Paper No. ID 013

Topic and Discussions on the Performance Standard and Inspection Methods of CFL

Guan Fumin
GFL Lighting Group China
Dale Reynolds
Harmony Light, Inc. USA

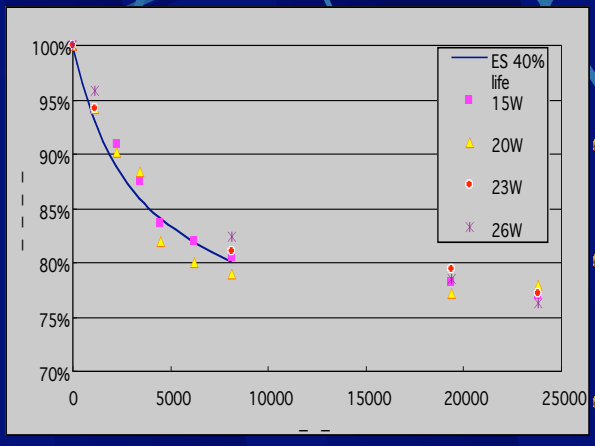
The problems of existing inspections methods for CFL reliability & Lumen efficiency performance

- The existing life test methods are time consuming, and are expensive; With the improvement of CFL products, the measurements have become more difficult.
- The uncertainty of relationship between ON/OFF cycle of lamp life.
- Light depreciation takes a long time to determine. Inaccurate inspection methods & the standard maybe easy to conclude the wrong judgment,
- There is a lack of the standard to inspect the life reliability of CFL, whose life is over 10,000hrs.

The existing standard

Performance characteristics	Energy Star	EST	ELI	GB/T17263
Average rated lamp life	6000h, 10000h	10000h, 5000h	6000h	5000h
	IEC 60969	IEC 60969	IEC 60969	IEC 60969
Lumen maintenance	1000h life≥ 90%	L 2000h≥ 88%	2000h≥ 80%	2000h≥ 80%
	40% of model's	S 5000h≥ 75%		
	rated life≥80%	N 2000h≥ 80%		
Starting time	≤ 1.0 sec	≤ 2sec	≤ 1.5sec	≤ 4.0sec
Rapid cycle stress test	5min on, 5min off 1/2 of rated lamp life 5 out of the 6 lamp≥ cycles	0.5min on, 4.5min off until 50% sample failure. ≥ 2 times of life	5min on; 4.5min off until 50% sample failure	10-15min off, 10 min on

How long is needed to inspect a CFL with life of 25,000 hrs



- To confirm lumen maintenance at 40% of rated life, a time frame of more than one year is needed for completion.
- To establish the entire life of the product the time needed is about three years.
- If this CFL has been developed before year 2002, it will not finish final certification until 2008
- The products has been blocking by inspect proceeding.

The basic reasons of lamp failure

- The normal life exhausted is caused by the emitting powder consumption.
- Sputtering occurs on cathode at the moment of starting
- Filament structure and quantity's defeat
- Leakage of lamp
- Mercury consumption

The picture of electrodes failed respectively in two circumstances

Normal end of life, without emitting powder

Lots of emitting powder remained after Strong pulsing destroyed the filament

Time break of regular life test procedure

	Rated life	On	Off	Circle	Total On	Total Off	Test Time
	Hrs	Min	Min		Hrs	Hrs	Day
Regular	10,000	180	20	**3,000**	**9,000**	1,000	**417**
	6,000			**1,800**	**5,400**	600	**250**
China GB	10,000	>10	10 / 15	N/A			**417**
	6,000			N/A			**250**

The inspection were composed by two parts: ON//OFF cycles & continuously ON

Accelerated Inspection

– ON/OFF Cycles Test

- Inspect Time = appointed cycles x cycle periods
- Cycle Periods = ON time + OFF time
- ON time should assured the ignition of the lamp。
- OFF time should assured that the lamp could be recover to its original state.
- The ON/OFF test is mainly impacting the electrodes when starting, which has less effect to the emitting powder consumption.

Time Break of different circle test procedure

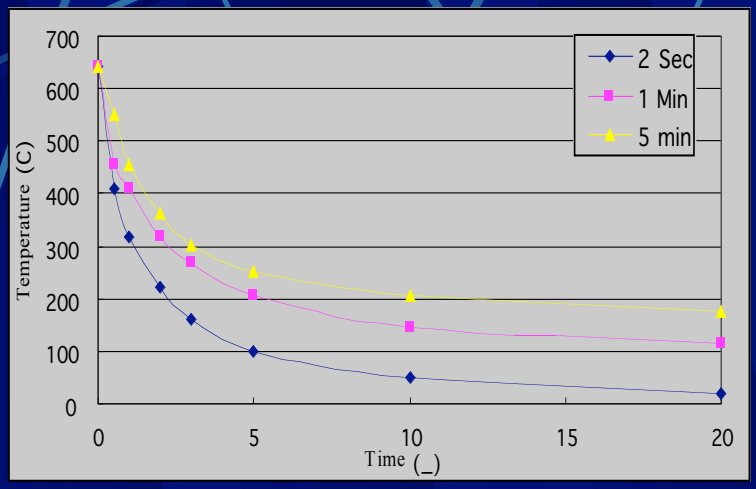
	Rated life	On	Off	Circles	Total On	Total Off	Test Time	Equivalence*
	Hrs	Min	Min		Hrs	Hrs	Day	Hrs/circle
Energy Star	10,000	5	5	5,000	418	418	35	4.3
	6,000			3,000	250	250	20.4	4.3
ELI & ET	10,000	0.5	4.5	20,000	166	1500	69.5	1.8
	6,000			12,000	100	900	40	1.8
Suggestion		Sec	Sec					
Pre-heat	10,000	5	25	10,000	13.9	69.5	3.5	1.6
	6,000			6,000	8.3	41.7	2	1.6
Rapid Start	10,000	2	8	10,000	5.6	22.2	1	1.6
	6,000			6,000	3.3	13.3	0.5	1.6

* Functional equivalence: Each circle added is equivalent to hrs operation while switching test is compared with regular life test.

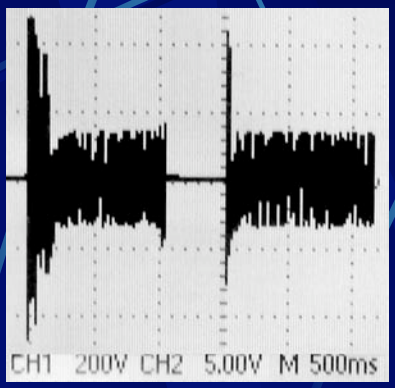
Description of ON/OFF Test

- In general, the ignition of CFL should be completely done within 2sec.
- The cooling time for filaments to recovery should be about 5sec, 10sec. Higher wall temperature of the lamp tube would prolong the recovering time.
- Using ON/OFF cycle with ratio of 1:5 could not only shorten the ignition period and guarantee electrode cooling, but also improved the efficiency of ON/OFF inspection.

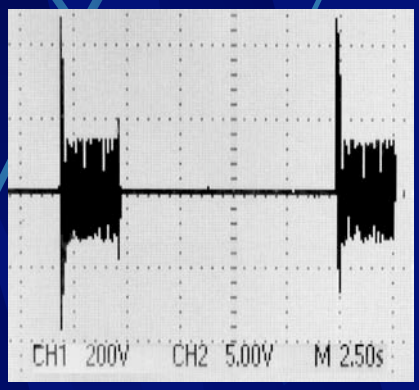
Cooling Curve of a big CFL Filament



Relationship between filament start & cooling time



Lamp turned off after 1sec on
restarted after an interval of 0.5s (0.5sec/div)



Lamp turned off after 1sec on
restarted after an interval of 10s (2.5sec/div)

Result tested with different cycles period

	Circle (On//Off)					
Sample	2 //10	5// 25	30 // 90	_EST_ 30//270	_ES_ 300//300	_ES_ 300//300
1#	11134	9569	8898	11702	5700	
2#	13208	11549	9983	13186	12150	12150
3#	9895	14403	13025	8764	11386	11386
4#	9764	12309	14027	10059	10356	10356
5#	10052	10567	11750	12227	9630	9630
_ _	**10811**	**11679**	**11537**	**11188**	**9844***	**10881****
Deviation	1446	1839	2112	1767	2509	1111
Circle Time with each 10000hrs (Day)	1.3	3.5	13.8	34.7	69.4	
*With one abnormal record lamp						
**Result exclude the abnormal record						

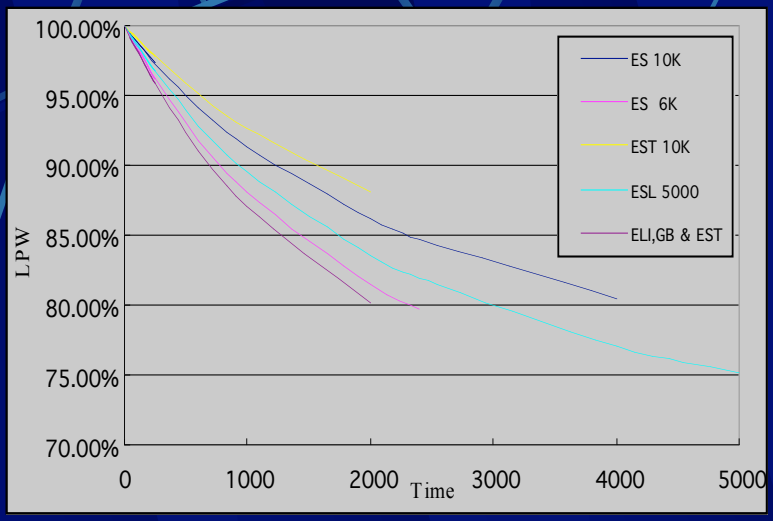
Possibility of Accelerated inspection for CFL continuously operation

- The continuously ON life is decided by the tube load and ON time.
- Principally, the over-load could shorten the life usage.
- The actual relationship should be set between over-load and ratio of shortens life based on more experimental data.
- Using the rated quick instant start ON/OFF cycle or plus over-load rated operation to inspect life reliability. This is helpful to shorten the life inspect period.

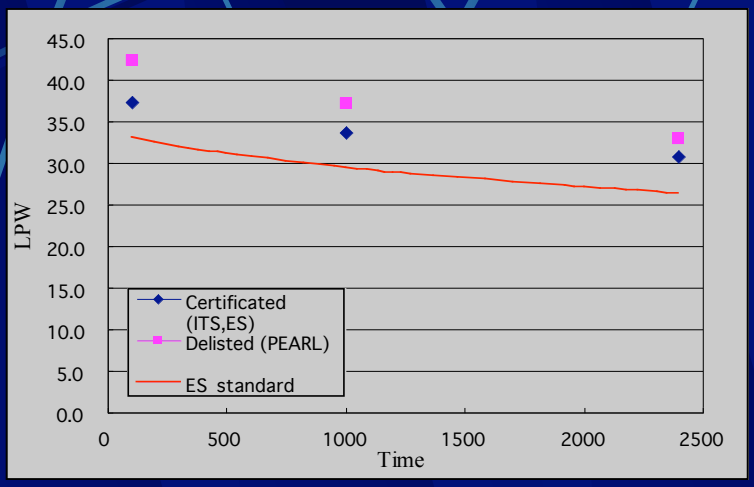
Discussion on illumination efficiency and light output depreciation

- Environment and dynamic movement of the gas inside the tube affect CFL light output, which is hard to be measured precisely.
- The calculation of % depreciation is always based on the initial LPW at 100hrs, which may be easily influenced by the following results of light depreciation.
- Light depreciation is the relative numerical value of different time, can not be repeat. So that it is hard to be checked & corrected.
- Light depreciation is not an energy efficiency standard. There is no solid relationship between light depreciation & actual efficiency of product instead of Lumen depreciation. A better method is using the light efficiency of life.
- Light depreciation could be forecasted, because it is an regular physics procedure.

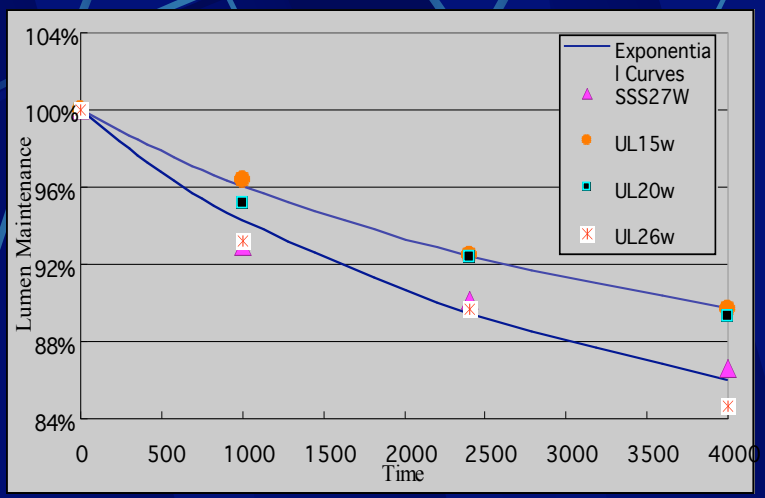
Light depreciation curves related to existing standard



A good product rejected unreasonably based on existing light maintenance depreciation standard



LPW maintenance from ITS report compared with exponential depreciation curves



LPW reducing by the life time

- The actual LPW depreciation was coincides with theorical depreciation inference.
- LPW depreciation could be forecasted according to the theorical curves.
- The forecast ability will depend on the accuracy and errors of LPW measurement.
- If the accuracy could be controlled within ±0.5%, the difference of existing standards can be distinguished,, and after 1000hrs measurement.

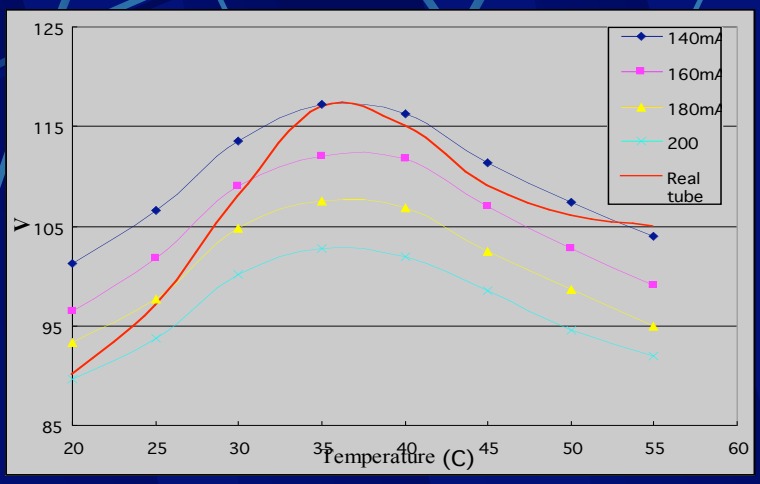
Lumen maintenance in first 1000hrs based on existing standard

Existing Standard	500hrs	1000hrs	2000hrs	2400hrs	4000hrs	5000hrs	8000hrs
ES 20K	96.30%	93.50%					80%
EST/L 10K	95.80%	92.70%	88%				
ES 10K	95.10%	91.40%			80%		
EST/S 5000	93.90%	89.50%				75%	
ES 6K	93.20%	88.30%		80%			
ELI,GB & EST/N	92.40%	87.10%	80%				

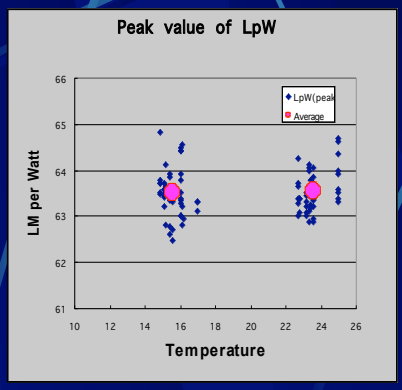
Improvement of LPW measurement

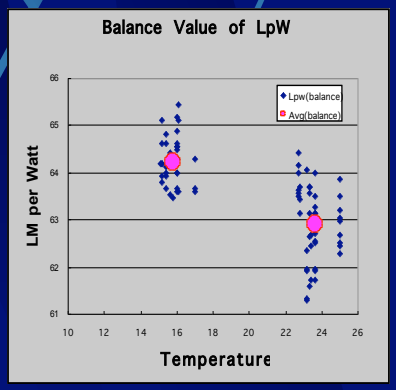
- Light output of CFL fluctuates and is unstable, it's affected by many factors..
- The accuracy of measurements is not only decided by the accuracy of the equipment, but also depends on the environment condition control.
- The present methods try to control the products under the stable condition.
- CFL's light output has a stable & inherent peak. Measure the peak value could avoid the influence of environment, and have higher repeatability.
- The forecast of light depreciation should be based on the LPW measurement.

V-I-T curve during the lamp run up period



The data distribution of the multi-measurement reading from same sample group under two different controlled temperature conditions





Comparisons of Reading Accuracy between Peak and Balance Value

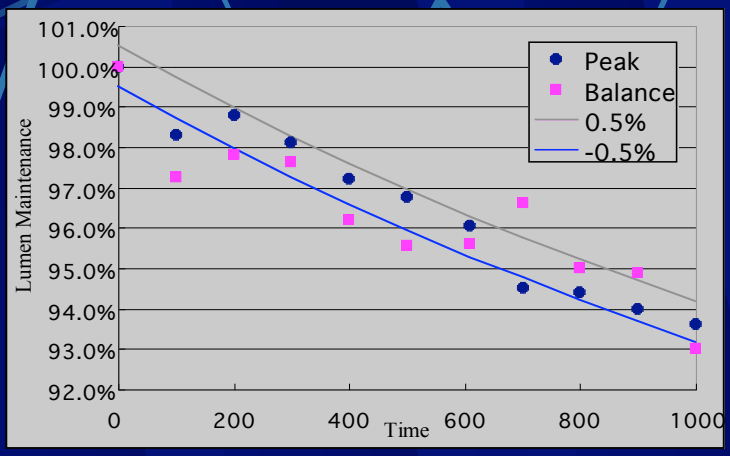
——statistic calculation of the 180 readings.

	Peak Value	Balance
Wattage	0.80%	1.70%
Lumen Output	0.40%	2.40%
LPW	0.70%	1.20%

Comparison of environment influence between Peak & Balance Value

	Peak Value	Balance
Wattage Average	-0.07%	-0.80%
Lumen Output Average	-0.06%	-1.10%
LPW Average	-0.01%	-0.30%

Comparison of 1,000hrs measurement reading of LPW maintenance and fluctuation between the peak & balance methods



Conclusion

- Time consuming, high in cost, impracticable are the disadvantages of existing CFL inspection. A more effective method should be sought.
- It could short the procedure of inspection, if we use the improved accelerated rapid inspection & over-load continuously ON method to test life reliability instead.
- The existing LPW measurement is hard to be precise because of the environment, but Peak-Value could get the better results.
- The Life Efficiency is more reasonable than the existing method of LPW depreciation calculation. It could avoid the initial test errors.
- Using the methods of index curve and following initial measurement with higher accuracy could forecast the light depreciation and improve the efficiency.

Thank You