OF ITT, WEDECO LBX 1000 UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL DECEMBER 2007

The California Department of Public Health (Department) Drinking Water Program's Water Recycling Committee (WRC) has reviewed the revised submittal entitled "LBX 1000 UV Disinfection System Validation Report" (Carollo Engineers, December 2007)[1] which contains the bioassay results of the testing in Portland. The Wedeco LBX 1000 closed-vessel UV disinfection system was tested and the results analyzed in accordance with the 2003 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/AWWA Research Foundation. This system has a 65.5-cm chamber and forty 330-W low-pressure high-output (LPHO) lamps oriented parallel to the flow. It has a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the LBX 1000 UV system is a function of flow rate (Q), UVT, and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the LBX 1000 reactor for flow rates ranging from 0.58 to 3.51 MGD (403 to 2,438 gpm) at UVTs ranging from 54 to 77 percent, and sensor intensities ranging from 1.9 to 7.5 mW/cm^2.

The WRC finds that the validation testing and report have sufficiently demonstrated the ability of the LBX 1000 UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for

[1] Agencies interested in this technology can obtain copies of the December 2007 Carollo Engineers report from Oliver Lawal, Director of Engineering – Americas, ITT - Water & Wastewater, 14125 South Bridge Circle, Charlotte, NC 28273.

recycled waters that have received treatment through an accepted membrane filtration process.

The acceptance of the validation report is conditioned on the following: The following criteria must be met and/or demonstrated.

1. Since this reactor was only tested using potable water, acceptance is limited to recycled water applications in which the filtration process is a membrane. LBX 1000 UV Disinfection System must be preceded by membrane filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320 (b).

2. Conditional acceptance for the LBX 1000 reactor is limited to the following parameter ranges:

    a. from 0.58 to 3.51 MGD (403 to 2,438 gpm)
    b. UVTs at or above 54 percent[2],
    c. UV sensor intensities ranging from 1.9 to 7.5 mW/cm^2.

3. Two empirical equations were developed based on the performance data collected during the validation test and they must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S = e^{-7.919} \times e^{0.0367\ UVT} \times P^{1.229}$$

$$RED_{calc} = 10^{1.2771} \times A_{254}^{-0.9793} \times [S/So]^{0.8751} \times [1/Q]^{0.9036}$$

    Where:

    S = Measured UV sensor value (mW/cm^2).
    So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves, typically expressed as a function of UVT (mW/cm^2).
    P = Power setting, either 210 W, 270 W, or 330 W for the witnessed tests
    RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
    A_{254} = UV absorbance at 254 nm (cm^{-1}).
    Q = Flow rate (million gallons per day [mgd]).
    B = Number of operating banks of lamps within the UV reactor (= 1 in this case).

4. To verify performance to the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2007 report from Carollo Engineers. The on-site bioassay

[2] At UVT values above 77 percent, the value (77 percent UVT, or A_{254} =0.114) should be used as the default value in the RED calculation.

protocol must be approved by the Department and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the Department for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (DVGW, 2006; ÖNORM, 2001) and is integral to the performance monitoring of the system.

6. The LBX 1000 uses Wedeco's XLR30 UV lamps, which have a maximum power of 330 Watts. These lamps have been tested and approved by CDPH for an end of lamp life (EOLL) factor of 0.88 over 10,074 hours of operation[3]. However, this validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated. Detailed information related to the UV sensors to be employed under this project is presented in Appendix A in the 2007 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the Department. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. The LBX system provides the option of an automated mechanical wiping mechanism to reduce sleeve fouling; however, this is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings.

9. On-line monitoring of flow, UVT, and intensity must be provided at all times.

10. The LBX 1000 UV system is designed with a built-in automatic reliability feature that must be triggered when the system is below the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV reactor in question must alarm and start the next available reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the Department's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

[3] The lamp testing results are documented in "10,074-Hour Lamp Aging Report - SLR 32143 HP Lamp, Final, May 2005", by Carollo Engineers.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Jeff Stone (jeffrey.stone@cdph.ca.gov; 805.566.9767).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

June 28, 2016

Dr. Christian Bokermann
Xylem Services GmbH
Boschstrasse 4-14
32051 Herford, Germany

CONDITIONAL ACCEPTANCE OF XYLEM WATER SOLUTIONS WEDECO LBX 1500E UV SYSTEM 2012 NWRI VALIDATION REPORT, FINAL REVISED SEPTEMBER 2015

Dear Mr. Bokermann,

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Xylem Water Solutions WEDECO LBX 1500E UV System NWRI 2012 Validation Report" (Carollo Engineers, September 2015)[1] which contains the bioassay results of the testing in Portland, OR. The Xylem Water Solutions WEDECO LBX 1500E UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. The LBX 1500E UV disinfection system is a closed channel reactor with a horizontally aligned, stainless steel cylinder, 1515 mm in length and a 32-mm internal diameter. Lamps are configured parallel to flow. The system uses 60 amalgam low pressure gas discharge 320-W lamps (WEDECO Model SO 20101 part number), arranged in four concentric circles with 5, 11, 18 and 26 lamps progressively in each circle. A flow conditioner was used, consisting of three concentric stainless steel rings mounted inside the inlet portion of the reactor flush with the inlet flange. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. There is one intensity sensor per module (WEDECO Model SO 20101). The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

Besides MS2, test microorganisms included T1UV and T7 coliphages, and Bacillus pumilus spores. Only the MS2 data analyzed according to the 2012 UV Guidelines was included in the report. The analysis for the reduction equivalent dose (RED) equation was limited to testing performed at flow rates ranging from 0.5 – 13.5 MGD, at UVTs from 19.87 – 98.04 percent, and sensor intensities ranging from 7.37 – 310.7 W/m^2.

The reduction equivalent dose (RED) for the Xylem Water Solutions WEDECO LBX 1500E UV reactor is a function of flow rate (Q), UV absorbance at 254 nm (UVA), percent ballast power (P_L) and normalized UV sensor value (S/ S_{pred}). Detailed testing was performed to determine the

[1]Agencies interested in this technology can obtain copies of the September 2015 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

validated flow-specific performance of the Xylem Water Solutions LBX 1500E UV reactor for flow rates ranging from 0.5 to 13.5 MGD, at UVTs from 19.9 to 98.04 percent, and sensor intensities ranging from 7.37 to 310.7 W/m^2.

The DDW finds that the validation testing and report have demonstrated the ability of the Xylem Water Solutions WEDECO LBX 1500E UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

1. The Xylem Water Solutions WEDECO LBX 1500E UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Xylem Water Solutions LBX 1500E UV disinfection system is limited to the following parameter ranges:
    a. Up to 13.5 MGD per reactor
    b. UVTs at or above 19.9 percent,
    c. UV sensor intensities ranging from 7.37 to 310.7 W/m^2,
    d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = (A \times B^{UVA} \times UVA^{C}) \times (D \times E + F \times P_L{}^{G} / E \times P_L{}^{G})$$

$$RED_{MS2} = 0.929 \times 10^{A+BxUVA} \times UVA^{C+D*UVA} \times [S/ S_{pred,100\%} / Q]^{E+FxUVA^2}$$

Where:

S_{pred} = Predicted UV sensor value (W/m^2),

UVA= UV absorbance at 254 nm

S = Measured UV sensor intensity value (W/m^2).

$S_{pred,100\%}$ = Predicted UV intensity at full lamp power, corresponding to new lamps with clean sleeves (W/m^2).

P_L = Percent ballast power setting (100% = 100)

RED_{MS2} = UV dose per reactor (mJ/cm^2).

Q = Flow rate in MGD[2]

A - G = Empirical constants, whose values are listed in the validation report for each equation.

[2] At flow rates below 0.5 MGD, this value (0.5 MGD) should be used as the default value in the RED calculation

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The WEDECO LBX 1500E disinfection system uses UV lamps by WEDECO, Lamp Part No. SO 20101, which have a maximum power of 320-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[3] Detailed information related to the UV sensors to be employed under this project is presented in the 2015 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

[3] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each module (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The WEDECO LBX 1500E UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant UV reactor include the following:
    a. The UV dose goes below 105% of the minimum UV dose
    b. Ballast failure
    c. Multiple lamp failure.
17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose
    b. UVT is below the minimum UVT of 19.9%
    c. UV intensity below the minimum validated of 7.4 W/m2
    d. Complete UV reactor failure
    e. Flow above the maximum flow validated of 13.5 MGD
18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.
19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment, including lamps, should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Keel Robinson
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Nicola Fontaine
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2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

September 24, 2012

Mike Fiore
Project Manager - WEDECO Products
14125 S. Bridge Circle
Charlotte, NC 28273

CONDITIONAL ACCEPTANCE OF XYLEM / WEDECO TAK-55 320W UV DISINFECTION SYSTEM, VALIDATION REPORT, FINAL JANUARY 2010

The California Department of Public Health (CDPH) Drinking Water Program's Recycled Water Committee (RWC) has reviewed the revised submittal entitled "Wedeco Open Channel TAK-55 Wastewater UV Reactor 320W Validation Report" (Carollo Engineers, January 2010)[1] which contains the bioassay results of the testing in San Jose, CA. The Wedeco TAK-55 320W UV disinfection system was tested and the results analyzed in accordance with the 2012 Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse published by the National Water Research Institute/Water Research Foundation (NWRI). This system utilizes 320-Watt low-pressure high-output (LPHO) lamps (Wedeco WLR30). The lamps are mounted horizontally and parallel to the flow, with a spacing 110 mm. It has a calibrated germicidal sensor that meets international standards (DVGW) and is integral to the performance monitoring of the system.

The reduction equivalent dose (RED) for the Wedeco TAK-55 320W UV reactor is a function of flow rate (Q), transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the flow-specific performance of the Wedeco TAK-55 320W UV reactor for flow rates ranging from 0.426 to 4.745 MGD (296 to 3,295 gpm) per bank, at UVTs ranging from 54.1 to 72.7 percent, and sensor intensities ranging from 1.42 to 4.68 mW/cm^2.

The minimum flow per lamp tested was 8.2 gpm/lamp and the maximum was 92.1 gpm/lamp. Therefore, at flow rates below 8.2 gpm/lamp, this value (8.2 gpm/lamp) should be used as the default value in the RED calculation.

The validation report test data has been analyzed and evaluated in detail in light of the 2012 NWRI Ultraviolet Disinfection Guidelines.

[1] Agencies interested in this technology can obtain copies of the January 2010 Carollo Engineers report from Mike Fiore, Project Manager - WEDECO Products, 14125 S. Bridge Circle, Charlotte, NC 28273.

The RWC finds that the validation testing and report have demonstrated the ability of

the XYLEM / Wedeco TAK-55 320W UV reactor UV Disinfection System to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through an tertiary filtration process accepted by CDPH.

The acceptance of the validation report is conditional based on the following criteria, which must be met and/or demonstrated:

1. The Wedeco TAK-55 320W UV Disinfection System must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Wedeco TAK-55 320W UV reactor is limited to the following parameter ranges:

    a. from 8.2 gpm/lamp to 92.1 gpm/lamp
    b. UVTs at or above 54 percent,
    c. UV sensor intensities ranging from 1.42 to 4.68 mW/cm^2.
    d. Ballast input up to 320 Watts (up to 360 W uses different equations).

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S = e^{-0.5876} \times e^{0.0456 \times UVT} \times P^{0.9574}$$

$$RED_{calc} = 10^{1.8871} \times A_{254}^{-1.4460} \times [S/So]^{0.9821} \times [1/Q]^{0.7970} \times B$$

Where:

UVTs at or above 54 percent[2],
S = Measured UV sensor value (mW/cm^2).
So = UV intensity at 100 percent lamp power (new lamps) with clean sleeves (0.32 kW/lamp), typically expressed as a function of UVT (mW/cm^2).
P = Measured ballast power setting, kW per lamp
RED = RED calculated with the UV dose-monitoring equation (mJ/cm^2).
A_{254} = UV absorbance at 254 nm (cm^{-1}).
Q = Flow rate per lamp, calculated as gpm divided by the number of lamps in one bank [3],
B = Number of operating banks.

[2] At UVT values above 72.7 percent, the value (72.7 percent UVT, or A_{254} =0.138cm) should be used as the default value in the RED calculation.
[3] At flow rates below 8.2 gpm/lamp, this value (8.2 gpm/lamp) should be used as the default value in the RED calculation..

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage in a method similar to that demonstrated in the 2010 report from Carollo Engineers. The on-site bioassay protocol must be approved by CDPH and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the California Code of Regulations, must be submitted to the CDPH for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that is integral to the performance monitoring of the system, and which meets international standards (DVGW) or the USEPA UV Disinfection Guidance Manual (UVDGM), where the sensor is calibrated against a traceable standard.

6. The Wedeco TAK-55 320W UV reactor uses UV lamps by Wedeco WLR30, which have a maximum power of 320 Watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4] . Detailed information related to the UV sensors to be employed under this project is presented in the 2010 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to the CDPH. The site specific engineering report must specify the frequency that calibration checks should be performed.

8. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

9. On-line monitoring of flow, UVT, and intensity must be provided at all times.

10. The Wedeco TAK-55 320W UV reactor UV system must be designed with a built-in automatic reliability feature that must be triggered when the system is below

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging as described in the EPA UVDGM, (unless another operational procedure can be developed and demonstrated) “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each row/bank (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

the target UV dose. If the measured UV intensity goes below the minimum UV Intensity, the UV system must alarm and start the next available bank or reactor. Further conditions that should shut a reactor down include: intensity monitor failure, reactor failure, multiple lamp failure, and ballast high temperature.

Review and acceptance of individual systems will be handled on a case-by-case basis by the CDPH's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's Water Reclamation permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@cdph.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@cdph.ca.gov; 619.525.4022).

Sincerely,

Original signed by

Brian Bernados, P.E.
Technical Specialist

Cc Water Recycling Committee

Mr. Andrew Salveson
Carollo Engineers
2700 Ygnacio Valley Road, Suite 300
Walnut Creek, CA 94598

July 30, 2015

Dr. Christian Bokermann
Xylem Services GmbH
Boschstrasse 4-14
32051 Herford, Germany

CONDITIONAL ACCEPTANCE OF XYLEM WATER SOLUTIONS DURON UV SYSTEM 2012 NWRI VALIDATION REPORT, MINOR REVISION, FINAL REVISED FEBRARY 2015

Dear Mr. Bokermann,

The Division of Drinking Water (DDW) has reviewed the submittal entitled "Xylem Water Solutions Duron UV System 2012 NWRI Validation Report" (Carollo Engineers, February 2015)[1] which contains the bioassay results of the testing in Minden, Germany. The Xylem Water Solutions Duron UV disinfection system was tested and the results analyzed in accordance with the *Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse* (National Water Research Institute/Water Research Foundation, August 2012), hereinafter called the *2012 NWRI UV Guidelines*. This system utilizes 600-W low-pressure high-output (LPHO) lamps (ECORAY ELR60 part number). The lamps are configured perpendicular to the flow at a 45 degree angle, within an open channel reactor. The tested system consisted of one channel of four UV modules. Each module contained 12 lamps, with two staggered rows of 6 lamps. Integral to the performance monitoring of the system is a calibrated germicidal sensor that meets international standards (ÖNORM), where the sensor is calibrated against a traceable standard. There is one intensity sensor per module (Model SO 20101) The operating approach uses a "dose-pacing" methodology, relying on detailed and accurate UV sensor readings.

The reduction equivalent dose (RED) for the Xylem Water Solutions Duron UV reactor is a function of flow rate (Q), UV transmittance (UVT), and normalized UV sensor value (S/S_0). Detailed testing was performed to determine the validated flow-specific performance of the Xylem Water Solutions Duron UV reactor for flow rates per lamp ranging from 28 to 480 gpm (0.04 to 0.691 MGD), at UVTs from 36 to 83 percent, and sensor intensities ranging from 1.9 to 101.1 W/m^2.

The DDW finds that the validation testing and report have demonstrated the ability of the Xylem Water Solutions Duron UV disinfection system to meet the minimum coliform and virus disinfection criteria found in Title 22 of the California Code of Regulations (CCR) for recycled waters that have received treatment through a tertiary filtration process accepted by DDW.

The acceptance of the validation report is conditioned on the following:

[1]Agencies interested in this technology can obtain copies of the April 2013 Carollo Engineers report from Carollo Engineers, 2700 Ygnacio Valley Road, Suite 300, Walnut Creek, CA 94598

1. The Xylem Water Solutions Duron UV disinfection system must be preceded by filtration meeting the definition of "filtered wastewater" under CCR, Title 22, Section 60301.320.

2. Conditional acceptance for the Xylem Water Solutions Duron UV disinfection system is limited to the following parameter ranges:
   a. Up to 480 gpm (0.691 MGD) per lamp
   b. UVTs at or above 36 percent,
   c. UV sensor intensities ranging from 1.9 to 101.1 W/m^2,
   d. Power range 50 to 100 percent.

3. The following two empirical equations based on the performance data collected during the validation test must be used for calculation of the RED value in actual installations. These equations are to be used as part of the automatic UV disinfection control system for calculating UV dose and should be specified as a permit provision.

$$S_{pred} = 10^{-7.97} \times UVT^{4.491} \times P^{0.6804}$$

$$RED_{module} = 0.877 \times 10^{2.1242} \times UVA^{-1.104} \times [S/So]^{0.722} \times [1/Q_{lamp}]^{0.7167} \times M$$

   Where:

   S_{pred} = Predicted UV sensor value (W/m^2),
   UVT= Percent UV transmittance expressed as a decimal (55% = 55),[2]
   UVA= UV absorbance at 254 nm
   S = Measured UV sensor intensity value (W/m^2).
   S_o = Predicted UV intensity at full lamp power, corresponding to 600W for new lamps with clean sleeves (W/m^2).
   P = Percent ballast power setting expressed as a decimal (100% = 100)
   RED_{module} = UV dose per module calculated with the RED-monitoring equation (mJ/cm^2).
   Q_{lamp} = Flow rate in a channel, calculated as gallons per minute (gpm) divided by the number of modules in parallel in one channel and then divided by 12 lamps (gpm/lamp)[3]
   M = Number of operating modules.

4. To verify performance on the site-specific recycled water, upon completion of construction and prior to operation, an on-site check-point bioassay must be performed on the reactor using seeded MS2 coliphage as described in *2012 NWRI UV Guidelines*. The on-site bioassay protocol must be approved by DDW and must be conducted over a range of flows. Results, documenting virus disinfection performance of the system to the standards found in Title 22 of the CCR, must be submitted to DDW for approval.

5. Conditional acceptance is predicated upon using a calibrated germicidal sensor that meets international standards (ÖNORM) and is integral to the monitoring of the system.

6. The Xylem Water Solutions Duron UV disinfection system uses UV lamps by ECORAY, Lamp Part No. ELR60, which have a maximum power of 600-watts. This validation report does not address the determination of lamp aging or lamp fouling factors. Instead, this validation is based upon dose-pacing methodology, relying on detailed and accurate UV

[2] At UVT values above 83 percent, the value (83 percent UVT) shall be used as the default value in the RED calculation

[3] At flow rates below 28 gpm/lamp, this value (28 gpm/lamp) should be used as the default value in the RED calculation

sensor readings to confirm adequate UV dose delivery similar to drinking water UV applications, so that the regulated UV dose is delivered and the combined effects of lamp aging and sleeve fouling are incorporated.[4] Detailed information related to the UV sensors to be employed under this project is presented in the 2015 report from Carollo Engineers.

7. The accuracy and repeatability of the on-line UV sensors must be demonstrated to DDW.

8. On-line monitoring of flow, UV intensity, UVT, UV lamp operation hours, and power must be provided at all times.

9. The flow meters, UV intensity sensors, and UVT analyzers must be calibrated in accordance with procedures and frequencies recommended by the manufacturers to ensure proper disinfection.

10. At least monthly, all duty UV intensity sensors must be checked for calibration against a reference UV intensity sensor.

11. For all UV intensity sensors in use, the ratio of the duty UV sensor intensity to the reference UV sensor intensity must be less than or equal to 1.2. If the calibration ratio is >1.2, the failed duty UV sensor must be replaced by a properly calibrated sensor and recalibrated by a qualified facility. The reference UV intensity sensors shall be recalibrated at least annually by a qualified facility using a National Institute of Standards and Technology (NIST) traceable standard.

12. The duty online UVT analyzer must be inspected and checked against a reference bench-top unit to document accuracy on a weekly basis.

13. The on-line UVT analyzer must be recalibrated if the reading varies from the bench-top spectrophotometer UVT reading by 2% or more. The recalibration must be conducted by a procedure recommended by the UVT analyzer manufacturer.

14. The flow meters measuring the flow through the UV reactor must be verified to determine accuracy on a monthly basis. The verification must compare the flow meter readings with other flow determination methods.

15. The Xylem Water Solutions Duron UV disinfection system must be designed with built-in automatic reliability features that must be triggered by critical alarm setpoints.

16. Conditions triggering an alarm and startup of the redundant UV bank include the following:
    a. The UV dose goes below 105% of the minimum UV dose,
    b. Ballast failure and
    c. Multiple lamp failure

[4] Since the UV Intensity sensor monitors more than one lamp, the lamps should be rotated once a quarter to ensure uniform intensity due to aging. Unless another operational procedure can be developed and demonstrated, the rotation of lamps described in the EPA UVDGM should be followed quarterly, “If UV sensors monitor more than one lamp, verify that the lamp with the lowest intensity value is closest to the UV sensor by replacing the lamp closest to the UV sensor with one-fourth of the lamps in each module (minimum of three). Place the lowest intensity lamp next to UV sensor.” “If all the lamps monitored by a UV sensor are close in age (i.e., their age varies by less than 20 percent), it is not necessary to check the output of each lamp. In this case, the oldest lamp should be placed in the position nearest the UV sensor.”

17. Conditions that should divert the UV system effluent to waste include the following:
    a. UV dose is below the minimum UV dose,
    b. UVT is below the minimum UVT of 36%,
    c. UV intensity below the minimum validated of 1.9 W/m2,
    d. Complete UV reactor failure, and
    e. Flow above the maximum flow validated of 480 gpm/lamp.

18. The facility should be operated in accordance with an approved operations plan, which specifies clearly the operational limits and responses required for critical alarms. The operations plan should be submitted and approved prior to issuance of the operating permit. A copy of the approved operations plan should be maintained at the treatment plant and be readily available to operations personnel and regulatory agencies. A quick reference plant operations data sheet should be posted at the treatment plant and include the following information:
    a. The alarm set points for flow, UV dose, UV intensity, UVT, and power.
    b. Values of flow, UV dose, UV intensity, and UVT when effluent must be diverted to waste.
    c. The required frequency of verification and calibration for all meters/analyzers measuring flow, UV intensity, and UV transmittance.
    d. The required frequency of mechanical cleaning and equipment inspection.
    e. The UV lamp tracking procedures and replacement intervals.

19. The validation report did not address sleeve fouling. Each site should address the fouling potential of the wastewater. Each site must demonstrate proper cleaning procedures are in place. Proper maintenance and cleaning must be performed. The dose equation does not incorporate a fouling factor. This is not essential due to the fact that this reactor is proposed to be controlled via a calibrated germicidal sensor, which will account for the amount of lamp fouling in its intensity readings. However, the design engineer must consider fouling in the overall design capacity calculations.

20. Substitutions of equivalent equipment should not be accepted without an adequate demonstration of equivalent disinfection performance.

Review and acceptance of individual systems will be handled on a case-by-case basis by DDW's individual District offices. Approval for the use of your technology in any and all water recycling applications is granted through the Regional Water Quality Control Board's permitting process.

Should you have any questions regarding the content of this letter, please feel free to contact me at (brian.bernados@waterboards.ca.gov; 619.525.4497) or Randy Barnard (randy.barnard@waterboards.ca.gov; 619.525.4022).

Sincerely,

Original signed by

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Technical Specialist

Cc Water Recycling Committee

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