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Fixture Conditions Affect Lamp Performance

M.J. Siminovitch, F.M. Rubinstein,
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M.J. Siminovitch, F.M. Rubinstein and R.R. Verderber

Lighting Systems Research Group
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Abstract

This article discusses the major parameters that affect fluorescent lamp performance under fixture conditions. These parameters include fixture type, and HVAC integration, which directly determine the minimum lamp wall temperature (MLWT), and therefore, the resulting light output of the lamp/ballast system. Experimental data is presented showing that the lumen output of the lamp/ballast system can vary by as much as 20% and that the system efficacy can vary by 10% depending upon the type of fixture and HVAC system employed.

Introduction

This study was designed to measure the range of lamp/ballast performance as a function of MLWT under a range of fixture conditions occurring in most applications. It compares two types of fixtures, an air handling enclosed fixture, and a parabolic fixture. Engineers who need to compare and select lighting systems and design lighting layouts that meet both illuminance and energy code requirements, need accurate data documenting the combined performance capabilities of fluorescent lamp, ballast and fixture systems operating under realistic building conditions.

Fixture type and HVAC integration are major factors that affect the thermal environment surrounding the lamp, the operating minimum lamp wall temperature, and therefore, the light output of the system. The functional dependence of light output on the minimum lamp wall temperature (MLWT) of an F40 lamp and CBM ballast is well documented. For a standard ballasted F40 lamp system, the lamps should operate either at a MLWT of 35°C ± 1°C for maximum light output, or at 40°C ± 1°C to obtain maximum efficacy. These conditions occur as the MLWT determines the mercury vapor pressure within the lamp, and therefore, the mercury concentration available to the discharge. Fluorescent lamps photometered under reference ANSI conditions (25°C ambient) tend to operate at or near their optimum with a MLWT of approximately 35°C-40°C. However, when lamps are operated in a fixture, the MLWT can increase due to the constricted thermal environment that inhibits thermal dissapation. Our laboratory studies have shown that the MLWT can range from 30°C-60°C, depending upon the fixture type and HVAC system. At elevated MLWTs, the lumen output of the lamps can decrease by as much as 20% with a corresponding reduction in system efficacy of 12%. Currently, very little published data is available documenting these temperature based performance variations under actual fixture conditions and lighting engineering base their estimates from lamp manufacturers rating obtained under optimum ANSI conditions. Therefore, the objective of this research is to identify how different fixtures and their relative operating conditions, in terms of HVAC integration, affect lamp/ballast performance.

Experimental Method and Apparatus

The methodology employed in the fixture studies relies on a two-part experimental procedure. The first part uses a temperature-controlled integrating chamber to characterize the thermal performance of the lamp/ballast combination used in the fixture tests. The performance characterization is expressed in terms of light output and efficacy as a function of variations MLWT and is generated for the range of temperatures typically encountered in interior lighting applications. Figure 1 shows a corss section of the temperature controlled integrating chamber, indicating the relative scale and position of the major components.

The second part uses a luminaire/plenum HVAC simulator to determine the specific MLWT that exists in a particular luminaire application as a function of luminaire type, mounting configuration, plenum integration, and room air temperature. 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. The MLWTs, thus measured, are used in conjunction with the lamp/ballast performance data to determine application-specific values of light output and efficacy for a given lamp/ballast/luminaire system. Figure 3 illustrates schematically the overall experimental procedure for determining light output and efficacy under specific fixture and HVAC conditions.

Fixture Configurations Tested

This article will describe results obtained from eight fixture experiments. These studies were based on two fixture types; a parabolic troffer and a lens troffer. These types were selected as representative of office lighting practice. The following lists the configurations studied.

1. Four lamp lens troffer: a standard non-airflow 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 volumetric flow rate of 20 cfm.

8. Four lamp parabolic troffer: an air flow fixture with lamp compartment extract only at volumetric flow rate of 50 cfm.

Experimental Data and Results

Figure 4 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. 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, producing a higher velocity of air flow and greater convective cooling on the lamp wall. In the parabolic fixtures, air enters the compartment relatively undistributed, which reduces the cooling effect with respect to the lens troffer.

Stabilized MLWT Results

Figure 5 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 specific fixture and HVAC conditions.

Table I 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 I

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 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 described in this article 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, layouts can result that operate at a reduced efficacy and with illuminance levels that are below those specified.

Acknowledgement

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[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.

Figure Captions

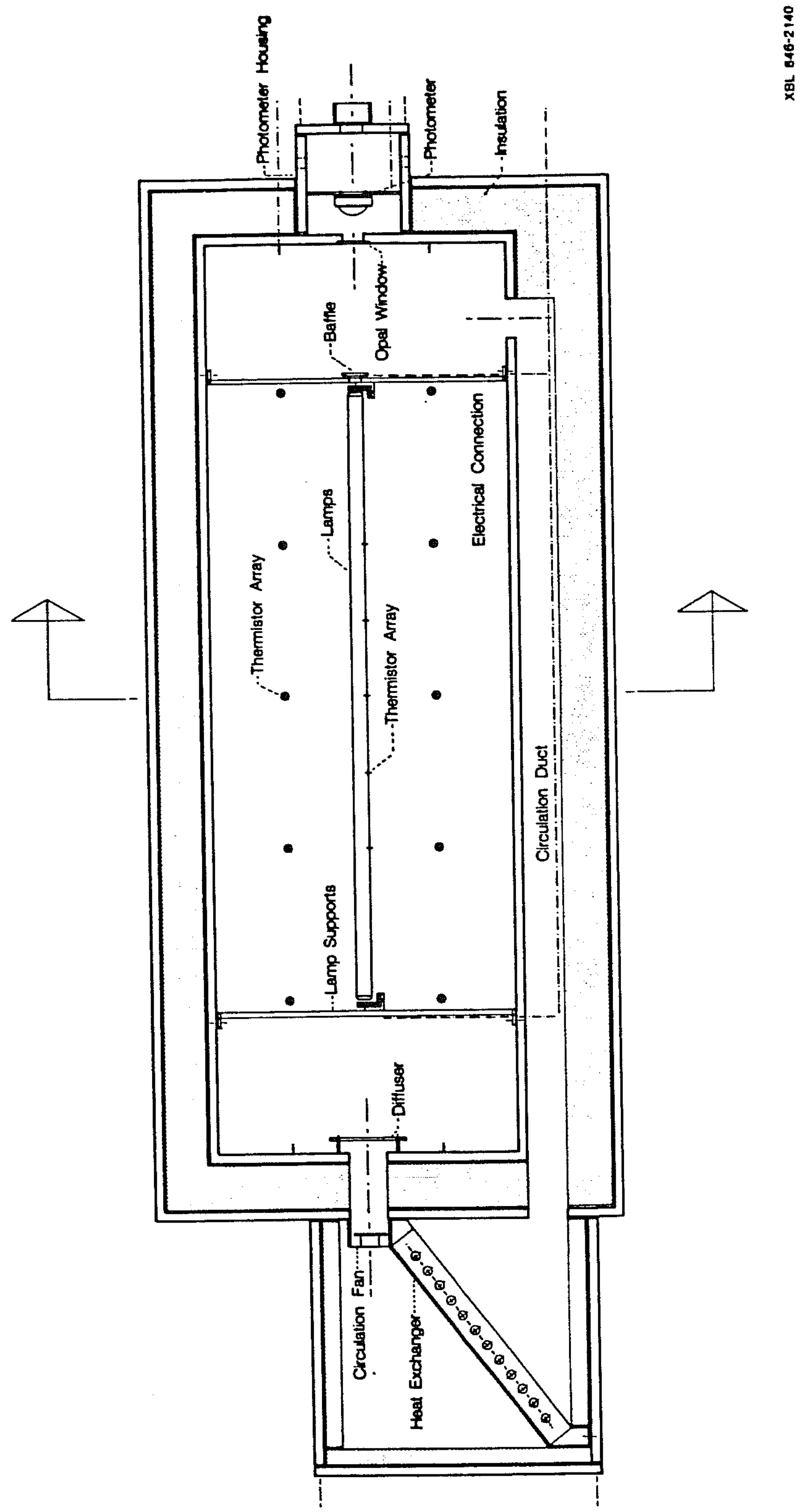
Figure 1. Cross Section of Temperature Controlled Integrating Chamber

Figure 2. Cross Section of Luminaire/Plenum/HVAC Simulator

Figure 3. Testing Procedure

Figure 4. Dynamic changes in MLWT

Figure 5. Light Output and Efficacy Versus MLWT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Photometer
Insulation
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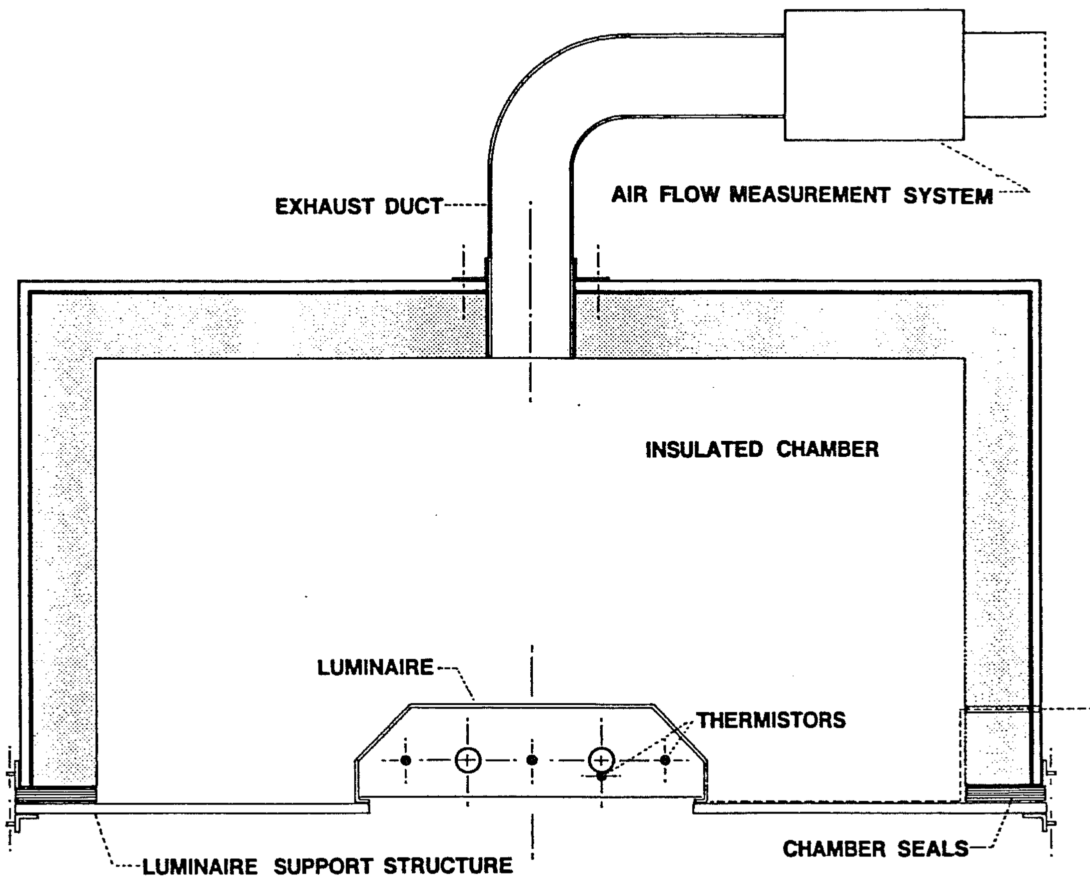
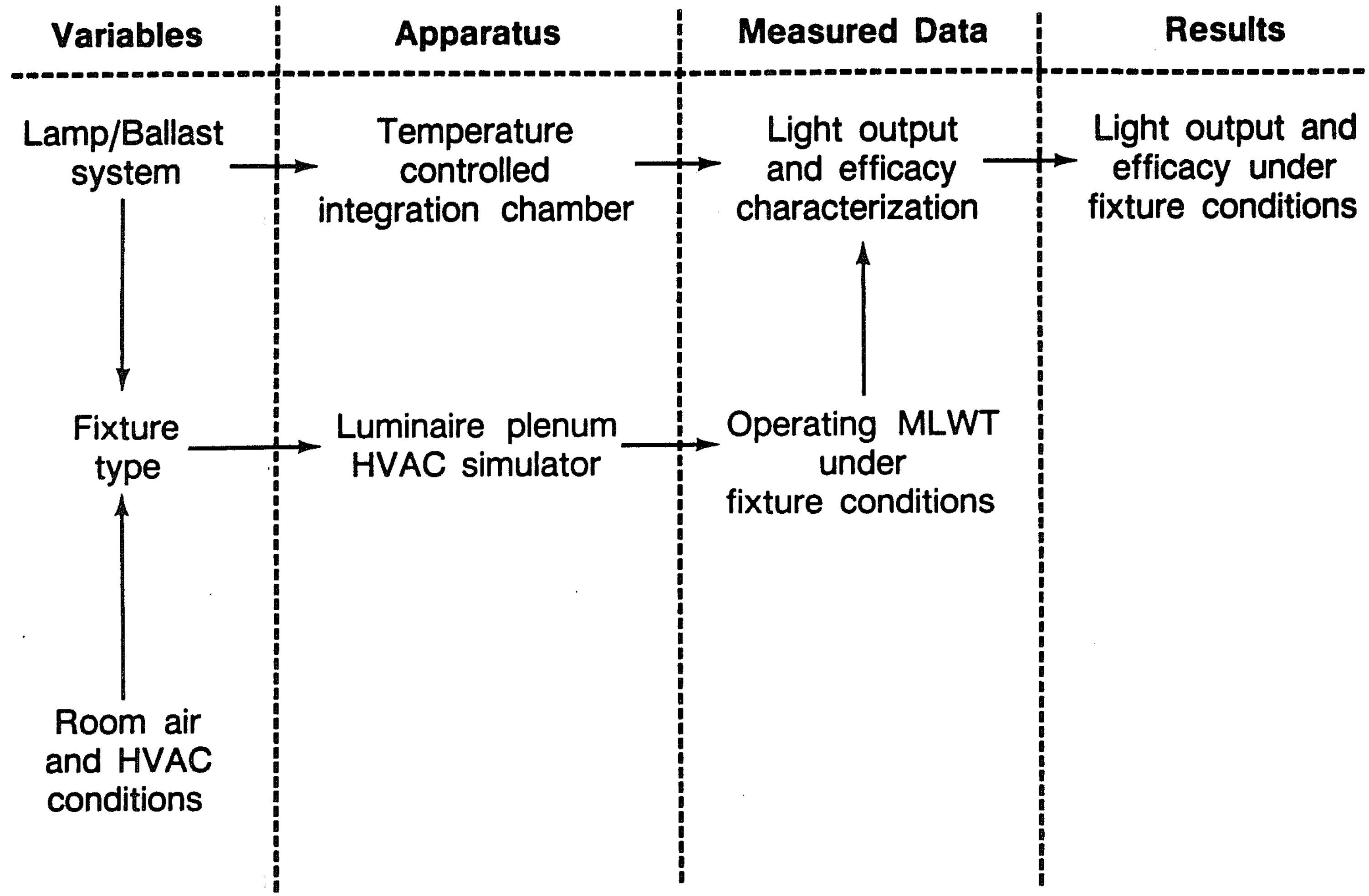
Heat Exchanger
XBL 846-2140

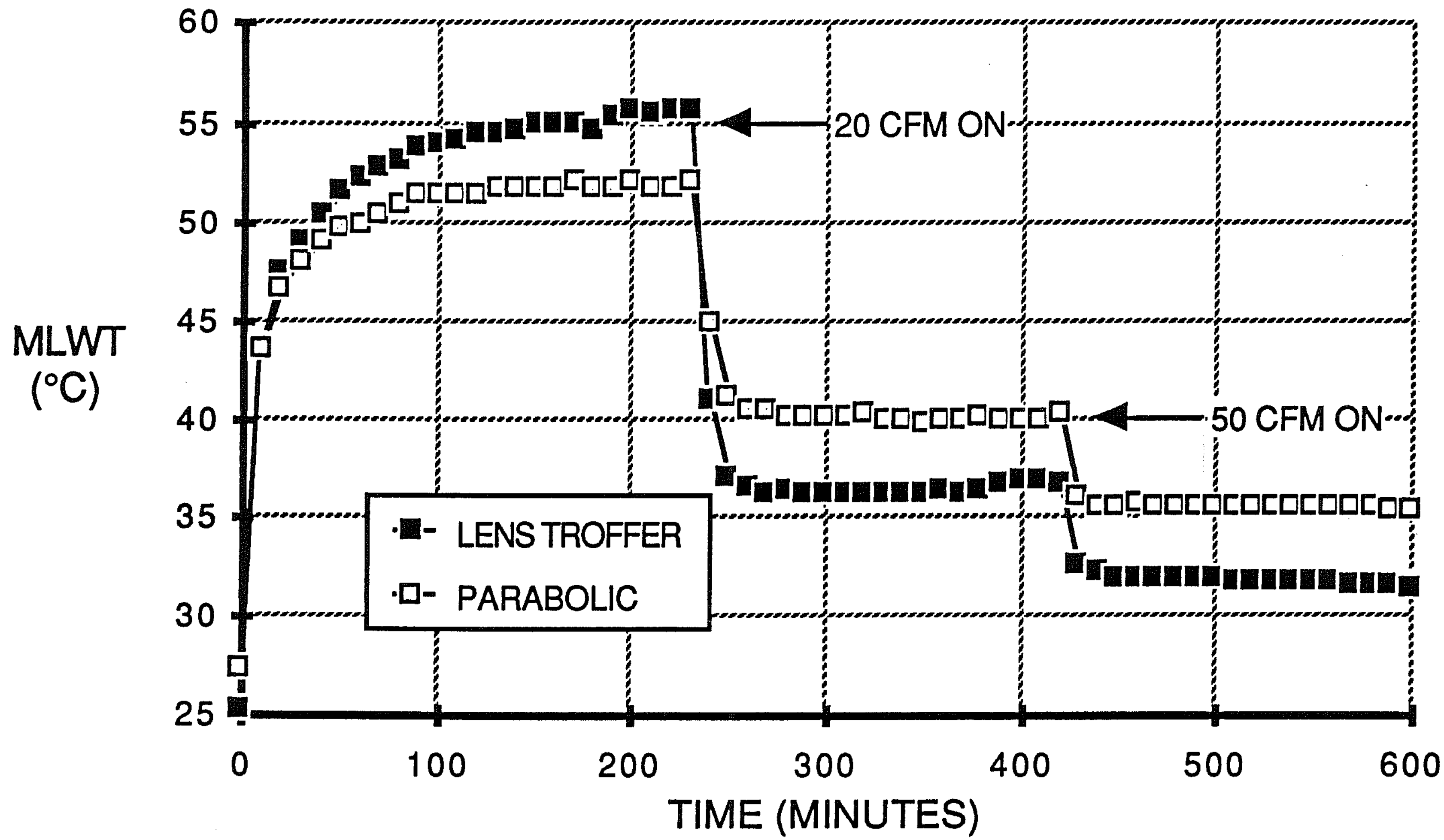

EXHAUST DUCT
AIR FLOW MEASUREMENT SYSTEM
INSULATED CHAMBER
LUMINAIRE
THERMISTORS
LUMINAIRE SUPPORT STRUCTURE
CHAMBER SEALS

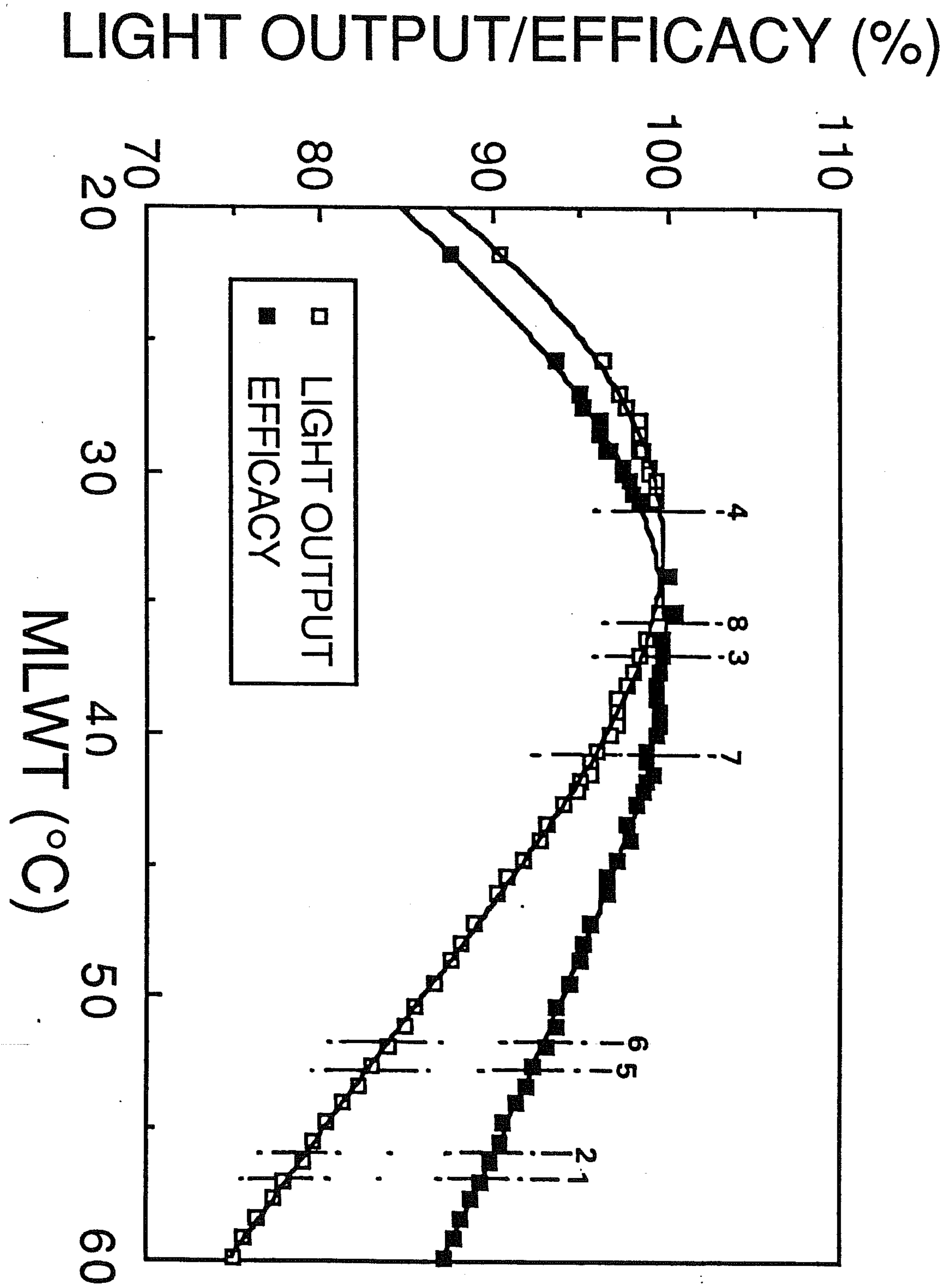
XBL 846-2145


Variables
Apparatus
Measured Data
Results
Lamp/Ballast system
Temperature controlled integration chamber
Light output and efficacy characterization
Light output and efficacy under fixture conditions
Fixture type
Luminaire plenum HVAC simulator
Operating MLWT under fixture conditions
Room air and HVAC conditions

XBL 868-3062

DYNAMIC VARIATIONS IN MLWT




LIGHT OUTPUT/EFFICACY (%)
110
100
90
80
70
20
30
40
50
60
MLWT (°C)
LIGHT OUTPUT
EFFICACY
4
8
3
7
6
5
2
1

XBL 868-3068