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Measurement of actual efficacy of compact fluorescent lamps (CFLs)

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ABSTRACT

The use of compact fluorescent lamps (CFLs) in domestic residences has increased rapidly due to their higher energy efficiency and longer life expectancy when compared with traditional incandescent light bulbs. Through measurement of illuminance, actual power and apparent power, the actual efficacy and associated power factor of CFLs are studied in this paper. It is found that for an individual CFL, although its power consumption and lighting output (i.e. luminous flux) may be higher or lower than the stated values provided by the lighting manufacturers, the actual efficacy would most likely be equal to or better than the efficacy calculated from the given rated power and lumen from the manufacturers. The typical power factor for CFLs was 0.63.

1. Introduction

Buildings, as one of the most significant infrastructure sectors in modern society, are responsible for 40% of the world's total energy use [1]. In Australia, buildings are a particularly significant energy user and a major contributor to greenhouse gas emission, due to their heavy reliance on grid-supplied electricity which is mostly generated from fossil fuels (predominantly coal). It was found that when combined, the commercial and residential building sector consumes more than half of the total electricity in Australia [2].

Energy used by lighting contributes a large share of energy use in the building sector. Generally, artificial lighting is estimated to account for 25–40% of the energy consumption for commercial buildings [3] and represents nearly one-fifth of the total electricity consumption in the average home [4]. For industrialized countries, lighting accounts for 5–15% of total electric energy consumption [5]. In Australia, lighting represents about 11% of greenhouse gas emissions from households [19] and about 21% from the commercial building sector [20]. In order to improve building energy efficiency, the use of energy-efficient compact fluorescent lamps (CFLs) has often been suggested [6–11].

A compact fluorescent lamp (CFL) is a fluorescent lamp that has been designed to fit into light fixtures which were formerly used for incandescent lamps. The lamps consist of a tube, which is compressed to fit into the space of a standard-size incandescent light bulb. An electronic ballast is also placed in the base of the lamp [12]. Compared to general-service incandescent lamps giving the same amount of visible light, CFLs typically use one-fifth to one-third of the electric power, and last eight to fifteen times longer.

In the last decade, compact fluorescent lamps (CFLs) have been widely promoted as a key alternative to replace incandescent lamps. Some initial issues have been reported, including higher initial cost, perceived poorer light quality, shorter life than advertised, inability to dim these lamps, and difficulty in finding suitable lamp fittings. Most of these issues have been progressively addressed by the industry over the past 15 years. However, the question of whether the actual performance of CFLs may vary markedly from their rated output has remained.

In this paper, the performance of current, commonly available CFLs is investigated. After a brief introduction on the study background, the methodology used in the study is described. This includes the test methodology, test equipment, test procedure and the selection of sample CFLs. Experimental measurements will then be discussed, including the lamp ageing process, the calibration of testing receptacles and data recording. Finally, experimental results will be analysed, and the findings and conclusion discussed.

2. Methodology

2.1. Test methodology

The current Australian/New Zealand Standards applicable to CFLs include:

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- AS/NZS 4847.1:2010 [14] self-ballasted lamps for general lighting services part 1: test methods–energy performance.
- AS/NZS 4847.2:2010 [15] self-ballasted lamps for general lighting services part 2: minimum energy performance standards (MEPS) requirements.
- AS/NZS 4782.3(Int) [16]: 2006 double-capped fluorescent lamps–performance specifications–procedure for quantitative analysis of mercury present in fluorescent lamps.

This study has aimed to follow the requirements of AS/NZS 4847.1 as closely as possible with regard to efficacy testing. It includes:

- A minimum sample size of 10 lamps per brand was used as per the standard.
- The ambient temperature of the lamp ageing room shall be in the range of 15 °C to 40 °C.
- During the lamp ageing process, lamps shall be cycled repeatedly, such that they are on for 2 h 45 min and off for 15 min.
- Ageing of each lamp was performed for a period of 100 h prior to efficacy testing.
- All lamps were kept in the same vertical, cap up position prior to and throughout the testing period.
- All lamps were handled carefully at all times to avoid disturbing the mercury within the fluorescent tube.
- Supply voltage from mains electricity to the lamps was recorded, but was not controlled to the standard's specification via a regulated power supply. Frequency and total harmonic content were not measured or controlled as per the standard.
- Each lamp was 'warmed up' for a period of 15 min prior to efficacy testing as per the standard.
- The light meters were placed in the same location immediately below the lamp in each testing receptacle.

2.2. Test equipment

The instruments used for the test include CFL ageing test rig, testing receptacles, timer, light meters and power/energy meters as follows:

- The CFL ageing test rig was an in-house constructed lamp-holding frame with a controller set by Lab View software. This custom-built frame was able to hold 20 lamps at one time.
- Testing receptacles were also custom-built within a steel cabinet where all the inner surfaces were lined with aluminium foil. The test results from these testing receptacles were calibrated against the integrating sphere to comply with the AS/NZS 4847.1 requirement and to ensure their accuracy and consistence.
- Digitech lux meters were used with an error of + or −5% for readings <10,000 lux.
- Power/energy meters were Energy Monitor 3000 models. These are a true RMS meter with an error of less than 1%.

2.3. Test procedure

Prior to testing (in addition to the ageing process), the test lamps were lit continuously for the 15 min immediately preceding testing. This is to ensure the cessation of any fluctuations in the light output of the lamp.

After this stabilization period, the supply voltage was noted, and observations began. The doors of the testing receptacles were closed, and a measure of the light intensity was taken from a hand-held 'lux meter'. At the same time, the power consumption – both real and apparent – was noted on the 'energy monitor', connected to the power source.

Table 1
Common configuration of CFLs in tested sample.

CFL brand	Configuration of tube	No. of bulbs	Rated power (W)	Rated lumens (lm)
Brand 1	U-tube	10	11	610
Brand 2	U-tube	10	11	600
Brand 3	Spiral	10	12	700
Brand 4	Spiral	10	13	810

This process was repeated at thirty-second intervals, for a period of five minutes, giving ten readings for each testing lamp.

At the conclusion of each test, the supply voltage was again recorded.

2.4. Sample size of various brand lamps

For this study, sample CFLs were selected based on the following criteria:

- must be a common size, which could be used to replace incandescent lamps;
- must be common brands, produced by reputable manufacturers;
- must have similar rated power; and
- must be readily available at major supermarkets in Australia.

As a result, four major brands were selected from two dominant supermarket chains in Australia, with two from the Woolworths supermarket chain and the other two from the Coles supermarket chain. A minimum sample size of 10 lamps per brand was used as required by the standard AS/NZS 4847.1. In addition, the sample CFL bulbs, as shown in Fig. 1, were of the 'U-tube' or 'spiral' configuration, depending on availability at the time of purchase, with all having a bayonet connector (BC). The tested models were rated at the lower end of the scale between 11 and 13 W and were deemed suitable to replace incandescent globes rated to around 60 W (Table 1). It is noted that the "Rated lumens" for Brand 4 was estimated and was based on the given information of "13 W CFL equals to 65 W standard incandescent lamp".

3. Experimental measurement

3.1. Lamp ageing process

Since the aim of this study was to collect data that is representative of lamps that have been in use for some time, in accordance with the relevant Australian standard (i.e. AS/NZS 4847.1), all sample CFL lamps were therefore artificially aged for a period of 100 h. This was accomplished in a custom-built ageing rig, which was an in-house constructed lamp-holding frame able to hold 20 lamps at one time.

The ageing 'on/off' duty cycle as specified in the standard was controlled via a laptop computer using Lab View software as shown in Fig. 2, and was programmed to operate at regular intervals as shown in Table 2. For example, in a given three-hour period, lamps were switched on for 2 h 45 min, and later were switched off for 15 min. They were programmed for 36 cycles, with the last "On" cycle being for one hour.

Table 2
Programming of time cycles.

Status	Number of cycles	Time (h)
'On'	36	2.75
'Off'	36	0.25
'On' (last cycle)	1	1
Total 'On', Σ(cycles × time)		100