Facts and Figures About Compact Fluorescent Lamps or CFLs: Advertisements Versus Measurements

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In order to launch a retrofit rebate program of 150,000 Compact Fluorescent Lamps (CFLs) in Guadeloupe--a French off-shore territory in the Carribean Islands--a selection of 8 different specimens from various manufacturers, in and outside the European Economic Community, have been tested and compared.

The CFLs were chosen to provide an alternative to a 75 W incandescent source, thus offering a wide range of variations, including sources with electronic or electromagnetic ballasts, screw or bayonet bases, reusable ballasts, etc. All lamps had integral ballasts.

In the paper, lighting characteristics (luminous flux and its change during life of the lamp, luminous efficacy, life duration) as well as electric characteristics (safety, power factor, harmonic distortion) are presented for a sample of 20 CFLs covering every type.

The effects of the particular electricity supply conditions on the rebate program location--namely a wide voltage variation, ±20%--have also been analyzed for both fluorescent and incandescent bulbs.

As a conclusion, the paper proposes specifications for a "best choice" and describes the basis for a standard measurement test procedure for CFLs, as no standard currently exists in Europe.

Introduction

Compact Fluorescent Lamps (CFLs) can be a fundamental component in a rebate program within the residential sector. However CFLs can be difficult to select. They vary in price depending on a number of characteristics and negotiations with manufacturers on deliveries and discounts may be difficult.

Moreover, the lamp choice has to take into account the location of the rebate program--in an equatorial climate safety problems can be encountered with humidity penetrating into the lamp base, between cap and cap-holder--as well as the situation of the electric utility because the distribution network and electric current quality may impact selected appliances and reduce program success--for example, on a small or medium island, electricity is generated by fossil fuel power station(s), mostly motor driven generator(s), and operating voltage may differ from rated voltage and can thus be continuously varying.

The French Environment Protection and Energy Conservation Agency (Ademe--French acronym) is planning to launch a rebate program using 150,000 CFLs in Guadeloupe. A characterization of CFLs has been carried out with 3 aims: (1) verify manufacturer's claims on several different products; (2) survey lamp behaviour when supplied with non-stabilized electric power; (3) define the requirements of a future standard measurements test.

Methodology

Planned measurements are based on an existing test[1] concerning tubular fluorescent sources which was adapted for a reduced sample size. We focused on useability and restricted ourselves to verify primary safety requirements.

All test measurements are carried out on 20 samples of each model, distributed as follows: (1) 10 samples tested with 220V a.c. (rated voltage) for safety verification and

characteristics measurements; (2) 5 samples tested with 260V; (3) 5 samples tested with 180V.

The following measurements were conducted : (1) cap size and dimensions (safety verification)[2]; (2) luminous flux immediately after startup and after 400 hours, 1000 hours and 2000 hours of operation for all lamps[3] (3) electric characteristics (power, power factor, harmonics distortion) for CFLs under rated voltage supply after 400 operating hours. This delay is due to a necessary break-in period for the electrodes of tubular fluorescent sources and we postulated that a similar minimum delay was needed for CFLs.

These measures were completed by 2 specific tests: (1) CFLs tested with 260 V have been lit up under 160 V and vice versa; (2) a sample of 10 lamps of one specific brand has been compared to a sample of 10 - 75 W incandescent bulbs, all supplied with a continously varying voltage, between 180V and 260V.

Description of Sample

The selected models were chosen as replacement options for a 75 W incandescent bulb. All but one are manufactured in Europe and available on the French market. Comments regarding the table follow:

- Specimens OS & OG are based on the same technology, by the same manufacturer and differ only by the plastic globe (OG) encapsulating the twin bare tubes of model OS.
- Models PE and MZ are the same technology but marketed under different brands.
- Type PS is an 8 to 10 year old technology that is common in domestic and commercial applications in France and represents for most consumers, up to now, the "compact fluorescent lamp" though it is large and heavy.
- MT is a southeast Asian product, introduced in the study both to try to assess its performance and to help in price and discount negotiations with European manufacturers.

Table 1. Description of Selected CFLs

Lamp	Wattage (W)	Envelope	Base Type	Ballast Type	Reusable	Retail Price ($-VAT excl.)
OS	15	bare	B22	Electronic	No	31.64
OG	15	plastic globe	Screw	Electronic	No	38.36
PE	15	bare	Screw	Electronic	No	37.45
PS	18	plastic globe	B22	Core coil	No	30.55
CL	15	bare	B22	Electronic	Yes	32.55
MZ	15	bare	Screw	Electronic	No	37.45
TG	18	plastic globe	Screw	Electronic	No	27.81
MT	15	bare	Screw	Electronic	Yes	6.22

1 $ = 5.50 French Francs VAT = Value Added Tax (18.6%).

Results

Safety

Basic requirements include verifications of manufacturing dimensions--plus and minus limits--of source caps.

Measurements on source caps show that all lamps comply with the existing standard currently in application in Europe[2], except for type "MT". Moreover 4 items of this type burned out when measurements were initiated and had to be replaced. Finally, there were only 5 "MT" still operating after 400 hours. This model can definitely not be marketed in our country.

Electric Characteristics

The results are summarized in Table 2 hereafter [1]. Values indicated are average results for 10 samples of each type, except for type "MT" (see above), after 400 hours operating time. This duration has been chosen in accordance with the above mentioned standard for tubular fluorescent sources.

Remarks regarding Table 2 follow:

- Power consumption is below the rated wattage. This rather surprising observation is favorable to energy conservation; yet this can be explained by the fact that all lamps are marked "220V - 240V" and that nothing on the packing specifies which is the rated voltage to use in assessing the other characteristics (luminous flux, life duration) whereas we conducted all the measurements under 220 V (for example a 240 V supply would raise power consumption by about 10% but we do not know the effect on luminous flux).

- Power factors are very poor. This fact is of little account when the CFLs are installed in the housing sector. One or two CFLs per house will have very little effect on the grid, and customers are not billed for reactive power within the domestic sector. However it will have to be considered when rebate programs are introduced to the commercial sector.

- When referring to standard NFC712124, only 3 lamp types--PS, CL & TG--comply with maximum harmonic distortion rates[5] (respectively 5%, 15%, 7%, 4%, 3% for the 2nd, 3rd, 5th, 7th and 9th harmonics). It appears that compliance might be easier for higher wattage sources (PS and TG are rated 18 W and CL runs with a reusable ballast that can be fit with a different tube size, which means it can be fit with up to "20 W tubes").

Table 2. Electric Characteristics After 400 Hours Operation at Rated Voltage Supply

					Harmonic Distortion				
	Voltage (V)	Rated Wattage (W)	Measured Power (W)	Power Factor	2nd	3rd	5th	7th	9th
OS	220.30	15	13.72	0.492	0.47%	92.75%	81.59%	64.90%	51.73%
OG	220.13	15	12.96	0.496	0.00%	92.42%	79.34%	61.16%	48.75%
PE	220.02	15	13.97	0.465	0.07%	93.03%	81.65%	67.20%	57.58%
PS	220.31	18	17.83	0.418	0.43%	13.08%	0.83%	1.66%	0.77%
CL	220.34	15	12.85	0.447	0.35%	10.04%	1.35%	0.81%	0.58%
MZ	220.21	15	14.44	0.473	0.00%	93.12%	81.39%	65.87%	49.92%
TG	220.03	18	13.97	0.425	0.51%	14.27%	1.50%	1.26%	0.84%
MT	220.20	15	13.30	0.562	0.01%	82.07%	55.89%	34.19%	29.52%

Luminous Flux

How or When to Measure Flux? An integrating sphere is used to measure the total lumens delivered by the lamp. As can be seen on Figure 1, steadiness of discharge and luminous flux is only obtained after a 15 minute delay.

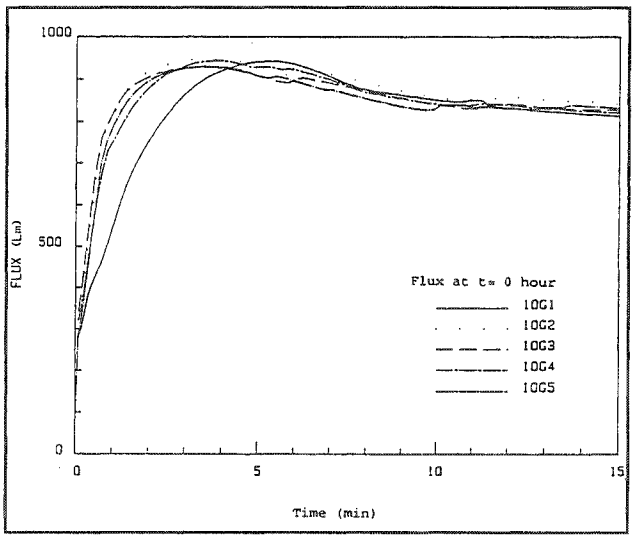

Figure 1. Change in Luminous Flux During 15 min. After Lighting at T = 0 Hour Running Time (220 V a.c.) for 5 Specimen of OG Lamp Type

From Figure 1 it can be seen that it takes only 2 to 5 minutes to reach maximum flux output. This is less than the widely advertised "about 5 minute minimum".

Magnitude of Luminous Flux. Knowing what the real flux will be is essential, both to verify manufacturer's claim and in order to equitably propose a replacement for an incandescent source. Moreover, we have decided to evaluate life duration by using the change of luminous flux as a parameter. When rated luminous flux is reduced by 50%, the lamp will be considered dead, even if it is still working.

In this test we decided to consider the "rated" luminous flux as the value obtained after 400 hours of cyclic operation, and 15 minutes after being turned on with 220V a.c. supply.

Lamp Life Duration

Except for model "MT" whose tube duration is indicated as 2000 hours (reusable ballast is supposed to last 40,000 hours), all other CFLs have a rated life-time of 8000 hours or more. The tests were aimed at verifying these claims and at checking whether or not there is an influence of voltage on life duration.

Lamps Working Under Rated Voltage Conditions. Because our definition of lamp failure was defined by a level of efficacy reduction, we have chosen to study the change of the luminous efficacy of the samples. Figure 2 presents the average luminous efficacy of each lamp type sample. It can be seen that:

- Efficacy values lay between 45 and 65 Lm/W which is in agreement with manufacturer's literature.
- Models OS and OG have almost the same results considering that the 150 Lm flux drop is due to the acrylic globe enveloping the tube.
- A similar statement can be made for "PE" and MZ" which is not surprising considering that both sources are based on similar technologies, developed by the same research staff.
- "PS" model is disadvantaged both by its "old" technology (core coil ballast) and by its plastic cylindrical envelope.
- "MT" model experienced not only a drastic drop in luminous flux (24% to 36% after 2000 hours compared to the value after 400 hours running time but we must keep in mind that tubes are sold for no more

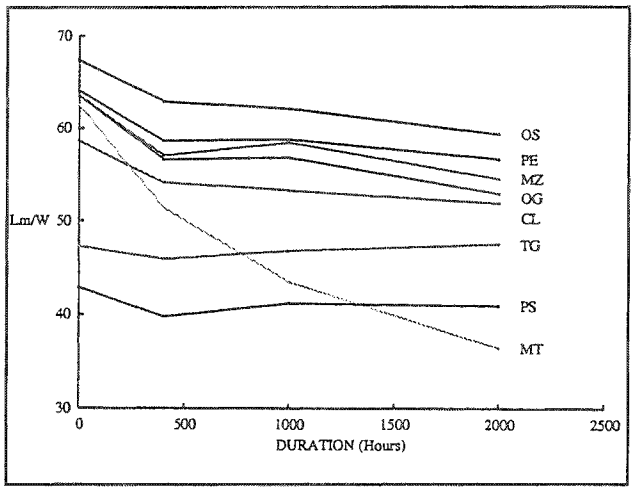

Figure 2. Comparison of Sample Average Luminous Efficacy of 8 Models of CFLs as a Function of Operating

than 2000 hours duration), but also had too many failures--only 3 specimens were still in operation after 2000 hours.

One of the objectives of this test was to determine a correlation between luminous flux emission and operating time to be able to predict or define the rated life time of CFLs. We have not succeeded in this attempt. Very raw linear regressions indicate a minimum lifetime of 6000 to 10,000 hours, which is too large an approximation to constitute satisfactory results but does not contradict manufacturer's claims (when referring to NFC 72-2101 for tubular fluorescent sources it is indicated that luminous flux must not be lower than 85% of initial luminous flux after 2000 hours operating time: thus we see that CFLs comply with this requirement).

Lamps Supplied with Varying Voltage. A varying voltage does not seem to have much effect on lamp operation. Overvoltage seems to accelerate lamp stabilization--"running-in" of the electrodes in most models, which is shown by the shorter operating period necessary to reach a stabilized discharge within the 15 starting minutes. However, for "MT" (none left operating out of 5 after 400 hours) and "PS" (1 left operating after 400 hours, none after 1000 hours), overvoltage seems to accelerate lamp failure !

All other sources supplied with 260 V were still burning with a 180 V supply and vice versa.

A 4 % decrease in luminous flux is observed for the sources supplied with continuously varrying voltage compared to sources supplied with 220V. In comparison,

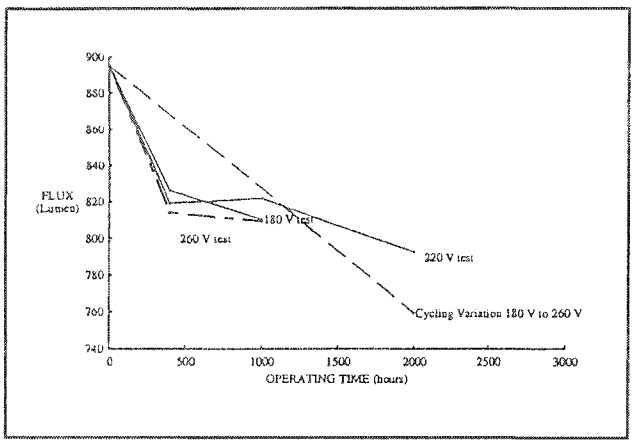

Figure 3. Influence of Voltage Supply on Lamp Duration Illustrated by Evolution of Sample Average Luminous Flux in Each Test Measured in Same Conditions (220 V - 15 min. delay)

under the same voltage supply a sample of ten incandescent bulbs scored an average life of 780 hours which is about 20% less than rated. Other authors [2] indicate that :

- When gradually decreasing the voltage from 220 V, the light went out completely when the voltage was respectively 51 V and 60 V for two models of the 11 W compact fluorescent source,

- When gradually increasing the voltage from 40 V, lamp lit, but with a very low light intensity, when the voltage was respectively 68 V and 71 V. A normal light intensity was obtained around 145-150 V.

- The maximum voltage before failure was also determined for the same models by gradually increasing the voltage from 220 V up to 300 V: none of the lamps failed, both tube and electronic parts were still in good condition at 300 V.

Most CFLs can survive varying voltage supply conditions much better than incandescent bulbs, which makes them more suitable to be installed in areas with variable voltage delivery.

Conclusions

Product Selection

After discussion with the electric utility, power factors and harmonic distortion were not considered a nuisance for operation, so the choice for the Guadeloupe project was initially limited to the most efficient products "OS" and "PE". A request for proposals has been issued to obtain discount prices and a joint effort with a manufacturer and his retailer's network. A definitive choice might be "PE" model as they have proposed, during marketing negotiations, to provide lamps at a discounted price of 70 FF, Value Added Tax (VAT) included (12.72 $). Yet if they appear not to be able to deliver the requested quantity in time, the "OS" model will be selected (price per unit will be about 90 FF/16.36 $).

Following preparation of this paper, 100,000 "OS" lamps were marketed in Guadeloupe, and all were purchased in two days! The consumer interest in this product appears great.

Standard Definition

Some progress was made in the definition of a standard measurement test, both for electric and luminous lamp characteristics. However we were unable to determine the

minimum test duration for assessing lamp life. More measurements are needed on a limited sampling--4 totally different lamp types--with flux and electric characteristics measured every 200 hours of operating time. The size of the sample for a satisfactory test is 10 specimens and could be reduced to 5 for exploratory tests. In the meantime, a regulation defining a minimum performance level is being studied by the European Community Commission, within the SAVE6 program, which could use some valuable information from the present survey.

Summary

A panel comparison test of 8 different CFL types has led to a selection of products based on efficiency characteristics. The test partially verified the manufacturer's claims about luminous efficacy. Non-declared characteristics, such as power factor or harmonics distortion were found to be poor. Data and knowledge were acquired to allow preparation of a measurement test standard for one of the most cost effective retrofitting solutions in the residential and commercial sectors.

Acknowledgements

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Endnotes

1. French Standard NFC 72-210--Electric lighting sources: tubular fluorescent lamps for general lighting service--defines all measuring conditions such as sample size, ageing of lamps, electric and luminous characteristics measurement method etc.
2. European standard CEI 432: Electric lighting sources: safety requirements for tungsten filament lamps for domestic and similar general lighting purposes.
3. Luminous flux is measured on all lamps supplied with 220 V including those under life duration test at 260 V and 180 V. All lamps are operated together under the same "4 hours running, 1/2 hour stop" sequence.
4. NF C 71-212: French certified standard on fittings for discharge lamps concerning tubular fluorescent lamp auxilliaries: ballasts for tubular fluorescent lamps.
5. Confirmed by a personal communication with M. MATRAT from PHILIPS and the French Lighting Trade Union.
6. Decision du Conseil des Communautés Européennes (Decision of the European Community Coucil) - 29 oct 1991

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