THERMAL CHARACTERIZATION OF FLUORESCENT FIXTURES

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A new application for a computer program called "Lights" is to model the thermal characterization of fluorescent fixtures. This program is a powerful tool for the fixture designer because it handles the interaction between thermal heat transfer and lumen output of the fixture. It has previously been used to model the interaction between lighting and heating, and air conditioning design for buildings, but can also be used by fixture designers. This paper shows the ease of using this computer program and outlines the effect of the number of lamps on the temperatures within the fixture as an example.

Introduction

The heat transfer properties of a fixture plays a key role in energy consumption and lumen output of the lumen/ballast systems. The lamps and ballast are heat sources that interact with the luminaire, causing a complex heat transfer problem where radiation, convection and, to a lesser extent, conduction is involved.

Siminovitch (1) pointed out that energy consumption and lumen output are tied to the minimum wall temperature (MLWT) of the fluorescent lamp. As the MLWT exceeds the optimum value, energy consumption increases and light output decreases. See Figure 1. This higher energy consumption will interact with the luminaire cavity air temperature, causing a higher equilibrium temperature and thereby increase the MLWT. The interaction between heat transfer rates and MLWT has been well known and is an important factor for the fixture designer.

Figure 1
Light Output and Efficacy of Fluorescent Lamps
as a Function of Temperature

A computer program developed by Sowell called "Lights" (2) has been successfully used to model the heat transfer rates from lighting to a room for Heating Ventilation and Air Conditioning (HVAC) design (3). This paper will use the same program, but will be modeling inside the fixture in lieu of inside a room. The program handles the rigorous heat transfer problem using Newton-Raphson numerical interaction.

The "Lights" program uses an IBM/PC or compatible machine and is easy to use with a little bit of practice. The program can model up to eight (8) light sources within one fixture and 50 nodes. Heat transfer rates and lumen output from a particular fixture design can be evaluated and such factors as type of lamps and various thermal and radiation material properties of the fixture which may not be constant but rather wave length dependent can be studied. This program can handle steady state and transient conditions as well as vented and non-vented luminaires. Finally, geometry and the fixture can be easily input into the program and optimum design achieved.

Description of the Model

A four (4) lamp fluorescent fixture using 40 Watt FT-12 cool white lamps was used in the model. Figure 2 details the geometry used.

LENGTH DIMENSION NOT SHOWN, 48 INCHES

Figure 2
Geometry Used

The sides of the fixture are at 90° and the ballast was located outside the luminaire in the plenum air for simplicity. The plenum and room air nodes were held constant and were the heat sinks for the problem.

The following is a description of the convection, radiation and conduction heat transfer mechanisms that the model uses.

A). Convection

Natural convection is assumed in this non-vented fixture used in the model. Heat transfers from the lamps to the luminaire cavity air. This air conveys the heat by convection to the enclosure formed by the luminaire's sides, top and lens. Because the top and bottom of the lamp have different heat transfer film thickness, the convection for the lamp was not treated as one node with an average heat transfer coefficient of convection. In order to model the lamp

accurately, each lamp is broken up into two parts and average heat transfer coefficients for top and bottom for a horizontal cylinder was used. This technique resulted in a temperature difference between the top and the bottom of this lamp and closely correlated temperature differences observed in the lab. The luminaire enclosure also uses natural convection to transfer the heat to the plenum air and room air.

Again, natural convection is assumed but the program can handle forced, natural or mixed convection. The use of forced convection would accurately model air handling troffers.

B. Radiation

Radiation heat transfer within an enclosure is governed by laws of conservation and reciprocity. Sowell (4) outlined a method of using these laws to solve the view factor matrix with a minimum of input. The complex geometry of a fixture can be calculated with minimum calculation of view factors. The program determines heat transfer rates by flux conservation within a wave length band. This capability of the program should be helpful for the fixture designer if they are evaluating different thermal and radiation properties of fixture materials in their design.

C. Conduction

The heat is conducted from inside the fixture to the outside where the heat is convected away.

Computer Model Results

The model assumes that the temperature of the room and plenum to be heat sinks. Our results from a room air temperature of 75° F. and the plenum air of 85° F are:

Case	No. of Lamps	Temperature Top of Lamps	Luminaire Air Temperature	Luminaire Inside Temp.
1	4 Lamps	151.4°F	142.6°F	126.6°F
2	3 Lamps	146°F	131.7°F	120.2°F
3	1 Lamp	130°F	108°F	101°F

This program was run for conditions similar to work done by Parks (5) and good correlation was observed as shown below.

Lamp Surface Temperature:

Computer Model	158°F
Park's Work	157°F (not at electrodes)

Conclusions

A computer program that allows detailed modeling of lighting thermal and luminous effect has been described. The program solves the heat transfer problem and gives the designer the lumen output as well. The designer is able to evaluate changes in the following.

1. Ballast Location
2. Lamp Types
3. Geometry of Fixture
4. Material of Construction

The program can run on a PC and the number of nodes can be selected depending on accuracy.

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References

- Siminovitch, M., ET al (1990). *Thermal Performance of Compact Fluorescent Fixtures*, Lawrence Berkeley Laboratory.
- Sowell, E.F. (1989). *Lights User's Guide*, Department of Computer Science, California State University Fullerton.
- Sowell, E.F. (1990). *A Numerical Lighting HVAC Test Cell*.
- Sowell, E.F., (1972). *Environmental Radiation from Fluorescent Ceiling System*, PhD Dissertation, University of California Los Angeles.
- Park, K.S., (1966). *Thermal and Airflow Performance of Perforation Ceiling with Luminaire*, Thesis Master, University of California Los Angeles.