

# Proposal for a Luminaire Specific Index for the Description of Photometric Properties of Interior Luminaires Taking into Account the Efficient Use of Energy

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## ABSTRACT

The ratio between the achievable illumination level, expressed in terms of average horizontal illuminance on the utilisation plane, and the necessary electric power depends on the selection of lamps, ballasts, and luminaires, as well as on the appearance of the interior, expressed in terms of average reflectances of all interior surfaces. For lamps and ballasts it is common practice to use energy-dependent quantities, such as luminous efficacy or ballast-lumen-factors, which could be classified easily. However, for luminaires the obvious measure, the light output ratio, is not a suitable quantity, as there exists no relationship to the achievable illumination level. For general lighting in interiors only an index based on utilisation factors could describe photometric properties while taking into account the necessary electric energy, as the utilisation factor is in proportion with the light output ratio and is dependent on the luminaire flux distribution for given standard conditions. Therefore a standard room has been defined concerning dimensions, luminaire layout, and reflectances. For a larger number of different luminaire types for direct illumination the utilisation factors have been calculated for the defined standard room alongside with the glare rating. The glare limitation has been checked using the tables of unified glare ratings which will be a standard part of oncoming luminaire documentations. On the basis of calculated utilisation factors and glare ratings a classification system will be proposed which could be used to describe the photometric properties of interior luminaires for direct illumination taking into account the efficient use of energy.

## INTRODUCTION

Lighting requirements concern the criteria illuminance level, luminance distribution, glare limitation, modelling, colour appearance and colour rendition /1/. For general lighting in interiors with luminaires for direct illumination /2/, i.e. the luminaires have a downward flux fraction not smaller than 0,90, the quality criteria luminance distribution, and modelling can be fulfilled using a regular layout of luminaires with spacing-to-height ratios of about 1, and sufficiently high reflectances of all room surfaces. Colour appearance and colour rendition are generally determined by the properties of the selected lamps. The quality criteria illuminance level and glare limitation have to be considered especially dependent on the selected luminaire type for a particular installation.

Besides the photometric quality criteria special attention is paid to the costs for acquisition, installation, and operation of the illumination. Here it is of particular interest to what extent the total costs could be reduced by utilizing lamps with higher efficacy, ballasts with lower losses, and luminaires with higher light output ratios and more appropriate luminous intensity distributions.

Taking into account the effective use of energy it is desirable to achieve the highest illumination level with a minimum use of energy, without disregard of the other photometric quality criteria, especially the limitation of glare.

Based on utilisation factors and glare ratings a system for classifying luminaires in terms of energy efficiency will be proposed.

## SCOPE

The ratio between the achievable illumination level, expressed in terms of average horizontal illuminance on

the utilisation plane, and the necessary electric power depends on the selection of lamps, ballasts, and luminaires, as well as on the appearance of the interior, expressed in terms of average reflectances of all interior surfaces. For lamps and ballasts it is common practice to use energy-dependent quantities, such as luminous efficacy or ballast-lumen-factors, which could be classified easily. However, for luminaires the obvious measure, the light output ratio, is not a suitable quantity, as there exists no relationship to the achievable illumination level. For general lighting in interiors only an index based on utilisation factors could describe photometric properties while taking into account the necessary electric energy, as the utilisation factor is in proportion with the light output ratio and is dependent on the luminaire flux distribution for given standard conditions. Therefore a standard room has been defined concerning dimensions, luminaire layout, and reflectances. For a larger number of different luminaire types for direct illumination the utilisation factors have been calculated for the defined standard room alongside with the glare rating. The glare limitation has been checked using the tables of unified glare ratings which will be a standard part of oncoming luminaire documentations /3/. On the basis of calculated utilisation factors and glare ratings a classification system will be proposed which could be used to describe the photometric properties of interior luminaires for direct illumination taking into account the efficient use of energy.

#### STANDARD ROOM

The calculation of utilances and utilisation factors is based on a room with a length of 4 h and a width of 8 h. Here h denotes the height of luminaires above normal sitting eye height (height of observer), which is usual practice for glare evaluation. It is assumed that the luminaires are evenly distributed in the luminaire plane, i.e. the ceiling. The distance between utilisation plane and luminaire plane is 1,175 h. For the common assumption of a distance  $h = 2$  m the room has a length of 8 m, a width of 16 m, and a height of 3,20 m; with a height of observer of 1,20 m and of the utilisation plane of 0,85 m above floor. The room index of this standard room is  $k = 2,27$ . Following the recommendations DIN 5035 /1/ the average reflectances are taken as 0,70 for the ceiling, 0,50 for all walls, and 0,20 for the floor cavity. This room is in accordance with the reference room specified in the LiTG report on unified glare ratings /4/.

#### LUMINAIRE SELECTION

The investigated luminaires have been selected from a collection of more than 100 commercially available luminaires in Germany. This collection has been built up originally for a LiTG study concerning the unified glare rating system /4/ and has been supplemented for this report. Only luminaires for direct illumination have been considered, suitable for tubular fluorescent lamps 58 W with a luminous flux of 5 200 lm.

#### CALCULATIONS

Based on the tabulated luminous intensity distributions, light output ratios and luminaire classifications according to DIN 5040 /2/, CIBSE TM5 /5/, and UTE C71-121 /6/ have been calculated for all selected luminaires. Due to the given restrictions only luminaires with classification A60, A50, A40, and A30 according to DIN 5040, with classification A to E according to UTE C71-121, and with BZ-classes between 1 and 5 according to CIBSE TM5 have been chosen (for further explanation of the DIN system see appendix). The calculation of direct ratios, utilances, and utilisation factors has been carried out following the procedure described in LiTG Publication 3.5 /7/, which has been regarded as the most suitable under practical conditions /8/. The utilances and utilisation factors for the standard room with  $k = 2,27$  have been evaluated by inter-polation of the corresponding tables. The tables of unified glare ratings (UGR) have been calculated accordingly to the method described in CIE Publication No. 117 /9/. However, the background luminances have been determined taking into account the different heights of utilisation plane and observer's eye above floor following the LiTG utilisation factor method /7/. After correction of the tabulated values for a luminous flux of 5200 lm per lamp the resulting glare ratings in the standard room have been found (the standard room corresponds with one of the 19 rooms of the complete table). In the following paragraphs only the more critical glare ratings for observation lengthwise or crosswise will be considered.

#### RESULTS

On the basis of the calculated light output ratios, utilances and utilisation factors as well as glare ratings, functional relations can be represented for the 36 types of luminaires (figures 1-3). Figure 1 shows the distribution of light output ratios as a function of glare ratings evaluated in the standard room. (The numerals 3 to 6 correspond to the first digit of the luminaire classification according to DIN 5040). In figure 2 the distribution of utilances (standard room with room index  $k = 2,27$ ) is represented as a function of glare ratings. As expected there is a tendency to lower utilances for broader intensity distributions, i.e. a change of luminaire classification from A60 to A50 to A40 according to DIN 5040, together with a simultaneous increase of glare rating values. As luminaires of the same luminaire class are distributed over more than 3 UGR classes, no functional dependence between the luminous flux distribution and glare rating can be expressed. This confirms the assumption that illuminance level and glare restriction have to be considered separately and installation dependent. Figure 3 shows the distribution of utilisation factors as a function of glare ratings in the standard room. The frequent occurrence of utilisation factors around a value of 0,60 – independent of glare ratings – makes it possible to introduce a luminaire specific index, which takes into account the illuminance level as well as the glare rating.

#### PROPOSAL FOR AN EFFICIENCY CLASS SYSTEM AND A LUMINAIRE SPECIFIC INDEX

Based on the calculated values and the derived relationships it is possible to propose a 3-class efficiency system for general lighting in interiors with luminaires for direct illumination (figure 4). This system should be constructed around a centre value of 0,60 in terms of utilisation factor (UF). The middle class should have a bandwidth of about  $\pm 0,10$  UF. The resulting system could show the following three classes:

	UF > 0,7	Efficiency class	E1 (very good)
0,7	UF > 0,5	Efficiency class	E2 (good)
0,5	UF	Efficiency class	E3 (less good)

The luminaire specific index, which, besides the efficiency class determining the illumination level, takes into consideration the glare restriction, could be generated by addition of the appropriate glare rating value. A luminaire of efficiency class E2 with a glare rating UGR = 19 in the standard room could have the luminaire specific index

E2/GR19.

Such an index would simplify the luminaire selection under the specified conditions without disregard of photometric quality criteria.

#### FUTURE DEVELOPMENTS

Although the proposed efficiency class system has been derived on the basis of the luminaire classification according to DIN 5040 and the calculation of utilisation factors described in LiTG Publication 3.5, the tabulated luminaire classifications according to CIBSE TM5 and UTE C71-121 let anticipate similar results based on British or French recommendations. This in particular, as the standard room under consideration has a room index for which larger deviations between different calculation methods are not to be expected /8/. Furthermore the proposed system could also be applied for different standard rooms, and other types of luminaires in respect of classification and/or shape. ●

#### APPENDIX

In the DIN system /2/ luminaires are classified according to their luminous flux distribution, and in dependence of direct ratios for utilisation plane and ceiling in a standard room (room index  $k=1,23$ ) with 4 times 2 luminaires. The letter (A to E) corresponds to the downward flux fraction, e.g. a letter 'A' is used for a downward flux fraction between 0,9 and 1,0. The first (0 to 8) and the second digit (0 to 4) correspond to the direct ratios for utilisation plane (DRU) and ceiling (DRC) respectively. A '6' as the first digit is used for DRU between 0,7 and 0,8, a '5' for DRU between 0,6 and 0,7, a '4' for DRU between 0,5 and 0,6, and a '3' for DRU between 0,4 and 0,5. The second number '0' is valid for all luminaires with a downward flux fraction of 1.

#### REFERENCES

- /1/ DIN 5035, Beleuchtung mit künstlichem Licht, 1990
- /2/ DIN 5040, Leuchten für Beleuchtungszwecke, Teil 1 (1976) und Teil 2 (1995)
- /3/ Stockmar, A. Leuchtendokumentation entsprechend der vereinheitlichten europäischen Blendbewertung. Tagungsband LICHT'92, Saarbrücken, S. 313-323
- /4/ Stockmar, A. Untersuchung zur vereinheitlichten Blendbewertung. Bericht für den LiTG-Fachausschuß "Innenbeleuchtung", 1991
- /5/ CIBSE Technical Memorandum 5, The calculation and use of utilisation factor, 1980
- /6/ UTE C71-121, Méthode simplifiée de prédétermination des éclairagements dans les espaces clos et classification correspondante des luminaires, 1993
- /7/ Projektierung von Beleuchtungsanlagen nach dem Wirkungsgradverfahren. LiTG-Publikation 3.5, 1988
- /8/ Stockmar, A. Leuchtenklassifikation im europäischen Vergleich. Vortrag LICHT'90, Varna
- /9/ Discomfort glare in interior lighting. CIE Publication No. 117, 1995

Note: *More figures on the following pages.*

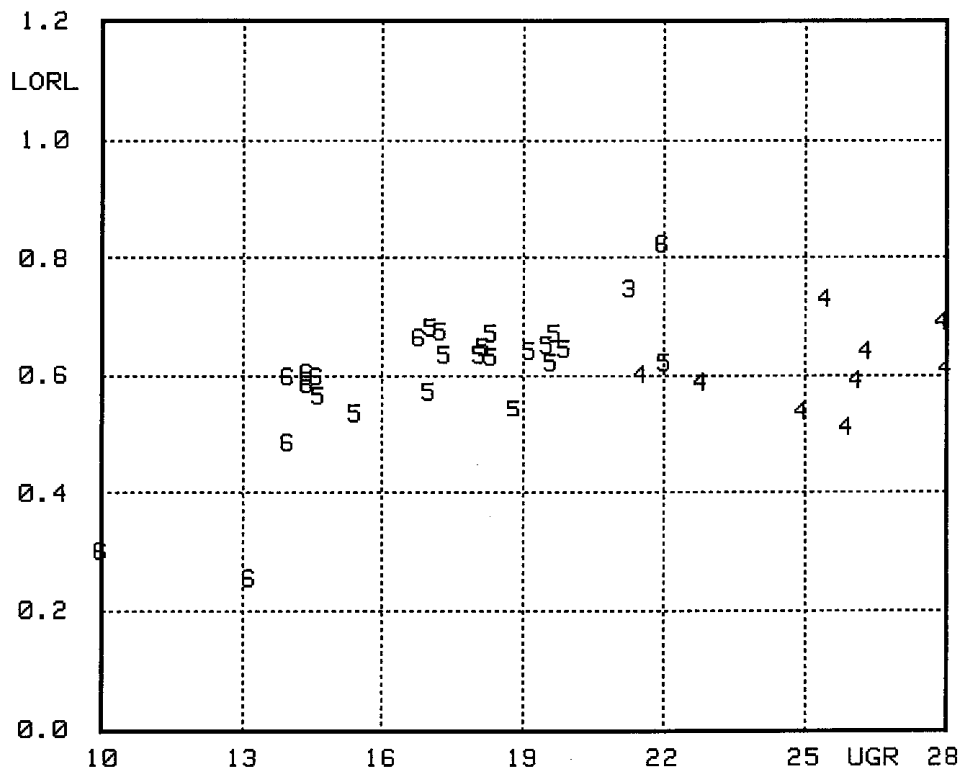


Figure 1: Distribution of light output ratio luminaire LORL as function of glare rating UGR in standard room for 36 luminaires L58W, (numerals 3 to 6 correspond to 1. digit of classification according to DIN 5040 /2/)

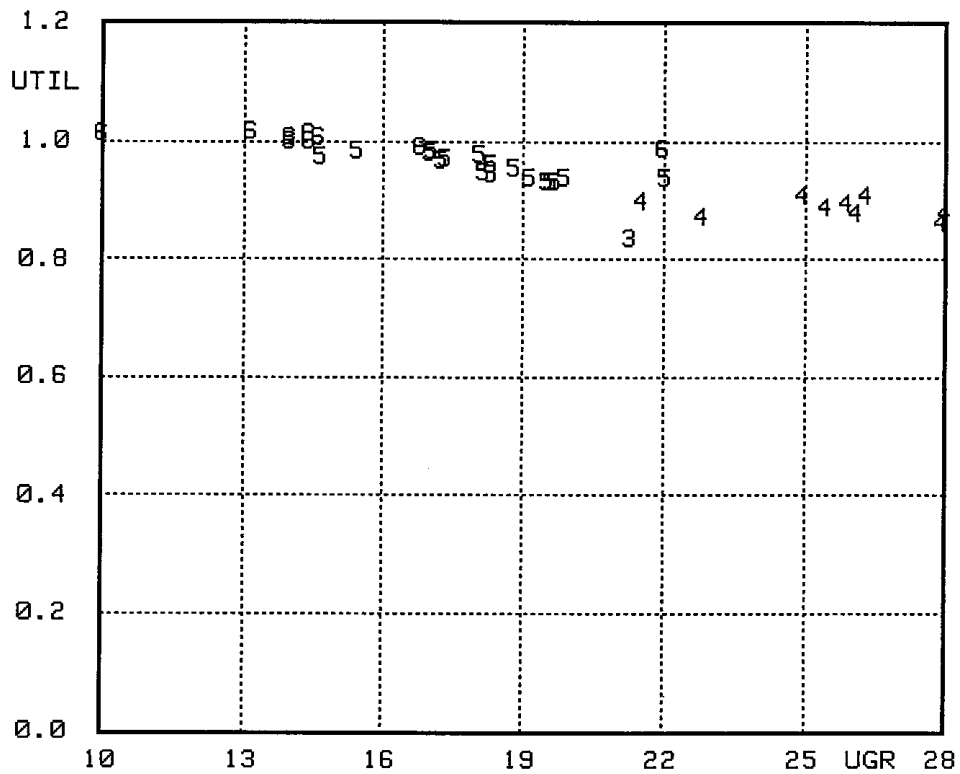


Figure 2: Distribution of utilance UTIL calculated according to LiTG-method /7/ as function of glare rating UGR in standard room for 36 luminaires L58W, (numerals 3 to 6 corresponds to 1. digit of classification according to DIN 5040 /2/)

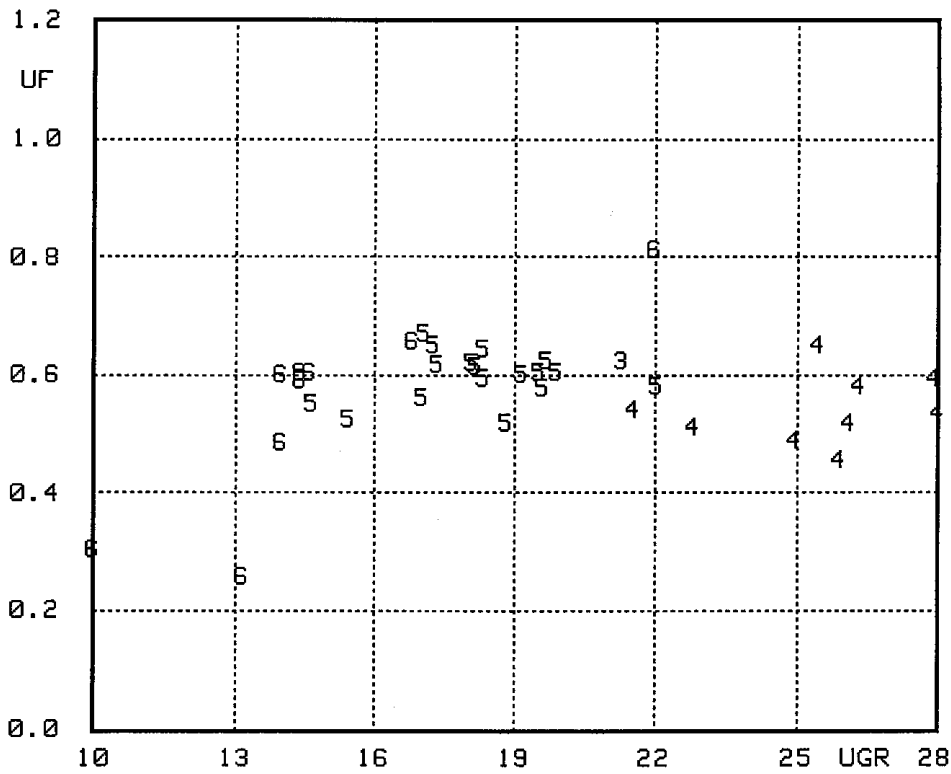


Figure 3: Distribution of utilisation factor UF calculated according LiTG-method /7/ as function of glare rating UGR in standard room for 36 luminaires L58W, (numerals 3 to 6 correspond to 1. digit of classification according to DIN 5040 /2/)

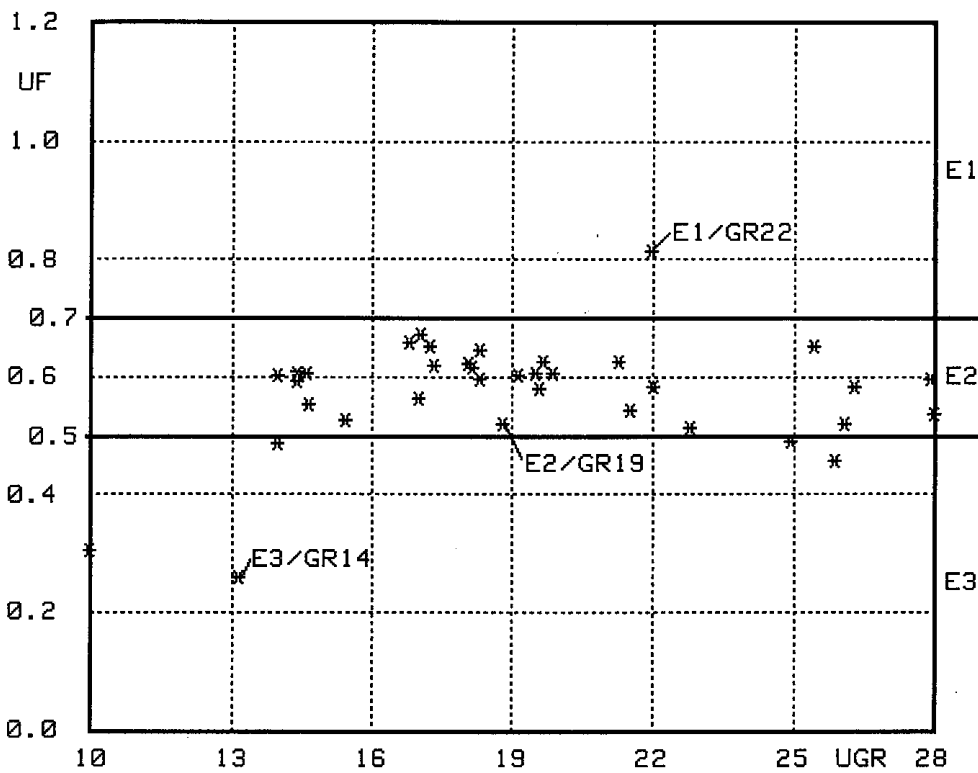


Figure 4: Proposal for efficiency class system  
 E1 ... efficiency class 1 (very good)  
 E2 ... efficiency class 2 (good)  
 E3 ... efficiency class 3 (less good)  
 Luminaire specific index e.g. E2 / GR19

