Lecture

A Little Light Provocation and the New Challenges

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Current attitudes to daylighting and electric lighting design need reviewing, revitalizing and redirection. Daylighting design methods involving static concepts such as daylight factor and average or mean skies are criticised. Similarly, consideration of electric lighting design as the means of providing uniform horizontal illuminances and glare checks in satisfaction of code requirements are also criticised as limited. Consider the light sources. Fixed spectrum and fixed light output from electric light luminaires on the one hand, and variable spectrum, variable direction and variable, fluctuating, output from sun and sky on the other hand. This is the contrast to be recognised and incorporated in integration of the two light sources. This is one challenge in lighting design in satisfaction of human needs. Many existing computer programs for lighting calculations do not recognise these realities. Static concepts for daylight are not lighting design, and integration of such programs into energy conservation calculations are quite misleading. New computer programs incorporating variability of daylight as it occurs naturally present a further challenge. The Commission internationale de L'Eclairage (C.I.E.) International Daylight Measurement Programme (IDMP) aims to provide the necessary daylighting design data for a new approach to lighting design and energy conservation in lighting. Of course, new computer programs will be developed from this data. For this daylight measurements programme special equipment specifications have been defined and participants must comply with strict standards of data acquisition and reporting. In electric lighting design, new work is required to develop design methods for variability in spatial illuminance, and also to build on earlier work involving vector and scalar illuminances in modelling, and applications of semi-cylindrical and cylindrical illuminance in a 4-dimensional approach to lighting, where the fourth dimension can be considered to be time, or change, or variety/variability in satisfaction of human needs. With changed attitudes in lighting engineers the problems of daylight and electric light, new windows and people, will provide an exciting challenge for the future.

Introuction :

Within the general theme of the 1991 Annual Conference of the Illuminating Engineering Institute of Japan : "Lighting the Way to a New Age through Technology and Applications" and the particular theme for the afternoon session of the International Symposium : "Lighting Towards the 21st Century, taking account of World Energy and Environmental Issues", it is necessary to consider, first of all, **where we are at present** as a springboard for the twenty-first century and you will see that there is much work to be done. This is particularly important and relevant to the aspects and issues which I have been asked to develop, namely, "the integration of daylight and electric light for buildings taking into account energy conservation and environmental matters".

To *integrate* means "to make into a whole" or "to combine

the parts into a whole". However, before one can do this it is necessary to understand the whole and be able to define the problem. It is also very necessary to have a good understanding of the parts, and if the desirable information about the parts is not available, then clearly it follows that the integration will be incomplete or difficult to achieve. So where can we start ?

It is this author's belief that we should start by examining ourselves and our current attitudes because if our attitudes are at fault then there is no possibility of a successful integrated solution. It is necessary to examine the attitudes we have to daylight and daylighting, to electric lighting design, and to the needs of people. Once this is done we may hope to come nearer to the integration we desire. We need to review, revitalize and redirect *ourselves* **before** we can begin "Lighting the Way", and this 75th Anniversary Conference is a good place to start, especially as we look

Fig. 1 AVERAGE ANNUAL CLOUDINESS VARIABILITY GRAPHS FOR CITIES IN AUSTRALIA
(from Australian Bureau of Meteorology records)

forward to the twenty-first Century.

A Question of Attitude :

Many lighting engineers would never stop to question the formulae they use in their professional work. Why should they ? This is a problem of attitude : everyone should question What they are doing ? Why they are doing it ? How they are doing etc.

Let me give you an example. Many years ago I used to believe in the daylighting calculation method using the Daylight Factor -that is, until I left my home country, England and travelled to live in Australia. That was over thirty years ago. In the mid 1950's and early 1960's daylighting experts developed the international daylighting guide using the Daylight Factor. But I felt uncomfortable with it. Why ? My eyes told me that the grey overcast skies in Great Britain and Northern Europe were different from those in Australia, indeed, those in Australia were not stationary, which the Daylight Factor theory required. Indeed, when I subsequently returned to Britain and Europe I found that those grey skies were not as stationary as I had first thought. I also felt that designing for a minimum condition of daylighting was unsatisfactory when, for most of the time, other daylighting conditions prevailed from a mixture of blue skies and clouds. Nowhere was it indicated how one designed for the most commonly occurring daylight sky (see Fig.1).

I felt uncomfortable, so much so that from then on I felt impelled to argue against the use of the Daylight Factor. I made a time-lapse film to demonstrate the dynamic aspects of daylight^{1,2} in an attempt to convince others -but attitudes and convictions are often deeply held. It is a problem !

I also felt uncomfortable about electric lighting design in rooms without people moving around in them and without shadows. I felt uncomfortable about only designing for a horizontal illuminance level on a working plane when I, and others, spent some of our time looking across a room or out of a window. Satisfying Lighting Code requirements did not satisfy me either, nor did the results of others using the Code produce pleasant lighting results. So something, I argued, was not "right".

For the problem of integration in lighting design we need to consider the parts, the two light sources and their differences. On the one hand electric lighting is largely fixed spectrum and fixed light output from the luminaires whereas, on the other hand, depending on window accessories and human behaviour using these accessories, the available external daylight received indoors has a variable spectrum, variable direction, and variable fluctuating output from the particular sun and sky condition.

There is much present-day lip-service given to utilisation of daylight in lighting design especially for energy conservation ; but which daylighting basis is used ?

Of course, you guessed it, quite often it is the old Daylight Factor basis. So those computer programs cannot be much value in accurately predicting the energy conservation from daylight when they are based on static, grey overcast skies. Indeed, Littlefair in U.K. has shown that even with measurements of daylight factor under real overcast skies, let alone conditions under commonly occurring skies, these have a

standard deviation of between 15 and 25 per cent³. Thus, scientifically, with the daylight factor approach one cannot measure or guarantee the calculated results of daylight factor in a practical situation with any degree of confidence. Others demonstrated this about thirty years ago but still the use of daylight factor persists in government publications, codes of practice, text books, and in computer programs. Such is the depth of conviction about daylight factor as a reflection of entrenched **faulty** attitudes about daylighting in the minds of many people. People must be more open to changing their thoughts in this area, and this is quite a challenge.

In fact, no matter how advanced the electric lighting world may become, there is no hope of properly integrating daylight with electric light unless the field of daylighting is studied to at least the same extent. Thus electric lighting manufacturers should support daylight research in order to ensure the proper use and application of their products in conjunction with available daylight.

Daylight Variability :

In an attempt, a few years ago, to try to find a new way to approach the problem of applying daylight *availability* data I undertook a research project into daylight *variability*. (*Note the similarity of English spoken sound and English spelling of these two words with quite different meanings. Availability means "capable of being made use of", and Variability means "something which is subject to variations"*)

The research project was concerned to examine daylight variability in building interiors^{4,5} and several black and white model rooms fitted with matching photocells were placed outdoors under natural daylight conditions of sun and clear sky on the one hand, and days with clouds and blue sky on the other. Model rooms faced North, South, East and West and measurements were taken concurrently of global and diffuse illuminances.

The comparison of daylight variability between clear sky days and those with clouds and blue skies give evidence of the different internal conditions to be taken into account in lighting design (see Fig.2).

The comparison of daylight measured in black rooms compared with white rooms gives a measure of the effect and influence that interior reflectance can have on the extent of interior daylight variability.

The comparison of daylight measured in East, West, North and South white rooms on clear sky days compared with results obtained on days with clouds and blue sky (see Fig.3) demonstrate the variability which occurs in reality but which is not embodied in any known lighting design calculation method. These daylight and dynamic variabilities will actually occur in practice if there is a window in the room whether they have been incorporated in an interior lighting design or not.

One interesting aspect amongst several that occurred with this project was to discover that *at the same moment of time as daylight variability occurs externally that inside a building interior there will be the experience of greater variability* (see Fig.4)

This happens because there is a lower ambient daylighting

Fig. 2 COMPARIS OF PHOTOCCELL READINGS IN BLACK AND WHITE MODEL ROOMS ON CLEAR SKY DAY AND DAY WITH CLOUDS AND BLUE SKY

level indoors than that outdoors at that moment. Glass, dirt on glass, curtains and other window accessories usually dampen down or reduce this effect -but again, by accident, not by design.

From all of this it is clear that daylighting calculations and computer programs which are based on static concepts of daylight availability do not recognise the realities of daylight variability. As a consequence, energy conservation calculations based on such static daylight concepts are quite misleading and unhelpful. New computer programs are required.

The International Daylight Measurement Programme (IDMP) :

The need for world-wide daylight availability data is therefore seen to be of vital importance in validating research algorithms and in developing the capability of predicting daylight availability anywhere on the surface of the earth.

Since 1983 a technical committee (TC307) of the Commission Internationale de l'Eclairage (C.I.E.) under my chairmanship has been working towards this objective and indeed 1991 has been declared the International Daylight Measurement Year (IDMY)^{6,7}. It will be officially launched in Melbourne in July 1991 by the President of the C.I.E., Professor Hans Bodmann.

A draft Daylight Measurement Guide in three parts, A, B and C has been produced by the efforts of several technical committee members and is progressing through the C.I.E. publications procedures.

The relevance and significance of the data for building designers has been described as :

- Spatial distribution of daylight illuminance within daylit rooms, for various outside conditions and solar positions.

- Statistical distribution of daylight illuminance levels over the course of a year at specific locations in a daylit room.
- Impact on thermal comfort of occupants.
- Luminance distributions inside rooms.
- Impact on annual building energy usage.
- Impact on peak building electrical demand.

and for validation of current research topics the relevance of the data to the following areas is recognised :

- The association between daylight, total radiation and other meteorological data.
- Derivation of mean sky luminance distributions.
- Prediction of daylight illuminance for solar altitude and cloud type.

It is also believed that the daylight availability data would be useful to :

- Special problems of museums, art galleries
- Design of electric lighting control devices
- Prediction of use of electric lighting at airports and in sports stadia (and in relation to television).
- Hours of work on building sites (and other outdoor occupations).
- Tunnel entrance lighting.
- Psychological and physiological effects on people.
- Interaction between radiation and pollution (if u.v. measurements are included in the programme).
- Degradation of materials.
- Plant growth
- Animal behaviour

It can therefore be seen that the IDMP can have considerable benefit for people in daylit buildings, for conservation of energy, and for economic reasons.

The technical committee has recognised that there should be two classes of participant, namely, *General Class* and

Fig. 3 COMPARISON OF PHOTOCELL READINGS IN BLACK AND WHITE MODEL ROOMS ON CLEAR SKY DAYS AND DAYS WITH CLOUD AND BLUE SKY

Fig. 4 COMPARISON OF GLOBAL AMPLITUDE EFFECTS

Research Class. It was agreed that the most important information required for developing the necessary algorithms by the *Research Class* of measurement station was a map of the angular distribution of sky luminance, together with direct beam solar illuminance.

The basic set of measurements for a *Research Class* station is :

- Global horizontal illuminance
- Diffuse horizontal illuminance
- Direct beam illuminance
- N, E, S, W vertical illuminance
- Global horizontal irradiance
- Direct beam irradiance
- N, E, S, W vertical irradiance
- Air temperature
- Dewpoint temperature
- Sunshine duration
- Zenith luminance
- Total cloud amount
- Sky luminance distribution

A description of measurements required of a *General Class* station was described in *CIE Research Note* in a supplement to *CIE Journal*, Vol.6, 1987.

The IDMP will insist on accuracy of measurements. This is strictly a highly scientific programme where the eventual data can be assured and be dependable. Proper calibration procedures are essential.

A number of countries world-wide have indicated their intention to participate and grants are known to have already been made to fund research projects in Japan, Australia, Scandinavia, Great Britain, Germany, France, Israel and others are in-the-pipeline. In all about forty countries are hoping to participate to varying degrees. The Programme has the full support of the C.I.E. and also the World Meteorological Organisation (W.M.O.).

For this International Daylight Measurement Programme special equipment specifications have been drawn up and participants must comply with strict standards of data

acquisition and reporting. It is planned to hold the first IDMP Data Conference for early daylight measurement results in Edinburgh, Scotland in April 1993.

Windows and Glazing : Briefly :

Another component of the integration problem is the window.

The new computer programs will also need to include a section which deals specifically with the window and its performance. New concepts of "smart" windows and "intelligent" windows or window walls, which are altered or acquire variable transmission properties depending on the external conditions are becoming available, and these developments will need to be incorporated.

Electric Lighting and Human Needs :

In parallel with the International Daylight Measurement Programme and the Window Information needs it is clear that an innovative Electric Lighting Design Research Programme (ELDRP) is required for improvements of approaches to interior lighting design. Something to equal the effort being put into the IDMP is required to lift the standards of electric lighting design generally. There has to be an accepted quantum leap in the quality of electric lighting design, perhaps to build on earlier work involving vector and scalar illuminances in modelling of light and shade ; the applications of semicylindrical and cylindrical illuminance measurements ; and the developments of new approaches to spatial illuminance possibly including variability.

We have a two-dimensional approach to lighting when we design for horizontal illuminances on the working plane when what is really required is a four dimensional approach. The fourth dimension can be considered to be time, or it can be change, or it can be variety/variability. This dimension is included to allow for satisfaction of human

needs which are not presently incorporated in lighting design approaches. Indeed, "human needs" in the lighting field is an area where some valuable research is and has been undertaken but has not as yet filtered through into general lighting practice.

Time does not permit the treatment of the human component of lighting design that it deserves. It needs to be stated however that the "eye and vision" approach to lighting design that has served us well since the 1930's is an inadequate approach to lighting for the twenty-first century.

There is so much more to be known about human behaviour in relation to lighting design. Indeed it is perhaps inappropriate to require "integration" in lighting design until we have this essential input of the human factor. Such is the state of the art today as we prepare for the twenty-first century.

A New Approach :

One of the most important aspects of lighting design developments during the last decade of the twentieth century in preparation for the twenty-first century should be the development of a new philosophical approach to design to achieve the objectives. To me a more embracing approach than the "integration" approach is *an holistic approach* to lighting design and associated energy and environmental issues.

Holism, by definition has, "the idea that the whole is *greater* than the sum of its parts". Thus, to design holistically would seem to be the preferred design target. To achieve this objective, complacency and old attitudes must be replaced by new ones.

Under the "integration" approach we would need to understand more about the "parts to be combined into a whole". Thus, more information about electric lighting and design ; the variability and control of daylight ; the window and the new windows ; the human behaviour aspects of the problem ; and not least, to understand our own bias in the design situation.

The "holistic" approach, on the other hand, embraces everything, and a knowledge of the "parts" does not necessarily produce a holistic solution -indeed, a lateral thinking approach may be the alternative way of arriving at "a whole which is greater than the sum of the parts." The holistic approach is the ultimate challenge in "Lighting the Way to the New Age".

Conclusion :

All of this is relevant and of importance *only* if it is related to human needs and cultural factors. The advancement of technology and applications in lighting the way to a new age in the 21st century taking into account energy and environmental issues is of little account unless everyone in the field of lighting can learn to change their attitudes, substitute the total response of the human being for the "eye and vision" concept of the human, and building on the past, develop new approaches to lighting design for building interiors to produce poetry in light.

This then is my "Little Light Provocation" to you and the "New Challenges" which are to be faced.

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