An Evaluation of Five Low-Energy Office Lighting Systems

*By Warren G Julian**

Introduction

As part of the Enex-Asia '96 exhibition, five small office lighting systems were designed and installed by four manufacturers/agents. Each office was identical in size and furnishings. The manufacturers were supplied with a detailed brief of the lighting and energy performance expected.

It was implicit but not expected that the task lighting requirements could be met by local lighting. The quality criteria, in terms of energy and lighting, meant that consideration had to be given to both horizontal and vertical tasks.

The brief

The brief was developed by Bo Steiber of Vision Studio (Singapore) with the assistance of the IESANZ(NSW) and was based on a similar "competition" conducted in Sweden in 1993 by Nutek called "Ljusa Korridorer".

Each office was 3000 x 2500 x 2700 with white walls (Nippon Emulsion paint 9012, reflectance 0.8), white ceiling (Celotex mineral wool, reflectance 0.8) and grey needle punch carpet floor (reflectance 0.10). The furniture comprised Diethelm Industries desk and cabinet with reflectances of 0.45. A Mitsubishi VDU was placed on each table.

Each manufacturer was required to provide detailed information on the performance of their systems against the criteria set out in the brief. The criteria are shown in the table summarising the results (see page 23).

The solutions

Four Singaporean companies submitted five solutions which are described in the photographs and captions.

All used triphosphor tubular fluorescent lamps and electronic control gear to meet the energy, colour rendering and flicker criteria. Three of the schemes included desk mounted task lights to provide supplementary lighting over the "reading field" — an A3 size area to the right of the VDU.

The solutions were installed in an area of the Enex-Asia '96 exhibition called the Lighting Technopark and attracted a lot of interest from visitors to the trade show.

The evaluations

Each of the solutions was tested for light-technical performance and energy consumption. The quality criteria were really demanding, especially the requirement for high contrast rendition (the avoidance of unwanted reflections).

The lighting systems were measured without the fourth wall (the opening of each stand). While some light from the exhibition hall entered each office, the missing wall reduced the interreflection of light, resulting in reduced illuminances and luminances. However, the effect would be similar to that in a real situation where an office door might be open, where part of the wall would be glazed, and where wall hangings would have reflectances less than those of the walls.

Illuminances were measured using a Minolta CL-100 chroma-meter, luminances using a Hagner S2 universal photometer and contrast reduction using a Brüel and Kjaer Type 1100 luminance contrast meter.The contrast rendering factor (CRF) was determined from the contrast reduction (R). The technique used with the Brüel and Kjaer instrument involves determining the luminance of a standard task, calculating the contrast and determining the contrast reduction (as a percentage of the maximum contrast possible from the task under a reference lighting condition).

The method and the standard task were developed by the Danish Illumination Engineering Laboratory at the Academy of Technical Sciences. The standard task simulates ink (or pencil) on paper and comprises two ceramic discs, one white and one black and each with a slight gloss, similar to that of most papers and inks (on paper) or pencil graphite.

The area that is evaluated for reading or writing horizontal tasks is an A3 size area. The instrument is designed to adjust the viewing angle to the task and includes the effects of body shadow on the parts of the task near to the observer.

As noted above, the CRF indicates the performance of

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the lighting at points on the reading field relative to that of a reference lighting system. Since the standard task has some gloss, the contrast between the black and white discs will be reduced when any light source is imaged in the discs. So, a choice has to be made regarding the reference lighting system.

One choice is that used when the IESNA recommended equivalent sphere illuminances (ESI). Basically, an efficient lighting system was one which achieved a high ESI for a "low" horizontal illuminance (implying that unwanted reflections were avoided). If ESI is used as the reference, the implication is that the task is located in a uniformly lit sphere. It should be noted that this is not the best way to light glossy tasks in order to achieve maximum contrast, since part of the "bright" sphere will always be reflected towards the observer's eyes from the task. However, the sphere illumination might simulate the effects of walls (in small offices), where the reflected component of the lighting can be significant and where the wall luminances could reduce contrasts. On the other hand, sphere illuminance is a simple concept and is useful as a reference lighting system. The maximum contrast possible with the standard discs, under sphere illumination is 0.91 (91 per cent), however, the maximum achieved with directional light is 0.98 (98 per cent).

In the evaluations used on the five lighting systems the much more difficult criteria of a directional reference lighting system was used, rather than sphere illumination. This choice was made because many offices are large, many modern workstations have low reflectance surrounds and many lighting systems are "direct", with the possibility of imaging lamps in the task. The charts show CRF (as a per cent) for the maximum contrast of 0.98. The contrast reduction, R, is 100-CRF. If the contrast reduction is needed for sphere illumination where the maximum contrast is 0.91, it can be derived using $R_{91} = (0.98R-5)/91$. Thus, for example, a contrast reduction of 16 per cent when the maximum contrast is 0.98 becomes a reduction of 9 per cent when the maximum contrast is 0.91.

In the charts whenever the CRF is greater than about 94 per cent, the CRF under sphere illumination will be greater than 100 per cent, that is, the lighting system will reveal the task better than a sphere illumination system.

The systems which used desk lamps for task lighting were not evaluated with the task lighting on — this is because the desk lamps could be located to either improve or (significantly) diminish the contrast rendering on the task area. Unless desk lamps can be located at the side of the task area or high, almost above the observer's head, they will result in veiling reflections in glossy tasks.

Another point of interest for those involved in on-site evaluations: the measurements were taken on two different days. Each of the CRF charts shows a rough sketch of the desk top and spot illuminances. The detailed illuminance measurements are shown on the plan of the rooms. In both cases the readings were taken with the experimenter seated in the office chair. The difference in the readings is partly the result of the experimenter wearing a white shirt for the detailed illuminance measurements (rather than a dark blue shirt for the contrast measurements).

The results

The results are given in the various diagrams and charts and are summarised in the table against the criteria of the brief. It should be noted that the values measured are "initial", since the installations were new. The assumed LLF for design purposes was 0.85.

As can be seen from the table, all of the systems achieved the design objectives in terms of illuminances but the more indirect schemes needed the task light to be used. The schemes using ceiling mounted (suspended) uplight/downlight luminaires were the least efficient and failed to achieve the desirable objective of an electrical load density of <12W/m².

System 4, which used a recessed luminaire was, to some extent, compromised by the ceiling grid. For example the CRF was lower than possible because the luminaire was mounted over the reading field (see photo over page). A better result would have been achieved if the luminaire were over the seat position, parallel to the wall.

Considering the limitations imposed by the display stand module, all systems had commendable features. In terms of both lighting quality and energy minimisation, the systems that had some upward component but with a major downward component were better than other options. In a small office, System 5 produced excellent results but required the placement of the uplighter as shown: the upward component lighting the walls and ceiling and the downward lighting the reading field from the appropriate side. (In this case it is better suited to left-handed people, although the light surfaces result in good indirect flux, softening any direct shadows.) ►

Criterion	Mandatory	Desirable	System 1	System 2	System 3	System 4	System 5
Reading field illuminance[1]	≥ 500 lux		>750 lux	>380 lux	~500 lux	>420 lux	>480 lux
Desk illuminance	≥ 300 lux		>400 lux	>300 lux	>360 lux	>280 lux	>200 lux
General illuminance (at 850mm)	≥ 100 lux		>300 lux	>300 lux	>350 lux	>270 lux	>200 lux
Vertical illuminance (bookcase etc)		≥ 100 lux	~290 lux	~230 lux	~260 lux	~270 lux	~230 lux
Vertical illuminance (on VDU)[3]		≤ 200 lux	~350 lux	~250 lux	~250 lux	~190 lux	~230 lux
Luminance in working area	≤ 500 cd/m²		Yes	Yes	Yes	Yes	Yes
Luminance outside working area	≤ 1000 cd/m²		Yes	Yes	Yes	Yes	Yes
Luminance ratio in working area[4]		10:3:1	Yes	Yes	Yes	Yes	Yes
Maximum luminance range[5]		≤ 20:1	Yes	Yes	Yes	Yes	Yes
CRF[6]	80%		Yes	Yes	Yes	Yes[7]	Yes
Ra	≥ 80		Yes	Yes	Yes	Yes	Yes
CCT		2700-4000K	Yes	Yes	Yes	Yes	Yes
Flicker	Imperceptible		Yes	Yes	Yes	Yes	Yes
HF control	Yes		Yes	Yes	Yes	Yes	Yes
Installed load[8]		<12W/m²	9.33W/m²	14.67W/m²	20W/m²	9.33W/m²	10W/m²

Notes:

1 These illuminances are from the main lighting system. Those with task lights produced higher illuminances than shown and all complied with the requirement for ≥500 lux.

2 The vertical illuminance on the book case was measured at seated eye-level (1200mm).

3 While most systems exceeded the recommended 200 lux on the screen, image quality was good since the reflections were of the walls.

4 The desirable luminance ratio (10:3:1) indicated the ratio that should be exceeded. As can be seen from the diagrams, the small offices were very uniform in luminance distribution due to the high reflectance surfaces.

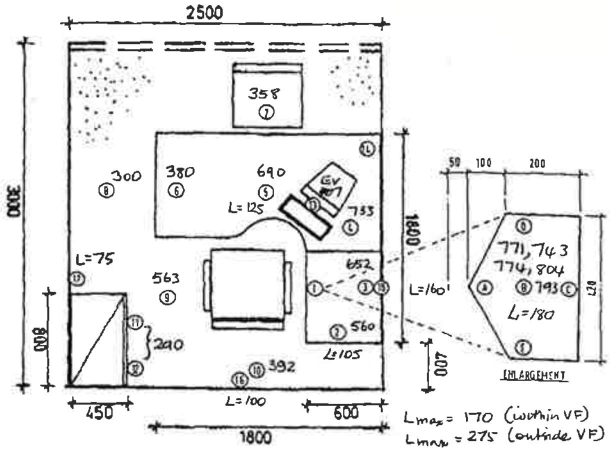
5 Similarly, the maximum luminance ratio was small due to interreflections. Luminance luminances were higher but, due to the size of the room, more were in the field of view.

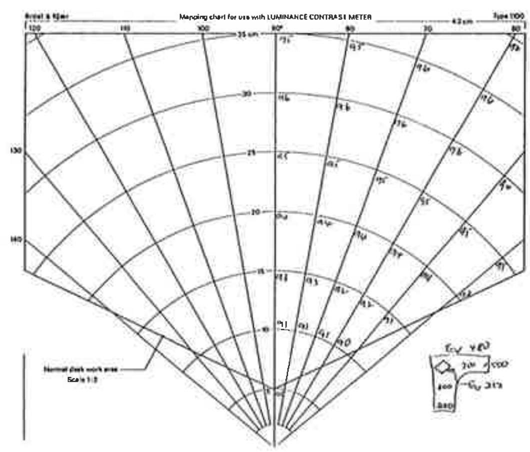
6 The brief stated a maximum contrast reduction of 15% and it is assumed that the criterion was based on the sphere illumination reference conditions, where the maximum contrast possible with the standard task is 91%. As noted in the text, the tests were conducted with a maximum contrast of 98%. Converting the test results sets the CRF at 80% (or a maximum contrast reduction of 20% based on the direct lighting reference condition).

7 This system did not meet the criterion at the "bottom" of the reading field. This was also predicted by the designer, but to the side of the test area due to the luminaire location (determined by the ceiling grid).

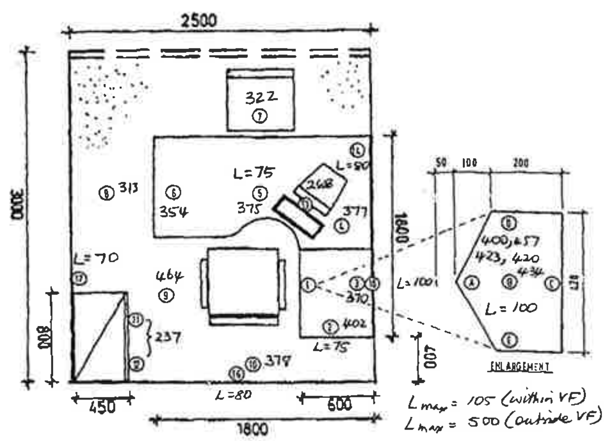
8 Systems 3 and 5 provided no information on loads, so they were estimated from the lamps installed and losses.

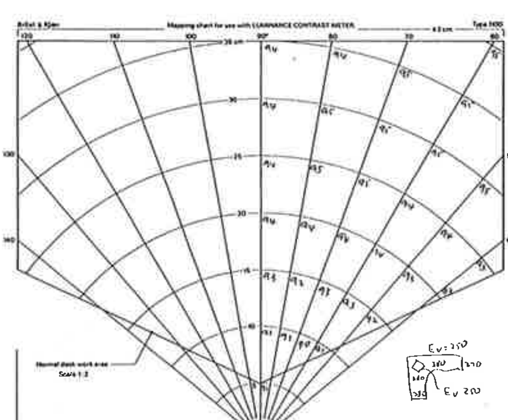
System 1. *This used a Zumtobel Spheros SAC-ID 2x32 watt luminaire supplied by Elite Manufacturing Co, Singapore.*

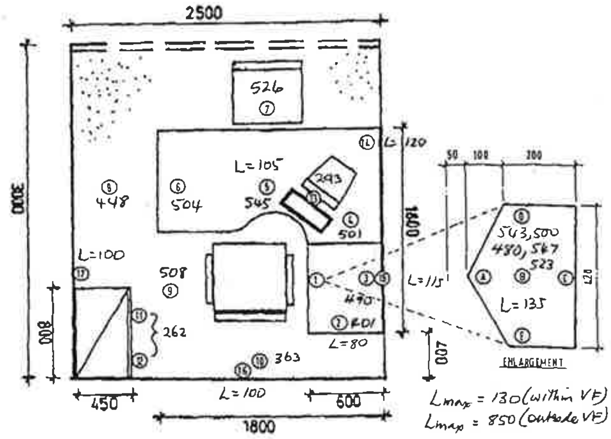


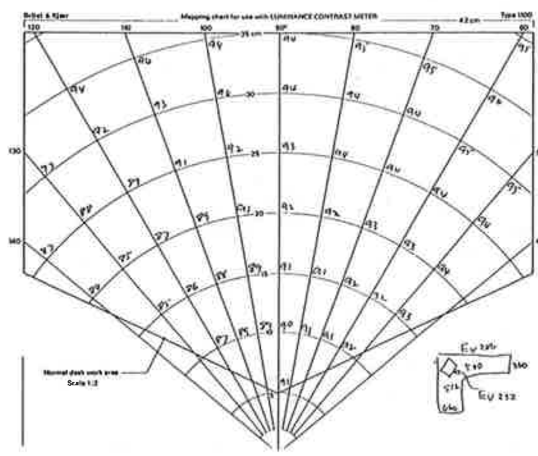


System 2. This used a Waldmann Corto LKP258 2x58 watt luminaire supplied by Waldmann Lighting, Singapore. The task light was a Waldmann F1, 1x18 watt "flat lamp".

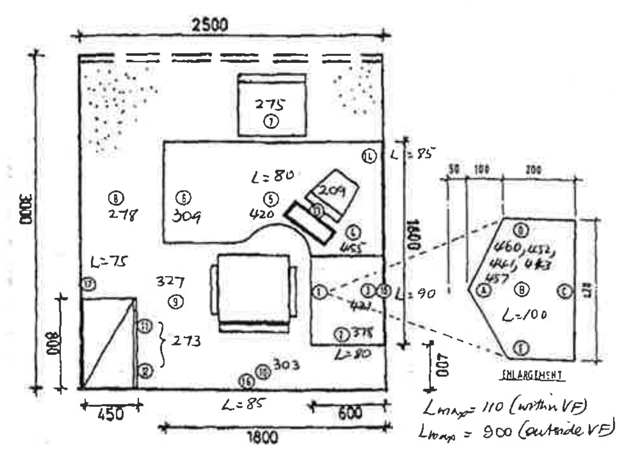


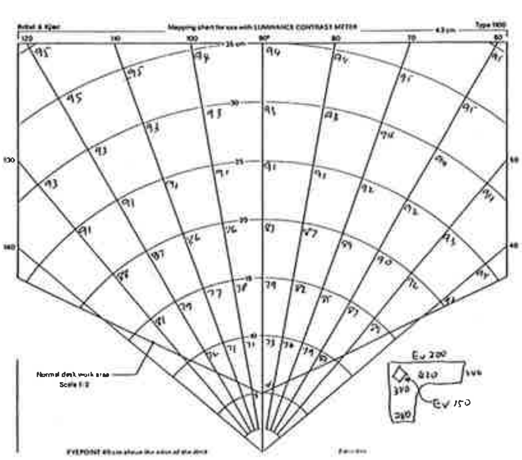






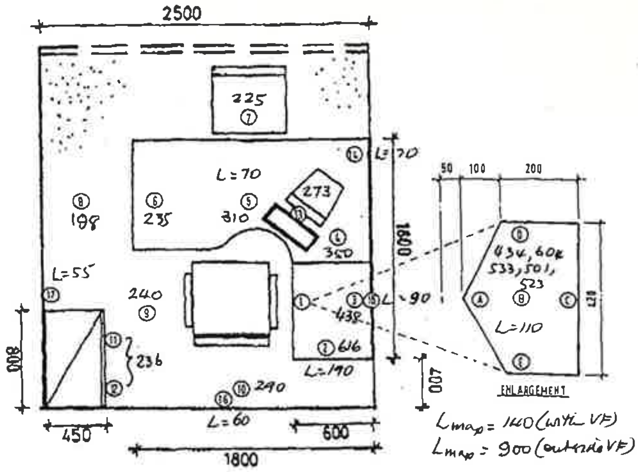
System 3. This used a Cosmolight 4x36 watt (TC-L) luminaire supplied by Thorn Lighting, Singapore.

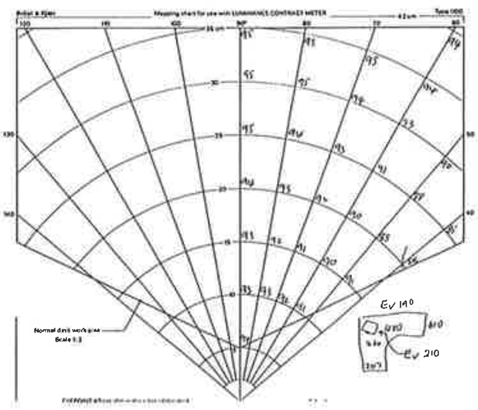




System 4. This used a Zumtobel RCE 2x32 watt (Mellowlight) luminaire supplied by Elite Manufacturing Co, Singapore. The task light was a Zumtobel OC-T 2x9 watt.

System 5. *This used an Iguzzini Vela 2x36 watt uplight (with a downward component) and a Tavolo 1x11 watt task light from Relex Lighting (FE), Singapore.*





Conclusions

The Lighting Technopark was an interesting addition to the ENEX trade show since it provided visitors with examples of how good lighting can be produced with low energy consumption. The companies that entered systems in the competition gained from the experience both in terms of visitor interest and in trying to achieve design objectives in advance of those normally applied in office lighting design briefs.

It would be interesting to see similar competitions held at other exhibitions since the realistic environments provided more information than the assembly of competing luminaires usually found in manufacturers' stands. ❖

Bo Steiber's Vision

THE Lighting Technopark at Enex Asia '96 was made possible by Bo Steiber of Vision Design Studios, Singapore. Bo joined VDS in 1993 as NSW manager after working for ASEA-Atom in Sweden, Rankine and Hill in Sydney and as a director of Donnelly Simpson Cleary Engineers in Sydney. He has 20 years experience in electrical engineering and lighting and was appointed VDS Regional Manager in Singapore in 1994.

Bo's interest in lighting developed after his move to Australia in 1982 and he enrolled in the Graduate Diploma in Design Science (Illumination) at the University of Sydney in 1983. From his approach to lighting he has become a lighting designer, working closely with architects to add value to their design through complementary lighting. He has developed a special expertise in lighting for the hospitality industry but also takes a keen interest in lighting for the workplace. It was that interest that led to the Lighting Technopark idea for Enex. Being a member of the IESANZ, he worked with other IES members in Sydney to develop the concept.

Bo's projects include Hanoi Sailing Club, Singapore Tourist Promotion Board Headquarters, Bank of China, the Hilton International and Omni Marco Polo hotels in Singapore, and the Glen Marie Country and Golf Resort in Malaysia. He has won six lighting awards in Australia, including one for the Novotel, Darling Harbour, Sydney.

VDS in Singapore has become a major design office competing successfully with US firms for lighting design work in the region. The office has grown and has four designers: with Bo are Amanda Choi, Gina Gow and Eunice Heng. Bo sees an exciting future for lighting design in Singapore and the region and is looking forward to the establishment of an IES and the introduction of lighting education. He can be contacted at Vision Design Studios, Singapore. Ph:(65) 224 2886. Fax:(65) 224 9203. ❖ *(Warren Julian)*