Influence of Cold Starting on the Life of T5 Fluorescent Tubes and CFLs

Nikolaos G. Chondrakis, and Frangiskos V. Topalis, Member IEEE
National Technical University of Athens, School of Electrical and Computer Engineering
9, Iroon Politechniou St., Zografou, 15780 Athens, Greece
Tel: +30-2107723627, Fax: +30-2107723628, chonniko@ central.ntua.gr, topalis@ ieee.org

Abstract—**The paper presents an experimental investigation of the parameters that influence the life of T5 and compact fluorescent lamps (CFLs) operating with instant start ballasts. Measurements were carried out during the starting period of the systems as well as during operation. Results reveal that cold ignition has a strong impact on the life of the systems. Lamp life was found to be less than 5,000 operating cycles. The same lamps operating with ballasts providing warm start achieved a life of more than 70,000 starts. Five groups in different operating cycles were tested. Starting time, starting voltage and inrush current were measured during the starting period and their influence on lamp life was examined. The paper also investigates the hypothesis that in every ignition a constant quantity of emissive material is lost and another quantity is also lost during every hour of operation. In general, the results establish that predictions for the lamp life of these systems cannot be drawn, because of the absence of deterministic effects that can be attributed to fluorescent lamps.**

Index Terms — **Fluorescent lamps, instant start ballasts, lamp life, lighting, operating cycles.**

I. Introduction

Fluorescent lamps are driven either by magnetic or electronic ballasts. For the same light production the former waste more energy than the latter. This is the main reason that magnetic ballasts tend to be superseded by electronic ballasts. In fact according to the European Directive 2000/55/EC, low efficiency electromagnetic ballasts have been phased out. A new generation of ultra-low-loss magnetic ballasts for T5 are expected to go into trade this year. Electronic ballasts extend lamp life, exhibit higher lumen maintenance and provide better quality of light in general [1]. Their disadvantage is that they are a lot more expensive than electromagnetic ballasts.

Electronic ballasts are divided into two categories: instant start and preheating start. From the moment the fluorescent lamp is switched on, instant start ballast supplies the lamp with a high voltage and the discharge is accomplished within a few milliseconds. Afterwards, voltage supply decreases to the proper value for the discharge to be maintained. The other types of ballasts follow various scenarios to preheat the lamp electrodes before the arc is obtained in the tube. The preheat period varies from half a second to almost two seconds depending on the scenario of the operation of the ballast [2].

The electrodes of the fluorescent lamps are made of a tungsten filament coated with a mixture of Ba, Ca and Sr oxides. These materials reduce the work that is needed for the emission of the electrons from electrodes during the ignition and operation. This facilitates the discharge and lowers the electrode temperature during operation, resulting in longer lamp life. Electrode temperature during ignition and steady state should be between 700°C and 1000°C. Low temperature causes sputtering that weakens the emissive oxides of the electrodes [3]-[5]. Correspondingly, high temperatures result in evaporation of the materials which cover the electrodes, decreasing the lamp life.

Instant start ballasts ignite the lamp very quickly, in less than 100 ms, in order to avoid excessive sputtering during ignition when the electrodes are cold, (cold ignition). Preheat start ballasts heat the electrodes to a temperature as close to 700°C as possible or a little above before glow to arc transition. At this temperature thermionic electrons are emitted from the hot electrodes that help the discharge and the lamp ignition. During preheating time glow current should be less than 25 mA to minimize sputtering. When the electrode reaches the desired temperature, a medium voltage is applied to the lamp and the discharge is accomplished. This starting scenario diminishes the impact of sputtering on the electrodes.

II. Experimental Setup

The best way to predict and to determine the characteristics that affect the lamp life is an experiment with many real samples of lighting systems [6]. In this study a large number of samples were examined in order to find a method of predicting lamp life. Such a multi-sample experimental investigation gives more reliable results than a theoretical analysis and/or single-sample experiments.

Though there are several studies on T8 and T12 fluorescent lamps, very little information has been published on the starting of these systems, especially of the T5 tubes. According to manufacturers, T8 lamp life is 25% shorter when they operate with instant start ballasts (ISB), than with ballasts with preheat during starting. This assertion was also examined during the experiments. For this purpose, two different types of lamps were tested, 14W T5 tubes and 18W CFLs with external ballast. 88 lamp ballast systems were tested in total: 40 with preheat ballasts and 48 with instant start ballasts. The systems were grouped and operated in 5 different operating cycles. 20 lamp tubes and 20 CFLs operated with preheated starting whereas the other 20 tubes and 28 CFLs operated with instant start ballasts with a well known brand name. The gear was simple half bridge, running with self-resonant frequency. Table I shows the combinations of systems and their operating cycle. The fluorescent tubes were fitted horizontally on an iron sheet 65 cm in length and 10 cm width with a starting aid distance of 8mm. The CFLs were mounted horizontally on a wooden support.

TABLE I
TYPES OF TESTED SYSTEMS AND BURNING TIME.

System	165' on 15' off	45' on 15' off	5' on 15' off	1' on 15' off	20" on 15' off
ISB – T5	4	4	4	4	4
ISB-CFL	4	8	4	8	4
Preheat – T5	4	4	4	4	4
Preheat-CFL	4	4	4	4	4

Three short and two long operation cycles were used. The first long cycle is the standard European operating cycle with 165 minutes power-on and 15 minutes power-off. The off time of the systems was 15 minutes for every cycle, slow or rapid, so that the lamps had time to acquire the room temperature, which was kept at 25±3°C. Other experimenters with systems in short cycles, reported in the literature, keep the off time shorter than 15 minutes.

Each group of systems in the same operating cycle was mounted on a separate wooden frame, 175 cm high. A programmable controller switched on and off the systems at the corresponding time. All the systems were seasoned for a hundred hours under the standard operating cycle before the start of the tests.

Various lamp and ballast characteristics were measured at fixed cycle or time intervals. For the lamps operating with ISB, these measurements were carried out at approximately every 500 operating cycles or fewer. Note that for eight CFLs in the groups B and D only their lifetime was measured. The following figures and tables present the results in average values of these consecutive measurements. The measurements were conducted with an oscilloscope Tektronix DPO 4034, (4 channels, 350 MHz, 2.5 GS/s, 10 Megapoint record length), for every system separately. From the acquired waveforms inrush current, (peak to peak, p-p), starting voltage, (p-p) and starting time were estimated. The lamp current was recorded with the Tektronix TCP202 and P6021 current probes and the lamp voltage with a Tektronix P5200 high voltage differential probe. The p-p and the rms current were also recorded in steady state operation. The current crest factor was estimated. In order to have comparable values of the characteristics which were measured, the scale of the oscilloscope was the same throughout the measurements.

All the systems were examined daily for any probable failure. Lamps driven by ISB failed when one of the electrodes was cut. This was verified by measuring electrodes' electric resistance, which was found to be infinite. Heavy blackening was observed at the end of the cut electrode, in contrast to the other end, which was blackened lightly.

The characteristics which were measured during ignition separately for every system were: inrush current (p-p), starting voltage (p-p) and starting time. After steady state operation for one hour, the frequency, lamp voltage and lamp current, (both p-p and rms), were measured. Prior to any measurement and while the lamp was off under ambient temperature for at least one hour, the electrode resistance was measured and accordingly the electrode resistance at 25°C was estimated in order for it to be used for further elaboration. One hour of cooling is accepted as quite enough time for the purpose of this experiment, though it is known that the lamp electrodes need several hours to acquire ambient temperature [7].

III. RESULTS - DISCUSSION

One objective of this experiment was to investigate the parameters affecting the life of cold ignition lamps. All the lamps operating with instant start ballasts failed. The results are shown in Tables II and III. Another investigation in progress deals with the systems operating with ballasts providing heat to the electrodes prior to the ignition process. Up until now just a few preheated lamps have failed. Most of these systems with preheating ballasts are still operating after more than 70.000starts. Table II shows the mean life of the lamps, that is the average life in cycles or in hours of the lamps of a system. Table III shows the corresponding median life that is the number of cycles or hours at which 50% of the lamps of each system failed.

TABLE II
MEAN LIFE OF THE SYSTEMS

System	Operating cycle		T5		CFL	
	On	Off	Cycles	Hours	Cycles	Hours
A	165'	15'	2712	7441	2497	6840
B	45'	15'	4949	3746	2695	2029
C	5'	15'	3855	323	1995	167
D	1'	15'	4717	79	1808	30
E	20"	15'	3594	20	1980	11

TABLE III
MEADIAN LIFE OF THE SYSTEMS

System	Operating cycle		T5		CFL	
	On	Off	Cycles	Hours	Cycles	Hours
A	165'	15'	2557	7008	2782	7625
B	45'	15'	4928	3734	2596	1949
C	5'	15'	3950	330	1990	166
D	1'	15'	4785	81	1898	32
E	20"	15'	3358	19	1800	10

There is a remarkable similarity in the values of the two tables. This is an indication that the systems operated in the right way without unexpected failures or malfunctioning of the steady state operation. Though the numbers of cycles and hours are comparatively low the representatives of the product company assured that ballasts and lamps are fit to operate together. The manufacturers' rated life was 30,000 hours for T5 systems and up to 10,000 hours for CFLs. These values are for operation with preheating ballast under the standard operating cycle. Apparently the lamps did not meet the manufacturer's rated life.

Fig. 1 and Fig. 2 present the variation of lifetime of the T5 lamps, in cycles and in hours respectively. As previously stated, four lamps of T5 type operated at every cycle. Firstly, it is concluded that short cycles, (C, D, and E), do not give reliable results when lamp life is measured in cycles. The reason is that after ignition the lamp electrodes need about ten minutes to become stabilized and for their coating to be arranged normally on the tungsten filament [8]. These operating cycles were used in this experiment because a correlation was expected to be found between short cycles and mean lamp life when both instant start and preheating ballasts were used.

The curves for A and B groups exhibit a rational behaviour. Lamps in group A endured a smaller number of cycles but more hours in comparison with lamps in group B. It was expected in this experiment that the more rapid the cycle is, the shorter the time life of the lamp, because it is considered that each start of the lamp consumes an amount of the electrode coating and another amount is lost in every operating hour. This is the reason for mentioning earlier that groups C, D and E gave unreliable results.

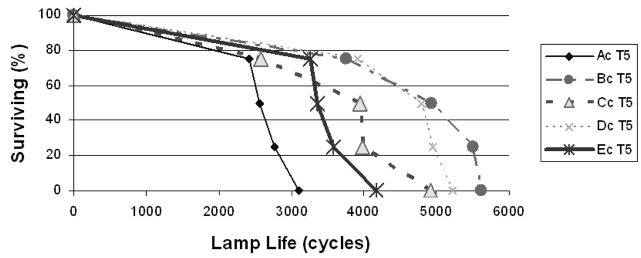


Fig. 1. T5 Lamp life vs. cycles of operation.

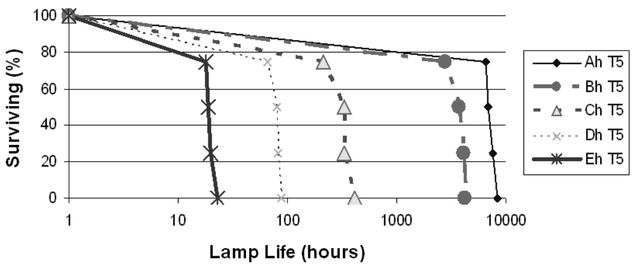


Fig. 2. T5 Lamp life vs. hours of operation, (logarithmic scale).

Lamp life curves in hours, as Fig. 2 presents, are quite normal. The less the burning time, the shorter the life is, regardless of the life in cycles.

Furthermore, Figs. 3 and 4 present the results for lamp life of every CFL lamp separately. Curves for cycles A, C and E resulted from measurements in 4 systems and the curves for operating cycles B and D resulted from 8 systems.

It is obvious that the CFLs' life is shorter than that of T5 lamps. However, a conclusion regarding the life in cycles of groups A and B cannot be derived as their curves in Fig. 3 overlap. It seems that the lamps had a longer life in cycles when they operated in slow cycles than when they operated in short cycles without reference to the exact switching on time. The two lines of A and B groups are not as clearly distinguishable as in T5 lamps. The situation is more complex in C, D and E groups. The reason for these results is assumed to be the short CFL life. Other researchers have deduced that rapid cycles are not suitable for the evaluation of lamp life [9], [10].

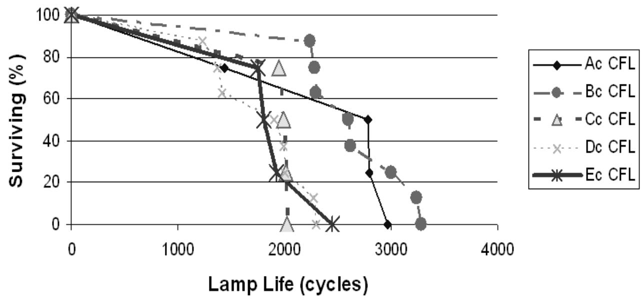


Fig. 3. CFL life vs. cycles of operation.

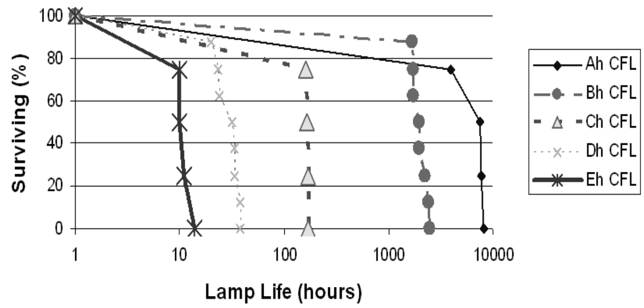


Fig. 4. CFL life vs. hours of operation, (logarithmic scale).

It is clear that the first lamp in group A failed much earlier than the others, (after 1439 cycles out of the 2497 cycles which were the average life of the group). This didn't happen accidentally. This system experienced poor values in its characteristics. The starting time was 82 ms, the inrush current 19.7 A p-p and the starting voltage 1538 V p-p while the averages of the other systems of the group were 32 ms, 16 A p-p and 1480 V p-p respectively.

An objective of this experiment was to investigate which parameters affect lamp life. According to other investigations, the most affecting parameters are the starting time and the starting voltage [8], [11]-[13]. Tables IV and V present the lamp life for each lamp separately in hours and cycles. In addition, the average values of the successive measurements of some characteristics are shown. These are: inrush current, starting voltage, start time, operating frequency, operating lamp voltage, operating lamp current and the estimated current crest factor. From the results no unambiguous conclusion can be drawn concerning the influence of starting time, starting voltage or any other characteristic on the lamp life.

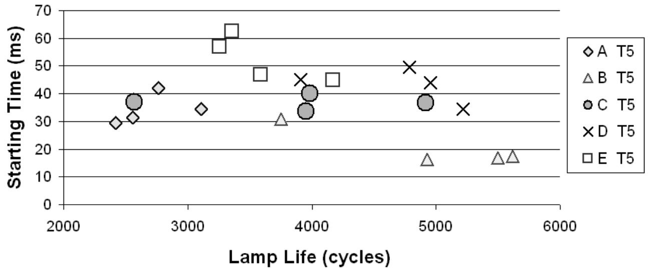


Fig. 5. T5 Lamp life vs. starting time.

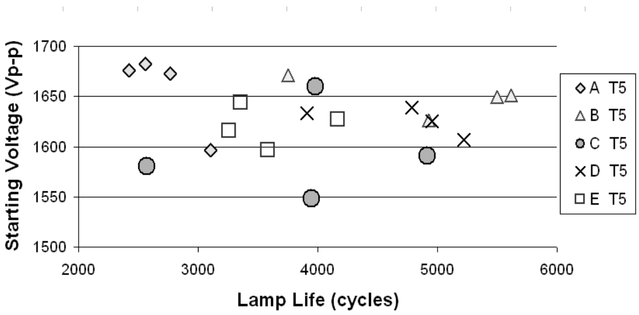


Fig. 6. T5 Lamp life vs. starting voltage.

As an example, the graphs in Figs. 5 and 6 present the lamp life in cycles versus starting time and starting voltage respectively for T5 lamps. It is clear that no connection exists between the variables.

The general opinion is that the longer the starting time, the shorter the lamp life is. During the starting period high glow current and sputtering are caused resulting in lower lamp life. ANSI established 100 ms as the maximum limit for instant start ballasts. Groups D and E for T5 lamp systems and group B for CFLs show a tendency to follow the former law but it is

TABLE IV

LAMP-BALLAST CHARACTERISTICS OF T5 SYSTEMS

System (T5)	Sample	Lamp life (hours)	Lamp life (cycles)	Starting period			Steady state operation		
				Inrush current (A p-p)	Starting voltage (V p-p)	Starting time (ms)	Frequency (kHz)	Lamp voltage (V rms)	Lamp current (mA rms)
A	1	8513	3105	10.2	1596	35	30.79	87.7	141
	2	7008	2557	9.0	1683	31	31.66	88.9	137
	3	7581	2766	10.4	1673	42	30.37	89.6	139
	4	6662	2421	7.5	1676	30	30.83	87.9	138
B	1	4167	5501	9.9	1649	17	30.75	89.2	144
	2	3734	4928	8.1	1626	16	30.55	89.1	141
	3	4254	5617	9.8	1651	17	30.97	88.7	138
	4	2829	3750	7.9	1671	31	30.97	89.4	141
C	1	333	3982	11.4	1660	40	30.78	87.4	144
	2	215	2572	9.0	1580	37	29.51	87.4	150
	3	412	4916	12.4	1591	37	30.75	87.9	141
	4	330	3950	10.3	1549	34	29.27	86.6	148
D	1	83	4952	13.7	1626	44	31.14	88.3	142
	2	81	4785	12.6	1639	50	30.78	88.7	143
	3	66	3910	13.0	1633	45	30.30	87.8	143
	4	88	5219	11.3	1607	34	30.10	87.7	143
E	1	19	3358	10.2	1644	62	29.24	85.9	140
	2	23	4171	14.4	1627	45	30.43	87.5	145
	3	20	3587	12.9	1597	47	30.31	86.9	147
	4	18	3258	13.1	1616	57	30.51	88.7	144

TABLE V

LAMP-BALLAST CHARACTERISTICS OF CFL SYSTEMS

System (CFL)	Sample	Lamp life (Hours)	Lamp life (Cycles)	Starting period			Steady state operation		
				Inrush current (A p-p)	Starting voltage (V p-p)	Starting time (ms)	Frequency (kHz)	Lamp voltage (V rms)	Lamp current (mA rms)
A	a	7625	2782	16.1	1508	34	28.27	81.4	197
	b	3927	1439	19.7	1538	82	28.25	82.0	194
	c	7668	2797	16.9	1450	29	28.13	80.9	189
	d	8141	2968	15.0	1475	34	28.01	81.0	192
B	a	1975	2617	22.1	1504	48	28.02	80.9	193
	b	1691	2241	21.1	1515	47	27.94	80.1	194
	c	1727	2288	19.3	1510	95	27.99	79.3	189
	d	3280	2475	21.0	1553	63	28.30	80.3	190
C	a	163	1950	22.3	1567	57	27.81	73.3	178
	b	169	2026	19.5	1513	20	27.80	72.0	180
	c	166	1990	19.3	1560	37	27.49	71.0	181
	d	168	2014	19.7	1540	53	27.50	71.3	182
D	a	32	1898	24.6	1540	70	27.75	72.0	187
	b	23	1367	23.2	1440	30	27.74	72.8	183
	c	33	1988	19.3	1550	35	28.35	80.0	183
	d	20	1229	23.0	1455	30	27.80	70.5	185
E	a	11	1924	18.3	1533	37	27.72	72.7	185
	b	14	2447	25.0	1545	45	27.64	72.6	184
	c	10	1800	19.3	1553	100	27.70	73.0	188
	d	10	1750	22.3	1593	53	27.70	75.0	182

obvious that confirmation of the law cannot be accepted as a matter of fact. An explanation for these conclusions is that the starting time is too short and the lamp life does not depend on this.

Other researchers [12] found a correlation between the starting lamp voltage and the lamp life. In this experiment there is no indication of any connection between the two variables. Perhaps this is due to the small differences among the measured values of starting voltage. From system to system of the same group the difference in the starting voltage was not more than 100 V. Such insignificant differences are unlikely to cause a change in lamp life. The differences among the starting voltage of the examined systems were of the order of 1000 V [12].

The authors of this paper believe that for this kind of measurement, lamp life should be considered in cycles, which are a better means of representation than hours. The reason is that instant start ballasts are best suited to lamps operating for a long uninterrupted time rather than intermittent operation. Measurements of lamp life in hours are not suitable in short cycle operation. Cold ignition ruins the electrodes faster due to sputtering connected with their erosion after one hour of continuous operation [12], [14]. Inrush current, current crest factor and operating frequency were examined also for any possible correlation with lamp life, but no clear connection was found.

The authors of [12] assume that there is a constant rate of loss of the electrodes' emissive material during each start as well as during every operating hour. They suppose that 'α' percent of the total coating is lost during each start and 'β' is the hourly percentage loss of the coating. According to these assumptions and admitting that a lamp fails when all its emissive material is lost, the following equation is applied:

$$1 = N_c \cdot \alpha + N_h \cdot \beta \tag{1}$$

where N_c is the number of starts and N_h is the number of operating hours. Two different operating cycles of the same type of lighting system are taking into account. After the end of lamp life the numbers of starts N_c for either system are known and also lamp life in hours N_h. Next, from expression (1) the unknowns α and β are calculated.

Considering the measurements presented in this paper, it was not always possible to estimate the values of the parameters α and β. Taking into account Table III, the parameters α and β can be calculated for several pairs of groups. When groups A and C of T5 lamps are considered, they gave a loss of the emissive material of $4.34 \cdot 10^{-5}$ percent per start and $2.50 \cdot 10^{-5}$ percent per hour. Hence, if the assumption of constant loss per start and operating hour is valid, the loss per start is almost twice the hourly loss. This assumption does not hold true for all the combinations of the systems. Consequently, the law of constant loss is inconsistent and vulnerable to rapid operating cycles. In the previous paper [12] it was also found that there is no consistent connection between the two ways the emissive material is lost, for all the systems.

The phenomenon of cold start in fluorescent lamps is too complicated to be correlated with simple laws, especially in rapid operating cycles. In [8] it is claimed that systems need to be switched on at least ten minutes before stabilization of their emission activity. This explains the irregularities in the current results concerning the short cycles. In addition, emitter depletion is not the only reason for a lamp failing since it is usual for a coil to brake before its emitter is entirely lost [14]. Several lamps were cut at their ends after their failure in the experiment here presented and observation of the filaments revealed that many of them were broken before the entire coating had depleted. Some of the unbroken filaments were well coated but most of them had just a little coating.

The determination of lamp life in connection with a particular parameter is important for the improvement of lamp operation and the extension of its life. For that purpose measurements of specific parameters were carried out during the course of time for the starting of the systems as well as the steady state operation, as was mentioned earlier. All these parameters were measured for each lamp-ballast system separately. The measurements were conducted three to ten times for each system until it failed. The aim was to investigate any change in them in the course of time so that any systematic and continual change that was detected would help to predict the time of the lamp failure. Inrush current, starting voltage and start time did not indicate that the lamp failure was imminent.

Particular care was given to the electrode resistance, which was found to be almost stable during the lamp life. Nearly all the lamps presented a small resistance increase, up to 2.3%, at the last measurement before the lamp failure. Table VI shows the resistance for each group of lamps. The average value is the mean resistance according to the measurements at 25°C. The other value (last R1 or R2) is the last measurement before lamp failure. R1 is the resistance at the lamp stamp side and R2 is the resistance at the other side of the lamp.

TABLE VI

AVERAGE RESISTANCE IN COMPARISON WITH LAST ONE MEASUREMENT

Group	Average R1	Last R1	Average R2	Last R2
A-T5	8.26	8.33	8.33	8.43
B-T5	8.20	8.23	8.28	8.35
C-T5	8.38	8.38	8.48	8.49
D-T5	8.24	8.28	8.54	8.55
E-T5	8.20	8.20	8.40	8.34
A-CFL	5.73	5.81	5.81	5.90
B-CFL	5.91	5.99	5.86	5.82
C-CFL	6.11	6.23	5.98	5.95
D-CFL	6.01	6.11	5.96	6.00
E-CFL	6.10	6.24	5.95	5.98

According to the results of the measurements, there was a gradual increase in frequency during the operation of many systems and a consequent increase in lamp voltage plus a reduction in lamp current. These three parameters attained good linear change versus lamp life in the systems which operated at slow operating cycles, e.g. system designated A and B and especially the tube type lamps. Fig. 7 shows the variation of these parameters for successive measurements made during the experiment until the failure of the lamp. The Figure refers to a typical system (A1-T5) but the sample is representative. Polynomial trendlines have been used.

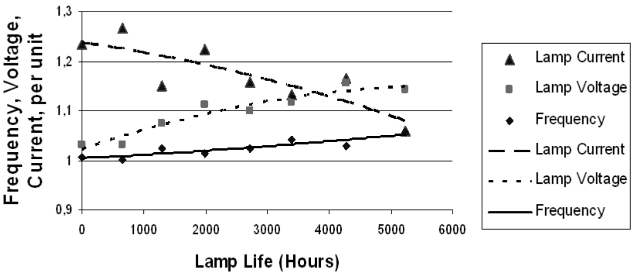


Fig. 7. Variation of frequency, lamp voltage and lamp current of the system A1, T5 until its failure. Units: Frequency: x30 kHz, Voltage: x80 V, Current: x120 A.

Compact lamps lived for too short a time and only three or four measurements were carried out in the systems C, D and E. Thus the results for these systems were unreliable. Systems with tube type lamps attained at least six measurements for the tested parameters but rapid operating cycles for C, D and E systems did not show any linear change for any parameter. Consequently, constructively reliable results were drawn only for A and B systems of tube lamp systems and for A of CFL systems. The results were processed mathematically with MS Excel. Every parameter was related to lamp operating time in cycles and the correlation coefficient squared (R^2), was calculated for every group with identical systems.

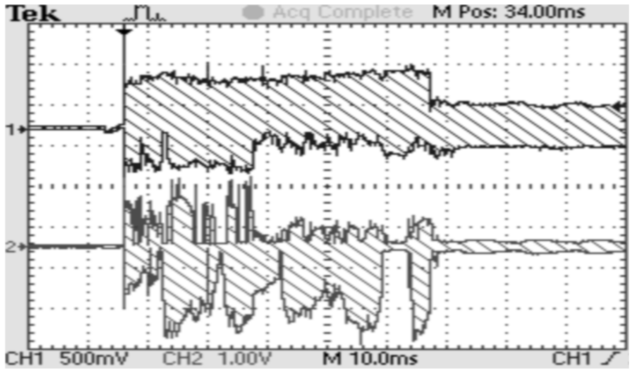
Table VII presents R^2 of the groups which attained a considerable value. The results show a tendency for the ballast to increase the frequency and voltage and to reduce the lamp current which is attributed to the aging of the systems. This is the reason why short cycle systems did not show the same tendencies: systems C, D and E did not have a long lamp life.

TABLE VII
CORRELATION COEFFICIENT R^2 FOR SPECIFIC PARAMETERS IN CONNECTION WITH THE LAMP TIME IN CYCLES, (AVERAGE VALUES)

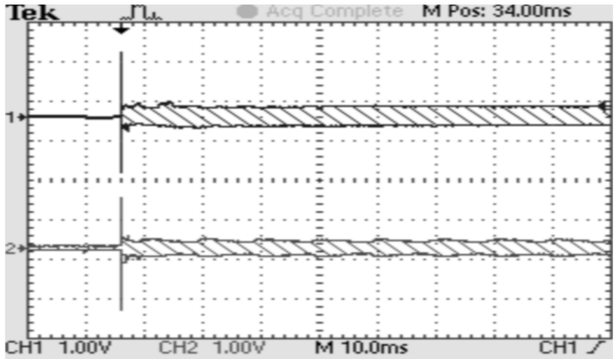
Group	Frequency (kHz)	Lamp voltage (rms)	Lamp current (rms)
A - T5	0.772	0.928	0.821
B - T5	0.902	0.848	0.473
A - CFL	0.714	0.794	0.729

Fig. 8 presents two waveforms which show the differences between the starting modes of two specific systems: T5 and CFL. According to the waveforms, T5 system on the left had a starting time of 54 ms approximately, while CFL's on the right hand side was in the order of one millisecond. T5 was a typical system and the CFL was selected because it had a very short start time. The acquisitions were recorded with the oscilloscope Tektronix TDS 2014.

Fig. 9 presents also the ignition waveforms of two systems. The left traces concern a typical T5 system during a random time period of 20 μs during the starting, while the right traces concern the previous CFL system at an 80 μs time period including the entire process of ignition. At the top of the pictures the captures of lamp voltage and current for 400 ms are shown. These experimental results were recorded with an oscilloscope Tektronix DPO 4034 using 1M record length.

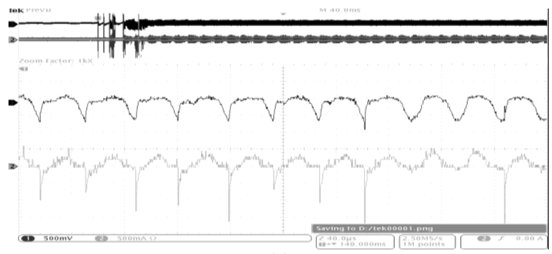


(a)



(b)

Fig. 8. Lamp voltage, (upper trace) and current, (lower trace) vs. time, (10 ms/div) at starting. (a): T5, (250V/div, 2 A/div), (b): CFL, (500 V/div, 2 A/div).



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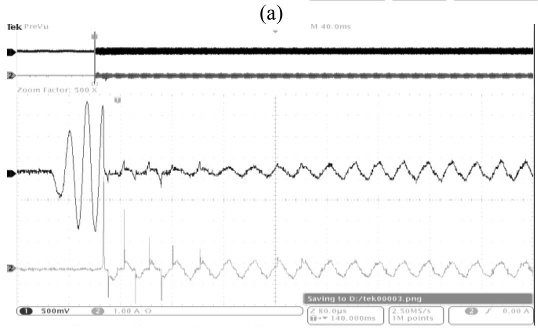

(b)

Fig. 9. Lamp voltage, (upper trace) and current, (lower trace). (a): T5 starting, (250 V/div, 0.5 A/div), (b): CFL starting, (250 V/div, 1 A/div).

IV. CONCLUSIONS

The paper reports the results of an experiment which examined two different types of instant start ballasts for fluorescent lamps in various operation cycles. In parallel, warm start systems were operating with the same type of lamps in the same operating cycles in order to compare the results with instant start systems. The latter experiment is still in progress and just a few lamps have failed till now. The remaining warm start systems operate properly and many of them achieved several times longer lamp life; the ones on fast switching cycles have been ignited more than 70,000 times. This fact shows explicitly that cold ignition limits a long lamp life. The conclusion of this experiment is that the tested ballasts are not worth their cost.

The results verify that lamp life in short time operating cycles might be counted in cycles rather than in hours. Nevertheless, the main conclusion is that rapid cycles are inappropriate as a criterion for the determination of the lamp life. A similar outcome has been drawn from other experiments in various laboratories for T8 lamps and screw base CFLs. Furthermore, the generally accepted opinion about ignition in gas discharge is that it is a strong quantum phenomenon, which means that its quantitative analysis is beyond normal simple rules. As a result, a lamp life prediction based on short operating cycles is ineffective. It is worth noting that no inference can be drawn from the lamp life in cycles when the systems operate in short cycles. It was expected that the shorter the time of the cycle the more the achieved cycles from the system, provided off time is constant. However, the results indicate that there seems to be some difficulty colligating the on time duration of operation of the systems with their life.

It is alleged that starting time and starting voltage are two factors which influence the lamp life of instant start systems. From the quoted Figures, Tables and the research of the authors it is obvious that such an effect has not been confirmed in this experiment. The explanation is that the fluctuation of these variables in the already described experiment is too small to give significant diversities. All the systems conformed to ANSI limits for starting time which is 100 ms.

Three groups showed a regular increase in frequency and operating lamp voltage and a corresponding reduction in operating lamp current. This is explained as a fall in the light output because of the aging of the lamps. Various electric characteristics were measured at steady intervals with the purpose of predicting the system's failure. The result is that no conclusive evidence can be drawn. The exception of the small increase of electrode resistance can not help because it happens at the end of the system's life. Nevertheless, failure is expected since increasing blackening obscures the end of the tube.

In conclusion, this experiment is a useful tool for evaluating the operation of instant start systems. It was shown that rapid operation cycles do not help towards the determination of the mean life of T5 and compact fluorescent lamps operating with instant start ballasts. In addition, this kind of ballast (electronically simple and with small dimensions) does not operate properly with the aforementioned lamps because they do not achieve a large number of cycles.

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