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ABSTRACT

This paper describes the effects of fixture type and lamp compartment air extract characteristics on lamp/ballast performance.

A luminaire/plenum/HVAC simulator was used to measure minimum lamp wall temperature inside four fixture types while varying lamp-compartment extract conditions. Experimental data show that the lumen output of the lamp/ballast system varies by 20% and system efficacy by 10%, depending on the type of fixture and lamp-compartment extract technique employed.

INTRODUCTION

The impact of ambient temperature on the performance of fluorescent lamps has been well established[1,2]. However there is currently very little experimental data that documents precisely how various fixture parameters affect minimum lamp wall temperature (MLWT) and therefore the light output and power input properties of the system. Fixture type and HVAC integration are major factors affecting the thermal environment surrounding the lamp and therefore the MLWT. Lighting designers generally do not explicitly take thermal factors into account and only use performance data of lamps obtained under reference ANSI conditions (25°C ambient) when lamps tend to operate at or near maximum light output with a MLWT of approximately 37-40°C. However, when lamps are operated in a fixture, the MLWT can increase due to the constricted thermal environment that inhibits thermal dissipation. Our laboratory studies have shown that the MLWT can range from 30-60°C in a 25°C ambient temperature, depending on the fixture type and HVAC system. At elevated MLWTs, the lumen output of the lamps can decrease by as much as 25%, with a corresponding reduction in system efficacy of 12%. The objective of this paper is to identify how different fixtures and operating conditions affect minimum lamp wall temperature.

EXPERIMENTAL METHOD AND APPARATUS

The experimental methodology in this research is based on a two-part procedure. In the first part a temperature-controlled photometric integrating chamber is used to independently characterize the thermal performance of the lamp/ballast combination used in the fixtures tested[3]. This performance characterization is expressed in terms of light output and efficacy as a function of MLWT, and is generated over a wide range of temperatures, encompassing the conditions encountered in fixture environments. This apparatus permits the ambient air temperature surrounding the lamps to be continuously controlled and monitored between 10°C and 60°C. The apparatus is also instrumented to measure lamp lumen output, lamp/ballast system power, and minimum lamp wall temperature. Figure 1 shows a cross section of the temperature-controlled integrating chamber, indicating the relative scale and position of the major components.

In the second part of the experimental procedure, a luminaire/plenum/HVAC simulator is used to determine the operating MLWT for each luminaire configuration tested as a function of fixture type and HVAC integration[4]. The simulator consists of an insulated volume instrumented internally with an array of thermistors for making both luminaire and plenum temperature measurements. The apparatus allows for the mounting and instrumenting of a variety of luminaire types, and has a calibrated air-handling system for controlled testing of lamp compartment extract techniques. Figure 2 shows a cross section of the simulator with a test fixture installed.

Lamp wall temperature is measured with a series of thermistors on 8-inch centers attached underneath both the inboard and outboard lamps. An array of thermistors along the length of the lamp was used instead of one thermistor because the location of

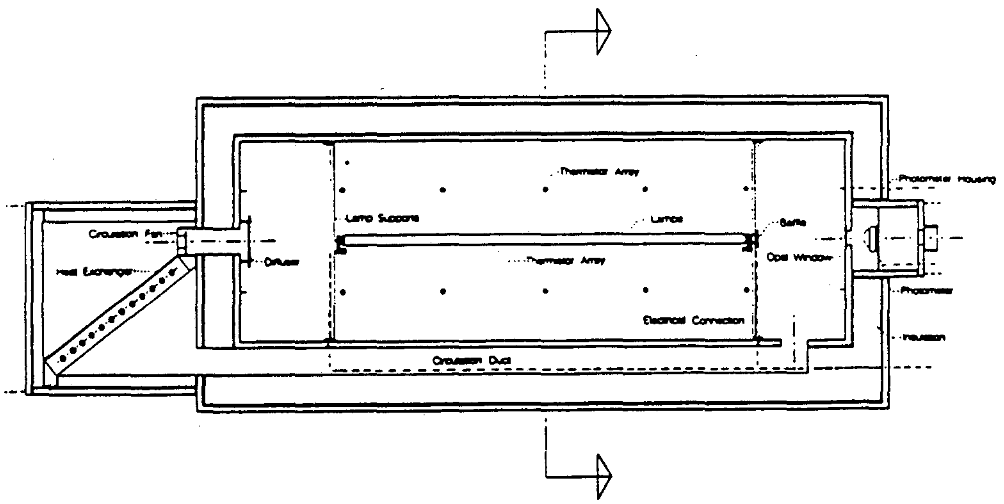

Figure 1: Cross section of temperature controlled integrating chamber.

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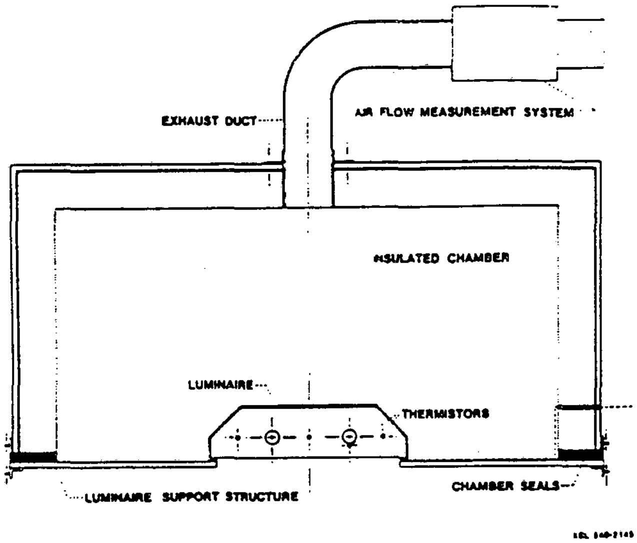

Figure 2: Cross section of luminaire/Plenum/HVAC simulator.

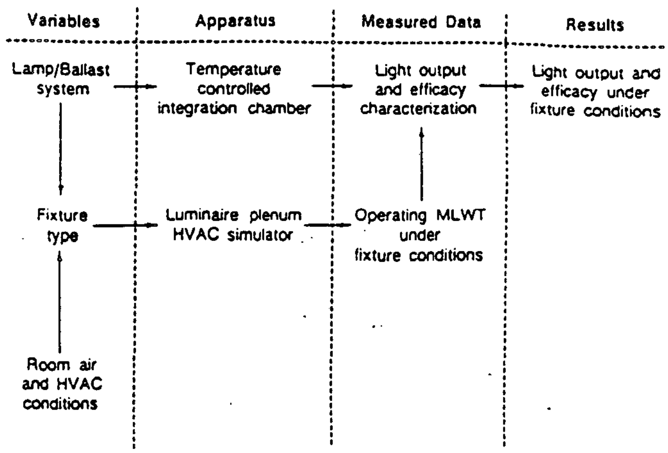

Figure 5: Experimental procedure.

the MLWT varies as a function of asymmetric air-flow conditions within the lamp compartment. Figures 3 and 4 show the placement of thermistors along the lamps. The measured operating MLWTs are then used in conjunction with the overall lamp/ballast performance characterization to determine specific values of light output and efficacy for each luminaire configuration tested. Figure 5 illustrates schematically the overall experimental procedure for determining light output and efficacy under specific fixture and HVAC conditions.

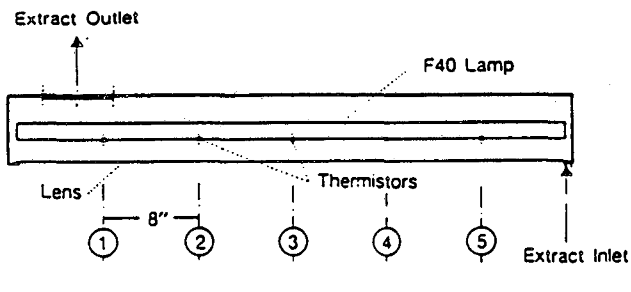

Figure 3: Cross section of lens fixture.

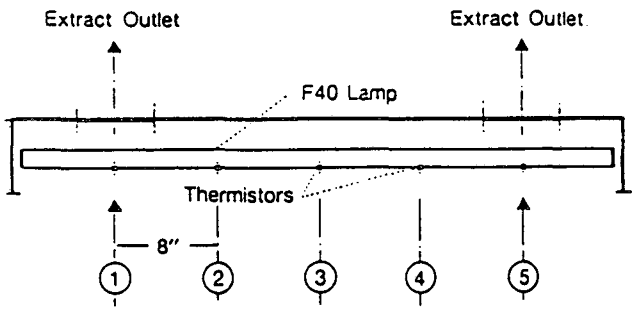

Figure 4: Cross section of parabolic fixture.

<u>Luminaire Types and Configurations</u>

A four-lamp parabolic troffer and an enclosed four-lamp lens troffer were studied while operating with a range of lamp-compartment extract techniques. These fixture types were selected as being representative of office lighting practice and because their designs are significantly different to provide a contrast for comparison. A standard two-lamp CBM ballast and 40 watt rapid-start lamps were used throughout these tests. All the luminaire configurations tested were lay in troffers supported by NEMA-G type ceiling system with a room air temperature of 25°C. Figures 3 and 4 schematically show the two fixture types, indicating the location of air-flow vents and the lamp wall thermistors.

The following configurations were tested:

1. Four-lamp lens troffer: a standard non-air-flow fixture without slots or extract vents.
2. Four-lamp lens troffer: an air-flow fixture with side slots and extract vents. This configuration was tested statically without plenum or lamp-compartment extract.
3. Four-lamp lens troffer: an air-flow fixture with lamp-compartment extract only, at a volumetric flow rate of 20 cfm.
4. Four-lamp lens troffer: an air-flow fixture with lamp-compartment extract only, at a volumetric flow rate of 50 cfm.
5. Four-lamp parabolic troffer: a non-air-flow fixture without side slots or extract vents.
6. Four-lamp parabolic troffer: an air-flow fixture with side slots and extract vents. This configuration was tested statically without plenum or lamp-compartment extract.
7. Four-lamp parabolic troffer: an air-flow fixture with lamp-compartment extract only, at an volumetric flow rate of 20 cfm.
8. Four-lamp parabolic troffer: an air-flow fixture with lamp-compartment extract only, at a volumetric flow rate of 50 cfm.

EXPERIMENTAL RESULTS

Spatial Variations in Lamp Temperature

Figure 6 shows the variations in temperature along the inboard and outboard lamps as a function of the rate of lamp compartment extract under stabilized conditions for the four-lamp lens troffer. The abscissa shows the relative position of each thermistor, numbered 1 through 5, along the 4-foot lamp. Thermistor 1 is closest to the extract outlet and thermistor 5 is closest to the inlet. Figures 3 and 4 shows the positions of the thermistors on the lamp as installed within the fixture.

Under static conditions, without lamp compartment extract, the lamp temperature is relatively even along both lamps with a stabilized MLWT of approximately 56°C. There is a slight reduction of .5-1°C in lamp temperature for the outboard lamp. This is a function of the relative position of the extract outlet, which is closer to the outboard lamp at the end of the luminaire. Under static conditions there is a certain amount of natural venting and convection through the fixture, producing a slight cooling of the lamp wall.

With lamp compartment extract at 20 cfm there is a 10-20°C reduction in temperature across the lamps in comparison to the lamp temperature under static conditions. The lamp temperature is lowest towards the end of lamps in proximity to the extract inlet. This is due to the cooling effect produced by the 25°C room air entering the fixture. The temperatures at this location on both lamps are very similar as they share directly in the cooling effect of incoming room air. In addition, the temperature is lower towards the opposite end (thermistor 1) of the lamp in proximity to the extract outlet. This is due to the constricted venting, producing more turbulence at this location and increasing convective cooling on the lamp surface.

The data show a widening in the temperature differential between the inboard and outboard lamps with increasing air flow. This is thought to be because the extract outlet, being closer to the outboard lamp, directs more air flow across it than the inboard lamp. Under stabilized conditions the MLWT was approximately 37°C with an extract rate of 20 cfm. This is approximately 20°C cooler than the static configuration.

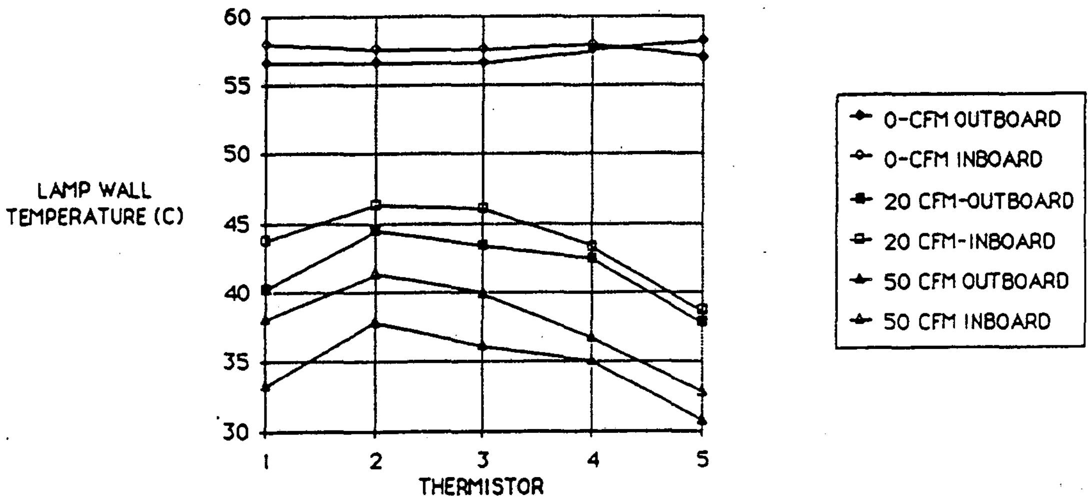

Figure 6: Lamp temperature - lens fixture.

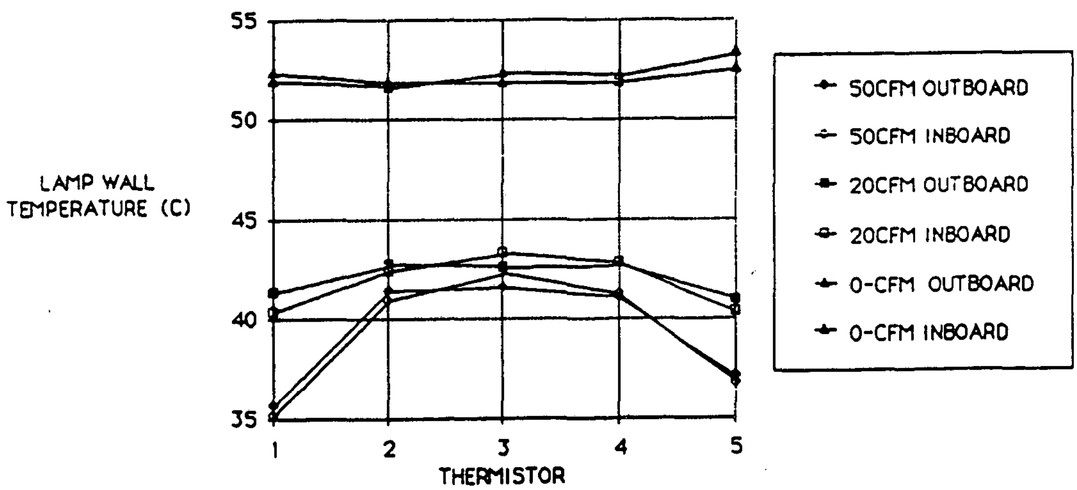

Figure 7: Lamp temperature - parabolic fixture.

At 50 cfm lamp temperature is further reduced across the lamp with the same characteristic reductions towards the ends of the lamp due to inlet and outlet air flow characteristics. MLWT stabilized at approximately 32°C. The temperature differential between the inboard and outboard lamps widens even further, illustrating the directional nature of air flow across the outboard lamp, due to the alignment of the extract outlet.

Figure 7 shows the variations in temperature along the inboard and outboard lamps as a function of lamp compartment extract under stabilized conditions for the four-lamp parabolic luminaire. In this fixture the extract outlets are located symetrically above the inboard/outboard lamps, towards the ends of the lamp (at location thermistor 1 and 5).

Under static conditions without lamp compartment extract, the lamp temperature is relatively even along both lamps with a stabilized MLWT of approximately 52°C. Employing lamp compartment extract reduces lamp temperature, with the largest reductions taking place near the extract outlets (locations 1 and 5).

Temperature variations are symmetrical relative to the position of extract outlets and there is relatively little effect on lamp temperatures with increased air flow towards the middle of the lamps.

Dynamic Lamp Temperature Variations

Figure 8 shows the dynamic changes in MLWT that occur as a function of using different rates of lamp-compartment extract for the two fixture types tested. Both luminaires are operated without lamp-compartment extract until temperature conditions stabilize (four hours). The luminaires are then operated with lamp compartment extract at 20 cfm or 50 cfm until the temperature conditions stabilize.

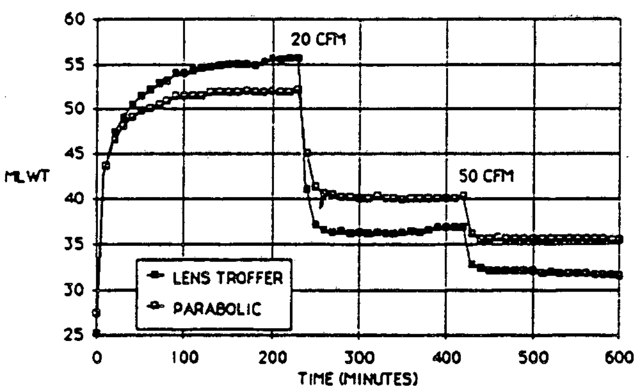

Figure 8: Dynamic changes in MLWT.

The data show a rapid increase in MLWT for both luminaires after they are turned on. The lens troffer stabilizes at approximately 56°C and the parabolic at 53°C. The parabolic runs slightly cooler due to its open geometry.

Activating the air-flow system at 20 cfm produces a rapid decrease in MLWT for both fixture types, with the lens troffer stabilizing at 36°C and the parabolic at 40°C. At 50 cfm the lens troffer stabilizes at 32°C and the parabolic at 36°C, with the MLWT approximately 4°C lower in the lens troffer. This is due to the constricted extract inlet on the lens troffer, producing a higher velocity of air flow and greater convective cooling on the lamp wall. In the parabolic fixture, air enters the compartment relatively undistributed, which reduces the cooling effect with respect to the lens troffer.

Stabilized MLWT Results

Figure 9 shows the relative light output and efficacy as a function of MLWT for two F-40 lamps operated with a standard core-coil CBM ballast. These data were obtained using the temperature-controlled photometric integrating chamber described previously and the same lamp/ballast system as used in the luminaire tests. The measured values of stabilized MLWT for each luminaire configuration are included on the lamp/ballast performance curve, showing the relative values of light output and efficacy under measured fixture and HVAC conditions.

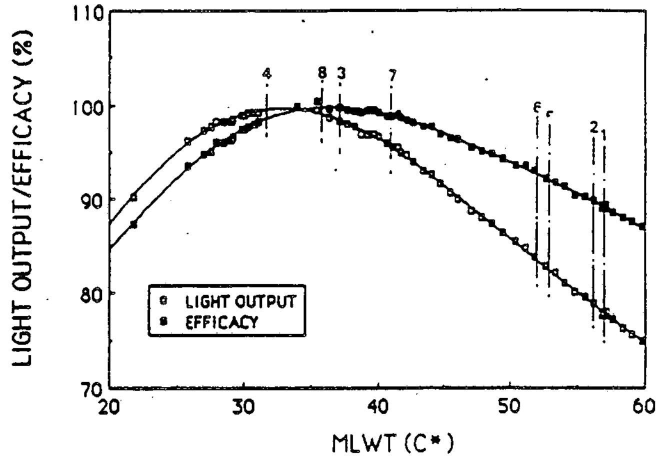

Figure 9: Light output and efficacy versus MLWT.

Table 1 shows the operating MLWTs for each luminaire configuration tested, showing the stabilized relative light output and efficacy expressed in terms of the performance at 25°C free air conditions.

TABLE 1

Luminaire Configurations	MLWT	Relative* Light Output	Relative* Efficacy
1. Non-Air-Flow Lens Troffer	56.6	78.3	89.4
2. Air-Flow Lens Troffer (Static)	55.8	79.2	90.0
3. Air-Flow Lens Troffer (20 cfm)	36.7	98.3	99.3
4. Air-Flow Lens Troffer (50 cfm)	31.5	99.4	98.0
5. Non-Air-Flow Parabolic Troffer	53.1	82.2	91.9
6. Air-Flow Parabolic Troffer (Static)	51.8	83.8	93.1
7. Air-Flow Parabolic Troffer (20 cfm)	40.9	95.6	98.8
8. Air-Flow Parabolic Troffer (50 cfm)	35.7	99.0	99.8

* Expressed as a percent of the light output at 25°C open air conditions.

The static and non-air-flow configurations for both the lens and parabolic fixtures show the highest stabilized MLWTs and therefore the lowest light output and system efficacy for the range of conditions used in this study. The parabolic non-air-flow stabilizes at a MLWT of 53°C approximately 4°C cooler than the lens troffer under static conditions. The cooler operation of the parabolic is a function of its open-cell geometry in comparison to the enclosed geometry of the lens fixture.

Under static conditions (i.e. without air flow but with vents open) the air-flow lens and parabolic fixture shows a slight reduction in MLWT compared to the non-air-flow configuration. This is due to the natural venting that occurs as warm air leaves the fixture through the extract vents and is replaced by cooler 25°C room air.

Employing lamp compartment extract causes a large reduction in the operating MLWTs for both the lens and parabolic troffers. The lens troffer showed a lower MLWT than the parabolic under the same conditions of air flow at both 20 and 50 cfm. This is a function of the inlet/outlet extract geometry: the inlet geometry for the lens troffer provides a constricted air flow, which results in a higher velocity flow across the lamps and a higher rate of lamp cooling at the same volumetric flow.

For example, at 20 cfm the lens troffer is operating closer to optimum performance than the parabolic at 20 cfm, due to the increase in air flow velocity across the lamps in comparison to the parabolic.

At 50 cfm the lens troffer is starting to operate at just below the optimum lamp temperature as is indicated by the reduced efficacy in comparison to the parabolic at 50 cfm.

DISCUSSION

The experimental data presented demonstrate that lamp/ballast performance can vary substantially, depending on the particular fixture type and HVAC integration technique used. For example, the elevated MLWTs encountered in an enclosed lens troffer can reduce light output by more than 20% and efficacy by 10%.

Though it was generally thought that the parabolic would operate the lamps closer to an optimum MLWT due to its open geometry, results indicate only a slight improvement in performance. This results because the geometry of the parabolic traps a layer of warm air, preventing convective cooling of the lamps.

Employing lamp compartment extract can reduce the operating MLWT for both types of fixture tested. However, the flow rate must be optimized for each particular system, requiring an examination of both light output and efficacy as performance criteria. For example, at 50 cfm the lamp/ballast system is starting to operate below optimum efficacy in the lens troffer. At 20 cfm the lamp/ballast system operates at very near optimum, maintaining both light output and efficacy. This suggests that a lower volumetric flow rate is optimal for the lens troffer.

For the parabolic fixture, a volumetric flow of 20 cfm results in the lamps operating at a reduced light output and efficacy. At 50 cfm both light output and efficacy are near optimum, indicating that a higher flow rate is optimal for the parabolic fixture.

CONCLUSION

The experimental data desribed in this paper illustrates that the lumen output and efficacy characteristics of the lamp/ballast system can change as a function of the type of fixture and its operating conditions.These changes are due to variations in minimum lamp wall temperature which affects both the light output and efficacy of the lamp ballast system. Lighting designers need to understand and explicitly account for these temperature based variations within the design process. If these factors are not considered, the resultant lighting system may operate at reduced efficacy and provide illuminance levels that are below those specified.

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REFERENCES

[1] C.W. Jerome, "Effect of bulb wall temperatures on fluorescent lamp parameters," *Journal of the I.E.S.*, Feb. 1956.

[2] E.E. Hammer, "Improved 35-watt low energy lamp ballast systems," *Journal of the I.E.S.*, Apr. 1980.

[3] M.J. Siminovitch, "Determining lamp ballast system performance with a temperature controlled integrating chamber," *Journal of the I.E.S.*, Vol. 14, No. 1, Oct. 1984.

[4] M.J. Siminovitch, "A luminaire/plenum/HVAC simulator," to be published in I.E.E.E. Trans. on Industry Applications, 1985.

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