NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Specifier Reports

Specular Reflectors

Retrofit specular reflectors for 2' x 4' fluorescent luminaires

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Contents

Introduction

In recent years, specular reflectors have been promoted as a potential source of energy savings for fluorescent lighting systems. A specular reflector is a luminaire component that has a highly polished surface. Although the specular reflector itself does not save energy, applications of specular reflectors that increase luminaire efficiency can save energy by reducing the number of lamps, ballasts and/or luminaires that are required. Thus, the installation of a specular reflector can be a successful energy conservation strategy.

The increased promotion and use of specular reflectors has raised some performance concerns. Specular reflectors differ from technologies such as reduced-wattage fluorescent lamps and energy-efficient fluorescent lamp ballasts because the photometric distribution of a luminaire is altered when a specular reflector is installed. Furthermore, the initial properties of the specular materials may not be representative of their properties over time because the reflectivity of the material may degrade.

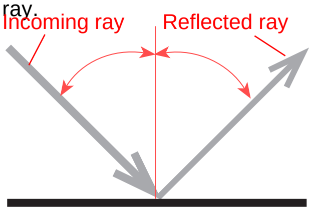
To address these and other concerns, the National Lighting Product Information Program (NLPIP) evaluated the performance of a variety of specular reflectors currently on the market. Results are presented in this issue of *Specifier Reports*. Evaluations were conducted for two-foot by four-foot (2' x 4') four-lamp fluorescent luminaires with prismatic lenses in which two lamps were removed and a specular reflector installed. This is the most common application for specular reflectors.

The production of this report involved important contributions from many people. D. Ranieri of Lithonia Lighting coordinated the acquisition and shipping of the luminaires used in the project. I. Lewin of Lighting Sciences Inc. contributed a preliminary text for this report. L. Stafford of Lighting Sciences Inc. managed the photometric testing phase of the project. C. Goodspeed, Y. Ji, and K. Sasiadek of the Lighting Research Center (LRC) project team conducted the application analyses and compiled all the data reported. Other LRC members who contributed include P. Boyce, J. Ceterski, K. Conway, R. Leslie, D. Maniccia, and M. Rea.

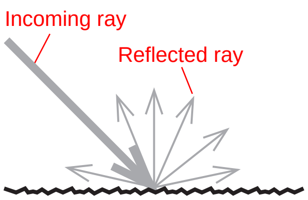
Technical reviews were provided by D. Anderson, Performance Associates; J. Barron, New York State Energy Research and Development Authority; C. Biasucci, United States Environmental Protection Agency; W. Blitzer, The Genlyte Group; D. Burbank, HEC Energy Services; B. Collins, National Institute of Standards and Technology; S. Dagher, New England Power Service Company; S. Feldman, Wisconsin Center for Demand-Side Research; R. Gunn, Northern States Power Company; R. Kwartin, United States Environmental Protection Agency; K. Laubacher, Rochester Gas and Electric Corporation; I. Lewin, Lighting Sciences Inc.; J. Lindsey, Southern California Edison Company; T. McGowan, GE Lighting; K. Nemer, Wisconsin Electric Power Company; C. Occhino, National Association of Lighting Management Companies; B. Pozesky, Bruce Environmental; D. Ranieri, Lithonia Lighting; D. Smith, D.K. Smith and Associates; and J. Stimmel, ICF Incorporated.

Specular and Diffuse

Light striking a *specular* (polished) surface is reflected in one direction, at an angle equal to that of the incoming ray.



Light striking a *diffuse* (matte) surface is reflected equally in all directions.



Illuminance

According to the Illuminating Engineering Society of North America (IESNA), *illuminance* is "the density of luminous flux incident on a surface." It is commonly expressed in units of footcandles (lumens/square feet) or lux (lumens/square meter).

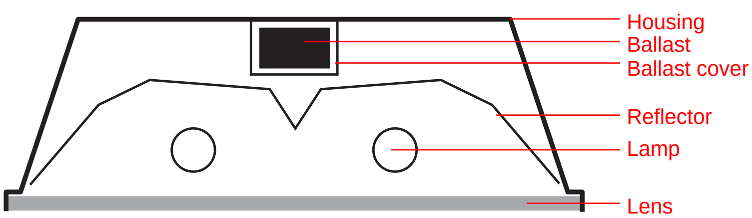
Background

Applications

Specular reflectors can be used in new fluorescent luminaires or installed in existing luminaires as a retrofit strategy. The most common retrofit application is to install a specular reflector in a 2' x 4' four-lamp fluorescent luminaire. Usually, the installer removes two of the existing lamps and disconnects the associated ballast, repositions the sockets for the remaining two lamps, and then inserts the specular reflector that has been designed to reflect and redirect the light from the lamps in a generally downward direction. Figure 1 shows the position of a specular reflector within a luminaire. The existing lamps are replaced with new lamps, and the luminaire and lens are cleaned. When these steps are taken, the connected power to the luminaire is approximately half of that prior to the retrofit, but the average illuminance may be greater than half, in some cases by a substantial margin.

Although the application described above is the most common for specular reflectors, other applications include open-strip fluorescent lamp installations and new luminaires. In both cases, the increased efficiency of the lighting system can result in energy savings because fewer luminaires are needed to deliver a given horizontal illuminance.

Figure 1. Cross Section of Luminaire



The most common fluorescent lamp used today is the T12 (1.5" diameter) lamp. T8 lamps (1" diameter) are also popular; they are often used in conjunction with specular reflectors and replace existing T12 lamps. Not only do the smaller diameter lamps typically use more efficient phosphors than the T12 types, but their smaller diameter also allows for improved optical performance.

As part of the testing for this report, two of the aluminum specular reflectors and two of the silver specular reflectors were tested separately with T12, T10 (1.25" diameter), and T8 lamps. Manufacturers of these specular reflectors indicated that the products could be used with any lamp diameter. The results showed that lamp type had very little impact on luminaire efficiency. The impact would likely be greater for specular reflectors that are designed for a reduced diameter lamp.

Materials

Many companies offer specular reflectors for fluorescent lighting systems. They all use one or more of three material types: anodized aluminum, enhanced (or coated) anodized aluminum, and silver film that is applied to a metal substrate. Fewer than ten materials companies supply these materials to the specular reflector companies which in turn design and form the specular reflectors. In some cases, the specular reflector company also bonds the silver film material to a substrate; in other cases, the film manufacturer supplies film already bonded to a substrate. Many of the specular reflector companies offer a selection of materials for their products. Performance characteristics of the materials are discussed later in this report. Table 1 (p. 10) shows the materials used and the material suppliers for the companies which participated in this report.

The long-term performance of the retrofitted luminaire is affected by its material's characteristics. Any degradation of material during its life will affect the luminaire's ongoing performance. The material can degrade when it is oxidized, exposed to ultraviolet light, or scratched. Furthermore, if the material is not properly applied to a substrate, it may bubble and delaminate. Material degradation and durability are discussed later in this report, but no testing for these factors was conducted.

Specular Reflector Design

The effectiveness of a specular reflector depends significantly upon its shape. The goal in designing an efficient specular reflector is to create a shape and surface that reflects light directly out of the luminaire, without creating multiple reflections and without directing light back onto the lamp. A simple type of specular reflector, in which the specular material is applied directly to the inside of the luminaire housing, may not reflect light in the directions that are most favorable for high luminaire efficiency.

The ideal and most efficient specular reflector would have a curved profile, which is difficult to manufacture accurately. Instead, most specular reflectors are formed in a series of flats and bends so that their performance approaches that of a curved specular reflector.

Specular reflector efficiency increases as the number of flats increases and the size of each flat decreases because the reflec-tor's profile more closely approximates the ideal curve. Manufacturing costs increase as the number of bends increases, leading some manufacturers to offer different grades of products, some with few flats and bends and others with more.

Questionable Performance Claims

Questionable claims have been made about retrofit specular reflector performance. These claims usually relate to the before-and-after performance of the lighting system. Specular reflector retrofits commonly are combined with other strategies that also increase system efficiency; these strategies include delamping, cleaning, and installing new lamps. Thus, the total efficiency of the system is improved not simply by the specular reflectors, but by the combination of strategies.

Claims that "half the lamps can be removed with no effect on light levels" usually contrast an old, depreciated system with a new system. Although the initial performance of the new system may compare favorably with the performance of the old system, the new system will depreciate over time as the lamps age and the luminaire surfaces degrade. Sales claims that fail to explain these effects have made some users skeptical of the benefits of installing specular reflectors.

Depreciation Factors

The IESNA identifies three factors that account for losses in light output over time from a lighting system. Maintenance can minimize these losses in light output.

Luminaire dirt depreciation (LDD) accounts for losses due to dirt accumulating on the surfaces of the luminaire and the lamps. LDD depends upon the type of luminaire, the luminaire's environment, and the frequency of cleaning. LDD is measured as a percentage, with 100 percent representing the light output of a new luminaire. For recessed and enclosed luminaires, typical LDD values range from 70 percent to 90 percent, meaning that from 10 percent to 30 percent of the luminaire's initial light output is lost over time.

Lamp lumen depreciation (LLD) accounts for the loss in light output from lamps as they age. LLD is measured as a percentage, with 100 percent representing the light output of a new lamp. For fluorescent lamps, typical LLD values range from 80 percent to 90 percent, meaning that from 10 percent to 20 percent of the lamp's initial light output is lost over time.

Luminaire surface depreciation accounts for light output losses that occur when the surfaces of the luminaire components degrade. For example, after many years of use, the white paint on luminaires may crack and peel. IESNA does not provide a method for estimating this factor.

Losses due to both LDD and LLD can be recovered when a specular reflector is installed, especially if the luminaire is cleaned and new lamps are installed. These gains, however, are temporary because the system will begin to degrade again. For losses due to luminaire surface depreciation, the recovery in light output may be more substantial, since the depreciated reflective surface of the luminaire is covered by the new specular reflector. The magnitude of this gain depends on the condition of the original luminaire and the long-term performance of the new specular reflector.

The table below summarizes one manufacturer's measures of some of these incremental effects.

Incremental Effects of Retrofit Changes

Condition	Luminaire Efficiency (%)
A. 4-lamp, uncleaned, high-loss ballast	54.8
B. Same as A with low-loss ballast	58.4
C. Same as B but cleaned	66.7
D. Same as C but with 2 inboard lamps only	73.4
E. Same as D but with 2 relocated lamps and reflector	85.4

Data in this table are reported in a Lithonia Lighting application update. Similar results were reported by McGowan and Whitmore in 1988 and Lindsey in 1989.

A specular reflector often concentrates the light directly beneath the luminaire, directing less light to other angles. Common anecdotes report that some specular reflector installers only measure the illuminance directly beneath the luminaire. This practice ignores potentially significant decreases in illuminance between luminaires, and it is a misleading measure of system performance.

An understanding of loss factors and measurement practices should alert specifiers and users to exercise caution when evaluating performance claims, but it should not lead to an immediate rejection of the technology. Many companies involved in the specular reflector business speak out against such measurement practices and try to ensure that their own sales staff and installers do not conduct misleading evaluations.

Performance Evaluations

Method of Testing

Specular reflectors are usually custom-designed, so it was not feasible for NLPIP to acquire specular reflectors on the open market for this project. Instead, NLPIP sent specular reflector companies a brief project statement and asked them to respond if they were interested in participating. Those who responded were provided with detailed instructions for the project. Each participating company indicated whether they wanted to submit one or two specular reflectors for testing, based on the lighting layouts shown in Figures 2 and 3. One or two Lithonia luminaires (catalog number 2SPG 440 A12) were then sent to each company. This luminaire model is a typical 2' x 4' recessed fluorescent luminaire, approximately 4.5 inches deep, and uses a pattern-12 acrylic prismatic lens. NLPIP charged participants a $100 fee per luminaire to cover purchase, shipping, and handling costs. Participants were instructed to install their product(s) in the luminaire(s) and ship the modified luminaire(s) to Lighting Sciences Inc. for photometric testing. NLPIP paid all testing costs.

The photometric testing was conducted according to standard industry procedures. The same lamps (F40/CW), ballasts (low-loss magnetic), and lens (pattern-12 acrylic) were used in each test to remove any potential variability due to these sources. Three test conditions are referred to in the analyses as the base case conditions; the base cases establish reference conditions for later analyses. For Base Case 1 a new luminaire was tested without a specular reflector and with all four lamps installed. For Base Case 2 the luminaire was tested with only the two inner (inboard) lamps installed. For Base Case 3 the luminaire was tested with only the two outer (outboard) lamps installed.

The photometric data were used to perform application analyses for the lighting layouts shown in Figure 3. The two lighting layouts demonstrate a wide range of possible conditions that are important for specular reflector installations. Lighting Layout A has a relatively high (but not unusual for older installations) average maintained horizontal illuminance with the four-lamp luminaire and staggered spacing for good uniformity of illuminance. For Lighting Layout B, the average maintained horizontal illuminance is closer to the values currently recommended by IESNA. In Lighting Layout B the luminaire spacing approaches the maximum recommendation using the spacing criterion (see sidebar on p. 6). NLPIP asked participating companies to indicate if they had specifically designed the specular reflector for one or the other of these lighting layouts, or if the same specular reflector could be used in both lighting layouts. Analyses of average illuminance, illuminance uniformity, and vertical illuminance were performed using Lumen-Micro™ software.

The following sections describe the performance characteristics of specular reflectors and summarize the results of

NLPIP surveys and testing. Three areas are discussed: photometric testing, application analyses, and other issues such as maintenance, long-term performance, and snapback.

Photometric Testing

Power usage. When four fluorescent lamps and two ballasts are operated in an enclosed recessed luminaire, the minimum lamp bulb wall temperature often rises to between 40°C (104°F) and 50°C (122°F), which lowers power consumption and reduces light output. This effect is shown in Figure 4 (p. 6).

When two lamps are removed from a four-lamp luminaire and the associated ballast is disconnected, the wattage is reduced by slightly less than 50 percent, because the temperature in the luminaire decreases. The light output decreases by slightly less than 50 percent. For the luminaires tested in this project, the measured input power was 162 watts for the four-lamp luminaire, and 84.5 watts on average for the delamped luminaires containing a specular reflector. The measured input power of a delamped luminaire with no specular reflector was the same as a luminaire with a specular reflector.

Material reflectance. Materials and reflectance data for specular reflectors that were tested are given in Table 1 (p. 10). Reflectance measurements were conducted according to standard industry procedures. The base case luminaire was a new unit with highly reflective white paint (87.6 percent), which had a primarily diffuse reflectance. In contrast, the specular reflector units have little diffuse reflectance but high specular reflectance. These data represent the materials' performance when new; no data were collected to assess the effects of degradation over time. These effects are discussed in the "Long-term performance" section.

The reflectance of the white paint used in fluorescent luminaires has been improved during the last ten years, so that the reflectances reported here are probably higher than those that would

Figure 2. Perspective View of Lighting Layout A

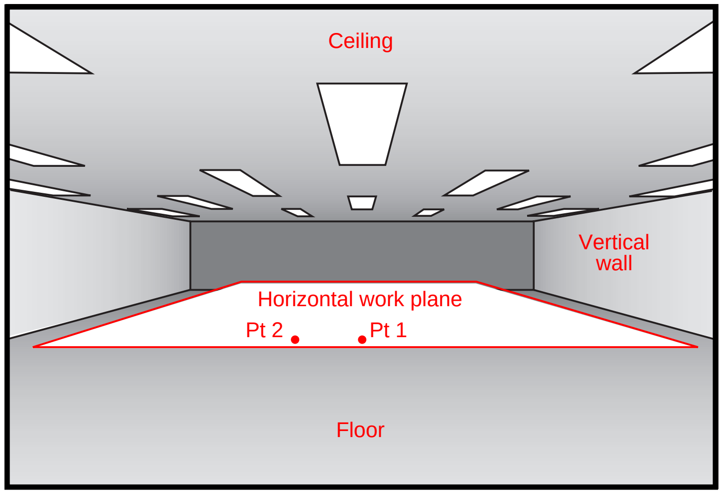
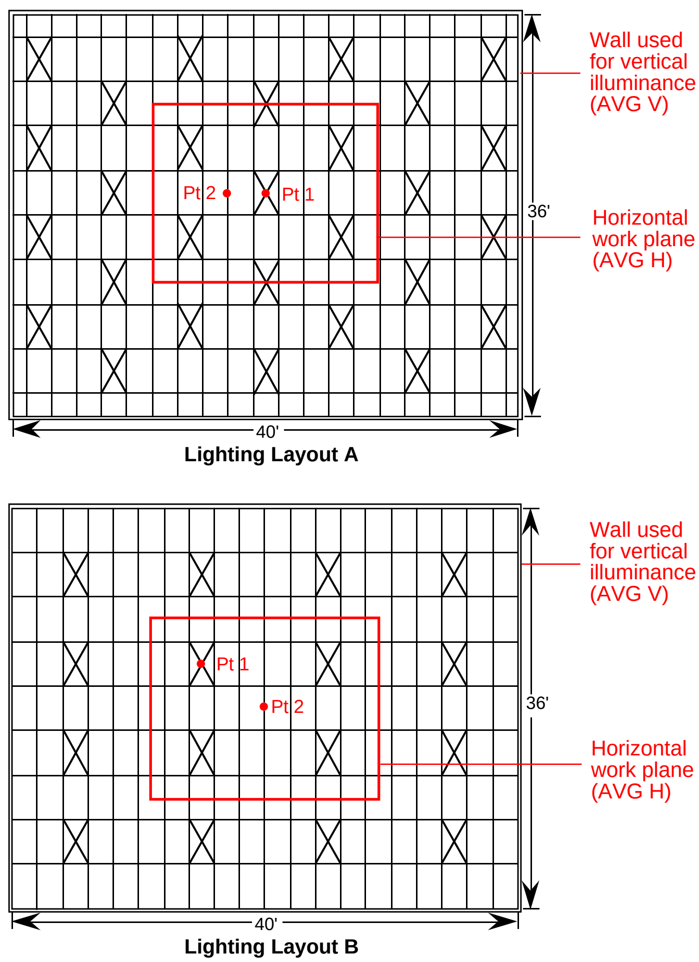


Figure 3. Plan View of Lighting Layouts for Computer Benchmark Analysis



Spacing Criterion

The spacing criterion (SC) is used to estimate the limit of acceptable luminaire spacing where uniform illuminance on a horizontal plane is desired. Multiplying the SC by the luminaire mounting height (the distance between the horizontal work plane and the luminaire) establishes the maximum distance at which luminaires should be spaced (center-to-center) to assure uniform illuminance. If the actual spacing between the luminaires exceeds this maximum, the lighting installation results in nonuniform illuminance patterns.

be found in field installations of older luminaires. Reflectance values of 80 percent to 85 percent are more typical for these older luminaires.

Luminaire efficiency. Although reflectance data can be used to compare the materials from which specular reflectors are made, a more important criterion for lighting system evaluations is luminaire efficiency. Luminaire efficiency is defined by the IESNA as "the ratio of the luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein."

Specular reflectors usually increase the efficiency of a fluorescent luminaire because the reflectance of the specular material is higher than that of the painted interior surface of the luminaire. In addition, the specular reflector is usually designed to direct more light out of the luminaire.

Factors other than higher reflectance and optical design can cause the total light output measured for a luminaire with a specular reflector to increase. For instance, the removal of two lamps increases luminaire efficiency due to thermal effects and the optical advantages of having fewer lamps present to block reflected light within the luminaire. Also, the common retrofit practice of replacing all old lamps with new lamps increases light output because it offsets the lamp lumen depreciation losses. Finally, cleaning the luminaire surfaces increases light output because it offsets luminaire dirt depreciation losses. See the "Depreciation Factors" sidebar (p. 3) for one manufacturer's measures of these incremental effects.

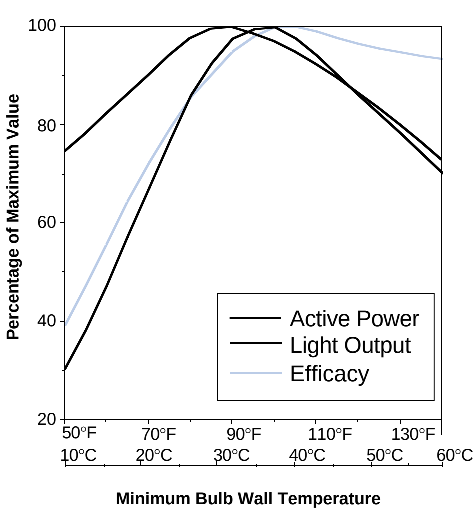
Table 2 (p. 11) presents the luminaire efficiency data measured for the products submitted for this report. The base cases show that removal of two lamps increases efficiency from 65.5 percent to over 70 percent, largely due to thermal effects. Efficiency values for the specular reflector products range from 73.2 percent to 84.8 percent, compared with 65.5 percent for the four-lamp luminaire.

Distribution of light. In addition to increasing luminaire efficiency, a specular reflector retrofit often changes the distribution of light by redirecting light that would normally exit the luminaire at high angles (close to horizontal) to a more concentrated, downward direction. The spacing criterion (SC) found in standard photometric reports can be used to assess the effect of a specular reflector on the distribution characteristics of a luminaire.

By concentrating light downward, specular reflectors typically decrease the SC. For example, Table 2 shows that the SC for Base Case 1 (four-lamp) is 1.3; the SC for specular reflectors range from 0.7 to 1.4. Only four of the 27 specular reflectors tested equal or exceed the SC for Base Case 1. In some cases, the specular reflector companies optimized the optical design for the lighting layouts used in the application analyses. A lower SC value indicates a narrower distribution pattern, which could result in nonuniform illuminances if the luminaire spacing is too great. The impact on illuminance uniformity is discussed in the "Application Analyses" section.

Table 2 also reports the light intensity (candlepower) at zero degrees (straight down). This column is included in the table to illustrate that the specular

Figure 4. Effect of Temperature on Performance Characteristics



As the temperature of a fluorescent bulb increases, both the light output (red curve) and the active power consumption (black curve) also increase. However, as the temperature rises above 32°C, the power consumption gradually begins to decrease. The light output continues to increase until the temperature reaches approximately 38°C, at which point it begins to drop dramatically. The system efficacy (pink curve), defined as light output divided by active power, is therefore maximized at approximately 40°C. (Adapted from the *IES Lighting Handbook: Reference Volume.*)

reflector manufacturer must often accept a reduced zero-degree light intensity in order to achieve a more uniform light distribution. Thus, the specular reflectors that achieve a high candlepower value at zero degrees tend to have a narrower light distribution, indicated by a lower SC value.

Discomfort glare. The concentration of light normally associated with a specular reflector retrofit may reduce discomfort glare, because light from high angles contributes to discomfort glare. For luminaires with prismatic lenses, the most common type used in specular reflector retrofits, the visual comfort probability (VCP) tables on a photometric report provide the conventional assessment of discomfort glare.

Some forms of retrofit specular reflector designs reduce glare, as indicated in Table 2 by their higher VCP values. Delamping usually improves VCP, simply because the amount of light emitted by the fixture is reduced. VCP increases substantially for the specular reflector luminaires relative to Base Case 1, but the increase in VCP relative to Base Cases 2 and 3 is much less.

Application Analyses

Photometric testing provides important performance information for specular reflectors, but a complete evaluation should include an assessment of the product in an application. When considering a specular reflector retrofit for a specific lighting installation, an analysis similar to that described below should be conducted. Three criteria are used to evaluate the application: average illuminance, uniformity of illuminance, and vertical illuminance on a wall surface.

Average illuminance. As shown in Tables 3A and 3B (pp. 12–13), the calculated average initial illuminance decreased substantially for all the specular reflector products tested relative to Base Case 1. For a field installation where depreciation has occurred, the reduction in horizontal illuminance will be less. The increased efficiency provided by the specular reflectors is demonstrated by the increased illuminances relative to Base Cases 2 and 3.

Illuminance uniformity. Light distribution can be evaluated by comparing the calculated or measured illuminance at selected points in the rooms. For these analyses, two points were selected: Point 1 (PT 1) is located directly beneath a luminaire; Point 2 (PT 2) is located between luminaires. Figure 3 (p. 5) shows the locations of these points for each of the two lighting layouts; Tables 3A and 3B show the calculated illuminances at these points. The ratio of Point 1 to Point 2 (PT 1/PT 2) expresses the uniformity of illuminance. For Lighting Layout A, the PT 1/PT 2 ratio increases slightly for some of the specular reflectors compared with the base cases. A few of the specular reflectors have a PT 1/PT 2 ratio less than 1.0, meaning that the illuminance at PT 2 is greater than that at PT 1. Table 3B shows that uniformity is a greater concern for Lighting Layout B, because the PT 1/PT 2 ratios increase for the specular reflectors to a greater extent than they do in Lighting Layout A.

Vertical illuminance. In addition to the level and uniformity of horizontal illuminance, the effect of the installation of specular reflectors on vertical illumi nances is also a concern. By focusing light downward more than the four-lamp luminaire does, luminaires with specular reflectors create the potential for dark walls, which may in turn influence occupants' perceptions of the room. Furthermore, vertical illuminance on objects in the space is important in some applications, particularly merchandising.

Tables 3A and 3B show the average vertical illuminance (AVG V) on a wall for Lighting Layouts A and B. For both lighting layouts, the average vertical illuminance decreased 40 to 50 percent for the delamped luminaires and the specular reflectors relative to Base Case 1.

Other Performance Issues

Maintenance. According to IESNA luminaire dirt depreciation data, dirt build-up can reduce light output by as much as 30 percent for a fluorescent

Visual Comfort Probability

According to the IESNA, *visual comfort probability* (VCP) is "the rating of a lighting system expressed as a percentage of people who, when viewing from a specified location and in a specified direction, will be expected to find it acceptable in terms of discomfort glare." Discomfort glare is a sensation of discomfort or unease that can be caused by an excessively bright light. Different styles of luminaires create different levels of discomfort glare; some shield the emitted light from the eyes with louvers or other control media whereas others diffuse the light and are usually very bright at normal viewing angles. For general office spaces, a minimum VCP of 70 is recommended by IESNA; the minimum recommended VCP increases to 80 for areas where video display terminals (VDTs) are used.

Uniformity Ratios

Although no standards for illuminance uniformity exist in North America, a number of sources suggest that a maximum-to-minimum illuminance ratio no greater than 1.3 to 1.4 is acceptable. For example, Odle and Smith reported a maximum acceptable ratio of 1.3. An interior lighting code in Great Britain requires a minimum-to-maximum illuminance ratio of at least 0.7; this converts into a maximum-to-minimum ratio not to exceed 1.43. This British code is typical of other European standards.

As shown by the PT 1/PT 2 ratio in Tables 3A and 3B, all of the specular reflector products that NLPIP tested satisfy these limits on illuminance uniformity for Lighting Layout A; however, few do so for Lighting Layout B.

luminaire. Maintenance is particularly important for lighting systems where delamping is performed and the illuminance is reduced from the original building design level. Overall fixture performance will be reduced if the specular reflector material deteriorates due to improper cleaning, for example by scratching due to abrasion. Manufacturer recommendations for cleaning should be followed to avoid damaging the reflective surface.

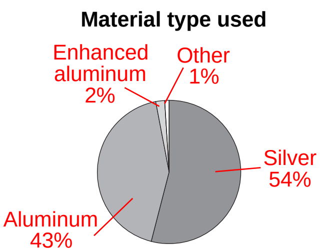
Access to the ballast chamber in the luminaire is also a maintenance issue with specular reflectors. Because the specular reflector covers the ballast chamber cover, the labor involved in reaching the ballast increases. The method and ease of removal of the specular reflector should be assessed in the evaluation process. Alternatively, some specular reflectors are made with a heavier gauge metal so that they may satisfy building codes for a ballast chamber cover, negating the need for retaining the existing cover. In this case, the user pays a higher first cost for the heavier specular reflector in anticipation of reduced maintenance costs in accessing the ballasts.

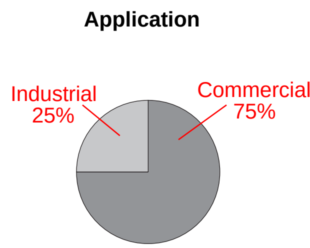
Long-term performance. In addition to maintenance effects, deterioration of specular reflector materials reduces long-term performance. Humidity, chemical action, exposure to ultraviolet radiation, and temperature cycling can affect these materials. Although a number of accelerated materials testing procedures exist, the correlation between the accelerated tests and actual hours of use is unknown. Furthermore, many of these tests were developed to test materials that are used in outdoor environments. These tests may not be appropriate for materials used in indoor commercial lighting systems. No long-term performance testing was conducted by NLPIP for this report.

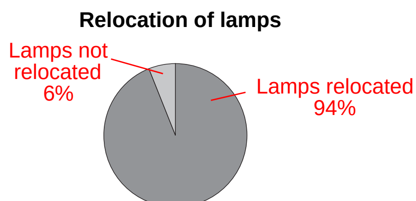
Snapback potential. When a utility company offers an incentive for a power-saving device, the user could install the device and collect a rebate but then remove the device and return the lighting system to its previous condition. Reverting to an older, less efficient technology is referred to as snapback. If users find the resultant illuminance, uniformity, or vertical illuminances on the walls unacceptable, then specular reflector installations may be subject to snapback. However, the work involved in reverting to the old system can be substantial because it involves removal of the specular reflectors, rewiring of ballasts, and possibly repositioning of lamp sockets.

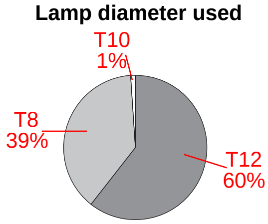
Recent Market Information

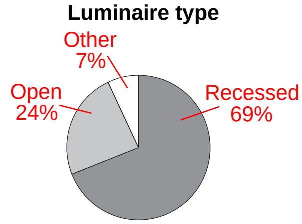
In addition to providing specular reflector products for testing, the participating companies were asked to complete a brief questionnaire. This questionnaire documented the material type and the material supplier that the participant used and requested summary market information for specular reflectors that were sold in 1991. These data, presented below, have not been validated by NLPIP.











Alternative Approaches

Delamping and Cleaning

Removal of half of the lamps in a luminaire will provide the same energy savings as does a specular reflector retrofit that includes similar delamping. By installing new lamps and cleaning the fixture and the lens, the resultant average illuminance may be considerably greater than half that of the original. Furthermore, relocating the sockets for the remaining lamps can minimize the effect of delamping on the brightness uniformity of the luminaire's lens. When evaluating the usefulness of a retrofit specular reflector, therefore, its performance should be compared not only with that of the original lighting system, but also with that of the lighting system if it were delamped, relamped, and cleaned. The latter is a lower cost option that can be considered as an alternative approach. Base Case 2 and Base Case 3 compare the performance of delamping alone to delamping and adding a specular reflector.

Power Reducers

Various devices can be placed within fluorescent lamp luminaires to limit the current drawn by the lamps, thus reducing power. Power reducers that provide from 20 to 50 percent reduction in power are available. Illuminances are usually reduced, though to a slightly lesser degree than the power reductions. The photometric distribution of the luminaire is not affected by installing a power reducer. NLPIP *Specifier Reports: Power Reducers* contains more details on these products.

Reduced Wattage Lamps and Ballasts

Many combinations of lamps and ballasts that operate as energy-saving devices are available. For example, 34-watt fluorescent lamps can be substituted for standard 40-watt lamps. Ballasts that have lower power losses than standard equipment also are available. In fact, low-loss ballasts are now required by federal law. Substitution with such equipment provides energy savings with a small loss of light output. For any installation, performance data for the specific lamp/ballast combination should be reviewed to ensure the compatibility of these components.

Triphosphor Lamps and Electronic Ballasts

Recent and ongoing developments in lamp and ballast technology offer power reduction without sacrificing illuminance or lighting quality. For instance, the use of newer triphosphor lamps can provide higher lumens per watt, resulting in a higher illuminance for equivalent power or equivalent illuminance for lower power, relative to systems that use traditional halophosphor lamps. These newer phosphors also provide improved color rendering. Reduced diameter T8 lamps that utilize triphosphors offer the further advantage of increased luminaire efficiency due to thermal and optical efficiency improvements relative to T12 lamp diameters.

The use of electronic ballasts in place of magnetic core-and-coil ballasts also can provide power reductions. Circuit power losses are reduced, and fluorescent lamps operate more efficiently at the high operating frequency of these ballasts. NLPIP *Specifier Reports: Electronic Ballasts* provides more information on these products.

New Luminaires

Removing existing luminaires and replacing them with new, more efficient luminaires is often an acceptable alternative to installing specular reflectors. This option should be considered for computer-intensive office applications, because the prismatic lens used in most specular reflector retrofits does not meet current IES RP-24 recommendations for these spaces. To meet the requirements for glare control, it may be necessary to install new luminaires. New luminaires often incorporate a specular reflective material of the type described in Table 1 (p. 10).

Table 1. Materials and Reflectance Data

Designation[a]	Manufacturer	Material Supplier[b]	Price ($)[b,c]	Reflectance (%)[d]		
				Total	Specular	Diffuse
Base Case 1	Lithonia w/ 4 lamps	—	—	87.6	2.9	84.7
Base Case 2	Lithonia w/ 2 inboard	—	—	87.6	2.9	84.7
Base Case 3	Lithonia w/ 2 outboard	—	—	87.6	2.9	84.7
			Average	**87.6**	**2.9**	**84.7**
Aluminum 1	Brayer Lighting, Inc.	Alanod	46–55	85.0	83.2	1.8
Aluminum 2	Harris Manufacturing, Inc.	ALCOA	26–35	83.8	76.5	7.3
Aluminum 3	Mirrorlight, Inc.	Metaloxyd	46–55	86.6	85.1	1.5
Aluminum 4	ML Systems	ALCOA	36–45	84.5	82.2	2.3
Aluminum 5	Parrish Lighting and Engineering, Inc.	ALCOA	26–35	85.3	79.6	5.7
Aluminum 6	Tamarack Corp.	ALCOA	26–35	83.6	77.7	5.9
Aluminum 7	Ulster Precision, Inc.	ALCOA	26–35	83.7	76.3	7.4
Aluminum 8	Western Lighting Industries, Inc.	ALCOA	16–25[e]	84.5	78.3	6.2
Aluminum 9	Wismarq Lighting Company, Inc.	ALCOA	36–45	84.5	80.0	4.5
			Average	**84.6**	**79.8**	**4.7**
Enhanced Alum. 1	Light Energy Corp.	OCLI	36–45	95.2	92.4	2.8
Enhanced Alum. 2	ML Systems	ALCOA	46–55	94.3	92.6	1.7
Enhanced Alum. 3	Wismarq Lighting Company, Inc.	ALCOA	>56	94.6	90.0	4.6
			Average	**94.7**	**91.6**	**3.0**
Silver 1	Badger USA, Inc.	Metro-Metals	36–45	96.2	94.1	2.1
Silver 2	Badger USA, Inc.	Metro-Metals	36–45	95.6	94.3	1.3
Silver 3	Brayer Lighting, Inc.	Courtaulds	46–55	95.6	94.6	1.0
Silver 4	Dynamic Energy Products, Inc.	3M	36–45	96.2	93.6	2.6
Silver 5	Energy Dezign Corp.	Courtaulds	36–45	96.0	94.0	2.0
Silver 6	Metal Optics, Inc.	Pre-finish Metals	26–35	95.6	93.2	2.4
Silver 7	Metal Optics, Inc.	Pre-finish Metals	26–35	95.6	93.8	1.8
Silver 8	Parke Industries, Inc.	Pre-finish Metals	46–55	94.2	93.0	1.2
Silver 9	Parke Industries, Inc.	Pre-finish Metals	46–55	94.2	92.9	1.3
Silver 10	Parrish Lighting and Engineering, Inc.	Pre-finish Metals	26–35	94.7	92.2	2.5
Silver 11	Reflective Light Technologies	Metro-Metals	36–45	96.4	95.0	1.4
Silver 12	Reflective Light Technologies	Metro-Metals	36–45	95.5	92.1	3.4
Silver 13	Roth Brothers, Inc.	3M	36–45	96.7	93.2	3.5
Silver 14	SilverLight Corp.	Courtaulds	36–45	95.8	95.3	0.5
Silver 15	Wismarq Lighting Company, Inc.	Pre-finish Metals	46–55	95.9	95.3	0.6
			Average	**95.6**	**93.7**	**1.8**

[a]Designation identifies each product in subsequent tables.

[b]Information supplied by manufacturer.

[c]Approximate price for an installed unit in an application similar to Lighting Layout A as shown in Figure 3 (p. 5).

[d]Measured data.

[e]Material price only; installed price not reported.

Table 2. Photometry

Designation	Manufacturer	Efficiency (%)	0°CP (candelas)	SC	VCP 1[a] (%)	VCP 2[a] (%)
Base Case 1	Lithonia w/ 4 lamps	65.5	3210	1.3	57	49
Base Case 2	Lithonia w/ 2 inboard	70.9	1672	1.4	69	63
Base Case 3	Lithonia w/ 2 outboard	72.1	1774	1.3	70	64
	Average of Base Cases 2 and 3	**71.5**	**1723**	**1.3**	**70**	**64**
Aluminum 1	Brayer Lighting, Inc.	74.8	2318	1.0	73	66
Aluminum 2	Harris Manufacturing, Inc.	73.2	2509	0.9	75	68
Aluminum 3	Mirrorlight, Inc.	76.0	2736	0.8	75	67
Aluminum 4	ML Systems	74.7	2463	1.0	76	68
Aluminum 5	Parrish Lighting and Engineering, Inc.	74.4	2113	1.2	75	67
Aluminum 6	Tamarack Corp.	75.1	2525	0.9	74	67
Aluminum 7	Ulster Precision, Inc.	74.9	2580	0.9	75	67
Aluminum 8	Western Lighting Industries, Inc.	73.5	2749	0.8	77	69
Aluminum 9	Wismarq Lighting Company, Inc.	74.3	2628	0.8	74	66
	Average	**74.5**	**2513**	**0.9**	**75**	**67**
Enhanced Aluminum 1	Light Energy Corp.	80.9	1986	1.4	71	64
Enhanced Aluminum 2	ML Systems	82.7	2792	1.0	73	65
Enhanced Aluminum 3	Wismarq Lighting Company, Inc.	81.4	2899	0.8	73	65
	Average	**81.6**	**2559**	**1.0**	**72**	**65**
Silver 1	Badger USA, Inc.	84.8	3594	0.7	74	66
Silver 2	Badger USA, Inc.	83.6	3143	0.8	75	66
Silver 3	Brayer Lighting, Inc.	82.7	2557	1.0	72	64
Silver 4	Dynamic Energy Products, Inc.	83.4	3424	0.7	76	67
Silver 5	Energy Dezign Corp.	83.3	2956	0.9	75	66
Silver 6	Metal Optics, Inc.	82.0	2202	1.3	71	63
Silver 7	Metal Optics, Inc.	81.4	2010	1.4	70	63
Silver 8	Parke Industries, Inc.	81.0	2261	1.1	69	62
Silver 9	Parke Industries, Inc.	81.5	2607	1.0	71	64
Silver 10	Parrish Lighting and Engineering, Inc.	83.0	2406	1.2	73	65
Silver 11	Reflective Light Technologies	82.9	1999	1.4	68	62
Silver 12	Reflective Light Technologies	83.1	2267	1.2	70	63
Silver 13	Roth Brothers, Inc.	81.9	2762	0.9	73	65
Silver 14	SilverLight Corp.	83.3	3029	0.9	75	66
Silver 15	Wismarq Lighting Company, Inc.	83.5	2981	0.8	72	64
	Average	**82.8**	**2680**	**1.0**	**72**	**64**

[a]VCP 1 gives the VCP for a 20'x20' room with a 8.5' ceiling when the luminaires are viewed perpendicular to the axes of the lamps. VCP 2 gives the VCP for a 40'x40' room with a 10' ceiling when the luminaires are viewed perpendicular to the axes of the lamps. Both values are based on standard IESNA procedures, which assume a uniform illuminance of 100 footcandles and a viewer seated four feet from a wall and facing into the room.

Table 3A. Application Analysis for Layout A[a]

Designation	Manufacturer	AVG H[b] (fc)	PT 1[c] (fc)	PT 2[c] (fc)	PT 1/PT 2[d]	AVG V[e] (fc)
Base Case 1	Lithonia w/ 4 lamps	183	189	186	1.02	75
Base Case 2	Lithonia w/ 2 inboard	99	103	100	1.03	41
Base Case 3	Lithonia w/ 2 outboard	101	104	102	1.02	41
	Average of Base Cases 2 and 3	**100**	**104**	**101**	**1.02**	**41**
Aluminum 1	Brayer Lighting, Inc.	104	113	102	1.11	41
Aluminum 2	Harris Manufacturing, Inc.	102	113	98	1.15	39
Aluminum 3	Mirrorlight, Inc.	106	119	101	1.18	40
Aluminum 4	ML Systems	104	114	102	1.12	40
Aluminum 5	Parrish Lighting and Engineering, Inc.	104	108	106	1.02	40
Aluminum 6	Tamarack Corp.	105	115	101	1.14	40
Aluminum 7	Ulster Precision, Inc.	104	116	100	1.16	40
Aluminum 8	Western Lighting Industries, Inc.	102	116	97	1.20	38
Aluminum 9	Wismarq Lighting Company, Inc.	103	117	98	1.19	40
	Average	**104**	**115**	**101**	**1.14**	**40**
Enhanced Alum. 1	Lighting Energy Corp.	114	114	118	0.97	45
Enhanced Alum. 2	ML Systems	115	127	112	1.13	44
Enhanced Alum. 3	Wismarq Lighting Company, Inc.	113	128	108	1.19	43
	Average	**114**	**123**	**113**	**1.10**	**44**
Silver 1	Badger USA, Inc.	117	140	106	1.32	43
Silver 3	Brayer Lighting, Inc.	115	125	114	1.10	45
Silver 4	Dynamic Energy Products, Inc.	116	135	107	1.26	42
Silver 5	Energy Dezign Corp.	116	129	112	1.15	43
Silver 6	Metal Optics, Inc.	115	119	117	1.02	45
Silver 8	Parke Industries, Inc.	113	120	112	1.07	46
Silver 10	Parrish Lighting and Engineering, Inc.	116	121	118	1.03	45
Silver 11	Reflective Light Technologies	116	118	119	0.99	47
Silver 13	Roth Brothers, Inc.	114	126	111	1.14	43
Silver 14	SilverLight Corp.	116	130	111	1.17	43
Silver 15	Wismarq Lighting Company, Inc.	116	131	110	1.19	44
	Average	**115**	**127**	**112**	**1.13**	**44**

[a]Manufacturers indicated whether a specular reflector was specifically designed for Lighting Layout A or B or if the same specular reflector could be used in both lighting layouts.

[b]AVG H is the calculated average initial horizontal illuminance on a work plane 2.5 feet above the floor for a central part of the room as shown in Figure 3 (p. 5).

[c]PT 1 and PT 2 are the calculated initial horizontal illuminances on a work plane 2.5 feet above the floor at specific points shown in Figure 3.

[d]PT 1/PT 2 gives the ratio between the illuminances at these points.

[e]AVG V is the calculated average initial vertical illuminance for the entire wall as indicated in Figure 3.

Table 3B. Application Analysis for Layout B[a]

Designation	Manufacturer	AVG H[b] (fc)	PT 1[c] (fc)	PT 2[c] (fc)	PT 1/PT 2[d]	AVG V[e] (fc)
Base Case 1	Lithonia w/ 4 lamps	110	124	99	1.25	39
Base Case 2	Lithonia w/ 2 inboard	59	66	55	1.20	22
Base Case 3	Lithonia w/ 2 outboard	60	69	54	1.28	21
	Average of Base Cases 2 and 3	**60**	**68**	**55**	**1.24**	**22**
Aluminum 1	Brayer Lighting, Inc.	63	80	51	1.57	21
Aluminum 2	Harris Manufacturing, Inc.	62	82	47	1.74	19
Aluminum 3	Mirrorlight, Inc.	64	87	50	1.74	20
Aluminum 4	ML Systems	63	81	50	1.62	20
Aluminum 6	Tamarack Corp.	63	83	50	1.66	20
Aluminum 7	Ulster Precision, Inc.	63	83	50	1.66	20
Aluminum 8	Western Lighting Industries, Inc.	62	86	47	1.83	19
Aluminum 9	Wismarq Lighting Company, Inc.	63	84	49	1.71	20
	Average	**63**	**83**	**49**	**1.69**	**20**
Enhanced Alum. 1	Light Energy Corp.	68	75	60	1.25	23
Enhanced Alum. 2	ML Systems	70	91	55	1.65	22
Enhanced Alum. 3	Wismarq Lighting Company, Inc.	69	93	53	1.75	22
	Average	**69**	**86**	**56**	**1.55**	**22**
Silver 2	Badger USA, Inc.	71	99	52	1.90	21
Silver 3	Brayer Lighting, Inc.	70	88	56	1.57	23
Silver 4	Dynamic Energy Products, Inc.	70	103	49	2.10	21
Silver 5	Energy Dezign Corp.	70	96	52	1.85	21
Silver 7	Metal Optics, Inc.	68	76	61	1.25	23
Silver 9	Parke Industries, Inc.	68	88	56	1.57	23
Silver 12	Reflective Light Technologies	70	82	60	1.37	24
Silver 13	Roth Brothers, Inc.	69	90	55	1.64	22
Silver 14	SilverLight Corp.	70	96	52	1.85	21
Silver 15	Wismarq Lighting Company, Inc.	70	95	55	1.73	22
	Average	**70**	**91**	**55**	**1.68**	**22**

[a]Manufacturers indicated whether a specular reflector was specifically designed for Lighting Layout A or B or if the same specular reflector could be used in both lighting layouts.

[b]AVG H is the calculated average initial horizontal illuminance on a work plane 2.5 feet above the floor for a central part of the room as shown in Figure 3 (p. 5).

[c]PT 1 and PT 2 are the calculated initial horizontal illuminances on a work plane 2.5 feet above the floor at specific points shown in Figure 3.

[d]PT 1/PT 2 gives the ratio between the illuminances at these points.

[e]AVG V is the calculated average initial vertical illuminance for the entire wall as indicated in Figure 3.

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