ASSIST Application Design Guide: Industrial Lighting

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Introduction

It is generally agreed that lighting for industrial applications should support the accurate, fast, and safe performance of workers while providing a visually comfortable environment. Although it is true that productivity is a function of many aspects including personal and environmental factors, it is generally hoped that good lighting will promote, if albeit indirectly, productivity in the workplace. *Industrial lighting* is a term that refers to a very diverse range of activities and environments, from food processing to metal works of large scale to printing to repair or assembly of extremely small components. Each one of the potential applications will have a range of visual tasks that will require prioritization; for example, whether color discrimination is more important than high visual acuity when machining a precision metal part. It is the job of the lighting designer to understand all of the potential visual tasks that need to be supported by the lighting and what features are necessary so that the end users can extract the information they need to conduct their work. As in other applications where there is potential for shift work, industrial lighting should also support natural rhythms of sleeping and wakefulness of workers. Needless to say, maintenance costs and energy use of industrial lighting should be minimized.

This *ASSIST Application Design Guide* is meant to assist lighting specifiers in identifying appropriate metrics for quantifying the benefits of lighting relative to their costs, and in doing so, maximize the value of the specified lighting system.

Application Issues

Lighting for visibility

In spite of the ever-increasing modernization of industrial processes, the success of many industries still depends on the correct visual function of their workers when conducting their tasks, whether it involves receiving, manufacturing, inspecting, storing, or shipping. Industrial lighting applications imply a wide range of visual conditions corresponding to flat or three-dimensional objects of different visual sizes, surface finishes and colors, different task plane locations, and often movement.

Generally speaking, visual tasks in industrial settings can be put in three broad categories: orientation and navigation, common visual tasks (in different sub-categories depending on visual size, contrast and speed), and special visual tasks that occur near threshold. The observer's age together with the visual size, the luminance contrast, and the color difference of the task determine the amount of light needed on the task plane for high visibility. The **photopic illuminance** on the task is the primary basis for the recommendations for industrial lighting. While light level is an important variable, the designer should also provide input in terms of potential changes to the task itself (e.g., changing contrast or visual size) that may facilitate the visual component. In industries where color identification or color discrimination are important, the color rendering properties of the light source, in addition to the light level, are important considerations for successful visual performance.

It is important to emphasize that the eye-source-task geometry often plays a key role in determining how visible the task is. By controlling the spatial distribution of the light on the task, direct or indirect glare can be prevented, as well as veiling reflections that may reduce the contrast of the task, thus making it more difficult to see. It is worth noting here again that the lighting designer needs to determine if the distribution of the light on the source can be used to enhance the task's visibility by providing highlights or other patterns on the task's surface. This technique is particularly useful in inspection areas where defects on three-dimensional surfaces are more easily seen through the creation of highlights or shadows from either diffuse or directional lighting as appropriate.

In applications with high spatial resolution or monochromatic tasks (i.e., where visual acuity is important) such as reading small type sizes or assembly of small components, there is no expected gain in visual performance by increasing the correlated color temperature (CCT) of the light sources. It is particularly important to emphasize that such a change to a higher CCT should not be a reason to reduce the photopic illuminance on the task. While a higher CCT does not detract from visual performance and may result in the appearance of a brighter environment, such brightness perception is not a surrogate for increased visual performance. Visually demanding tasks should be illuminated at the recommended photopic illuminances.

In several industries (e.g., food processing, printing, assembly of colored parts) color quality can be critical in the performance of many crucial visual tasks performed by workers in these environments. The lighting design should support the correct color rendering of the tasks at hand. Helping ensure that the color of lighting does not appear unnatural or unpleasant is an important design concern. Research has shown consistently that a two-metric approach to characterizing the color rendering properties of light sources helps reduce the uncertainty in specifications when the task is not fully specified or can vary. ASSIST recommends using the general **color rendering index** (CRI, R_a) and the **gamut area index** (GAI) as the two metrics to specify good color rendering for industrial tasks.

Lighting for safety

Proper task visibility is just the starting point in providing a safe environment in industrial applications, especially for those tasks where machinery or other moving parts are present. In those cases, **flicker** or **stroboscopic effects** from the illumination can pose a hazard to the worker by creating the appearance that a moving part is static. Although virtually all types of lighting systems produce flicker to some degree, the impact on the task will be determined by the frequency and how large the variation is in the light output. Here again, the lighting designer should anticipate measures in the planning of the lighting system so that these effects are eliminated, when possible, or minimized. Throughout different areas, the **uniformity** of illumination is an important consideration, primarily to avoid sharp shadows and to ensure that areas between luminaires are not so dark that hazards become difficult to see.

Lighting for visual comfort

The lighting design of an industrial space should also consider the visual comfort of the workers as they often spend long hours performing a similar task. A reasonable **uniformity** of illumination on the task reduces the need for visual adaptation at different light levels, which may reduce visual fatigue. Controlling direct and reflected **glare** and veiling reflections will also contribute to increased visual comfort.

Benefit Metrics

Lighting for Visibility

The **photopic illuminance** on the task is the primary basis for current recommendations for industrial lighting, and illuminance is a useful metric for illumination that determines visual performance of tasks where speed and accuracy are important. Recommended **uniformity** ratios of illumination help reduce visual fatigue. For visually demanding tasks, photopic illuminance should not be reduced based on the CCT of the light source. The use of **Class A color** sources, that is, sources with a general color rendering index of at least 80 and a gamut area index between 80 and 100 will provide optimal ability to distinguish among colors. Class A color sources are those that in addition have minimum tint. The use of light sources with **Class A color** characteristics not only will help in performing visual tasks involving color perception, but will provide illumination that is likely to be judged as natural and pleasant in appearance by occupants of industrial facilities.

Lighting for Safety

In applications where movement is part of the visual task, special care should be taken to eliminate or reduce **flicker** and **stroboscopic effects**. The severity of the stroboscopic effects is a function of the light waveform (amount of variation and frequency). When light source flicker cannot be eliminated, ASSIST provides recommendations to estimate the detectability and acceptability of stroboscopic effects on different tasks.

Reducing Costs to Optimize Lighting Value

As in other applications, reducing the costs of lighting is a reasonable goal of designers and facility managers. An effective way of reducing costs of industrial lighting is to maximize the effectiveness of the lighting system at delivering light where it is needed. This minimizes losses, which also results in a reduction of the number of luminaires needed and a consequent reduction in energy use. Determining the **application efficacy** of alternative lighting solutions facilitates the selection of those that are more energy- and cost-effective at providing the illumination needed for the task.

Summary

The following criteria and metrics should be considered for general industrial lighting:

- **Photopic illuminance** at the plane of the visual task and uniformity to meet consensus recommendations. Illuminance recommendations are based on the visual size and contrast of the task as well as the age of the observers.
- **Class A color** for the correct identification of safety colors and for quick and accurate task performance when color is an important part of the visual task. The two-metric approach (CRI+GAI) in the Class A color definition reduces the uncertainty in choosing light sources that provide good overall color rendering.
- **Flicker and stroboscopic effects** for the correct light distribution in the space for orientation and navigation and on the task for visual performance and comfort.
- **Application efficacy** for task lighting to maximize energy and cost effectiveness while meeting all target illumination requirements.

Resources

This short design guide is meant to assist specifiers with a few preliminary considerations for general industrial lighting applications and is not meant to provide comprehensive guidance. Many companies and organizations have specific requirements for different industries that must be considered in the lighting design. The following resources describe the application metrics discussed here and point the reader to additional information.

ASSIST. 2010. *ASSIST recommends…Guide to light and color in retail merchandising.* Vol. 8, Iss. 1. Troy, NY: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/lightcolor.asp.

ASSIST. 2010. *ASSIST recommends…Recommendations for specifying color properties of light sources for retail merchandising.* Vol. 8, Iss. 2. Troy, NY: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/lightcolor.asp.

ASSIST. 2012. *ASSIST recommends...Flicker parameters for reducing stroboscopic effects from solid-state lighting systems.* Vol. 11, Iss. 1. Troy, NY: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp.

ASSIST. 2014. *ASSIST recommends…Application considerations related to stroboscopic effects from light source flicker.* Vol. 11, Iss. 2. Troy, NY: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp.

ASSIST. 2015. *ASSIST recommends…Recommended metric for assessing the direct perception of light source flicker.* Vol. 11, Iss. 3. Troy, NY: Lighting Research Center. Internet: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/flicker.asp.

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Rea MS. 2013. *Value Metrics for Better Lighting.* Bellingham, WA: SPIE Press.

About ASSIST: The Alliance for Solid-State Illumination Systems and Technologies (ASSIST) was established in 2002 by the Lighting Research Center as a collaboration among researchers, manufacturers, and government organizations. ASSIST's mission is to enable the broad adoption of solid-state lighting by providing factual information based on applied research and by visualizing future applications. ASSIST members include: 3M; Acuity Brands Lighting; Amerlux; BAE Systems; Bridgelux; Cree; Crouse-Hinds by Eaton; Dow Corning; Federal Aviation Administration; GE Lighting Solutions; Hubbell Lighting; Legrand; Lumileds; New York State Energy Research and Development Authority (NYSERDA); OSRAM SYLVANIA/OSRAM Opto Semiconductors; Philips Lighting; Samsung Electronics Co.; Seoul Semiconductor; United States Environmental Protection Agency.