Lab Notes

Issue 1

Uniformity of Illuminance

One of the basic premises upon which the Australian Lighting Standards have been built is that the illuminance distribution over the working area, within the work place, should be relatively uniform. (1)

AS1680.1 requires that Emin/Eavg for an unobstructed work plane should not be less than 0.8

AS1680 states that the task should be able to be carried out anywhere within the defined work space. It is also considered that sudden changes in the illuminance of the work place are likely to cause distraction or dissatisfaction, so effecting visual performance. This sudden change in illuminance is often referred to as the “Transient Adaptation” effect.

The current edition of the Australian Standard AS1680-1 requires that the ratio of the minimum to average illuminance (Emin/Eavg) on an unobstructed work place, bounded within the space and delineated by the outer row of luminaires, should not be less than 0.8. (2)

Step by Step Guide to the Spacing Diagram

From your lighting layout, determine the Transverse and Axial spacings between the luminaires, in metres.
Calculate the Transverse SHR, and the Axial SHR, by dividing the luminaire spacings by the height of the luminaires above the working plane.
Plot the calculated SHRs on the Spacing Diagram for the proposed luminaire.
If the plotted point falls within the clear area on the Diagram, the uniformity (Emin/Eavg) within the “inner four” luminaires for a 4 x 4 grid will be greater than 0.8, and will therefore satisfy the current requirements of AS1680-1.
If the plotted point falls within the hatched area, then the uniformity (Emin/Eavg) will be less than 0.8, and will therefore not meet the requirements of AS1680-1.

Example :
Luminaires for a particular layout are spaced 3.0m in the Transverse (CO) direction, and 2.4m in the Axial (C90) direction. Mounting height is 2.7m above floor level, and the working plane is taken as 0.7m.

Transverse spacing = 3.0 / (2.7- 0.7) = 1.5 : 1
Axial spacing = 2.4 / (2.7- 0.7) = 1.2 : 1
These points have been plotted on Figures 7 and 8.

For Figure 7, the point is within the hatched area and so the uniformity will be less than 0.8.
For Figure 8, the point is within the clear area and so the uniformity will be greater than 0.8.
Therefore the use of the ULB luminaire will result in non-conformance with the current requirement of AS1680, ie. for the uniformity to equal or to exceed 0.8.

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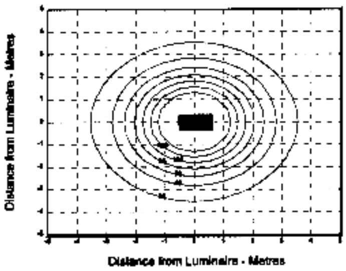

Figure 1: Illuminance distribution of a typical vitreous enameled 2x40W luminaire.

Early Debate on Uniformity

Over many years there has been much debate regarding the provision of a uniform illuminance level over a working plane. The renowned British Lighting Engineer Mr.W.R.Stevens, who was later to fill the position of President of the CIE from 1971 - 1975, wrote in his 1951 book, "Principles of Lighting" (3) :

If the MPR is not less than 0.7, a uniformity of 0.8 will be achieved over an area bounded by the 4 central luminaires.

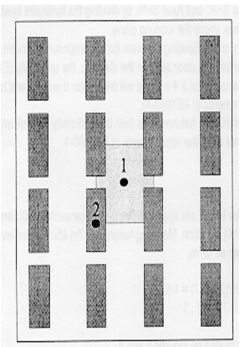

Figure 3 : Calculation points for determination of Mid Point Ratio (MPR).

"A uniform illumination was for many years a hallmark of good light, but it is now not held in such high esteem as it was, particularly since it is expensive to provide over the whole working area the high illuminations which are required. A diversity ratio of 1.5 to 1 in illumination has been generally accepted as permissible, but there is no reason why this should not be 3 or 4 to 1, perhaps even more, provided there is adequate light on desks or other working areas, and the transition from one level to another does not look unpleasant."

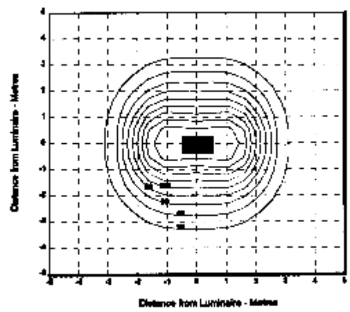

Figure 2 : Illuminance distribution from a typical 1990s batwing 2 x 36W low brightness luminaire.

The third edition of the "IES American Lighting Handbook," which was published in 1959, has a good deal to say about Luminaire Spacing. The Tables of Co-efficients of Utilisation included in this volume contained maximum permissible spacing values for each particular luminaire type which was being used at the time. The text of the book went on to state :

"Observance of such limitations will ensure satisfactory uniformity of illumination throughout the major portion of the room, so that all parts of the area will be equally suitable for the intended use. Peripheral areas may require special treatment as indicated below. In general, with greater mounting height and closer spacing, greater uniformity is achieved. Uniformity of illumination is generally considered to be satisfactory if the minimum value, (often between luminaires), is two thirds or more of the maximum value, (often under the luminaires). If the minimum value is one half or less of the maximum, perceptible differences in illumination exist."

The typical commercial luminaire of the 1950s used a vitreous enameled reflector, and it produced a near symmetrical illuminance distribution as shown. (Refer Figure 1.) Contrast this with the Isolux Plot from a currently available 2 x 36W low brightness luminaire shown in Figure 2.

Current Practice : The Mid Point Ratio

At the 1979 Kyoto Session of the CIE, an important paper was presented by Bean, Bell and Simons from the United Kingdom. The paper was entitled “Problems in Calculation of Utilisation Factors.” (5)This paper introduced the concept of Mid Point Ratio, or MPR for an array of luminaires. The MPR is the ratio of the illuminance at Point 1, compared to the illuminance at Point 2 as depicted in Figure 3.

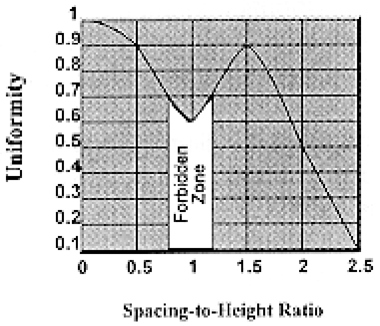

Figure 4: Forbidden zone diagram

If the MPR is not less than 0.7, it can be reasonably assumed that a uniformity of 0.8 will be achieved over an area bounded by the 4 central luminaires.

The conventional method calculates the MPRs for a series of spacing to height ratios or SHRs, commencing at SHR = 0.5 and increasing in 0.25 steps. For linear sources, this method includes aspect factor calculations to allow for non point source luminaires.

With the advent of the batwing type of luminaire, the MPR may be calculated to be considerably greater than 0.7, and can result in the method being invalid. As the paper (6) states :

For linear sources this method includes aspect factor calculations to allow for non point source luminaires.

“It is found with certain luminaires, such as those which give a batwing distribution, that the MPR is likely to rise above 1.2. If this should happen, the MPR method becomes invalid because the maximum and minimum illuminance **may not occur** at the MPR calculation points.

The paper also, includes a graphical form of uniformity versus SHR which has become known as the “Forbidden Zone Diagram.” For many batwing luminaires the profile of this diagram will be similar to that shown in Figure 4, where the 0.7 uniformity value can have several points of inflection on the graph. The “forbidden zone” is where the min/max uniformity drops below 0.7, before rising again.

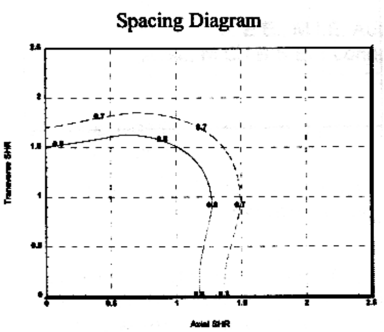

Figure 5 : Chart showing Max.SHR

When included in a photometric report this concept can be very useful to assist lighting designers, as it enables the designer to determine the uniformity for a particular SHR. However it only tells part of the story - ie. for luminaires which are **not spaced equally in the C0 and C90 directions.**

It is interesting to note that the authors of the 1979 paper were then involved in the production of the Thorn photometric data publication which includes a variation to the “forbidden zone diagrams” in the form of a chart. This is a chart for various uniformity values which plots the Axial (C90) SHR against the Transverse (C0) SHR. Refer Figure 5.

In our testing work at the LightLab Laboratory over the years, we have observed the intensity distributions of many batwing luminaires. This concept of a graphical presentation of allowable SHRs appeals to us, and we also understand that the calculation of SHRs for some luminaires using the MPR method is clearly incorrect. This is particularly the case for luminaires which have highly specular reflector/louvre light control systems, and especially true when used in conjunction with clear lamps such as Clear HPS or Metal Halide.

As an example consider the luminaire with an Intensity distribution shown in Figure 6. The Intensity distribution in the C0, C45 and C90 planes, are considerably different in shape. Because of the relatively abrupt changes in the Intensity distribution, the illuminance distribution produced within the inner four luminaires, ie. the area shaded light grey in Figure 3, will be irregular.

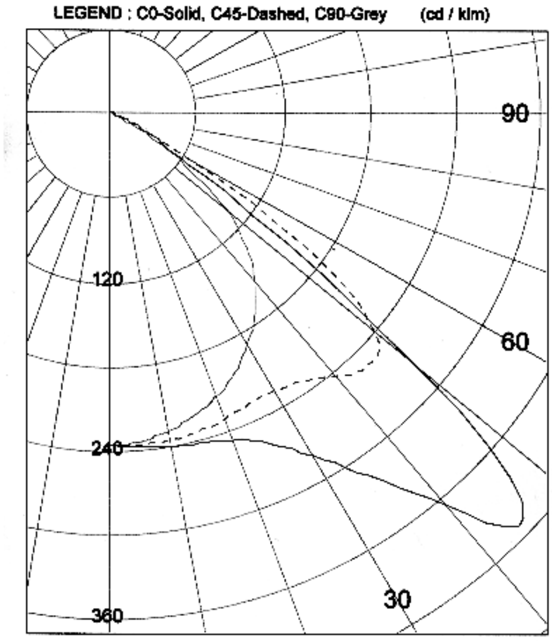

Figure 6: Polar curve for 2x36W ULB.

The differences in illuminance distribution will have a significant effect on the uniformity across the working plane. The Spacing Diagram shown in Figure 7 is a graphical method for illustrating this point. This can be seen when comparing two similar fluorescent troffer luminaires. The first is a 2 x 17 cell specular "ULB" type louvre which has an intensity distribution similar to Figure 6. This luminaire will produce a Spacing Diagram as shown in Figure 7.

The second luminaire has a prismatic panel which gives the intensity distribution a more symmetrical shape. The difference in illuminance uniformity between the two luminaires is dramatically shown when a comparison is made between Figures 7 and 8.

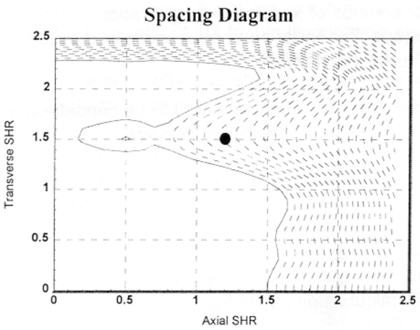

Figure 7 : Spacing Diagram for a batwing ULB.

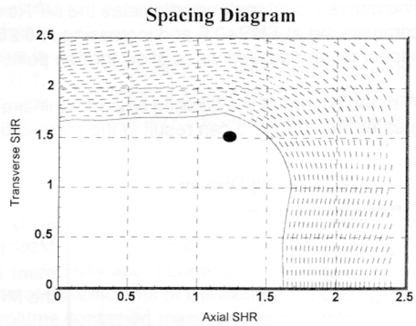

Figure 8 : Spacing Diagram for a typical prismatic troffer.

Figure 7 has a very irregular pattern and the lighting designer would have to take great care when planning a layout using these luminaires. Figure 8 has a more regular SHR distribution pattern, up to an SHR of 1 : 16, and so the arrangement of an array of luminaires is of little concern.

These spacing diagrams **should not** be regarded as a form of Isolux diagram. They are graphical representations of "go - no go" regions of SHR spacings. The clear area bounded by the solid line indicates the SHR spacings which will result in the illuminance uniformity being greater than 0.8. Within the hatched area the illuminance uniformity will be less than 0.8.

As lamp technology changes, so most of the methods of calculation need to be changed or refined. In the case of luminaires where the intensity polar solid is distinctly asymmetric, the illuminance distribution across a horizontal working plane will also be distinctly asymmetric.

If uniformity is to be regarded as an important item in the technical parameters of a lighting installation, then a Spacing Diagram is a much more effective and descriptive indicator than any which has been previously used.

REFERENCES

(1) AS1680.1-1990 Australian Standard Interior Lighting, Part 1: General Principles and Recommendations, Section 3.4, Page 17.

(2) AS1680.1-1990 Australian Standard Interior Lighting, Part 1: General Principles and Recommendations, Section 3.4.2, Page 17.

(3) Stevens W.R. "Principles of Lighting" - 1951
Constable, Page 237.

(4) IES Lighting Handbook, 3rd Edition 1959
Published by the Illuminating Engineering Society of North America
Pages 9-20 and 9-21.

(5) Bean A.R., Bell R.I., Over T., and Simons R.H. "Problems in the Calculation of Utilisation Factors"
Proceeding from the CIE Kyoto Session 1979, Section P 79-16, Pages 267-271.

(6) Bean A.R., Bell R.I., Over T., and Simons R.H. "Problems in the Calculation of Utilisation Factors"
Proceeding from the CIE Kyoto Session 1979, Page 269.

LightLab is able to supply SHR Diagrams for your luminaires.

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