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Information

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Prezentări tehnice

Conferințe şi simpozioane

Informații

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PHILIPS

ENERGY EFFICIENCY AND NEW TRENDS IN LIGHTING

Dr. Florin POP, Professor

This issue has two noticeable characteristics: (a) it is mainly devoted to the papers presented at the Third International conference on lighting ILUMINAT 2005 & BALKANLIGHT 2005 with Energy Efficiency and New Trends in Lighting as the main themes, and (b) it presents the new modality to be edited, with the financial support of our sponsors, main players in the lighting field on the Romanian market. The main two lighting companies offered their support such that the INGINERIA ILUMINATULUI journal may continue to appear: PHILIPS Romania, Lighting Division for this issue no. 15 – Summer 2005, and OSRAM Romania for the next one, issue no. 16 – Winter 2005. It is an honourable duty to say THANKS to them.

The first paper by **Dobre** and **Achard** describes the characterization relating to the computer-simulation phase to determine the light pipe recurrence laws, and the optical simulation phase in the production of a light pipe model. The paper emphasizes the scientific results of a doctoral thesis, presented in the previous issue of the journal (issue no. 14), and of the research of Professor **Achard** team (issue no. 13).

In order to understand the light pipe extraction system and be able to produce an optical model, the authors established the recurrence laws related to the extracted fluxes and the fluxes carried within the light pipe divided into unit sections, considered to be uniformly distributed along the pipe. The fluxes can be given as a function of the injection flux of lamp/lamps, or as a function of the fluxes entering each unit section. Given that the simulation of a light pipe is complicated mainly due to the size/shape of the prismatic microstructures, the authors produced a simplified optical model using the APILUX software, which allows the predicted illumination to be calculated. The model design comprises a series of transparent yet reflective concave mirrors, that can reproduce the same guiding and diffusion functions of the simulated light pipe. The reflectance, transmittance and absorbance in a case with losses, are set by applying the previously determined recurrence laws. The characterization and optical modelling of a light tube using the APILUX software enables prototype light pipes to be produced for specific applications - pipes supplied by a combination of natural and artificial light; pipes with light transmitting modules of different luminance levels, pipes with opaque light transmitting modules.

The paper of **Ikeda** and **Noda** refers to the colour rendering properties of the High Intensity Discharge (HID) lamps, which recently come into general use for indoor lighting. In order to investigate the perceived colour appearances under various HID lamps, perceived appearances of 40 Munsell colours with value of 6 and chroma of 8 have been subjectively evaluated under Xenon lamp (Standard illuminant D65), Incandescent lamp (Standard illuminant A), Metal halide lamp MT400DL, Fluorescent Mercury lamp HF400X and High Pressure Sodium lamp NH360. These psychological attributes have been compared with predicted metric quantities in Nayatani, Hunt, CIECAM, and NC-IIIC spaces. Then, it is found that metric quantities of test colours in the new uniform colour space NC-IIIC correspond more properly with perceived attributes under the illuminations of HID lamps than those in traditional colour spaces. Therefore, in the specification of colour rendering properties of light sources, the NC-IIIC space is superior to other colour spaces. The final conclusion of the paper is that new colour space NC-IIIC is appropriate for the consistent evaluation of perceived colour appearances and colour shifts under any test illuminant.

Ratz and **Yaneva** present a MAT LAB model for the simulation of both static and dynamic characteristics of Sodium High Intensity Discharge lamp. The proposed model is helpful for a preliminary design of electronic ballasts. Experimental results on Sodium - HID lamps at different conditions are presented and they appear to be in good agreement with the simulation results up to 1000 Hz.

Katerina TSIKALOUDAKI analyses the relationship between solar shading and daylighting. The applicability of several types of conventional sun shading devices in the Mediterranean climate is studied, with respect to their potentiality to act both as sun protection and daylight elements. The study is focused on the analysis of visual and thermal conditions, which prevail on the models of a parametric study. The analysis included both thermal and daylight aspects and was conducted by means of simulating programs - ADELINE for daylight estimations, and Thermal conditions were simulated with SUNCODE for thermal conditions. The author concludes that the investigation of the optimal shading device seen from both daylighting and thermal behaviour aspects has so far shown conflicting results. Therefore, the integration of efficient shading devices necessitates a prior decision upon the hierarchy of the objectives of the design; perhaps the solutions given for the achievement of optimal visual conditions, thermal environment or the environmental performance may vary.

Szabó, Zágoni and **Oltean** synthetisize the various activities involved in the process of investment implementation of lighting technology, from solution study to final reception. The design aspects of historical building lighting for the units included in the investment programme are exemplified with the execution *in situ* of the three projects that compose the III MILLENNIUM programme: the Commercial Center, Baia Mare, Romania.

Şuvăgău continues his very interesting and exhaustive column The Lighting in The New World with the presentation of the guidelines of the new ASHRAE/IESNA standard 90.1-1999. The standard clarifies requirements and provides simplified compliance paths. More importantly, the 1999 edition expands the code's scope to new and existing buildings and systems. The standard specifies limits on the total wattage used for lighting throughout a building by establishing a total LPA (lighting power allowance). The ILPA (Interior LPA) is calculated as the product between the building/specific area square footage and the LPD (Lighting Power Density - total lighting W/ft^2 specified for that building type). The standard also specifies limits on the total wattage used for exterior building entrance and exit lighting by establishing a total exterior lighting power budget. This is determined by totalling the lighting power allowed for all exits, entrances, and canopied areas of entrances. This budget can he used at the lighting designer discretion. The presentation concludes that the ASHRAE/ IESNA energy code offers only minimum energy standards. Consequently, property owners and their design professionals are urged to exceed these minimums to create more productive, profitable and comfortable environments.

The **ENERLIN** EIE SAVE program, coordinated by Professor **ZISSIS** proposes to develop and validate robust scenarios for CFL promotional campaigns in European, national and regional levels. The residential lighting market is still dominated by inefficient incandescence lamps (GLS). Market research has indicated that to achieve durable market transformation and to substantially increase the use of Compact Fluorescent Lamps (CFLs) in the residential sector, it is essential to develop and market attractive and goods quality CFLs. 14 partners from 14 countries constitute the ENERLIN consortium, covering a large part of the Europe form North to South and from East to West. The ultimate objective of this program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries, and offering them good arguments necessary to overcome the above-cited barrier can do this.

OPTICAL MODELLING OF A DIFFUSING PRISM LIGHT PIPE USING THE APILUX SOFTWARE

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Savoy University, Superior School of Engineer in Chambery (ESIGEC)
Optimisation of the Conception and Engineering of the Environment Laboratory

In the framework of the co-tutored thesis entitled "Contribution to the calculation and design of interior lighting systems by light pipes", supervised by the thesis directors: Prof. Dr. Eng Cornel BIANCHI (UTCB, Romania) and Prof. Dr. Eng. Gilbert ACHARD (LOCIE, France), we characterized photometrically a diffusing prism light pipe of 6 m in length and 10 cm in diameter, supplied either bilaterally by two identical HQI 70 W lamps, or unilaterally by an 80 W LED lamp. This paper describes the characterization relating to the computer-simulation phase to determine the light pipe recurrence laws, and the optical simulation phase in the production of a light pipe model.

1. Light pipe study context

The external horizontal illuminance from the unobstructed sky in Paris attains a level of 20,000 lux between 07h00 and 17h00 for about 50% of the year.

With a daylight factor DF of 2% in the central area of a room, we obtain an illuminance level of 400 lux for the same time periods and percentage of the year. This level is necessary to ensure visual comfort in a daylit office. We observe that it is necessary to use complementary electric lighting in daytime periods in room areas situated away from windows, where the daylight factor is much less than 2%, and yet there is an overabundance of natural light outside. The same applies in the central areas of rooms when the external illuminance level is below 20,000 lux, that is to say about 50% of the year, even though in spite of this reduction there is still an abundance of external natural light.

Natural light should be better used for the natural daylighting of office buildings by dividing its penetration into the rooms into two parts:

- Windows ensuring the penetration of natural light to the centre of the rooms. These natural light inputs will also be managed according to their thermal contributions, which are welcome in winter but can be excessive in summer. The design of the windows and window components must of course also take into account problems of dazzling as well as the acoustic and architectural requirements.
- Light pipes essentially ensuring the natural lighting of the room areas situated furthest from the windows. The natural light must therefore be carried to these less well lit areas where it will be distributed thanks to the light pipe extraction function.

The light pipe system will therefore consist of a first opaque light-carrying section linked to a natural light source (on the building facade for example), coupled to a second section comprising a diffusing prism pipe running parallel to the wall in which the windows are mounted (see Figure 1).

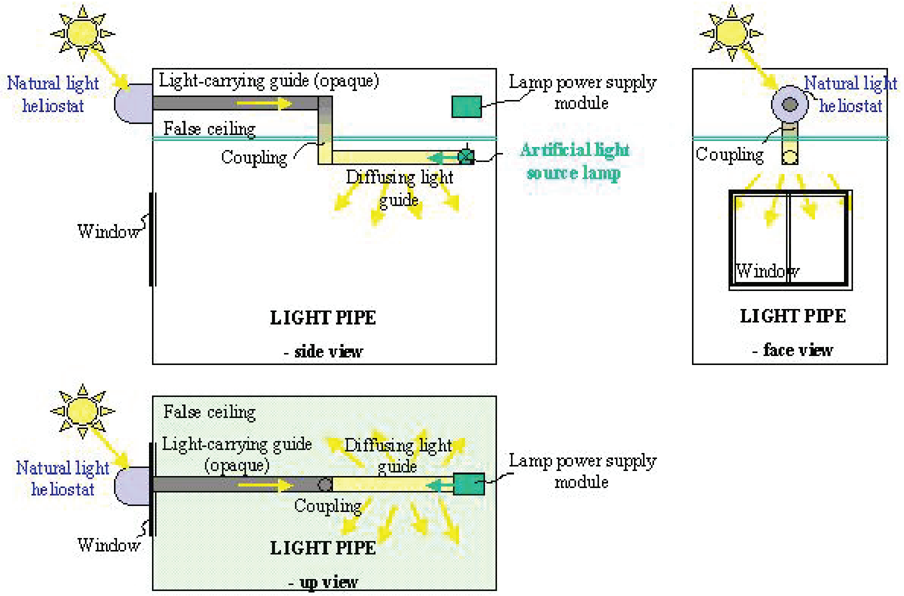

Figure 1 Use of light pipes to illuminate a deep room with natural light

During nocturnal periods, the diffusing light pipe can also be injected with electric light to complement the natural light, by coupling one or both of its ends to appropriate lamps, thereby constituting an innovative lighting system that represents one of the originalities of this study.

2. Composition and functioning of the light pipe

The light pipe used for the photometric characterizations is illustrated schematically in longitudinal and transverse sections in Figure 2 below.

The complete light guide comprises a diffusing light pipe filled with air, with an electric light source at one end of the pipe, and at the other end a reflective mirror at the other capable of reflecting all the light remaining in the pipe so that it can be extracted and diffused. If a bilateral light supply is used, the mirror is replaced by the second light source and we have a symmetrical system.

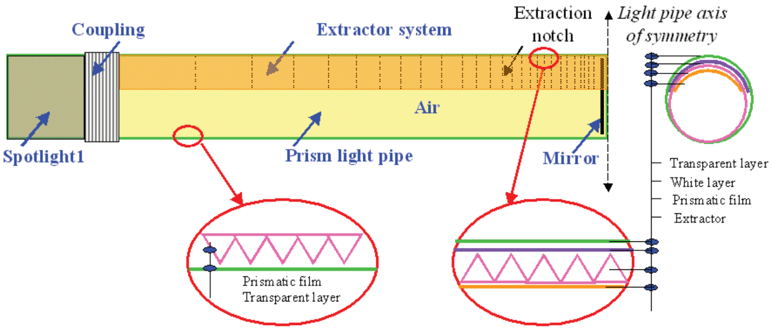

Figure 2 Longitudinal and transverse sections of the characterized light pipe

The light pipe consists of several concentric cylindrical layers. The outer layer is a transparent protective and supporting cylinder within which is a cylindrical half-layer made up of a white reflective film that prevents the light from diffusing upwards. Inside this layer is an optical film with a smooth inner surface and a prismatic surface that pipes the light inside the cylinder. The innermost layer consists of a metal strip extending the entire length of the pipe and featuring extraction slots at intervals that become closer together as the distance with respect to the electric light source increases, in order to compensate for light attenuation within the pipe and ensure uniform extraction. This extraction strip permits the downward diffusion of light on the outside of the pipe.

The light rays emitted by the electric light source are guided along the length of the light pipe by internal reflection off the surface of the prismatic optical film (see Figure 3) at certain incidence angles below a given maximum angle.

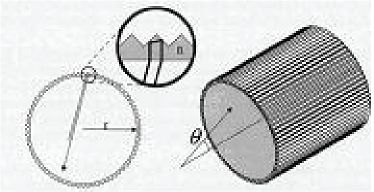

Figure 3 Prismatic film placed inside a light pipe to pipe the light**.**

This maximum angle is given as a function of the refractive index (*n*) of the prismatic optical film material. In the most commonly encountered case where n = 1.5 (polycarbonate), the maximum angle at which total internal reflection is ensured is 27.6°.

$$\theta \le \cos^{-1}\left(\frac{1-n^2\cdot\sin^2 22{,}5°}{1-\sin^2 22{,}5°}\right)^{1/2} \le \theta_{cr} = 27{,}6° \quad (1)$$

The light pipe diffuses those rays of light whose incidence angle exceeds the maximum angle as a result of their change in direction caused by the metal strip and its extraction notches.

3. Characterization of a diffusing prism light pipe

The light pipe taken both as a whole and divided into 13 cm long extraction sections, and the lamps, were photometrically characterized using several types of measuring instrument (T-10M luxmeter, LS-100 luminance meter). In order to be able to perform a comparative study, two types of lamp were used to inject light into the light pipe, namely a 70 W HQI lamp (see Figure 4) fitted with a 6400 lm bulb, and a prototype lamp with 16 white LEDs (see Figure 5).

Figure 4 HQI 70 W Halogen lamp

Figure 5 80 W LED lamp

The characterization served several aims:

a) To produce the lighting distribution isolux curves (see Figures 6, 7 and 8) as a function of distance (plotted on the surface of a meshing placed a certain distance from the lamp or light pipe). The mesh is represented by a 5 cm x 5 cm square. As the light pipe was symmetrical with respect to its environment, we have shown only half its isolux curves:

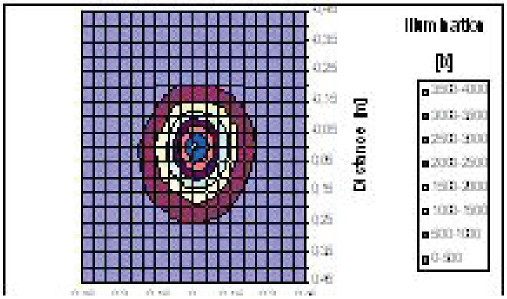

Figure 6 Isolux curves of the HQI70W Halogen lamp (distance 1.2 m)

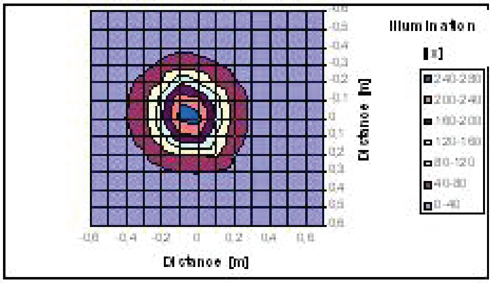

Figure 7 Isolux curves of the 80 W LED lamp (distance 1 m)

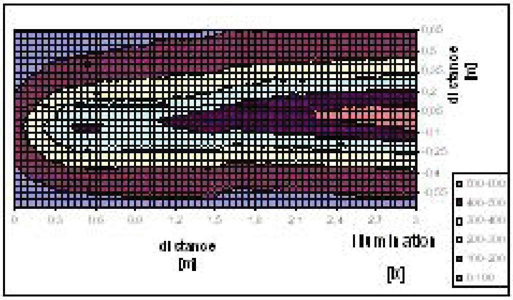

Figure 8 Isolux curves of half the light pipe with light injected by 2 HQI70 W lamps (distance 1.3 m)

b) To produce the polar indicators (see Figures 9, 10 and 11), i.e. curves of intensity distribution as a function of emission angle, which can be put into a standard format (IES, PHILLUM, etc.) and be used in the databases of certain lighting simulation software programs. At half the maximum intensity we obtain the emission or aperture angle of the studied lamps and light pipes, and this value is used to calculate the efficiency of the light pipe. Figure 11 shows the transverse indicators of the light pipe (in planes perpendicular to its optical axis) at varying distances from the source lamp.

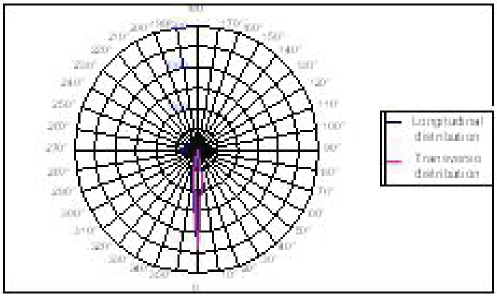

Figure 9 Polar indicators of the HQI70W Halogen lamp

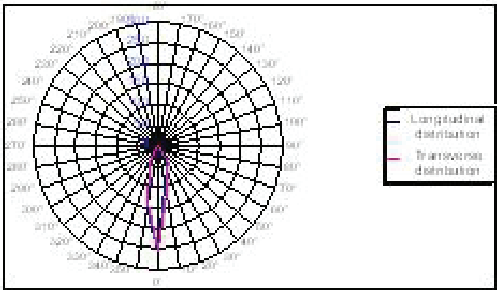

Figure 10 Polar indicators of the 80W LED lamp

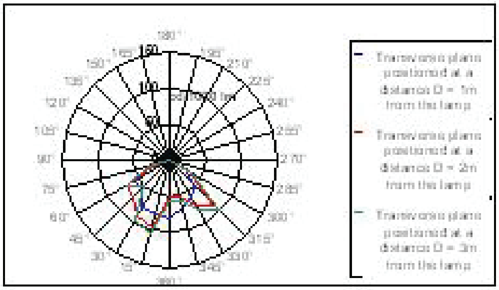

Figure 11 Transverse polar indicators of the light pipe

c) To calculate the emitted fluxes and efficiencies using the utilization factor (standard NE C71-121 of the UTE Union Technique de l'Electricité) and the excitance (or emittance) method that takes into account the inter-reflections on the walls of the room in which the studied light pipe is situated. The efficiency of the tube was verified using Lorne A. Whitehead's method corrected by a ray tracking approach.

d) To determine the light pipe recurrence laws (put into analytical, exponential and matrix forms).

The characteristic curves of the lamps and the light pipe were used to validate an optical model of a light pipe designed using the APILUX software that will be described later.

4. Light pipe recurrence laws – analytical form

In order to understand the light pipe extraction system and be able to produce an optical model, we established the recurrence laws relating to the extracted fluxes and the fluxes carried within the light pipe divided into unit sections for both the ideal case without losses (see Figure 12), and the true case with losses (see Figure 13) considered to be distributed uniformly along the pipe.

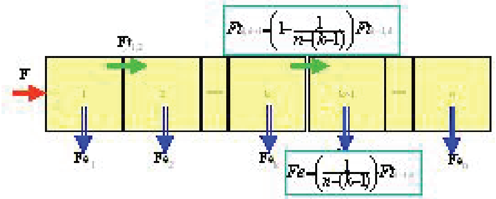

Figure 12 General recurrence laws – ideal case without losses

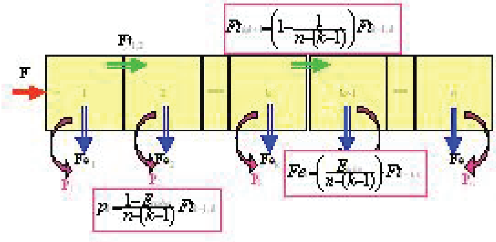

Figure 13 General recurrence laws – true case with losses

The fluxes can be given as a function of the injection flux of one lamp (unilateral light source) or two lamps (bilateral light source), or as a function of the fluxes entering each unit section.

5. Production of an optical model of a light pipe through an APILUX simulation

Given that the simulation of a light pipe is very complicated owing to the size of the prismatic microstructures, we produced a simplified optical model using the APILUX software, which allows the predicted illumination to be calculated.

The model design comprises a series of transparent yet reflective concave mirrors angled at 45°, that can reproduce the same guiding and diffusion functions of the simulated light pipe. The reflectance, transmittance and absorbance in a case with losses, are set by applying the previously determined recurrence laws, with each section of the light pipe being simulated by a mirror. The number of mirrors per model is set such that its distribution of light on the surface of a detector is close to that of the actual light pipe.

The model, injected with light from a point source simulating the light pipe source lamp, is placed a certain distance from a detector (see Figure 14) that is capable of measuring all the light incident on its surface and drawing its isolux curves (see Figure 15).

By placing the model inside a volume detector (see Figure 16), we can see how the light is distributed in the room and make various sections (see Figure 17, 18 and 19).

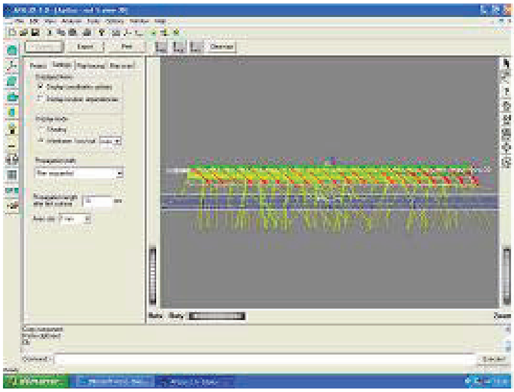

Figure 14 3D representation of a 1 m light pipe

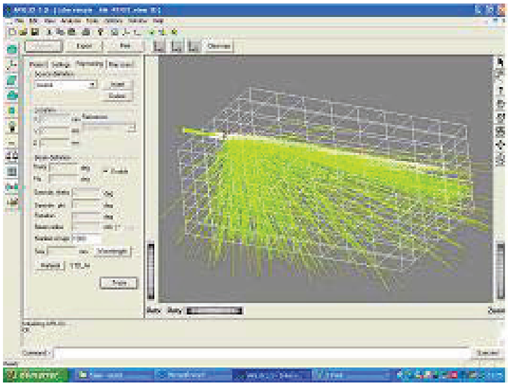

Figure 15 3D representation of a 6 m light pipe

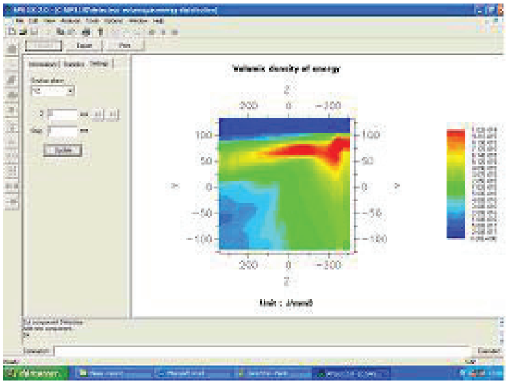

Figure 16 Vertical longitudinal section of the model

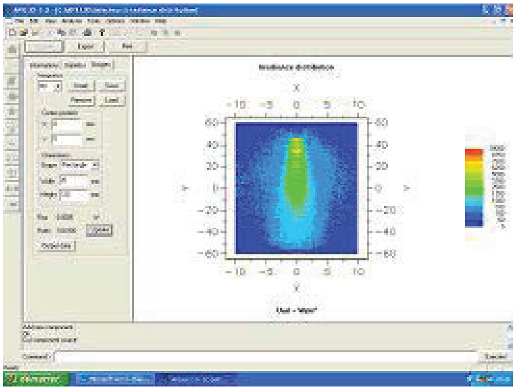

Figure 17 APILUX isolux curves

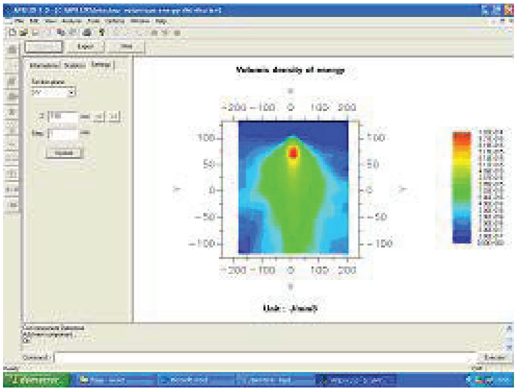

Figure 18 Transverse section of the model 3m from the source

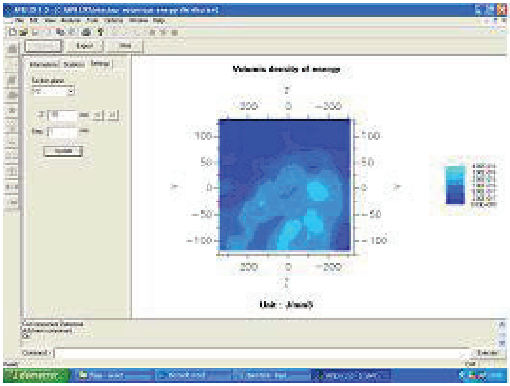

Figure 19 Distribution of light on a side wall parallel longitudinal axis of the model

6. Conclusion

One of the major advantages of the light pipe lies in the fact that a point source (represented by a lamp) is transformed into a linear source, which results in a lower luminance level and therefore greater lighting comfort. The uniformly distributed light avoids having the dazzling spots often associated with high-efficiency point sources. The lamp, the ballast, the electrical connections and the heat sources can be situated far from illuminated areas that are sensitive (e.g. museum) or hazardous (industrial risk zone).

The characterization and optical modelling of a light tube using the APILUX software enables prototype light pipes to be produced for specific applications (pipes supplied by a combination of natural and electric light; pipes with light transmitting modules of different luminance levels, pipes with opaque light transmitting modules, etc.)

The optical model produced provides the following advantages:

- Ease of design for all types of light pipe (can be divided into 1 m long sections);
- One can determine the extraction that meets the needs of a given application by adjusting the mirror arrangement (localized lighting or opaque blind area applications);
- Dual light sources can be used (bilateral light pipes, light pipes supplied by combined natural/electric sources);
- The flux and emission angle of the light injection source can be varied;
- Direct, indirect or combined lighting can be used.

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Paper presented at the International Conference ILUMINAT 2005 & BALKANLIGHT 2005, 2-3 June 2005, Cluj-Napoca, Romania

PREDICTION OF COLOUR APPEARANCES IN NAYATANI, HUNT, CIECAM AND NC-IIIC SPACES FOR COMPARISON WITH PERCEIVED ATTRIBUTES OF MUNSELL COLOURS

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High Intensity Discharge (HID) lamps have been commonly used in the field of stadium and open space. However, recently, HID lamps come into general use for indoor lighting. Accordingly, specification of colour rendering properties of HID lamps becomes necessary for practical lighting design. In this study, in order to investigate perceived colour appearances under various High Intensity Discharge (HID) lamps, perceived appearances of 40 Munsell colours with value of 6 and chroma of 8 have been subjectively evaluated under Xenon lamp (Standard illuminant D65), incandescent lamp (Standard illuminant A), metal halide lamp MT400DL, fluorescent mercury lamp HF400X and high pressure sodium lamp NH360. These psychological attributes have been compared with predicted metric quantities in Nayatani, Hunt, CIECAM and NC-IIIC spaces. Then, it is found that metric quantities of test colours in the new uniform colour space NC-IIIC correspond more properly with perceived attributes under the illuminations of HID lamps than those in traditional colour spaces. Therefore, in the specification of colour rendering properties of light sources, the NC-IIIC space is superior to other colour spaces.

1. Introduction

It is generally known that colour appearances vary according to the change of the illuminant in spite of the chromatic adaptation of the visual system. These characteristics of illuminant on colour perception are called colour rendering properties of light source.

For the specification of colour rendering properties of light source, the uniform colour space *U*V*W** was recommended by the CIE in 1974 to calculate colorimetric quantities of test colours under test and reference illuminants.

This colour space, however, has been used only for the calculation of colour rendering indices and not for other colorimetric purposes. Also this space is inadequate to specify coordinates of colours because of enormous spatial distortions in the regions of red and green colours.

Then a new method for the assessment of colour rendering using CIE chromatic adaptation formulae and the uniform colour space *L*a*b** was proposed by the Technical Committee 1-33 of the CIE in 1996. In *L*a*b** space, however, chroma is estimated larger in the yellow region, and conversely smaller in the blue region. For the reason of these spatial distortions in the *U*V*W** space and the *L*a*b** space, three components of colour shift, i.e., differences of hue, lightness and chroma, cannot be represented orthogonally and independently.

Further more, Nayatani model, Hunt model, CIECAM model and NCIIIC space have been developed for the prediction of colour appearances under various illuminants.

Practical evaluations of these models, however, have not been sufficiently completed enough, because quantitative data for comparison between predicted appearances in these spaces and subjectively estimated perceived appearances are not plentiful enough.

2. Nayatani, Hunt, CIECAM97s and NC-IIIC spaces

Further studies with respect to the prediction of colour perception have been carried out, and several colour appearance formulae such as Hunt model, Nayatani model, CIECAM97s model and NC-IIIC space were developed for the prediction of colour appearances under various illuminants.

Formulae of these spaces are composed of weighted attributes, i.e., metric-correlates of hue, lightness and chroma, in order to approximate colour appearances of object colours under any light source.

(1) Nayatani Colour space

The formulae of Nayatani colour space are expressed as follows.

$T = (488.93 / \beta_1(L_{or}))E_s(\theta)\ [\beta_1(R_0)\log((R+1) / (Y_n\xi+1))$
$\qquad - (12/11)\ \beta_1(G_0)\log((G+1) / (Y_n\eta+1)) + (1/11)\ \beta_2(B_0)\log((B+1) / (Y_n\zeta+1))\ ]$
$P = (488.93 / \beta_1(L_{or}))E_s(\theta)\ [\ (1/9)\ \beta_1(R_0)(\log((R+1) / (Y_n\xi+1))$
$\qquad + (1/9)\ \beta_1(G_0)\log((G+1) / (Y_n\eta+1)) - (2/9)\ \beta_2(B_0)\log((B+1) / (Y_n\zeta+1))\ ]$
$E_s(\theta) = 0.9394 - 0.2478 \sin\theta - 0.0743 \sin 2\theta + 0.0666 \sin 3\theta - 0.0186 \sin 4\theta$
$- 0.0055 \cos\theta - 0.0521 \cos 2\theta - 0.0573 \cos 3\theta - 0.0061 \cos 4\theta$
$R = 0.40024X + 0.70760Y - 0.08081Z \quad : \quad \xi = (0.48105x + 0.78841y - 0.08081) / y$
$G = -0.22630X + 1.16532Y + 0.04570Z \quad : \quad \eta = (-0.27200x + 1.11962y + 0.04570) / y$
$B = 0.91822Z \quad : \quad \zeta = 0.91822(1 - x - y) / y$
$R_0 = Y_0E_0\xi / 100\pi \quad : \quad \beta_1(R_0) = (6.469 + 6.362R_0^{0.4495}) / (6.469 + R_0^{0.4495})$
$G_0 = Y_0E_0\eta / 100\pi \quad : \quad \beta_1(G_0) = (6.469 + 6.362G_0^{0.4495}) / (6.469 + G_0^{0.4495})$
$B_0 = Y_0E_0\zeta / 100\pi \quad : \quad \beta_2(B_0) = 0.7844(8.414 + 8.091B_0^{0.5128}) / (8.414 + B_0^{0.5128})$
$: \quad \beta_1(L_{or}) = (6.469 + 6.362L_{or}^{0.4495}) / (6.469 + L_{or}^{0.4495})$

(2). Hunt Colour Space

The formulae of Hunt colour space are expressed as follows.

$M_{RG} = 100[C_1 - C_2/11][e_m(10/13)N_cN_{cb}] \quad : \quad C_1 - C_2/11 = R_m - (12/11)G_m + (1/11)B_m$
$M_{YB} = 100[(1/2)(C_2 - C_3)/4.5][e_m(10/13)N_cN_{cb}F_t] \quad : \quad C_2 - C_3 = R_m + G_m - 2B_m$
$e_m = e_1 + (e_2 - e_1)(h_m - h_1) / (h_2 - h_1)$
$f_n(C) = 40\ [C^{0.73} / (C^{0.73} + 2)] \quad : \quad F_L = 0.2k^4(5L_A) + 0.1(1 - k^4)^2(5L_A)^{1/3}$
$R_m = R_{BF}[f_n(F_LF_RR/R_W) + R_D] + 1 \quad : \quad F_R = (1 + L_A^{1/3} + h_r) / (1 + L_A^{1/3} + 1/h_r)$
$G_m = G_{BF}[f_n(F_LF_GG/G_W) + G_D] + 1 \quad : \quad F_G = (1 + L_A^{1/3} + h_g) / (1 + L_A^{1/3} + 1/h_g)$
$B_m = B_{BF}[f_n(F_LF_BB/B_W) + B_D] + 1 \quad : \quad F_B = (1 + L_A^{1/3} + h_b) / (1 + L_A^{1/3} + 1/h_b)$
$h_r = (3R_W/R_E) / (R_W/R_E + G_W/G_E + B_W/B_E) \quad : \quad R_{GF} = 10^7 / [10^7 + 5L_A(R_W/100)]$
$h_g = (3G_W/G_E) / (R_W/R_E + G_W/G_E + B_W/B_E) \quad : \quad G_{GF} = 10^7 / [10^7 + 5L_A(G_W/100)]$
$h_b = (3B_W/B_E) / (R_W/R_E + G_W/G_E + B_W/B_E) \quad : \quad B_{GF} = 10^7 / [10^7 + 5L_A(B_W/100)]$
$R_D = f_n[(Y_b/Y_W)F_LF_G] - f_n[(Y_b/Y_W)F_LF_R]$
$G_D = 0$
$B_D = f_n[(Y_b/Y_W)F_LF_G] - f_n[(Y_b/Y_W)F_LF_B]$
$F_t = L_A / (L_A + 0.1) \quad : \quad N_{cb} = N_{bb} = 0.725\ (Y_W/Y_b)^{0.2}$
$N_c = 1.0, 1.0, 0.95, 0.90, 0.75, \quad Y_b = 30, \quad Y_W = 100, \quad L_A = (1000/\pi)(30/100) : (V=6)$
$h_m = \tan^{-1}[\ ((1/2)(C_2 - C_3) / 4.5) / (C_1 - (C_2/11))\ ]$

	Red	Yellow	Green	Blue
h_1, h_2	20.14	90.00	164.25	237.53
e_1, e_2	0.8	0.7	1.0	1.2

(3) CIECAM97s Colour Space

The formulae of CIECAM97s Colour Space are expressed as follows.

$a' = aC/(a^2+b^2)^{1/2}$, $b' = bC/(a^2+b^2)^{1/2}$: $M_{RG} = aCF_L^{0.15}/(a^2+b^2)^{1/2}$, $M_{YB} = bCF_L^{0.15}/(a^2+b^2)^{1/2}$

$a = R_a' - (12/11)G_a' + (1/11)B_a'$: (R-G Response), $b = (1/9)(R_a' + G_a' - 2B_a')$: (Y-B Response)

$C = 2.44\, s^{0.69} (J/100)^{(0.67n)} (1.64 - 0.29^n)$: (Metric Chroma), $M = CF_L^{0.15}$: (Colorfulness)

$s = 50(a^2+b^2)^{1/2}\, 100\, e_m (10/13) N_c N_{cb} / (R_a' + G_a' + (21/20)B_a')$: (Saturation)

$A = (2R_a' + G_a' + (1/20)B_a' - 2.05)N_{bb}$: (Brightness), $J = 100(A/A_W)^{(0.69\ SZ)}$: (Metric Lightness)

$R_a' = 40(F_L R'/100)^{0.73} / [(F_L R'/100)^{0.73} + 2] + 1$

$G_a' = 40(F_L G'/100)^{0.73} / [(F_L G'/100)^{0.73} + 2] + 1$

$B_a' = 40(F_L|B'|/100)^{0.73} (B'/|B'|) / [(F_L|B'|/100)^{0.73} (B'/|B'|) + 2] + 1$

$R' = 0.683162\, R_C Y + 0.296681\, G_C Y + 0.020099\, B_C Y$

$G' = 0.284373\, R_C Y + 0.649080\, G_C Y + 0.066518\, B_C Y$

$B' = -0.008529\, R_C Y + 0.040043\, G_C Y + 0.968487\, B_C Y$

$R_C = [D(1.0/R_W) + 1 - D]R$, $G_C = [D(1.0/G_W) + 1 - D]G$,

$B_C = [D(1.0/|B_W|^P)(B_W/|B_W|) + 1 - D][|B|^P (B/|B|)]$

$R = 0.8951(X/Y) + 0.2664 - 0.1614(Z/Y)$, $G = -0.7502(X/Y) + 1.7135 + 0.0367(Z/Y)$

$B = 0.0389(X/Y) - 0.0685 + 1.0296(Z/Y)$, $P = (|B_W|/1.0)^{0.0834}$

$L_A = (E_0/\pi)(Y_b/Y_w)$, $K = 1/(5L_A + 1)$, $D = F - F/(1 + 2L_A^{1/4} + L_A^2/300)$,

$F_L = 0.2K^4(5L_A) + 0.1(1-K^4)^2(5L_A)^{1/3}$, $N_{bb} = N_{cb} = 0.725(1/n)^{0.2}$, $sz = 1.0 + F_{LL} n^{1/2}$

$c = 0.69$, $Nc = 1.0$, $F = 1.0$, $F_{LL} = 1.0$, $n = (Y_b/Y_w)$, $Y_b = 30$ (V=6), $Y_w = 100$,

$e_m = e_1 + (e_2 - e_1)(h_m - h_1)/(h_2 - h_1)$: (Chromatic strength)

$h_m = \tan^{-1}(b/a) = \tan^{-1}(b'/a') = \tan^{-1}(M_{YB}/M_{RG})$: (Hue angle)

	Red	Yellow	Green	Blue
h_1, h_2	20.14	90.00	164.25	237.53
e_1, e_2	0.8	0.7	1.0	1.2

(4) NC－IIIC Colour Space

A new uniform colour space NC-IIIC has been developed according to the stage theory. Spatial distortions in the NC-IIIC space has been compensated by introducing nonlinear opponent functions.

The formulae of NC-IIIC Colour Space are expressed as follows.

$L^* = 116(Y/Y_n)^{1/3} - 16$

$a\dagger = \mathbf{k_1 k_2}\, a''$ (Nonlinear R - G response)

$b\dagger = \mathbf{k_1 k_2}\, b''$ (Nonlinear Y - B response)

$a'' = 255\Gamma[(X/X_n)^{1/3} - [\gamma(Y/Y_n)^{1/3} + (1-\gamma)(Z/Z_n)^{1/3}]]$

$b'' = 255[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$

$\Gamma = 2.614040$, $\gamma = 0.974180$

$\mathbf{k_1} = 1 - 0.10153[1 + 0.210\sin(\boldsymbol{\theta} - \boldsymbol{\theta_0})]^8$ (Y - B opponent nonlinearity)

$\mathbf{k_2} = 1 - 0.00264[1 - 1.830\cos(\boldsymbol{\theta} - \boldsymbol{\theta_0})]^4$ (R - G opponent nonlinearity)

$\boldsymbol{\theta} = \arctan(b''/a'') = \arctan(b\dagger/a\dagger)$, $\boldsymbol{\theta_0} = 6.6$┌

Here, X, Y and Z denote the tristimulus values of an object colour, and X_n, Y_n and Z_n are those of the illuminant. The coefficients $\mathbf{k_1}$ and $\mathbf{k_2}$ represent the non-linearity and non-symmetry as to Y-B and R-G opponent response mechanisms at the second stage of the visual system . The angle$\boldsymbol{\theta_0}$ indicates the lean of directions of Y-B and R-G opponent responses from a† and b† axis. The Y-B opponent response axis and R-G opponent response axis cross at right angles each other in this colour space.

Physiological and psychological meanings of the nonlinear opponent colour response mechanisms in NC-IIIC space are shown schematically in Figure 1.

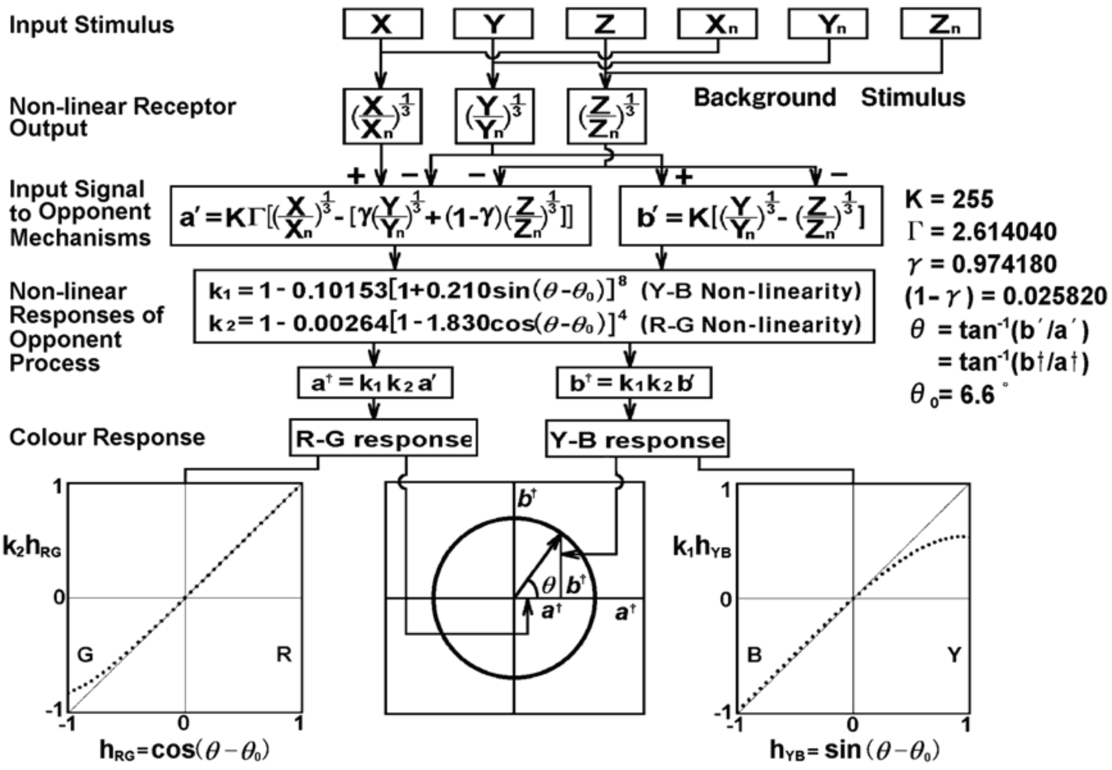

Figure 1 Schematic diagram of nonlinear opponent colour response mechanisms in NC-IIIC space

3. Hue circles of munsell colours in U*V*W*, L*A*B*, Nayatani, Hunt, CIECAM97s and Nc-Iiic spaces

The regularity of coordinates of Munsell colours on the plane of lightness V = 6 in Munsell space are examined to evaluate the uniformity of these colour spaces in terms of colour specification. The hue circles of Munsell colours with value of 6 and chroma of 2 - 14 in U*V*W*, L*a*b*, Nayatani, Hunt, CIECAM97s and NC-IIIC spaces under illuminant C are shown in Figure 2 .

As a natural result, it is expected that the hue angle, the radial distance from the origin and the interval of vertical height in a colour space should correspond to perceived hue, chroma and lightness, respectively.

However, U*V*W*, L*a*b*, Nayatani, Hunt and CIECAM97s spaces have failed to represent hue, value (lightness in Munsell space) and chroma of Munsell colours under illuminant C uniformly with proper correspondence to metric quantities, because the tangential directions of hue circles and equi-chroma loci in these spaces do not meet at right angles mutually, i.e., the direction of hue shift and that of chroma shift are not orthogonal to each other. Furthermore, the independence and orthogonality between metric-correlates of hue and chroma had not been accomplished yet.

By contrast, hue circles which are warped in the conventional colour spaces approach uniform circles in new colour space NC-IIIC. The coordinates of colours with same chroma lie on a circle of constant radius in new colour space NC-IIIC. So chroma can be expressed as the radius of hue circle, i.e., metric-chroma, and hue will be indicated by the hue angle, i.e., metric-hue, independently. This space can show hue, lightness and chroma in orthogonal directions. In this new space, the relative deviation of Hue circle from the circumference is reduced from 13.6 ˜ 14.5 % to 1.26 % , i.e., the uniformity in the direction of chroma is improved to the level of almost completeness for practical purposes.

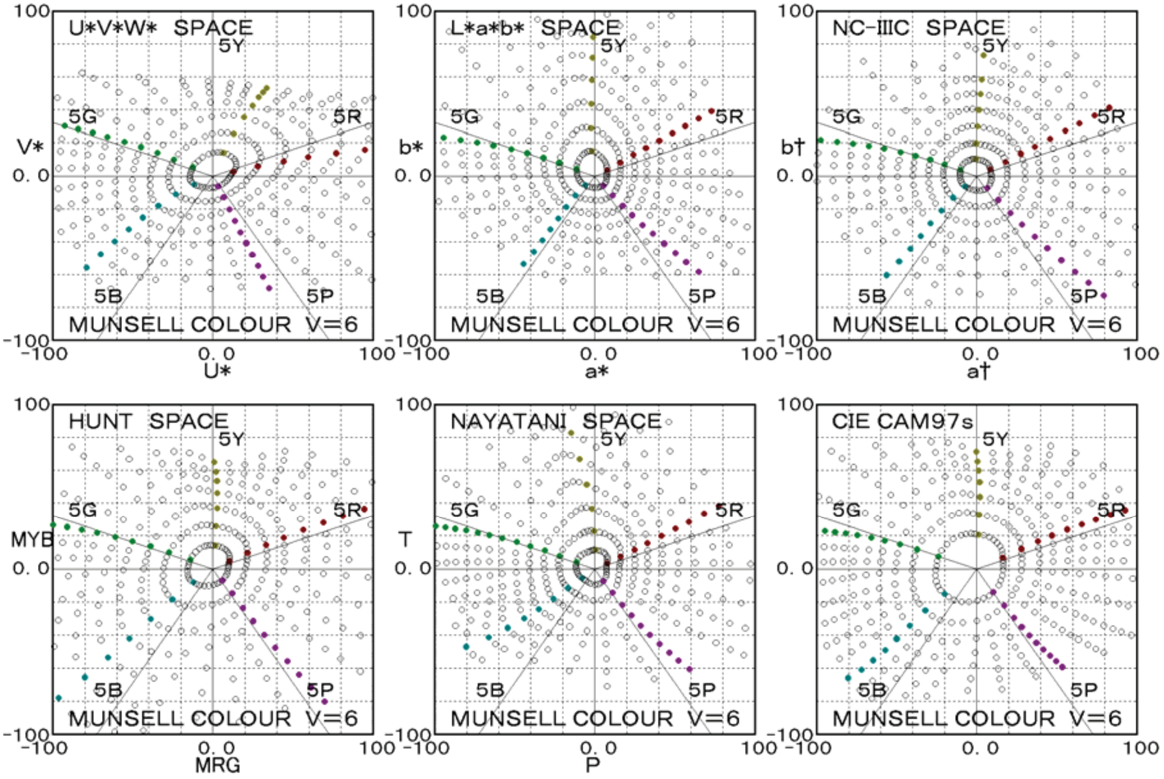

Figure 2 Hue circles of Munsell colours with value of 6 in uniform colour spaces

4. Subjective Evaluation Of Perceived Colour Appearance

4.1 Test colours for visual experiment

Test colour samples are 40 colours which are selected from Munsell colour samples with value of 6 and chroma of 8. A list of test colour samples with Munsell notation is shown in Table 1.

Table 1 Munsell notation of test colour samples

No.	1	2	3	4	5
Munsell notation	2.5R6/8	5R6/8	7.5R6/8	10R6/8	2.5YR6/8
No.	6	7	8	9	10
Munsell notation	5YR6/8	7.5YR6/8	10YR6/8	2.5Y6/8	5Y6/8
No.	11	12	13	14	15
Munsell notation	7.5Y6/8	10Y6/8	2.5GY6/8	5GY6/8	7.5GY6/8
No.	16	17	18	19	20
Munsell notation	10GY6/8	2.5G6/8	5G6/8	7.5G6/8	10G6/8
No.	21	22	23	24	25
Munsell notation	2.5BG6/8	5BG6/8	7.5BG6/8	10BG6/8	2.5B6/8
No.	26	27	28	29	30
Munsell notation	5B6/8	7.5B6/8	10B6/8	2.5PB6/8	5PB6/8
No.	31	32	33	34	35
Munsell notation	7.5PB6/8	10PB6/8	2.5P6/8	5P6/8	7.5P6/8
No.	36	37	38	39	40
Munsell notation	10P6/8	2.5RP6/8	5RP6/8	7.5RP6/8	10RP6/8

Tristimulus values of the test colours under Xenon lamp (Standard illuminant D65), incandescent lamp (Standard illuminant A), metal halide lamp MT400DL, fluorescent mercury lamp HF400X and high pressure sodium lamp NH360 are calculated from the spectral energy distributions of the illuminants and the spectral reflectances of the test colour samples. Metric hues, chromas and lightnesses of colour samples in U*V*W*, L*a*b*, Nayatani, Hunt, CIECAM97s and NC-IIIC spaces are derived by substituting the tristimulus values of the test colours into the formulae specifying these three spaces.

4.2 Test lamps for visual experiment

In this experiment, 6 lamps are used as test illuminants as shown in Table 2. Correlated colour temperatures (Tcp) of these test lamps are also shown in Table 2.

Table 2 Test lamps used in experiment

Lamp	Tcp [K]
Illuminant D_{65} (Xenon lamp)	6504
Illuminant A (Incandescent lamp)	2856
MT400DL (Metal halide lamp)	6500
HF400X (fluorescent high pressure mercury vapor lamp)	4100
NH360DL (High pressure sodium vapor lamp)	2150

4.3 Experimental set up and viewing condition

A board of neutral gray with value of 6, on which 5 straight lines showing main hues, i.e., red, yellow, green, blue and purple, are drawn from the origin in a equiangular radial pattern and concentric circles are described to indicate constant chroma loci, is prepared for the visual evaluation experiment. This board serves both as a background of the test colours and a chart symbolizing the perceptual colour space as shown in Figure 3. A booth for visual experiment is constructed as shown in Figure 4.

Colour chips on the background are illuminated uniformly by Xenon lamp (Standard illuminant D65), incandescent lamp (Standard illuminant A), metal halide lamp MT400DL, fluorescent mercury lamp HF400X or high pressure sodium lamp NH360 equipped on the ceiling of the booth.

Average illuminance on the board is about 1000 [lx] .

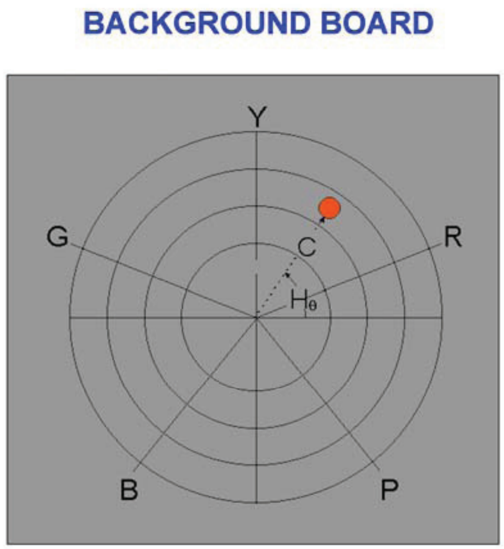

Figure 3 Board of background chart

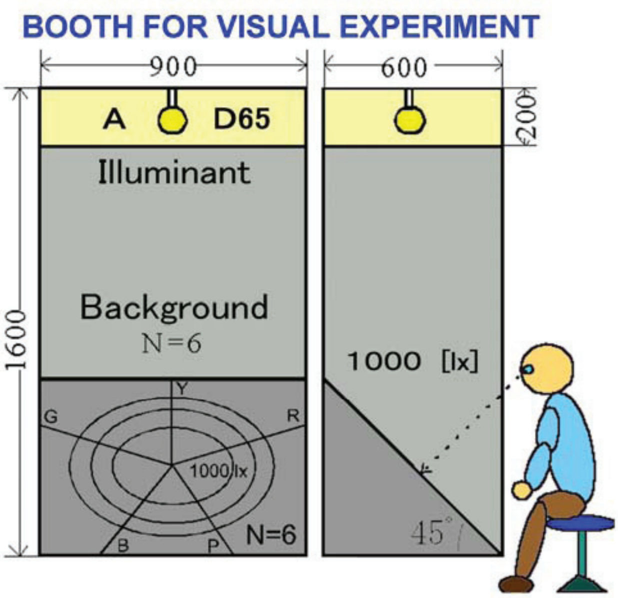

Figure 4 Booth for visual experiment

4.4 Visual estimation of colour appearance

Each observer watches colour chips placed on the board and evaluates perceived hue, lightness and chroma. Three under graduate students aged 22 to 24 with normal colour vision are adopted as observers for visual experiment.

Each observer is asked to estimate subjectively the perceived attributes, i.e., hue, chroma and lightness, of test colour samples placed on the uniform neutral gray background with value of 6 viewing thorough binocular vision as shown in Figure 4 and 6.

Hue is evaluated with correspondence to red, yellow, green, blue and purple taking perceptual distances from these hues into consideration. Chroma is estimated by way of perceptual magnitude of chromaticness taken from neutral gray as origin. Lightness is appraised as relative brightness compared with black and white. The lightness of black is assumed to be 0 and that of perfect white to be 10.

Observers express their estimated appearances by putting the test colour chips at corresponding positions on the chart representing appropriate hue and chroma.

According to this procedure, the observers equate their perceived quantities with geometrical distances on the chart of the psychological configuration colour space.

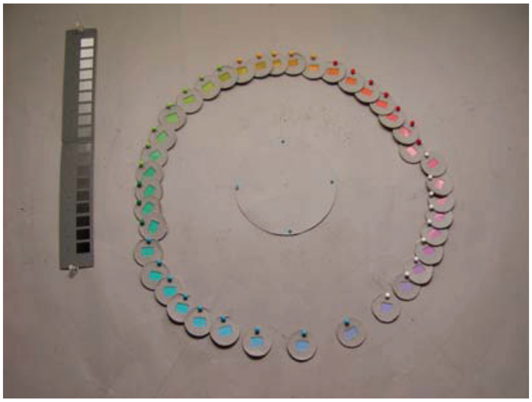

Figure 5 Colour samples of the background

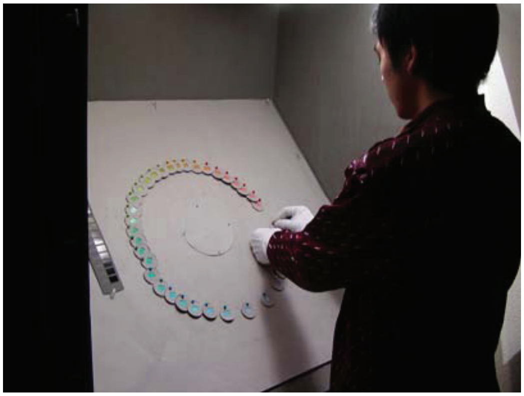

Figure 6 Visual experiment in the booth

5. PERCEIVED ATTRIBUTES AND METRIC QUANTITIES

The perceived hues, chromas and lightnesses evaluated by the observers are compared with the metric hues, chromas and lightnesses in U*V*W*, L*a*b*, Nayatani, Hunt, CIECAM97s and NC-IIIC spaces as shown in Figure 7 to 11.

Colorimetric quantities of test colour samples prescribed in Munsell colour system under various light sources are calculated from the spectral reflectance of each test colour sample.

Perceived attributes of the test colours are compared with the metric quantities in accordance with following procedures.

(1) Mean separations between the metric hues and the perceived hues.

(2) Average deviations of the metric chromas from the perceived chromas.

(3) Mean distances of the metric lightnesses from the perceived lightnesses.

(4) Total dislocations of the metric quantities from the perceived attributes.

Perceived attributes of colour appearances are desired to be predicted appropriately by corresponding metric quantities in a proper colour space or an adequate colour appearance model.

Xenon Lamp (Illuminant D_{65}) ●: Metric, ○: Perceived, □: 5R,5Y,5G,5B,5P

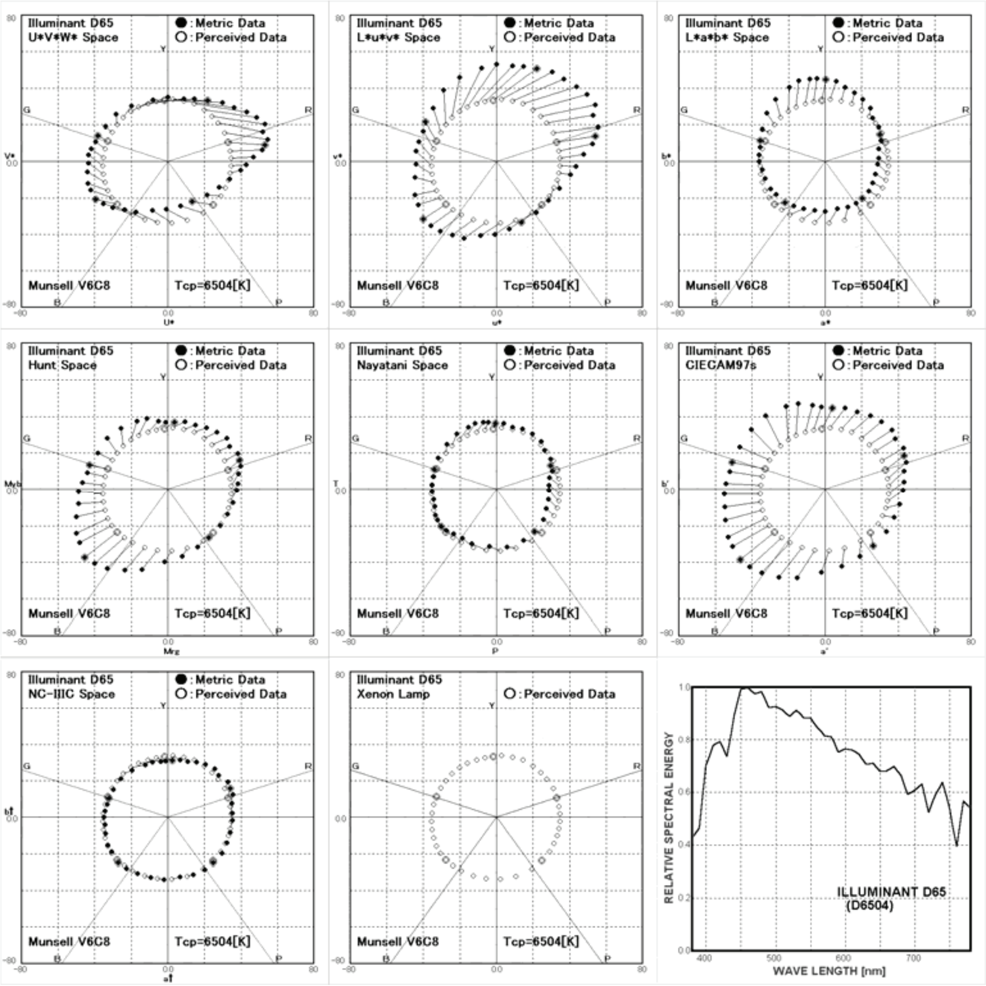

Figure 7(a) Perceived attributes and metric quantities of hue and chroma

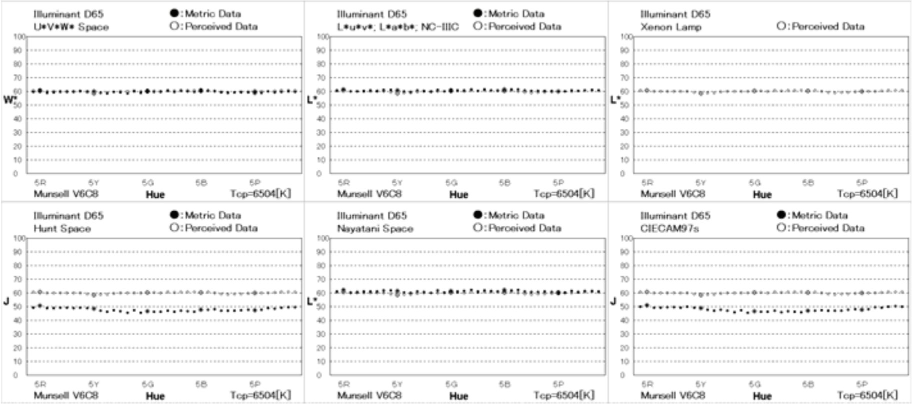

Figure 7(b) Perceived attributes and metric quantities of lightness

Incandescent Lamp (Illuminant A) ●: Metric, ○: Perceived, □: 5R,5Y,5G,5B,5P

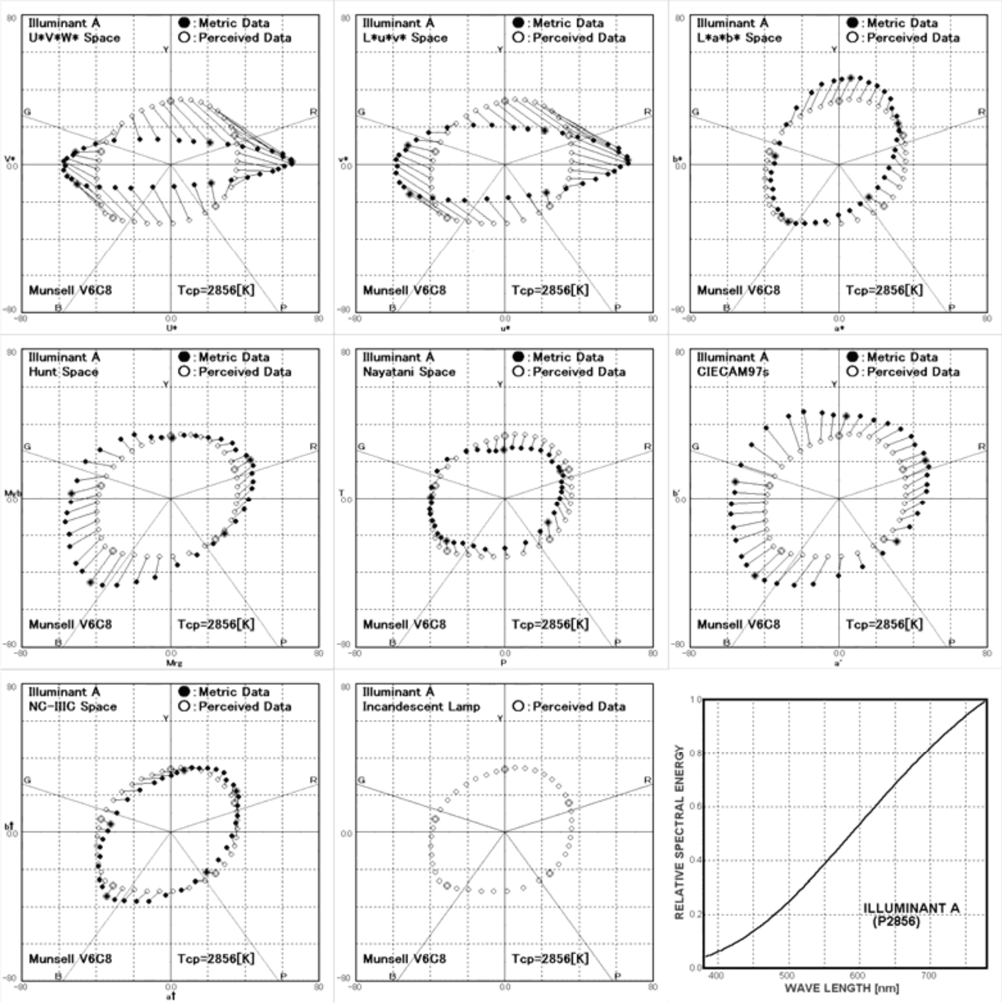

Figure 8(a) Perceived attributes and metric quantities of hue and chroma

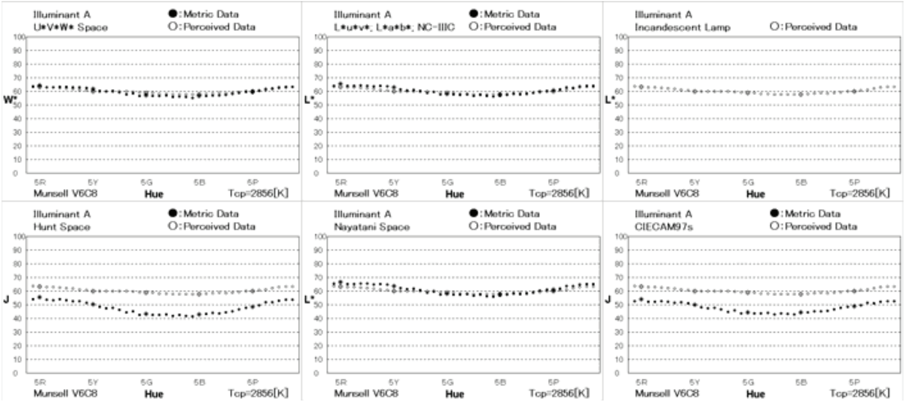

Figure 8(b) Perceived attributes and metric quantities of lightness

Metalhalide Lamp (MF400DL 6500K) ●: Metric, ○: Perceived, □: 5R,5Y,5G,5B,5P

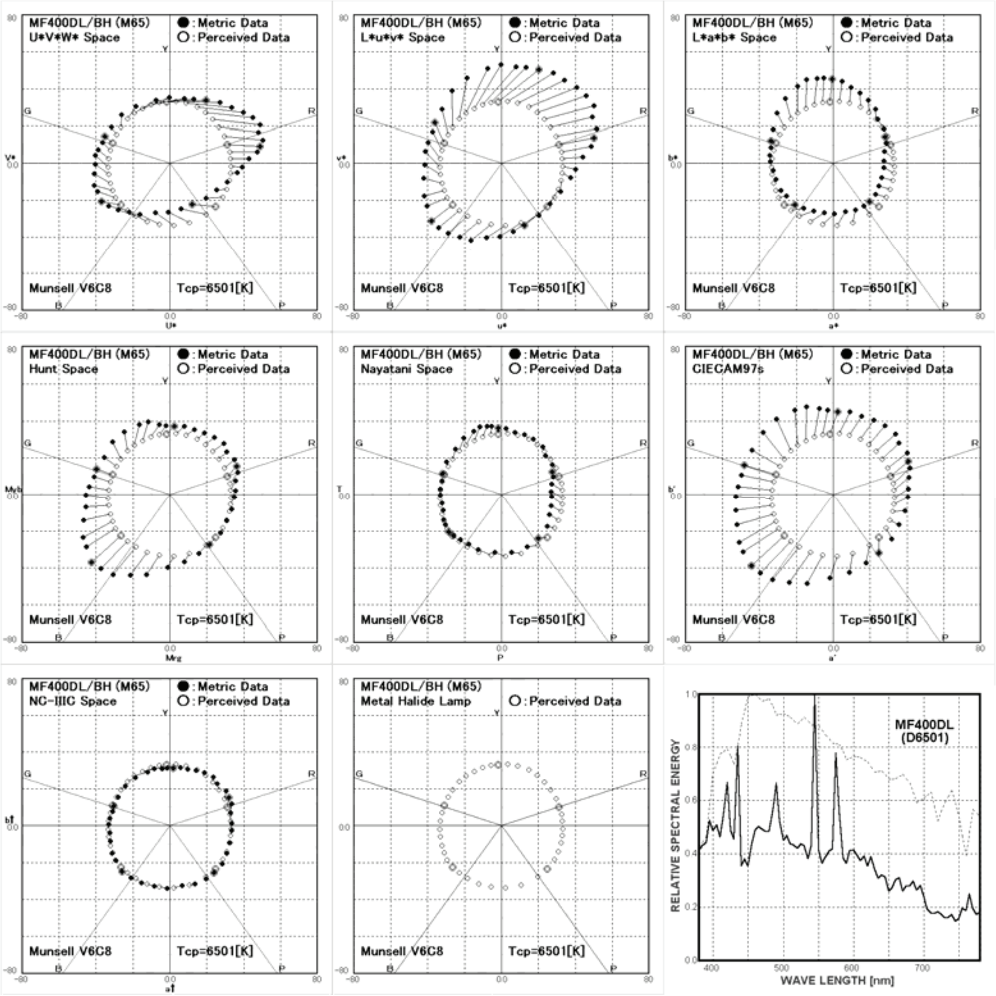

Figure 9(a) Perceived attributes and metric quantities of hue and chroma

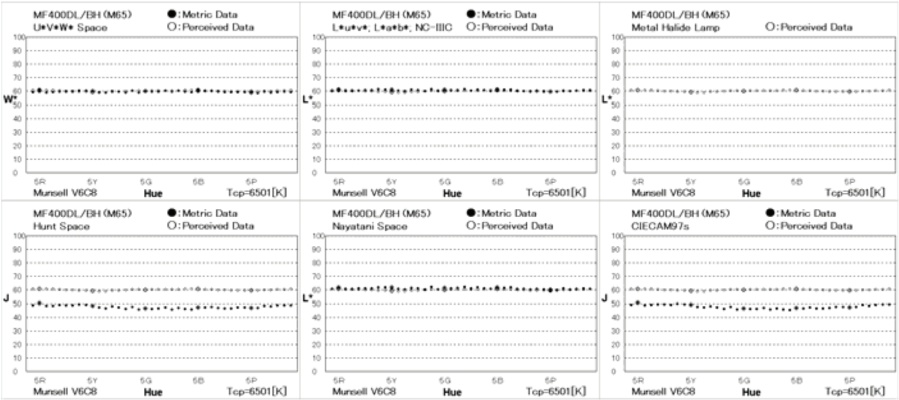

Figure 9(b) Perceived attributes and metric quantities of lightness

Mercury Fluorescent Lamp (HF400X) ●: Metric, ○: Perceived, □: 5R,5Y,5G,5B,5P

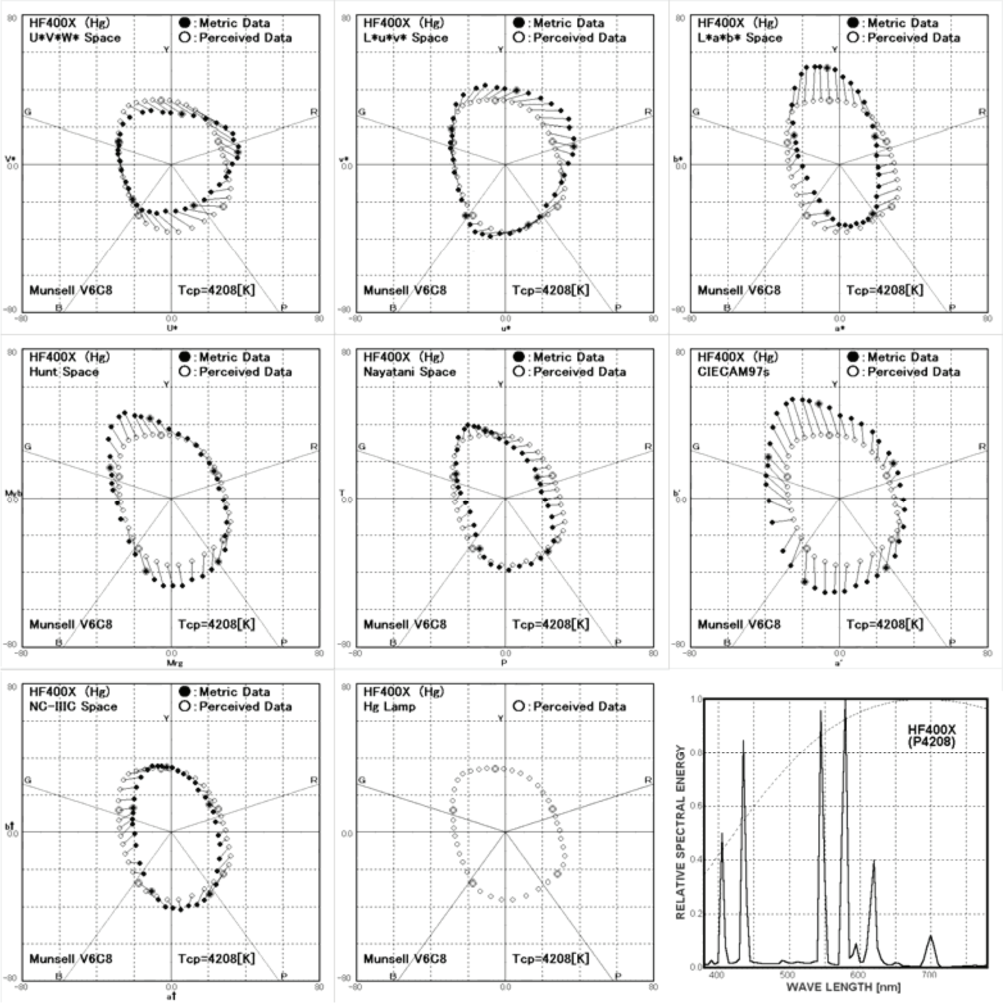

Figure 10(a) Perceived attributes and metric quantities of hue and chroma

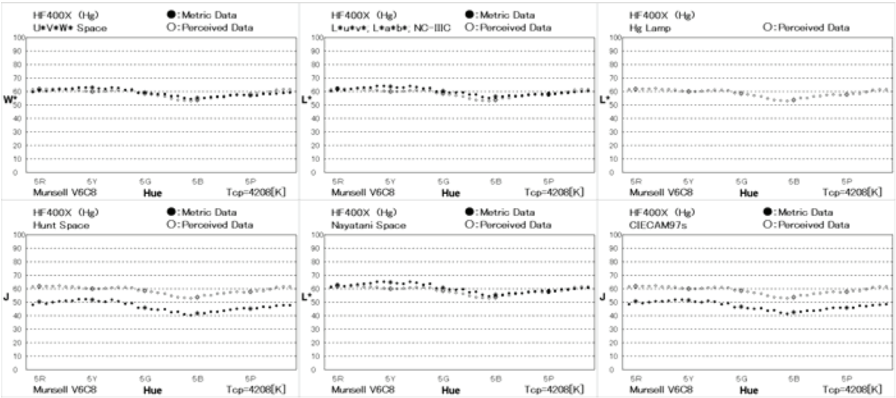

Figure 10(b) Perceived attributes and metric quantities of lightness

High pressure sodium Lamp (NH360DL) ●: Metric, ○: Perceived, □: 5R,5Y,5G,5B,5P

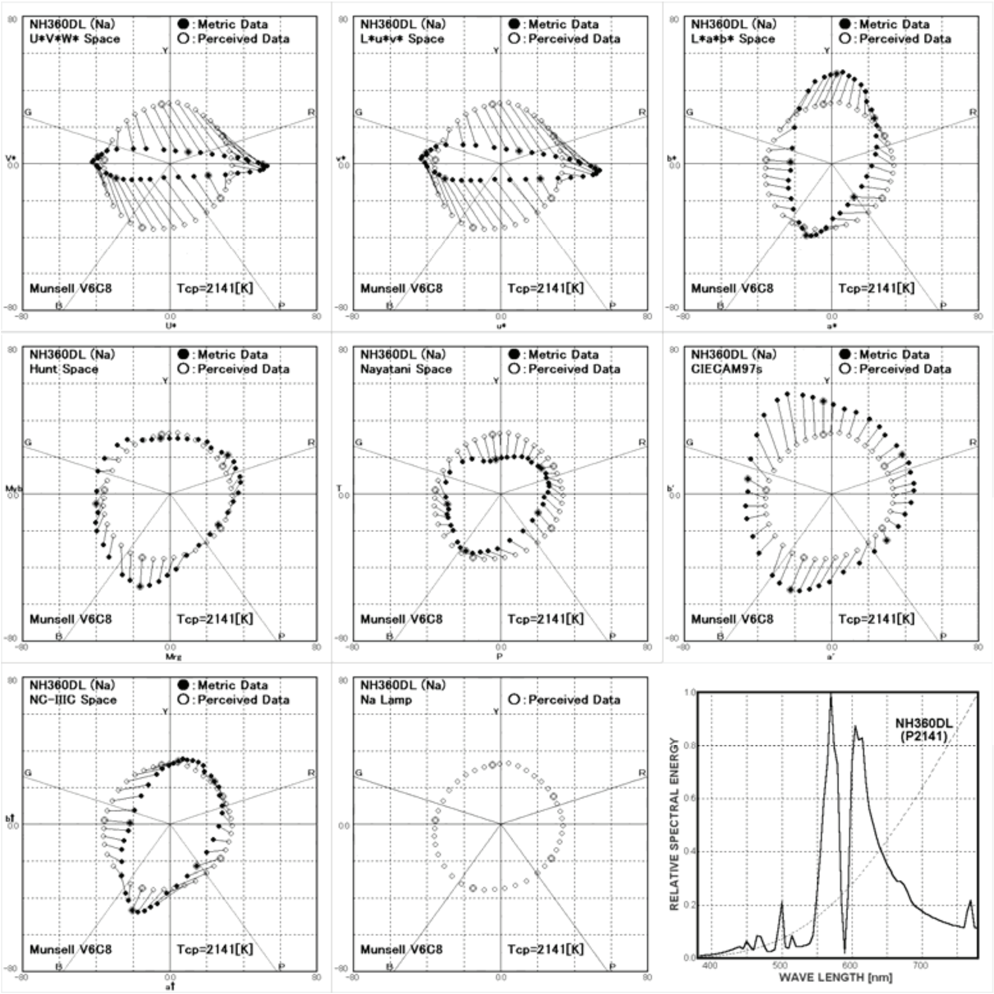

Figure 11(a) Perceived attributes and metric quantities of hue and chroma

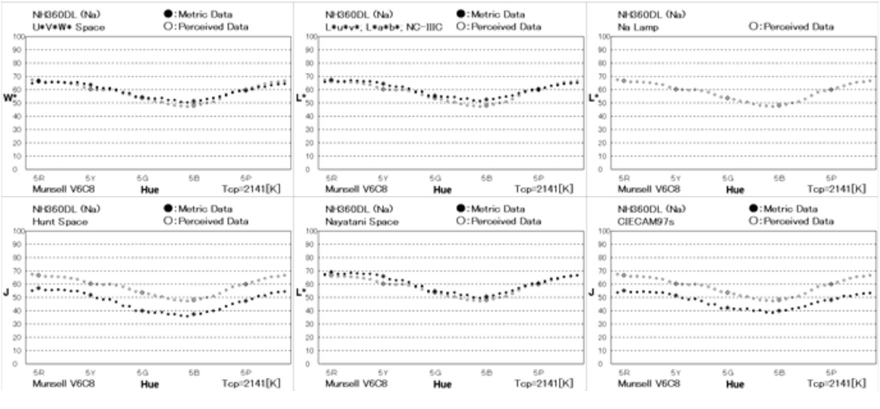

Figure 11(b) Perceived attributes and metric quantities of lightness

5.1 Differences between predicted appearances and perceived attributes

Predicted appearances are compared with perceived appearances. Hue difference can be represented only by the change of the hue-angle keeping up constant radial distance, and the chroma difference can be expressed by the variation of radial distance without the change of the hue-angle.

Colour differences are specified according to next formulae.

$$\Delta E = [(\Delta L^* / k_L)^2 + ((\Delta a\dagger)^2 + (\Delta b\dagger)^2) / (k_{ab})]^{1/2}$$
$$= [(\Delta L^* / k_L)^2 + (\Delta H / k_H)^2 + (\Delta C / k_C)^2]^{1/2}$$
$$\Delta H = [2 C_A C_B (1 - \cos (\Delta\theta))]^{1/2} = 2 (C_A C_B)^{1/2} \sin (\Delta\theta / 2)$$
$$\Delta\theta = \theta_B - \theta_A = \tan^{-1} (b_B\dagger / a_B\dagger) - \tan^{-1} (b_A\dagger / a_A\dagger)$$
$$\Delta C = (C_A - C_B)$$
$$\theta_A = \tan^{-1} (b_A\dagger / a_A\dagger) \quad : \quad C_A = [(a_A\dagger)^2 + (b_A\dagger)^2]^{1/2}$$
$$\theta_B = \tan^{-1} (b_B\dagger / a_B\dagger) \quad : \quad C_B = [(a_B\dagger)^2 + (b_B\dagger)^2]^{1/2}$$

Here, $(a_A\dagger , b_A\dagger)$ and $(a_B\dagger , b_B\dagger)$ are coordinates, C_A and C_B are chromas and θ_A and θ_B are hue angles of predicted colour and perceived colour, respectively, under a test illuminant.

$\Delta\theta$ is the shift of hue angle, ΔH is the hue shift expressed as a geometrical distance in the cylindrical coordinates and ΔC is the chroma shift under a test illuminant.

k_L , k_H and k_C represent the weighting coefficients of lightness, hue and chroma, respectively. The weights of lightness, hue and chroma in new space NC-IIIC can be applied independently to three perceived attributes of colours for the reason of the consistent uniformity of the new space . In this study, these coefficients are set equal to 1, i.e., $k_L = k_H = k_C = k_{ab} = 1$.

Table 3 Differences of predicted attributes with perceived attributes

	Hunt space				Nayatani space				CIECAM97s space				NC－IIIC space			
Lamp	**ΔH**	**ΔC**	**ΔL**	**ΔE**	**ΔH**	**ΔC**	**ΔL**	**ΔE**	**ΔH**	**ΔC**	**ΔL**	**ΔE**	**ΔH**	**ΔC**	**ΔL**	**ΔE**
Xe	4.08	10.41	1.53	11.29	4.01	2.91	1.31	5.13	4.25	15.55	1.87	16.23	3.45	1.50	0.85	3.86
A	4.00	11.49	3.96	12.80	4.13	4.53	1.97	6.44	3.60	15.00	2.75	15.67	4.99	4.06	1.30	6.56
MT400	3.45	9.92	1.41	10.60	3.73	3.09	1.18	4.99	3.71	15.54	1.78	16.08	3.28	1.22	0.75	3.58
HF400	4.97	7.59	2.14	9.32	4.41	4.44	2.34	6.69	5.77	13.16	1.62	14.46	6.27	3.96	1.96	7.67
NH360	4.74	6.63	2.70	8.59	4.79	7.95	2.47	9.60	5.52	14.78	1.40	15.84	9.30	7.54	2.58	12.25

5.2 Hunt space

Overall hue differences between the metric quantities and the perceived quantities are not so large in this space. On the contrary, the metric chromas deviate fairly from the perceived chromas generally except purple region even under illuminant D65 as shown Figure 7 to 11.

This space cannot specify colour appropriately even under illuminant D65, not to speak of under illuminant A as represented in Figure 7 and Table 3.

Accordingly, this space can not represent colour shift with the change of illuminant with proper correspondence to perceived colour change on account of incomplete compensations for chromatic adaptation, and colour perception can not be estimated properly. Moreover, metric chroma change irregularly with hue due to the warp in this space.

5.3 Nayatani space

General differences between the metric chromas and the perceived chromas are relatively small under illuminant D65. Chroma under illuminant A, however, is estimated rather smaller in the blue, purple, red and orange regions, i.e., colour shifts in these regions are greater than those in other region.

Nayatani space contains chromatic adaptation formulae of modified Von Kries type with noise and is expected to predict colour appearance rather well so that the general colour appearances are represented with somewhat properness.

However, entire deviations of the metric chromas from the perceived chromas are considerably large under the illumination of high pressure sodium lamp as shown in Figure 11(a).

For the reason of inhomogeneity in this colour space, predicted colours under high pressure sodium lamp illumination can not be represented uniformly over the whole range in the colour space, i.e., chroma varies with hue even though the perceived chroma is constant.

Contour of constant chroma loci vary inhomogeneously with hue by reason of non-uniformity in this space.

5.4 CIECAM97 space

Hue differences between the metric quantities and the perceived quantities are generally not so large in this space. Metric chromas, however, deviate largely from the perceived chromas generally except purple region even under illuminant D65 as shown Figure 7(a).

On account of large differences of metric chroma, this space cannot specify colour appropriately even under illuminant D65 not to speak of under the illumination of HID lamps as represented in Figure 7 to 11.

This space can not represent colour shift with the change of illuminant with proper correspondence to perceived colour change on account of incomplete compensations for chromatic adaptation.

5.5 NC－IIIC space

This space is succeed to specify precisely colours with proper correspondence to perceived attributes, i.e., hue, lightness and chroma, under any illuminant as well as under D65 . In other words, this space is able to indicate colour shifts in accordance with colour perceptions as you can see in Figure 7 to 11 .

In NC-IIIC space, total separations between the metric quantities and the perceived quantities are generally small in regard to both chroma and hue among these spaces as shown in Table 3 .

Further more, colour shifts are expressed uniformly over the whole sphere in this space and colour appearances are represented properly without irregularity throughout the entire hue.

NC-IIIC space has appropriate chromatic adaptation transforms in its formulae of opponent response functions as well as Von-Kries type compensations of cone responses, the shift of attributes are specified well under any illuminant and the colour appearances are represented uniformly irrespective of hue over the entire sphere in the space.

Also the NC-IIIC space is able to indicate three components of colour shift orthogonally, i.e., differences of hue, lightness and chroma can be shown independently as you can see in Figure 2.

The metric lightnesses do not show considerable difference from the perceived lightnesses in any space.

6. CONCLUSION

Summarized experimental results show following aspects of colour spaces tested in this study.

The distances between perceived attributes and metric quantities in the *U*V*W** space are generally large throughout the colour space, especially under illuminants of low colour temperature. In the *L*a*b** space, the differences are fairly large particularly in yellow region. Hunt space and CIECAM97s space have not been successfully achieved to manifest the perceived attributes of object colours even under standard condition, e.g., the case for Munsell colour samples under illuminant D65. Nayatani space also do not succeed to predict appropriately the subjective appearances of the object colours under the illumination of high pressure sodium lamp NH360DL. As results of this study, it is found that metric quantities of test colours under the illuminations of HID lamps in the traditional colour spaces cannot represent appropriately perceived attributes of test colours. These spaces do not contain nonlinear opponent response functions such as k_1 and k_2 with reference to the specification of colours and the prediction of colour shifts under test illuminant. Stevens effect, Hunt effect and Helson effect can not be represented in these spaces, because these spaces do not contain such terms as express these effects in its formulae. So these spaces also should be improved to be able to express these qualities.

Judging from above points of view, new colour space NC-IIIC could represent the attributes of perceived colours in the case observed under the illumination of any HID lamp as well as under illuminant D65.

The results obtained in this study stand for the fact that the nonlinear opponent colour response mechanisms represented by the functions k_1 and k_2 at the second stage of the new space NC-IIIC are superior to simple chromatic strength compensation structures of other traditional colour spaces.

In this respect, the colour space for the representation of colour appearances ought to have suitable compensation formulae for chromatic adaptation in its expression .

In the new space three attributes of colour perception can be specified appropriately, and the colour shift is able to be estimated independently with proper correspondence to hue, lightness and chroma, respectively.

Then, new colour space NC-IIIC is appropriate for the consistent evaluation of perceived colour appearances and colour shifts under any test illuminant .

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COMBINED HIGH PRESSURE SODIUM LAMP MODEL REFLECTING THE LAMP VOLT-AMPERE BAHAVIOR

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This paper presents a MAT LAB model for the simulation of both static and dynamic characteristics of Sodium high intensity discharge (HID) lamps. The proposed model was developed from the combination and modification of the classical Francis and Mayr equations. It is helpful for a preliminary design of electronic ballasts. Experimental results on sodium-HID lamps at different conditions are presented and they appear to be in good agreement with the simulation results.

1. Introduction

High-pressure sodium discharge lamps are applied widely in the road and tunnel illumination because of their high effectivity and long lifetime. Like most of the discharge lamps, they have also negative differential resistance at work. As a consequence current limiting components called ballasts are connected to the lamp in series. Apart from the classical inductive ballasts, wider application finds so called electronic ballasts. The last provide higher luminance yields, higher luminance indexes and longer exploitation lifetime. Some of the ballasts allow dimming o the lamp what leads to energy economy. In order to design electronic ballast a simulation of the cooperation between the ballast and the high-pressure sodium lamp is needed first. The luminance source model that has to describe adequate the behavior of the electrical parameters and the luminance flux is also needed. It is very difficult and uncomfortable for the engineer, to analyze the chemical-physical processes in the discharge tube when designing electronic ballasts and thus to model the lamp as system with distributed parameters. The paper is representing a high pressure sodium lamp model as a two pole with concentrated parameters, which variables are current flowing trough the lamp and the voltage on lamp terminals. The luminous flow is expressed by the lamp electrical parameters.

2. Mathematical model of the sodium lamp.

The experimental and theoretical investigations show that for chemical-physical point of view the current flowing process in the discharge tube of the HID lamp is too complicated and multifarious. The developed descriptions are observing the arc usually with certain restrictions, mainly constant power of the arc [1]. Mayr consider that the attitude of the arc depend on the square of the amplitude of the current and analytical enunciate the equation for the arc conductance:

$$\frac{d\left(\frac{i}{u}\right)}{dt} = \frac{i}{\tau u}\left(\frac{u\,i}{P_0} - 1\right) \quad (1)$$

where:
u, i are the voltage and the current of the arc, τ - the time constant of the arc, which Mayr defines as ratio of the reserved energy in volume unit of the arc and the give up power from this unit, P_0 – dispersed power from the arc.

The equation (1) corresponds very well for small values of current. For bigger current values the Francis equation (2) is much more suitable. Which is further developed in [4] for work with HID lamp during dimming. This equation can be transformed into next form:

$$\frac{d\left(\frac{i}{u}\right)}{dt}=\frac{i}{\tau u}\left(\frac{u^2}{u_{pk}^2}-1\right) \quad (2)$$

u_{pk} is the voltage over-striking peak value.

Typical for (2) is the suggestion that the arc characteristics are defined by its power. By combining both equation the arc electrical values dynamics could be expressed:

$$\frac{d\left(\frac{i}{u_d}\right)}{dt}=\frac{i}{\tau u_d}\left(\frac{u_d^2}{u_{pk}^2}+\frac{u_d i}{P_0}-1\right)+\frac{g_0}{\tau} \quad (3)$$

The quantity g_0 is the gas environment conductivity at the beginning before the arc formation, u_d is the voltage upon the light arc of the lamp and u_{pk} is a parameter, by which you set up the striking voltage. An equation is extra added to the mathematical model. This equation reflects the electrical behavior of the anode and cathode areas, which conductivity is in direct ratio to the arc conductivity and in reverse ratio to a function of the conducted current.

$$\frac{i}{u_a}=\frac{i}{u_d\left(\alpha|i|^n+\beta\right)}+g_0 \quad (4)$$

According to [6], the index n varies in the limits from 0.34 to 1.38. According to [3], for luminescent lamps is equal to 2. In accordance with Fugenfirov [7, page 10], the index n is linearly dependable on the type and on the temperature of the electrodes. In the examined case the exact value of n will be determined by tuning up the program model during simulation. An equation for the full voltage on the lamp terminals should be included in addition

$$u=u_d+u_a, \quad (5)$$

where: u is the voltage drops on the lamp, u_d - voltage drop on the light arc and u_a - voltage drop for the cathode and anode areas.

The given analytical model of the HID lamp expressed by equations (3), (4) and (5) consists of six parameters – τ, α, β, u_{pk}, P_0, g_0. During work in nominal conditions is presumed that these parameters are constants. The values of the parameters are determined at the time when tuning the simulation model. They are picked up in such a way that the behavior of the model is the closest to the behavior of the lamp at the experiments.

3. Simulation model in Mat Lab environment

A modeling of the HID lamp SON-T Pro 250 W with inductive ballast supplied with network voltage is conducted in Mat lab environment in order to investigate the proposed model (Figure 1). This calculating environment is very comfortable for system level investigation, what is very useful in the beginning of the designing of certain ballast. With no problem could be changed the power source, the inductive ballast and the parameters of the lamp model. There could be connected a number of measuring devices, analyzers and monitoring resources accessible in the Mat Lab library. The model on Figure 2 is build as a subsystem based on equations (3), (4) and (5). The parameters of the model are bring out in a mask Figure 3, and can be changed during the tuning of the model for the corresponding HID lamp. First, the transfer function of the inductive ballast should be determined. In the specific case, the function is

$$W(s)=\frac{I(s)}{U(s)}=\frac{1}{0.196s+1} \quad (6)$$

In the next way ought to be proceeded during tuning up the model of the lamp:

The value of u_{pk} is selected in such a way that the strike voltage result of the simulation to correspond to the experimentally measured value, in the specific case u_{pk}=115 V.

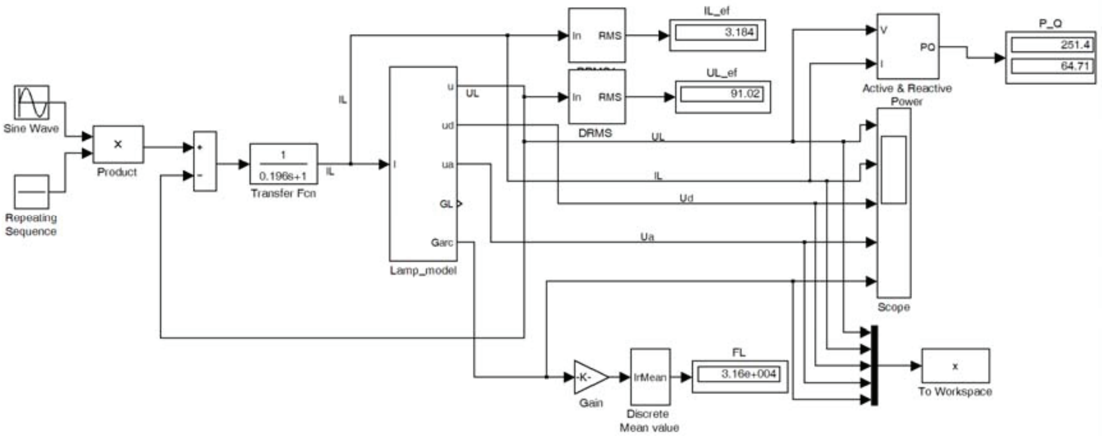
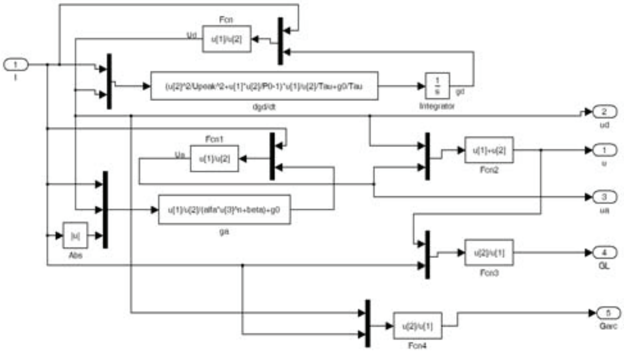
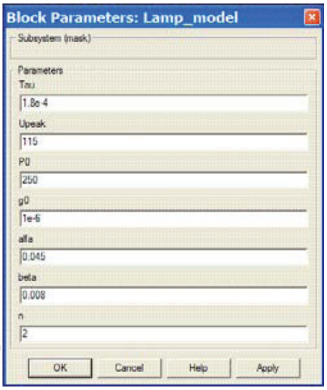


Figure 1 Simulation model of HID lamp with inductive ballast supplied with network voltage

- P_0 is assigned in such a way that the lamp effective voltage value to agree to the experimentally measured in certain regime. It is purposeful that this parameter is equal to the power of the lamp, in this case P_0=250 W.
- The values of the time constants are fixed at τ=180 µs, of the initial conductivity at $g_0=10^{-7}$, grade index n=2. These parameters can vary during the simulation process in order to obtain the best approach to the experimental volt-ampere behavior of the lamp.
- The parameters α and β, reflecting the anode and cathode voltage drop are tuned similarly by comparing the situational and experimental voltage shapes of the lamp, in the specific case α=0,045 and β=0,008.





Block Parameters: Lamp_model

Subsystem (mask)

Parameters

Tau: 1.8e-4

Upeak: 115

P0: 250

g0: 1e-6

alfa: 0.045

beta: 0.008

n: 2

Figure 2 HID Lamp model structure in Mat Lab

Figure 3 HID Lamp model mask initialized for 250 W power

4. Experimental and simulation results

The changes of 250 Watt HID lamp voltage and current sequences at nominal regime are recorded by storage oscilloscope with voltage and current probe in laboratory conditions Figure 4. The same changes are obtained from simulation with the evolved model and are given on Figure 5. All the characteristics are obtained by scanning the different quantities with sampling frequency 12.5 kHz.

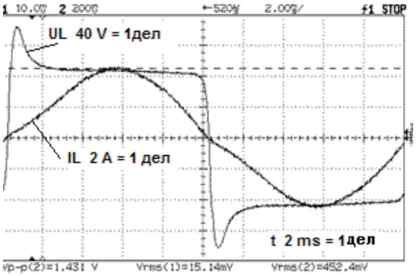


Figure 4 250 Watt HID lamp voltage and current experimental oscillograms

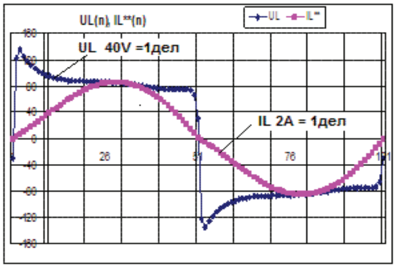


Figure 5 250 Watt HID lamp voltage and current simulation oscillograms

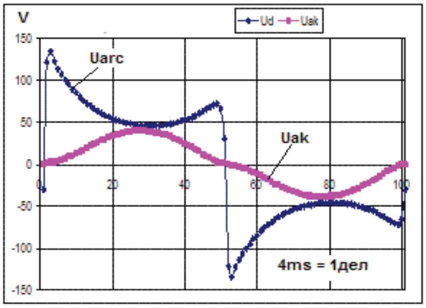


Figure 6 Simulation oscillogram of the illumination arc voltage drop U_{arc} and the anode and cathode areas voltage drops U_{ak} for 250 W HID lamp

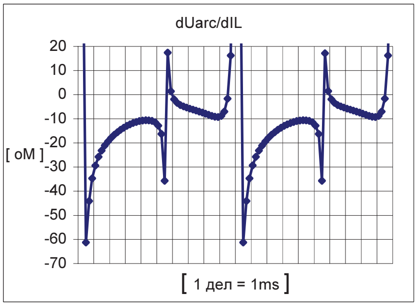


Figure 7 Illumination arc differential resistance change for one period of the supply voltage at frequency 50 Hz

The simulation volt-ampere dependences in time are corresponding adequate with the experimental. This model allows recording the voltage drop of the illumination arc as well as the anode and cathode areas voltage drops. It can be seen that the illumination arc has strong negative differential impedance from the graph on Figure 7.

The obtained during simulation 250 Watt HID lamp volt-ampere characteristics powered by sinusoidal voltages with frequencies respectively 50 Hz and 500 Hz are given on Figure 8 and Figure 9. During increasing the working frequency of HID lamp a volt-ampere characteristic linearization is observed. It can be considered that the HID lamp differential resistance takes positive values at frequencies higher than 500 Hz. This means that increasing the frequency of the supply voltage allows to decrease the size of the induction ballast and to improve significantly the stability at work.

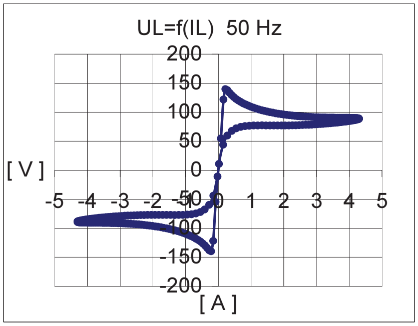


Figure 8 Volt-ampere characteristics during work simulation of 250 W HID lamp supplied with sinusoidal voltage with frequency 50 Hz

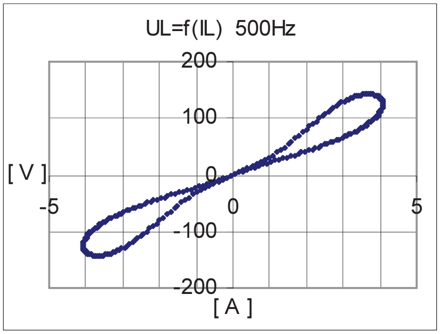


Figure 9 Volt-ampere characteristics during work simulation of 250 W HID lamp supplied with sinusoidal voltage with frequency 500 Hz

5. Conclusions

A combined high pressure sodium lamp analytical and program model is developed and examined. The model agrees with the experimental measurements. Volt-ampere dependencies of the illumination arc, anode and cathode areas are obtained. The anode and cathode areas electrical properties stabilizing role on the HID lamp work is determined, because of their improvement on the lamp differential resistance. The developed model is suitable for HID lamp simulation with ballasts for work up to 1000 Hz.

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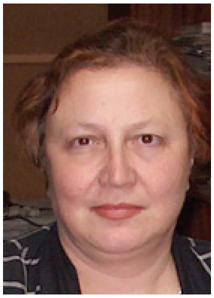

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A STUDY ON INTEGRATING EFFICIENT SHADING DEVICES IN OFFICE BUILDINGS

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The main objective of the proposed paper is the analysis of the relationship between solar shading and daylighting. Moreover, the applicability of several types of conventional sun shading devices in the Mediterranean climate is studied, with respect to their potentiality to act both as sun protection and daylight elements. The study is focused on the analysis of visual and thermal conditions, which prevail on the models of a parametric study. The models share the same geometrical and optical characteristics, but differ on the type and function of shading devices. Furthermore, they encompass the typical characteristics of a contemporary office; the basis of this approach emerges from the fact that the indoor environment in such spaces is almost always artificially controlled, since the requirements for their use with regards to indoor temperature and lighting are specific, leading thus to high energy consumption.

1. Introduction

Transparent elements are considered as the most sensitive component of the building envelope, since they are often associated with excessive thermal losses and direct heat gains, glare, poor acoustical conditions, as well as feeling of insecurity and loss of privacy. In Mediterranean climates, problems of overheating dominate and are often confronted by the implementation of shading devices. However, the shading devices do not only prevent the solar radiation from entering the room, but also regularly lead to the reduction of lighting levels indoors. In such cases, the demands result in the increase of artificial lighting use, which can also cause overheating during the summer period. Therefore, the careful design of sun-protective devices with respect to their impact on daylighting is very important for the overall function and the energy behaviour of the building.

Solar protective devices can be classified according to their position with respect to the opening: they can be applied externally (i.e. overhangs or vertical fins), internally (i.e. louvers, blinds, curtains), or they can be incorporated in the fenestration (i.e. solar control glazing). The decision upon their type and characteristics are based on the geometry and orientation of the opening. Typically, the integration of external solar protection devices is more efficient, at least in terms of thermal conditions, since they block the solar radiation before entering the interior. Conventional solar control glazing can reduce the heat gains significantly, but its low light transmittance may cause increased artificial lighting demands and therefore indirect cooling load. However, the use of reflective glazing is very common for office buildings in Greece.

The impact of sun protective devices on the quantitative assessment of indoor daylight levels focuses mainly on the limitation of the visible patch of sky, since the adequacy of daylight levels is usually examined for the worst outdoor conditions, i.e. under overcast skies. Furthermore, beam sunlight is assumed to contribute to the formation of indoor daylight conditions indirectly, through the determination of the reflected component. Additionally, the orientation of the façade does not influence the levels of daylight factor, since under overcast conditions the luminance of a sky patch depends merely on its altitude on the sky dome.

The scope of the current paper is to investigate the interrelationship of shading and daylighting, i.e. to analyse the impact of sun protective devices on the indoor thermal and daylight conditions. It was performed as a parametric study, by comparing the indoor conditions prevailing in spaces with three types of sun protection. The indoor thermal and daylight environment of an existing space without any solar control comprised the benchmark of the study; the models shared the same geometrical and optical characteristics with the reference space, but had different types of sun protective devices mounted on their openings. The examined shading systems were selected upon their position with regards to the opening and comprised conventional systems used for office buildings in Greece.

Nowadays it is acknowledged that the energy consumed in operating buildings forms a significant proportion of the final energy consumption in OECD countries. Particularly for the European OECD countries, the building sector consumes the highest amount of energy (40%) in comparison to the transport (22%) and industry sectors (38%) [1]. In office buildings, the energy consumption concerns mainly electricity, used for covering lighting and cooling demands.

2. Methodology

As the reference case of the study, an existing space with design features representative for office buildings was adopted -named Model-0 (Mod-0)-. The space is located on the 4th floor of the building housing the Department of Civil Engineering of the Aristotle University of Thessaloniki and has unobstructed view to the sky dome. It is of rectangular plan (4,50x7,00m); the reflectance of the surfaces covering the floor, ceiling and walls was measured and found equal to 18%, 30% and 30% respectively [2]. The office is lit by one window (4,00mx1,75m, windowsill height: 1,00m), which represents a 20% ratio of window to floor area (Figure 1). The opening is covered with a conventional single glazing in metal framing (visible transmittance T_v=85%) and is orientated due southwest.

In order to derive more general results about the relationship between shading and daylighting, a south-orientated opening was assumed for this particular study. This assumption does not have any impact on the levels of daylight factor, since it refers to overcast sky conditions and is independent of orientation. On the contrary, orientation is strongly related with the indoor thermal conditions, since it determines the amount of incident and transmitted radiation.

Three types of solar protection were selected for the analysis and were incorporated in three respective models:

- A horizontal overhang was applied on the *exterior* of Model-1 (Mod-1). Its geometry was decided upon its optimal function: the admittance of solar radiation should be fully allowed during the winter and prevented during summer. By using simple mathematical formulas it was found that these requirements could be fulfilled with an overhang of 1.00m in depth, positioned 0,20m above the window.
- In Model-2 (Mod-2), shading was *incorporated* in the opening by means of a solar control glazing. Such a strategy is very common among office buildings in Greece, usually in the form of a reflective transparent glass. The visible transmittance of the glazing was assumed to be equal to 50%.
- Venetian blinds were installed on the *interior* of Model-3 (Mod-3). For the simulation it was

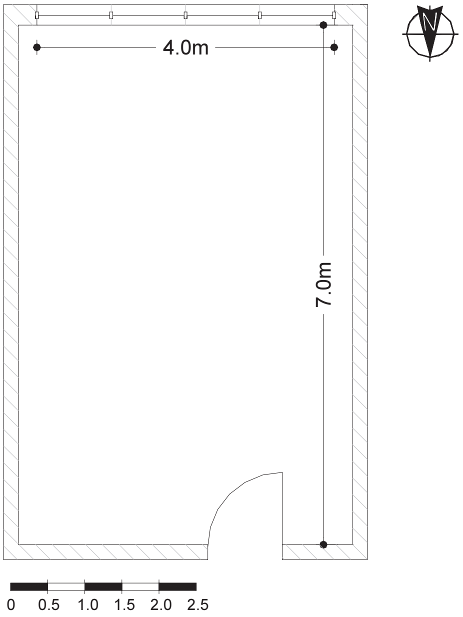

Figure 1 Plan view of the reference model Mod-0.

assumed that the slats are adjusted to eliminate direct transmission of solar beam, as well as that the slats are perpendicular to the solar beams. The shading provided by the interior blinds was estimated on the basis on EN 13363, according to which the visible transmittance of an assembly composed by clear glazing and interior blinds with a slat inclination of 45^{o} is considerably decreased [3], resulting in a glazing transmittance equal to 40% and total solar energy transmittance equal to 0,45. These values were incorporated in the description of Model-3. In order to extract comparable results for the thermal simulation, it was assumed that the U-value of the glazing of Model-2 and Model-3 remained unaffected.

The analysis of the conditions prevailing on the reference model (Mod-0) and the models of the parametric study (Mod-1 to Mod-3) included both thermal and daylight aspects and was conducted by means of simulating programs.

More specifically, the computer program ADELINE was used for daylight estimations. The calculation technique used in ADELINE is based on the exchange of radiation flux between surfaces (radiosity method), in which space surfaces are divided into a mesh of small elements and the amount of light distributed from one mesh element to another is calculated [4]. Main criteria for the analysis were the average values and the distribution of daylight factor, as well as the estimation of the percentage of time during which autonomy in lighting was achieved calculated on an annual basis.

Thermal conditions were simulated with SUNCODE, an hourly simulation model, which incorporates detailed solar algorithms designed for use in multi-zone structures and is appropriate for most residential and small commercial buildings [5]. The estimated differences in the loads covering the heating and cooling requirements between the examined models were the criteria for the assessment of thermal conditions.

By the comparative analysis of the results, the impact of sun shading on thermal and daylight performance is highlighted and the assessment of the optimal selection for sun protection for each case is enabled.

3. Parametric study

3.1 Assessment of the daylight conditions

The evaluation of the daylight conditions was based on quantitative criteria: daylight factor is regarded as the most appropriate indicator for the adequacy of lighting indoors. It represents the illuminance at a specified point indoors, expressed as a percentage of the simultaneous horizontal illuminance outdoors under an overcast sky. The orientation of the opening does not play an important role on the determination of daylight factor, since the standardized overcast sky presents only altitudinal asymmetry, featured by illuminance at the zenith three times greater than on the horizon [6]. On the contrary, differentiations on the angular height of the visible sky patch and on the glazing transmittance influence the daylight factor patterns significantly.

The mean value of daylight factor prevailing on the working plane of the models is presented on Figure 2. In the case of a horizontal projection (Mod-1), the daylight factor is reduced by 14,5% compared to the relevant conditions prevailing on the unobstructed reference Mod-0. The basis of daylight reduction is depicted from the distribution of daylight factor across the symmetry axis of the working plane of the examined modules, which is displayed on Figure 3. For Mod-1, areas along the opening receive less daylight than the respective surfaces of reference case Mod-0. The effect of the overhang is obvious in areas with depth reaching the center of the space. On the contrary, there is not any remarkable differentiation in daylight factor on areas located close to the rear wall. This is due to the fact that the overhang blocks the view of the

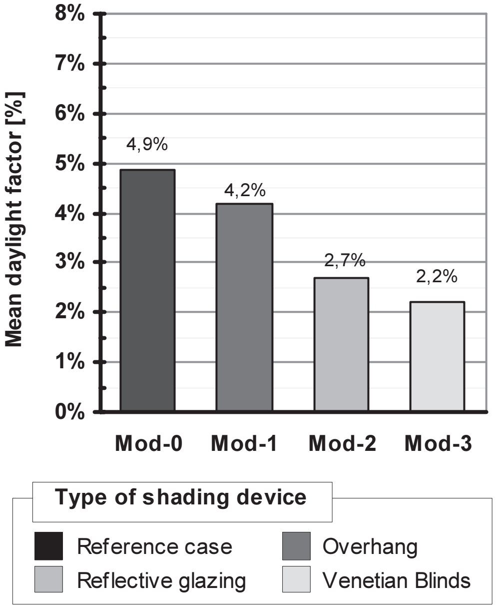

Figure 2 The average daylight factor prevailing on the working plane of the examined models.

higher parts of the sky vault, which could be seen from areas close to the opening. The remote areas hardly see any sky patch, so there is not any significant alteration on the daylight factor levels. The almost negligible difference is attributed to the component of reflected daylight, which reaches low levels under overcast sky conditions.

The low light transmittance of the glazing of model Mod-2 has a remarkable impact on the formation of indoor visual environment. The average daylight factor does not exceed 3%, while the reduction is equally distributed to the entire working plane.

Similar distribution, though ranging on even lower levels, is observed across the symmetry axis of model Mod-3: the assumed low visible transmittance of the system "clear glass & interior blinds" result in poor daylight conditions. Average daylight factor does not reach 2,5% and the threshold of 2% for daylight factor is not exceeded for most areas of the working plane. However, it must be mentioned that the lack of direct solar radiation in overcast sky conditions does not necessitate shading; therefore the venetian blinds would probably not be used and consequently the daylight levels would be higher.

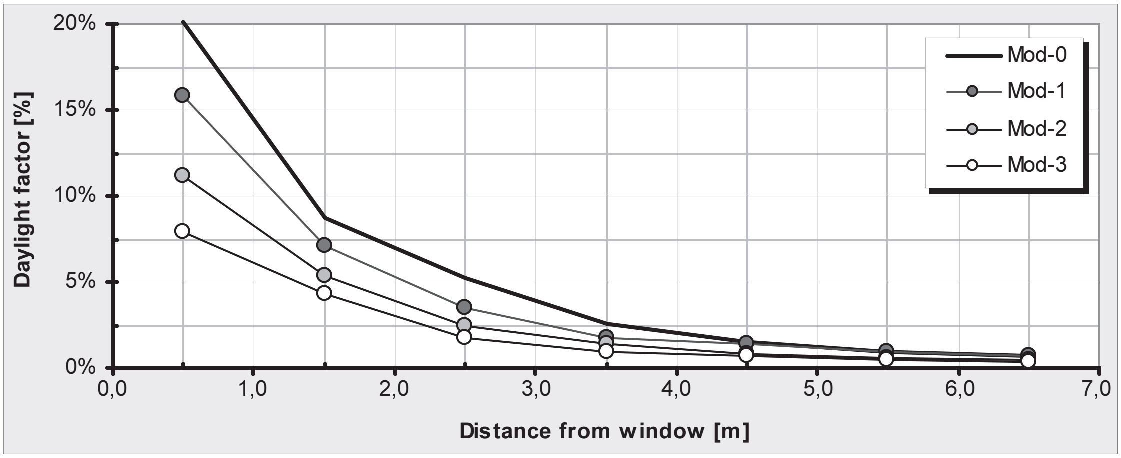

Figure 3. The distribution of daylight factor across the working plane of the examined models.

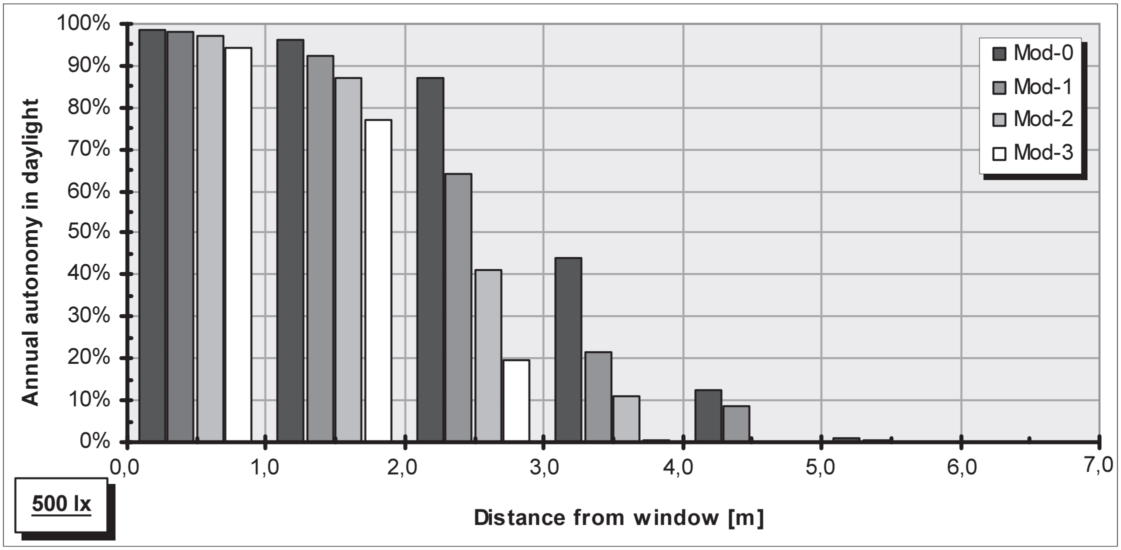

Figure 4 The availability of daylight across the working plane of the examined models, when the threshold for illuminance is considered equal to 500lx.

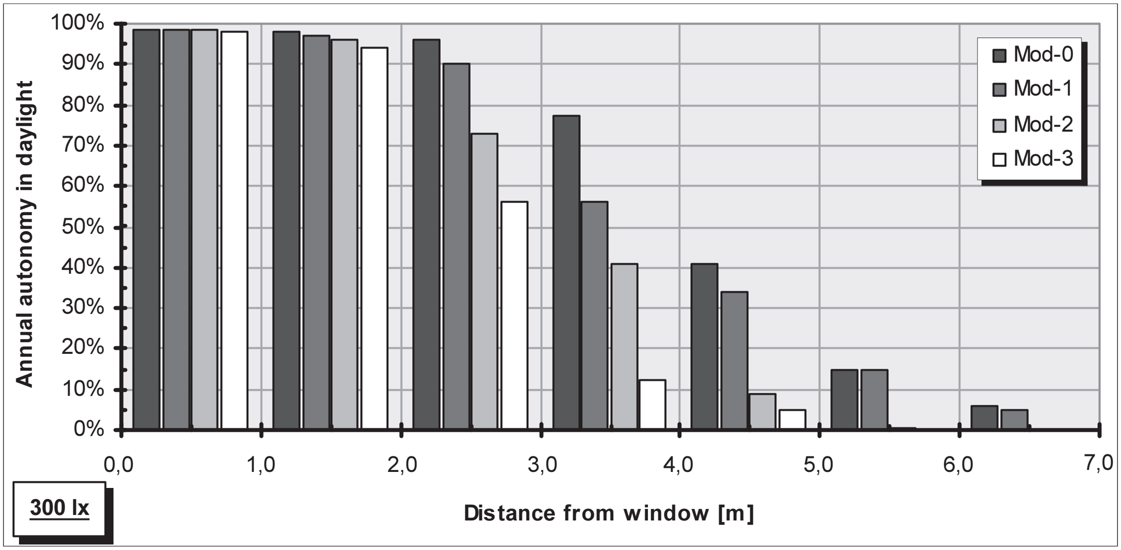

Figure 5 The availability of daylight across the working plane of the examined models, when the threshold for illuminance is considered equal 300lx.

The impact of sun shading devices on the availability of daylight during the year is presented on Figures 4 and 5 for two thresholds of lighting adequacy: 500lx and 300lx respectively. For all kinds of solar control the availability of daylight is slightly affected on areas near the window and close to the rear wall of the model. This is because the areas along the window receive more daylight than needed, while on areas close to the rear wall the daylight levels are formed mainly by the internal reflections and are not influenced by exterior elements at a great extend.

When 500lx are regarded as the threshold, the energy demands of Mod-1 are considerably increased in the center of the space; the period with daylight autonomy is decreased by 50% with respect to the reference case Mod-0. For the same threshold, the central area of Mod-2 is autonomous only for the 10% of the annual working hours. Additionally, the central and rear areas of Mod-3 need artificial lighting during the entire annual occupancy of the office.

If the activity conducted on the central areas requires 300lx, the decrease on daylight availability of Mod-1 with respect to the base case accounts for 27%. Daylight levels prevailing on the center of Mod-2 are adequate for 40% of the annual occupancy hours. For Mod-3 daylight autonomy is restricted to only 10% of the working hours.

3.2 Assessment of the thermal conditions

The assessment of the impact of the examined shading devices on the formation of the indoor thermal environment was based on the estimation of the thermal loads (heating and cooling) required for the achievement of comfort conditions in the interior of each model. The desired indoor temperature during the working hours (09:00-17:00) was considered equal to 20°C in winter and 26°C in summer and was achieved with the operation of the heating and cooling system. The ventilation rate was set to the minimum required for office buildings (2ACH) [7], while especially for the summer period it was assumed that the openings would allow the inflow of exterior air in case that the ambient air temperature ranged in levels lower than the ones prevailing indoors.

Main factors determining the indoor thermal environment are the properties of the elements of the building envelope. In Greece thermal protection was introduced in buildings in the early 80s; the examined building was erected in the late 50s and therefore its envelope is not thermally insulated. The load bearing structure consists of beams and pillars made of reinforced concrete and the external masonry is double brickwork. The lack of thermal insulation and the large opening surfaces result in extended heat losses during the winter months and high indoor temperatures in summer. For that

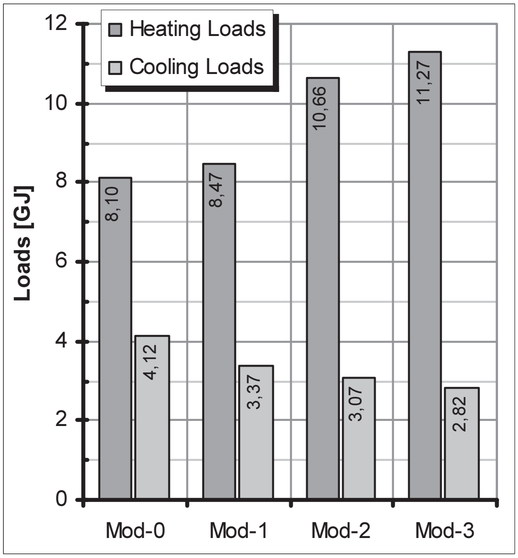

Figure 6 Annual cooling and heating demands estimated for the examined models.

reason, the heating and cooling loads required for achieving indoor thermal comfort during the operation hours are relatively high: simulation with SUNCODE showed that on an annual basis 8,1GJ are consumed for heating and 4,1GJ for cooling a single office space of the building.

The integration of shading devices would have a double impact on the determination of energy demands: the limitation of solar gains would increase the heating requirements during the winter period and on the other hand would reduce the cooling loads during summer. For assessing the optimal shading device, it is worth studying the quantitative differences of the energy consumed for heating and cooling between the models of the parametric study Mod-1 to Mod-3 with respect to the base case model Mod-0 (Figure 6).

From the diagram it can be depicted that horizontal projections on the building's façade have little influence on the heating loads of the space: the annual increase on heating requirements for Mod-1 accounts for 5% compared to Mod-0. On the contrary, cooling loads is notably reduced for Mod-1 (18%), indicating that the horizontal projection offers the desired sun control protection during summer, without blocking direct heat gains in winter months.

The incorporation of reflective glazing (Mod-2) can lower the cooling needs significantly (26%), but its steady reduction of global radiation transmittance results in a high rise of heating demands (32%). Similar are the results for the case of internal blinds: the significant decrease of cooling loads (31.5%) is counterbalanced with the increase of heating load (39%). It is worth mentioning that the simulation results refer to blinds tilted by 45^o throughout the year; their adjustability, however, allows for their seasonal use according to the weather conditions. In that case, the blinds can be used during the warm period and reduce the cooling loads of the space and occasionally in winter, resulting in a slight increase of heating requirements.

4. Conclusions

The investigation of the optimal shading device seen from both daylighting and thermal behavior aspects has so far shown conflicting results. For example, the highest decrease on cooling loads, and therefore the optimal shading, is achieved with blinds, but, on the other hand, the admittance of daylight is considerably reduced. Although under clear skies the ambient illuminance ranges in very high levels and the internal shading would probably act as glare protection as well, it must be mentioned that artificial lighting may be necessary for covering the needs of the rear spaces.

It is then derived that the selection of solar protective devices cannot be based solely on the elimination of direct heat gains during summer. Other aspects, such as daylighting, should also be included in the design analysis. From a strictly ecological point of view, lighting and cooling loads have a more significant impact on the environment, since for the consumption of 1kWh of electricity (0,0036GJ), 3.12 kWh of primary energy is needed in Greece, which result in the emission of 3,8064kg of carbon dioxide and significant amounts of sulphur dioxide, nitrogen oxides and suspended particles [8]. Therefore, the integration of efficient shading devices necessitates a prior decision upon the hierarchy of the objectives of the design; perhaps the solutions given for the achievement of optimal visual conditions, thermal environment or the environmental performance may vary.

Apart from presenting the results of a technique for selecting and assessing shading devices, the main objective of the paper was to highlight the interrelation of shading and daylighting. These two vital functions have proven to be contradictory in the mentioned case, where the study of an existing building is concerned. However, shading and daylighting can be totally combined, when both are examined at the early stage of the building design. In such cases, the designer should take into account the various functions of the transparent elements during the decision upon the envelope and the geometry of the building, with regards to its use, geographical location and user's needs. Furthermore, the ongoing study and development of advanced strategies, which act both as solar control and daylighting intensifiers, resolve the barriers identified above and promote the design of sustainable buildings.

The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment. Such strategies either rely primarily on admitting diffuse skylight and rejecting direct sunlight, or use primarily direct sunlight, sending it onto the ceiling or to locations above eye height. Main representatives of advanced systems that combine shading and daylighting are the prismatic and laser-cut panels, anidolic openings, light shelves and reflective blinds or louvers.

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SOME APPLICABLE RESULTS OF THE LIGHTING SCIENCE – FROM CONCEPTION TO UTILISATION: *„MILLENNIUM III BAIA MARE” PROGRAMME.*

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The objective of this writing is to synthetize the various activities involved in the process of the investment implementation, from the solution study to the final reception – in the lighting technologies speciality.

This investment received the specialists appreciation and was awarded the „Nicolae Ghica – Budești” prize and the 2004 Great Trophy by the Ministry of Culture and Religion at Romanian Cultural Heritage 2004 awarding of prizes.

The design aspects of the historical building lighting for the units included in the investment programme were partially discussed at CNRI Conference from Cluj, year 2003 – under the title: „The main criteria of inside and outside lighting design of the historical buildings from No. 4 Matei Corvin street, Cluj-Napoca and Black Eagle in Baia Mare”.

The execution in situ of the three projects that compose the programme was discussed in the work: “THE LIGHTING OF HISTORICAL BUILDINGS. The Commercial Center Baia Mare, România” at the International Lighting Conference in Cluj, on 2005.

The aim of this work is to share the method of achieving the connection between the lighting technology science and the application, as part of the investment, of the proposed solution.

Having experience in designing and execution of the electrical installations in historical buildings, we can specify the stages of the project from the starting point to the final reception of the investments. In the stages of prefeasibility and feasibility studies, the specialist in lighting design has no direct contact with the elaboration of the work.

The lighting designer joins the designing team after the auction documentation is prepared and makes proposals on the grounds of architectural themes.

In the analysed case, that of historical buildings, these proposals are formal, as the art history studies and the archaeological prospects that can modify the architectural theme are not carried out in the auction stage, consequently, the solutions for lighting are also formal.

Nevertheless, in this stage, the importance of approaching the lighting solutions, depending on the destination of the locations, their configuration and finishing, is a first step in recognizing the methods of project execution and generally there are also references to the cost of the proposed lighting systems.

After contracting the designing work, the lighting design is necessary for the elaboration of the Building Authorization Project stage without which the general scheme with the total power consumption of the investment and the documentations for the authorizations and agreements regarding the electric power supply cannot elaborated .

The tehnical project will contain the complete solutions with calculations and diagrams, together with the list of lamps' type and applicances, light sources and other elements belonging to the installed systems. We must specify here all the features of lighting appliances : the shape, colour and the material, the features of light sources: the power, the colour, UV protection etc., all the facts needed for an accurate identification to be bidded by the executer.

The documentation for the execution auction will be created based on the lists. The connection between the notes in the design auction offer and the lists form the technical project can be noticed: when estimating the investment, the beneficiary considered the initially offered amount, and that must not significantly differ from the amount on the reference (initial) price estimation based on the lists in the technical project.

Certainly, the difference in favour of the investor is received favourably, but if the difference is large, the designer might lose his credibility.

The execution details are used for the accurate specification of the lighting appliances installation methods and quotes, their position and gorge details, etc., details that answer the lighting design proposed in solution.

As part of the technical assistance, the designer's primary duty is to handle the solution modfications as a result of some architectural modifications of the historical buildings. Circumstances that were left unsolved during pre-design stage usually appear during rehabilitation: unused spaces in old buildings, formerly obturated chimneyes, built-in enframement, secret underground tunnels that are worth emphasizing. These modifications can lead to changes in destination, finishings, details of walls and ceilings, as well as modifications of the lighting design.

There are cases in which the rehabilitation cost exceedes the funds, the beneficiary being compelled to economize the values. Thus, the initial lighting solutions are often entirely or partialy put aside. Therefore, the designer's task is important: professionally made compromises that ensure the specified visual confort.

On the presented work, all the stated stages were run through, the assistance stage in colaboration with the consulting firm Louis Berger ensured the European community exigence concerning the approach of solution changes. At the end of the investment cycle the quality compromises regarding the lighting technologies were not accepted, the necessary funds for the design agreed upon were obtained instead.

The method of approaching the various stages and the issues within, led to the acomplisment of the investment in due time, the results being appreciated both by the investor and the Ministry of Culture. The rental of the historical centre locations immediately after their reception indicates the successfull working.

Finally, we chose a few lighting details that are ment to support the presented lighting technologies implementation concept.

Figure 1 Lighting of the basement entry, Building A, Black Eagle

Figure 2 Lighting of the ground floor passage, Building A, Black Eagle

Figure 3 Lighting of the rebuilt conference room, Building C, Black Eagle

Figure 4 Lighting of the former basement entry, Building M2, emphasized detail

Figure 5 Lighting of the vaulted council chamber, Lendvay house

Figure 6 Lighting of the old chimneys, attic of Black Eagle building

Figure 7 Lighting of walking halls, first floor, Black Eagle building

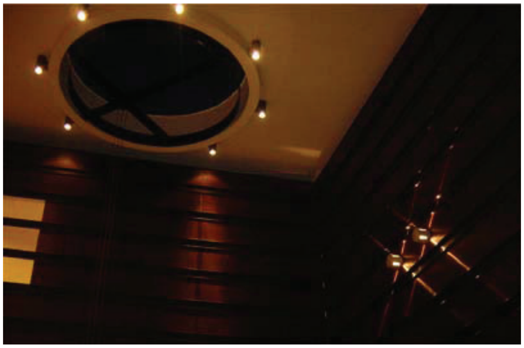

Figure 8 Lighting of the inner yard, Building M2

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LIGHTING IN THE NEW WORLD

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The ASHRAE/ IESNA Energy Code

The world is dependent on energy - for home, office, industry, lighting, heating, fuel, transportation and all delivery of goods. In the mid 70's, the Middle Eastern oil export embargo has found North America and most of the Western world, with weak national policies on energy issues, and generally high consumption, triggering a world-wide energy crisis. On a positive note, the 70's energy crisis was a significant wake-up for the way the whole world was using and consuming energy. Many states have since then revised their energy policies and downsize the energy consumption, in parallel with significant research and investments in alternative non-fossil energies.

While important measures have been focused on producing energy more efficiently in United States and Canada, a significant effort was orientated to the efficient energy consumption as well. It has been estimated that as much as 40% of the energy that used to heat, cool and illuminate buildings would be saved through the effective application of existing technology without reducing building performance or occupant comfort.

Therefore in 1973, NCS/BCS (National Conference of States on Building Codes and Standards) solicited recommendations on content of standards to become basis for energy codes for buildings. ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) started to develop an energy code in 1974 and a year later the first version, ASHRAE standard 90-75 was published. Politicians got involved and the energy code for building has been continuously reviewed and its endorsement debated. In 1989 the ASHRAE standard 90.1 was adopted as national energy policy and became energy low for buildings in all of the 52 American states.

ASHRAE/IESNA standard 90.1-1989

The standard is aimed at new buildings except low-rise residential buildings. It was approved and published jointly by ASHRAE and IESNA Illumination Engineering Society of North America). ASHRAE/IESNA 90.1 covers the building envelope lighting, power and HVAC with the purpose to:

- set minimum requirements for energy efficiency in new buildings
- provide criteria for evaluating the energy efficiency of the design
- provide guidance for sound design

The document does not dictate design procedure, but the maximum power that may be used for the lighting. The lighting designers and engineers are given the mandate to design and select the appropriate lighting equipment that meets the wattage limitations and also provides adequate lighting. Also 90.1 focuses on comfort conditioning rather than industrial, manufacturing or commercial purposes.

Lighting requirements for 90.1-1989 cover all interior and exterior lighting for new constructions except lighting for: stage/ television, audio-visual presentation, outdoor sport arenas, displays for museum and art galleries, signs, plant grow as well as for medical/ dental luminaires.

In order for a lighting design to comply with the standard, it has to satisfy several general and mandatory requirements and the proposed calculated lighting power should be less than the estimated LPA (Lighting Power Allowance).

General requirements

- *Ballasts*: all ballasts must have a power factor of 0,9 or greater, except for CF, HID under 100W and dimming ballasts. Ballasts for T12 lamps must meet given minimum BEF (Ballast Efficiency Factors represents the ratio between the Ballast Factor in percents and the power input to the lamp-ballast system) values.
- *Controls:* all lighting, except for emergency or exit, must be controlled with manual, automatic or programmable controls, located within the room. Each room should have a minimum of one control. Additional controls are required depending on the size of the room, number of task locations and total connected load. For example, office tasklights may be counted as additional controls if they are readily accessible. Occupancy sensors for daylighted spaces must have manual-on or photocell-on override. The standard offers control credits; a multiplier can reduce interior lighting load if automated controls are used.

Compliance Calculation Paths

Interior and exterior calculated power for lighting must not exceed their calculated LPA. The LPA value is a sum of the building's ILPA (Interior Lighting Power Allowance) and the ELPA (Exterior Lighting Power Allowance) values.

For interior lighting, the designer has a choice of two calculation pathways/ methods for the ILPA:

- *Prescriptive Criteria* – simple criteria based on building type only; fast but with limited accuracy and flexibility.
- *System Performance Criteria* – greater flexibility and accuracy; requires more detailed and time-consuming procedure.

For exterior lighting, the ELPA is easier to calculate tabulated values per area type.
In a multi-building facility ILPA and ELPA must be calculated separately and trade-offs involving ILPA or ELPA are not allowed.

Prescriptive Criteria

This calculation method is based on the primary occupancy for which the building is intended (offices, retail, school, etc.). The ILPA (in Watts) is calculated as a product between UPLA (Unit Power Lighting Allowance- W/ft^2) and Gross Lighted Area. UPLA maximum values are tabulated function of size ranges for the lighted areas. Where building occupancies are different and each over 10% of the total building surface, they can be processed separately and then ILPA's totalled.

System Performance Criteria

This method is much more detailed and time consuming than the PC but much more accurate; requires knowledge of how space will be used. The system calculates the LPB (Lighting Power Budget) for each area within the space ant then totals them; LPB is a product between the UPD (Unit Power Density -W/ ft2), the AF (Area Factor for the room) and A (the space area - ft2).

UPD values are tabulated and given according to the area and activity much like the illuminance values in the IESNA guidelines. AF's have to be determined from a diagram function of the space area (A) and a family of curves that represent various ceiling heights. The process could go on a room-by room or same activity area basis.

For example, let's calculate the LPA for a McDonald's Restaurant with 4,000 ft^2:

- *Prescriptive Method* - under this method the building would be allowed an UPLA of 1.34 W/ ft^2 resulting in an LPA of 5520 Watts.
- *System Performance Criteria* – the building was broken into specific activity spaces and given the proper ceiling height. The UPD tabulated values vary from 1.4 W/ft^2 for the

kitchen, to 1.3 W/ft^2 for eating area and to 0.8 W/ ft^2 for corridors and washrooms. The total value for the LPA is 6080 Watts under this method.

ASHRAE/IESNA standard 90.1-1999

In its first version, the code has been criticised for its disadvantages and therefore was subject to multiple revisions mainly as a result of market feedback. The latest version represents a complete revision of ASHRAE/ IESNA 90.1-1989. Reorganised for ease of use, the new 90.1-1999 standard clarifies requirements and provides simplified compliance paths as well as separate tables for imperial (IP) and metric (SI) units. More importantly, the 1999 edition expands the code's scope to new and existing buildings and systems.

Changes in the Document

The lighting section has also been revised. Changes in this section are intended to encourage energy conservation, primarily by requiring the use of lighting controls and creating total building wattage limitations. Both interior and exterior applications are included. These revisions include:

- Interior lighting control requirements are designed to ensure that lighting is turned off when facilities are unoccupied (except where safety or security is involved), primarily through programmable building lighting controls and occupancy sensors.
- Exterior lighting control requirements are designed to ensure that the lights are off during daylight hours, primarily through photosensors.
- There are individual manual control requirements for accent, task, and demonstration lighting. The connected power associated with the following lighting equipment is not included for the calculation of the total connected lighting power: *specialised medical, dental and research lighting, professional sports arena and playing field lighting, display lighting (for exhibits galleries, museums, and monuments), guest room lighting (in hotels, motels, etc.), emergency lighting automatically off during normal building operation.*

The standard specifies limits on the total wattage used for lighting throughout a building by establishing a total LPA (lighting power allowance). The ILPA (Interior LPA) is calculated as the product between the building/specific area square footage and the LPD (Lighting Power Density - total lighting W/ft2 specified for that building type). Using LPD tables, ILPA can be determined in two ways:

- *Building area method:* LPD tabled information for building type. Total wattage may he used at the lighting designers discretion.
- *Space-by-space method:* Wattage for each individual space is allowed to build a total lighting wattage budget. This budget can he used as the lighting designer chooses.

LPD values for both individual spaces and whole buildings have been developed by IESNA using currently available efficient lamp/ballast/fixture data, and illuminance values from current IESNA illuminance recommendations. In this way, the needs of the occupants are taken into account and energy-efficient design is promoted through the resulting lighting power densities (see www.iesna.org).

Additional lighting power is allowed for decorative lighting, luminaires designed to minimize glare on VDT screens, and retail accent lighting. If this lighting equipment is not installed, no additional power is allowed.

The standard also specifies limits on the total wattage used for exterior building entrance and exit lighting by establishing a total exterior lighting power budget. This is determined by totalling the lighting power allowed for all exits, entrances, and canopied areas of entrances. This budget can he used at the lighting designer discretion.

Additional lighting power is also allowed for facade lighting. This power budget is based on the total area of the exterior building surface being illuminated. It is not part of the total exterior lighting budget and is only allowed if façade lighting is installed.

Code Enforcement

The USA Energy Policy Act (EPAct) requires each state to certify that their energy codes meet or exceed the ASHRAE/ IESNA Standard 90.1-1989. Also EPAct requires that the US Department of Energy (DOE) evaluate subsequent revisions of the standard to determine whether they improve energy efficiency in commercial buildings. The DOE posted results of its quantitative analysis on its own web site at www.eren.doe.gov._The report observes that the 1999 edition could increase the energy efficiency with 8-12% when compared with the 1989 edition.

ASHRAE/ IESNA Standard 90.1-1999 has already begun to be incorporate in US states energy codes and is set to be adopted by all the American states by the end of 2002. Moreover, the 1999 standard has been included in the International Energy Conservation Code (IECC) model 2000 code proposed by the International Code Council (ICC).

Canada has supported the 90.1-1989 standard as well, however the regulations are not enacted at federal levels, but left with the municipalities. At present, not all the Canadian municipalities endorse this particular energy code. Some municipalities have begun to enforce the 1999 edition over the old standard. Also, Canada has developed its own energy code, the Model Energy Code for Buildings (MNECB) in 1995, that differs from the ASHRAE/IESNA code by referencing Canadian standards and regulations, using metric (SI) units and including only enforceable requirements.

In conclusion, the ASHRAE/IESNA energy code offers only minimum energy standards. Consequently, property owners and their design professionals are urged to exceed these minimums to create more productive, profitable and comfortable environments.

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Lighting engineer at BC Hydro, in Vancouver, Canada. Member of CIE and IESNA Board of Directors for BC. Lighting research, technical articles and project designs for institutional, commercial and industrial indoor and outdoor facilities in North America. PhD from the Technical University of Construction, Bucharest in 1995. Assistant Professor at the Lighting and Electrical Installations Chair, Faculty of Installations until 1995.

Received 20 July 2005

THE 3rd INTERNATIONAL CONFERENCE ILUMINAT 2005 & LIGHTING BALKANLIGHT 2005

June 2-3, 2005, Cluj-Napoca, Romania

Florin POP
Universitatea Tehnică din Cluj-Napoca

The current event represented the third edition of the **ILUMINAT** International Conference**,** run together with the third edition of the Balkan Lighting Conference **BALKANLIGHT 2005**.

The organizers of the conference were, as at the first two editions, the Technical University of Cluj-Napoca through the Lighting Engineering Center, ELECTRICA S.A. Transilvania Nord The Electric Energy Distribution and Supply Branch and S.C. EnergoBit Schréder Lighting Cluj-Napoca.

The Third International Conference ILUMINAT 2005 & BALKANLIGHT 2005, June 2-3, 2005, Cluj-Napoca, Romania was a regional forum regional to present, discuss and debate the most recent developments concerning the energetic and environment impact aspects of lighting systems, the policies and programs adopted and planned by the European Union and Romania, the strategies to be implemented in order to ensure the future progress and technical and commercial novelties, in what it concerns the market dissemination of lighting energy efficiency.

The conference included 9 invited presentations and run 6 plenary sessions with 39 papers and four posters, with 90 authors, among which 34 national and 56 international authors. 46 authors were present to defend their papers, among which 20 national and 26 international. 46 persons participated as registered audients or with open entrance (undergraduate, graduate and doctoral students, designers and architects). Specialists of high performance and representativity expressed their positions, research programs and novelties in the field of lighting energy efficiency. Exhibitions were organized with lighting apparatuses created by a collective from the University of Arts and Design in Cluj-Napoca, and with lighting equipments, organized by the conference sponsors.

The audience was represented by the community of lighting professionals in Romania, Balkan countries, European Union, other European countries, countries in other areas, scientists and researchers in lighting and building science, engineers, system designers, managers, academics and experts, urban architects and planners, government and local authorities, promoters of energetic and market policies, national and international organizations and agencies, producers and dealers, students. The participation of young researchers contributed to the success of the conference and to the improvement of their knowledge on the field.

The participants at the conference "Energy Efficiency and Modern Trends in Lighting" developed their contributions around the following topics: Vision and Color, Lighting Design and Interior Lighting, Public and Architectural Exterior Lighting, Natural Lighting and Integrated Systems, Lighting Power Installations, Architectural Lighting Design, Other Applications. We acknowledge the efforts of Major Offices towards public lighting rehabilitations; the conference presented some of the most remarkable national and international developments. The conference allowed the knowledge of the newest policies and strategies of the European programs (Framework Program 6, Green Light) to increase the energy efficiency, to support the environment and to have a durable development and created an international and Balkan regional cooperation framework of the lighting professionals.

The invited papers presented new research directions in the lighting field. We mention here the following: Axel STOCKMAR, President of the German National Lighting Committee – Tunnel lighting design in view of different European regulations, Michel de BRUYN, Belgium - The urban photometry, Luciano Di FRAIA - Energy and Maintenance Problems in Lighting, Koichi IKEDA, Japan – Prediction of Colour Appearances in Nayatani, Hunt, CIECAM and NC-IIIC Spaces for Comparison with Perceived Attributes of Munsell Colours, Janos SCHANDA, Hungary – LED Photometry and Colorimetry, Miomir KOSTIC, Serbia and Montenegro – Influence of the Theory of Mesopic Vision on Road Lighting Design, Sermin ONAYGIL, Turkey – The Effect of Observer Position and Movement on Road Lighting Criteria, Andrej ORGULAN, Slovenia – Slovenian Experience with the Enforcement of Light Pollution Legislation, Florin POP, Romania – Demands, Efficiency and Costs of Daylighting, Hristo VASSILEV, Bulgaria – High Efficiency Street Luminaires.

The conference hosted a special session dedicated to LAEL – Light & Architectural Environment Laboratory, Kyung Hee University, Korea. Under the coordination of Prof. Jeong Tai KIM, director of LAEL, five papers and three posters of high scientific contents have been presented and appreciated by the participants.

The papers from the conference program constitute research results in this field, presentations of case studies concerning modern equipments and efficient use of energy in lighting, exploitation difficulties of street public lighting installations, integration of electric lighting with natural lighting and with buildings architecture. The conference has become, in this way, a forum for promoting the newest research results, and will allow their valorisation in the mutual interest of the collaborators. It is a natural fact that lighting is aimed at the users, it is a component of buildings, and thus modern lighting is benefic to the whole chain – energy, construction, environment, users.

Mr. Wout van BOMMEL, president of CIE – International Lighting Commission – perfectly synthesized the role and the aim of the ILUMINAT Conference in the lighting domain, in his opening message addressed to the conference participants:

> Where the lighting world has studied the visual aspects of lighting over a period of more than 500 years, we still learn interesting and important new things about the visual aspects of lighting. It is impressive to see how fast the Romanian lighting community has developed. This not only concerns areas of lighting research but also areas of innovative industrial products. The participant can learn about all this at the 3rd International Conference **ILUMINAT 2005** & the 3rd Conference on Lighting **BALKANLIGHT 2005**, being organized at the Technical University of Cluj-Napoca.
>
> It is sensational that only recently the medical, biological and lighting world discovered that lighting also has important non-visual effects that directly relate to health and well-being. These new findings demonstrate that the subject of light and lighting is even more important than we thought.
>
> One of the roles of CIE, the International Commission for Illumination, is spreading the knowledge on light, lighting and image technology. In this respect “ILUMINAT 2005 & BALKANLIGHT 2005” is important because it helps spreading up-to-date information to the lighting community in Romania and in the Balkans. Being already the third BALKANLIGHT Conference the lighting community of the Balkans is already accustomed to the high quality of these Conferences and I am sure the Cluj-Napoca Conference will prove this point again. But not only that: in the meantime Lighting Conferences in Romania have become famous outside Romania as well. I am convinced that, also at this Conference, discussions between the Romanian and international participants will be of important mutual benefit.

Professor Cornel BIANCHI, President of the Romanian National Committee on Illumination, underlined in his message:

> The theme of the two conferences, "Energy Efficiency & New Trends in Lighting", is a very generous one. I am sure that topics like Vision & Colour, Daylighting & Integrated Lighting Systems, Lighting Design & Interior Environment, Architectural Lighting Design, Lighting Supply

Installations, will allow us to discuss on modern solutions for lighting, and to find solutions to some old problems.

We have the privilege to work in this fascinating domain where Science, Technique and Art are joining in a harmonious way, so we must see the fact that the dynamism of the time we are living marked the lighting domain too.

The quality of modern life has the "Environmental Comfort" as a basic part, which only a well designed, well realized, well used and well maintained lighting system can provide for.

I dare say that nowadays the world "rediscovers" the values of LIGHT, its place and role in civilization and progress. For lighting specialists of today, this reality is, without doubt, a source of satisfaction and assumed high responsibilities.

I am sure that our foreign quests find with pleasure data about the Romanian Lighting School, with remarkable contribution both to the university education of the specialized engineers and to the promotion of high technical level research.

The conference provided an optimal framework for knowledge, information exchange, deepening existing cooperation, developing new connections for national and international cooperation. The following fundamental objectives have been aimed and marked, some of them with general character by the role and nature of an international conference, other being, however, specific to the activities developed by the Technical University of Cluj-Napoca through its Lighting Engineering Center and by the co-organizers:

(a) Opening an development of new directions of research;

(b) Identification of new directions of international cooperation in the fields supported by the Framework Program 6, IEA – International Energy Agency – the Energy Conservation in Buildings and Community Systems (ECBCS) program, Green Light for Europe;

(c) Stimulation of the demand for research, development, innovation, by presenting some stringent needs of users of the interior and public lighting systems; for example, urban lighting rehabilitation programs of the Major Offices in Cluj, Dej, Reşiţa, Braşov;

(d) Dissemination of the results and presentation of the Romanian scientific research through the participation of the most important research and design collectives in the Academic Centers from Bucharest, Cluj, Timişoara, Iaşi, and the presentation of Ph.D. Theses in this field;

(e) Knowledge of the newest developments in the domain of the conference.

The development of professional contacts and integration of the members of the Lighting Engineering Center and of other Romanian specialists in the activities of the international scientific community is essential to the increase of professional performances and competitivity in research and design. The members of the scientific community, collaborators of the Technical University of Cluj-Napoca, answered with collegiality and interest at the development of the ILUMINAT Conferences, both by their presence in the Scientific Board, and by their direct participation with papers and presentations.

The conference proceedings have been distributed on printed volumes and on electronic versions on CDs.

Photos - Professor Cătălin Daniel GĂLĂŢANU

The Conference Board POP Florin, PÉTER Pal, SCHANDA János, KÜÇÜKDOĞU Mehmet Şener, PETRINA Mircea, BOROŞ János, STOCKMAR Axel, COSTEA Dorin

Dr. Axel STOCKMAR, Opening Lecture

LAEL team together with Professors
Luciano Di FRAIA, Jeong Tai KIM, Florin POP

Professor Koichi IKEDA

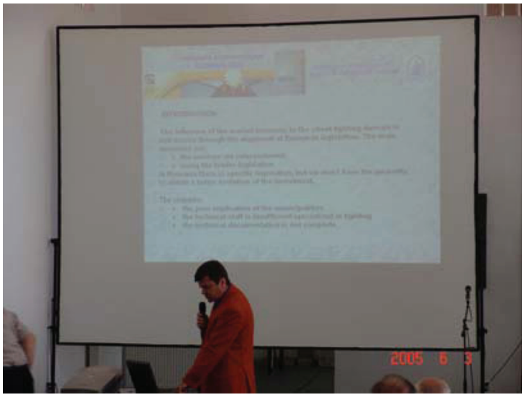
Dr. Michel De BRUYN

Professor Florin POP

Professors Luciano Di FRAIA, János SCHANDA
and Mrs. Manu BANAV

Professor Mircea CHINDRIŞ

Dr. Janos BORSANYI



Professor Cătălin Daniel GĂLĂŢANU

Dr. Nicolina YANEVA and Associate professor Krasimir VELINOV

Associate Professor Dorin LUCACHE

Farewell party

The scheduled program of the 3rd edition of the International conferences **ILUMINAT 2005 & BALKAN LIGHT 2005**

Wednesday, 1 June
EXHIBITION OPENING
Luminaires created by designers Alexandru ALAMOREANU and Gabriel PADUREAN

Thursday, 2 June
OPENING SESSION
Opening by Florin POP, Chairman of the Conference
Welcome in Cluj-Napoca in the name of Emil BOC, Mayor of Cluj-Napoca
Message in the name of Nicolae COROIU, General Manager of Electrica S.A.
Message of Radu MUNTEANU, Rector of Technical University of Cluj-Napoca
Message in the name of Wout van BOMMEL, CIE President
Message in the name of Cornel BIANCHI, CNRI President

OPENING LECTURE
Axel STOCKMAR, President of CIE - German National Committee on Illumination
Tunnel lighting design in view of different European regulations

INVITED PAPERS
Chairmen: Sermin ONAYGIL, Florin POP

Michel de BRUYN, Luc de LAMALLE, Belgium
The Urban Photometry
Luciano Di FRAIA, Italy
Energy and Maintenance Problems in Lighting
Koichi IKEDA, Shinichiro NODA, Japan
Prediction of Colour Appearances in Nayatani, Hunt, CIECAM and NC-IIIC Spaces for Comparison with
Perceived Attributes of Munsell Colours
Janos SCHANDA, Hungary
LED Photometry and Colorimetry

BALKAN LIGHT SOCIETY INVITED PAPERS
Chairmen: Axel STOCKMAR, Mehmet S.KÜÇÜKDOGU, Dorin BEU

Miomir KOSTIC, Lidija DJOKIC, Dejan POJATAR, Natasa STRBAC-HADZIBEGOVIC Serbia and Montenegro
Influence of the Theory of Mesopic Vision on Road Lighting Design
Sermin ONAYGIL, Önder GÜLER, Emre ERKIN, Turkey
The Effect of Observer Position and Movement on Road Lighting Criteria
ORGULAN Andrej, VORŠIC Jože, Slovenia
Slovenian Experience with the Enforcement of Light Pollution Legislation
Florin POP, Romania
Demands, Efficiency and Costs of Daylighting
Hristo VASSILEV, Krassimir VELINOV, Gancho GANCHEV, Bulgaria
High Efficiency Street Luminaires

COLOR AND VISION
Chairmen: Janos SCHANDA, Dorin BEU

Cornel BIANCHI, Camelia BURLACU, Florin BALTARETU, Hrisia Elena MOROLDO, Ioan PAUT, Romania
Right Choose of the Light Apparent Color in the Urban Lighting, Determinant Criterion of the Environment Quality
Banu MANAV, Mehmet S. KÜÇÜKDOGU, Turkey
Effects of Illuminance and Color Temperature on pleasantness: a Case Study for Office Settings
Henk ROTMAN, The Netherlands
New Lamps and Gear System for Outdoorlighting - The Story of CosmoPolis
Aleksandra STOJKOVIC - Van GOETHEM, Belgium
Pedestrian Crossing: How to light it Corectly?
Silviu STEFANESCU, Andi OSTROVEANU, Antoniu TURCU, Romania
Solid State Lighting a new Trend in Lighting Technology
Cristian SUVAGAU, Roy HUGHES, Canada
Lighting for Good Health

LIGHT, THE SHAPE OF SPACE
Chairmen: Michel de BRUYN, Alexandru ALAMOREANU

Peter DEHOFF, Austria
Office Lighting in Europe and Around the World
Ana DRNDAREVIC, Serbia and Montenegro
Decorative Illumination of St. Marko's Church in Belgrade
Ferenc HAASZ, Hungary
Modern Art Gallery was born
James Earl JEWELL, Alan Lawrence LINDSLEY, USA
Three Bridges
Zoltán MAKAI, Romania, Ferenc HAÁSZ, Hungary
The Light of Putna
Elisabeta SZABO, Csaba ZAGONI, Romania
Lighting of the Buildings Historical Monuments – Millenium III Commercial Center Baia Mare
Katerina TSIKALOUDAKI, Greece, José Roberto GARCIA CHAVEZ, Mexico
Shading and Daylighting: Synonymous or Antonynous Functions of the Building Façade?
Serban TIGANAS, Romania
Light in the Digital Era Architecture

Friday, 3 June
SPECIAL SESSION - LAEL, Kyung Hee University, KOREA
Chairmen: Henk ROTMAN, Jeong Tai KIM, Florin POP

Jeong Tai KIM, Gon KIM
Redesign of the Differentiated Window System Composed of the Daylight and View Pane of Glass
Ki Hoon MOON, Min Gu HWANG, Gil Dong CHOI, Hyun Tae AHN
Lightscape as an Evaluation Tool of Daylighting and Visual Performance
In Young JEONG, Min Gu HWANG, Ki Hoon MOON, Jeong Tai KIM
Daylighting Performance Evaluation of Sloped Lightshelf by Using Scale Model
Hyun Jeong KIM, Hwa Young SHIN, Jeong Tai KIM
Luminous Characteristics on the Lightscape of Hwaseong Fortress
Yoon Seok CHOI, So Mi YI, Hyun Tae AHN, Min Gu HWANG, Jeong Tai KIM
Validation of Lightscape as Exterior Lighting Simulation by using Digital Photometer

POSTERS
You Sook KIM, Jin Seok DO, Beom Seok LEE, In Young JEONG, Ki Hoon MOON
Mirror Sunlighting System : Development and Performance
In Bo SHIM, In Hye YU, Bong Kyun KIM, Hyun Tae AHN, Jeong Tai KIM
Characteristics of Seoul Outdoor Lighting Award
Hae Mi SHIN, Chan Su KIM, Gil Dong CHOI, Jeong Tai KIM
Outdoor Lighting Master Plan of Cheonggyecheon Restoration Project in Seoul

LIGHTING EQUIPMENTS
Chairmen: Axel STOCKMAR, Virgil MAIER

Mircea CHINDRIS, Andrei CZIKER, Romania
Influence of Lighting Sources on Lighting Networks
Silvia-Maria DIGA, Virginia IVANOV, Romania
Interaction Three-Phase Transformer Supply – Lighting Network with the Discharge Lamps
Stefan FASSBINDER, Germany
Some Basic Facts and some Advanced Information on Ballasts for Fluorescent
Dorin LUCACHE, Mihai ALBU, Dan IOACHIM, Romania
High Frequency Centralized Supply of the Fluorescent Lamps
Sermin ONAYGIL, Emre ERKIN, Önder GÜLER, Turkey
Applicable Light Points in the Residences for Compact Fluorescent Lamps and Potential Energy Saving
Calin ORAVITAN, Romania
Experimental Study on the Sodium Lamps as Electromagnetic Pollution Sources

EXTERIOR LIGHTING
Chairmen: Luciano DI FRAIA, Catalin Daniel GALATANU

Photos - Professor Cătălin Daniel GĂLĂȚANU

Janos BORSANYI, Hungary
Decorative lighting
Catalin Daniel GALATANU, Iulian GHERASIM, Jan IGNAT, Alina OTEL, Romania
Aspects of Street Lighting Quality in the Market Economy
Virgil MAIER, Corina MARTINEAC, Sorin PAVEL, Romania
Numerical Calculus of the Luminous Flux
Gyula MAJOR, Hungary
Stadium Lighting in Hugary
Corina MARTINEAC, Virgil MAIER, Sorin PAVEL, Romania
Application of the Integral Flux Method on the Lighting Systems Luminous Parameters Verification
Angel PACHAMANOV, Radostin PACHAMANOV, Bulgaria
Automatic Control and Monitoring of Tunnel Lighting through Power Line Carrier Communication
Dessislava PACHAMANOVA, USA, Angel PACHAMANOV, Bulgaria
Optimization Model for Automatic Control of Tunnel Lighting using Power Line Carrier Communication
Neli RATZ, Emil RATZ, Angel PACHAMANOV, Bulgaria
Creation of High Pressure Discharge Lamps Compatible Models in MATLAB

POSTER
Daniel BREBENARIU, Romania
Energy Efficiency in the Public Lighting System of Resita City

INTERIOR LIGHTING
Chairmen: Koichi IKEDA, Mircea CHINDRIS

Paolo BERTOLDI, Calin CIUGUDEANU, Italy
Five - Year Assessment of the European GreenLight Programme

Cornel BIANCHI, Mihai HUSCH, Cosmin TICLEANU, Romania
Implementation of the Professional Structure in the Conception,Execution and Maintenance of the Lighting Systems – a Real Necessity
Cornel BIANCHI, Cosmin TICLEANU, Romania
Modern Utilization of Daylight in Interior Lighting
Dorin BEU, Florin POP, Romania
Energy Efficiency in Interior Lighting – a Romanian case Study
Paul DINCULESCU, Romania
On the Reference Conditions in General Interior Lighting Calculations
Oana DOBRE, Gilbert ACHARD, France
Optical Modelling of a Diffusing Prism Light Pipe using the Apilux Software
Catalin Daniel GALATANU, Romania
Quantitative Approach in Virtual Reality
Adrian GLIGOR, Horatiu Stefan GRIF, Florin POP, Romania
Aspects on an Itelligent Control System for an Efficient Lighting
GRIF Horatiu Stefan, GLIGOR Adrian, POP Florin, Romania
Daylight Control using Internal Model Control Principle
Monica MUNTEAN, Canada, Ioan SORA, Romania
Modeling Methods for Interior Lighting Systems – Local and Global Illumination Models

LIGHTING ENGINEERING CENTER – LEC UTC-N
FIVE YEARS ANNIVERSARY

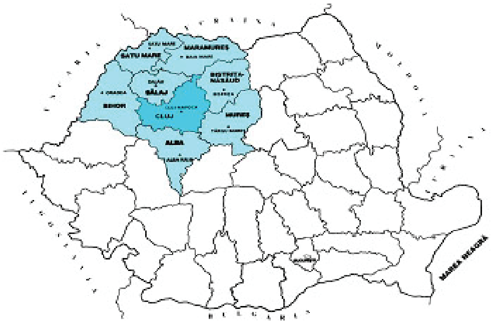
Florin POP
Universitatea Tehnică din Cluj-Napoca (Technical University)

Lighting Engineering Center - LEC – was created following the Tempus-Phare programme CME-03551-97 [15 December 1998 – 14 March 2000] – see the web site **http://bavaria.utcluj.ro/~lec.**

Co-ordinated by Professor Florin POP, the CMEs project entitled ***Lighting Engineering Centre - LEC*** involved the university Lighting Laboratories from Barcelona – Professor Ramon SAN MARTIN, the contractor of the project, Helsinki – Professor Liisa HALONEN and Naples – Professor Luciano DI FRAIA, and specific departments from Babes Bolyai University, Department of Computer Science – Professor Horia F. POP, Universitat Politecnica de Catalunya, Department of Student Guidance, Theresa BOFILL GORINA, Electric Suply Branch of Electrica – General manager Gabriel RUGA, and Energobit Schréder Lighting – Vice-president Pál PETER.

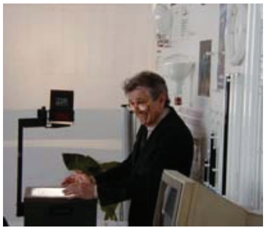
Professors Florin POP and Ramon SAN MARTIN

Its milestone was the creation of an excellence centre for consultancy and continuing education in lighting field in direct link with the needs of the labour market, in the North-Western Romania, to support the process of university reform at management level with a view to develop managerial and administrative skills, taking into consideration: - the undergraduates' problems concerned with their further placement on the job market; - the employees' problems concerned with a possible redistribution of the work force caused by the current economy restructure; - the necessity to refurbish almost entirely old lighting installations; - the achieving a permanent co-operation between university and a specific economic sector, one of the ways that increase the reform process in Romanian education and economy system in one of their aspect, the lighting field.



The LEC UTCN-N area of activity

14 March 2000 – Seminar dedicated to the end of the LEC - Tempus-Phare program and the inauguration of the modernized Electric Installations and Lighting Laboratory, with the financial support of the Universitatea Tehnică and the sponsorship of PHILIPS Romania /FLASH Transilvania, ABB Romania, Total Quality/ACI – Cluj-Napoca.



Dr. Florin POP, Professor

Dr. Dorin BEU, Reader

25 April 2000 – Decision of the Technical University Senate Council to establish the Centrul de Ingineria Iluminatului – UTC-N – Lighting Engineering Center (LEC), under the frame of the Continuing Education and Distance Learning Department.

LEC main objective

Development of a center of excellence in lighting field in North-Western Romania in direct link with the needs of the labor market and the improvement of the university curricula

Specific objectives

- Support graduates contacts with enterprises and offices in the lighting field
- Offer continuous formation for employees with lighting activities
- Create an information network with a large database and communication facilities
- Symposiums and Seminaries for the presentations of the companies involved in lighting and electrical installations, Round tables targeted to the Energy Efficiency and Quality in Lighting aspects
- Postgraduate short courses in Management of Lighting and Electrical Installations
- Support graduated university in professional relation with the lighting design offices, manufacturer and dealer companies
- Editing the INGINERIA ILUMINATULUI (Lighting Engineering) journal
- Organization of the International Conferences ILUMINAT
- Dissemination of the results achieved through European projects and programs
- Cooperation with Romanian National Committee on Illumination - CNRI – and Commission Internationale de l'Eclairage – CIE
- Scientific, curricula and research cooperation with Lighting Laboratories, Departments and Research Centres from the national or abroad universities, to enhance the participation at international networks LIGHT and CIE-EDU

In 2001, together with BEST (Board of European Students of Technology) office of the Technical University was developed a European Summer Course "Light & Lighting, Ambience, Management and System" with the participation of 21 students from Europe. The course presentation and the written support were performed in English.

9–22 October 2003 Dr. Florin POP was invited to participate at the International Seminar **Advanced Daylighting and Electric Lighting Systems in Architecture**. The Seminar was organized by the Light & Architectural Environment Laboratory – LAEL, Kyung Hee University, Seoul, Korea, director Prof. dr. Jeong Tai KIM. Professor Florin POP presented the conferences "Recent Research Trends on Advanced Daylighting System", for the Master students in Arhitecture and "Lighting in Eastern Europe: A Romanian Case Study", for LAEL members.

Two agreements for university cooperation were signed: The Memorandum of Understanding between the College of Architecture and Civil Engineering, Kyung Hee University, Korea, and the Universitatea Tehnică din Cluj-Napoca, Romania and (signed by Prof. Florin POP on behalf of the Rector of U.T.C.-N.) and The Memorandum of Understanding between Light & Architectural Environment Laboratory, Kyung Hee University and Lighting Engineering Center, Universitatea Tehnică din Cluj-Napoca. The activity of Professor Florin POP was recognised with a diploma - Award of Appreciation.

Professors Inhan KIM (chairman, major in Architecture), Jeong Tai KIM (director of LAEL), Florin POP, Byung Ik SOH, Dean, Hee-Cheul KIM, Sun Kuk KIM (chairman, major in Architecture)

International conferences ILUMINAT

Opening Lecture of Prof. Ir. Wout van BOMMEL
CIE President

Conference Conclusions
D. COSTEA,
C. BIANCHI, F. POP

ILUMINAT 2001

ILUMINAT 2003

ILUMINAT 2005 & BALKANLIGHT 2005

An important result of the project is the editing of the **INGINERIA ILUMINATULUI (*Lighting Engineering)*** journal, the first scientific Romanian review in the lighting field with 14 issues printed until today. The first four issues (nr. 1-4) were edited under the frame of the CME Tempus project. Then, the ELECTRICA Local Distribution Branch – Transilvania Nord offered its participation until the 14th issue. The journal represents one of the best form of the dissemination through professionals – students, graduates, employees, designers and architects – of the specific lighting topics on technologies, design and application techniques, computer programmes, energy saving measures, trends in education and research, new EU's policies and programmes. Its scientific presentation and content is targeted to the continuing education in the lighting field, without any insertion of the commercial advertisings inside of its pages. The journal has a half-yearly appearance, 64 pages, printed in English. The first 14 issues offered the Romanian translation of the main content of the articles. So, its special bi-lingual format was well received by readers and many of our colleagues and professionals from Romania and abroad considered this review as very interested one. There is an international reviewing board. The editorial consortium consists of the Technical University and MEDIAMIRA printing house, and also ELECTRICA Local Distribution Branch – Transilvania Nord (until the 14th issue). The journal is spread by free to the Romanian university libraries, lighting specialists - professors, designers, and abroad, to the university libraries and lighting offices closed with our previous activity.

LEC members are involved in working-out of different **lighting systems optimization studies** and **lighting design projects** for local owners. An interesting study was initiated by the City Council in May 2004 for the rehabilitation of pedestrian lighting in residential areas of Cluj-Napoca city and conducted by the Lighting Engineering Center of the Technical University of Cluj-Napoca in two areas. The aims of this study are: a) to survey the existing situation; b) to present the new European and national regulations concerning this matter; c) to propose a modern energy efficient system, and d) to generate specific GIS maps of the whole lighting system and electric network.

On the university cooperation field, there is continuity under the frame of the UE institutional university programmes SOCRATES - ERASMUS. There are signed Bilateral Agreements of cooperation between Universitatea Tehnică din Cluj-Napoca (Dr. Florin POP, Professor, Dr. Dorin BEU, Reader) and Helsinki University of Technology (Professor Liisa HALONEN, Lighting Laboratory), Universitat Politecnica de Catalunia (Professor Ramon SAN MARTIN, Estudios Luminotecnicos), and University of Liverpool (Dr. David CARTER, Reader, Lighting Research Unit).

The Lighting Engineering Center LEC is developing its activity on the Lighting and Electrical Installations Laboratory of the Building Services Department of the Technical University of Cluj-Napoca. The rehabilitation and technical modernization of its space was partially financed by the Tempus-Phare programme, the university resources, the funds received on the research grants, and postgraduate courses and sponsorships of lighting/electric installations companies and former students:

PHILIPS Romania/FLASH Transilvania
OSRAM Romania
TOTAL Quality/ACI Constructions and Installations
LEGRAND Romania/Electro Daniella
PRAGMATIC Comprest
ABB Romania
ELBA

EUROPEAN EFFICIENT RESIDENTIAL LIGHTING INITIATIVE ENERLIN

co-ordinator **Georges ZISSIS**, CPAT-UT3 - Université Toulouse 3

Proposal under the frame of the
Commission of the European Communities Directorate-General for Energy and Transport
EIE PROGRAMME – SAVE

In the context of the Kyoto Agreement, the European Community and individual Member States are looking for cost-effective measures to reduce CO_2 *emissions and combat climate change. The residential lighting market is still dominated by inefficient incandescence lamps (GLS). Market research has indicated that to achieve durable market transformation and to substantially increase the use of Compact Fluorescent Lamps (CFLs) in the residential sector, it is essential to develop and market attractive and goods quality CFLs. The ENERLIN EIE SAVE program proposes to develop and validate robust scenarios for CFL promotional campaigns in European, national and regional levels. Concerning energy savings from CFLs, assuming that there is 150 million households in Europe the energy economy by replacing only one additional 75W GLS lamp by one 15W CFL is in the order of 22.5 TWh or 4 MTEP per annum, this corresponds to 1.2 Mtonnes of less* CO_2 *per annum.*

1. Objectives of the ENERLIN action

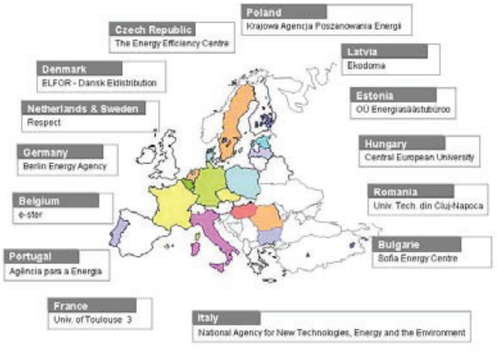
Improving the efficiency with which energy is consumed is a central theme of energy policy within the European Community, as indicated in the White Paper “An Energy Policy for the European Union”, since improved energy efficiency meets all three goals of energy policy, namely security of supply, competitiveness and protection of the environment. Lighting represents an important part of building energy consumption in the EU – around 10% of the total electricity consumption, ranging from 5% (Belgium, Luxemburg) to 15% (Denmark, Netherlands, and also Japan). The global electric lighting energy use may be split in four sectors: services 48%, residential 28%, industrial 16% and street lighting and other 8% [Mills 2002]. Overall electric appliances in households, industry and the tertiary sector represent 40% of the EU’s total electricity consumption, its generation being one of the most important sources of CO_2 emissions. However, the European Union has very limited scope to influence energy supply conditions. Within the EU, the household and private and public services sector buildings are important power consumers. In both cases lighting represents a large part of their energy consumption. Several EU and National Initiatives and Directives tented to promote energy efficient lighting for services sector buildings. These efforts can be judged as very successful because nowadays the Compact Fluorescent Lamp (CFL) market share represent 20% of the global European market whereas the same figure in world scale is limited to 17%. The rate of the households owning a CFL covers the range from 0,8 CFLs per household in UK to more than 3 CFLs per household in Denmark; the SAVE projects have found that there is at least room for 8 CFLs per home [Kofod 2002, Loe & Jones 2002, Palmer & Boardman, *DELight* 1998]. An analysis on the lighting pattern in 100 Danish homes denotes that the monthly average lighting consumption varies between 5% and 21% of the total respective monthly consumption, and 24% of the lamps (including halogens) still represent 30% of the sales. The bulk of these inefficient light sources concern the residential sector

There are several reasons explaining that residential sector still use a large amount of incandescence lamps:

- It seams difficult to convince individual customers that the payback time is so rapid.
- There is still a large part of customer unaware of the environmental and economic benefits of CFLs
- Low quality (and probably lower cost) CFLs are widely available in the Western European markets; customer buying these devices due to the attractive price is very rapidly disappointed due to reduced lifetime, bad lumen output due to wrong information from manufactures about how to replace incandescent and bad lumen maintenance of these lamps.
- Older generation of CFLs were almost unable to offer to customers an acceptable ambiance within the residence, this due to poor colour rendering index, limited choice of colour temperatures, ungracious shapes and aesthetic incompatibility with luminaries; most of these inconveniences are now overcame but there is still a large part of customer unaware of that progress.
- For households lighting can be purely practical or a very architectural feature or a combination of both, therefore energy efficiency is often just one consideration and probably not the prevailing one.
- CFL lamps are not suitable for applications with short on-off cycles as this reduces lamp life; therefore it is necessary to educate the customer on how to use them effectively.
- The warm up time of the CFL before full lumen output does that the user should not use in a staircase or elsewhere where they need the full lumen output immediately.
- CFL lamps are very sensitive to voltage variation; of course, in many countries the mains voltage is very well regulated, but in other countries and especially eastern European regions the voltage may fluctuate and this is still an important issue for CFLs.
- Find a nice design luminaire suitable for CFL's is, is in nearly all countries, a difficult thing; many nicely designed luminaries for incandescent are not visually the same if CFLs are use in them.

Promoting CFLs by using solid argumentation, which answer to the specific individual questions and fears of the customer and then add imitative measures seems to be the right way to act. It should be noticed here that “rational” arguments is not appropriate for all customer segments. To reach the last customer segment we need new CFL solution and new control features that create added value. Identifying all possible reasons of pouting CFLs, compile them and provide the good answers (scientifically proved) and then translate them to a clear and understandable argumentation for the non-specialist, is the main barrier to overcome. Furthermore, barriers to information about energy-efficient technologies (including lighting) exist on several levels, each of which has implications for penetration rates. The most widespread problem in many countries, to varying degrees, is that of a lack of awareness of energy efficiency. Members of the general public simply cannot define what it means for a technology to be energy efficient. Information barriers are important to policy makers as well. The ultimate objective of this program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries, and this can be done by offering them good arguments necessary to overcome the above cited barrier. It is also important to promote the wide-scale availability of a high spectrum of low-cost CFLs suiting a wide range of needs including different sizes, shapes, colour rendering, wattage (particular problem in some counties like Hungary is that the typical good CFLs are of lower wattage and therefore provide limited illumination levels), and bases. Furthermore, to achieve successful residential market transformation we should promote that both light fixture outlets as well as design and specialty stores display their luminaires with CFLs (good and aesthetic ones) rather than incandescent. At the same time the program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting. The major part of the program will design implement and evaluate a common promotional campaigns for CFLs that meet the European CFL Quality Charter along with dedicated fixtures. These national or regional campaigns shall be conducted in collaboration with lamp manufacturers, retailers, consumer and environmental organisations, and electricity utilities. On the other hand the elaboration of the argumentation should be based as deep as possible to quantitative and scientific arguments. This last, may lead to the creation or/and use of independent test facilities allowing to examine different proposed solutions before adopt them in the final argument list. All the program objectives will lead to a higher market share for the most efficient CFLs and dedicated luminaires. The main stakeholders concerned by this program are manufacturers' associations, consumers' associations, buyer's groups, energy agencies and other intermediates, utilities, training institutes, retailers, installers and other professions. The final beneficiaries will be end-users of equipment mainly in domestic sector.

2. ENERLIN Consortium



The ENERLIN consortium map

14 partners from 14 countries constitute the proposed consortium, covering a large part of the Europe form north to south and from east to west. This is an important issue; because, concerning lighting the reaction of the individual customers is quite different form a country to the other (north countries prefer low colour temperatures lamps –hot ambiance- and south countries are more sensitive to high colour temperatures –cold ambiance-). The consortium includes western countries with high GDPs compared to eastern countries that they just integrated EU (Poland, Hungary, Czech Republic, Latvia and Estonia). These countries are in full market transformation at this moment. Finally, two candidate countries (Bulgaria and Romania) are also members of the consortium. The ENERLIN consortium is strongly cross-disciplinary including National or Regional Energy Agencies (ADENE, KAPE, ENEA, SEC, SEVEn, BE), one ESCO in Belgium, academic institutions (France, Hungary and Romania), a values-based consultancy focussing on sustainability (Respect) as well as independent consulting SMEs (Ekodoma, Energy Saving Bureau). Each partner has solid experience with EU projects (especially from DG TREN), and strong links with international organisms like CIE and projects like ELI, other European networks (COST-529) and programs (GreenLight). Some consortium partners are quite influential for policy-making bodies in both national (regional) and European levels.

3. Target groups and key actors for the ENERLIN action

The objective of ENERLIN is to address all target groups and key actors, which are esteemed essential to fulfil the aim of the program. To achieve this objective the consortium is in close contact with key actors in the domain. The present program has been elaborated in agreement with these "key actors" who will be invited to participate to "advisory committee" during the program operation. Thus ELC (European Lighting Companies Association) will participate to AdCom together with other institutions like Eurelectric and Joint Research Centre in Ispra and national institutions like ADEME in France.

The main target groups for ENERLIN are:

- National Energy Agencies because they have in several case the material possibility to proceed to large scale promotional campaigns in their countries.
- Energy utilities, energy distribution and energy service companies, energy gains affecting directly the activity of these organisms.
- Lighting manufacturers, increasing market parts of CFLs in household being an important issue for Lighting Industry; the European Lighting Companies Association (ELC) is associated to this program passing through the European CFL Quality Charter working group.

- Consumer defend associations can promote to a very effective way all positive arguments issued from ENERLIN; this type of institutions will be invited to participate to the ENERLIN AdCom.
- Individual consumers - this is the final target of the program because they are the CFL end-users, but, however, this is the most difficult group to deal with; the proposed way of interaction will be "one way" from ENERLIN to the consumer passing through a "legible" and user-friendly web page, promotion campaigns and Gallup pools and other communication tools, like quizzes.
- Lamp and luminaire retailers constitute the interface between the end-user (customer) and all above cited groups; they will be involved in the ENERLIN work indirectly by testing and using the promotional arguments issued from the Consortium.
- Engineers working on building construction; architects - a simple questionnaire will be distributed in order to know the information they need in order to make the best use of the results of the ENERLIN program, and to design the distant learning courses and the web data base.
- Policy makers in National, European and International level, such as CIE, COST-529 and CEN.
- Politicians is a very important group because they can directly use the results concerning energy gains and environmental impact of CFL promotion and, in consequence, they can propose new incitement legislation in this domain.

It should be noticed that each consortium partner would work in close collaboration with local actors in the domain of CFLs: in Romania three other bodies will join this activity: Electric Energy Distribution and Supply Branch "Transilvania Nord", EnergoBit S.R.L. - electric designer and energy management provider -, and PRAGMATIC Comprest S.R.L. - electric/ lighting retail company.

Ultimately, the program outputs can be transferable to other countries, but obviously need to be modified to reflect local interests and values. This competences transfer can be done passing through international organisms like CIE, IAEEL, or national bodies like IESNA in North America, of JIES (Japan Illuminating Engineering Society) in Japan. In parallel COST-529 and Efficient Lighting Initiative (ELI) may be a vector for this transfer. Of course, developed nations could implement similar programs and labelling of exports may help savvy companies in developing nations to adopt more efficient lighting technologies.

4. Program work plan

The ENERLIN program should have the following phases:

- ***Phase one***: to review the current European CFL Quality Charter, and to investigate quality and efficiency issues to arrive to a new version; the consortium should also collect existing information and define the questions to be addressed by the test facility.
- ***Phase two***: design of a common CFL promotion campaign - target areas, customers, promotional messages -, the development of common and well-structured information and dissemination material freely available in the website of the program.
- ***Phase three***: implementation of national/regional promotion campaigns.
- ***Phase four***: collection of the campaign results and general assessment concerning the efficacy of the campaign; development of methods to assess the "real" energy and carbon value of the CFL campaigns to assign it to the regional/national CFL campaign promoter for possible exchange with carbon credits or, where existing, white certificates; gathering all information about residential penetration of CFL, and market potential in order to develop the baselines.
- ***Phase five***: creation of dissemination package to allow countries/regions/stakeholder not participating in the program to benefits from the results and experience made in the program to design, carry out and evaluate CFL promotion campaigns - printed material, CD-roms, a comprehensive website with downloadable documents and with distant learning courses for different target users; this web page will be accessible at least in three levels: individual consumers, retailers and other institutions like ESCOs, Lighting industry, Energy agencies.

5. Conclusions

The European Climate Change Programme (ECCP) identified residential lighting as an important area to CO_2 emission reductions. After a considerable number of promotion and rebate schemes, about 135 million CFLs are used today in European homes. However only 30% of household in the EU have at least one CFL, with those households that own them having an average of three or four. The ENERLIN EIE SAVE program is aiming at promoting to all the stakeholders a quality charter to assure that the CFL that are marketed and promoted can deliver savings which last overtime and meet the customer expectations of high quality lighting, and the ultimate objective of the program is to substantially increase the efficiency of residential lighting in a number of Member States and Candidate Countries.

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