Eneref Institute

CIRCADIAN LIGHTING

A REPORT TO ADVOCATE FOR SOCIALLY RESPONSIBLE SUSTAINABLE DEVELOPMENT

EXAMINATION AND USE OF SPECULAR REFLECTORS IN **FLUORESCENT LUMINAIRES**

INTERVIEWS AND RESEARCH BY ENEREF INSTITUTE SHOW THAT BETTER PERFORMING REFLECTORS ARE WORTH STRIVING FOR, EVEN WITH THE ENGINEERING AND AESTHETIC CHALLENGES FOR THE DESIGNER, PRICE-POINT HURDLES FOR THE MARKETER AND ROI QUALMS FOR THE FACILITY OWNER

Despite the best intentions of a variety of stakeholders- . from the lighting designer to the luminaire manufacturer to the facility manager-energy efficiency is too quickly abandoned in many commercial retrofit lighting projects, even before the luminaires are installed, as short-term economic interests trump sound energy decisions for numerous owners.

As part of its research for an upcoming report on the obstacles to speedier implementation of energy-efficient buildings, the Eneref Institute, a research and advocacy organization that studies, examined one slice of the commercial lighting retrofit process: the use and potential effectiveness of specular aluminum luminaire reflectors in retrofit projects. The difficulty of "holding the spec" as it pertains to the use of these reflectors offers a window into some of the overall impediments to advancing more energy-efficient commercial buildings.

Though the reflector material choice for a luminaire in commercial retrofit projects can be driven by the manufacturer or end-user, better results may occur when optical (reflective) surfaces are specified by a lighting designer or lighting engineer. Both diffused and specular optical surfaces are available to luminaire manufacturers with total reflectivity in the high 90 percent range. The total reflectivity of a surface equals the specular reflectivity plus the diffused reflectivity. A diffused reflection that scatters light is defined as "the process by which incident flux is redirected over a range of angles," whereas a mirror-like "regular (specular) reflection" is "the process by which incident flux is redirected at the specular angle," according to the IES Handbook.

Both the highly reflective white surfaces and specular surfaces minimize light loss; however, our report is limited to specular materials, which can reduce energy usage in luminaires through the way they direct and control light. Of course no material is ideal for all applications, and often a variety of materials can meet the goals and tasks. And further, in some instances, specular material is in fact used as a sales tactic rather than as a lighting approach in order to increase light output by creating a narrow beam just below the fixture, thereby demonstrating "more light for less energy," when, in fact, the light has only been redistributed.

Mark Jongewaard, president at LTI Optics explains: "It's important to make sure light is controlled where it needs to go; when you talk about energy efficiency, like lumens per watt, that's not the whole story." L TI Optics makes the popular Phot- Opia optical design software, which produces performance evaluations for non-imaging optics.

FACILITY MANAGERS WEIGH CHOICES

In the commodity luminaire market especially, luminaire manufacturers need to "value engineer" costs out of a fixture to remain competitive. As such, a more reflective specular material is sometimes reduced in size or sacrificed to lower materials cost in fixtures that may have benefited from better performing optics.

For facility managers, the return on investment for precision optical surfaces can be confusing. A nd it is the exception a 1 facility manager who understands that spending a few dollars more on a fixture can offer hundreds of dollars in energy savings over time.

"A designer, architect or engineer writes a spec for materials or optical design that performs extremely well-one that puts fewer fixtures in the room," explains Reed Bradford, director of new product design for Cooper Lighting. "But those fixtures are pricier, so the contractor is under pressure to go back to the electrical distributor. And, the end-user suffers because the products are not as efficient, or don't perform as well as they could," says Bradford.

But without a lighting professional's specification, optical design is too often ignored in commercial retrofits. Well over 60 percent of retrofits in commercial buildings are specified by someone unaware of the role photometric distribution plays in energy-efficient lighting, according to several lighting manufacturers and facilities managers interviewed for this report.

Anyone who recommends a light fixture to a facility manager is in essence writing the specification. More often than not, a simple recommendation, such as, “Oh, this guy told me this fixture is the best, so that’s what I’m going with,” determines which fixtures are retrofitted into a facility. But the retrofit market is largely payback-driven RESEARCH REPORT and often on smaller projects the dollars are simply unavailable to employ a lighting designer to write the specification, since that cost appears to dilute the payback.

According to several luminaire manufacturers interviewed for this report, even in a number of 300,000 and 400,000-sq-fl buildings, facilities management executives made decisions without the benefit of a professional lighting specification. In multiunit retail stores, we found instances in which the retailers’ energy departments, rather than their design departments, made significant lighting decisions, leading to either inferior lighting design or sub-par energy-efficiency results, and sometimes both.

Sometimes, the facility manager assigns the task to the warehouse manager, who acts as a gatekeeper. The proper lighting solution may never reach the facilities manager, who ends up instead having to choose between the lowest cost, but subsequently least effective, optics.

The energy services company (ESCO) performance contract is an incentive to employ the most energy saving optics-which can reduce the total number of fixtures installed and minimize energy use and maintenance. But even here, ESCOs continue to push manufacturers to offer cheaper and cheaper fixtures. And some ESCOs, although certainly not most, are inadequately prepared to sell lighting on such features as watts per sq. ft. or cut-off angles.

MANUFACTURING QUESTIONS

As one would expect, when energy efficiency played a larger role in the marketing of a manufacturer’s luminaire, the use of a better optical material was a more straight forward decision.

“The cost difference between 95 per cent reflective specular and 98 percent is not that much. So if we can get slightly more efficient fixtures it’s worth it [or us,” says Apurba Pradhan, product applications manager for Luxim, a leader in the development and production of light-emitting plasma.

The challenge in designing luminaires with specular reflectors is to achieve a number of goa ls simultaneously, ranging from photometric distribution to glare control, while holding to a competitive price. To reduce costs, luminaire production is scrutinized for everything from materials to the commonality of screws. But, at times, cost reductions are at odds with the original design intentions.

Reflective optical surface material might appear to be an easier place to find cost reductions than for components such as lamps and ballasts, which cannot be simply eliminated (except, of course, when the high-performance reflector design achieves the necessary illumination to remove a lamp). Frequently a cheaper lamp and ballast combination can drive up energy use. And lamp and ballast prices are fiercely negotiated between vendor and manufacturer, so there is little room for price reductions.

One route to lowering the costs of manufacturing the luminaire is to reduce the size of the reflector by reducing the amount of material. Another is replacing a more reflective specular material with a low-cost material, Sell as one with a lower reflectivity. Yet those options give up either light control or reflectivity, and therefore energy savings.

“The more specular reflector you have wrapping around the source, the more all that light is actually under your control and you can put it where it needs to go,” explains LTI Optics’ Jongewaard.

And a less reflective material can be especially penalizing, depending on how much of the light captured by the reflector requires more than one bounce to exit the luminaire. The benefit or difference of using a more reflective material instead of a less

IT'S THE WAY IN WHICH YOU DESIGN THE FIXTURE AND FACE THE REFLECTOR TO MAXIMIZE EFFICIENCY

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reflective one increases exponentially with each bounce.

It is an understandable conundrum when a luminaire designer provides management with a $100 bill of materials to build a fixture that, in order to sell to a certain market, needs to be built for $90. However the actual cost difference between the most-and least- optimal reflectors can sometimes be as little as just a few dollars per fixture. Admittedly, for multiple or large facilities, those dollars add up. But on the other hand, so do the lost opportunities in energy savings.

SPECULAR APPLICATIONS

A high mounting height is one application where specular material has been prevalent, helping fluorescents replace HID in high bay applications. The penetration of specular material in the high bay market is at least partially due to the fact that it is well suited for a warehouse layout. The growth in retail outlets has also given rise to retail distribution centers, which tend to have tall shelving units with narrow aisles. The specular material punches a narrow beam of light to the bottom shelf and avoids waste above the top shelf.

But it's not just the optical material, explain s Jay Goodman, CEO of Westinghouse Lighting Solutions, "it's the way in which you design the fixture and face the reflector to maximize efficiency."

Specular material is one in a list of many reasons that high-intensity fluorescent (HIF) has been gaining traction in the low-/ high-bay market, says Michael Myer, lighting engineer at Pacific Northwest National Laboratory (PNNL). Better lumen maintenance, the use of controls (linear dimming, multi-level switching or occupancy sensors), higher fixture efficiency and better distributions than metal halide low-/ high-bay fixtures are other reasons, he says. Myer participates in teams at PNNL researching and commercializing lighting (solid-state and conventional) and improving buildings' energy efficiency for DOE to increase U.S. energy capacity.

Yet when an optical surface material is faceted so that it couples the light control from specularity with the minimum light loss that comes with high reflectivity, such that fewer lamps can still achieve the necessary foot candles, then the energy savings are compelling. That's because the specular reflection allows optical materials to be shaped so as to precisely control light distribution- from extremely narrow to extremely wide.

Hurdles and solutions

Owner's short-term thinking: the american economy discourages long-term energy savings and favors short-term decisions in some retrofit projects.

Lighting specifications absent: the retrofit market is payback-driven and oftentimes owners feel the cost of a professional lighting specification may dilute the payback.

New technologies require a ughting professional's involvement: with new technologies coming to market, the need for lighting specifier to get involved in facility lighting retrofits may increase.

Better metrics aid owners: accessible metrics from manufacturers can help facility managers make smarter energy decisions when a lighting designer's specification is absent.

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A specular material, though, also increases the challenges of designing luminaries. "You can aim the light in the wrong direction," says Cooper's Reed Bradford. "You've got to have the talent and the knowledge to put the light distribution of the fixture in the right place."

Also, specular material can pick up anomalies such as optical striations, can require tighter tolerances or, in the worst-case scenario, can be a glare bomb. But recent innovations in semi-specular, highly-reflective materials solves some of these concerns by offering a matte finish with enough specularity to control light without the excessive glare, while maintaining some or the control and resulting energy savings.

THE ART OF THE REFLECTOR

Specular materials with 98 percent total reflectivity undergo complex processes before the reflectors find their way into a luminaire. The surfaces are coated by running five-ton aluminum substrate coils through a vacuum line. Silicone oxide and titanium oxide are layered on top of a thin deposit of pure silver to achieve the surface reflectance. In order to maintain color neutrality and reflectivity, the layers must be exactly proportional with each other. The titanium layer also filters the silver from ultraviolet (UV) radiation to protect it from yellowing.

Since the tolerances of the surface layers are measured in nanometers, the highest quality optical surfaces are run continuously on the same vacuum line, rather than alternated to run different surfaces on the same line. A few nanometers off and the reflectivity can be reduced by several percentage points or shifted slightly in the electromagnetic spectrum to either the UV or infrared direction. Therefore, having separate vacuum lines to run each surface type is preferred, which is significant, since a single 400-ft-long line is a $25 million dollar investment.

Slitting or cutting the metal down to size also needs to be precise in order to keep the reflective surface free from contaminants. Coils are shipped with a protective film and usually slit with the film on to protect the surface. If the film is peeled off before slitting, residue, such as oil, can ruin the surface. With lighter gauge material, deviations in the machinery can imprint marks in a continuous pattern onto the aluminum. Therefore, manufacturers of high quality materials take extreme precautions to avoid damaging the surface during slitting.

More bends to a reflector usually means better optical control. Linear reflectors are typically formed in a press brake-a somewhat labor-intensive bending process. Larger runs employ a roll former, which is as much an art as a science. Segmented optics-more typically used in outdoor lighting follows the same logic, in that more segments potentially offers greater optical control.

NEW METRICS

More comprehensive, yet approachable metrics m ay help facilities managers make smarter energy decision s. "The most efficient thing to do is to get light out with-out a bounce, but that is not always the most effective," explains Jeff Quinlan, vice president of technology for Acuity Brands.

Mike Brennan, CEO of Energy Planning Associates, agrees and takes it a step further with something he calls "capture and control efficiency," which he describes as the amount of the lamp light captured and controlled by the fixture. "How much of the light that is getting out of the fixture doesn't necessarily mean anything. What's the light doing? Where's it going?" asks Brennan.

Brennan uses the example of a 5-1 n.-wide, highly reflective specular low-/h1gh-bay linear reflector compared to a to-in.-wide reflector of the same material. For this application, explains Brennan, the larger reflector captures and controls 30 percent more light.

Communicating the complexities of lighting design is a goal expressed by others, as well. Cooper's Bradford says, "Fixture efficiency doesn't tell the story. We try to provide metrics that are broader than just a single efficiency number."

The development of metrics likely follows the history of lighting design. "Today, it's about trying to make the visual environment as easy to work in as possible," says Acuity's Quin lan. "We've brought balance to the whole thing again. We have high efficiency and quality."

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LEDS AND DAYLIGHTING

New luminaire technologies may only serve to obscure the intricacies of optical surfaces for owners and facility managers. Depending on the application, LED luminaires may take advantage of optical surfaces to shield light sources, avoiding transmission loss and aging from lenses. And separating the light source from the optics may allow for alternative distribution s and interchangeable modules.

Dr. John Koshel, speaking for the Optical Society of America, sees a number of advantages to hiding LEDs behind a reflector, but three in particular are minimizing light trespass (i.e., stray light); better emission control and thus efficiency over lenses; and a "desired look and feel." Koshel is vice president of consulting/ principal illumination engineer at Photon Engineering.

Complicating LED installation s for the typical owner (although less so in retrofit projects) is that the technology .is developing. "Due to construction schedules, sometimes what is specified during the design phase is different or may not be the same product at the time of installation," explains PNNL's Myer.

In daylighting, as well, facilities managers have optical material decisions where, in solar tubes for example, multiple bounces can substantially reduce light output. In their own office building in Colorado, the National Renewable Energy Laboratory uses specular reflectors to bounce incoming daylight from the window upward to a highly reflective diffused white ceiling that scatters the light.

"At NREL we're trying to get the message out that daylighting is not automatically energy efficient. You have to follow the process through and control the electric lights," says Rob Guglielmetti, multidisciplinary engineer in NREL's Commercial Buildings Group.

Optical control is of course just one weapon in the energy-efficiency battle, but it may offer a view to a larger picture-that when commercial retrol1t projects opt for low-cost commodity fixtures over a lighting designer's expertise, they may also be choosing short-term economy over long-term energy savings.


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