Compact Light Source Performance in Recessed Type Luminaires

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Abstract - Photometric comparisons were made with an indoor, recessed, type luminaire using incandescent, high intensity discharge and compact fluorescent lamps. The test results show substantial performance advantages, as expected, for the discharge light sources where the efficacy gains can be in the order for 400% even when including the ballast losses associated with the discharge lamps. The candlepower distribution patterns emerging from these luminaires are also different from those associated with the baseline incandescent lamps, and which are in some ways, even more desirable from a uniformity of illuminance perspective. A section on fluorescent lamp starting is also included which describes a system having excellent starting characteristics in terms of electrode starting temperature (RH/RC technique), proper operating frequency to minimize unwanted IR interactions, and satisfactory current crest factor values to help insure life performance.

INTRODUCTION

There is a large installed base of recessed fixtures which use incandescent lamp types in all segments of the lighting marketplace. It is this particular application segment that discharge lamps are being used because of their energy saving value as well as other performance attributes such as color variety and long lamp life. Much of the growth of the CFL lamps, for example, are expected to be focused in these type of recessed fixtures for both new and existing fixtures. The purpose of this work, therefore, was to quantify some of the primary performance differences between these different light source technologies and compare them to the existing incandescent lamp in terms of light output, candlepower distribution and system efficacy. Although other experimenters have presented related data on this subject, this report further quantifies the photometric differences by using a common type luminaire for all the variations. A section on lamp-ballast compatibility was also included to emphasize that there are also electrical

criteria that must be satisfied to insure that complete system performance is ultimately achieved.

PROCEDURE

The fixture photometry measurements were done according to ANSI/IES protocol in the Mirror Photometry section at Nela Park. Two similar recessed type cylindrical fixtures were used for all the measurements which were taken at 25°C ambient temperature using 100 hr. seasoned lamps. Other photometric measurements were made on a rotary beam photometer to measure the candle power distribution profiles to show the center-beam candlepower values and the maximum beam angle point. The electronic ballast used for the CFL lamps was a rapid start type and it was located in the outer rim of the fixture design. A removable reflector was made and inserted inside the cylindrical fixture to provide a better reflector surface for some of the lamp types so that the performance improvement characteristics with/without the reflector could be compared for a given light source. In the case of the discharge lamp types, the lamps were stabilized overnight in the fixture which was mounted in proper position for the Mirror photometry measurements. Some repeat measurements were made with some of the lamp-ballast combinations to show repeatability of the results which were within 1.5% of each other. All the lamps used for the experiments were also photometered in an integrating sphere at 25°C to obtain the ANSI reference lamp characteristics prior to installing them into the test fixture. After the completion of the fixture photometry in the Mirror Lab, the CFL discharge lamps were then tested in the Engineering Systems lab where the starting/operating scenario measurements were made.

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PHOTOMETRIC COMPARISONS

Table 1 summarizes the photometric data taken with the Mirror Photometer system at 25°C for six light source conditions using four different light source

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technologies. Four of these comparisons involved incandescent lamps, one involved a high intensity discharge source, and two used compact fluorescent lamp technology. The four incandescent, one electrodeless, and one high intensity discharge source all used exactly the same six inch cylindrically recessed fixture, whereas, the two CFL sources used another cylindrically recessed fixture, which was geometrically equivalent to the other fixture. The only reason for using the second fixture was because the base socket for the lamps had to be slightly modified to accept the CFL lamps. Examining the results with the 100W incandescent sources, one generalization that can be made is that the system efficacy value ranged from 8.8 to 10.3 lpw. Since the same 100w incandescent lamp was used for the comparisons, the input wattage was the same at 101.5. However, there was a substantial increase in the lumen level to 1,046 and to the efficacy value at 10.3 lpw when a reflector was added to the fixture. When a 150w incandescent lamp was measured with no reflector added to the fixture, the lumen level was 1454 at an efficacy of 9.5. Basically, then, these comparisons indicate that an increase in the lamp wattage will give essentially a proportional increase in light output with an 8% improvement in efficacy from 8.8 to 9.5. If the incandescent wattage is kept constant and an appropriate reflector is added, the lumens and lpw values were improved by approximately 17%.

To evaluate the performance of an HID light source in this recessed fixture, a 32w/MXR type lamp was used with the same reflector employed for the previous 100w incandescent lamp comparison. The overall significance of this comparison indicated that the light output value (1134) is higher than the 100w incandescent lamp (1046) with a substantial reduction in wattage to 44.2 and approximately a 250% increase in system efficacy to 25.7 lpw. However, it should be noted that the profile of the candlepower distribution curve was also changed specifically in regards to center-beam candlepower and maximum beam angle. The final two comparisons were made with plug-in type CFL lamps having nominal lamp ratings of 26w and 32w. The obvious improvements associated with this light source technology in these applications are that the efficacy gains relative to incandescent are approximately 400% and the system wattage values were reduced to about 22% of the comparative incandescent wattage values. Although not to be discussed in this report, it is strongly suggestive that cost of light analysis and pay back times for these

systems will certainly yield favorable economic benefits.

CANDLEPOWER DISTRIBUTIONS

Notwithstanding the absolute values of the photometrics that show the energy savings and efficacy gains associated with using discharge type lamps in these indoor, cylindrically recessed type fixtures, it is also necessary to evaluate the changes in candlepower distribution that may be expected. These changes in the profile of the candlepower distribution curves can be expected because the light source is being changed from essentially a point source (incandescent) to a diffuse discharge source. Figure 1 illustrates the 'bat-wing' curve typical of an incandescent light source used in such fixtures. Another way to characterize this candlepower distribution is shown in Figure 2, which plots the candlepower distribution as a function of the angle from nadir. Two important metrics to mention about this curve are that the center-beam (0 degrees) candlepower was 214 and that the maximum of this candlepower distribution occurred at 45 degrees with a maximum candlepower value at 350. Such values, therefore, calculate that the intensity of the light output at maximum beam angle will be about 66% higher than it is at the nadir (0 degrees). Now, considering the distribution characteristics of the 26w CFL light source, we observe a similar 'bat-wing' type distribution curve with a more uniform light output pattern that will be delivered to the task surface, as illustrated in Figure 3. The improvement in the uniformity of the light output profile is shown in Figure 4. As indicated, the maximum beam angle is much wider than with the incandescent source and the resultant ratio with the center-beam candlepower value is lower (1.36) which will result in a more uniform light output profile.

Two other light sources that were also evaluated in Table 1 were a 90w halogen IR lamp (Figure 5) and a screw-in 20w electrodeless fluorescent lamp (Figure 6). The different feature associated with the halogen IR lamp in this case was that the centerbeam candlepower (0 degrees) position has the highest candlepower value, suggesting that this would be better for spot source applications. With respect to the electrodeless fluorescent lamp, the profile of the candlepower distribution was most uniform suggesting that this would be better for floodlight type applications as indicated by the ratio of the candlepower at various angles from nadir

relative to its center rated value. In this case, that ratio was as low as 1.13.

STARTING/OPERATING CHARACTERISTICS

In evaluating lamp-ballast compatibility, we analyze the starting and operating characteristics of the particular lamp-ballast system. Considering the 26w/CFL lamp herein discussed, but measured in a bench-top environment outside of the fixture at 25°C, we measured the operating current crest factor at 1.45 with a lamp operating current of 309 MA. With the rapid start ballast used in this experiment, we estimated the electrode starting temperature to be 871 degrees centigrade based on an RH/RC ratio of 5.09 as shown in Figure 7. This ratio is measured in real time by dividing the RMS cathode voltage (upper trace) by the RMS cathode current (lower trace) just prior to the glow to arc transition time and then dividing that hot resistance value (RH) by the cold resistance value (RC) in ohms.

This is a favorable ratio because it results in a glow-to-arc transition time with minimum electrode sputtering as shown by the profile signatures of the lamp voltage and lamp current in Figure 8. Another favorable metric associated with the electronics ballast used in the evaluation was the operating lamp frequency at 45 kHz. This is one of the recommended frequencies for use with CFL lamps because it should not result in any unwanted interactions with IR remote control devices. The starting time measurements indicated that the CFL lamps started in 600 to 700 milliseconds which is well within the suggested guidelines for such a rapid start system. Subsequent rack cycling tests with this electronic ballast and CFL lamp combination were stopped at 40,000 cycles with no failures indicating that the starting process is completely satisfactory as would certainly be expected with a ballast having a dynamic RH/RC ratio value of 5.09.

Table 2 is included to show the various evaluation criteria that were used to help analyze the degree of lamp-ballast compatibility with this innovative recessed type luminaire.

SUMMARY

There is a continuing major shift in the type of light source being used for cylindrically recessed type luminaires. The shift is from using incandescent lamps to using discharge lamps. The prime drivers for this change are substantially improved life,

higher efficacy, diverse choice of colors, all of which result in favorable cost of light and payback time benefits. The life improvement is basically ten-fold and the efficacy gains as high as +400% when discharge type lamps are used with electronic ballasts. However, the candlepower distributions can be substantially different between the various light sources when compared within the same recessed luminaire. In order to insure the anticipated lamp life improvement relative to the to the incandescent light sources, pertinent lamp-ballast compatibility criteria was included. This data suggests that the CFL lamps used in these fixture measurements will meet their expected life values, particularly because of the favorable RH/RC ratios at starting and the relatively low operating current crest factors as related to the specific ballast design used in these experiments.

ACKNOWLEDGMENT

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TABLE 1

Recessed Luminaire Photometry Comparisons

Light Source	L	W	LPW	CBCP	MAX CP	Ratio MAX/CB
1. 100w/INC	897	101.5	8.8	180	256	1.42
2. 100w/INC/R	1046	101.5	10.3	214	350	1.66
3. 150w/INC	1454	153.8	9.5	250	419	1.68
4. 90w Halogen IR	965	90.0	10.7	484	484	1.0
5. 32w/MXR	1134	44.2	25.7	451	616	1.37
6. 20w Electrodeless	587	19.9	29.5	190	215	1.13
7. 26w/CFL	914	22.4	40.8	219	297	1.36
8. 32w/CFL	1346	33.5	40.2	353	439	1.25

NOTES:

- A.
1. 100w incandescent, no reflector, 6" recessed luminaire
 2. 100w incandescent with reflector, 6" recessed luminaire
 3. 150w incandescent, no reflector, 6" recessed luminaire
 4. 90w Halogen IR with reflector, 6" recessed luminaire
 5. 32w/MXR (HID Lamp) with reflector, 6" recessed luminaire
 6. 20w Electrodeless Fluorescent with reflector, 6" recessed luminaire
 7. 26w/TBX plug-in CFL with reflector, 6" recessed luminaire
 8. 32w/TDX plug-in CFL with reflector, 6" recessed luminaire
- B. All measurements in Mirror Photometer taken at 25°C ambient temperature, per IES protocol.
- C.
- L = Lumens
- W = System Wattage
- LPW = System Efficacy
- CBCP = Center Beam Candle Power
- Max CP = Maximum Candle Power
- Ratio Max/CB = Maximum Candle Power ÷ by Center Beam Candlepower

CANDLEPOWER DISTRIBUTION CURVE S0602A5

Figure 1
Candlepower Distribution Curve
For 100w Incandescent Lamp
With Reflector in Recessed Fixture

Figure 2
Angle From Nadir (Degrees)
For 100w Incandescent Lamp
With Reflector in Recessed Fixture

CANDLEPOWER DISTRIBUTION CURVE S0602K5

Figure 3
Candlepower Distribution Curve
For 26w/TBX Plug-In CFL Lamp
With Reflector in Recessed Fixture

Figure 4
Candlepower vs. Angle From Nadir
For 26w/TBX Plug-In CFL Lamp
With Reflector in Recessed Fixture

Figure 5
Candlepower vs. Angle From Nadir
For 90w Halogen IR Incandescent Lamp

Figure 6
Candlepower vs. Angle From Nadir
For 20w Electrodeless Fluorescent Lamp

Figure 7

RH/RC Estimated Electrode Temperature
During the Starting
Scenario of F26w/TBX Lamp

Figure 8

Good Glow-To-Arc Starting Signature
For F26/TBX Lamp

Lamp Type	100% Line F26TBX	100% Line F32TBX	100% Line 32W T/E
Cathode Fall (Volts)			
Current Crest Factor	1.45	1.45	1.45
Lamp Operating Current (mA)	309	277	273
Lamp Volts	82.8	110	113
Lamp Watts	25.3	30.2	30.6
Cathode Volts (Start)	9.5	8.7	11.8
Cathode Volts (Operate)	2.15	2.56	3.44
Rh/Rc Ratio	4.85	4.46	4.37
Cathode Rc (Ohms)	2.55	2.62	3.92
Electrode Start Temp. (°C)	825	747	733
Open Circuit Volts	855 During Start Pulses		
Glow Current (mA.)	<5	<5	<5
Starting Time (mSec.)	624	604	664
System THD (%)	151	140	140
System Power Factor (%)	53.6	56.0	56.0
Lamp Frequency (kHz.)	45.4	48.1	48.7
Input Volts	120	120	120
Input Current (mA.)	437	509	520
Input Power (W)	28.1	34.2	35.0

Table 2
Evaluation Criteria for CFL
Starting / Operating Measurements