Comparison of UV Power Measurement of Low Pressure UV-lamps by a worldwide Round Robin Test

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ABSTRACT

In spring 2008 the IUVA manufacturer's council agreed, after a lively discussion, on a standard methodology for the measurement of low pressure (LP) amalgam lamp's output, determining the UV-power of a LP-mercury lamp as the only comparable value, independent from distance, direction, and measuring the maximum output, even independent from environmental conditions like the place of the laboratory and its staff.

In order to verify this method and to proof the suitability of the method a round robin test was started in the mid of last year, including participants from different industries: lamp manufacturers, equipment manufacturers and one sensor manufacturer.

Now the first round is finished, the lamps have been measured by seven laboratories and checked afterwards by the starting laboratory (measurement lab of the Heraeus Noblelight GmbH).

This paper is giving a short overview over the results of this trial. Unfortunately some labs did not deliver the expected data completely, so the data collected so far are not sufficient to give some reliable over all statistical statement. The statements published in this paper are only qualitative consequently, as long as we collect more data to start a reliable statistical evaluation. We intend to carry on with the intercomparison and enlarge the data base for the final decision on this methodology.

Key words: Ultraviolet; UV disinfection; Low Pressure Lamp; UV Intensity; Measurement Protocol; Round Robin

ROUND ROBIN SETUP

The Round Robin test of the proposed method for measurement of the output of monochromatic LP-lamps was coordinated by Heraeus Noblelight, Germany, up to now seven laboratories of well established commercial companies have been taking part. One of them measured not according to the instruction and will not be respected in the following evaluation.

Starting in Hanau, Germany, participants received the same samples and devices one after the other, sending it back to Germany for performing the final measurement at the starting lab.

Participants

Up to now the lamps have been measured by (in alphabetical order)

Calgon Carbon Corporation, Pittsburgh, USA
Infilco Degremont, Richmond, Virginia USA
Dr. Gröbel UV-Elektronik GmbH, Ettlingen, Germany
Heraeus Noblelight GmbH, Hanau, Germany
Light Sources, Inc. Orange, CT, USA
OSRAM GmbH, Muenchen, Germany
Trojan Technologies, London, Ontario, Canada

Test Samples

After some trials with different combinations of lamp and ballast suitable for a worldwide test we selected a rather short lamp because of the better ruggedness and shorter measurement distances necessary to fulfill the Keitz formula's requirements. As ballast we chose electronic ballast with a wide range power input to eliminate the problem of different mains voltage and frequencies, being aware of the problem of measurement of electrical lamp data at higher frequencies and non sinusoidal waveforms.

As a feasible combination we chose the Heraeus lamp NNI 125/84 XL and the electronic ballast EVG 160-200W/2A-PH. This combination showed the expected behavior according to the proposed methodology, a slightly overheated lamp, showing an easily detectable maximum output during warming up for a wide range of environmental temperature. The lamps have been aged for 100 hours to eliminate some possible initial drop of intensity and selected for a good repeatability of optical and electrical parameters.

As result of these trials we identified a set of 5 lamps for measurement and one single lamp, showing a good stability in steady state operation, for the detector testing.

Type of lamp: Heraeus low pressure amalgam lamp

Model: NNI 125/84XL

Five lamps for measurement according to the IUVA methodology

One lamp for measurement and evaluation of the laboratory's UV detector

Electronic ballast EVG 160-200W/2A-PH

Additionally we supplied an UVC - Sensor (Heraeus Disinfection Control) for independent monitoring and additional comparison of the UVC-values. This detector was intentionally unadjusted, in order not to influence the measurement data by comparing absolute data from the proprietary sensor to the reading taken from the provided one.

The participating laboratory had to provide

- calibrated UVC-irradiance radiometer
- power meter for mains power measurement and an adjustable AC-Power supply 230V 50/60Hz, in order to eliminate the uncertainties caused by mains voltage
- optional: a power meter for lamp power measurement, suitable for measurement of electronic ballast output values.

The lamps have been measured in the beginning, after an initial aging of 100h as required by the Proposed Method and at the end of that trial by the laboratory of Heraeus Noblelight in order to achieve information about changes of lamp output over the testing period. The final data comply with the initial data, so the lamps are regarded stable for the recent measurements and will be sent out again to the next participants.

MEASUREMENTS

Within this round robin, each laboratory conducted two different measurements by means of an instruction manual and the “Proposed method for measurement of the Output of monochromatic (254nm) low pressure UV-Lamps”(1).

Step 1: Determination of minimum measurement distance (validation of the cosine correction properties of the sensor)

First step was evaluation and validation of the UVC-sensor concerning the quality of the cosine correction as a preparatory test for determination of the optimum measurement distance for the individual setup and sensor.

According to Keitz’ formula the calculated UV power is independent from measurement distance, observing some additional terms like measurement setup (in compliance with the requirements of the Keitz’ formula and its preconditions) and influences by distance (and background signal handling)

In practice, as shown in **graph 1**, the reported values are not constant at all. In this case the reported UV-power values depend on the chosen measurement distance, leading to high uncertainties in UV power calculation.

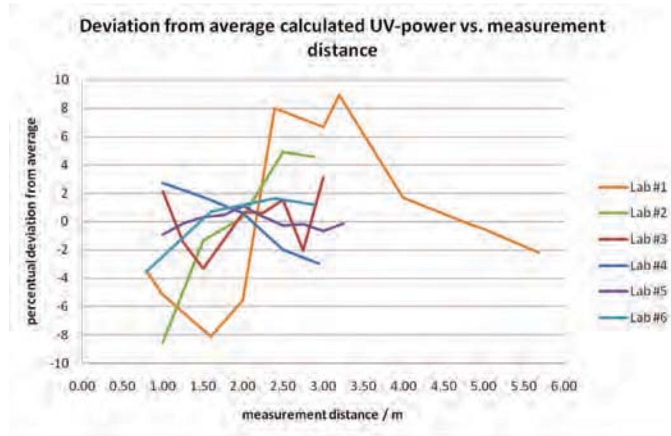

Figure 1: Relative deviation from average UV-Power

Some laboratories reported relatively high deviations from the expected constant UV power value, using the same sensor as another participant. With the assumption of nearly the same cosine response this fact gives a strong hint to influences by background signal, reflected light or a poor signal-to-noise ratio. This is a subject to be analyzed to get better confidence in the future.

Only one lab reported the measures taken to minimize these influences and data concerning background signal, as requested in the instruction manual, so that there is no opportunity to distinguish the straylight or scattered light (setup) from the cosine error (sensor) effect.

Further examination concerning cosine error and the appropriate consideration of reflected light is necessary to achieve an acceptable level of uncertainty deriving from these terms, reducible by good measurement practice.

In Step1, the optimum distance between detector and lamp at the individual laboratory setup and detector type has been determined. All subsequent measurements should have been conducted using this setup.

Step 2: Determination of UV Power at Maximum Output

Measurements had to be carried out according to the paper, “Proposed Method for Measurement of Output of Monochromatic (254 nm) Low Pressure UV Lamps”(1) which was attached to the instruction manual.

According to the method the irradiance had to be monitored from turn-on instant until steady state operation. Important was the recording of the whole set of lamp parameters (voltage, current, electrical power) at the point of maximum UV irradiance, also the steady state values had to be reported.

These tests had to be carried out for each of the five lamp samples five times, in order to get some information about the repeatability of the irradiance and the electrical parameters.

Distance between lamp and sensor was not predefined and was chosen by each laboratory according to the initial measurement, conducted in **step 1**.

The final evaluation was the determination of the average maximum irradiance derived from the 5 measurements for each individual lamp and the calculation of UV power, using the Keitz formula as well as the calculation of system efficiency (UV-power in relation to the electrical power consumption at the point of maximum irradiance).

Independence from ambient conditions

According to the proposed method lamps should show a much better repeatability of the peak irradiance compared to the irradiance recorded at steady state conditions. This is shown in **figure 2**, where the benefit of the peak measurement is obvious.

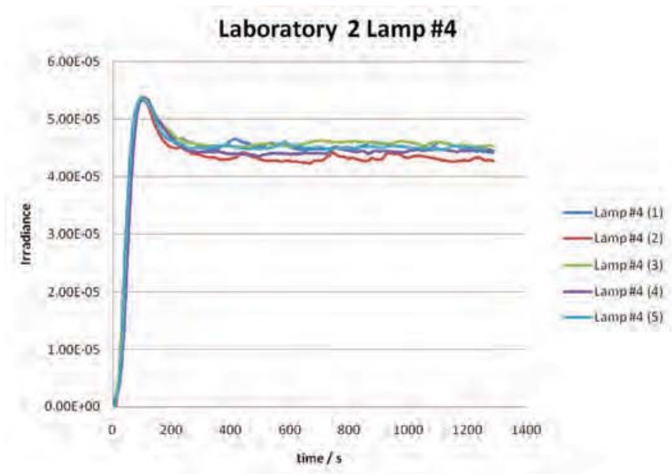

Figure 2: Example for warming up behavior of sample 4

If a laboratory has good control over the ambient conditions, the measurement curves may look like these shown in **figure 3**.

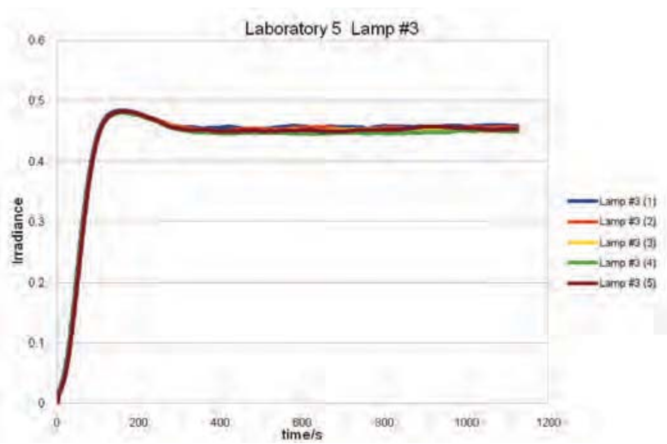

Figure 3: Example for warming up behavior of sample 3

Even when at this lab one measurement happened to be different from the others, the maximum irradiance was not affected. (**Figure 4**)

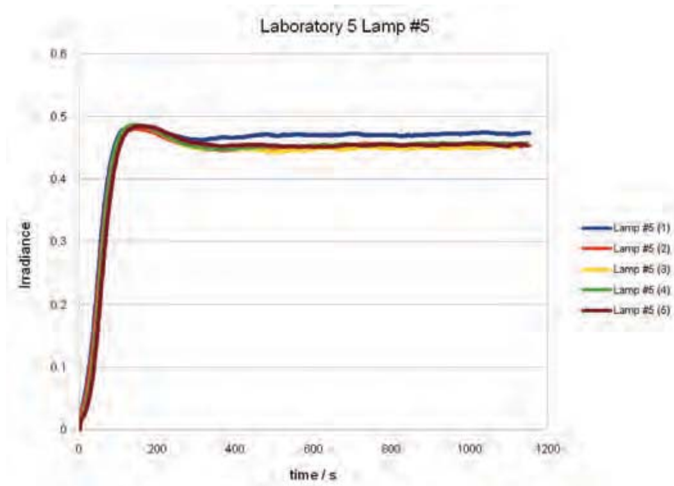

Figure 4: Example for warming up behavior of sample 5

It has to be noted, that there occurred also measurements showing atypical warming-up behavior, affecting the maximum UV-output. Therefore the lamps have been measured at least three times in order to determine the characteristic output of the lamp and identify potentially "bad" measurements.

UV power measurement

Measurements show (one exclusion) a feasible correlation between the individual lamp measurements, the absolute values differ about 15%, a result which reflects in general what could be expected for the assumed measurement uncertainty measuring UV with respect to the different calibration sources and methods. Further evaluation could be done as far as the concerning data, especially uncertainties, would have been provided by the participants.

Figure 5 shows the UV power data at maximum irradiation for each laboratory. Data reported here are given in arbitrary units in order to continue the round robin without influencing subsequent results.

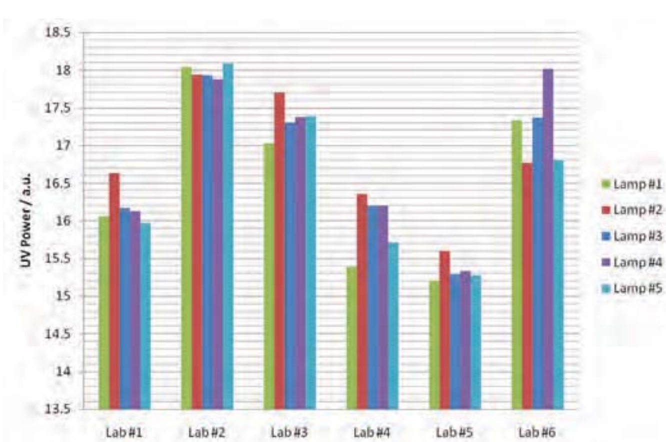

Figure 5: Reported UV power of the five sample lamps

CONCLUSIONS

Reported UV-power values depend on three main factors, cosine error of the sensor, sensor calibration source and method and the appropriate consideration of reflected light in the specific setup, leading to relatively high uncertainties in UV power calculation.

For further evaluation it is important to have some knowledge about the measurement uncertainties the laboratories calculated for their data. Unfortunately not all of the participants provided the full set of required information.

One of the labs did not measure according to the instruction and was not respected in the evaluation.

A detailed statistical evaluation will be published in a report when the Round Robin is finished.

REFERENCES

1. Oliver Lawal et al., "Proposed Method for Measurement of Output of Monochromatic (254 nm) Low Pressure UV Lamps", IUVA News Vol. 10 No. 1, April 2008