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Appendix

The Accuracy of Photopia

Photopia can be very accurate but it is impossible to quote a single number that encompasses this issue. First of all, in order to obtain the most accurate results, the Photopia model must match the physical luminaire in all respects, including:

- **Optical Component Geometry** – make sure reflector and lens shapes are accurately manufactured, which they often are not especially for sheet metal parts.
- **Optical Surface Properties** – make sure the materials used in Photopia match those used in the physical parts.
- **Lamp Type and Modeled Orientation** – in the case of MH lamps care must be taken because the arc shape and position can shift as the lamp is aimed in different orientations.

If the optical model does not match the physical luminaire in any of these respects then the comparison of accuracy will be consequently affected.

Photopia photometric predictions are also affected by the manner in which the design was analyzed. Important analysis settings include:

- **Luminaire Orientation** – orienting the luminaire model appropriately within Photopia's coordinate system.
- **Ray Resolution** – tracing an appropriate number of rays and reflections.
- **Angular Range** – specifying the appropriate range of angles in the candela distribution.
- **Angular Resolution** – specifying the appropriate angular resolution in the candela distribution.

If the analysis is not properly set up then the results can potentially be completely incorrect. Contact LTI if you are unsure of how to setup your luminaire analysis.

If the Photopia model matches the physical model and if the analysis is properly setup, then the accuracy can be divided into two parts:

1. **Efficiency** – the prediction of the total luminaire efficiency (LOR).
2. **Candela Distribution** – the prediction of the shape of the candela distribution.

Efficiency (LOR)

The prediction of the total luminaire efficiency is often within 1 or 2% of the measured values but can be off has much as 5 or 10% in some cases. HID luminaires generally have the most accurate efficiency predictions with fluorescent, and especially compact fluorescent (CFL) luminaires having the least accuracy. The fluorescent luminaire output is often a function of how the light interacts with the lamp when it is redirected back into the lamps off of the reflector. Although Photopia attempts to trace rays through the fluorescent lamps in as accurate a manner possible, the amount of absorption in the fluorescent phosphors varies from lamp to lamp and this value is fixed in Photopia at about 5%. This value comes from measurements on fluorescent lamp samples, but the sample set was limited. While in reality the phosphor types and thickness varies on different lamps. Fluorescent lamp output is also affected by temperature, something Photopia completely ignores. Thus, the physical test on a fluorescent luminaire will have an efficiency that is a combination of an “optical efficiency” and a “thermal efficiency.” Photopia only attempts to calculate the “optical efficiency.” The temperature issue is especially important with CFL’s, linear T5 fluorescents and induction lamps. With CFL’s the lamp output can decrease when the lamp is running within the reflector where the temperature is much greater than that of the surroundings. With T5 and induction lamps the lamp output can increase when the lamp is running within the reflector where the temperature is greater than the surroundings. Depending on how the bare lamp lumen output is determined at the particular laboratory used for T5 and induction lamp tests, the measured efficiency can be significantly greater than the “optical efficiency” predicted by Photopia.

Candela Distribution

In regards to the accuracy of the candela distribution, Photopia has shown over the years that the shapes are very close to the measured shapes. But it is difficult to assign a single tolerance to all candela values in a distribution. For example, if a fluorescent luminaire has a peak candela value directly below the luminaire of 1000 candelas, then Photopia might predict this to be 1050, a difference of 5%. But as the distribution tapers off and the candela values become very low then the percent difference between the predicted and measured values can be very high. For example, if the measured value at some angle near the cutoff of the beam was only 5 candelas and Photopia predicted 10 candelas, then Photopia would be off by 100%. But in reality this is a very small number of lumens in regards to the entire distribution. So in general it can be concluded that the tolerance increases as the candela values decrease compared to the larger values in a distribution. Peak candelas, their location and the general shape of the distribution are all quite accurate with tolerances of 10% being typical. One other issue that can effect the candela distribution significantly in some luminaires is anisotropic materials. These are materials that scatter light differently depending on the material's lateral orientation. Strongly grained, semi-specular aluminum is an example of an anisotropic material. Photopia assumes isotropic materials. Scattering data for anisotropic materials is generated by averaging measurements made from light incident in the plane along the grain direction with light incident in the plane across the grain direction.

Finally, the tolerance of the physical measurements should be noted in any comparisons to predicted values. If two luminaires of the same type were built and sent to the same laboratory at different times, it is very unlikely the measured values would be identical. This is due to a variety of issues including part accuracy, lamp output consistency, laboratory calibration and laboratory setup consistency. All manufactured parts have tolerances so they cannot be expected to be identical. Although it is true that certain processes result in more consistent parts than others. Processes that offer the most inconsistency in manufactured shapes are generally related to sheet metal fabrication, especially rolled reflector shapes. Material finish processing such as polishing and anodizing are not consistent even across parts made during a single day. Photometric laboratories must keep their sensors in calibration, but their sensitivity does change between calibrations. Even presumably simple issues such as using a "standard" lamp can be problematic. HID lamps such as metal halides have deposits on their arc tubes. These do not completely evaporate during a test and this does affect the bare lamp distribution. Overall lamp lumen output can be checked and accounted for, but heat issues affecting lamp output inside the luminaire are not isolated. Simple fluorescent tubular lamps such as T8's and T5's suffer from symmetry problems due to inconsistent phosphor coatings on the inside of the lamps. Thus, these lamps may produce varying luminous intensities within the plane that passes perpendicular to the tube when in theory all directions within this plane should be identical. Good testing labs will recognize these issues and try and account for them but not all laboratories work according to the same set of standards.

Conclusion

If results from Photopia are found to differ greatly from those that are measured then the first thing to check is that the analysis was done properly for the given type of luminaire. If the analysis settings were correct, then any remaining differences are most likely due to a difference between what was measured and what was modeled. If a systematic review of the above listed issues does not isolate the source of the differences, then the project should be sent to LTI for review.