Evaluation of Low Energy Lights for Minor Road Lighting

Twin 14 & 24W T5
32 & 42W CF
50W HPS

Produced by the *Victorian Sustainable Public Lighting Action Group (VSPLAG) – Technical Reference Group*.

Final Report : 12th March 2008

Table of Contents

1 Introduction

Victorian Councils require a reduction in their energy consumption to meet their Greenhouse Gas emission reduction targets and to benefit the environment.

Approximately 40% of Council's Greenhouse Gas emissions are attributed to Public Lighting energy consumption.

Councils wish to introduce low-energy lighting to reduce their energy consumption & reduce their Greenhouse Gas emissions.

The VSPLAG Technical Reference Group was established in mid 2006 to evaluate energy efficient public light options for minor roads & approve those that were deemed to be technically acceptable and have comparable or better performance than the current standard 80 W mercury vapour (80W MV) light.

The VSPLAG Technical Reference Group is represented by :

- Distribution Businesses ie SP AusNet (Mark Butson), Powercor/CitiPower (Brent Dawson/Rick Hemley) & Alinta (Max Demko/Karl Edwards)
- Councils – Hume & Darebin (Stuart Nesbitt)
- Sustainability Victoria - (Doug McPherson)
- Essential Services Commission - (Carmine Piantedosi)
- Ironbark Sustainability (Technical Consultant) – (Paul Brown/Ray Simms)

2 Findings

The VSPLAG Technical Reference Group found that the T5 (twin 14W & twin 24W) & the compact fluorescent (CF) (32W & 42W) low-energy lights were comparable or better in performance than the current standard, the 80W MV.

The Pierlite T5 (twin 14W & twin 24W) is deemed technically acceptable having received VSPLAG Technical Reference Group approval of the manufacturing drawing and the luminaire sample – refer to *Appendix 9* for approved manufacturing drawing.

The CF is deemed technically acceptable pending the following :-

- some minor modifications to be made to the luminaire (refer to *Appendix 1*)
- VSPLAG Technical Reference Group approval of the manufacturing drawings, showing the above-mentioned modifications, provided by the Supplier
- VSPLAG Technical Reference Group approval of a sample luminaire, incorporating the above-mentioned modifications, provided by the Supplier
- satisfactory results, due mid-2008, of a field trial to overcome lamp failure problems due to vibration (refer to *Section 5*)

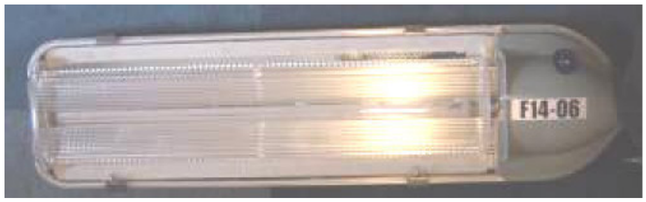
The 50W HPS light was found to be unacceptable due to its yellow light and relatively higher energy consumption.

3 Evaluation Process

The VSPLAG Technical Reference Group evaluated the following low-energy lights :-

- T5 Twin 14W & Twin 24W (Pierlite)
- 32W & 42W Compact Fluorescent (CF) (Sylvania)
- 50W High Pressure Sodium (HPS) (Sylvania)

80W MV (current standard)



T5 twin 14W (Pierlite) low-energy light

42W CF (Sylvannia) low-energy light

50W HPS low-energy light

The evaluation by the VSPLAG Technical Reference Group consisted of :-

- **Light output** : assessing light outputs, spacing tables, colour, light output depreciation, start-up times, voltage and temperature effects.
- **Reliability** : assessing reliability by reviewing manufacturer data and results from field trials in Victoria & interstate
- **Replacement cycles** : establishing replacement cycles of lamps, PE cells & electronic ballasts – these figures assist the Distribution Businesses to determine their OMR rate to charge Councils for operating, maintaining & replacing lights.
- **Field feedback :** Obtaining & reviewing field-feedback from public lighting Contractors
- **Energy consumption :** Performing load tests on these luminairs & applying for these loads to the placed on NEMMCO's load table

The VSPLAG Technical Reference Group established the criteria for the above & evaluated each of the low-energy lights and determined if the criteria was met - details of the evaluation are contained in the following sections.

4 Light output

The following light output parameters were assessed.

- Spacing Tables
- Colour
- Maintenance Factor (Light output depreciation over time)
- Effects of Temperature Variations
- Effect of Voltage Variations

4.1 Spacing Tables

Criteria : Low-energy lights must have comparable or better spacing table values to the current standard 80W MV light.

Analysis : Spacing tables indicate the theoretical required spacing between light poles to achieve a light output that meets AS/NZS 1158.3.1:2005 Pedestrian area (Category P) for a particular light based on a certain road reserve width & light mounting height. The spacing tables are determined using lighting software. The spacing tables below are based on a lamp test chamber ambient temperature of 25 degrees Celsius.

AS/NZS 1158.3.1:2005 nominates two different light output standards :-

- **Category P4** which applies to new lighting schemes. *Table 1* below shows the minimum required pole spacing to meet the P4 standard. A light mounting height of the 5.5m which applies for standard URD lighting poles has been assumed. * However an increased light mounting height of 6.5m has also been included as this may be adopted as the standard light mounting height in the future as it has the advantages that :-
  - light pole spacings can be increased
  - a T5 twin 14W can be used for a 20m road reserve rather than a T5 twin 24W

- **Category P5** which applies to retrofits of existing lights installed on distribution network poles. The spacing table to meet the P5 standard is shown in the *Table 2* below. A light mounting height of 7.5m has been assumed.

Category P4 Lighting								
	15m road reserve				20m road reserve			
Maximum Pole spacing	5.5m light height		* 6.5m light height		5.5m light height		* 6.5m light height	
80W MV (Urban)	55m		61m		46m		53m	
T5 twin 14W	58m	✓	63m	✓	34m	✗	57m	✓
T5 twin 24W	66m	✓	71m	✓	63m	✓	68m	✓
32W CF	54m	✗	60m	✗	46m	✓	54m	✓
42W CF	60m	✓	65m	✓	53m	✓	60m	✓
50W HPS	56m	✓	61m	✓	48m	✓	54m	✓

Table 1 : Spacing Table for New Lighting Schemes (Category P4 Lighting)

✓= light spacing same or greater than that of an 80W MV

✗ = light spacing less than that of an 80W MV

Category P5 Lighting				
7.5m Mounting Height	**15m road reserve**		**20m road reserve**	
80W MV (Urban)	82m		78m	
T5 twin 14W	83m	✓	82m	✓
T5 twin 24W	92m	✓	91m	✓
32W CF	77m	×	76m	×
42W CF	84m	✓	84m	✓
50W HPS	81m	×	79m	✓

Table 2 : Spacing Table for Retrofitting Lights on Power Poles (Category P5 Lighting)

✓= light spacing same or greater than that of an 80W MV

× = light spacing less than that of an 80W MV

Conclusion : T5, CF & 50W HPS lights have comparable or better light output parameters to the current standard 80W MV light.

4.2 Colour

Criteria : Low-energy lights must have acceptable light colour.

Analysis: 50W HPS lights have a yellow light which results in reduced colour rendition and definition compared to a white light thus reducing the perceived levels of safety of pedestrians. Under a yellow light many colours appear less bright or even brown. Results of surveys of the public performed by the Northern Alliance for Greenhouse Action in 2004 & 2005 indicated that the respondents did not support the yellow colour of the 50W HPS lights when compared to the wwhite light of T5 & CF lights.

Conclusion : T5 & CF both have an acceptable white light.
However the 50W HPS light is unacceptable due to its yellow light.

4.3 Maintenance Factor

Criteria : Low-energy lights must have a comparable or better maintenance factor to the current standard 80W MV light

Analysis: A light's maintenance factor is a measure of the reduction in light output as the light ages, usually over 4 years (ie typical lamp replacement cycle) – the lower the maintenance factor, the lower the light output. See *Table 3* below.
See *Appendix 5* for more details.

Lamp Type	**Maintenance factor** (after 4 years)	
80W MV	0.55	
T5	0.76	✓
CF	0.67	✓
50W HPS	0.76	✓

Table 3 : Maintenance Factor

Conclusion : T5, CF & 50W HPS low-energy lights have maintenance factors that exceed that of the 80W MV light.

4.4 Effects of Ambient Temperature on Light Output

Criteria: Low-energy lights must have a comparable or better light output variation to a standard 80W MV light

Analysis : The light output of a linear fluorescent lamp is affected more by ambient temperature variations than the current standard 80W MV lamp whose light output is virtually independent on ambient temperature. For a fluorescent lamp, low temperatures reduce the light output marginally and increase start-up time slightly.
However, test results on a T5 with twin 14W non-amalgam lamps indicate that even at an ambient temperature of 0 degrees Celsius, its light output is equivalent to an 80W MV (whose output is virtually independent of temperature).
The Bureau of Meteorology statistics indicate that an 'average' middle suburb of Melbourne experiences only 0.2% of nighttime hours under 0 degrees Celsius.

The effects of temperature variations on light output for linear fluorescent lamps are reduced with amalgam lamps.
At the time of this report, T5 amalgam lamps were only available in the 24W rating with amalgam 14W lamps possibly being available in the future.
42W CF lamps are currently available with and without amalgam.
It is recommended that :-

- amalgam 42W CF lamps be utilised
- amalgam 24W T5 lamps be utilised
- when available, amalgam 14W T5 lamps be utilised

Appendices 6 & 7 provide more information on the performance of the T5 light with temperature.

Conclusion : The T5, CF & 80W HPS lights meet the above criteria for effects of temperature on light output.

4.5 Effects of Voltage variations on Light Output

Criteria : Low-energy lights must have a comparable or better light output variation with voltage changes to that of the 80W MV light.

Analysis: The light output of the T5 & 42W CF fluorescent lights are affected less by supply voltage variations than the current standard 80W MV light. This is because the T5 & 42W CF lights incorporate electronic ballasts which are less susceptible to voltage changes than iron-core ballasts used in the current standard 80W MV & 50W HPS lights.

Results show that lights with 'electronic control gear' such as the T5 and CF lights are largely unaffected by voltage variation whereas the 80W MV, which has an iron core ballast, varied in light output by around 30% between 220V and 260V.

Conclusion : The T5, CF & 50W HPS lights meet the above criteria for performance with voltage change.

4.6 Light Output Conclusion

From the analysis, the CF and the T5 luminaires are suitable for use. As the 50W HPS does not meet the requirements for colour, it was not reviewed any further.

5 Reliability

5.1 In-service Failure Rates

Criteria : Low-energy luminaires must have comparable or better in-service failure rate to the current standard 80W MV luminaire ie **20-25%** (approx) in-service failure rate[1] over a 4 year period. [1] Based on average failure rates (for any reason) of Victorian distributors listed in United Energy's 'Submission to the Essential Services Commission' dated 28 June 2004.

Analysis: The results of field trials by Integral Energy, Energy Australia & AGL (Victoria) were analysed to evaluate the failure rates of the T5 & CF with the following results (details of the trials are in *Appendix 4).*

Failure rates of the Energy Australia trial of 1000 T5 lights was found to be 5.8% over a 3 year period. Extrapolating[2] this failure rate out to 4 years gives a rate of 11.7%.

Integral Energy's trial of approximately 4000 T5 lights over a 4 year period has found the failure rate is acceptable to Integral Energy (no quantitative assessment was performed on the trial).

Results of 42W CF field trials identified excessive lamp failures due to vibration. Two modes of failure were identified :-

1. Vibration causing lamp to fall out of lamp holder – this problem has been addressed by the introduction of a twist-lock lamp holder where the lamp is rotated through 90 degrees to lock lamp in holder
2. Vibration causing glass portion of lamp to fracture where it attaches to the lamp base – a possible solution has been put forward by Sylvannia which consists of a wire loop which supports the lamp & reduces effects of vibration. Powercor are currently performing a field trial of 100 lights to monitor the effectiveness of the wire loop solution – it is anticipated that results of the trial will be available mid 2008. Subsequent to the 'wire loop' solution, Sylvania has developed another lamp support arrangement which 'clips' to the lamp – field trials of this solution are anticipated to occur in early 2008.

Conclusion : T5 lights have an in-service failure rate that meets the above criteria. Field trials of CF lights are currently being performed to assess their lamp vibration/breakage performance – results are expected in mid-2008.

[2] From the T5 lamp life expectancy curve in *Appendix 2*, at 3 years (12483hrs) the lamp failure rate is 2% approx. Converting from 3-hr switching to 11-hr switching using a factor of 1.17, 3 year lamp failure rate is 2%/1.17 = 1.7%. For two lamps, 3 year failure rate is 2 x 1.7% = 3.4%.

For two lamps, the 4 year failure rate is 8.6% (refer to *Appendix 2* for details).

Therefore the additional **lamp** failure going from 3 years to 4 years is 8.6% – 3.4% = **5.2**%

From the T5 ballast life expectancy curve in *Appendix 3*, over 8 years the failure rate is approximately linear at about 0.7% failure per year (based on a 70 degrees C curve).

Therefore the additional **ballast** failure going from 3 years to 4 years is **0.7**%.

Total additional failure rates going from 3 years to 4 years (ignoring PE cell failure rate) is 5.2% (lamps) + 0.7% (ballast) = **5.9**%

So T5 extrapolated 4 year failure rate = **5.8**% (failure rate at 3 years) + **5.9**% (failure rate in 4th year) = **11.7**%

5.2 Theoretical Failure Rates

Criteria : Low-energy lights must have comparable or better theoretical failure rates to the current standard 80W MV light ie **15%** (approx) theoretical failure rate[1] over a 4 year period.

[1] Based on lamp failure rates from manufacturer's data sheets – refer to *Appendix 2.*

The majority of 80W MV luminaire failures are due to lamp failures - ballast failures are negligible due to the robustness of the magnetic (non-electronic) ballast.

However, for the T5 & CF luminaires, the majority of failures is due to the combined failures of lamps and ballasts which are electronic and have limited life-spans.

Failures due to PE cells have been ignored in this study as the PE cell (D2) predominantly used in 80W MV luminaires will also be used in all low-energy luminaires considered in this report.

Analysis : The manufacturers have provided the following data for the expected failure rates of their equipment – refer to *Appendix 2* for lamp failures & *Appendix 3* for ballast failures.

	Theoretical Average Failure Rates per year				
	T5 (twin lamps)			CF	
	4 yr	5 yr	6 yr	4 yr	5 yr
Lamps	2.2%	6.6%	18%	3.5%	>10%

	Theoretical Average Failure Rate per year		
	8 yr	10 yr	12 yr
Electronic Control Gear (CF & T5) [1]	0.7%	1%	1.1%

[1] Both the CF & T5 luminaires utilise the same electronic control gear technology.

T5 Theoretical Failure Rates

From the T5 lamp life expectancy curve in *Appendix 2*, the T5 lamp failure rate at 4 years is 8.6% (for twin lamps).

From the T5 ballast life expectancy curve in *Appendix 3*, over 8 years the failure rate is approximately linear at about 0.7% failure per year (based on a 70 degree C curve[2]).

[2] Actual temperature is not known, 70 degrees C is seen to be a 'worse case' temperature

So the theoretical 4 year failure rate for T5 luminaires (ignoring PE cell failure which is assumed small) based on 4 year replacement cycle on lamps and 8 year replacement cycle on the ballast is 8.6% (lamps) + (4 x 0.7)% (ballast) = **11.4**%

CF Theoretical Failure Rates

From the CF lamp life expectancy curve in *Appendix 2*, at 4 years the CF lamp failure rate is 14%.

From the ballast life expectancy curve in *Appendix 3*, over 8 years the failure rate is approximately linear at about 0.7% failure per year (based on a 70 degrees C curve).

So the theoretical 4 year failure rate for CF luminaires based on 4 year replacement cycle on lamps and 8 year replacement cycle on ballast is :-

14% (lamps) + (4 x 0.7)% (ballast) = **16.8**%

Conclusion : With a replacement cycle of 4 years on the lamps and 8 years on the electronic control gear and the PE cell the T5 and CF luminaries theoretical failure rates are comparable or better than the 80W MV.

6 Replacement Cycles

Criteria : Low-energy lights must have comparable or better replacement cycles to the current standard 80W MV light.

Analysis: Replacement cycles refer to scheduled maintenance for components that need replacing during the luminaires life ie

1. Lamps
2. PE cells
3. Electronic Ballasts (complete with MOVs*)

* MOVs are electronic components which help to protect the light from voltage surges.

Refer to *Appendices 2 & 3* for details on lamp & ballast failure rates.

Conclusion : VSPLAG Technical Reference Group has established that the following replacement cycles for T5 & CF lights :-

1. Lamps – bulk change every 4 years (same as 80W MV)
2. PE cells - bulk change every 8 years (same as 80W MV)
3. Electronic Ballasts (complete with MOV's) - bulk change every 8 years (no bulk change of ballast required for 80W MV)

In establishing the replacement cycles, consideration was given to 'fit in' with the current replacement cycles of the 80W MV.

Note : due to the lack of long-term in-service history for T5 & CF lights and no available actual failure rate data, the above replacement cycles are **estimates only** and may change when long-term in-service failure rates become available.

7 Technical Specification

For supply of new low-energy luminaires the following requirements must be met :-

- Distribution Business customers eg Councils must endorse the use of the luminaire

- Low energy consumption (minimum of 55 lumens per watt)
- Low-energy lights must meet AS 1158
- Easy to replace lamp, PE cell & ballast (with MOVs)
- Removable gear tray or Plug-in ballast
- Adequate voltage surge protection over life of light eg MOVs at supply cable terminals (A-N & A-E) & MOV on ballast which will be replaced when ballast is replaced
- Twist lock 42W CF lamp
- Means of preventing failure of CF lamp due to vibration
- Electronic ballast must be an approved type. Approved types are : Osram ECG QUICKTRONIC® DE LUXE and Vossloh-Schwabbe
- T5 lamps must be an approved type. Approved types are :
  - 14 watt - Philips Master TL5 HE 14W/840 (non-amalgam)[1]
  - 24 watt – Osram FQ 24W/840 HO CONSTANT FLH1 (amalgam)

[1] At the time of this report, T5 14watt amalgam lamps were unavailable. When they become available they will replace the non-amalgam as the approved T5 14watt lamp.

- PE cells must be an approved type. Approved types are : Selcon Kaga 2 amp D2.
- Lights to be supplied with lamp/s fitted
- Manufacturing drawings, showing the above details where applicable, are to be provided by the supplier for review & approval by the VSPLAG Technical Reference Group
- Sample of luminaire is to be provided by the supplier for review & approval by the VSPLAG Technical Reference Group

For maintenance, other types of lamps (including T5 long-life), PE cells & electronic control gear may be approved by individual Distribution Businesses.

8 Load Testing

The VSPLAG Technical Reference Group organised load testing of the T5 & CF (at a NATA accredited laboratory) – load testing of the 50W HPS was not carried out as VSPLAG assessed it as not being technically acceptable due to the light being a yellow colour.

Load test results were sent to NEMMCO for their approval & insertion into their load table – this is the official site which nominates the load of a particular light.

Appendix 2: Lamp Failure Rates

T5 Lamp Failure Rates

Based on data from "Philips Master TL5 lamps – February 2006" produced by Philips Lighting B.V.

Life expectancy curve below is from page 23[1].

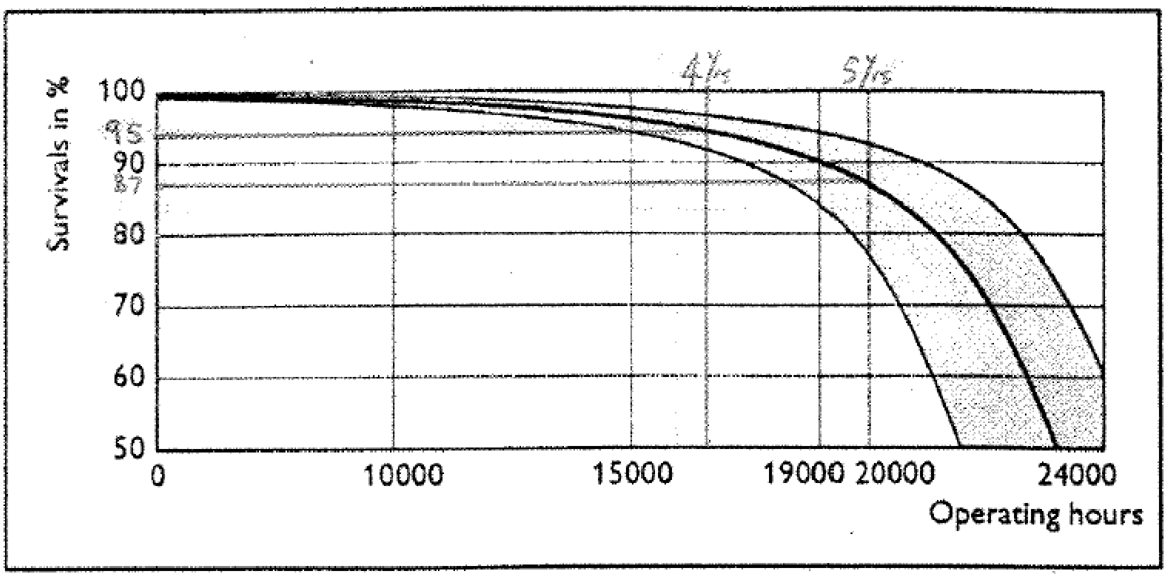


Figure 4.4.1 Life expectancy with a 3-hr switching cycle

Calculation of lamp life expectancy:

From the figure above, at 4 years (16644 hours), the survival rate of a single lamp based on a 3 hr switching cycle is 95%.

Converting from a 3-hr switching cycle to a 11 hour switching (the actual switching cycle for a PE controlled light) results in 17% (see overleaf for copy of page that refers to this figure) greater life expectancy.

A single T5 lamp 4 year failure rate is 5.0% for 3 hour switching.

A single T5 lamp 4 year failure rate is 5.0/1.17 = 4.3% for 11hour switching.

The twin T5 lamp 4 year failure rate is 4.3% x 2 = 8.6% or 8.6/4 = 2.15% per year average

[1] "Philips Master TL5 lamps – February 2006" produced by Philips Lighting B.V.

4.5 Lifetime performance

If the MASTER TL5 lamps are operated on electronic gear, designed according to the specifications mentioned in this documentation, at a 3-hour switching cycle (165 minutes on, 15 minutes off), the lamps will have a rated average lifetime of 24.000 burning hours.

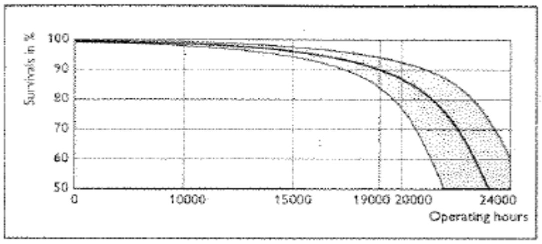


Figure 4.4.1 Life expectancy with a 3-hr switching cycle

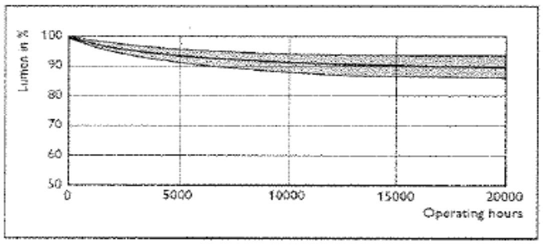


Figure 4.4.2 Lumen maintenance /800 colours

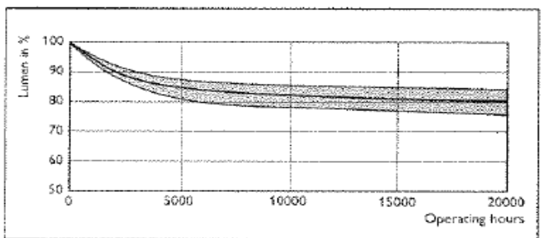


Figure 4.4.3 Lumen maintenance /900 colours

Notes on life expectancy curves:

Lamp lifetime is specified as the total number of actual operating hours under specific operating conditions. Philips MASTER TL5 lamps are designed for operating with proper preheated electrodes before lamp ignition is established and in accordance with IEC 60901. This is to ensure also reliable long life when the switching frequency is higher than the standard IEC cycle (165 minutes on, 15 minutes off).
The published curves give typical average values based on measurements made by Philips Quality Department Lighting based on large production batches of lamps and tested under laboratory conditions in accordance with IEC 60901.
In practice, the performance of individual lamps or groups of lamps may deviate from the average.
Lamps are tested in conjunction with commercially available preheat controlgear (ballasts).
The rated average lamp life is the expected time at which 50% of any large number of lamps reach the end of their individual lives.
Actual operating conditions deviate in most cases from the applied test conditions. The differences can have a significant influence on lamp performance.

Switching cycle effects

The rated average lamp life of MASTER TL5 lamps is negatively affected when the switching frequency is higher than the IEC cycle (3 hrs cycle: 165 minutes on, 15 minutes off).
The table below gives an indication of the relation between the amount of switching and the lamp life.

Operating cycle time min	Rated average lamp life h	Lamp life	Switches nr.
660 on, 60 off	28.000	117%	2550
480 on, 30 off	27.000	113%	3380
165 on, 15 off	24.000	100%	8730
90 on, 15 off	22.000	92%	14.667
45 on, 15 off	19.000	79%	42.200

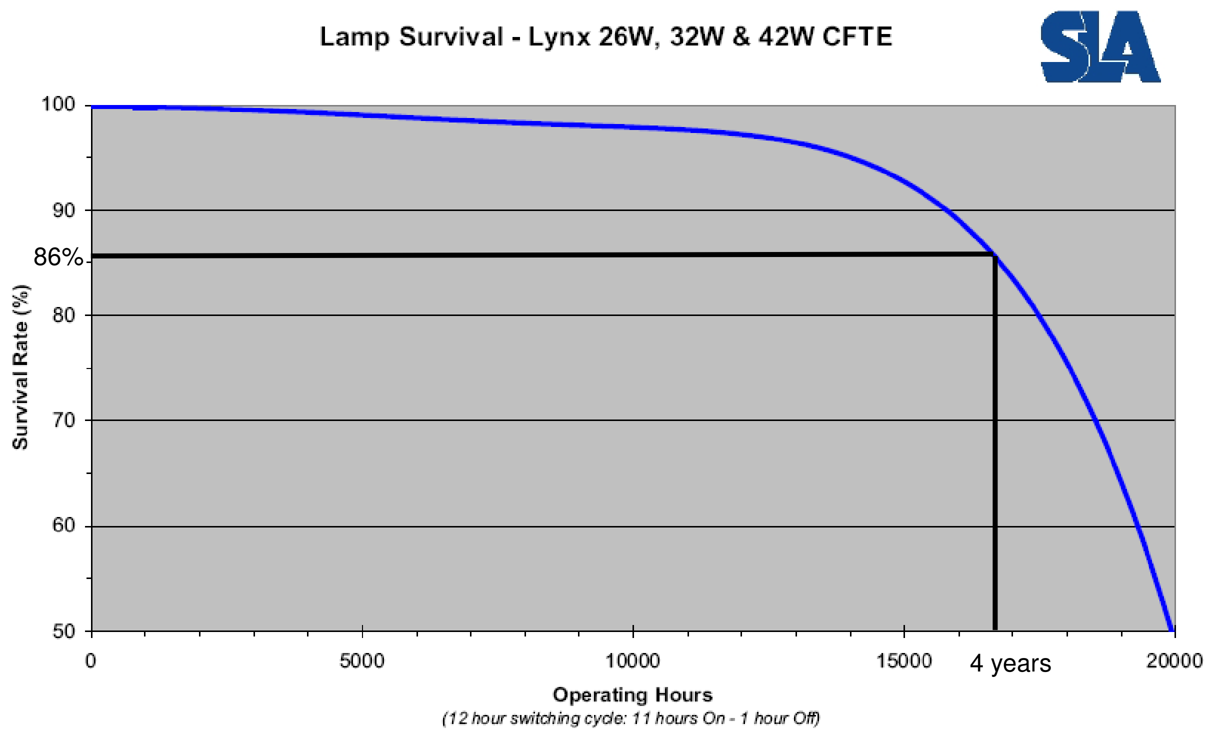
Note: *Lifetime figures depend on ballast type. In practice lifetimes can deviate.*

Extract of page 23 of "Philips Master TL5 lamps – February 2006" produced by Philips Lighting B.V.

Where standard <u>Philips Master TL5</u> lamps are used, the VSPLAG recommends the following replacement cycles and failure details for these luminaires.:

- The recommended lamp replacement period for bulk changes is 4 years.
- The expected failures rate between bulk changes is 8.6% (average annual failure rate of 2.15%)

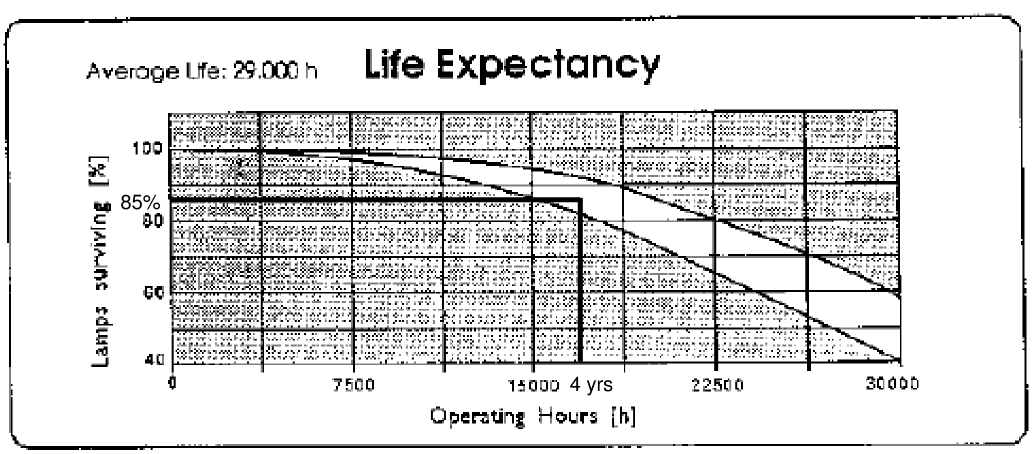
CF Lamp Failure Rates



Calculation of lamp life expectancy:

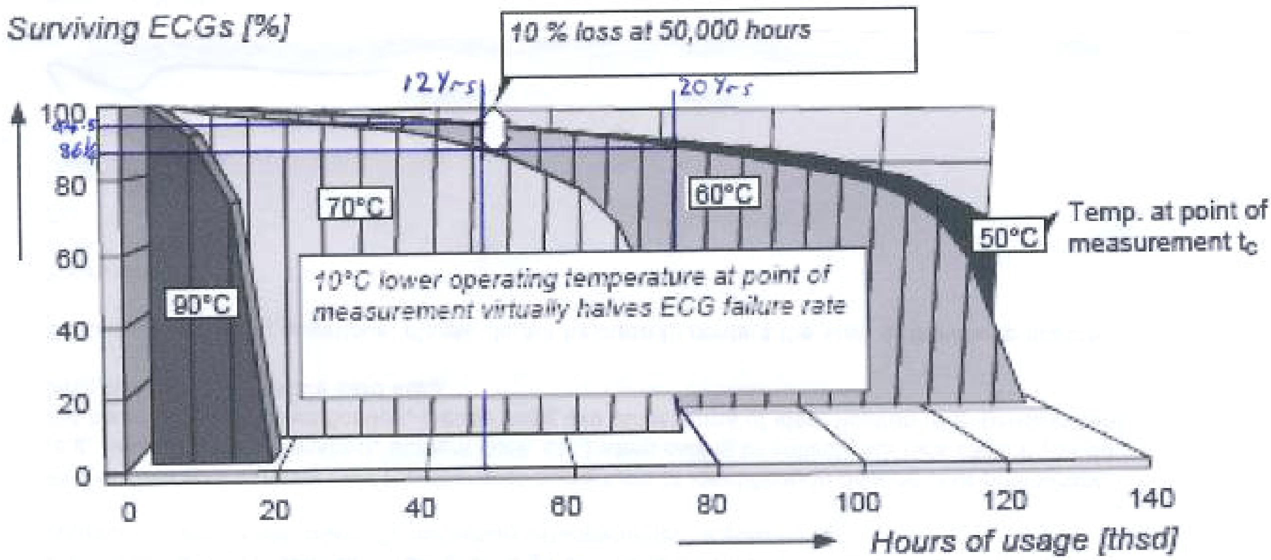
From the figure above, at 4 years (16644 hours), the survival rate of a CF lamp based on a 11 hr switching cycle is 85% or 15% failure rate (or 15/4 = 3.75% per year average).

80W MV Lamp Failure Rates



Appendix 3 : Electronic (Ballast) Control Gear (ECG) Failures Rates

Life expectancy curve below[2].



Calculation of ECG life expectancy:

The table below summarises the expected life of the ECG at different maximum temperatures at the T_c point. Note that this is conservatively based on 3 hour switching cycle. It is expected that there will be increased life for 11 hr switching cycle (for lamps the life is increased by 17%). ECG life is dependent on maximum temperature.

Temperature	Failure rate at 8 Years	Failure rate at 12 Years	Failure Rate at 20 Years
50 °C	3%	5.5%	10.75%
60 °C	3%	5.5%	13.75%
70 °C	5.5%	13.75%	100%

It was noted that electronic control gear (such as the Osram used as standard for the Twin T5 luminaire) is sensitive to temperature. The higher the peak temperature over the life of the ECG the shorter that life is expected to be. It was noted that further research is required to determine the peak temperature at the "cool spot" (Tc) of the ECG over Summer periods in Victoria. It was further noted that the following information will be reviewed based upon the research determining peak summer Tc temperature.

- An expected max. temperature of 60 deg will give an expected failure rate of 5.5% at 12 years (equal to an average annual failure rate of 0.46%)
- The expected worst case max. temperature of 70 deg will give an expected failure rate of 5.5% at 8 years. (equal to an average annual failure rate of 0.69%)

[2] From Page 20 of "ECG for T5 fluorescent lamps - Technical Guideline May 2005" produced by Osram.

It was decide to adopt a bulk replacement at 8 years with a 5.5% failure rate before bulk changes - this will be reviewed based upon testing and in field failure in existing large scale trials.

Further testing of ECG temperature will be carried out in an in field situation over the summer in 2007/8.

From Page 20 of "ECG for T5 fluorescent lamps - Technical Guideline May 2005" produced by Osram.

Appendix 4 : Information from Field Trials

The information from other trials includes the following (in order of appearance on the proceeding pages) :

1. Information on trials from Bill Harrigan (Integral Energy) dated Sept. 2007 and email dated 30 March 2007.
2. Report from Pierlite on the total failures for the Energy Australia trial (installed in 2003/4) and the reasons for each failure. The reports are from (1) A summary of all the issues from the trial establishment to September 2007 (2)February 2006 and (3)November 2006.
3. Report on AGL/NAGA sustainable public lighting trials

These reports immediately follow a summary and discussion of these reports, which is found below.

Integral Energy

Integral Energy has been instrumental in bringing this product to market. They went to the manufacturers and asked them to develop a more efficient light for Category P roadlighting. As a result Pierlite developed the 2x14W T5 Greenstreet.

At the time of writing this report there were between 7-8000 of the 2x14W and 2x24W T5's installed in Integral Energy's area. These were first installed in 2003. The Greenstreet is now the standard fitting for minor road lighting for 60% of Integral Energy's Councils.

Bill Harrigan, from Integral, has been involved in the program from the beginning and had this to say about the technology (see full email later in this Appendix):

"Apart from some early problems with the T5 luminaire itself we are not seeing any evidence of unsatisfactory lamp performance including survival rates with few failures to date.

We do recognise that at present the electronic control gear employed in the luminaire will not be as robust or last as long as the ferro-magnetic gear presently used.

We believe that the benefits of: longer lamp life, reduced losses, lower lumen depreciation and higher efficiency combined with stable light output under varying voltage conditions more than offset this."

Energy Australia

The Energy Australia trial started in 2004 where 1,000 T5 luminaires were installed. The table below describes the failures recorded up until the Sept. 2007 (i.e. 3 – 3.5 years installed). These failures are well within expected failures noted by manufacturers.

Reason for failure	Number	Action/Comment
General breakages (eg clips, lense etc.)	4	
Lamps not turned into holder properly	11	This was "an early production problem" – no further issues.
Lamps missing/failed	26	Worked after replacement. Manufacturers allow 2% per year.
PE cell base	3	New design reduces stress on base.
Ballast failed	4	
No fault	5	Cell installation fixed unit
PE cells	5	Cell replacement fixed unit
Total	58	

NAGA and AGL

The NAGA and AGL trial also began in 2004. 120 lights were installed including 80 2x14W T5 Greenstreets. The program was a joint program between AGL and the Northern Alliance for Greenhouse Action (NAGA) comprising nine Councils in Melbourne's North.

Recently the final report on the trial was concluded. It should be noted that only small numbers of 42W cfls were trialled and this report is most appropriate for analysing the field performance of the 2x14W T5. The conclusion reads as follows:

"The AGL and NAGA trials tested the field and laboratory performance of energy efficient lights that can replace the existing 80 watt (W) Mercury Vapour (MV) technologies. The trial lights were:

- Pierlite Greenstreet 2x14W T5
- Sylvania Urban 50W High Pressure Sodium (HPS)
- Sylvania Suburban 42W Compact Fluorescent (CFL)

Pierlite Greenstreet 2x14W T5

Based on the results of these trials we recommend the use of the T5 as a standard direct replacement for the 80W Mercury Vapour. The T5 luminaire has an International Protection (IP) rating similar to other accepted luminaires. Maintenance is slightly increased which results in increased maintenance cost, because of two lamps and electronic control gear that may require periodic replacement.

Although unit cost is slightly increased in terms of maintenance and purchase the benefits of better uniformity of light across and along the street, better colour rendering and visibility, best current technology in terms energy performance, less lumen depreciation and lamp failure rate far outweigh the costs.

Sylvania Urban 50WHPS

Based on the results of these trials we do not recommend the use of the 50W HPS as a standard direct replacement for the 80W MV because of the reduced colour rendition and poor visibility to the human eye.

Sylvania Suburban 42W CFL

Based on the results of these trials we recommend the use of the 42W CFL as a direct replacement for the 80W MV only where 2x14W T5 cannot be used (e.g. some decorative streetlights)."

Appendix 5 : Maintenance Factor Determination

The Maintenance Factor is the product of the Luminaire Maintenance Factor (LMF) and the Light Loss Factor (LLF). The LLF is also known as the Lamp Lumen Depreciation Factor: Therefore MF = LMF x LLF

The Lamp Lumen Depreciation Factors used in these calculations have been interpolated from Lumen Depreciation Curves supplied by the various Lamp Manufacturers

	Initial lumens	Energy use (W)	Initial lm/W	4 year lm/W	Lumen Depreciation factor	4 year luminaire maintenance factor	4 Year Maintenance factor
80W MV – B2224	3800	96	39.6	26.1	66%	0.76	0.50
80W MV – Urban	3800	96	39.6	26.1	66%	0.84	0.55
2x14W T5	2400	30.5	78.7	70.8	90%	0.84	0.76
2x24W T5	3500	47	74.5	67.0	90%	0.84	0.76
26W CFL	1800	28	66.7	53.4	80%	0.84	0.67
32W CFL	2400	34	64.9	51.9	80%	0.84	0.67
42W CFL	3200	44	72.7	58.2	80%	0.84	0.67
50W HPS	3300	61.7	53.5	38.5	90%	0.84	0.76

Appendix 6: Lumen depreciation with temperature

High Intensity Discharge Lamps (HID), such as MV or HPS types can operate within a very wide range of ambient temperatures. Fluorescent lamps however are more temperature dependent.

The issues of interest include whether the T5 lamps will start in cold temperature and the impact on light output from these low temperatures.

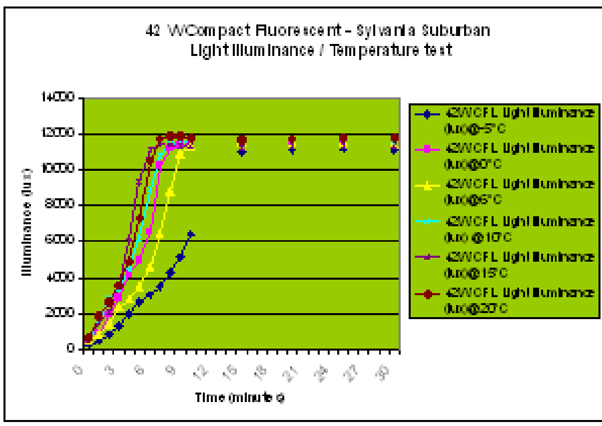
Starting

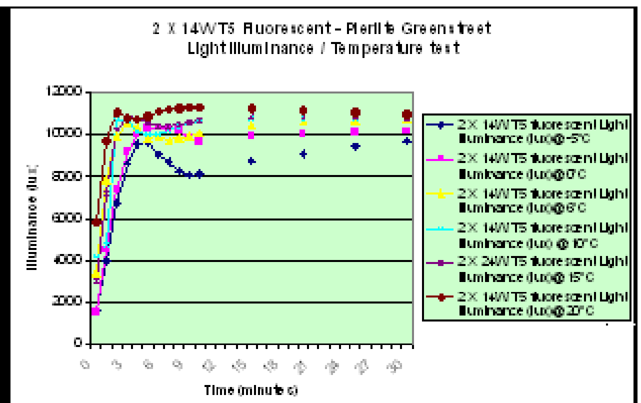
Light output vs time tests were carried out on a twin 14W T5 luminaire with non-amalgam lamps for ambient temperatures down to -5°C (see curve below) with successful lamp starting at all temperatures down to -5°C.

Noting that the lamps start at between 4pm and 6pm in Winter (close to the peak temperature for any given location at that time) it is unlikely that starting will be a problem for any T5 luminaires in Australia. Further information on start up temperature performance of the T5 lamps has been provided by Pierlite and is provided in *Appendix 7.*

Light depreciation in low temperatures

Light output vs time tests were performed on a twin 14W T5 luminaire with non-amalgam lamps for ambient temperatures down to -5°C (see curve below) with results showing that after about 30 minutes from lamp startup, there was little variation in light output eg after 30 minutes from statup, there is a 7% drop in light output between outputs at 0°C and 20°C and a 12% drop in light output between outputs at -5°C and 20°C.





A similar test was performed on a 42W CF with an amalgam lamp (see curve above) with the result that after 15 minutes there was little difference in light outputs over the ambient temperature range of 20°C to -5°C.

Also, the on-site measurements of trial areas of 2x14W T5 luminaires with non-amalgam lamps over the past three years have shown that there has been no significant difference between Summer and Winter illuminance readings once the luminaires have fully warmed up.

At Viewbank (a middle suburb of Melbourne) the coldest temperature measured over a 5 year period was -1.1°C. The temperature measured under 0°C less than 0.1% of the time.

Site	**Viewbank**	**Falls Creek**
Time	2002-7	2002-7
Coldest temperature in period	-1.1	-8.5
Number of days under 0^{o}C	20	767
Average hours under 0^{o}C on these days	2.1	14.1
% of time under 0^{o}C	0.095%	24.623%
Number of days under 5^{o}C	201	
Average hours under 5^{o}C on these days	3.7	

In Falls Creek (one of the coldest places in Victoria) the temperature remained under 0^{o}C almost 25% of the time and reached a coldest temperature of -8.5 ^{o}C.

The spacing table below (based on light outputs after 4 years of service taking into account lumen depreciation and maintenance factors) was produced using T5 non-amalgam lamp light levels at 0^{o}C (a 7% drop in output from the 20 ^{o}C level) & -5^{o}C (a 12% drop in output from the 20 ^{o}C level) to compare the light spacings with 80W MV lights.

Category P5 Lighting		
7.5m Mounting Height	**15m road reserve**	**20m road reserve**
80W MV (Urban)	82m	78m
80W MV (B2224)	76m	74m
T5 twin 14W (at **0^{o}C**)	82m	80m
T5 twin 14W (at **-5^{o}C**)	80m	78m

This information shows that even at 0^{o}C & -5^{o}C the T5 luminaire with non-amalgam lamps will generally perform to a similar or better standard than the 80W MV either in the Urban (the new style of luminaire) or the B2224 (the older style that is by far currently the largest installed by volume).

For any new installations, designs should take into account the implications of extremely low temperatures. However, it is recommended to make designs easier by utilising the amalgam lamp as the standard 14W T5 lamp when it becomes available.

Appendix 7 : T5 Temperature Start-up Test

PIERLITE®
professional lighting solutions

Pierlite Pty Ltd
ABN 62 008 173 359
96 – 112 Gow Street, Padstow
PO Box 314, Padstow
New South Wales 2211
Telephone +61 2 9794 9300
Facsimile +61 2 9707 4190
E-mail lighting@pierlite.com.au
Internet www.pierlite.com.au

Laboratory Report **No. PLR0129**

Product: Green street luminaire

Manufacturer: Pierlite P/L

Test Type: Cold start test

Result: refer below

Date: 17-5-05

A 2x 24W Green Street luminaire was placed within the engineering freezer and left over a period of 48 Hrs in the off state, the freezer temperature dropped down to -15ºC.

The GS224 luminaire had power applied to it after the 48Hrs were it switched on at - 15ºC, the following ambient also tested without any delays in switch on,(note light levels were not measured in this test).

Temperature	Switch on
-5ºC	√
-10ºC	√
-15ºC	√

the test ended at -15C were the freezer could not drop the ambient any further.

Photo of Green Street in freezer
After testing.

George Ebejer

Senior Electrical Testing Engineering

Appendix 8 : Inputs into OMR Prices

The following data can be used to input into the ESC Public lighting OMR model.

	Pierlite T5	Sylvania CF
Depreciation Period – luminaire body	20 years	20 years
Lamps - bulk change	Every 4 years	Every 4 years
PE cell – bulk change	Every 8 years	Every 8 years
Gear Tray – bulk change	Every 8 years	Every 8 years
Proportion of lamps that fail between bulk changes	8.6%	14%
Proportion of Gear trays (ECG's) that fail between bulk changes	5.5%	5.5%