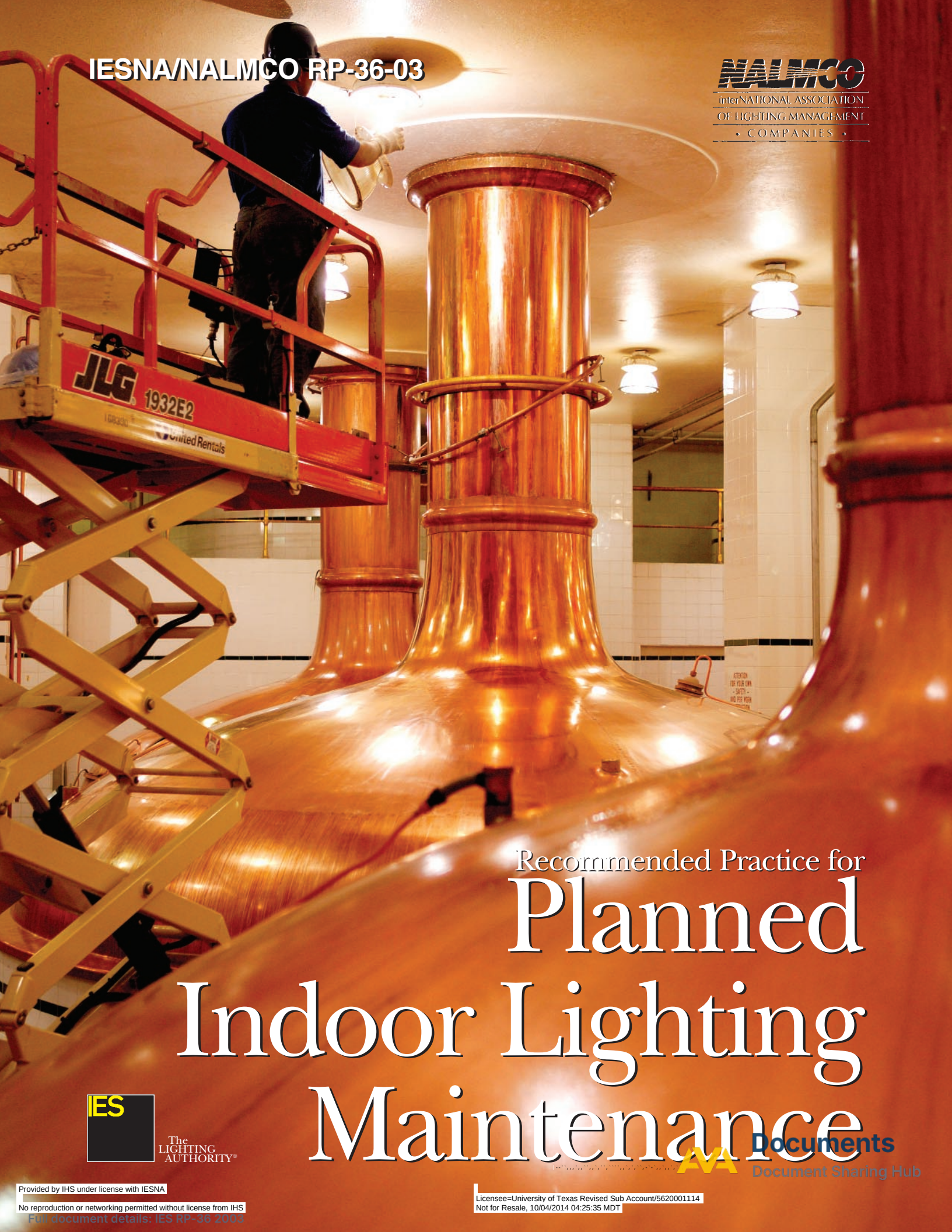


IESNA/NALMCO RP-36-03

NALMCO
InterNATIONAL ASSOCIATION
OF LIGHTING MANAGEMENT
• COMPANIES •



Recommended Practice for
**Planned
Indoor Lighting
Maintenance**



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Recommended Practice for Planned Indoor Lighting Maintenance

Publication of this Recommended Practice has been approved by the IESNA. Suggestions for revisions should be directed to the IESNA.

Prepared by:
The IESNA Maintenance Committee

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Recommended Practice for Planned Lighting Maintenance

1.0 INTRODUCTION

All lighting systems experience deterioration of performance during operation that affects illuminances and the appearance of the lighted space. Lamps and ballasts fail and need to be replaced. The visual appearance of the site may be altered due to lumen depreciation, loss of uniformity, and color shift. And the luminous flux of luminaires may be reduced due to dirt and dust accumulation on and degradation of reflector surfaces and lenses. Most of these phenomena are expressed as recoverable light loss factors, indicating that the light loss can be predicted and controlled using various maintenance methods. By extension, the maintenance method will influence the number of luminaires required in an original design and the component types allowed in an existing design, providing savings opportunities for both initial investments and operating costs.

When the initial lighting design is conducted for a site, there is an implied understanding of the maintenance methodology that will be used in coming years. Most lighting designs and lighting software have reactive maintenance as a built-in assumption—i.e., the owner will replace lamps, ballasts, and other components only when they fail and will not clean the luminaires. To compensate for the predicted light loss, which can be significant over time, and ensure that required illuminances are provided, new lighting systems are typically over-designed with a “depreciation cushion.” From day one such systems provide a higher illuminance than that recommended for the task.

Proactive, planned maintenance can produce tangible benefits for the owner compared to reactive maintenance methods. In a planned maintenance program, all lamps in a given system are replaced, room surfaces cleaned, and the lighting system inspected at predetermined intervals when a written maintenance policy is properly executed. Such a policy may stipulate:

- *Periodic Luminaire Cleaning:* Scheduled cleaning of luminaires and (if practical) the lamps they contain can result in significant gains in illuminances.
- *Group Relamping:* Scheduled relamping of all luminaires, with spot relamping of failed lamps in between group relamping cycles if practical, to achieve potentially significant labor savings and improve the visual appearance of the lighted space. Group relamping and luminaire cleaning can be combined for even greater labor economy.
- *Troubleshooting/Inspection:* During group relamp-

ing and as problems occur, good maintenance practices require routine inspection of luminaires to replace damaged and defective components, as well as troubleshooting to address immediate problems.

Planned maintenance can have a positive impact on initial and operating costs, safety, security, and the space’s visual appearance. Improved illuminances enable a reduction of the “depreciation cushion,” resulting in fewer luminaires required with attendant cost savings. Group relamping can achieve labor savings while improving the appearance of the space by promoting uniformity. In the case of certain high-intensity discharge (HID) lamps, group relamping can also reduce color shift, preserve components such as starters and ballasts that may fail due to “cycling,” and improve illuminances by replacing older “operating” lamps that exhibit severe luminous flux degradation.

As lighting systems become increasingly complex, maintenance requires more resources, expertise, and competence. Often, it is desirable for the owner to use a lighting management company and trained staff to maintain the system properly. Such companies are represented within the lighting industry by the interNational Association of Lighting Management Companies (NALMCO). Its members’ professionalism, experience, and lighting expertise are recognized by the Association’s Certified Lighting Management Consultant (CLMC) certification.

This Practice examines common lighting maintenance procedures and the central components of an effective planned maintenance program. Specifically, it will:

- Describe typical lighting system behavior, identifying those light loss factors that can be addressed by maintenance.
- Discuss a recent study on luminaire dirt depreciation (LDD) that gives new recommendations on determining this factor and new information significant to the luminaire count required in contemporary designs.
- Detail the components of an effective program, including planning, operations, methods, materials, and troubleshooting.

2.0 LIGHT LOSS FACTORS (LLFS)

Light loss factors (LLFs) are values that express the deterioration of illuminance on the workplane after various system characteristics and environmental conditions depreciate that amount. Light loss factors may be *recoverable* or *non-recoverable*.

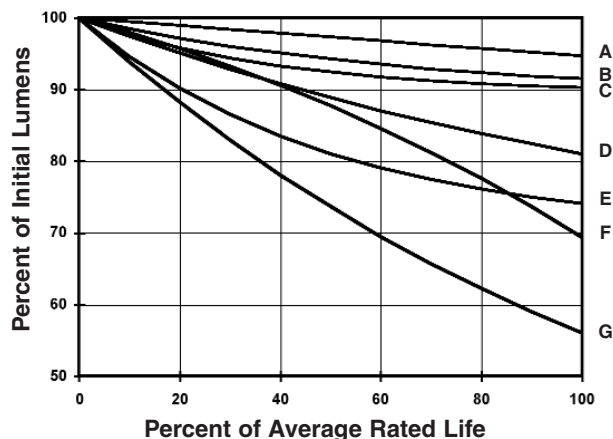


2.1 Recoverable Light Loss Factors

Recoverable light loss factors can be favorably affected by preventative maintenance and include:

- Lamp lumen depreciation (LLD)
- Luminaire dirt depreciation (LDD)
- Lamp burnouts (LBO)
- Room surface dirt depreciation (RSDD)

2.1.1 Lamp Lumen Depreciation (LLD). As a lamp is operated, its luminous flux gradually decreases over time. This phenomenon is called Lamp Lumen Depreciation (LLD). The rate of depreciation for various lamp types is suggested by the curves in **Figure 1**; refer to manufacturers' literature for specific lamp data.



- | | |
|---|-------------------------------------|
| A | Halogen Incandescent |
| B | T8 Fluorescent (triphosphor) |
| C | T5 and T5/HO |
| D | Incandescent |
| E | T12ES Fluorescent (halophosphor) |
| F | High Pressure Sodium |
| G | Mercury Vapor and Some Metal Halide |

Figure 1. Typical lamp lumen depreciation (LLD) curves for various lamp types.

2.1.2 Luminaire Dirt Depreciation (LDD). Dirt and dust are present in almost all spaces. As they accumulate on a lamp, the amount of light emitted is steadily reduced. As they accumulate on luminaire surfaces, the amount of light reflected or transmitted by these surfaces is also reduced. Dirt build-up on the luminaire's surfaces can also affect light distribution. For example, dirt on a specular aluminum reflector in a high-bay luminaire can widen the lighting distribution of that luminaire. The LDD factor also depends on the environment where the luminaire operates, the luminaire type, and the anticipated luminaire cleaning cycle.

2.1.2.1 LDD Factor Calculation Procedure. The LDD factor for indoor environments is determined using the following five-step procedure:

1. Characterize the operating environment according to the degree of dirt judged to be present:

CLEAN Spaces such as institutional, retail, office areas, and similar environments using filtered air circulation generally associated with heating, cooling, and ventilation systems; also other areas expected to maintain a similar cleanliness level.

MODERATE Spaces not expected to reach the level of CLEAN; light industry or manufacturing; areas with significant air introduced through windows; or areas without air filtering.

DIRTY Spaces where the normal activities introduce significant airborne dirt, such as heavy industry.

2. Place the luminaire into one of the following groups, according to its structural characteristics:

Group	Description
Open/ Unventilated	Open at the bottom (may have louvers or baffles), with a top enclosure which has no ventilating apertures to provide a free and steady path for the movement of air through the luminaire.
All Other	Any luminaire not properly described as Open/Unventilated. This group includes, but is not limited to, all enclosed units, bare lamps, fluorescent "strip" lighting, and luminaires with any significant openings at the top.

3. Determine the luminaire's CIE classification. Laboratory photometric reports normally identify this classification for indoor luminaires. Otherwise, it can be found from the percentage of the luminaire's output directed in the upward and in the downward directions (see **Figure 2**).

4. Determine a letter assignment (W, X, XY, Y, or Z) according to the appropriate environment/luminaire combination as presented in **Table 1**. (See step 5 for use of categories WX and YZ.)

5. Determine the LDD using the curve in **Figure 3**, which corresponds to the letter assignment made in step 4.

Although the curves shown in **Figure 3** should span almost all situations to be encountered, exceptional cases may justify using LDD values higher than curve W or lower than curve Z. For example, the designer might use an LDD value above those given in curve W when dealing with a manufacturing clean room where extraordinary precautions against the presence of dirt are in place. Similarly, in the occasional very dirty environment (airborne liquid particles, strongly corrosive agents, and exceptionally adhesive dirt are present), LDD values lower than those from curve Z might apply.

The designer should always apply judgment in borderline situations. For example, consider three enclosed luminaires: “L” (100 percent uplight), “M” (65 percent uplight/35 percent downlight), and “N” (55 percent uplight/45 percent downlight). For the CLEAN environment, **Table 1** dictates that curve X be used for luminaires L and M, while curve W be used for luminaire N. However, all else equal, the LDD characteristics for M and N will probably be more similar to one another than will those for L and M. Therefore, the designer may be justified in using curve WX for luminaires M and N. By

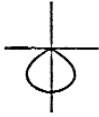
Classification	Percent up light	Percent down light	Typical candlepower distribution curve
Direct	0 – 10	90 – 100	
Semi-direct	10 – 40	60 – 90	
General diffuse	40 – 60	40 – 60	
Semi-indirect	60 – 90	10 – 40	
Indirect	90 – 100	0 - 10	

Figure 2. International Commission on Illumination (CIE) classifications for luminaires.

similar reasoning, curves XY or YZ can be used when appropriate.

In close decisions about environment ranking (is it CLEAN or MODERATE), there is some research evidence that justifies optimism. For example, an office lacking an air conditioning system might still qualify as CLEAN.

2.1.2.2 LDD in Outdoor Environments. The just-described procedure for finding LDD applies to indoor

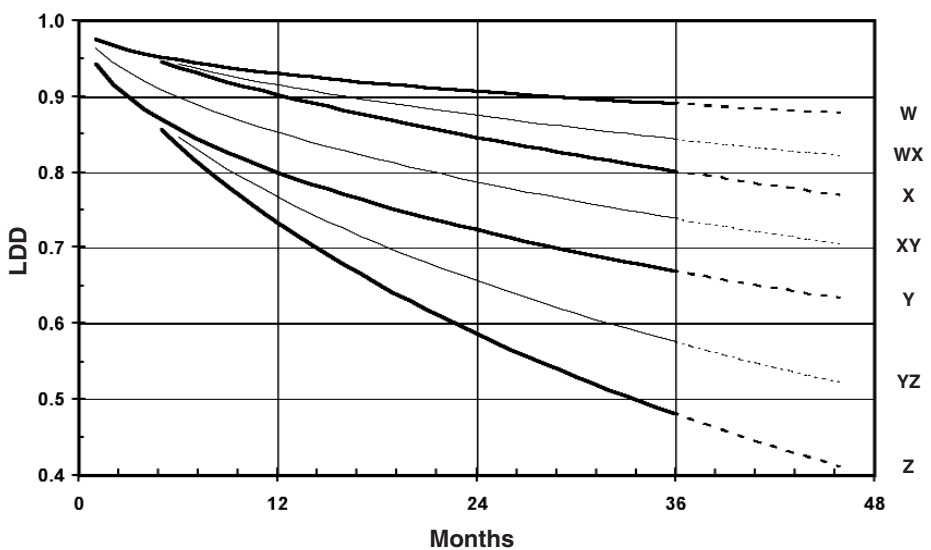
Table 1: Letter Assignment According to a Luminaire's Working Environment and CIE Classification

		CIE Classification				
		Direct	Semi-Direct	General Diffuse	Semi-Indirect	Indirect
Percent Uplight →		0-10	10-40	40-60	60-90	90-100
Percent Downlight →		90-100	60-90	40-60	10-40	0-10
CLEAN environment	Open/Unventilated	W	W	W	X	X
	All Other	W	W	W	X	X
MODERATE environment	Open/Unventilated	XY	XY	XY	Y	Y
	All Other	X	X	X	Y	Y
DIRTY environment	Open/Unventilated	Z	Z	Z	Z	Z
	All Other	Y	Y	Y	Z	Z

environments. For more information about outdoor lighting maintenance practices and procedures, consult IESNA DG-4-03, *Design Guide for Roadway Lighting Maintenance*, IESNA G-1-03, *Guideline on Security Lighting for People, Property, and Public Spaces*, IESNA RP-6-01, *Recommended Practice for Sports and Recreational Area Lighting*, and ANSI/IESNA RP-22-96, *American National Standard for Tunnel Lighting*.

2.1.3 Lamp Burnout (LBO). A lamp burnout (LBO) is a lamp that has failed and no longer continues to light. Lamp burnouts affect illuminances, lighting uniformity, the appearance of the space, and (in some cases) the operation of other lamps and components within the luminaire. For example, in a series-sequence fluorescent circuit, when one lamp fails, all other lamps on the same ballast will either light dimly or not at all. Such single-lamp failure can also cause rectification and high ballast current that reduces ballast life if the problem is not corrected quickly.

A large group of lamps of the same lamp type will fail in a predictable manner (see the lamp mortality curve of



Note:

These curves are defined by the equation:

$$LDD = e^{-At^B}$$

Where t is the elapsed time (in months, since the most recent cleaning), and the coefficients A and B are:

Curve	W	WX	X	XY	Y	YZ	Z
A	.024	.020	.018	.037	.059	.050	.044
B	.440	.596	.700	.586	.535	.670	.785

Figure 3. Luminaire Dirt Depreciation (LDD) curves (keyed to Table 1).

Figure 4). A lamp's *rated life* is defined as that point in time where half of the large group can be expected to have failed. The exception to this rule is the mercury vapor lamp. At rated life, 17-40 percent of a large group of mercury vapor lamps are expected to have failed, while the lumen output of those remaining in operation continue to depreciate to low values.

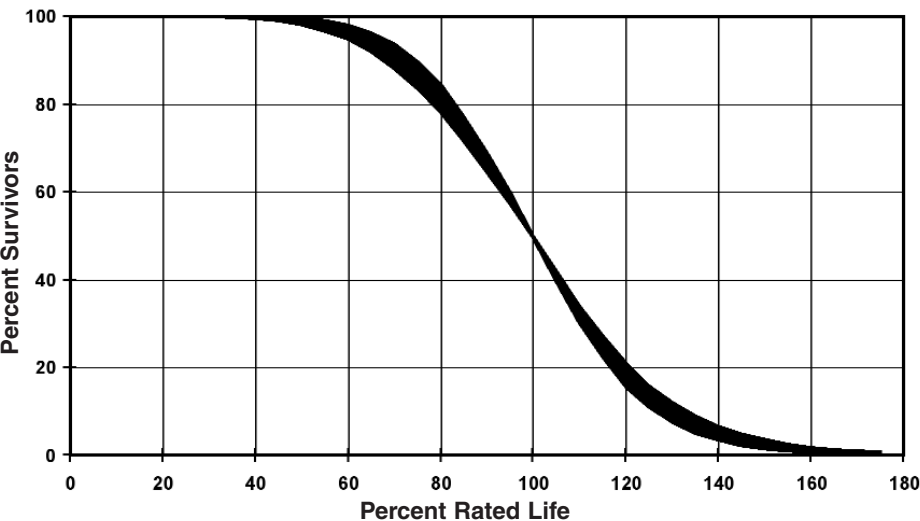


Figure 4. This typical lamp mortality curve shows the percent of a group of lamps that survive after operating for a period of time. The line thickening is used to suggest considerable uncertainty because the generic curve represents the performance of many common lamp types.

Published fluorescent lamp life data is based on three hours of operation per start (see LM-40-01, *IESNA Approved Method for Life Testing of Fluorescent Lamps*). High intensity discharge (HID) lamp life data is based on 11 hours per start (see LM-47-01, *IESNA Approved Method for Life Testing of High Intensity Discharge (HID) Lamps*). Deviation from these hours of operation between lamp starts significantly affects average life.* The life of fluo-

*NEMA, "Compatibility of fluorescent Lamps and electronic ballasts in frequency switched applications," August 18, 2003.

rescent lamps on conventional magnetic ballasts typically increases (relative to the rated life at three hours per start) as the number of operating hours per start increases. The improvement is about 30 percent for 10 hours per start, about 50 percent for 12 hours per start, and about 60 percent when the lamps operate continuously. These improvement percentages do not necessarily apply when new electronic ballast technologies are used. In many cases the change in life with hours per start depends on the specific ballast and lamp types. Fluorescent lamp operating life may be relatively independent of operating hours per start on program-start operation. Consult lamp and ballast manufacturers for specific information.

2.1.4 Room Surface Dirt Depreciation (RSDD). Light reaching the workplane comes directly from the luminaires in the room and from room surface reflections. Dirt and dust accumulation on room surfaces will reduce the amount of light reaching the workplane. In most cases, Room Surface Dirt Depreciation (RSDD) can be neutralized by cleaning the room surfaces in question.

RSDD depends on the amount of dirt in the environment, the room proportions, and the type of luminaire used. For example, with indirect lighting systems, all light is reflected from room surfaces. Since the available research data remains inadequate, it is not yet possible to meaningfully quantify the effect of RSDD. However, in a CLEAN interior environment, the RSDD factor is likely to be negligible.

2.2 Non Recoverable Light Loss Factors

Non-recoverable light loss factors are the fixed result of system operation, and may involve ballast losses, supply voltage variations, luminaire surface deterioration, and the luminaire's ambient temperature. Luminaire surface deterioration (LSD) is of particular concern to lighting maintenance programs because its rate of progression can be minimized through the choice of reflecting and transmitting materials.

LSD, as a cause of light loss, refers to effects on luminaire reflecting and transmitting surfaces that are permanent and therefore cannot be recovered by cleaning. Luminaire construction materials differ in their ability to reflect light and resist deterioration. Porcelain enamel, for example, retains its high reflectance and is relatively easy to clean. Processed aluminum finishes tend to depreciate at a lower rate than painted finishes.

The color and transmittance of plastics (acrylics, celluloses, polycarbonates, and vinyls) change over time from exposure to ultraviolet and infrared radiation. The rate of this change depends on the type of plastic, the lamp type used, the lamp's distance from the plastic,

and the temperature the plastic is subjected to during lamp operation. Improper cleaning materials and techniques can cause additional transmittance changes due to chemical action and surface scratching.

Existing experimental research data is too sparse to meaningfully quantify the effect of LSD. Most of this data primarily applies to roadway lighting. For CLEAN interior spaces, the effect of luminaire surface deterioration should be negligible. For DIRTY outdoor environments, permanent LSD effects have been reported as varying from less than one percent per year to more than five percent per year, depending on the luminaire's seals and/or construction. In any case, periodic luminaire cleaning has been shown to significantly mitigate LSD.

3.0 IMPACT OF A NEW LDD FIELD STUDY

A significant portion of this Practice is based on new information taken from a landmark Luminaire Dirt Depreciation (LDD) study. This three-year study was conducted by the interNational Association of Lighting Management Companies (NALMCO), promoted by the IESNA, and funded by the U.S. Environmental Protection Agency (EPA).

Study results suggest that in a typical commercial environment, the extent of dirt depreciation on luminaires in most spaces is less than the norms used by the lighting community since the 1950s. For example, in the time frame of a two- to three-year cleaning cycle, the new findings suggest light loss will be approximately 10 percent, whereas present lighting standards recommend light loss allowances of around 20 percent.

These new data can translate into less overlighting of spaces with new lighting systems, reducing equipment, installation, and operating costs for the system owner. These benefits can be magnified wherever a planned lighting maintenance program is in place.

3.1 Previous LDD Assumptions Updated

In the 1970s, anecdotal reports began to challenge older LDD assumptions. This led the IESNA Calculation Procedures Committee and the IESNA Maintenance Committee to promote a new LDD study, which was conducted by NALMCO from 1996-1999 with funding from the US EPA. In 2000, NALMCO completed this study, resulting in a new understanding of LDD, new recommended LDD factors, and a new LDD calculation procedure (Levin, et al 2002). All previously-recommended LDD factors were produced in the 1950s when the environmental conditions of interi-



or spaces were not representative of buildings today (for example, smoking indoors was then the norm and fresh air was provided by opening windows).

3.2 Source of New LDD Field Study Data

NALMCO's controlled LDD field study included more than 200 sites at office, retail, and school facilities in the US. Four popular recessed fluorescent lighting luminaire types were studied: 2 × 4 lensed, 2 × 4 louvered, 2 × 2 louvered, and 2 × 4 air exhaust louvered. Based on some estimates, this choice collectively represents some 90 percent of recessed luminaires operating in the U.S. (circa 1995). The split between lensed and louvered luminaires tested in the study was about 50/50.

Technicians at 10 lighting management companies gathered the test data using a Fluxometer (Brackett & Levin, 1996), an instrument specially designed to capture the total peak luminaire lumen output (flux) emerging from the luminaire (validation by Independent Testing Laboratories, Inc., Boulder, CO). For the initial set-up, eight luminaires at each site were thoroughly cleaned and relamped. After six months, one luminaire at each site was tested to record: 1) the as-is flux values with the lamps/luminaires dirty and 2) the flux values with these same lamps/luminaires cleaned. After 12 months, this same test was repeated on another luminaire at each site. The tests continued in identical fashion at each site after 18-, 24-, 30-, and 36-month intervals.

3.3 The New LDD Function

Figure 5 shows the new LDD function, as determined by the NALMCO test results, compared with traditional IESNA procedure for lensed and louvered luminaires in clean conditions (assumes better than average air filtration and some generated or ambient dirt). At 18 months, the LDD factor is 0.92 versus 0.84-0.85 using the traditional procedure, and at 36 months, the LDD factor is 0.89 versus 0.75-0.80. According to the study, lensed and louvered luminaires show virtually identical dirt depreciation. Varying the operating hours per year has a negligible effect.

3.4 Influence on New Installations

The NALMCO LDD data can significantly impact lighting design of commercial facilities where fluorescent, flat-bottomed (recessed or ceiling-mounted) luminaires are installed. In new installations, fewer lumi-

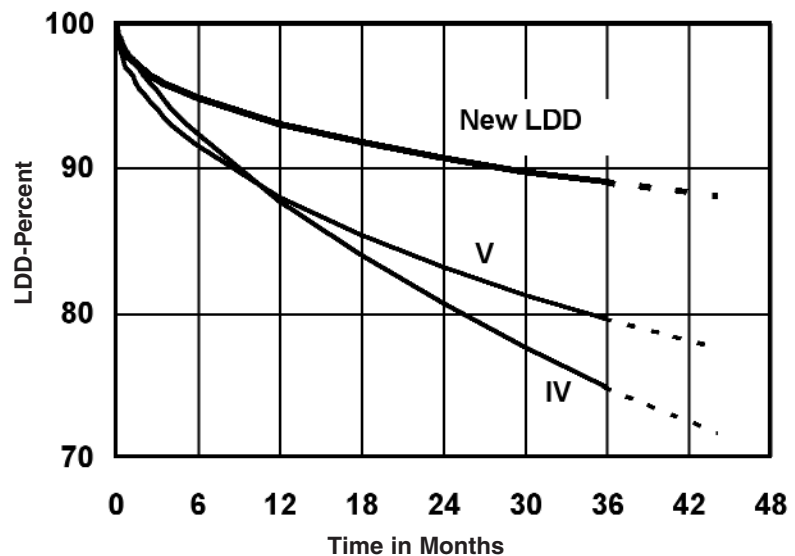


Figure 5. The LDD function for both louvered and lensed fluorescent luminaires determined by analysis of the NALMCO LDD study test results (top curve). Previous IESNA procedures place louvered luminaires into Maintenance Category IV and lensed luminaires into Maintenance Category V (their LDD curves are shown for comparison).

naires can be specified, installed, and operated thus generating initial investment and operating cost savings. In existing installations, the system can be redesigned or retrofitted using new ballast and lamp technologies, maximizing potential operating cost (energy) savings specific to application variances.

For new installations, the required number of luminaires (N) is determined from:

$$N = \frac{[(\text{Lighted Area}) \times (\text{Desired Illuminance})]}{[(\text{Bare Lamp Lumens/Luminaire}) \times \text{CU} \times \text{LLF}' \times \text{LDD}]}$$

Assuming a three-year cleaning cycle, the LDD factor for a lensed luminaire in an open office plan using the NALMCO LDD procedure is 0.89 and the LDD factor using the traditional procedure is 0.80. The following example illustrates luminaire savings resulting from application of the NALMCO LDD factor:

Area:

1,100 sq. meters (12,000 sq. ft.)

Desired Maintained Illuminance:

500 lux (50 fc)

Coefficient of Utilization (CU):

0.61

Other Light Loss Factors (LLF'):

0.74 — this is the product of all other loss factors (excluding LDD) such as lamp lumen depreciation and ballast factor

Luminaire type:

4-lamp louvered luminaire with 10,600 lamp lumens/luminaire

