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 valve, 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.

![Minimum Lamp Wall Temperature (C)](image)

**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 and 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.

![Figure 2](image)

**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:

<table>
<thead>
<tr>
<th>Case</th>
<th>No. of Lamps</th>
<th>Temperature Top of Lamps</th>
<th>Luminaire Air Temperature</th>
<th>Luminaire Inside Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 Lamps</td>
<td>151.4°F</td>
<td>142.6°F</td>
<td>126.6°F</td>
</tr>
<tr>
<td>2</td>
<td>3 Lamps</td>
<td>146°F</td>
<td>131.7°F</td>
<td>120.2°F</td>
</tr>
<tr>
<td>3</td>
<td>1 Lamp</td>
<td>130°F</td>
<td>108°F</td>
<td>101°F</td>
</tr>
</tbody>
</table>

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