Radiometer for Real-time Calibration of the Xenon Arc Lamps

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Abstract. A standard radiometer which can be used for real-time calibration of the irradiance of Artificial Accelerated Weathering Apparatus of Xenon Arc Lamps is developed. In the paper we study the zero error, relative measurement error, cosine response, nonlinearity and fatigue property of the standard radiometer. The instrument performance should meet the requirements of real-time calibration of radiation intensity of Xenon Arc Lamps. The measured results of the real-time radiometer coincide with standard radiometers.

1. Introduction
Artificial accelerated weathering apparatus is widely used to accelerate the aging of materials by simulating solar radiation, temperature and humidity in the natural environment. The Xenon Arc Lamps are widely used to simulate the spectral distribution of the sun. Through the combination of different optical filters, we can obtain the radiation of various spectral distribution. According to the cooling mode of Xenon Arc Lamps artificial climate aging test equipment, it can be divided into two kings, including water-cooled Xenon Arc Lamp and air-cooled Xenon Arc Lamp.

2. The calibration of Xenon Arc Lamps
Xenon Arc Lamps are usually calibrated at the wavelength of 340nm, 420nm, 300nm~400nm, 400nm~800nm or 300nm~800nm, according to different standard. Radiation detectors or radiometers are often used to calibrate the radiation intensity at the sample position in the testing chamber[1][2]. These radiometers consist of detectors, amplifying circuits and displays. Detectors generally consist of diffusers, filters and silicon photodiodes.

For the calibration of water-cooled Xenon Arc Lamps, the detector of standard radiometer or spectroradiometer should be placed in the sample holder. The distance between the receiving surface of detector and the lamp tube should be carefully adjusted so that the receiving surface is parallel to the axis of lamp, align the geometrical center of both two. For the calibration of air-cooled Xenon Arc Lamps, the detector of standard radiometer or spectroradiometer should be placed in the center of the bottom. The distance between the receiving surface and the center of the lamp tube also need to be adjusted as the same with water-cooled Xenon Arc Lamps. As shown in Figure 1, we usually choose three sample points to test the radiation uniformity of the Xenon Arc Lamp testing chamber.
3. Real-Time Calibrating Radiometer

This project developed a radiometer which can be used for real-time calibration of Xenon Arc Lamps. Real-time calibration means we can monitor and calibrate the radiation intensity of the lamp any time during the aging test. This radiometer is different from the common detectors which based on filter structures. The structure diagram of the radiometer is shown in figure 2. We only need to fix the probe and optical fiber of the radiometer inside the testing chamber of the accelerated weathering apparatus. The other parts of the radiometer are installed outside. High temperature and humidity resistance probe and optical fiber are chosen to reduce the influence of the radiation from the lamp during the aging test. The probe of the radiometer can work in the testing chamber for a long time without significant performance degradation and be easily replaced, which is very important for real-time calibration[3].

![Diagram of the radiometer]

**Figure 2.** The structure diagram of the radiometer.

3.1. Relative measurement error

The relative measurement error of the radiometer is tested under standard Xenon Arc Lamp. Both the receiving surface and the lamp tube are adjusted so that the receiving surface of the standard detector is parallel to the axis of the lamp. Adjust the position of the apertures between the source and the detector to make sure that they do not shield the radiation from lamp. We can obtain different illuminance by changing the distance between the light source and standard detector. Then, we place the detector of radiometer in the same position on the shelf, make sure that its receiving surface is the same with that of standard detector[4]. Two Q-Lab radiometers are chosen to test the relative measurement error, which are both calibrated before the testing. One radiometer is used as standard detector and the other is used to monitor the radiation intensity of lamp.

3.2. Cosine response

The cosine response of detector must meet the requirement that can be tested under a standard UV radiation source. Set the detector of radiometer on a rotating platform. The rotation axis of the platform passes through the center of the receiving surface of detector. Adjust the rotation platform to make the optical axis of detector consistent with the optical axis of UV radiation source. Several apertures are placed between the UV radiation source and detector. The apertures need to be adjusted
carefully so that they do not block the light way from the radiation source to the receiver. The distance between source and detector should be 15 times greater than the maximum linear extent of ultraviolet radiation source or detector's receiver.

Preheat the UV radiation source for 30 minutes before the test. Turn the platform to the left, adjust the radiation value to 50%-80% of the maximum intensity and record the angle of rotating platform at this time. Then, turn the platform to the right and repeat this procedure. The average value of these two angles is normal(0°) and record the display value of the radiometer at this angle. Turn the platform to ±5°, ±10°… ±85° and record the display values of radiometer at these angle. The cosine response of the detector can be calculated according to formula (1) and formula (2)[5].

\[ f_2(\varepsilon, \phi) = \frac{Y(\varepsilon, \phi)}{Y(0, \phi) \cos \varepsilon} - 1 \times 100\% \]  

\[ f_2 = \int_{\varepsilon=0}^{1.484} f_2(\varepsilon, \phi = 0) \cdot \sin 2\varepsilon \cdot d\varepsilon \]  

\( \varepsilon \): the incidence angle between the incident light and the normal line of detector's receiving plane, \( \phi \): the azimuth of the incident light and the horizontal line of detector's receiving plane, \( Y(\varepsilon, \phi) \): the display value of radiometer when the incident angle is \( \varepsilon \) and the azimuth is \( \phi \), \( Y(0, \phi) \): the display value of radiometer when the incident angle is 0 and the azimuth is \( \phi \).

The cosine response testing results are shown in figure 5.
3.3. Nonlinearity
The nonlinearity of the radiometer is tested. Fix the detector on a sliding guide and move light source to the position where the display value reach to 1/10 of full-scale. Then, move the radiation source to the position where the display value of radiometer is max. The nonlinearity of radiometer is calculated as shown in Table 1. The correction factors show that the linearity of the radiometer is satisfying.

Table 1. Testing result of linear error

| Standard value (W/m²) | measured value (W/m²) | Correction factor |
|----------------------|----------------------|-------------------|
| 0.087                | 0.089                | 0.980             |
| 0.486                | 0.496                | 0.980             |
| 0.752                | 0.767                | 0.980             |
| 1.515                | 1.546                | 0.980             |

3.4. Fatigue property
Two Q-Lab radiometers are chosen to test the fatigue property of radiometer, which are both calibrated before testing. Put the detector of the radiometer under aging test following different standards and test the fatigue property, the maximum fatigue error is 2.50%.

4. Conclusion
A standard radiometer used for real-time calibration of radiation intensity of Xenon Arc Lamps is developed. The relative error of radiometer is -0.9%, $U_{rel}$=7.0% ($k=2$). The cosine response error is 0.2%, and the fatigue error is 2.50%. The radiometer can overcome the influence of irradiance, temperature and humidity on the detector during the aging test. The measured results are consistent with those of ATLAS and Q-lab standard radiometers.

References
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