



**FIELD ASSESSMENT OF DAYLIGHTING  
SYSTEMS AND DESIGN TOOLS  
FINAL REPORT 1990-1993**

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**PREPARED BY:**

J.A. Love, Arch D., P. Eng.  
Faculty of Environmental Design  
The University of Calgary  
Calgary, Alberta, T2N 1N4  
(403)-220-7428

**SCIENTIFIC AUTHORITY:**

Joël Allarie  
Efficiency and Alternative Energy Technology Branch/CANMET  
Department of Natural Resources Canada  
580 Booth Street  
Ottawa, Ontario, K1A 0E4

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# Field Performance of Daylighting Systems and Design Tools

James A. Love  
Faculty of Environmental Design  
The University of Calgary

## Abstract

The performance of three buildings equipped with photoelectrically-controlled lighting systems was assessed. Detailed monitoring of illumination levels and lighting power demand were carried out at two of the buildings. Lighting and thermal interactions were examined in detail at one of the buildings. It was found that the designers and/or contractors had made conflicting decisions that resulted in negligible energy savings (e.g., the use of tinted glass admitting relatively little daylight in combination with lighting control systems dependent on the admission of daylight). The systems were also ineffectively operated because building users and operators had little understanding of the technology.

Studies were also conducted to better define the accuracy and appropriate application of scale model photometry as a design tool.

## Résumé

On a évalué le fonctionnement de trois bâtiments dotés de systèmes d'éclairage jumelés avec des contrôles photo-électriques. On a enregistré de façon détaillée les niveaux d'éclairage et l'utilisation de la consommation électrique de deux des bâtiments. Un des bâtiments a été le sujet d'un suivi de l'impact de l'éclairage sur les systèmes de contrôles thermiques. Les données indiquent que certaines décisions ont été prises résultant en une économie d'énergie beaucoup moins importante que possible. Par exemple, on a posé des fenêtres à vitrage teinté qui permettent peu de d'éclairage naturel des endroits où les contrôles photo-électriques auraient pu maximiser les économies d'énergies. De plus, les divers systèmes étaient utilisés inefficacement en raison du manque de compréhension de la part des occupants et gestionnaires des bâtiments.

On a également exécuté l'étude afin de déterminer la précision et l'application la plus appropriée de la photométrie fondées sur des maquettes à échelle réduite comme outil de conception.

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## 1.0 EXECUTIVE SUMMARY

Electric lighting is a major expense in the operation of commercial and institutional buildings, making large demands on nonrenewable fuels. The combustion of fossil fuels also has adverse environmental impacts. A simulation study funded by Natural Resources Canada (then Energy Mines and Resources Canada) showed that exploitation of daylight in conjunction with photoelectrically-controlled dimming systems should provide substantial reductions in electricity use and be cost-effective in Canada [1]. The significance of daylighting as a potential energy conservation measure has also been recognized by major industry organizations such as the American Society of Heating, Refrigerating and Air-conditioning Engineers and the Illuminating Engineering Society of North America [2-3]. Studies also suggest that people prefer spaces with daylight and views [4-8]. Very little data is available on the performance of daylighting systems and, prior to this study, none was available for Canadian buildings. Measured data from two buildings (one in the United States and one in England) showed that large reductions in lighting power use were realized [9-10]. According to the terms of reference of this study, office buildings in Calgary equipped with photoelectrically-controlled dimming systems were to be identified and their performance evaluated. The three buildings that were identified and assessed in this study did not achieve any lighting energy use reductions because:

- i) glazings with low visible transmittances were used (presumably as an approach to controlling solar gains), thus allowing minimal quantities of daylight to enter perimeter spaces,
- ii) in one building, the dimming zone extended to the core of the building, so that any level of dimming would have reduced light levels in spaces lacking windows (the degree of dimming had therefore been reduced to a negligible fraction of normal electric light output), and
- iii) in the other two buildings, the building operators has disabled the dimming controls for various reasons such as worker complaints regarding the appearance of dimmed lamps in comparison with those not in the dimming zone (the differing luminaire colour being attributed by workers to faulty lighting).

In addition, efforts were made to evaluate the performance of a high school built in 1990 and designed to exploit daylight. Daily readings of gas and electric meters over a two year period showed that it had an annual energy use per unit floor area at the median for seven Calgary high

schools. The daylit high school had clear (high visible transmittance) glazing, but lacked photo-electric dimming controls. Further, it was furnished with 300 personal computers, significantly increasing plug loads beyond those in the other schools. Further study is required (and is currently underway) to determine the energy end uses in the building so that the contribution of daylighting to energy conservation can be more accurately identified.

**Recommendation 1: Buildings with well-constructed and operated daylighting systems (including those with photo-electric dimming controls) should be identified or developed (either through retrofit or new construction) to show effective use of daylighting technology.**

The C2000 program to create demonstration energy efficient commercial buildings may help meet this need.

**Recommendation 2: That training courses be provided for the building industry on the effective application of daylighting concepts.**

The research showed that decisions regarding daylighting made by some members of the building design and construction team (e.g., the architect specifying the envelope and the electrical engineer specifying the lighting control system) were in conflict and that some decisions showed a complete lack of understanding of the technology.

The scope of monitoring was also unusual in that illuminances, lighting power demand, and cooling rates were monitored (the few preceding studies, including one carried out by a U.S. National Laboratory, addressed only illuminances and lighting power demand [9-10]). This is significant because knowledge of effects of lighting energy use reductions on cooling can allow for more accurate estimates of return on investment for energy conservation measures related to lighting. Results from the one office building that was intensively instrumented indicated that internal heat sources (lights, people, and equipment) had relatively little effect on cooling rates. This finding differs from that for a full-scale test zone constructed in a laboratory chamber by the U.S. National Institute for Standards and Technology in the United States, in which lighting did have a substantial effect on cooling requirements [11]. Apart from the information obtained, this study led to improvements in previously developed protocols for monitoring building performance.

**Recommendation 3: Further studies of lighting-cooling interaction in real buildings should be conducted to quantify the interactions that actually occur and thus provide better information for estimating energy savings and life-cycle costs.**

The study also provided improved knowledge of the accuracy and appropriate application of daylighting design tools.

## **1.0 RÉSUMÉ**

L'éclairage électrique représente une portion considérable du coût d'exploitation des immeubles commerciaux et de séjour permanent et exige la consommation d'une grande quantité de combustibles non renouvelables. De plus, l'utilisation des combustibles fossiles est nuisible pour l'environnement. Une étude en simulation financée par Ressources naturelles Canada (anciennement Énergie, Mines et Ressources Canada) indique que l'exploitation combinée de l'éclairage naturel et d'un système de gradation à commande photoélectrique devrait réduire considérablement la consommation d'électricité des bâtiments et constituer une technique rentable au Canada [1]. L'importance de l'éclairage naturel comme mesure possible d'économie d'énergie a également été reconnue par de grandes organisations industrielles comme l'American Society of Heating, Refrigerating and Air-conditioning Engineers et l'Illuminating Engineering Society of North America [2, 3]. Les études montrent en outre que les gens préfèrent les locaux offrant un éclairage naturel et une vue sur l'extérieur [4 à 8]. On dispose de très peu de données sur le rendement énergétique des systèmes d'éclairage naturel et, avant la présente étude, il n'en existait aucune sur les bâtiments canadiens. Les mesures effectuées dans deux bâtiments situés aux États-Unis et en Angleterre ont permis de constater que l'utilisation de ces systèmes entraînait d'importantes réductions de la consommation d'électricité d'éclairage [9, 10]. L'objectif de la présente étude était de trouver à Calgary des bâtiments munis de systèmes de gradation à commande photoélectrique et d'en évaluer le rendement. Dans les trois bâtiments observés, ces systèmes n'ont entraîné aucune réduction de la consommation d'énergie d'éclairage, pour les raisons suivantes :

- i) comme on avait utilisé des vitrages à faible transmittance visible (probablement dans le but de limiter les gains solaires), il entraînait très peu de lumière naturelle dans les locaux périphériques;
- ii) dans un des bâtiments, la zone reliée au système de gradation s'étendait jusqu'au centre des étages, de sorte que toute diminution de l'éclairage électrique entraînait une baisse d'éclairement dans les locaux sans fenêtres (on ne réduisait donc presque pas l'éclairage électrique par rapport à son niveau normal);
- iii) dans les deux autres bâtiments, le responsable de l'entretien avait mis hors-circuit les commandes du système de gradation pour diverses

raisons, notamment parce que les occupants se plaignaient du fait que les lampes dont l'intensité avait été réduite n'avaient pas le même aspect que les lampes situées à l'extérieur de la zone reliée au système de gradation (on attribuait cette différence de couleur entre les luminaires à une défectuosité du système d'éclairage).

On a en outre évalué le rendement énergétique d'une école secondaire construite en 1990 et conçue pour exploiter l'éclairage naturel. La consommation énergétique annuelle par unité de surface, calculée à partir des lectures des compteurs à gaz et à électricité effectuées quotidiennement pendant deux ans, était égale à la médiane obtenue pour sept écoles secondaires de Calgary. L'école observée était munie de vitrages transparents (à forte transmittance visible), mais ne possédait pas de système de gradation à commande photoélectrique. De plus, comme 300 ordinateurs personnels y étaient utilisés, la charge des prises de courant était beaucoup plus élevée que dans les autres écoles. D'autres recherches sont nécessaires (et sont actuellement en cours) pour déterminer l'utilisation finale de l'énergie dans les bâtiments observés, afin qu'on puisse évaluer plus exactement l'économie d'énergie réalisée grâce à l'éclairage naturel.

**Recommandation 1 : On devrait identifier les bâtiments qui comportent un système d'éclairage naturel bien construit et bien exploité (y compris ceux qui sont munis d'un système de gradation à commande photoélectrique) ou créer de tels bâtiments en les construisant de toutes pièces ou en modernisant des édifices existants afin de démontrer l'utilisation efficace des techniques d'éclairage naturel.**

Le programme C-2000 encourage la construction d'immeubles commerciaux mettant en application des technologies à haut rendement énergétique et peut aider à atteindre cet objectif.

**Recommandation 2 : On devrait donner aux membres de l'industrie de la construction des cours sur l'application efficace des concepts fondés sur l'éclairage naturel.**

Les études ont montré que certains membres de l'équipe de conception et de construction des bâtiments (par ex., l'architecte qui détermine les caractéristiques de l'enveloppe et l'ingénieur électrique qui détermine celles du système de commande

d'éclairage) prenaient des décisions contradictoires quant à l'éclairage naturel ou ne possédaient pas une connaissance suffisante de cette technologie.

Les paramètres observés, soit l'éclairement, la puissance d'éclairage et la vitesse de refroidissement, étaient plus nombreux que dans les quelques études antérieures - dont une a été menée dans un laboratoire national américain - qui ne portaient que sur l'éclairement et la puissance d'éclairage [9, 10]. Cette différence est importante car en déterminant l'effet d'une réduction de la consommation d'énergie d'éclairage sur le refroidissement, on peut évaluer plus exactement les bénéfices d'un investissement dans des mesures d'économie d'énergie liées à l'éclairage. Les données obtenues sur le seul édifice à bureaux dans lequel on a effectué des mesures systématiques indiquent que les sources internes de chaleur (la lumière, les occupants et les appareils) ont une incidence relativement faible sur la vitesse de refroidissement. Ce résultat va à l'encontre de la conclusion d'une étude américaine sur une zone d'essai construite en grandeur réelle dans un laboratoire du U.S. National Institute for Standards and Technology [11]. Outre l'information obtenue, la présente étude a permis d'améliorer des protocoles d'évaluation du rendement énergétique des bâtiments.

**Recommandation 3 : On devrait mener d'autres études quantitatives sur l'interaction entre l'éclairage et le refroidissement dans des bâtiments réels afin d'obtenir l'information nécessaire pour évaluer plus exactement les économies d'énergie et les coûts du cycle de vie.**

La présente étude a également permis d'acquérir de nouvelles connaissances sur l'exactitude et les méthodes d'utilisation des instruments de conception de l'éclairage naturel.