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Experimental Analysis on Electrical and Photometric Performances of Commercially Available Integrated Compact Fluorescent Lamp

Hu-Hsiao Hsu, Po-Ren Chung, Ming-Chin Ho, Chieh-Feng Tsai, Che-Ming Chiang, Shin-Ku Lee

Abstract**—**Lighting upgrades involve relatively lower costs which allow the benefits to be spread more widely than is possible with any other energy efficiency measure. In order to popularize the adoption of CFL in Taiwan, the authority proposes to implement a new energy efficient lamp comparative label system. The current study was accordingly undertaken to investigate the factors affecting the performance and the deviation of actual and labeled performance of commercially available integrated CFLs. In this paper, standard test methods to determine the electrical and photometric performances of CFL were developed based on CIE 84-1989 and CIE 60901-1987, then 55 selected CFLs from market were tested. The results show that with higher color temperature of CFLs lower efficacy are achieved. It was noticed that the most packaging of CFL often lack the information of Color Rendering Index. Also, there was no correlation between price and performance of the CFLs was indicated in this work. The results of this paper might help consumers to make more informed CFL-purchasing decisions.

Keywords**—**Compact fluorescent lamp (CFL), Efficacy, Color Rendering Index (CRI), Energy saving.

I. Introduction

CLIMATE change is becoming an ever more important issue in our lives and energy saving is an urgent topic of the world. Lighting accounts for around 10% of total energy consumption in a country, and this area offers considerable potential for energy savings. As well known, one of the strategies for achieving the goal of reducing electricity consumption of a building is by replacing energy inefficient incandescent lamps with energy efficient light sources such as compact fluorescent lamps (CFLs). Many countries [1-3] have developed energy rating systems to encourage consumers to use high energy-efficient lamps, especially for buildings with air conditioning.

Hu-Hsiao Hsu is with Architecture and Building Research Institute Ministry Interior, Taiwan, ROC (e-mail: hsuhh@abri.gov.tw).

Po-Ren Chung is with Department of Architecture, National Cheng-Kung University, Taiwan, ROC (e-mail: benjamin@archilife.ncku.edu.tw).

Ming-Chin Ho is with Architecture and Building Research Institute Ministry Interior, Taiwan, ROC (e-mail: ho@abri.gov.tw).

Chieh-Feng Tsai is with Architecture and Building Research Institute Ministry Interior, Taiwan, ROC (e-mail: 90f 006@abri.gov.tw).

Che-Ming Chiang is with Department of Architecture, National Cheng-Kung University, Taiwan, ROC (e-mail: cmchiang@mail.ncku.edu.tw).

Shin-Ku Lee is with Research Center for Energy Technology and Strategy, National Cheng Kung University, Taiwan, ROC (phone: 886-6-2757575 ext. 51030; e-mail: sklee@stu.edu.tw).

The efficacy value (lumens/watt) is the major criterion to determine whether a lamp can meet the specific energy efficiency requirement specified in the rating system. In the United States and Canada, the Energy Star program labels compact fluorescent lamps that meet a set of standards for starting time, life expectancy, color, and consistency of performance.

The intent of the program is to reduce consumer concerns due to variable quality of products.Those CFLs with a recent Energy Star certification start in less than one second and do not flicker. There is ongoing work in improving the "quality" (color rendering index, CRI) of the light. In the United Kingdom a similar program is run by the Energy Saving Trust to identify lighting products that meet energy conservation and performance guidelines. The Hong Kong government implements a mandatory energy efficiency labeling scheme (EELS) for specified electric appliances in Hong Kong. The compact fluorescent lamps (CFLs) are included.

In Taiwan, the government launched some programs targeted the legal, technical, and awareness aspects of lighting since 2008. An endorsement label system for energy efficiency lighting facilities had been developed in 2009. So far, 100 models from 13 manufacturers had been qualified in this label system. In order to increase the adoption rate of energy efficient light for achieving the national goal of reduction of GHG emissions generated by inefficient lighting, a new energy efficient lamp comparative label system (EELCLS) has been proposed in Taiwan.

This “Grading Type” energy label is divided into 5 grades. A light system with a Grade 1 label means that it is the most energy efficient product in the market. The luminous efficacy is the key factors to classify the energy efficiency grading of light system. Before launching this energy efficient lamp label system, Architecture and Building Research Institute, the Ministry of Interior, Taiwan conducted a pilot project for understanding the performance distribution of CFLs available in the market.

This paper reports on the results obtained from this project to conduct the electrical and photometric performance measurement of integrated CFLs. Several factors affecting the performance are analyzed and the deviation of actual and labeled performance of commercially available integrated CFLs is addressed.

II. EXPERIMENTS

A. Sample preparation

In order to get the representative samples in this study, 55 integrated compact fluorescent lamps contained 17 samples with tubular-type and 38 samples with helical-type are selected from the market. The electrical power inputs of selected lamps are less than 25 Watt.

B. Methods

Standard test methods are used to determine the properties for the selected CFL samples. The electrical and photometric performances of CFL were determined by using a luminous flux measurement system based on CIE 84-1989 [4] and CIE 60901-1987 [5]. The electrical characteristics measurement and procedures shall be as described in Section 1 and Annex B of IEC 60901. Lamp luminous efficacy is determined by computing the ratio of the measured lamp lumen output and lamp electrical power input at equilibrium for the test conditions. The general color rendering test based on CIE 13.3-1995 [6] is conducted to calculate the color rendering index of CFL.

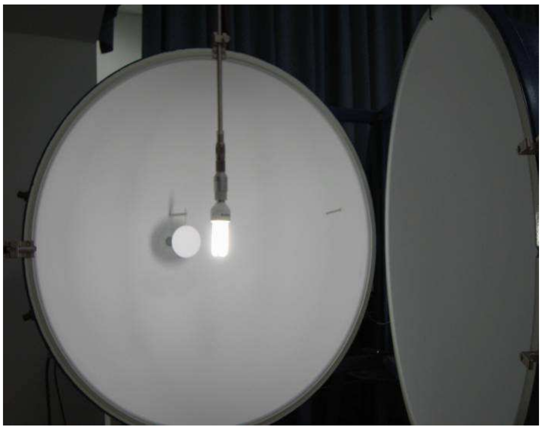

Fig. 1 Integrating sphere photometer

Fig. 2 Luminous flux measurement system

III. RESULTS AND DISCUSSION

The test results of electrical and photometric performance tests for the 55 CFL samples are summarized in Table 1. It was observed that the values of CRI for 2 samples (no. 35 and no. 44) were less than the limiting value (80%) that the endorsement label system is required. Also, no significant differences of voltages, watts and color temperature between measurement and nominal value in specification were observed for these tested samples. The averaged relative errors for watts and color temperature of these CFLs are –2.1% and 0.6%, respectively. This implies that CFL power output may depend on type of integrated ballasts (traditional magnetic or electronic high-frequency), and also depend on ballast manufacturer and quality of ballast. However, the averaged relative error for efficacy is considerably larger than for other parameters. The averaged relative error for efficacy of tubular-type CFLs and helical-type CFLs are 12.7% and 4.8%, respectively. It is worth to note that the measured efficacy of 16 CFL samples included 4 tubular-types and 12 helical-types were less than nominal value in specification. That means that many CFL efficacy claims were outright exaggeration, often by about 5 percent and in a few extreme cases by 15 percent. Furthermore**,** it was common that the indicated efficacy was inaccurate.

With the above-mentioned experimental results, some noteworthy observations are addressed as follows:

1) The information on packaging of CFL was often deficient in terms of Color Rendering Index.
2) Lower wattage CFLs have lower efficacies and higher wattage CFLs have higher efficacies. Generally lumens/ Watt for bare CFLs are as follows: less than or equal to 10 watts: 59.0 lumens/ Watt; 10-15 watts: 62.7 lumens/ Watt; 15-25 watts: 64.8 lumens/ Watt.
3) Lower color temperature of CFL has higher efficacies and higher color temperature of CFL has lower efficacies.
4) The experimental results indicated that there was no significant correlation between lamp length and efficacy of the CFLs.
5) This paper carried out electrical and photometric performance testing of 55 different CFLs from different manufacturers in the market concluded that there was no correlation between price and performance of the CFLs.
6) The minimum allowable luminous efficacy for grading of any CFL of a type is listed in Table 2. The number of CFLs that belong to each grade of a new energy efficient lamp comparative label system (EELCLS) in Taiwan is also listed in Table 2. Table 2 reveals that about two-fifth of samples are in grade 3, about 27% of CFLs are in grade 4 and only one sample is labeled in grade 1.

TABLE I
COMPARISON BETWEEN SPECIFIED AND MEASURE PROPERTIES FOR 55 SELECTED CFLS

#	Type	Wattage		Efficacy		Color temp.		CRI
		spec	mea	spec	mea	spec	mea	mea
1	Helical	5	4.7	69	58.9	2700	2727	83.9

2	Helical	5	4.9	59	55.4	6500	6182	84.0
3	Tubular	5	5.1	47	52.8	2700	2780	83.8
4	Tubular	5	5.3	46	50.6	6500	6210	84.1
5	Helical	8	7.8	72	71.6	2700	2725	83.3
6	Helical	8	8.2	65	65.1	6500	6351	84.4
7	Tubular	8	7.9	57	55.7	2700	2791	82.9
8	Tubular	11	10.8	49	54.4	6500	6347	82.1
9	Helical	13	13.8	61	67.6	6500	6001	80.0
10	Tubular	14	13.6	54	60.2	6500	6366	82.0
11	Helical	15	14.1	67	74.1	2700	2766	83.4
12	Helical	15	14.5	61	64.7	6500	6265	82.7
13	Tubular	18	16.4	57	66.1	2700	2751	84.1
14	Tubular	18	17.0	57	60.6	6500	6165	83.2
15	Tubular	20	17.9	70	69.3	2700	2701	83.5
16	Tubular	20	18.0	65	66.6	6500	6390	86.0
17	Helical	23	21.9	65	71.6	6500	6243	82.1
18	Tubular	20	17.8	56	60.2	2700	2715	83.5
19	Tubular	20	18.2	60	70.2	2700	2738	83.9
20	Tubular	20	17.8	57	64.1	6500	6347	85.6
21	Helical	20	19.5	60	75.2	2700	2793	82.6
22	Helical	20	18.1	56	64.4	6400	6195	83.0
23	Helical	23	21.0	60	69.8	6500	6521	83.5
24	Tubular	23	21.2	60	59.5	-	3070	85.1
25	Tubular	23	23.2	56	55.5	6500	6018	80.0
26	Helical	5	5.1	52	57.6	2800	2708	84.3
27	Helical	5	5.2	52	51.7	6500	6319	84.4
28	Helical	9	7.7	55	64.9	2800	2726	84.6
29	Helical	9	8.3	55	61.8	6500	6130	83.8
30	Helical	13	11.9	52	53.0	6400	6234	81.1
31	Helical	16	13.9	55	68.8	2700	2630	84.4
32	Helical	13	12.7	55	63.9	2800	2733	82.3
33	Helical	13	12.5	55	62.8	6500	6266	80.5
34	Tubular	21	19.8	-	57.4	2800	2904	81.0
35	Tubular	21	20.1	55	56.6	6500	6389	78.7
36	Tubular	23	21.0	55	67.4	2800	2936	80.9
37	Helical	23	21.3	55	59.6	6500	6331	81.8
38	Helical	5	5.2	55	58.8	2700	2732	84.0
39	Helical	5	5.1	50	55.5	6500	6335	84.5
40	Helical	5	5.5	55	53.7	4100	3928	86.2
41	Helical	9	10.2	60	58.6	6500	6484	84.2
42	Helical	9	9.6	65	65.6	2700	2826	83.7
43	Helical	9	9.6	65	65.2	4100	4086	84.7
44	Helical	11	11.1	60	61.8	6500	6261	78.0
45	Helical	11	11.4	65	68.8	2700	2781	84.5
46	Helical	11	11.3	68	61.5	4100	4285	84.8
47	Helical	13	13.8	65	69.6	2700	2895	82.5
48	Helical	13	13.3	60	62.0	6500	6504	82.5
49	Helical	13	13.3	65	67.1	4100	4133	84.8
50	Helical	21	21.0	70	69.0	2700	2884	82.9
51	Helical	21	20.8	63	64.4	4100	4124	84.3
52	Helical	21	19.9	65	60.4	6500	6350	83.8
53	Helical	23	22.6	68	65.0	4100	4285	82.5
54	Helical	23	24.0	70	64.3	2700	2798	83.9
55	Helical	23	23.7	65	60.9	6500	6318	83.1

IV. Conclusions

Saving energy and reducing installed cost of compact fluorescent lamps are significant concerns for popularizing CFLs. In this work, the standard test methods for measuring electrical and photometric performances of commercially available integrated CFLs were developed. The tests have found the poorest performing CFL to give 15% less efficacy than stated, while a few of the best gave slightly less (initially), and most somewhat over stated efficacy. It is worth mentioning that there are 35 qualified CFLs that can potentially meet higher than the grade 3 performance specification of new Taiwan CFL comparative label system. Also, there was no correlation between price and performance of the CFLs was indicated in this work. The results of this paper might help consumers to make more informed CFL-purchasing decisions.

TABLE II
Minimum Allowable Luminous Efficacy For Integrated Type CFLs

Rated Lamp Wattage	Minimum Allowable Luminous Efficacy (Lumen/W) (number)				
	Grade 1	Grade 2	Grade 3	Grade 4	Grade5
≤10W	>72 (0)	63<X<72 (0)	54<X<63 (2)	45<X<54 (0)	<45 (0)
10 – 15W	>74 (1)	66<X<74 (10)	58<X<66 (13)	50<X<58 (6)	<50 (0)
15 – 25W	>79 (0)	72<X<79 (1)	66<X<72 (8)	60<X<66 (9)	<60 (5)

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