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Operating Temperatures of Recessed Fluorescent Fixtures with Thermal Insulation

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Part of
The National Program
for
Building Thermal Envelope Systems
and Insulating Materials

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OPERATING TEMPERATURES OF RECESSED FLUORESCENT
FIXTURES WITH THERMAL INSULATION

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FOREWORD

This is one of a series of reports to be published describing research, development, and demonstration activities in support of the National Program for Building Thermal Envelope Systems and Insulating Materials. The National Program involves several federal agencies and many other organizations in the public and private sectors who are addressing the national objective of decreasing energy wastes in the heating and cooling of buildings. Results described in this report are part of the National Program through delegation of management responsibilities for the DOE lead role to the Oak Ridge National Laboratory.

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SUMMARY

Test results are given in this report for steady state operating temperatures for two recessed fluorescent fixtures of the type used in commercial or industrial applications. The fixtures were operated at power levels at or below the design value with and without thermal insulation installed above the fixtures.

The tests showed that thermal insulation above the fixtures resulted in temperatures sufficiently high to activate the heat switches in the ballasts with resultant intermittent operation. All observed temperatures were below 80°C. Satisfactory performance of fluorescent fixtures covered with thermal insulation will require minor changes in either the design or location of the ballasts which are the primary heat source. An uninsulated space above the area containing the ballasts permitted sufficient cooling to maintain ballast temperatures low enough for continuous operation.

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OPERATING TEMPERATURES OF RECESSED FLUORESCENT FIXTURES WITH THERMAL INSULATION

Introduction

The installation of thermal insulation above ceilings in commercial or industrial buildings is one of many energy conservation acts commonly considered. In many cases attention must be given to existing electrical systems and lighting fixtures as the installation of thermal insulation is specified. Previous reports in this series^{1,2} have dealt with the operation of recessed fixtures with incandescent lamps with and without thermal insulation around the attic side of the fixture. Results are given in this report for observed temperatures for two recessed fluorescent fixtures of the type currently in use. The two fixtures were instrumented with thermocouples and operated at or below the design power levels by disconnecting one or more of the tubes. The first fixture tested had been in place in a dropped ceiling for over five years. The second fixture was new. It was mounted in a rectangular wooden frame and placed approximately 0.6 m (24 inches) above the laboratory floor.

The purpose of the present study was to determine steady state surface temperatures for recessed fluorescent fixtures operated with and without thermal insulation on the top side of the fixture and identify potential problems associated with the installation of thermal insulation. In addition to measuring temperatures, means were sought by which the fixtures can be thermally insulated and operated without fire hazards or damage to the fixture.

Fluorescent tubes operate at lower temperatures than corresponding wattage incandescent lamps. Fixtures for fluorescent tubes, however, include one or more "ballasts" to provide the voltage needed for fluorescent

tube operation. The ballasts represent heat sources within the fixture and in addition typically contain a thermal switch which opens the power circuit with overheating.

Test Procedure

The measurement of fixture surface temperatures was accomplished by mechanically attaching copper-constantan thermocouples to the surfaces using machine screws. The thermocouples were read relative to a 0°C ice bath using a digital voltmeter³. Steady state temperatures for a given operating configuration were determined by keeping the fixture powered until all of the surface temperatures being monitored were constant to within $\pm 0.1^{\circ}\text{C}$ for at least 30 minutes. The ambient temperature in all cases was in the interval $20\text{--}28^{\circ}\text{C}$. The tested fixtures were operated with the design number of fluorescent tubes in place and with tubes removed. No attempt was made to overpower the fixtures.

Temperature data for two recessed fluorescent fixtures were collected in this study. The first, designated fixture A, was installed in a dropped ceiling that is suspended from a concrete pad. Fixture A was at a standard height of eight feet above the floor in an office. The second recessed fixture, identified as fixture B, was installed in a wooden frame 0.95 m (45 inches) wide, 1.75 m (69 inches) long, and 0.23 m (9 inches) deep. The bottom of the box was fabricated from 13 mm (.5 inch) sheet-rock to simulate a ceiling. The frame containing fixture B was positioned on wooden supports 0.6 m (24 inches) above the laboratory floor. The two fixtures were instrumented as shown in Figures 1 and 2. Five thermocouples were attached to the attic-side surface of fixture B. A single thermocouple was also attached to the surface of one of the fluorescent tubes in fixture B. Dimensions and label information for the two

- (a) NUMBERED CIRCLES ARE THERMOCOUPLE LOCATIONS
- (b) DASHED RECTANGLES INDICATE BALLAST LOCATIONS
- (c) SMALL SOLID RECTANGLE IS FIXTURE
- (d) LARGE SOLID RECTANGLE IS EXTENT OF INSULATED AREA

FIGURE 1: DIAGRAM OF FIXTURE A INSTRUMENTATION

- (a) NUMBERED CIRCLES ARE THERMOCOUPLE LOCATIONS
- (b) DASHED RECTANGLES ARE BALLAST LOCATIONS
- (c) SMALL SOLID RECTANGLE IS FIXTURE
- (d) LARGE SOLID RECTANGLE IS FRAME CONTAINING INSULATION

FIGURE 2: DIAGRAM OF FIXTURE B INSTRUMENTATION

fixtures is given in reference notes 4 and 5.

Fixture A is equipped with two ballasts and is designed for use with three 40 watt fluorescent tubes. The thermally uninsulated fixture was operated with one, two, or three tubes in place to determine the normal range of operating temperatures for the fixture. The fixture was then thermally insulated on the top side with fiberglass batts cut to form thermal barriers 0.38 m (15.0 inches) thick on the sides and 0.18 m (7 inches) or 0.28 m (11 inches) thick on the top. A cross-sectional view of the fixture and insulation appears in Figure 3. Fixture A was operated with the ceiling side cover partially or totally removed in addition to standard operation with the cover in place.

Fixture B is also equipped with two ballasts and is designed for use with four 40 watt fluorescent tubes. The fixture was wired in such a way that it can be operated with either two or four tubes powered. The wooden frame containing fixture B was filled to a depth of 0.25 m (10 inches) of loose-fill rock wool insulation at a density of 36.8 kg/m^3 (2.3 lb/ft^3) for study of the fixture under thermal insulation. Fixture B was also operated with the ceiling side cover open and closed. One series of measurements were made with an open ended wooden frame 0.15 m by 0.43 m (6 inches by 17 inches) centered on top of the thermally insulated fixture to provide an air space for convective cooling. A photograph of the top side of the fixture with the frame in position is shown in Figure 4.

Steady state voltage readings from the thermocouple circuits were converted to temperatures using standard tables⁽⁶⁾. The thermocouples were checked against a mercury-in-glass thermometer at room temperature to make sure that they were not damaged in installation. Temperature measurements are believed to be accurate to within $\pm 1^\circ\text{C}$. Electrical current through fixture A was measured with an A-C clamp-on Volt-Ammeter.⁽⁷⁾

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CONFIGURATION I

CONFIGURATION II

- (a) SMALL SOLID RECTANGLE IS FIXTURE
- (b) LARGE SOLID RECTANGLE SHOWS EXTENT OF INSULATION

FIGURE 3: ARRANGEMENT OF THERMAL INSULATION
AROUND FIXTURE A

Figure 4: Fixture B with Thermal Insulation Barrier in Place. Total Insulation Thickness Shown is 250 mm (10 inches) with 178 mm (7 inches) above the Fixture.

Electrical input to fixture B was monitored with an A.C. wattmeter⁽⁸⁾.

No unusual power variations were noted during the tests.

Discussion of Results

Temperatures on the surface of fixture A for twelve modes of operation are given in Table 1. It was observed that fixture surface temperatures of 78-80°C reflect internal ballast temperatures sufficient to open the power circuit. Consequently, temperature entries in Table 1 of 78-80°C indicate intermittent operation of the fixture. Cooling times in excess of one hour were required to return the fixture to operation after the thermal switch was activated. The internal temperatures of the ballasts were not measured but are certainly higher than the fixture surface temperatures. Operations of fixture A near 80°C resulted in a liquid dripping from the ballasts which would no doubt cause an early failure.

The maximum surface temperature recorded for fixture A operated without thermal insulation was 43°C or approximately 20°C above the surroundings. Lower temperatures were observed when one or two of the tubes were taken out of operation. Observed surface temperatures for fixture A were increased by placing fiberglass batts above and around the attic side of the fixture. The fixture temperatures approached the "cut-out" value when insulated with 0.18 m (7 inches) of fiberglass insulation. The operation of the fixture was intermittent with 0.28 m (11 inches) of fiberglass insulation and three tubes powered. The data in Table 1 show that opening the ceiling side cover or removing one tube from the fixture resulted in a drop in temperature to a level where continuous operation of the thermally insulated fixture was possible. The data in Table 1 reflect operation with minimal air movement on the room side of the fixture. It was observed that air movement resulting for example by room ventilation caused a decrease in operating temperatures. Figure 5 contains temperature data plotted against fixture power for operation of fixture A with

TABLE 1

Operating Temperatures for Fluorescent Fixture A
(Two Ballasts, Three 40 Watt Tubes)

Description of Operation	Nominal Fixture Power (watts)	Temperature(°C)					Average	Maximum	Room
		Location 1	2	3	4	5	Temp. °C	Temp. °C	Temp. °C
-----No Thermal Insulation-----									
One tube	40	33	34	32	35	33	33	35	23
Two tubes	80	36	38	38	38	33	37	38	23
Three tubes	120	40	43	41	43	38	41	43	22
-----254 mm (10 inches) of Thermal Insulation - Configuration I-----									
One tube ^(a)	40	47	48	45	50	46	47	48	23
Two tubes	80	53	57	57	57	50	55	57	25
Three tubes	120	67	70	67	72	64	68	72	25
-----356 mm (14 inches) of Thermal Insulation - Configuration II-----									
Three tubes	120	75	79	75	80	72	76	80	26
with ballast cover open		74	78	74	78	70	75	78	26
and fixture cover open		62	66	62	67	58	63	67	28
with ballast cover closed and fixture cover open (a)		61	65	61	67	58	62	67	
and 50% of fixture cover removed		68	73	68	74	64	69	74	25
and 25% of fixture cover removed		75	79	75	80	72	76	80	25

(a) Average for two sets of data. The maximum temperature shown is the maximum individual reading.

FIGURE 5: RECESSED FLUORESCENT FIXTURES OPERATED WITH AND WITHOUT THERMAL INSULATION

the cover closed.

Surface temperatures for fixture B are given in Table 2. The insulation of fixture B with a total depth of 0.25 m (10 inches) of rock wool, resulted in temperatures near the limit for continuous operation with four tubes. The insulation above the fixture was approximately R-21. The data in Table 2 show that the temperature of thermally insulated fixture B is lowered by opening the fixture cover. The operating temperature of the fixture can also be lowered by not covering a relatively small area on the top of the fixture. Operation of fixture B with an uninsulated area 0.15 m by 0.43 m (6 inches by 17 inches) above the ballasts resulted in an average surface temperature only ten degrees above that recorded for the fixture operated without thermal insulation. Temperature data for fixture B are also shown in Figure 5.

A thermocouple was banded to one of the fluorescent tubes in fixture B and tube surface temperatures were monitored and recorded as location 7 in Table 2. The tube temperatures were less than or equal to the maximum recorded fixture temperature in every case. The ballasts rather than the tubes are the primary heat source in the fixture. The fact that the fluorescent tubes operate at a lower temperature than incandescent bulbs accounts for the observation that opening the ceiling side cover has minimal effect on the fixture operating temperature. The fluorescent tubes are not hot enough to produce significant air movement through the fixture.

Surface temperatures for incandescent bulbs are strongly dependent on the ambient conditions, air flow around the bulb, and the positioning of the bulb in a fixture. A few surface temperatures for a 75 watt incandescent bulb in a closed fixture were measured by strapping a thermocouple to the surface of the bulb. Temperatures in excess of 200°C were recorded.

TABLE 2

Operating Temperatures for Fluorescent Fixture B
(Two Ballasts, Four 40 Watt Tubes)

Description of Operation	Nominal Fixture Power (watts)	Temperature(°C)								Average ^(a) Temp. °C	Maximum Temp. °C	Room Temp. °C
		Location 1	2	3	4	5	6	7	8			
-----No Thermal Insulation-----												
Four tubes	160	45	50	50	--	--	51	--	--	49	51	24
-----Fixture Insulated with 254 mm (10 inches) of Loose-Fill Rock Wool-----												
Two tubes	80	58	63	62	51	63	53	53	64	61	64	23
Four tubes	160	72	75	75	73	75	66	61	76	73	76	23
Two tubes and fixture cover open	80	49	54	54	52	55	44	45	55	52	56	23
Four tubes and fixture cover open	160	59	66	66	64	66	56	55	68	64	68	23
-----Fixture Insulated with 254 mm (10 inches) of Loose-Fill Rock Wool -----with 152 mm x 432 mm (6 inches x 17 inches) Barrier in Place-----												
Four tubes	160	57	58	57	59	60	55	61	59	58	61	20
Four tubes and fixture cover open	160	48	49	49	50	51	45	50	51	49	51	20

(a) Location 7 is not included in the average.

Thermocouple 7 was attached to the surface of one of the tubes in the fixture.

Conclusions and Recommendation

The thermal cut-out present in fixture A prevented operating temperatures above 80°C. Thermal insulation of the fixtures resulted in temperatures that approached the 80°C limit. The operation of fixture A with thermal insulation resulted in temperatures sufficient to melt the wax present in the ballast. A redesign of recessed fluorescent fixtures with special attention given to the location of the ballasts should be undertaken so that the fixtures can be thermally insulated. Consideration should be given to a ballast redesign which would result in less heat generation and improved heat dissipation. Existing fixtures can be insulated if the tops are left uncovered. The findings of this laboratory study are summarized below.

- The inclusion of thermal switches in fluorescent fixtures prevent them from being a fire hazard when covered with thermal insulation.
- Existing ballasts can be damaged by the higher operating temperatures that accompany thermal insulation of the fixtures.
- Operating temperatures of thermally insulated fluorescent fixtures can be lowered to levels which will not result in damage by leaving part of the top of the fixture uninsulated.
- Operation of thermally insulated fluorescent fixtures with the ceiling side cover open did not result in strong convective cooling because the tubes operate relatively cool.

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5. Fixture B was manufactured by Lithonia Lighting, Cochran, Georgia. Recessed type light fixture issue No. A-196-260. UL listed. Cat. Number: 2GL 44C A12, 412768, Series II. Fixture has two ballasts and is designed for four 40 watt tubes.
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