

The photometric connection —Part 4

Discussions by Messrs. Lewin, Lobdell, Ayers, Heinisch, Jones, Ballman, Clark, and Fairbanks, and author's reply

Robert E. Lewin

Discussion

Ian Lewin
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Dr. Levin has provided us with an excellent in-depth analysis of the numerous sources of error in photometry and its application. Several of the author's statements indicate that the candlepower distribution of a luminaire will change considerably due to certain variables. Examples of these variables are reflector material and its degree of specularity, arc tube alignment and lamp phosphor density in high-intensity discharge (HID) fixtures. In the case of floodlights and industrial luminaires, the most critically affected candlepower value by these variables is that at zero degrees vertically. Unfortunately, industry committees have chosen the nadir candlepower to classify spacing criteria for indoor luminaires, and National Electrical Manufacturers Association (NEMA) classifications for floodlights. Differences of 50 percent often can be attained in nadir candlepower simply by lamp position adjustment in a specular reflector, for instance, easily changing a floodlight from NEMA 2 to 3 or even type 4. A redefinition of these factors would assist greatly in overcoming this major difficulty in the photometric lab.

Dr. Levin is correct in stating that statistical sampling of luminaires and photometering each sample is not economically possible. However, another approach has been used which reduces costs to being manageable while providing similar benefits. At least one state highway lighting authority requires as part of a contract the random sampling from man-

ufacturer's stock of three luminaires for complete photometric and electrical evaluation. This has the obvious effect of increasing the quality and consistency of all luminaires in the lot to be supplied under the contract, even though costs are insignificant in terms of the overall job cost.

Dr. Levin's comment regarding HID indirect luminaires should be emphasized. Luminaires which are inverted from their normal operating position during photometric testing have been found to produce errors as high as 25 percent, rendering the testing virtually useless.

The author points out that the IES recommended temperature range in the photometric laboratory of $\pm 2^\circ\text{F}$ produces a range of several percent in lamp output. It is this discussor's opinion that holding temperature constant to $\pm \frac{1}{2}^\circ\text{F}$ is necessary if our wish is to attain an accuracy of ± 2 percent in fluorescent photometry. On metal halide luminaires, however, I hope that Dr. Levin is overstating the discrepancy between laboratories. If the key rules regarding lamp handling, stabilization time and orientation are followed, I feel a 5 percent range readily should be attainable.

One particular lamp type is omitted in the paper, that being low-pressure sodium (LPS). Probably less is known about the photometric characteristics of this lamp than any other, and probably no lamp requires more precautions during photometry. We are engaged currently in a research program on LPS lamps, and hope to present a paper on this subject next year.

It will be difficult to make the paper as stimulating and as valuable as this one by Dr. Levin.

Harry R. Lobdell
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Dr. Levin has done an excellent job in presenting an overview of a very complicated subject. This information should result in a better understanding by those professionals engaged in calculations of illuminance levels. The following questions and comments are offered in this vein.

The author states in his paper, "the consistency of rated lamp lumens is, to a large extent, a controllable manufacturing variable." What is the tolerance in this manufacturing variable, or as I would choose to define it, what is the "Lamp Factor" for actual average lumen output on the 3150 lumen F40CW lamp and what is the "Lamp Factor" on the 3050 lumen 34 watt low energy fluorescent lamp?

I would like clarification of the author's statement, "relative photometry... also permits compensation for aspects such as ballast factors on discharge lamps."

It would appear to me to be desirable for the paper to have included actual values for ballast factors. A reference in the paper makes note of the rough guidelines which have been established and published in the "reference volume" of the 1981 Handbook showing the gain in fixture efficiency when photometered

Table 1—Ballast factors/relative light output

Ballast Type	Lamp Type	Ballast—Factor	
		Cold*	Hot
Standard Premium Low Energy	Standard 40 W	Avg. = .95 "CBM" Min. = .925	Avg. = .93 Min. = .905
Standard Premium Low Energy		Low Energy 34/35 W	Avg. = .89 Min. = .865

* A percentage of rated lamp lumens produced by a given ballast/lamp combination-based on ANSI C82.2 Test Method.

The author: GTE Products Corporation, Lighting Group; Salem, MA. This is a series in four parts: Part 1: photometric testing, luminaires, lamps (Sept. LD&A); Part 2: lamp operation, goniophotometers, lighting design (Oct. LD&A); Part 3: meters, field measurements (Nov. LD&A); and Part 4: discussion and rebuttal (Dec. LD&A). The discussions and author's reply result from the paper's presentation at the 1981 IES Annual Conference, held August 9-13 in Toronto, Ontario, Canada.

using low energy lamps. However, the fact was not emphasized that the ballast factor, when applied to these low energy lamps, will not only negate this photometric efficiency gain but will actually produce less delivered illuminance than that calculated.

In reference to the illuminance produced by fluorescent luminaires, the ballast factors constitute the largest single derating factor. As shown in Table 1, an average rating ballast factor of 0.93 should be applied to lumen output of standard 40 watt lamps and a derating ballast factor of 0.87 is applicable to the output of a 34 watt low energy lamp.

This means a 13% reduction in lumen output without any consideration of lamp factor, voltage factor, thermal factor, etc.

The product of these various factors when using a low energy lamp can easily amount to a 20 percent reduction in delivered footcandles versus calculated footcandles.

The low energy lamp/ballast combination is the most efficient fluorescent system on the market today; however, we should be realistic about the actual illuminance they will produce.

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Dr. Levin has written an excellent paper which addresses many of the pitfalls of photometry and the uses of photometry. His stated objective has been more than met. The discussers would simply like to add a few notations and ask a couple of questions.

1. With regards to "energy conserving" lamps we have found some of them to be exceptionally sensitive to ambient conditions; to the point where significant variations arise even when I.E.S. conditions of $\pm 1^\circ\text{C}$ are maintained. Furthermore, not all of these lamps are this sensitive and lamp manufacturers have not altered lamp designations when the modifications creating this sensitivity were incorporated commercially.

2. In the section on goniophotometers the author discusses the differences between 'equivalent intensity' and 'true intensity.' Can he offer some typical values as to the magnitude of this difference?

3. While the paper does not directly address the subject it does provide a good forum to deride our industry's habit of overstating precision. In light of Dr. Levin's paper one cannot justify using the fourth or fifth digit of a candlepower value or reporting a luminaire efficiency to the second decimal place.

4. The author states that with regards to the assumption that room surfaces are perfectly

diffuse, "there is no viable alternative." The discussers would like to take minor exception to that; the mathematics has been developed which could provide such an alternative. The lighting industry has simply not applied the theory as of yet.

5. The discussers were recently part of a large project where the stated goal was the establishment of proper correlation between pre-determined illuminance figures and field measurements; we would have liked to have had Dr. Levin's paper about nine months ago. Having concerned ourselves with most of the problem areas brought up by the author we encountered differences in illuminance ranging from 3 to 7 percent.

6. Would the author care to extend his estimates of the anticipated correlation between calculations and field measurements when the metric is CRF and/or ESI?

*Bill F. Jones
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Bob Levin's compendium on variations to be encountered in calculations, laboratory measurements, and field measurements, is excellent, and should be required reading for anyone involved in the design and construction of lighting systems. It should be especially noted by the individual who insists on specifying the minimum illumination level to be attained at any point on a parking lot!

Being involved continually on all three sides of this problem, I am frequently questioned by clients who do not understand why a lightmeter in the field does not give the same wonderfully precise figures he saw on the computer readout. I have prepared a short explanation of the problem (and the magnitude of variations that may be expected under normal conditions) which follows my remarks. I try to stress that these are *normal* variations—I don't even start looking for problems unless the results are well outside these limits.

One other point Bob made needs to be further stressed. The programs which are used in computer computations of illuminance levels treat interreflected light within the room by truncating the distribution of flux on the various areas. To prevent the computations from requiring infinite computer capacity, time, and money, these are converged rapidly. The net result is that the higher the amount of interreflection in the area, the more the computations are likely to be in error—usually on the high side. So it pays one to be cautious—especially with indirect lighting systems. Or, make your measurements with one of the pocket meters in Figure [12] (Don't use the one which has apparently been dropped).

Agreement which may be expected between calculation and measurement for outdoor lighting systems

Frequently clients express disappointment when measurements made in the field fail to agree closely with the calculated performance of a lighting system. This is true whether the calculations are made by hand or by computer. It must be recognized that there are many things that affect the correlation of calculation and measurement. These fall into the following categories:

1. What variations in performance may be expected between the luminaire sample tested and the general production of that unit?
2. How close do the lamp and ballast combinations come to producing rated light output?
3. How do the field conditions vary from the test conditions?
4. What are the color and cosine characteristics of the light meter and how accurate is its calibration?
5. How carefully were measurement locations and meter orientation observed during field measurement?

The effects of these variables are different from luminaire type to type and from installation to installation. A luminaire with a very sharply controlled beam is likely to vary much more from unit to unit in its candlepower distribution than is one which uses a diffusing globe. While it is not possible in a short letter to give guidance on each of these factors, the following variations are those I have come to consider "normal" in my field experience, and may serve as a guide to what can be expected under normal conditions in the field.

Item	Variation, calc. vs meas
Average illumination overall	$-10\% \pm 10\%$
Average variation at a point*	$-10\% \pm 20\%$
Any individual reading	$\pm 50\%$

* This means, if you measured twenty points, how much could you expect them to vary, on the average, from the calculated values?

Generally, maximum variations occur halfway between units. Since this determines the average-to-minimum ratio, it is literally impossible to calculate this ratio with any confidence. It is also impossible to guarantee a minimum illumination at such a point. For these reasons, LRL does not guarantee illumination levels.

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There are two points that must be made with respect to this paper:

1. This document must be published in a way to receive the widest dissemination. With the critical nature of present lighting application, designers *must* be aware of the myriad sources of error.

2. One other error that was not emphasized was the absolute necessity for photometering all types of lamps. We have found that lumen to candlepower ratios for fluorescent lamps can vary ± 10 percent from the nominal value of 9.25 and can create a like amount of variation in the luminaire performance. This procedure is required in the "Practical Guide for Photometry."

George Clark
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In a lot of years of dealing with architects, engineers and other lighting designers I have collected many interesting, irritating and frequently costly episodes involving discrepancies between calculated predictions and measured results. With the rapidly growing use of computers and their aura of infallibility the issues raised in this paper are even more important. We should make it clear that the numbers we get are in no way absolute.

Along with the computer factor we have had the matter of energy conservation. Where in the past a moderate "fudge factor" kept many designers out of trouble there is today the requirement to meet a tight upper limit in illuminance values as well as a lower limit. Users are less tolerant of the safety factor since it costs them much more today than in years past.

Now for a couple of specific items:

(1) I am glad to see included in this paper the fact that the reflectances of saturated colors depend on the light source being used. So do those of low chroma colors but the differences can generally be ignored. While it is not important in most applications it can be in some.

(2) In general, with task oriented lighting *individual* lamp, ballast, and luminaire performance is involved, not the average with which we've been accustomed in the past in connection with lighting installations.

It should be kept in mind that this paper addresses the issue in terms of the ultimate care in design calculation—in other words the best we can do—not the customary approach. It can fairly be said that we should be surprised if measured results equal predictions rather than being surprised if they don't. This is not said cynically but rather as a realistic expectation. Furthermore, this may be quite satisfactory provided we understand it. This paper does an excellent job in helping to convey that understanding.

Kenneth E. Fairbanks, PE
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Occasionally a paper is written that should be made required reading for all lighting designers, users, and specifiers. This is such a paper.

Although Dr. Levin's compilation of factors affecting lighting system performance is quite thorough, I would like to entertain a few additional comments. The end user or specifier has certain responsibilities of obtaining and evaluating luminaire data before the performance of an actual lighting system can be related to the original conceptual lighting system design.

Manufacturers often have an unfortunate habit of omitting data on the performance of their product if it happens to be detrimental from a marketing standpoint. Other examples include the failure on the part of the manufacturer to indicate that the photometric data in a catalog is actually based on a prototype sample rather than a production sample; the failure to indicate that the photometric data for a luminaire is based on an open unit rather than the lenses unit that is specified; and failure to indicate that the cataloged photometric data for specific lamp type is prorated from another test. Manufacturers have the responsibility of establishing the authenticity and credibility of their published data.

Occasionally specifiers have the mistaken concept that a photometric test from an independent laboratory will assure their obtaining a specified level of luminaire performance that will help them avoid some of the pitfalls outlined in Dr. Levin's presentation. Simply stated, an independent laboratory provides a totally impartial testing of a submitted luminaire. Unfortunately, the independent laboratory has little control over the selection of the luminaire that is sent to it for testing. Often it is unknown whether the sample is from production, whether the sample has been modified, whether the sample is actually a prototype, or whether the catalog number is correct for the sample submitted. Keep in mind that only the "good" tests are kept and used in the catalog pages; "poor" tests are simply discarded by the manufacturer who is paying for the testing. Independent testing is best utilized if the specifier retains the option of selecting a luminaire from the job site to be sent to an independent laboratory for evaluation. Then the factors mentioned in this paper should be considered in determining the compliance of the luminaire with the performance specifications.

Another problem that can beset the unsuspecting lighting designer in his or her quest to assure meeting a certain set of lighting criteria is the use of an inappropriate computer application program. For example, the concept of using average luminance as a means of

evaluating discomfort glare in the interior environment is fine for fluorescent luminaires but is not applicable to HID luminaires. In a similar manner VCP calculations are based on direct lighting distributions and consequently can not be used for indirect lighting applications.

When all is said and done, the burden is still on the lighting designer and specifier to make evaluations, interpretations, and judgements of the performance of lighting equipment that is to be used in a particular application.

Author's reply

Robert E. Levin

I am pleased to see the interest represented by the discussions. Many of them add valuable information to the subject and require no further comment.

To Dr. Lewin: There is another problem with the NEMA classification. Two luminaires, one just above and one just below the dividing point, may be functionally identical although classified as different. On the other hand, two luminaires, one near each extreme limit of a class, may be functionally different but are classified together.

To Mr. Lobdell: The "Lamp Factor" varies with lamp category and type, with manufacturer, etc. It is not possible to quantify this with a single number. Relative photometry is normalized to the output of the lamp(s) used in the test; the actual luminous output is immaterial. The subject of ballast factors is complex and has not yet been completely resolved. Reference 7 provides some specific data.

To Messrs. Ayers and Heinisch: (2) This is a function of luminaire optics as well as distance. As examples, the error in the principal orthogonal planes for a flat 2-ft X 4-ft lambertian diffuser at 20 ft ranges from about -1 to +2 percent; for a wedge louver luminaire, the error can approach infinity as the intensity decreases at large angles from the louver axis. (3) Sometimes precision requires more digits than justified by accuracy. For example, common differencing techniques in standard calculations require luminance coefficients be given to three significant figures. (4) There is a considerable body of literature, especially dealing with black body cavities, which addresses non-lambertian surfaces. These are not only complex but, more important, require the directional reflectance characteristics of the surface. For example, the bi-directional reflectance distribution function requires the reflectance property for each angle of incidence paired with each angle of reflection; these angles are continuous functions through 2π sr. Even a sampling of data at only 5° spacing means approximately 70,000 values to measure and manipulate. In some cases, simplifications should be possible depending on the specific material involved; however, such procedures have not yet been developed. (6) No! □