Case Study of the Process to Implement UL 24480 into the Lighting Design for Denver Federal Center Building 48 Modernization Project

Introduction

Project Overview

In 2020, the General Services Administration (GSA) issued a request for proposal (RFP) for a design-build team to convert Building 48 (Figure 1) on the Denver Federal Center (DFC) campus in Lakewood, Colorado into a modern office facility for the Department of the Interior's (DOI) Interior Business Center (IBC). Building 48 was originally built in the 1940's as a World War II munitions plant. It was decommissioned shortly after the end of war, and has since received four building additions, becoming a 150,000 square foot warehouse used most recently by the National Archives and Records Administration. The building has been vacant since 2013. Prior to its redevelopment, Building 48 was primarily a single-story facility with a brick exterior with very few, small windows.

Figure 1. Exterior pictures of Building 48 on the DFC campus in Lakewood, CO prior to renovations.

DOI's Interior Business Center (IBC) has approximately 800 employees who currently work in three leased office buildings in a nearby office park in Lakewood, CO. The IBC performs human resource, contracting, procurement, and payroll services for the DOI as well as for other small Federal agencies. GSA required in their request for proposal that the Building 48 design adhere to the 2018 version of the P100 *Facilities Standards for the Public Buildings Service* , Tier 2 for lighting. The P100 establishes design standards and performance criteria for GSA-owned buildings. P100 tier 2 requirements related to lighting included that the building be energy efficient; maximize access to daylight; and provide a visually comfortable environment that supports a high-performance workplace. As of 2018, the P100 tier 2 did not include requirements for circadian-effective lighting.

Design Team

In August 2020, the project to modernize Building 48 was awarded to a design-build team including architecture firm (Cannon Design), engineering firm (The RMH Group), and builders (Centerre Construction). The project was considered a good candidate for a design-build contract because the building was vacant, offered a "clean slate" with which the team could work, and GSA believed that a fully integrated team at the onset of the project could maximize GSA's budget and expand the project's goals. During the RFP procurement, the design-build team collaborated to develop conceptual designs for the building including initial plans for the lighting and daylighting designs.

Decision to Incorporate UL24480 into the Design

In 2021, requirements to include circadian-effective lighting were incorporated into Tier 2 of GSA's P100 Facilities Standard. Aware that Building 48 was beginning the design development phase, Bryan Steverson from GSA's Office of Federal High-Performance Green Buildings, approached Jason Sielcken, GSA's Regional Chief Architect and senior project manager for the modernization of Building 48 about incorporating *UL 24480 Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People*, into the performance criteria for the building's design. Mr. Sielcken discussed this with the design team and the leadership team at the IBC. All parties were enthusiastic about including UL 24480 in the project. Both the design team and the leadership of the IBC felt that UL 24480 supported one of the chief design goals of the project which was to provide a high-performance workplace that enhanced all human factors including the health of building occupants.

Lighting Design Goals and Objectives

Overall Goals of the Lighting Design

By late 2020 when the concept phase of the project began, the United States was in the midst of the COVID-19 pandemic. This shifted the design goals for Building 48 to focus on creating an environment that would bring people back to the office and give them a reason to come into a central location for work. This led to an increased emphasis on the design of collaborative spaces, where people could work together. The design team also wanted to create an environment that supported occupants' health, productivity, and comfort – a building where people would want to come to work.

Because the building is large, with a deep floor plate, the design divides the structure into a series of "neighborhoods" each anchored by an open office area and areas for informal meeting and collaboration (Figure 2). These areas are surrounded by enclosed spaces such as private offices, huddle spaces, and conference rooms.

Figure 2. A design floorplan of one area of Building 48.

A major goal of the lighting design was to bring as much daylight into these spaces as possible. It was also considered important to provide views to connect occupants to the outdoors. Therefore, large windows (10 to 12 feet tall) and numerous skylights are placed throughout the open areas. Interior private spaces were designed to include glazing to allow these spaces to "borrow" daylight from the open areas as much as possible (Figure 3).

Another goal of the daylighting and lighting design was to provide a visually comfortable environment for people working in the building. Therefore, careful evaluation was done of the design, glazing, and interior treatments for the windows and the design and glazing for the skylights to help reduce direct glare from the sun into these spaces. Lighting fixtures were also evaluated and selected using the unified glare rating (UGR) as specified in the P100 standard.

Figure 3. Design rendering showing large windows.

Because the building is designed to be net zero energy, energy efficiency was an important consideration in the both the daylighting and lighting design. Glazing was selected to minimize heat gain and electric lighting was designed to provide lighting power densities (LPDs) 40% below the requirements of ASHRAE/IES 90.1, 2016, as was required by Tier 2 of the P100 standard as of 2020.

UL 24480 Impacts on the Lighting Design

Once the decision was made to incorporate the requirements of UL 24480 into the existing lighting/daylighting design, the design team reevaluated the design in accordance with UL 24480 requirements. This included:

Step 1: Incorporating additional photometric measurements into the lighting design software to assess vertical illuminance levels at locations throughout the various spaces in the building. Originally, only requirements for horizontal light levels (minimum 30 footcandles) had been included in the P100 standards. Therefore, the design team did not conduct vertical light level calculations. Because UL 24480 requires an assessment of light at the eye level of building occupants, vertical measurements were taken for a variety of positions and orientations throughout each building space.

Step 2: Conducting spectral analysis of the lighting/daylighting using the online Circadian Stimulus (CS) calculator tool (https://cscalc.light-health.org/). Lighting designers contacted representatives of the manufacturers of the luminaires they had specified for the design to obtain spectral output information for each product. Because the windows and skylights included spectrally neutral glazing, the designers used the daylight spectral information included in the CS calculator. They entered this information along with light levels calculations into the CS calculator to obtain CS levels for the various building spaces.

Step 3: Adapting the lighting/daylighting design where possible to optimize the CS levels to meet the requirements of UL 24480.

Open Plan Areas

The open plan areas of Building 48 represent nearly 70% of the floor space (Figure 4). The design team found that the minimum requirements of UL 24480 (providing a CS > 0.3 for at least 2 hours of the day) could be met primarily using daylight, in all open areas of the building, with minimal changes to the design. These changes included, first, to ensure that interior surfaces provided maximum distribution/reflectance of both the electric light and daylight throughout the space. The ceilings throughout the building were originally to be painted black, in keeping with an industrial

aesthetic. This was changed to matte white paint to better reflect daylight from the windows and skylights as well as from the direct/indirect linear pendant luminaires. These design choices significantly improved vertical illuminance and thus CS levels and uniformity in the open areas of the building.

The next change was to optimize the number and position of the skylights to ensure that all of the open areas in the building met UL 24480 requirements. This was important because CS contributions in these spaces came primarily from the daylight and the deep floor plate did not allow daylight from the windows to penetrate deep into the interior areas of the building, despite the size and height of the windows. The design for the windows was not changed during this process.

Figure 4. Design rendering of a skylight and electric lighting in one of the open office areas.

Enclosed Areas

Meeting the requirements of UL 24480 in enclosed spaces, such as private offices (Figure 5) and conference rooms, was more of a challenge. These spaces were in the interior of the building, away from windows, and although they had some glazing in the walls to allow daylight penetration, the glazed areas were reduced during the design development phase due to budgetary constraints. This meant that the ceiling-recessed electric lighting alone had to provide minimum CS levels in these spaces. The electric lighting had several constraints which severely limited the lighting designers' choices including requirements of the Buy American Act, fixture listing on the Design Lights Consortium Qualified Product List, budgetary and LPD restrictions. This led the design team to decide not to meet UL 24480 requirements in these spaces, and instead, encourage occupants to spend time in open, shared, collaborative areas throughout the day where CS levels were significantly higher.

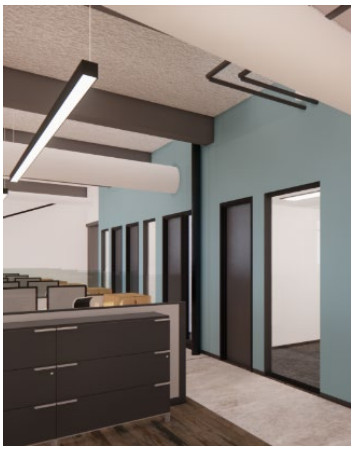

Figure 5. Private offices.

Lessons Learned

Several lessons can be learned from the experience of including UL 24480 into the design of Building 48.

1. Start Early in the Design Process

Many design decisions will affect the incorporation of circadian-effective lighting into a building or renovation project. These range from the location and configuration of interior spaces, the design of windows and skylights, selection of interior finishes, among many others. If a design team waits until the selection of luminaires, which is usually done quite late in the design process, it will be more difficult to ensure the availability of circadian-effective lighting for all building occupants.

In the conversion of Building 48 into offices, many important design decisions had already been made prior to adding the requirements of UL 24480 to the project. Some of these were difficult to

change. If UL 24480 had been included from the very beginning of the project, perhaps the private, enclosed spaces could have been designed, located, or configured differently to allow them to also include circadian-effective lighting. Or, perhaps, more funds could have been allotted to increase daylight penetration into these spaces or to consider other electric lighting options, such as localized, or furniture mounted lighting.

2. Teamwork Makes the Dream Work

One of the benefits of an integrated design/build team is that everyone is working together from the beginning of the project with a shared vision and shared goals. In the design of Building 48, GSA representatives, the leadership of the building's new tenant (IBC), and the entire design and construction team shared a vision of creating a healthy, productive environment for building occupants. Because changes to one aspect of the design can affect many others, realizing this vision takes contributions from all team members. Architects must often be willing to adapt building designs to bring in more daylight. Interior designers must carefully consider interior colors, finishes, and furniture selection and orientation to improve the distribution and availability of light for occupants throughout the space. Engineers and lighting designers must provide creative and thoughtful lighting and control solutions that will provide circadian-effective lighting comfortably and within design and cost constraints. And contractors must work with design team members to assess the impacts of product substitutions on design intent during the construction process.

In Building 48, the color of the ceiling needed to be changed to provide a reflective surface for light to distribute through the space. Even though a black ceiling was originally designed, because all team members shared the goal of promoting a healthy workspace this change was made to support that goal. Additionally, the team chose to add skylights in the collaborative spaces (Interact Zones). The addition of daylighting in these spaces met several project goals including providing access to circadian-effective lighting for all building occupants.

3. Standards and Recommendations May Conflict

Specification requirements and building standards, such as those included in the P100 or the power density limits of ASHRAE/IES 90.1, or recommended practices, such as those published by the IES, may conflict with one another. For example, selecting ceiling-mounted luminaires that provide more vertical illuminance, helpful for meeting the CS requirements of UL24480, may run up against requirements for selecting luminaires that have a low UGR rating, as included in the P100. Requirements for very low LPD levels, again a P100 Tier 2 requirement, may conflict with a desire to provide higher CS levels for at least 2 hours of the day, as specified in UL 24480. This will also come into play when building commissioning is done. If the commissioning agent is not aware of which standard they should be using, they may, for example, commission the space for a horizontal illuminance of 30 footcandles (an IES recommendation) and not for a vertical illuminance that provides a minimum CS of 0.3, as specified in UL 24480.

In the design of Building 48, lighting designers felt constrained by strict LPD limits for private offices, which ultimately limited their ability to provide circadian-effective lighting in those spaces.

4. Don't be Afraid to Seek Help

Once the idea of incorporating the requirements of UL 24480 into the design for Building 48 was embraced by the design team, the next question was, *what do we do now?* It seemed like a daunting task to many of the team members, so the GSA asked representatives from Mount Sinai's Light and Health Research Center (LHRC) to make a presentation on the guidelines to the team and be available to answer questions. After only an hour presentation, the team felt comfortable moving forward with the implementation process. The team's lighting designer was easily able to incorporate the additional lighting calculation and design steps needed to begin to

implement the requirements of UL 24480. The GSA has many resources available, including online videos and tutorials, to assist design teams to implement UL 24480 into their projects. Take advantage of these resources as you begin the design process. https://www.light-health.org/education/resources/ul-design-guideline-24480

5. Daylight is Your Circadian System's Friend

The design team for Building 48 benefited from the building being a single story, blank canvas that they could alter to meet the needs of the new building occupants. This allowed them to maximize the daylight penetration into the interior of the building. Large windows were fitted throughout the façade, and skylights were installed wherever they were needed to "flood the space with daylight," as much as possible. Obviously, not all buildings will allow for these daylighting measures, but designers must always consider daylight as part of a circadian-effective lighting design. Steps must be taken to bring daylight to the occupants and bring the occupants to the available daylight.

This might mean creating collaborative, flexible spaces, like those in Building 48, where people who work in darker, interior spaces can go for periods of time to have access to circadian-effective light. It can mean reorientation of a building interior to bring workers toward windows and move spaces where people spend less time, such as conference rooms, to the interior. When window reconfiguration is possible, bring daylight in high, through tall and/or clear story windows. Keep interior surfaces light in color to allow the daylight to reflect and be distributed throughout the interior.

Credits

The Light and Health Research Center would like to thank the following individuals who contributed to the development of this publication.

Bryan Steverson, Sustainable Design Program Expert
GSA

Jason Sielcken, Chief Architect, Rocky Mountain Region
GSA

Matthew Bartels, AIA, Principal in Charge, Architect
Cannon Design

Thomas Hanley, AIA, Design Principal, Architect
Cannon Design

Michelle Swanson, PE, Vice President
The RMH Group, Inc.

Shara Johnson, PE, LC, Electrical Engineer, Lighting Designer
The RMH Group, Inc.

Renderings and images provided by CannonDesign

Authors

Daniel Frering, MS; Jennifer Brons, MS; Mark S. Rea, PhD