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Publisher's version / Version de l'éditeur:

Transactions Canadian Society for Mechanical Engineering, 2, 3, pp. 169-174,
1973

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Cooling Load Caused by Lights

by
G. P. Mitalas

56645

Reprinted from
TRANSACTIONS
Canadian Society for Mechanical Engineering
Vol. 2, No. 3, 1973-74
p. 169-174

Research Paper No. 639
of the
Division of Building Research

OTTAWA

Price 10 cents

NRCC 14660

Charge thermique dégagée par des luminaires

SOMMAIRE

Une étude analytique de la charge thermique dégagée par des luminaires nous a indiqué la nécessité d'une détermination expérimentale de certains paramètres intervenant dans le calcul de cette charge de refroidissement. Pour répondre à ce besoin, une chambre calorimétrique à pleine échelle a été construite et équipée par la Division de la recherche du bâtiment du Conseil National de Recherches du Canada.

Cet article expose les résultats d'une série de tests effectués dans cette chambre, dans le but de déterminer la charge de refroidissement causée par des luminaires fluorescents.

Les conditions d'essais ont été multiples et comprennent des effets tels que: l'écoulement ou le non-écoulement d'air à travers des fixations, les coefficients de projet valables pour une gamme de fixations des luminaires, de taux de ventilation et de capacités thermiques de la chambre.

Les résultats de ces tests conduisent à la confirmation des conclusions de l'étude analytique et notamment, au fait que la relation entre une variation échelon de la puissance lumineuse et la charge thermique de refroidissement correspondante, peut s'exprimer par une expression du type exponentielle avec deux coefficients indépendants. Un de ces coefficients dépend de la capacité thermique de la chambre et l'autre est une fonction de la façon dont est arrangé le système de ventilation et du type de fixation des luminaires.

Cooling Load Caused by Lights*

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An analytical study of the cooling load resulting from power input to lights indicated the need for an experimental determination of some of the parameters involved in the calculations of this load. To meet this need a full scale calorimeter room was built and instrumented by the Division of Building Research of the National Research Council of Canada.

This paper presents the results of a series of tests that were carried out using this facility to measure the cooling load for fluorescent lights both with and without air flow through the fixtures, and a set of design coefficients for a range of light fixtures, ventilation rates, and room heat storage capacities.

The results of these tests confirm the conclusions reached by the analytical study, namely, that the relation between a step change in power input to lights and the corresponding cooling load component can be described by an exponential type of expression with two independent coefficients. One of them depends on the room heat storage capacity and the other is a function of the way the room ventilation system is arranged and the type of light fixtures that are installed.

Introduction

Electric lights have relatively low efficacy in terms of light output per watt. This fact, coupled with the trend toward higher and higher levels of illumination in buildings, has resulted in the power to the lights becoming a major source of heat in most modern office buildings. Initially part of this energy is in the form of radiation, which is absorbed by the surfaces that enclose the room, and these surfaces are warmed by it. Eventually this heat is transferred to the room air by conduction-convection but there is an appreciable delay before it appears as heat gain by the room air. The type of lighting fixtures that are used and the way that they are integrated into the air supply and exhaust systems also has an important influence on the amount of heat from the lights that enters the room. Both of these effects must be considered by the designers of heating and cooling systems for buildings if adequate and economical systems are to be achieved.

The general problem of calculating cooling load resulting from power input to lights was investigated analytically⁽¹⁾. That study indicated a need for experimental work to establish the appropriate values of the convective heat transfer coefficients in rooms with various air supply and exhaust arrangements as well as the proportion of input power that is transferred upward and downward from the light fixtures. Consequently, a full scale calorimeter room was constructed and instrumented⁽²⁾. It has been used to measure the cooling load for fluorescent lights both with and without air flow through the fixtures. This paper presents the results of these tests.

Description of the Test Facility and Testing Procedure

The test chamber is a small room 10 x 14 ft with a 9-ft-high ceiling and a 3-ft 6-in. space between the ceiling and the underside of the floor above. Figure 1 shows the room during construction. The floor consists of precast concrete slabs 6 in.

Figure 1 Calorimeter Room — Upper and Lower Concrete Floor Slabs in Place.

*Manuscript received July 11, 1973 and in a revised form Nov. 1, 1973. No. 73-CSME-32, EIC Accession No. 1420.

Figure 2 Calorimeter Room During Construction.

thick supported by a timber frame (weight of construction: 75 lb per ft² of floor area) and the floor of the room above is the same except that it is suspended from a structural steel frame. In this way there are no high thermal conductivity members passing from the test room to its surroundings. The walls of the room are 4 in. of foamed plastic insulation with ¼-in. sheets of plywood as facings. The inner face is covered by aluminum foil. The wall panels extend down 3 ft 6 in. below the floor to enclose the space between the bottom side of the floor and the ceiling below. These wall panels are backed by light steel members which also support the outer wall panels. Figure 2 shows the first row of wall panels in position. There is a space about 10 in. wide formed by the steel studs between the inner and outer panels through which air can be circulated. A ceiling of acoustic tiles and six 2-tube fluorescent light fixtures is installed in the room, and a duplicate is installed in the space below the floor. Figure 3 shows a schematic cross-section of the facility and also shows the air circulation circuits both in the room and in the guard spaces.

Air at the same temperature as the wall surface temperature was circulated through a space behind the insulated wall panels to prevent any heat transfer through the walls.

The air conditioning system was all-air with supply and return through one of the following:

- Supply:
- (1) ceiling diffuser
 - (2) wall-type fan coil unit
 - (3) light fixtures
- Return:
- (1) high wall return grille
 - (2) ceiling grille
 - (3) light fixtures

and with a reheat type of air temperature control where cooling is provided by "wild" cooling coil and reheat by electric heater.

Figure 3 Air Circulation System—Unvented Plenum.

The test room represents a section of an interior zone of a large building.

The main components of the room heat balance were the d.c. power of the room air temperature control heater, the heat removed by the chilled water cooling coil and the a.c. power supplied to the lights and to the blower inside the room.

The a.c. power input to the lights and the blower (approx. 600W) was measured by a domestic type watt-hour meter. The d.c. power supplied to the room air heater was determined by measuring the voltage drops across the heater and a current shunt.

The heat pick-up rate for the cooling coil in the room air circuit was determined by measuring the temperature rise of water in passing through the coil, ΔT_2 , the temperature rise when the water passed over an electrical heater, ΔT_1 ($\cong 1.8^\circ\text{F}$) and the power supplied to the water heater, H ($\cong 440\text{ W}$). The heat pick-up by the coil is, therefore,

$$Q = H \Delta T_2 / \Delta T_1 \quad (1)$$

Both ΔT_1 and ΔT_2 were measured by calibrated platinum resistance thermometers with a precision of $\pm 0.01^\circ\text{F}$.

The air temperature in the room was measured using thermistors placed at various points in the room.

The test procedure was very simple. First, the calorimeter room was equipped for a desired test condition (i.e., specific air circulation circuit was set up, etc.). A normal run, consisting of two tests, was started and allowed to continue for several days until steady state conditions were obtained. At this time the data recording system was started and a few hours later the lights were switched ON. The test was run for

Figure 4 Sample of Experimentally Determined and Calculated Cooling Loads Due to Lights When the Lights Were Switched ON.

several more days until steady state conditions again prevailed at which time the power to the lights was switched OFF to start the second test. This test was terminated after about 48 hours. A successful run required from 7 to 10 days.

The outputs of various transducers were measured once every 2 minutes and recorded on magnetic tape in digital form so that they could be processed by a digital computer. The output from this processing was a tabulation and a plot of room temperature and cooling load variations. Figures 4 and 5 show typical computer plots.

In addition, steady state tests were carried out to determine the fractions of the heat pick-up by the ventilation air above and below the ceiling. Two arrangements of ventilation air return were tested for a range of air flow rates. In both cases the supply was through slots at the side of the troffers and the return was through the center and around the tubes of the fixtures. The only difference between the two tests was that in one case the space above the ceiling was used as a plenum, and in the other the return air was ducted through the ceiling space and did not mix with the air in it.

The variation with time of the heat pick-up above and below the ceiling by ventilation air at non-steady conditions was checked by measuring the temperature of the ventilation air entering the room, temperature of the air as it passes through the ceiling, and the temperature of the air leaving the ceiling space. The ratio of the temperature rises gives the ratio of cooling load below and above the ceiling.

Method of Determining Z-Transfer Function Coefficients from the Experimental Results

The analytical study⁽¹⁾ indicated that the cooling required to maintain constant room air temperature can be represented quite well by an expression of the form

$$\frac{q(t)}{W} = 1 - Ae^{-Bt} \quad (2)$$

where

A and B are coefficients

$q(t)$ = cooling load at time t

W = constant power input to lights switched ON at time = 0

Figure 5 Sample of Experimentally Determined and Calculated Results for the Case When Lights Were Switched OFF.

t = time measured from instant when lights were switched ON.

This form of an exponential equation relating an excitation W and output $q(t)$ gives the following Z-transfer function, $K(z)$ ⁽³⁾:

$$\frac{q(z)}{W(z)} = K(z) = \frac{a_0 z^0 + a_1 z^{-1}}{1 - b_1 z^{-1}} \quad (3)$$

where

$$b_1 = e^{-B\Delta}$$

$$\Delta = \text{time interval}$$

$$a_0 = \frac{q(0)}{W} = 1 - A$$

$$a_1 = A \cdot e^{-B\Delta} \text{ since at steady state } q(\infty) = W$$

The cooling load can be expressed, therefore, as

$$q(t) = a_0 W(t) + a_1 W(t-\Delta) + b_1 q(t-\Delta) \quad (4)$$

The accuracy of the relationship between $q(t)$ and W can be improved somewhat by dropping the a_0 term and adding an a_2 term, where $a_1 = q(\Delta)/W$ and

$$a_2 = 1 - b_1 - a_1 \quad (5)$$

Thus,

$$q(t) = a_1 W(t-\Delta) + a_2 W(t-2\Delta) + b_1 q(t-\Delta) \quad (6)$$

The a_1 , a_2 and b_1 values for $\Delta = 1.0$ hr given in Table 1 were determined from experimental results as follows:

An exponential expression of the form $E(t) = W + k_1 - k_2 e^{-Bt}$ was fitted to the experimentally determined cooling load. It was assumed that light power input, W , and the coefficient k_1 , which represents the residual heat gain or loss by the calorimeter room to the surroundings, were constant. The measured values of cooling load for the first few hours were not used in these calculations, as the initial part of the cooling load curve contains additional exponential terms, which decay within the first few hours.

Table 1 Experimentally Determined Z-Transfer Coefficients for Lights.

Test No.	Coeff. of - Transfer Funct.			Ventilation										Furnishings	Other Conditions
	$K(z) = \frac{a_1 z^{-1} + a_2 z^{-2}}{1 - b_1 z^{-1}}$			Rate cfm	Supply			Return							
	a_1	a_2	b_1		Ceiling diffuser	Wall fan coil unit	Side slots of light fix.	Below ceiling	Ceiling space	Ceiling grille	Side slots of lights	Center of light fix.	Table, chair and filing cabinets	Carpet	
1	0.44	-0.35	0.91	100	✓			✓						Bare room Test No. 1, 2, 3 and 4	
2, 3	0.56	-0.45	0.89	100	✓				✓	✓					
4	0.50	-0.40	0.90	100	✓				✓	✓					
5, 6	0.55	-0.45	0.90	100	✓				✓	✓		✓			
7, 8	0.51	-0.43	0.92	66	✓				✓	✓		✓	✓	Starting with No. 4 test diffuser supply duct was insulated	
9, 10, 11	0.63	-0.56	0.93	140	✓				✓		✓	✓	✓		
12, 13	0.58	-0.51	0.93	140	✓				✓			✓	✓		
14, 15, 16, 17	0.53	-0.47	0.94	66		✓		✓				✓	✓	For test No. 20, 21 and 22 supply and return was ducted through ceiling space	
18	0.59	-0.52	0.93	66		✓			✓	✓		✓	✓		
19	0.55	-0.47	0.92	66		✓			✓		✓	✓	✓		
20, 21, 22	0.87	-0.80	0.93	140			✓				✓	✓	✓	For test No. 23, 24 and 25, 2-in. insulation was placed between carpet and floor slab	
23, 24, 25	0.59	-0.56	0.97	140	✓			✓				✓	✓		
26	0.58	-0.51	0.93	140	✓			✓							

The b_1 value was calculated by $b_1 = e^{-B\Delta}$ and using the B value determined by the exponential curve fit. The range of the b_1 values determined from the experimental results is 0.89 to 0.97, and the estimated error is ± 0.005 .

The a_1 coefficient was calculated using k_2 , b_1 and W values, i.e.,

$$a_1 = \frac{W - k_2 b_1}{W} \text{ for first test (i.e., lights switched ON)}$$

and

$$a_1 = \frac{W + k_2 b_1}{W} \text{ for the second test when lights are OFF.}$$

The experimental range of a_1 is between 0.44 to 0.87 and the estimated over-all accuracy of a_1 determined in this way is ± 0.03 .

The a_2 value is determined by Eq. 5, i.e., $a_2 = 1 - b_1 - a_1$.

The adequacy of the transfer functions determined in this way was checked by comparing an experimentally determined cooling load curve and cooling load values calculated using the derived transfer function.

Figures 4 and 5 show the agreement that obtains using a simple transfer function that is defined by three coefficients a_1 , a_2 and b_1 .

The fit of the calculated values at low values of t can sometimes be improved by using a transfer function with more than three coefficients. This improved fit is shown in Figure 4. The extended transfer functions were not calculated for the other tests because, in most cases, the fit of the simple transfer

function is as good as the data warrant as is shown in Figure 5 and, in other cases, the measured cooling load at low values of t is not sufficiently accurate to justify the determination of an extended transfer function.

Discussion Of Results

The " a_1 " Coefficients

As a_1 is the ratio of cooling load one hour after the lights are switched ON divided by the power input to lights, it depends on the short-term thermal storage characteristics of the room. These short-term characteristics depend, in turn, on the proportions of the light power that is dissipated by radiation and convection, the light fixture geometry, the ventilation rate, the ventilation air supply and return arrangement, and the type of ceiling, as well as the thermal properties of the surface layer of furniture, walls, floor, etc.

Values for the a_1 coefficient are given in Table 1 for several different ventilation arrangements in the calorimeter room. The lowest value, 0.44, was for the case where the supply of ventilation air was through a diffuser in the ceiling, the return was through a grille below the ceiling and the room was not furnished, while the highest value, 0.87, was for the case where ventilation air was supplied and returned through the light fixtures.

The values of a_1 should not depend on the long-term room thermal storage characteristics such as the total heat storage capacity of the floor slab and walls. This aspect of the dependence of a_1 on room details was confirmed as follows: two tests were carried out where the long-term thermal storage characteristics of the calorimeter room were modified drastically by adding 2 in. of foamed polystyrene insulation between the carpet and the concrete slab. The values deter-

Figure 6 Fraction of Light Power Input that Appears as Cooling Load in Ceiling Space Versus Air Flow Through Vented Light Fixtures.

mined from these tests were $a_1 = 0.58$ for the standard floor and $a_1 = 0.59$ for the floor with 2 in. of insulation. The good arrangement between them indicates that a_1 is not very dependent on the long-term heat storage capacity of the room.

The " b_1 " Coefficients

The b_1 coefficient defines the rate of cooling load increase or decrease after the lights are switched. The experimentally determined b_1 coefficients varied between 0.89 and 0.97. This variation was due to different ventilation rates, types of light fixtures and the way the ventilation air was supplied and exhausted but not because of the changes in room construction, as only one room construction was used for all the tests, (except for one special test of insulated floor already described).

Table 2 Design Values of " a_1 " Coefficient.

TABLE 11
DESIGN VALUES OF " a_1 " COEFFICIENT

Furnishings	Air Supply and Return	Type of Light Fixture	Value of " a_1 "
Heavyweight, single furnishings, no carpet	Low rate; supply and return below ceiling ($V \leq 0.5$)(a)	Recessed, not vented	0.45
Ordinary furniture, no carpet	Medium to high rate; supply and return below ceiling or through ceiling grille and space ($V > 0.5$)(a)	Recessed, not vented	0.55(b)(c)
Ordinary furniture, with or without carpet	Medium to high rate or fan coil or induction type air conditioning terminal unit; supply through ceiling or wall diffuser; return around light fixtures and through ceiling space ($V \geq 0.5$)(a)	Vented	0.65(c)
Any type of furniture	Ducted returns through light fixtures	Vented or free-hanging in airstream with ducted returns	0.75 or greater (d)

NOTES:

- V is room air supply rate in cfm per sq. ft. of floor area
- Increase a_1 by 0.05 when carpet is used
- The effect on a_1 value by furnishings decreases when light fixtures are used as air supply and/or return registers
- The a_1 value is equal to the fraction of the light power input that is picked up by ventilation air at light fixtures or 0.75, whichever is greater.

The lower values of b_1 were for the cases of the vented ceiling space and the higher values were for the unvented ceiling space and low ventilation rates. The addition of furniture into the room did not alter the b_1 value by a measurable amount, but the addition of carpet over all the floor surface increased the value of b_1 . The b_1 value was not altered when the light fixtures were used as air supply and return registers even though the a_1 value varied quite markedly.

In general, these results confirm the conclusion reached by the analytical study that b_1 values increase with the increase of heat transfer resistance between room air and various surfaces in the room. For example, lower ventilation rate, carpet cover of floor surface, etc., increased the thermal resistance between room surfaces and room air and thus increased the b_1 value.

The " a_2 " Coefficients

The a_2 coefficient is given by Eq. (5) i.e., $a_2 = 1 - b_1 - a_1$. Eq. (5) is based on the assumption that the cooling load and power input to lights eventually become equal. This is a valid assumption for the calorimeter room.

Room and Ceiling-Space Loads

The test results given in Figure 6 indicate a significant difference (approximately 30 per cent at usual ventilation rate) between the heat pick-up by ventilation air above and below the ceiling for ducted and non-ducted air returns through ceiling space. This is because some of the heat picked up by ventilation air is transferred back into the room through the floor slab and ceiling when the space above the ceiling is used as a return air plenum. The use of ducted returns reduces this heat leakage substantially.

The tests carried out to check the variation of the ratio of the cooling load above to the load below the ceiling showed that it is nearly constant with time after the light power is switched, i.e., in a typical case it varied only from 0.40 to

Table 3 The " b_1 " Values Calculated for Different Room Air Circulation Rates and Envelope Construction.

Room Envelope Construction*	2-in. Wood Floor	3-in. Concrete Floor	6-in. Concrete Floor	8-in. Concrete Floor	12-in. Concrete Floor	Room Air** Circulation and Type of Supply and Return
Specific Mass lb/ft ² of floor area	10	40	75	120	160	
	0.88	0.92	0.95	0.97	0.98	Low
	0.84	0.90	0.94	0.96	0.97	Medium
	0.81	0.88	0.93	0.95	0.97	High
	0.77	0.85	0.92	0.95	0.97	Very High
	0.73	0.83	0.91	0.94	0.96	
* Floor covered with carpet and rubber pad; for a floor covered only with floor tile take next b value down the column.						
** Low: Low ventilation rate - minimum required to cope with cooling load due to lights and occupants in interior zone. Supply through floor, wall or ceiling diffuser. Ceiling space not vented and $h = 0.4$ Btu/(hr) (sq ft) (°F) (where h = inside surface convection coefficient used in calculation of b_1 value).						
Medium: Medium ventilation rate, supply through floor, wall or ceiling diffuser. Ceiling space not vented and $h = 0.6$ Btu/(hr) (sq ft) (°F).						
High: Room air circulation induced by primary air of induction unit or by fan coil unit. Return through ceiling space and $h = 0.8$ Btu/(hr) (sq ft) (°F).						
▲ Very High: High room air circulation used to minimize temperature gradients in a room. Return through ceiling space and $h = 1.2$ Btu/(hr) (sq ft) (°F).						

0.34. This indicates that a single transfer function can be used to calculate the total cooling load caused by lights, and the loads in the ceiling space and room below are nearly constant fractions of this total.

Design Data Derived from Experimental Results and Calculations

The experimental results by themselves are of limited value for design calculations since they do not cover a broad range of room construction, type of light fixtures, or variations of installation and ventilation systems. The experimental results have been used, however, to derive a set of design data for calculations of room cooling load due to lights. These design data (i.e., coeff. a_1 and b_1) are given in Tables 2 and 3.

The set of design values of a_1 given in Table 2 for a range of types of light fixtures, ventilation rates, systems, and room furnishings, has been derived from the experimental results simply by grouping the features of the room light fixtures, and ventilation system that are appropriate for a single value of a_1 . The estimated precision of the a_1 value that can be obtained from Table 2 is about ± 0.05 .

The design values of b_1 given in Table 3 for different room constructions that are characterized by their mass per ft² of floor area, S , and for different room air circulation intensities were computed using the procedure described in References 4 and 5. (In these papers the b_1 value is called the ratio of successive terms.) This procedure takes into account heat storage by room envelope components, heat interchange between room air and room surfaces by convection, and heat interchange by radiation inside the room. In these calculations two parameters were varied: the heat storage capacity of the room, and the inside surface convection coefficient. The first depends on the floor slab thickness; the second on the room air circulation intensity.

There was good agreement between the calculated and the experimentally determined values of b_1 for $S = 75$ lb/ft² of floor area (S for the experimental room is approximately 75 lb/ft² also) indicating that this calculation procedure is

adequate for determination of b_1 values for typical room construction. The estimated precision of the b_1 values that can be selected from Table 3 for usual room construction is ± 0.01 for the higher values of b_1 and ± 0.02 for the lower ones. It should be noted that the addition of extra resistance between room air and floor slab, such as a heavy carpet, increases the b_1 value. This was demonstrated by an experiment where 2 in. of insulation was placed between carpet and floor slab. Although the S value remained unchanged, the b_1 value increased from 0.93 to 0.97. Thus, in special cases where the aptness of the value selected by Table 3 is in doubt and high precision is needed, the b_1 value should be calculated by the procedure outlined in References 4 and 5 or determined by test on a full-scale prototype.

Acknowledgment

The author wishes to acknowledge the assistance of R. Jaekel in running the test and J. G. Arseneault in the preparation of computer programs.

This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the Director of the Division.

References

1. Kimura, K. and Stephenson, D. G., *ASHRAE Transactions*, 74, Part II, 189-197, 1968.
2. Mitalas, G. P. and Kimura, K., *ASHRAE Transactions*, 77, Part II, 1971.
3. Ragazzini, J. R. and Franklin, G. F., *Sampled-Data Control Systems*, McGraw-Hill Book Co., Inc., 1958.
4. Mitalas, G. P. and Stephenson, D. G., *ASHRAE Transactions*, 73, Part I, 1967.
5. Stephenson, D. G. and Mitalas, G. P., *ASHRAE Transactions*, 73, Part I, 1967.

Nomenclature:

A	= coefficient
a_0, a_1, a_2, b_1	= coefficients of z -transfer function
B	= coefficient
$E(t)$	= exponential function of time fitted to the experimentally determined cooling load
$K(z)$	= z -transfer function
k_1, k_2	= coefficients
$q(t)$	= cooling load at time t
S	= parameter to describe room construction—total room component weight divided by floor area, lb of mass per sq ft of floor area
t	= time
V	= room air supply rate in cfm per sq ft of floor area
W	= constant power input to lights switched ON at time $t = 0$
z	= z -transform variable
Δ	= time interval
ΔT	= temperature difference

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