# A Smart Way to Validate UV Systems for Reuse Applications

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## ABSTRACT

*The NWRI/AwwaRF 2003 Ultraviolet Disinfection Guidelines describe a methodology for validating UV Systems for reuse applications.*

*The validation testing of pilot plants using modular, open channel configurations allows for an easy upscale of the bioassay results to full-scale UV systems. Because closed vessel UV reactors employ different number of lamps and may have variations in lamp arrangement, individual reactor certification would be required.*

*Sometimes viewed as "magic", this paper describes a robust methodology for combining the use of CFD prediction models with full scale biodosimetric testing, to obtain sound, consistent results that allow a design engineer to dependability size a UV system within the boundaries of the NWRI/AwwaRF guidelines.*

*Key Words: UV design, UV disinfection, NRWI/AwwaRF, Reuse, Bioassay, CFD*

## INTRODUCTION

Strict microbiological requirements are part of every reuse regulation. Therefore manufacturers of UV systems for reuse applications are supposed to validate their equipment according to the NWRI/AwwaRF 2003 Ultraviolet Disinfection Guidelines. The certification includes all process variables such as water level, UVT, flow, power, sleeve fouling, and lamp age. Since it is usually not practical to conduct testing for the specified UV Dose via a bioassay on an installed full-scale UV system, the guidelines describe a pilot plant, 10:1 ratio upscale approach. Verification of the full scale system is done via microbiological performance testing and measurement of velocity profiles.

Since their initial publication in 2000, several manufacturers have conducted 3rd party pilot tests and analyzed the results in accordance with the NWRI/AwwaRF guidelines. The vast majority of these UV systems are of a modular, open channel configuration. However there is an increasing need for smaller footprint, more efficient, closed vessel systems.

Open channel UV systems usually have lamps arranged in identical lamp spacing. Hence upscaling to full-scale UV systems is pretty straight forward. Closed vessel UV reactors are made of different sized vessels, employ different number of lamps and may have variations in lamp arrangement. Therefore individual reactor certification would be required.

ITT Water & Wastewater's WEDECO LBX series consists of 7 closed vessel UV reactors employing identical low-pressure high-output (LPHO) UV lamps. Testing the entire product line the conventional method (bioassay alone) was not feasible, because of estimated costs of more than one million dollars.

In early 2007, Carollo Engineers and ITT Water & Wastewater came up with an alternative method for testing: Conventional bioassay combined with CFD (Computational Fluid Dynamics). The UV testing facility at Portland, OR was used to complete full bioassays on 3 LBX closed vessel reactors; the smallest, medium and largest lamp vessel. To enhance the scale-up/scale-down process for the remaining 4 reactors within the range, Computational Fluid Dynamics (CFD) was employed.

| LBX Reactor | # Lamps per Reactor | Bioassayed | CFD Modeled |
|---|---|---|---|
| 90 | 4 | X | X |
| 120 | 6 | | X |
| 200 | 10 | | X |
| 400 | 16 | X | X |
| 550 | 24 | | X |
| 750 | 32 | | X |
| 1000 | 40 | X | X |

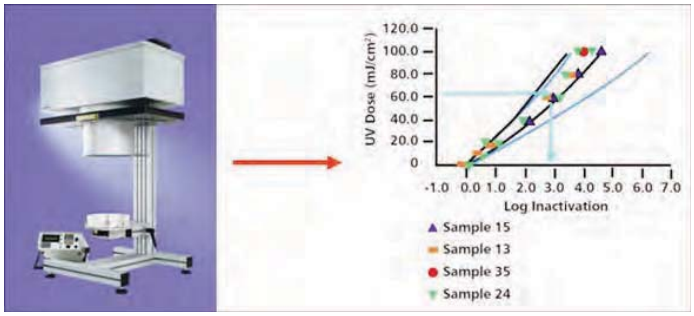
WEDECO LBX series

# METHODOLOGY

### Bioassay

The purpose of completing a bioassay is to determine, across a range of process conditions, the performance of the UV system, as related to the dose delivered to the microorganisms.

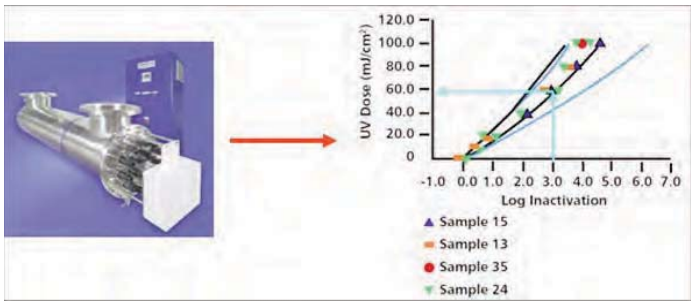
The first step of a bioassay is the Bench Scale Testing with a collimated beam device. A Petri dish with challenge organism is irradiated with different UV doses. The measured log inactivation results in a UV dose-response curve.




**Collimated beam device and UV dose-response curve**

The next step is the Full-Scale Reactor Testing. During the testing challenge microorganism are injected upstream the test reactor while influent flow rate, UVT and microorganism concentration are measured. In addition the UV intensity inside the test reactor is measured with a UV sensor. The effluent microorganism concentration is then measured and compared to influent to calculate the log inactivation.

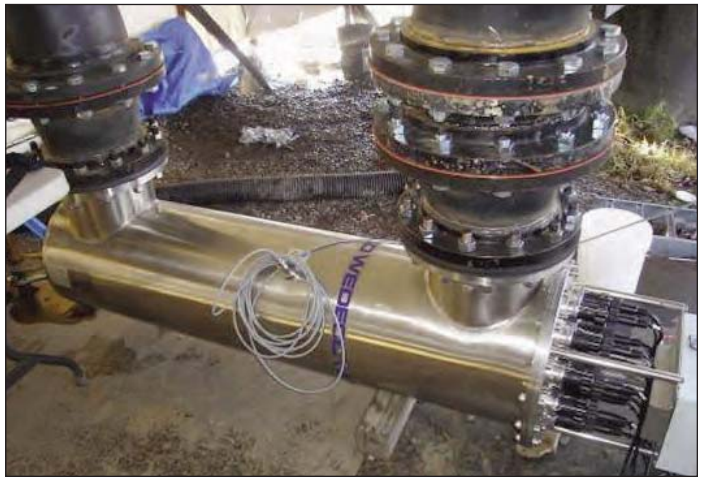
The Reduction Equivalent Dose (RED) is determined by putting the log inactivation from the Full-Scale Reactor Testing into the UV dose-response curve from the Bench Scale Testing.




**Full-Scale Reactor and UV dose performance curve**

### Computational Fluid Dynamics (CFD)

CFD seeks to predict this dose delivery by modeling the distribution of UV light and the flow tracks of the bacteria within the reactor. An effective CFD model will accurately predict dose delivery under a wide range of conditions and therefore it is important that it is shown to be calibrated as such. The steps for ensuring a fully calibrated and reliable CFD model are described in detail;



**Full-Scale Reactor and UV dose performance curve**

1. Initial CFD model is constructed for the complete range of UV vessels and each system performance is calculated using the same CFD model.
2. A single bioassay is completed on one of the UV vessels within the range.
3. The CFD model parameters are verified against the bioassay results to show the relative sensitivity of the CFD model and modifications to the model are made accordingly.
4. A second bioassay is completed on another UV vessel within the range.
5. The CFD model parameters are again verified and modifications made accordingly.
6. A third bioassay is completed on another UV vessel within the range.
7. Final CFD model verification undertaken and modifications made accordingly.
8. The conditions for a stable CFD model are used to determine the capacity of all intermediate UV systems.

The CFD modeling process combines 4 reactor characteristics:

- Hydraulics of reactor (velocity profile)
- How particles flow through reactor
- Light intensity of reactor lamps
- Biological validation component

# RESULTS AND DISCUSSION

Ideal CFD Predictions would exactly match the measured doses. The CFD models developed for the WEDECO LBX closed vessel reactors allow to predict the dose delivered to MS-2 phage under a number of UV output, flow and UV-

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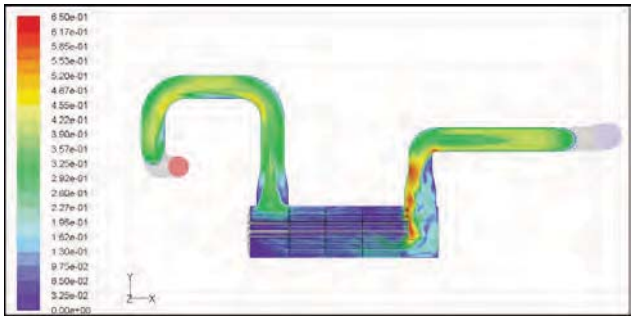
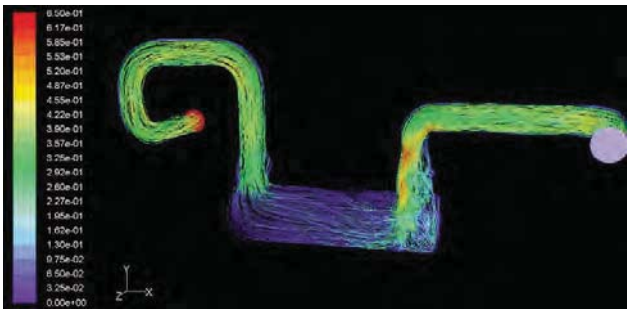
Transmittance conditions with high accuracy. Multivariate linear regression was performed on the sensor data set resulting in equations with high correlation factors ($R^2$ = 0.96 - 0.98). All terms were significant at a 95-percent confidence level.

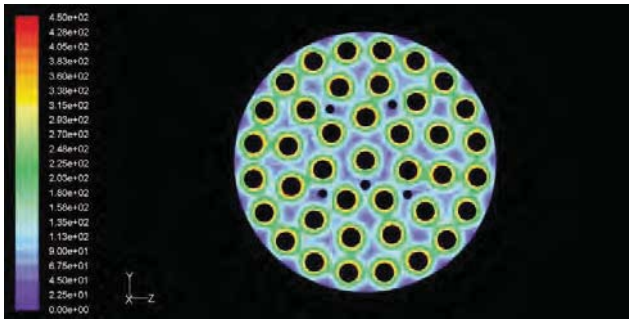
It could be demonstrated that CFD modeling together with rigorous bioassays allows to design with confidence. This method can be used to enhance the scale-up/down from pilot test validations whilst remaining within the scope of the NWRI/AwwaRF guidelines.



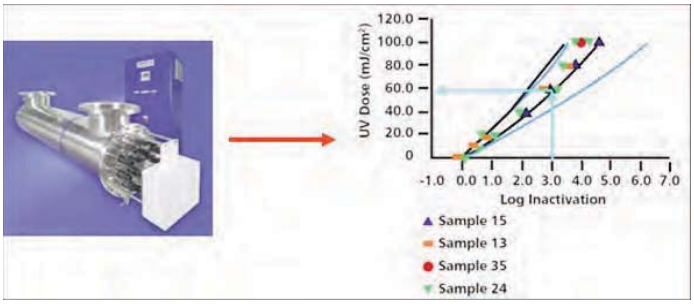
**Velocity Profile**



**Particle Trace**



**Light Intensity Distribution**




**Full-Scale Reactor and UV dose performance curve**

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