Lawrence Berkeley National Laboratory
LBL Publications

Title

Thermally Efficient Compact Fluorescent Fixtures

Permalink

https://escholarship.org/uc/item/9nr640rf

Authors

Siminovitch, M.J.
Rubinstein, R.E.
Whiteman, R.E.

Publication Date

1990-09-01

eScholarship.org Powered by the California Digital Library
University of California

LBL-29294

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE DIVISION

Presented at the IEEE 1990 Annual Conference,
Seattle, WA, October 7–12, 1990,
and to be published in the Proceedings

Thermally Efficient Compact Fluorescent Fixtures

M.J. Siminovitch, F.M. Rubinstein, and R.E. Whiteman

September 1990

U. C. Lawrence Berkeley Laboratory
Library, Berkeley

FOR REFERENCE

Not to be taken from this room

LBL-29294
Copy 1
Bldg. 50 Library.

APPLIED SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Presented at the IEEE 1990 Annual Conference
Seattle, WA, 7-12 October 1990.

LBL-29294
L-149

THERMALLY EFFICIENT COMPACT FLUORESCENT FIXTURES

Michael J. Siminovitch, Francis M. Rubinstein and Richard E. Whiteman

Lighting Systems Research Group
Applied Science Division
Lawrence Berkeley Laboratory
Berkeley, California 94720, United States

September 1990

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Building Equipment Division of the U.S. Department of Energy under Contract No. DE-ACO3-76SFOOO98.

THERMALLY EFFICIENT COMPACT FLUORESCENT FIXTURES

Michael J. Siminovitch, Francis M. Rubinstein and Richard E. Whiteman

Lighting Systems Research Group
Applied Science Division
Lawrence Berkeley Laboratory
Berkeley, California 94720, United States

ABSTRACT

This paper describes the development of thermally efficient compact fluorescent fixtures. Experimental data shows that decreases in fixture efficiency can approach 20% due to elevated temperature conditions inside the lamp compartment. These elevated temperatures increase the minimum lamp wall temperature of the compact fluorescent lamp and reduce the light output and efficacy of the lamp ballast system.

A series of prototype fixtures are described that employ convective venting and heat sinking to reduce elevated lamp temperatures. These cooling strategies can produce 20% increases in light output and efficacy.

INTRODUCTION

Compact fluorescent lamp systems are increasingly being used in commercial lighting applications. These include retrofit lamp/fixtures systems which are intended to replace existing incandescent sources and new fixture systems intended for new construction and major renovation. Both these applications can potentially reduce energy use and fixture maintenance as a function of their increased efficacy and lamp life in comparison to incandescent sources.

A major concern with the operation of compact fluorescent lamps inside small fixtures is their tendency to lose both light output and efficacy as a function of elevated lamp wall temperatures. Most compact fixtures present a constricted thermal environment to the lamp which inhibits thermal dissipation of the lamp to the surroundings. This produces elevated lamp compartment and lamp wall temperatures resulting in thermally based efficiency losses that can approach 20%.

The objective of these studies is to demonstrate the enhancement of both lumen output and efficacy obtainable with fixture systems that employ cooling techniques to reduce elevated lamp wall temperatures. The approaches involve cooling of lamps with small heat sinks that dissipate heat generated by the lamps to the surrounding ambient and the use of convective venting of the lamp compartment that results in cooler lamp temperatures.

METHODOLOGY

The lumen output and efficacy characteristics of a series of commercial fixtures and lamp ballast systems were studied. These fixtures were tested operating with and without lamp cooling approaches in order to assess the potential efficiency enhancements.

Two fixture types where examined:

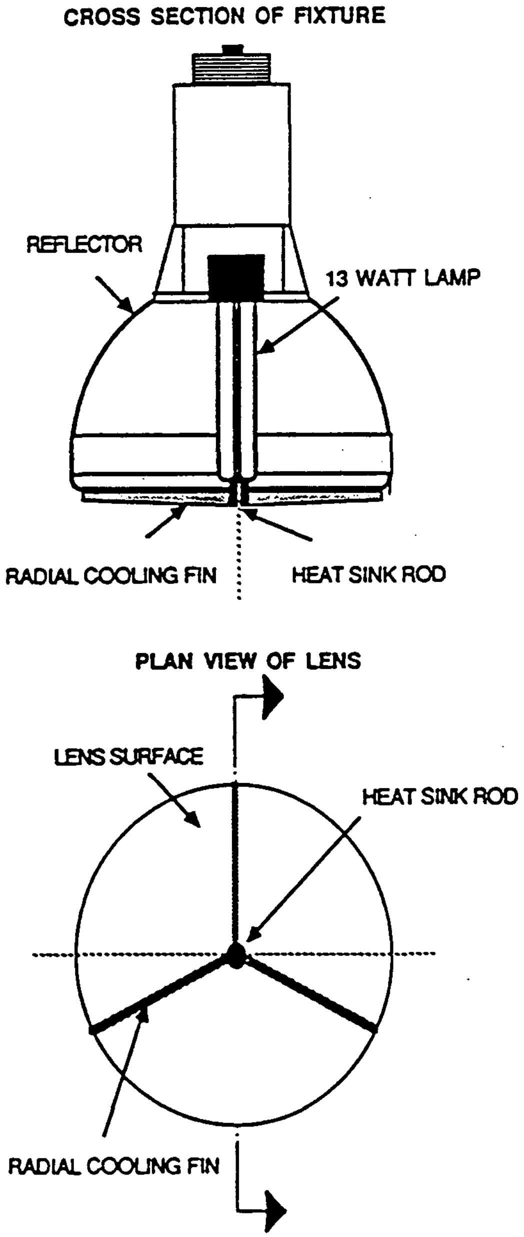
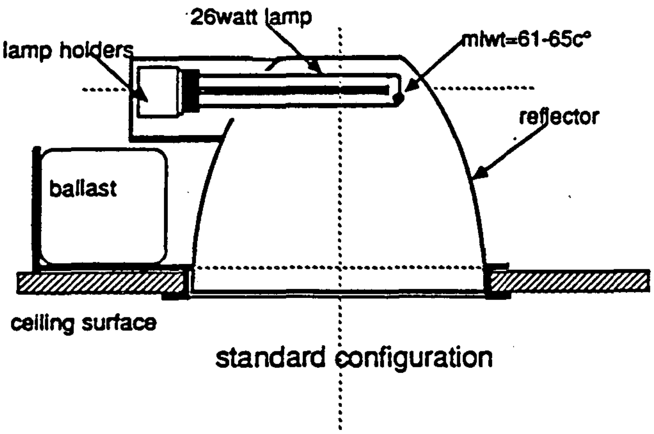
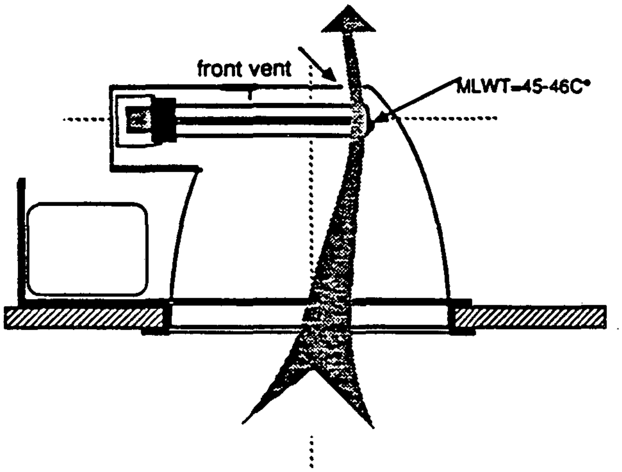


Figure 1. Cross section and plan projection of the 13 watt compact fluorescent screw-in fixture. Cross section also shows the position of the radial heat sink in contact with lamp.



standard configuration



vented configuration

Figure 2. Open down light fixture with and without venting system.

1) Screw-in 13 watt compact fluorescent fixture.

Figure 1 shows a schematic cross section of the fixture system indicating the geometry of the radial heat sink system. This fixture systems consists of a 13 watt compact fluorescent lamp mounted vertically within a reflector with an integral lens, ballast, and edison base. This fixture is used primarily as an incandescent replacement within a recessed down light fixture. The fixture is modified to incorporate a radial heat sink system in order to cool a small area on the ends of the lamp. This included a small contact shaft attached to the ends of the compact lamp. This shaft then extends through the lens of the fixture and is attached to a series of heat fins that radially project out along the outer surface of the lens. The radial heat sink system conveys heat away from the lamps through the lamp compartment to the outside ambient where it is dissipated by convection.

2) Recessed down light with two 26 watt compact lamps.

Figure 2 shows a cross section of both the standard and the modified fixture indicating the primary convection pattern through the lamp compartment.
This fixture includes two 26 watt compact lamps mounted horizontally within a spun open aluminium reflector. This fixture is typically mounted on a ceiling surface recessed into the plenum and includes two hard wired remote ballasts. This fixture was modified to incorporate convective venting with the use of small venting apertures located in the top of fixture reflector in direct proximity to the ends of the lamp. These vents where designed to set-up a primary convection across the ends of the lamp at the location of the minimum lamp wall temperature (MLWT).

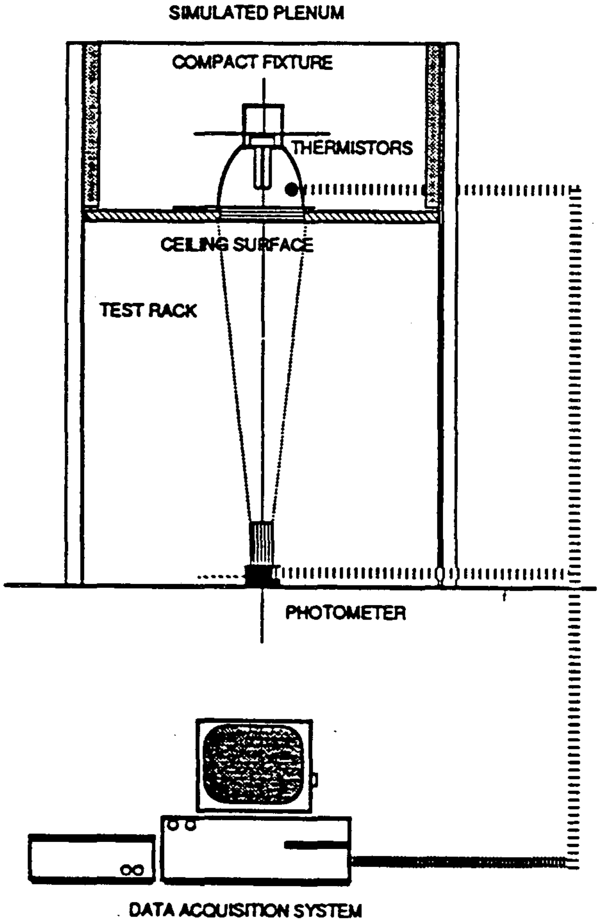


Figure 3. Experimental fixture rack for holding compact fluorescent fixtures during temperature and photometric studies. Included is the schematic of the data acquisition.

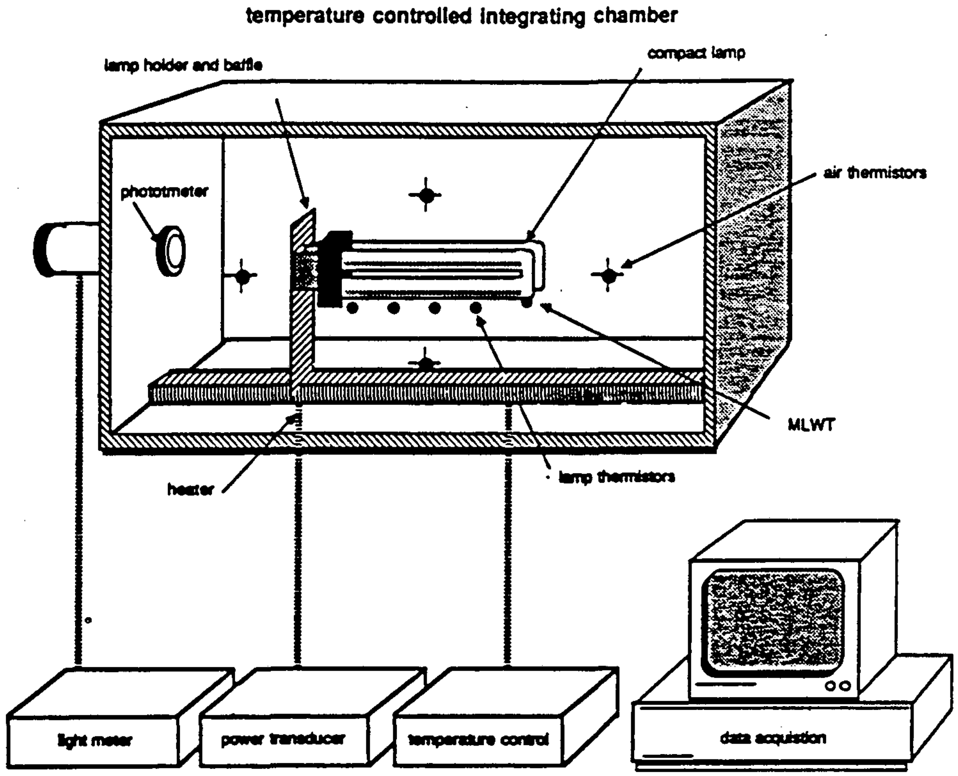


Figure4. Cross section of temperature controlled photometric integrating chamber for characterizing the the light output and efficacy characteristics of compact fluorescent lamps over a wide range of ambient temperatures.

Each of the test fixtures were mounted inside a simulated ceiling and plenum space and operated for a period of 3 to 4 hours until the fixture system reached thermal equilibrium. During each fixture test, lumen output and power input where monitored for both configurations of the fixture. Figure 3 shows a cross section of the experimental ceiling plane in which test fixtures were mounted. A study of the temperature sensitivity of a bare compact fluorescent lamp with a horizontal burning position was also conducted inside a temperature controlled integrating chamber. Light output and power input where measured over a wide range of ambient temperatures while measuring changes in lamp wall temperature. A series of thermistors were attached to the length of the lamp as well as the shoulders of the lamp in order to measure MLWT. Figure 4 shows a cross section through the integrating chamber indicating position of the lamp, photometer and thermistors.

EXPERIMENTAL RESULTS

Lamp -ballast temperature performance

Figure 5 plots the spatial variations in lamp wall temperature for the bare 26 watt compact fluorescent lamp at ambients of 25°C and 50°C ; also included is a schematic of the lamp showing relative positions of thermistors along the length of the lamp.

At 25°C ambient, the lamp wall temperature is at a minimum at approximately 36-37°C at the front ends of the lamp. Temperature then increases sharply to approximately 60°C and then levels off across the lamp. Toward the base the base of the lamp temperature increases to approximately 70°C. The spatial variations at a 50°C ambient are very similar to those obtained at 25°C with an approximately 20C° shift in temperature across the length of the lamp.

Figure 6 plots the light output and efficacy variations as a function of changes in MLWT. Light output and efficacy are maximal at a MLWT of approximately 40°C. With increasing lamp temperature there is a progressive loss in both light output and system efficacy. At a 60°C MLWT, these losses in light output and system efficacy approach 20%.

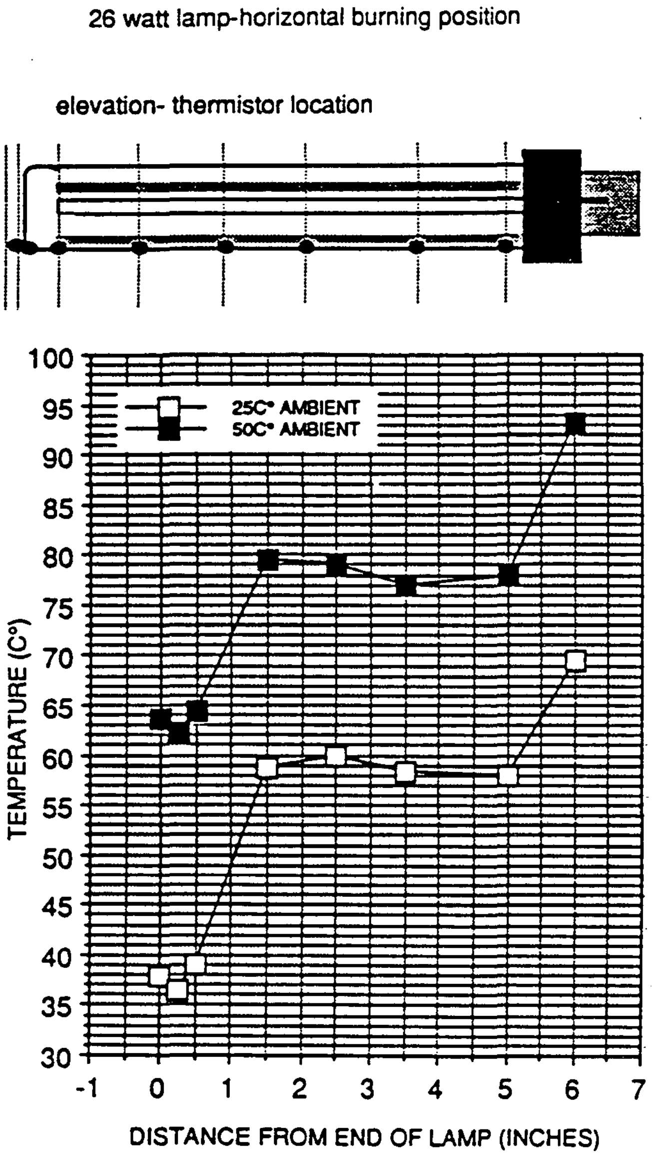


Figure 5. Spatial temperature variations across the compact lamp. and schematic of lamp showing thermistor locations.

Screw-in 13 watt fixture

Figure 7 plots the variations in efficacy and light output over time for both configurations of the screw-in compact fluorescent fixture. For the standard fixture both light output and efficacy reach a maximum after 5-6 minutes of operation. Both light out and efficacy then decline to 80% of the maximum after three hours of operation. For the fixture operating with the radial heat sink light output reaches its maximum somewhat later than the standard fixture; 20-30 minutes after the lamp is energized. System efficacy and light output are then maintained at 98-99% of the maximum for the duration of the experiment. In comparison to the fixture operating without the heat sink system this represents a approximately 20% increase in light output and system efficacy

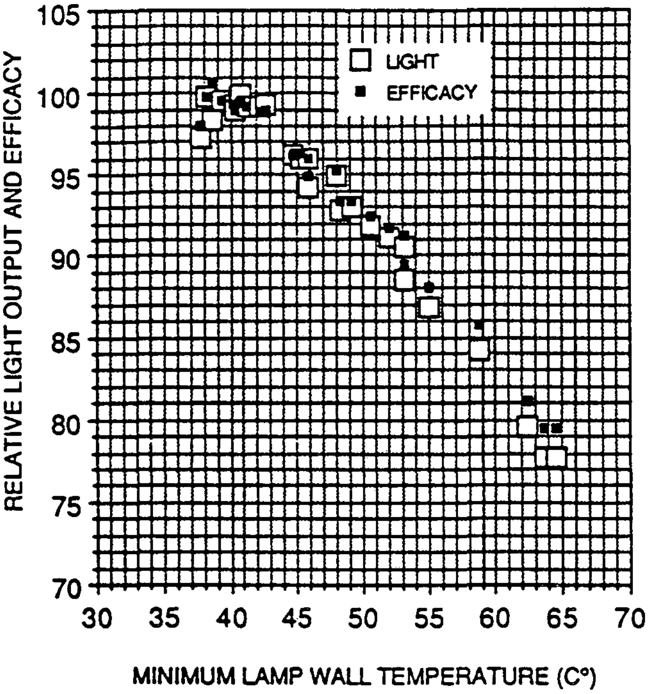


Figure 6. Light output and efficacy vs. MLWT for horizontal burning position of 26 watt compact fluorescent lamp.

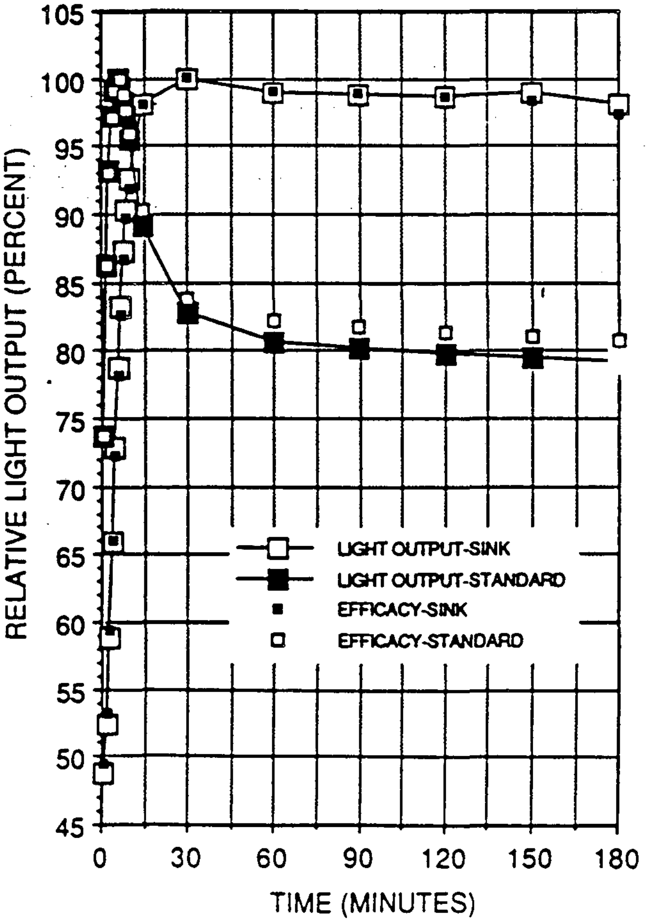


Figure 7. Variations in light output and efficacy for 13 watt fixture operating with and without the heat sink.

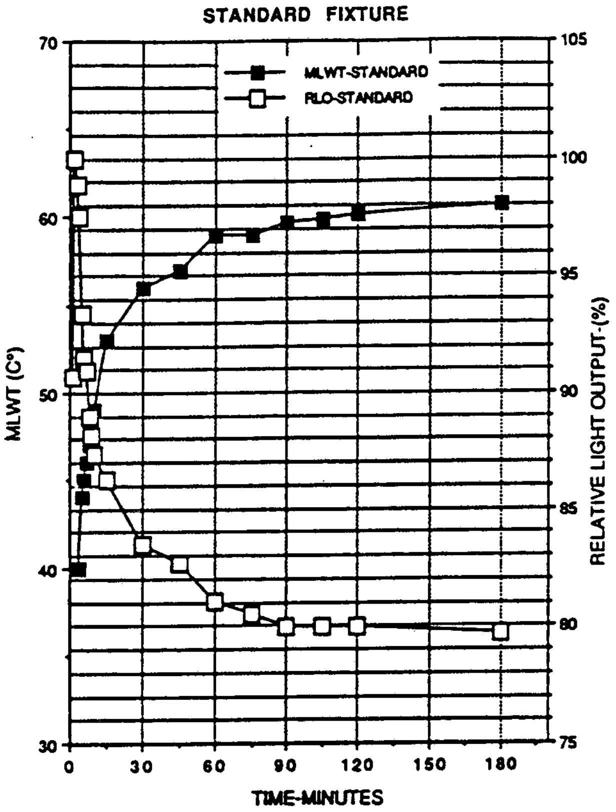


Figure 8. Variations in MLWT and light output for un-vented fixture.

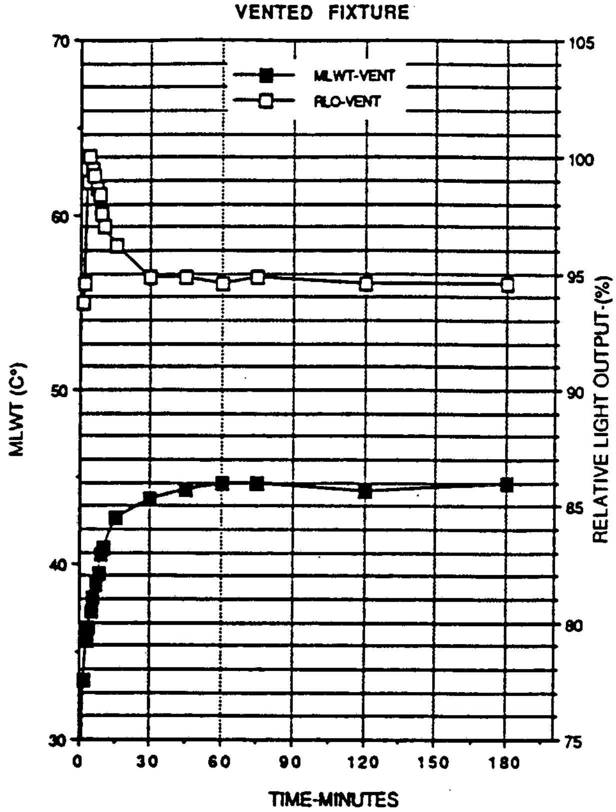


Figure 9. Variations in MLWT and light output for vented fixture.

Recessed down light with two 26 watt lamps

Figure 8 plots the changes in MLWT and light output over time for the standard recessed down light. MLWT shows a rapid increase after the fixture is energized reaching a maximum of a approximately 60°C after a period of 3 hours. Light output shows an inverse relationship to MLWT peaking shortly after the lamps are energized and steadily decaying to approximately 80% of full light output.

Figure 9 shows the same changes in MLWT and light output for the fixture modified to incorporate convective venting. MLWT reaches a asymptotic limit of 45-46°C, 15 C° cooler than the un-vented configuration. Light output reaches a maximum and then decays to approximately 95% of the maximum output. This represents approximately 20% increase in light output in comparison to the stock un-vented fixture.

Figure 10 plots the changes in system efficacy and light output for both the vented and un-vented 2x26 watt recessed down light fixture over the period of three hours For the stock fixture efficacy and light output reach a maximum 2-3 minutes after the fixture is energized. Both efficacy and light out reduce to approximately 83% and 80% of maximum respectively over the duration of the experiment. For the vented fixture light output and efficacy reach the their maximum at 5-6 minutes after the fixture is turned on. Both decay to approximately 95-96% of their maximum after three hours of operation. The cooler operation of the fixture produces approximately 15-20% increase in efficacy and light output.

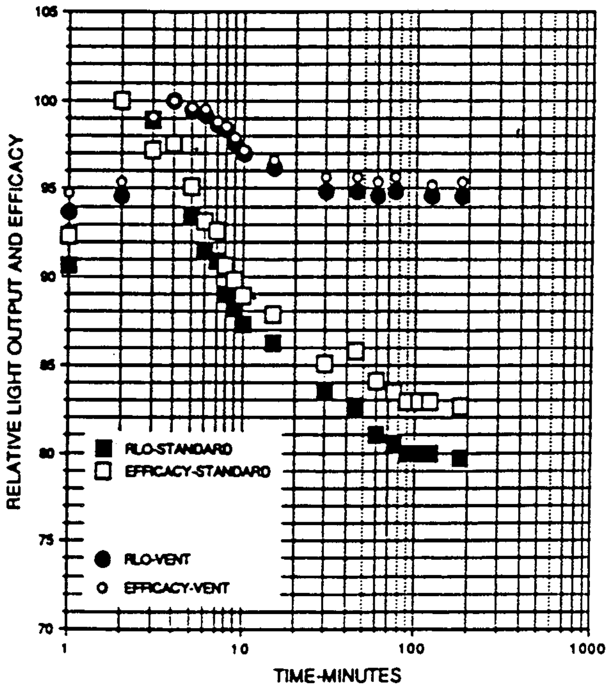


Figure 10. Variations in light output and efficacy for both standard and vented fixture configuration.

DISCUSSION

The results show that a highly constricted thermal environment of the compact fixture causes substantial losses in both light output and system efficacy. These losses occur as the compact fixture presents for the compact fluorescent lamp which results in high lamp wall temperatures.

For the screw-in fixture the lamp is completely enclosed by both the reflector and the lens system. Also this fixture is typically operated within an existing recessed fixture that restricts heat dissipation from the lamp. This type of compact lamp fixture system is used to displace 60 to 75 watt incandescent sources in existing fixtures. The rated lumen output of the compact lamp may closely match the lumen output of a 75 watt incandescent R-lamp. However with 20% thermal based losses in lumen output the lamp fixture system may fall well short of its ability to achieve comparable lumen output in comparison to the 75 watt R-lamp. The application of a heat sink system within the fixture allows the lamp to operate at or near its maximum output. With a 20% increase in lumen output, the compact fixture system will be able to displace the incandescent 75 watt R-lamp in many applications.

The recessed down light with two 26 watt lamps showed similar losses in both lumen output and system efficacy. Even with the open geometry of the fixture, the deep reflector allows a layer of air to stratify within the fixture restricting convective dissipation of heat from the lamps. Modifications to the fixture that allows for convective venting significantly reduced the MLWT of the lamps within the fixture resulting in a 20% increase in lumen output. These types of fixture systems are used in new construction and major renovation applications. A 20% increase in light output and system efficacy will significantly reduce power densities and potentially reduce building costs. This results as increased efficiencies will allow for less fixtures to be used to maintain a desired illuminance level.

The major concern with convective venting is the potential light losses that exist from the apertures in the top of the reflector and the potential for dirt depreciation. It was estimated that the light losses incurred from the venting apertures was on the order of 5-6%. It is anticipated that most of these losses can be recovered with appropriate baffle systems. Dirt depreciation should not be an issue due to the open geometry of the reflector and that air born dust or insects will not be enclosed or trapped with the lamp compartment.

CONCLUSION

Light losses due to thermal conditions within compact fluorescent fixtures can approach 20%. Similar losses in system efficacy also occur due to lamp heating. These thermally induced losses in light output and efficacy can be recovered with careful design of the fixture that reduces ambient and lamp wall temperatures. These approaches include the use of heat sinking the lamp directly to the surrounding air or with the use of convective venting through the lamp compartment.

Appropriate thermal control of the lamp/fixture system is a critical requirement in order to effectively realize the full potential of the compact fluorescent in terms of its ability to displace incandescent sources.

REFERENCES

[1] A. Bouwknegt. "Compact Fluorescent Lamps". Journal of the Illuminating Engineering Society July 1982.

[2] C. Verheiji. "New steps in Development of Compact Single-ended Fluorescent Lamps". Journal of the Illuminating Engineering Society Fall 1985.

[3] Siminovitch M., Rubinstein F. "Thermal Performance of Compact Fluorescent fixtures". Proceedings of the Lighting Efficiency Congress, Association of the Energy Engineers, Santa Clara 1990.

[4] PL lamps Technical Data, Philips Lighting Report P-1071-B

ACKNOWLEDGEMENT

The work described in this paper was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Buildings and Community Systems, Buildings Equipment Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
INFORMATION RESOURCES DEPARTMENT
BERKELEY, CALIFORNIA 94720