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AN APPRAISAL OF TASK-AMBIENT LIGHTING SYSTEMS

by A.W. Levy and E. Wotton

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SOMMAIRE

Les auteurs décrivent quatre modes d'éclairage travail/d'ambiance: luminaires au plafond seulement, torchères indirectes pour l'éclairage travail seulement, luminaires d'éclairage travail incorporés au mobilier et torchères indirectes pour l'éclairage travail et d'ambiance.

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An Appraisal of Task-Ambient Lighting Systems

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Four task-ambient lighting schemes are categorized: luminaires in the ceiling only, indirect torcheres for task lighting alone, task lighting luminaires built into furniture, and task and ambient lighting both provided by indirect torcheres. A photometric appraisal of each of these categories was performed on installations in Canada and the U.S.A. Photometric measurements included horizontal illuminance, equivalent sphere illuminance, contrast rendering factor, luminance and reflectance. Data were also collected on the total power loading per unit area of work space as found in the offices containing the various systems. The results are evaluated in terms of current North American recommended practice with a detailed discussion of each system appraised. It was concluded that none of the systems measured met North American recommended IES lighting levels and the quantity and quality of illumination varied enormously amongst the sample of task-ambient systems investigated. Low ambient lighting levels can significantly affect the overall quality of light and may also require the surfaces of surrounding vertical walls and partitions to be separately illuminated. Nevertheless, it is the opinion of the authors that, if properly designed, task-ambient lighting systems offer significant potential for power savings in office lighting systems.

INTRODUCTION

Like many other building services lighting has recently come under close scrutiny with respect to its energy efficiency and energy

consumption in buildings. One of the most common methods of regulating consumption is by setting an upper limit to the installed power loading in terms of watts per square metre of floor area.

A convenient method of complying with the new power loads is to use the concept of task-ambient lighting. The idea is not new but the current methods of achieving it are.

In simple terms task-ambient lighting schemes concentrate most of the light on the work station and reduce light levels elsewhere.

The traditional office lighting scheme of high uniform illuminance throughout an entire office is therefore being challenged as an energy-inefficient method of illumination. Power loadings to achieve a typical uniform illuminance of 750 lx can be anywhere between 30 and 70 W/m². In order to achieve lower power loadings the exploitation of the task-ambient lighting concept has become popular, in particular, task-luminaires built into office furniture and desks. It has been estimated that task-ambient lighting systems will constitute a \$10 to \$14 million investment in the U.S.A. alone, for the 1979 fiscal year [1].

For the purpose of this paper, task lighting can be defined as, illumination purposely installed and directed so as to provide the necessary illuminance for the execution of typical office tasks on a horizontal surface, e.g. reading and/or writing. Ambient lighting denotes the illumination provided in an office space as general lighting for access, circulation and for viewing non-critical visual tasks from the work station.

Task-ambient lighting schemes can be categorized into four approaches.

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1. Luminaires in the ceiling only. The luminaires provide light everywhere in the office but are located so as to direct most of their light to the work surface. This form of illumination is sometimes termed localized lighting.

2. Indirect torcheres, that is, an indirect floor lamp sending all or nearly all of its light upward to be reflected from the ceiling to the working plane. The torcheres are placed close to the work station so that most of the indirect light falls on the work surface.

3. Task lighting at each individual work station with ceiling mounted luminaires to provide ambient light.

4. Task lighting as in No. 3 but ambient lighting provided by indirect torcheres or by indirect luminaires built into the furniture.

A photometric appraisal of each of the four approaches is presented in this paper. An appraisal at this time is most appropriate in Canada because of the recent publication of federal energy conservation measures [2]. A lighting load of 22 W/m² is recommended for office spaces at current North American Illuminating Engineering Society (IES) lighting levels. Task-ambient lighting would appear to be a practical means of complying with this lower power loading which may be difficult to achieve adopting traditional office lighting design principles.

The purpose of this present study was to perform the appropriate photometric measurements in order to compare lighting quantity and quality between systems, and with recommended practice; to investigate the energy saving potential of the systems using available statistics on the use of office space; to formulate a competent appraisal method; and to aid potential users and designers in assessing the type of information required to usefully evaluate task-ambient lighting systems.

This study of commercially available task-ambient lighting systems was carried out with the understanding that the researchers would keep the source of their data strictly confidential. The systems appraised and reported here cannot, therefore, be described in complete detail.

*ESI takes the same units as illuminance, namely, lux. However, to distinguish the two, numerical values of the former are expressed in ESI units and the latter in lux.

PHOTOMETRIC MEASUREMENTS

Horizontal illuminance (the light flux incident per unit area) serves as a measure of lighting quantity; it can be measured and expressed in lux (lumens/m²).

Lighting quality can be pursued through to two separate factors: luminance, the objective brightness of a surface, and in particular, the luminance ratio of important surfaces; and "equivalent sphere illumination" (ESI). Luminance (in candelas/m²) is the photometric brightness of a surface. With the use of a standard of known reflectance, luminance measurements enable the reflectances of important surfaces at the work station to be calculated. ESI* is a measure of how well a lighting system renders contrast, and is therefore related to the level of visibility given by that system. The ESI concept is most important to the conclusions drawn from this work, therefore ESI and its measurement are discussed separately.

A Hagner Universal Photometer Model 2 was employed for all measurements, illuminance, luminance and ESI. For the ESI measurements specially constructed cylinders [3] were placed over the photocell and the results fed into a programmed desk calculator. The calculation also produced values of the "contrast rendering factor" (CRF).

EQUIVALENT SPHERE ILLUMINATION

For an achromatic object to be perceived there must be a difference in luminance between the task detail and its immediate background. Contrast can be measured as the "luminance difference ratio", between detail and background. Equally important for vision is the sensitivity of the eye to contrast which is largely dependent on the observer's state of adaptation, that is the level of light the eye is adapted to. Substantial evidence exists [4] that contrast and the eye's sensitivity to it (contrast sensitivity) is one of the most important factors in determining visibility, *i.e.* how well one can see the object of interest. Furthermore, it is possible to trade-off illuminance for contrast and retain the same level of visibility. Quite simply, within certain limits, lighting levels can be reduced with the level of visibility unaltered if contrast is

increased and *vice versa*. This important principle leads directly to energy-effective lighting design where the contrast of visual task is of paramount importance. Less light is required and therefore fewer fixtures if a lighting system can be designed such that the light flux incident on the visual task enhances its contrast.

Many factors that have a significant effect on visibility such as size, exposure time, disability glare, transient adaptation and observer age may be expressed in terms of a contrast multiplier. The importance of contrast for the visibility of common two-dimensional tasks requires the illuminating engineer to develop procedures to measure the effect on luminance contrast of different lighting installations. This has been accomplished through measurements of the "contrast rendering factor" (CRF) and "equivalent sphere illumination" (ESI).

An installation producing significant veiling reflection in a task will seriously reduce the visibility of that task. Veiling reflections are the minute specular reflections superimposed on diffuse reflections from an object, that partially or totally obscure details by reducing contrast. Reflected glare is an extreme and noticeable example of this condition where a luminaire itself can be seen by specular reflection in the surface of a visual task. However, veiling reflections occur to a greater or lesser extent in all real surfaces due to the combination of the reflecting properties of the visual task and the magnitude and direction of the incident light flux. Veiling reflections are quantified by the "contrast rendering factor" (CRF) which, for most practical purposes, can be measured as the ratio of the luminance contrast of a task in a given lighting system to its contrast under reference sphere lighting conditions.

"Equivalent sphere illumination" (ESI) quantifies the effects of veiling reflections (CRF) and the level of light adaptation that pertains. It provides a relative measure of visibility [5] for a given lighting installation and given visual task, and is the level of sphere illuminance that produces the same task visibility as the particular lighting installation of interest. Sphere illumination is that produced in a photometric sphere giving a perfectly diffuse illuminance and for which luminances are equal from point to point. It

was chosen as a reference lighting system because it is a convenient and easily reproducible reference lighting condition with very few veiling reflections possible. By definition, CRF must equal unity in the sphere. Values of the CRF close to and greater than unity indicate an installation producing very few veiling reflections and consequently potentially good visibility whilst the converse is true when the CRF is much less than unity. More complete and detailed discussions of ESI and related factors can be found elsewhere [4 - 6].

MEASUREMENT PROCEDURE

The distribution of test points for the measurement of illuminance, luminance and ESI (and CRF) are shown in Figs. 1 to 7.

Illuminance and luminance were measured without body shadow. The ESI cylinders incorporate a head and body shadow mask so that all readings taken with them automatically account for body shadow effects. The cylinders were positioned such that the body shadow was that which would be cast by a person sitting squarely behind a desk with their line of sight perpendicular to the front edge of the desk. For some readings, however, the cylinders were turned through 45° to simulate the effect created by a person bodily shifting his or her torso and line of sight to 45° either side of the desk-centre line, (see

Fig. 1. Location of test points.

DESCRIPTION OF SYSTEMS APPRAISED (See Table 1)

Systems A to E all incorporated task lighting luminaires built under a shelf on the vertical panel at the back of each work station. In system F two luminaires were mounted in line under a shelf to one side of the work station. Both systems G and H had movable luminaires on a swivel arrangement. For E and F, measurements were also taken for horizontal surfaces at right angles to the main horizontal desk area (marked with an asterisk

TABLE 1
Illuminance, ESI, CRF and Power Loadings

Appraisal	T-Task A-Ambient Description	(1x) Total System Illuminance	(1x) Task Illuminance Only	(1x) Total System E.S.I.	CRF	Total Lamp Wattage for Task Lighting (Watts)	Approximate Power Loading (Watts/sq.m)	Location of Test Points	Uniformity Ratio Task Area	Uniformity Ratio Work Surface
A1	T + A	503	364	405	0.962	40	31.0	Figure 1	0.78	0.43
A2	A	139		53	0.848			Figure 1	0.86	0.50
B1	A	346		116	0.829			Figure 1	0.92	0.30
B2	T + A	801	455	253	0.831	40	25.6	Figure 1	0.87	0.58
C1	T	528	528	287	0.894	40		Figure 1	0.47	0.31
C2	T + A	810		351	0.877	40	14.8	Figure 1	0.68	0.53
C3	T + A	1146		479	0.885	40	25.3	Figure 1	0.77	0.68
C4	T	960	960	459	0.878	40		Figure 7	0.56	-
C5	T + A	1517		612	0.881	40	25.3	Figure 7	0.79	-
C6	T	1105	1105	557	0.872	40		Figure 7	0.70	-
C7	T + A	1550		645	0.864	40	25.3	Figure 7	0.84	-
D1	A	179		102	0.941			Figure 1	0.84	0.43
D2	T + A	1017	838	215	0.793	40	22.5	Figure 1	0.84	0.58
D3	T + A	728	549	162	0.793	40	22.5	Figure 1	0.82	0.59
D4	T + A	803	624	234	0.822	40	22.5	Figure 7	0.85	-
E1	A	353		123	0.847			Figure 2	0.82	0.41
	A	388		157	0.873			Figure 2	-	-
E2	T + A	1098		312	0.832	30	20.0	Figure 2	0.78	0.71
	T + A	475		216	0.891	30	20.0	Figure 2	-	-
F1	A	512		202	0.877			Figure 3	0.98	0.91
	A	130		76	1.031			Figure 3	1.00	-
F2	T + A	532	20	224	0.888	40	18.7	Figure 3	0.98	0.92
	T + A	631	501	287	0.892	40	18.7	Figure 3	0.81	-
F3	T + A	528		244	0.899	40	18.7	Figure 7	0.97	-
G1	T	131	131	172	1.036			Figure 5	0.61	0.24
G2	T + A	483		334	0.947	44	24.0	Figure 4	0.79	0.47
H1	A	80		50	0.955			Figure 6	0.88	0.65
H2	T + A	815	735	570	0.948	84		Figure 6	0.74	0.55
H3	T + A	378	298	170	0.873	40		Figure 6	0.85	0.60
H4	T + A	539	459	486	0.989	44		Figure 6	0.74	0.53
H5	T + A	619	539	619	1.004	44		Figure 6	0.79	0.60
J1	T + A	416		146	0.839	85	18.7	Figure 1	0.91	0.85
K1	T + A	468		155	0.839	250		Figure 1	0.96	0.66
L1	A	844		337	0.896		27.5	Figure 1	0.99	0.89
M1	A	932		559	0.939		33.9	Figure 1	0.95	0.90
N1	Localized/ General	588		154	0.813		21.5	Figure 1	0.95	0.91
N2	Localized/ General	485		232	0.890		17.2	Figure 1	0.93	0.90

in Table 1). For appraisal A to H ambient lighting was provided by ceiling-mounted luminaires.

Systems J and K each incorporated a single luminaire in the work station itself which provided both task illumination and indirect

ambient illumination; L and M free-standing indirect torcheres and N ceiling-mounted localized-general luminaires.

RESULTS

The main body of the results obtained from the appraisal are given in Table 1.

The number following the letter assigned to each appraisal indicates a modification to the basic system, for example, a change in lens, or simply to distinguish between measurement of task illumination alone compared to task plus ambient lighting.

The second column in Table 1 indicates whether measurements were made on the combined task-ambient system or task or ambient lighting alone with the corresponding illuminance given in column 3. By simple subtraction, values for task illuminance can be calculated (column 4).

Values of ESI are tabulated for each appraisal but it is not possible to simply subtract to obtain data on task illumination alone because of the non-linear transformations in the derivation of ESI. Similarly, values of the CRF can only be listed as measured and no further calculations performed.

Column 7 contains the lamp wattage (excluding extra ballast wattage loss) for the task lighting alone; the higher values for J and K are a result of the additional indirect lighting function of these luminaires. However, the ballast wattage lost was taken into account when calculating the approximate power loadings given in column 8. Interpretation of these loadings requires some caution. The values given are for power loadings as found "on-site" where the systems were appraised. A number of the lighting systems appraised were small sample systems making it difficult to determine an accurate representative figure for the power loading expected in an actual office space. The power loadings given must be considered therefore as indicative only.

The uniformity ratio (columns 10 and 11) is defined as the ratio of the minimum illuminance to the average illuminance within a given area. Two areas were considered; the task area is the shaded area in Figs. 1 to 6 and the work surface the entire area of the horizontal desk surface. The ratio is employed to indicate the variation in illuminance within

these given areas. The British IES Code (1977) recommends that the ratio should normally be not less than 0.8 and this value is also used here as a criteria for acceptable uniformity.

The values given in Table 1 for illuminance, ESI and CRF refer to averaged data for each appraisal over the shaded area indicated in the figures. This corresponds to an area approximately 50 cm × 25 cm and is arbitrarily judged as the area most likely to contain visual tasks demanding the most critical visual attention. Those measurements obtained at the six positions shown in Fig. 7 are all averaged to give the values shown in the table. The measurement area in this case is a triangle with apex at the observer with base length 78 cm and height 39 cm.

The measurements of luminance and reflectance are given in Table 2. The ratio of the surround luminance of the desk surface to that of the task (a "standard" white reflectance card) are calculated for comparison with recommended practice.

DISCUSSION OF RESULTS

Unlike illuminance measurements, it is not possible to quantitatively separate task ESI and CRF values from the combined values for task plus ambient light by subtraction. Separate measurements must be performed for the two lighting systems. It is informative however to examine relative changes in these values within each appraisal and between different appraisals. In addition, one learns how useful this particular appraisal procedure of "on-site" survey can be. The changes in the CRF indicate the effect on contrast whereas the changes in ESI the combined effect of contrast and light level.

Appraisals A, B

For appraisal B, the ambient light accounted for over 43% of the total illuminance on the work surface. The addition of task light to ambient light more than doubled the ESI (from 116 ESI to 253 ESI) without improving the CRF. In A the addition of task light increased the ESI nearly eight times (from 53 ESI to 405 ESI) and also improved the CRF by 13% (from 0.848 to 0.962). Thus for A, ambient lighting makes a small contri-

TABLE 2
Luminance and Reflectance

Appraisal	Average	Average	(cd/m ²)	(cd/m ²)	Surround Luminance
	Reflectance of	Reflectance of	Average	Average	
	Horizontal Work Surface	Rear Vertical Panel	Luminance of Horizontal Work Surface	Luminance of Rear Vertical Work Surface	
					Task Luminance
A1	0.44	0.20	124	66	0.46
B2	-	0.08	-	16	
C1	0.52	0.42	130	105	0.87
C2	-	-	183	118	
C3	-	-	227	130	
D2	-	-	173	-	
D3	0.46	0.10	135	15	0.54
E2	0.49	0.05	193	11	0.56
E2*					0.36
F1	-	-	46	-	
F1*	-	-	18	-	
F2	0.23	-	45	-	0.28
G2	0.49	0.41	94	59	0.61
H1	-	-	-	18	
H2	0.52	0.63	159	154	0.67
H3	-	-	-	72	
H4	-	-	-	97	
H5	-	-	-	144	
J1	0.30	0.55	48	26	0.35
L1	0.56	-	156	-	0.66
M1	0.54	-	193	-	0.68
N1	0.19	-	42	-	0.23

bution to ESI whilst for *B* the contribution is more significant.

Appraisal C

Table 3 gives more details of appraisal *C*. Lenses α and β refer to acrylic lenses with different refracting properties. Appraisals *C4* and

C5 differ from *C1* and *C3* respectively in that for the former, appraisal measurements were taken at the positions illustrated in Fig. 7, whereas *C1* and *C3* followed the pattern of Fig. 1.

Referring to the values of illuminance, ESI and CRF in Table 1 the difference between

TABLE 3

Details of appraisal C

Appraisal	Task lighting	Ambient lighting
C1	Lens α 1 $\times$ 40 W lamp	
C2	Lens α 1 $\times$ 40 W lamp	2 $\times$ 40 W lamp
C3	Lens α 1 $\times$ 40 W lamp	4 $\times$ 40 W lamp
C4	Lens α 1 $\times$ 40 W lamp	
C5	Lens α 1 $\times$ 40 W lamp	4 $\times$ 40 W lamp
C6	Lens β 1 $\times$ 40 W lamp	
C7	Lens β 1 $\times$ 40 W lamp	4 $\times$ 40 W lamp

each of the *C* appraisals can be explored. The CRF altered very little from *C1* through *C7*; the mean CRF equals 0.879 with a standard deviation of $\sigma = \pm 0.009$. The uniformity ratio is generally poor amongst the *C* appraisals (less than 0.8 and as low as 0.31) and explains the large apparent difference in task illuminance alone between *C1* (528 lx) and *C4* (960 lx) where only the measurement locations were changed (see Table 3). Since the CRF is almost constant the changes in ESI are due solely to the changes in illuminance level. Perhaps these measurements could be used by a designer to lead him to re-design the luminaires and their location to improve the CRF as an energy effective method of improving ESI. Note that under the lighting systems common to many offices a 1% increase in the CRF results in a 7% increase in ESI at the same illuminance level. The alternative method of increasing ESI, as is clearly apparent from appraisal *C*, is to raise the illuminance level. This, of course, could be achieved in an energy effective fashion if it were possible to bring the lamps closer to the task area without introducing excessive glare or luminance ratios or detracting from the aesthetic appearance of the furniture.

Appraisal D

The ambient lighting in appraisal *D* was a combination of semi-indirect and indirect lighting producing a relatively high CRF (0.941) but low light level (179 lx). Task

lighting was provided by mounting a bare fluorescent lamp under a shelf on the vertical panel at the rear of each work station. Referring to Table 1, it can be seen that the CRF actually decreases upon the addition of task lighting. This is not surprising since the lamp is placed close to, or at, the specular reflection angle, an apparently popular location for many of the systems studied. In *D3* a prismatic lens was placed over the bare fluorescent tube which reduced the task illumination and did not improve the CRF; consequently the ESI was lower than for *D2* (162 ESI compared to 215 ESI). *D4* measurements are on the same system as *D3*, but taken at different measurement locations. The *D* system showed good illuminance uniformity over the task area but a poorer distribution over the entire work surface.

Appraisal E

Uniformity improved when task lighting was added to the ambient lighting for appraisal *E* (from 0.41 to 0.71). Here ambient lighting was supplied by semi-indirect torcheres with task lighting at the rear vertical surface of the work station mounted under a shelf. Like *D* this task lighting location produces rather poor CRF and ESI (maximum CRF and ESI, 0.891 and 312 ESI respectively).

Appraisal F

For appraisal *F* the task lighting came from one side of the work station with ambient lighting provided from an indirect luminaire built into the work station. Uniformity is excellent and the CRF values are close to 0.90. Comparing *F2* and *F1* it is immediately apparent that the main contribution of task illumination is to run off areas at positions 16-20 (see Fig. 3). The task light does little to illuminate the task area.

Appraisal G

Task lighting in *G* was from louvred movable luminaires clamped to the work station with ambient lighting provided by indirect luminaires. The optimum position for the task light is left to the judgement of the user. The measurements given in Table 1 show that although there was poor uniformity of illuminance (less than 0.5 over the work surface) the CRF was high but ESI low because of insufficient illumination.

Appraisal H

In a similar operation to *G*, system *H* allowed the user to control the position of the task lighting luminaires. One task lamp was fixed at the back of the work station with two others re-locatable on a horizontal axis at right angles to the observer's viewing direction. Incandescent lamps in the ceiling provided the ambient lighting which did not contribute significantly to the illuminance on the work surface (80 lx) but on the other hand had no deleterious effect on the CRF (CRF = 0.955 for ambient lighting alone).

Appraisals *H2* to *H5* all have the same ambient lighting conditions but differ in task lighting details. *H2* refers to the entire task lighting system of one "back" lamp and two relocatable lamps; for *H3* the back lamp only was lit; for *H4* only the relocatable lamps were on and *H5* is similar to *H4* except that the lens was removed from the two movable luminaires. The results in Table 1 demonstrate that the back lamp provided poor CRF (0.873) but good uniformity (with low ESI) on the task area. The movable lamps by themselves, *H4*, have excellent CRF (0.989) with moderate uniformity. The combination, *H2*, retains the moderate uniformity of *H4* but also gains improved CRF over *H3* (0.948 to 0.873). The removal of the lens in *H5* (compared with *H4*) shows a substantial improvement in ESI (619 ESI compared to 486 ESI) and in uniformity (0.60 compared to 0.53).

Appraisals J, K

Appraisal *J* is an example of a combined task-ambient luminaire built into the work station. The excellent uniformity is accompanied by moderate CRF and low ESI. *K* is a similar system with ESI, CRF and uniformity close in value to that of *J*.

Appraisals L, M

L and *M* are both examples of free-standing indirect luminaires. Both show excellent uniformity with *M* exhibiting the superior CRF and ESI.

Appraisal N

N is the only appraisal of ceiling-mounted localized luminaires. As may be expected from a ceiling system, the uniformity is good. However, the CRF is poor for *N1* (0.813). The conditions for *N2* were similar to those

for *N1* except that a luminaire immediately in front of the desk and parallel to its centre-line was removed. Notice the lower power loading but higher CRC (0.890) and ESI (234 ESI compared with 154 ESI for *N1*) for appraisal *N2*.

Summary of results

The results in Table 2 can be evaluated in terms of current recommended practice in North America. The recommended surface reflectances of furniture and office machines and equipment is in the range 0.25 to 0.44. Only appraisals *A* and *J* fall strictly within this range, with *C*, *D*, *E*, *G*, *H*, *L* and *M* all having higher reflectances and *F* and *N* values which are too low. The reflectance of walls should be in the range 0.40 to 0.60. If the vertical surfaces of the furniture are regarded as walls then *C*, *G* and *J* are correct, *A*, *B*, *D* and *E* are too low and *H* just a little too high.

The recommended luminance ratio between the task and adjacent surroundings is in the range of 1/1 to 1/3. Apart from *F* and *N* all the systems measured fell within this range. The task luminance is taken as the luminance of the standard white reflectance card (reflectance 0.80).

Figure 8 summarizes the results for all of the 37 appraisals (13 basic systems). The large scatter in illuminance, ESI and CRF values is immediately apparent. No system achieved the IES recommended value of 750 ESI and of the 37 appraisals, only 13 had illuminance values equal to or greater than 750 lx. CRF values varied from a maximum of 1.036 to a minimum of 0.793. It is noticeable that the appraisals exhibiting high CRF generally gave illuminance values less than 750 lx (e.g. *F1*, *G1*, *H4* and *H5*).

A common practice of using the ratio of ESI to illuminance level (sometimes referred to as the "lighting effectiveness factor") has been avoided as a figure of merit for the different systems appraised. The ratio can be misleading, for instance when the CRF is greater than unity but ESI less than horizontal illuminance. This situation arises from the method of calculation of ESI which uses a reflectance factor (range 0 to 1) to convert an effective reference sphere luminance to equivalent sphere illuminance but a luminance factor (range 0 to infinity) to originally convert the illuminance to luminance.

Fig. 8. Distribution of illuminance, ESI and CRF values.

Power loadings

Column 7 of Table 1 lists the wattage for the task lighting alone. The majority of systems where the task lighting is built into the furniture require a single 40 W fluorescent lamp. Assuming such a lamp can provide the correct quality and sufficient quantity of task illumination when combined with an ambient lighting system, providing 300 lx of illumination for circulation and access, it is interesting to speculate on the power loadings that could be achieved in conventional offices. However, an accurate speculation along these lines relies on good data on the use of space in modern offices.

A recent Canadian survey [7] of one million square feet of office space containing approximately five thousand work stations reveals an average area for a work station of 8.4 m². The work station area is defined as the space occupied by the office furniture plus the space required for access to it. Assuming that 300 lx is provided uniformly

everywhere in the space a power loading for ambient lighting using general diffuse fluorescent luminaires could be of the order of 13.4 W/m². If the office space is divided up such that there is one work station every 8.4 m² then the power loading for task lighting alone would be $(40 + 8^*)/8.4 = 5.70$ W/m². The total power loading is then projected at $13.4 + 5.7 = 19.1$ W/m². This figure is within current Canadian guidelines [2] and is deemed potentially energy-efficient when compared to contemporary office lighting power loadings. Of course the above values will vary depending on the actual work station area and the design of the ambient lighting system. However, compared with other recent estimates [8] the values given tend to be on the high side.

The use of power loadings in the evaluation of task-ambient lighting systems requires some caution. Many manufacturers of task-

*8 W accounts for the ballast consumption.

ambient lighting quite correctly promote their systems on the basis of low W/m^2 . It is also true that the power loading is invariant to the position of the furniture in a given space. However, if furniture containing task luminaires is relocated, its effectiveness in terms of the CRF and ESI in the task area can alter dramatically because of the non-linear addition of the CRF and ESI of the ambient lighting. Where no ambient lighting is installed in the ceiling the relocation of furniture is less apt to result in large changes in ESI and the CRF since it is only the proximity of different reflecting surfaces that will affect their final magnitudes.

A number of suppliers of task-ambient lighting systems provide a template by which the luminaires for ambient light may be laid out in the ceiling to provide a uniform horizontal illuminance on the working plane. It is then assumed that the furniture, and its incumbent task lighting, can be installed anywhere and still result in good ESI in the task area. A basic understanding of the principles of ESI leads one to conclude that this is an erroneous assumption. Perusal of Table 1 and Fig. 8 illustrates quite dramatically the separate qualities of task and ambient lighting and the significant changes in ESI and the CRF that can occur when they are combined.

The use of task-ambient lighting systems in office spaces requires the lighting designer to reconsider the importance of the reflectances of vertical surfaces and their illumination. Wall reflectances recommended by the IES (North America) are based on a ceiling system giving an illuminance of approximately 1000 lx. If, in task-ambient installations, the ceiling system provides only 300 lx then large areas of vertical surface (e.g. walls) will appear quite dull resulting in a gloomy impression of the entire interior. Perhaps up to $3W/m^2$ should be included in the total power loading in task-ambient systems for wall lighting. In any event, some provisions for improving the brightness of vertical surfaces should be included in final loading figure.

CONCLUSIONS

The quantity and quality of the illumination from the sample of task-ambient systems

investigated varied enormously. No system met North American recommended IES lighting levels [9] in terms of ESI and only a small minority met the levels in terms of horizontal illuminance.

Although appraisals could not be performed under controlled photometric conditions, it was possible to observe how task and ambient lighting interact to produce the resultant values of illuminance, CRF and ESI. The photometric appraisal procedure employed was found to be convenient, reasonably quick and provided data producing consistent, sensible results.

The type of data collected in Tables 1 and 2 could provide a suitable basis for both users and designers of task-ambient lighting systems to assess lighting quality. Illuminance, CRF, ESI, power loading, uniformity ratio and surface reflectances are all required to properly evaluate task-ambient lighting systems.

It is incorrect to assume that low ambient lighting levels have an insignificant effect in the quality of light at the work station. In addition, the low ambient light levels require that the reflectances of major vertical surfaces are well above the minimum recommended values. These surfaces should be separately illuminated and the resulting power loading included in the total W/m^2 .

The "contrast rendering factor" has recently been evaluated as a figure of merit for different lighting systems [10]. The present results show the danger in using the CRF for this purpose since the light adaptation level is so important to visibility as can be examined through the separate effects of the CRF and illuminance on the final ESI value. The authors are therefore not surprised at the negative conclusion regarding the use of the CRF as a figure of merit found in this recent study [10].

It is the opinion of the authors that task-ambient lighting systems offer significant potential for power savings for lighting energy consumption and that there is ample room for better designed systems to improve the quality and quantity of illumination in an energy-efficient manner. Furthermore, it is believed that with these improved systems it will be possible to comply both with the recent Canadian government recommendation of a lighting load not exceeding $22 W/m^2$ and cur-

rent North American IES recommended illuminance levels.

The paper has not considered the relative economic benefits or otherwise for the different task-ambient lighting systems nor investigated the difficulties and cost in getting power to the systems; these aspects have been discussed elsewhere [8, 11].

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