Sustainable Practice in Lighting: Remanufacturing of Compact Fluorescent Lamps

Práctica Sustentable en Iluminación: Remanufactura de Lámparas de Bajo Consumo

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ABSTRACT

Today the established paradigm in energy efficiency seems to have been symbolized by the so-called energy-saving lamps. However it is not possible to find scientific or technical publications which strongly support their use. On the contrary, it is not simple to find publications that refer to the problems that could be generated by their use.

These devices consist of two fundamental technological cores: the lamp and electronic ballast. Both have a high degree of incidence in the origin of discarding, when the user believes that the lamp has stopped working. However, a failure in the ballast may cause the discarding of an operating lamp.

In this paper, the results of faults survey that entail premature discard are shown and some practices for the remanufacturing of defective ballasts are proposed.

As a result it is concluded that up to 40% of discarded lamps can be repaired prolonging their useful life over a period of between six months and two years. In a country like Argentina, this would imply a reduction of up to 600kg of mercury per year in the dump to the environment.

Keywords: Energy-saving lamps, remanufacturing, sustainable practices, protocol.

RESUMEN

En la actualidad el paradigma establecido en eficiencia energética parece haber sido simbolizado con las llamadas lámparas de bajo consumo. Sin embargo no es posible encontrar publicaciones científicas o técnicas que avalen fuertemente su utilización. Por el contrario tampoco es simple encontrar publicaciones que hagan referencia sobre los problemas que podrían generarse por su uso.

Estos dispositivos están compuestos por dos núcleos tecnológicos fundamentales: la lámpara y el balasto electrónico. Ambos presentan un alto grado de incidencia en el origen del descarte, cuando el usuario considera que la lámpara ha dejado de funcionar. Sin embargo, un fallo en el balasto puede originar el descarte de una lámpara operativa.

En este trabajo se muestran los resultados obtenidos del relevamiento de las fallas que dan origen al descarte prematuro y se proponen prácticas para la remanufactura de los balastos defectuosos.

Como resultado se concluye que hasta un 40% de las lámparas descartadas pueden ser reparadas prologando su vida útil en un período de entre 6 meses y dos años. En un país como Argentina, esto implicaría una reducción en el volcado al medio ambiente de hasta 600kg de mercurio al año.

Palabras clave: Lámparas de bajo consumo, remanufactura, práctica sustentable, protocolo.

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Introduction

Since the last two decades, globally speaking, there have been discussions about energy efficiency as a sustainable practice and fundamental pillar of ecology. Consumers are looking to maximize the use of energy consumed, whether to reduce costs or put into sustainable practices that will help improve the environment.

Since 2007, Argentina has a National Program for the Rational and Efficient Use of Energy (PRONUREE) [1] in which the rational and efficient use of energy has been declared as national priority interest. Among the actions implemented, a replacement

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of incandescent lamps with compact fluorescent lamps, or CFLs was organized. Under the program, the government replaced more than 29.5 million incandescent bulbs with CFLs, in more than 8.2 million Argentine households [2].

Figure 1. CFL functional parts. On the left, the electronic ballast and on the right the compact fluorescent lamp. (Lux America 2010).

A CFL can be divided into two functional parts: the compact fluorescent lamp and the electronic ballast or auxiliary equipment (Figure 1). The compact fluorescent lamp is a miniature version of the traditional fluorescent tubes. In its composition, there is mercury in an estimated 5 to 2.5 mg [3] concentration. The auxiliary equipment is an electronic circuit, mostly based on an uncontrolled rectifier and an autoresonant inverter[4].

Since the LFC is a unique lamp-ballast, the failure of one of the two parts causes that the user must replace it with a new one. From this we can say that the expected discard of a CFL is when the fluorescent tube is dead, while the ballast is still functional, and a premature discard is when the equipment is discarded but the fluorescent tube is still functional. [4].

From previous investigations [5], it was found that between 57% and 69% of the CFLs are discarded prematurely. Considering only the lamps delivered by PRONUREE, there have been discarded between 16.8 and 20.3 million of CFLs. This represents between 84 and 102 kg of mercury dumped into the environment unnecessarily.

Methodology

Electronic ballast topology

The electronic ballast can be separated into two distinct parts: a autoresonant series inverter and an uncontrolled rectifier.

Figure 2 shows the autoresonant inverter circuit that is used in the great majority of CFLs.

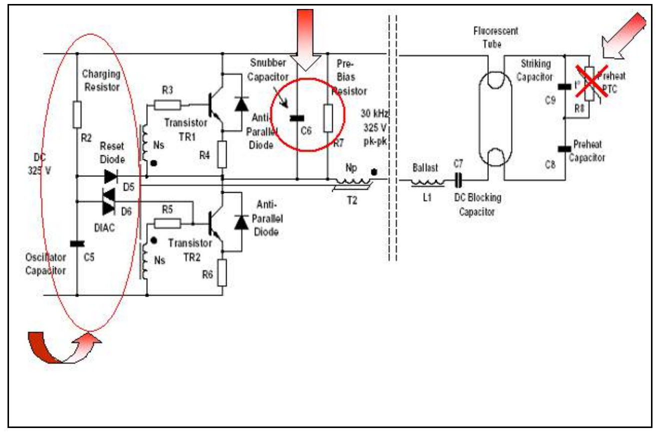

Figure 2. Complete topology of an electronic ballast for fluorescent lamps (Lux América 2010).

It can be seen that the compact fluorescent lamp is part of the series resonant circuit, connected by their filaments. In many cases, in order to cut costs, companies sacrifice the installation of some components (indicated by an arrow). Even though these are not essential in the LFC, they are necessary to improve its functionality and stability.

Figure 3 shows the uncontrolled rectifier which is responsible for passing the current to the previous circuit.

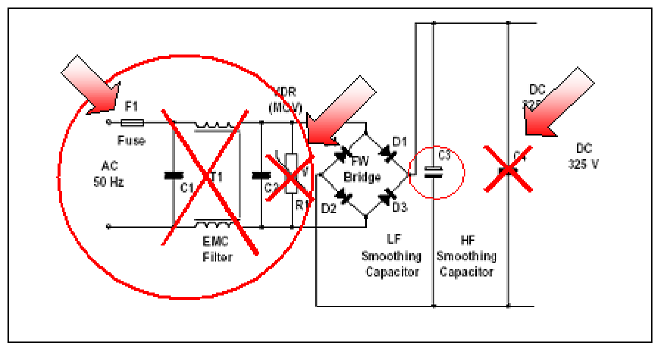

Figure 3. Entrance circuit for an electronic ballast without correction in the power factor (Lux America 2010).

Also, as in the investor, most manufacturers do not install the components indicated. But in this case, not installing one of these components does not affect the quality and stability of the lamp itself, but it generates electromagnetic pollution which affects other devices installed in the same power grid [6].

Typical faults detected.

From previous work [7], a variety of faults that generate premature discard of the lamps were detected. These are detailed in Table I.

Table I. Faults that generate premature discard and the percentage of incidence on discarded lamps.

Cut filament	**20%**
Transistor	**14%**
Electrolytic capacitor	**13%**
High temperature	**8%**
Humidity	**5%**

Welding	**4%**
Insects	**1%**
Faultless	**5%**

It should be noted that the last item (faultless) were lamps discarded by users that were still operational. This may be due to poor contact in the E27.

Looking at these data, 51% of faults correspond to cut filament, transistor, electrolytic capacitor and welding. Temperature failures often lead to failures in transistors, welding problems, among others, but if the lamp is repaired the fault will continue to exist.

Respect to relieved faults they can be projected to different countries given similar conditions on the quality of electrical service. In countries where electrical distribution systems are continuously audited it is expected a lower number of global failures. However, lamps purchased from other countries show as electronic ballast topology with the same construction deficiencies in regard to the safety elements indicated in Figure 3.

Security conditions and instruments for evaluating CFLs.

To evaluate and test energy-saving lamps, we must apply the voltage across its terminals respective supply (in Argentina this corresponds to 220 VAC). In order to do this, the use of isolation transformers is not advisable because if the operator accidentally touched two power cables, there would be no rescue device to help him. Instead, using a test box is recommended. The test box consists of a differential switch, a bipolar switch, E27 socket and a light indicator that shows when there is tension in the E27. In Figure 4, the diagram is described in detail.

In order to develop a correct detection and evaluation of CFLs, the following elements are recommended:

- Voltmeters and ampere meters for AC and DC.
- Meter diodes and transistors.
- Capacity meter.
- Ohmmeter.
- various test resistance: small values are used (from 1 to 100 ohms).
- Several compact fluorescent tubes of various powers
- Ballasts Several test of various powers.
- Transistors and electrolytic capacitors used in CFLs.

All measuring instruments can be replaced by a single tester.

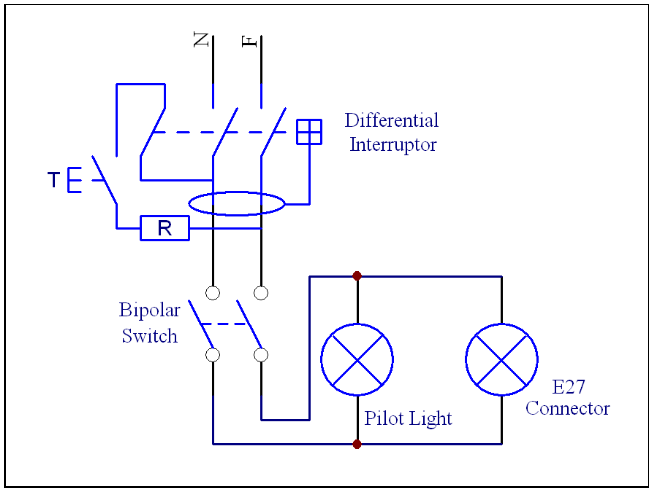

Figure 4. Electric Schema of evaluation and test for E27 equipment.

Protocol for fault detection and CFL evaluation oriented at premature discard detection and repair ballast.

The following evaluation protocol seeks to separate the problems of the lamp and the ballast.

Lamps with broken glass are separated from the ones with non-broken class. An evaluation of the proper functioning of the ballast only will be made to the former.

Lamps with non-broken glasses are connected to the test box and energized. If they turn on, they will have a simple cycling test done (they are turned on for15 minutes which is the time it takes for the light to enter steady state). If, after this, the lamp is stable (i.e. it does not turn off and turn on or it generates a blink), then it is left for final evaluation. If the lamp has an abnormality in its illumination, it is considered that the tube is dead. In this case, the ballast is recovered for later evaluation.

If the lamp does not turn on, then it is disassembled and the filaments are measured. If one of them is cut, then a resistor is connected in parallel with it to close the circuit autoresonant and try again. If this turn on, then it will have the cycling test done. If, after this, the lamp is stable, then it is left for final evaluation. If the lamp has an abnormality, then the filament was cut due to exhaustion. In this case, the lamp is discarded and the ballast is stored for later evaluation.

If the filaments are well, then the lamp is disassembled and evaluated with test ballast. If the lamp turns on, it will have the cycling test done. If, after this, the lamp is stable, measurements of voltage and current are performed. If they are within the acceptable parameters for the specified power, working ballast is installed and it is left for final evaluation. The original ballast is passed to the instance of evaluation.

Before starting the evaluation of ballast, it must be observed that there is no cold welding. If there, another evaluation is needed to see if the fault can be solved. If some fused track or input fuse (if the lamp has it) is observed to be open, then it must be verified that the transistors and electrolytic capacitor are not causing a short circuit.

To evaluate the correct functioning, a test lamp with the corresponding power is connected and the cycling test is performed. If after this period there are no abnormalities in the lamp and the temperature is normal, then the ballast is labeled as useful and stored for reuse.

If the lamp does not turn on, then the correct operation of the transistors has to be measured. If these are in short circuit and open, then they must be replaced and retested as a whole. If it doesn't turn on, the ballast is discarded.

If the transistors are well, then the value of the electrolytic capacitor has to be verified. If devalued, it must be replaced and the cycling test remade. If this is accomplished without abnormalities, then the ballast can be reused. Otherwise, the ballast is discarded.

Protocol for final evaluation of repaired lamps.

To consider a lamp to be good, a pilot cycling, and electrical and lighting measurements should be made.

The cycling, suggested a pilot, is turning on the lamp, letting it run for 15 minutes, turning it off and waiting for it to cool. This process should be repeated at least 5 times. Then, if there are no anomalies in cycling, power consumption measurements of the LFC and light intensity are performed. If these values are within the acceptable, the lamp can be considered to be good. Otherwise, it must return to the evaluation instance.

Discussion

Although there is a possibility of remanufacturing CFLs, it still remains difficult to carry out because each trade mark has different models of cabinets that are incompatible with each other. In the particular case of PRONUREE program, they have been used three different suppliers have been used but with the same lamp power. So this decision could facilitate the remanufacturing.

In addition, when the lamp is disassembled their cabinets are damaged because most of them are stuck and they have to be broken to separate the ballast from the lamp. A proposal for improvement would be to separate the fluorescent lamp from the electronic ballast, through a connector. This would help the final user to reuse the electronic ballast when the tube is dead.

Conclusions

CFLs are efficient lighting equipment, regarding the incandescent lamps, but these have failures because, in their manufacture, obsolete settings are used [8].

Current lighting technology is orienting to the use of LEDs. With this increased reliability and stability of the equipment is obtained, but they are still expensive and with similar and even lower levels of efficiency than CFLs [5].

Despite new technologies, CFLs are still used massively and are obligatory in some countries. Thus, the proposal of remanufacturing is presented as a viable alternative for reducing dump pollutants into the atmosphere, such as mercury and lead. Furthermore, remanufacturing involves a reduction in costs and an extension of the useful life of these devices, resulting in a more viable economic equation for those countries that are importers.

All the remanufacturing process presented here, from the evaluation stage of the failure to reinsericón can be applied in different countries in which the economic equation and the environmental impact permit. Largely, these two parameters depend on the number of lamps used annually and specific standar of processing and final disposal of dangerous waste.

References

[1] Secretaría de Energía, PROGRAMA NACIONAL DE USO RACIONAL Y EFICIENTE DE LA ENERGIA, Decreto 140/2007. Ministerio de Planificación, Presidencia de la Nación, 21 de diciembre del 2007, http://infoleg.mecon.gov.ar/infolegInternet/anexos/135000-139999/136078/norma.htm

[2] El Gobierno ya entregó 29,5 millones de lámparas bajo consumo. Télam, sección Economía, Energía, 3 de Marzo de 2014, http://www.jornadaonline.com/Econom%C3%ADa/110051-El-Gobierno-ya-entreg%C3%B3-295-millones-de-l%C3%A1mparas-bajo-consumo

[3] Preocupación por el mercurio de las bombillas de bajo consumo. Terra, Ecología Práctica , 20 de Enero del 2012, http://www.terra.org/categorias/articulos/preocupacion-por-el-mercurio-de-las-bombillas-de-bajo-consumo

[4] Vincitorio, F., Brutti, C., González, A., Ronchi, F., Romano, C., ESTUDIO DE FALLAS EN LÁMPARAS DE BAJO CONSUMO, DETERMINACIÓN DE LA INCIDENCIA DEL DESCARTE PREMATURO. LuxAmérica 2008 – Actas de congreso. Nov., 2008.

[5] Vincitorio, F., Frund, J. L., Balducci, D. N., Ríspoli, L. D., Fabre, J. CICLADO DE LFC COMO MÉTODO DE DETERMINACIÓN DE LA CONFIABILIDAD Y EL DESCARTE PREMATURO. XI Congreso Iberoamericano de Iluminación, Lux América 2012, Memorias, Oct. 2012, pp. 256-261.

[6] Frund, J. L., Vincitorio, F., Balducci, D. M. N., Freyre C. E., Chort, A., Favre, J. High Frequencies in AC Distribution Lines: a New Technical Challenge. VII Simposio Internacional sobre la Calidad de la Energía Eléctrica - SICEL 2013, Memorias, Nov. 2013, pp. 1-4.

[7] Vincitorio, F., Brutti, C., Frund, J. L., LA ELECTRÓNICA DE LAS LÁMPARAS DE BAJO CONSUMO VENTAJAS, DESVENTAJAS Y PROBLEMAS. X Congreso Iberoamericano de Iluminación, Lux América 2010, Memorias, Oct. 2010, pp. 365-372.

[8] Grunwaldt G.- “Electronic Ballast” US Patent 3084283. Apr. 1963.