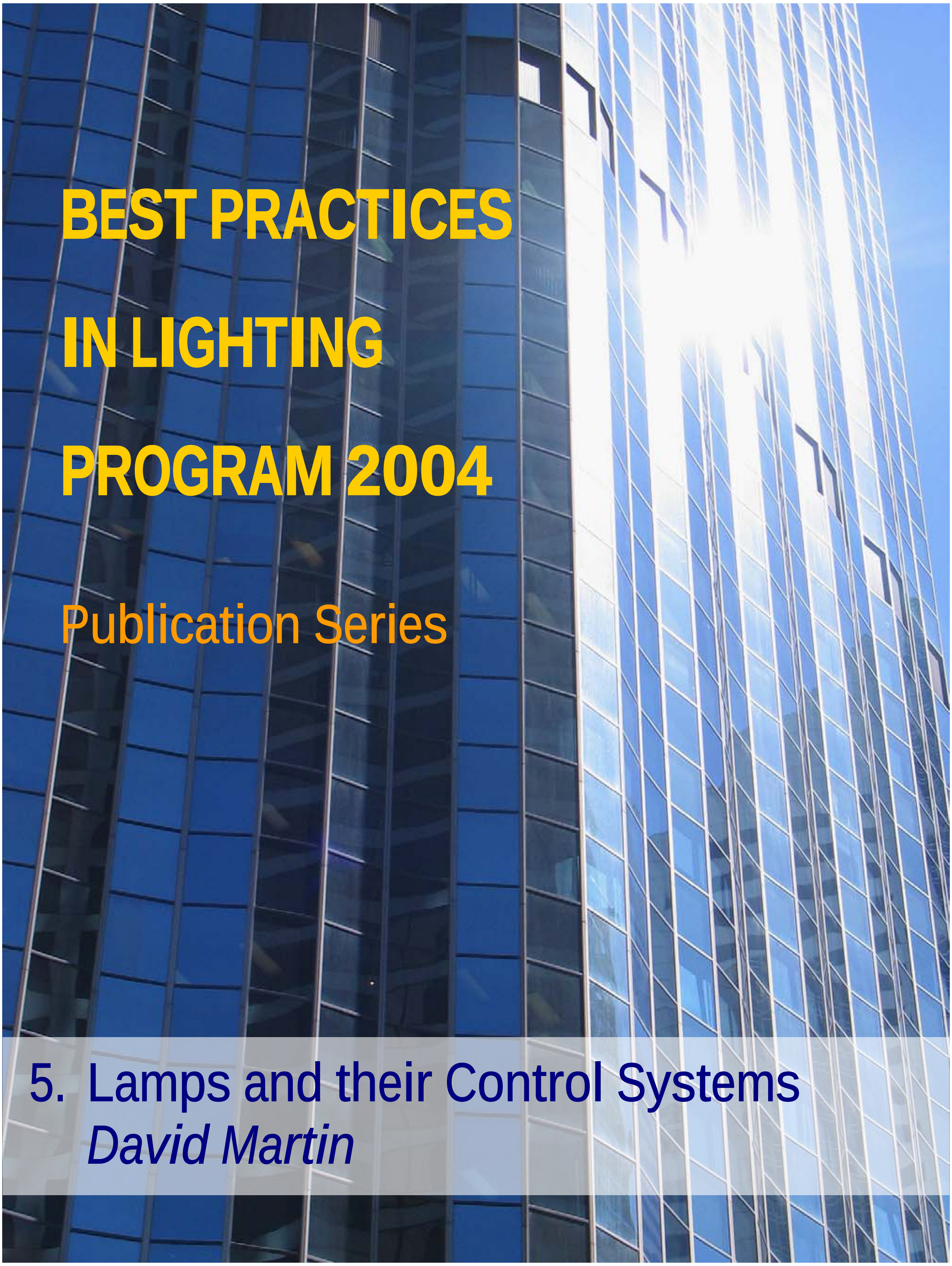

BEST PRACTICES IN LIGHTING PROGRAM 2004

Publication Series

5. Lamps and their Control Systems

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LAMPS AND THEIR CONTROL SYSTEMS

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LAMPS AND THEIR CONTROL SYSTEMS

1. Introduction to Lamps and their Control Systems

Planners can choose from an extensive range of electric lamps and associated control systems to provide predictable and generally controllable lighting, commonly termed artificial lighting - or perhaps it should be "replicable" lighting, a more meaningful and descriptive variance on the term. "Artificial" it may be but we have come to rely completely on "Electric Lighting" as a readily available commodity. It is part of our everyday existence and we have to learn to live in harmony with it just as we have needed to adapt to sunlight.

When wisely chosen, we can use lamps and controls to emulate nature, if desired. By providing a degree of variation in the lighting, we can manipulate the lighting levels to suit usage; we can create ambience; we can introduce additional economies and, through the right choices, reduce any environmental impact our decisions may have.

As with most things in life, we do have choices. Lamp manufacturers generally provide the designers with at least a couple of options with each type/style of lamp so it is imperative that those selecting lamps and systems establish the criteria for their choices.

For the achievement of "Best Practice" in Lighting, consideration should be given to the following:

- Lamp Efficacy*, and thus Energy Usage/Saving
- The degree of brightness control needed*
- Colour and Colour Rendering ability*
- The need for "instant" light
- Any safety or security requirements
- Controllability, both in the distribution and variation of light output
- If the lamp is to be a visual component of the decor, the effect required.
- Ease of maintenance and eventual disposal
- Overall costs of ownership*

* *See Glossary for further explanation*

By considering these points from the outset, then by applying the guidelines set out in available Standards/Codes of Practice, lighting of good long lasting quality should result.

1.1 Lamp Characteristics

Electric Lamp developers, right from the start, have accepted the challenges thrust upon them by this list of requirements: increased lumen output, longer life, better lumen maintenance have always been ongoing objectives.

Also flowing from the above considerations, are some more specific lamp characteristics, linked to the design process:

- Type of light source - Colour appearance of the lamps, Is a Reflector type beneficial?
- Size, shape - Can the parts be located conveniently?
- Compatibility with the electrical system - Voltage, Wattage, (Current)
- Type of Control Gear - Dimmability
- Burning position - Lamp life, colour stability.

This review will cover these topics where they become important in terms of lamp performance and application.

1.2 The Six Families of Electric Lamps

A review of the six families within the two principal lamp technologies used, Incandescent Filament and Gas Discharge, highlights the benefits to be derived from selected types and a closer analysis will identify the "Best in Class".

Table 1. Comparison of key lamp parameters

		Lamp Type	**Light output** (lm/W)	**% Drop over life**	**Colour in Kelvin**	**CRI**	**Average Life** (kh) (50% alive)
1	**INCAN**	Tungsten Filament	7 -18	30	2700K	100	0.75 - 2
2	**"**	**Tungsten Halogen**	12 -26	10	3000K	100	2 - 5
3	**GAS**	**Linear Fluorescent**	**45 - 104**	**30 to 5**	**≥ 6 options**	**60≥ 90**	**8 - 24**
4	**"**	**Compact Fluorescent**	33 - 75	18 to 12	≥ 5 options	60≥ 80	6 -15
5	"	Mercury (Phosphor coat)	42 - 60	35	3300,3800K	≅50	12 - 24
	"	**Metal Halide**	**65 - 120**	**45 to 10**	**≥ 5 options**	**65≥ 90**	**6 - 20**
6	**"**	**High Pressure Sodium**	50 -150	30 to 10	2000,2600K	20 -65	10- 50

Note: Low Pressure Sodium lamp omitted, as they are not commonly used – see later comments

Even though the use of the Incandescent lamp should be restricted as much as possible, there are some reasons why we continue to use them in commercial and institutional lighting. For this reason, the Halogen lamp using "Redirected Energy" has been chosen as a "Best Practice" option. As the GLS lamp has moved to Halogen, the Mercury Discharge lamp type has evolved over time into the Metal Halide lamp, so it also is not covered in detail. In the USA, the mercury lamp is being seriously considered for obsolescence for the same reasons applied to the T12 Fluorescent lamp: they are inefficient with poor colour rendering abilities and high mercury content.

Based on the normally compared lamp parameters, it can be seen that "Best" efficiency (energy saving) and therefore economy often come at the expense of colour rendering ability, while best colour rendering, along with better than mid range economy, is available in three lamp families only – the Linear/Compact Fluorescent and Metal Halide groups. In these families, T5 Linear and high wattage Compacts Fluorescent and Ceramic Arc Tube Low Wattage Metal Halide will be examined in more detail.

Of the latest lamp types on offer – **Light Emitting Diodes** (LEDs - a third "electric light" technology – electrically stimulated semiconductors) and **Induction lamps** (Induced magnetic field electrodeless Gas Discharge type) only the later has been included. These light sources presently display efficacies below those of Fluorescent and HID; however, they are fast finding applications in Effect and Special Purpose lighting situations because of their extremely long life expectancies with the reduction in what would otherwise be extremely high maintenance bills.

Before looking at the products selected, drawing conclusions as to how they will contribute and how they may best be applied, let's look at some of the more general considerations now facing the planners of lighting installations.

2. The emerging considerations for "Best Practices"

To achieve the best overall outcome in a lighting installation, we need to go beyond the selection of products that provide the lighting and consider the ongoing implications relating to our surroundings. When we examine the cost of providing lighting, very little thought goes into an assessment of the financial burdens our decisions may place, not only on those who eventually take ownership of an installation, but all of us in the longer term, by way of pollution, resource usage and even our own well-being.

2.1 Environmental Issues

Energy saving by reducing the lighting energy load is important for environmental protection but so too is control of resource usage and energy usage in the manufacturing of lighting equipment and eventually also, in minimising waste, particularly hazardous waste.

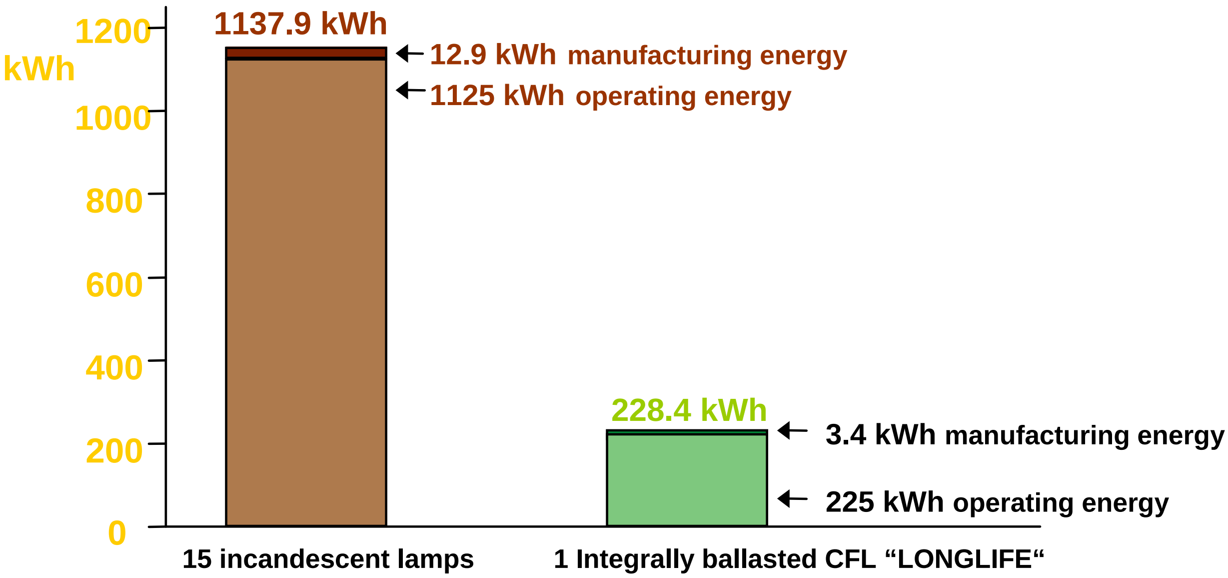


Figure 1 - Energy used in making and operating GLS Filament lamps and one CFL lamp - for same light over 15000 hours – does not include human energy in lamp replacements.

In this example we have a clear picture of the energy generated to make, and then operate two lamp types over an equal time period[i]. If this energy is from fossil fuels, apart from the release of "greenhouse effect" gases in related proportions, similar proportions of Mercury are also released into the atmosphere. There is now only a small amount of Mercury in all commonly used low-pressure Gas Discharge lamps and hence the threat from Mercury pollution, via fossil fuel energy production associated with the Incandescent lamp usage, is far greater than that imposed by many of the newer discharge lamps.

2.2 Control of unwanted Radiation

All lamps emit Ultra Violet and Infra Red radiation in proportions that vary with lamp type. Later, comments are made about the heat output to be expected from the Incandescent lamp and although not such an issue, High Intensity Discharge lamps. To withstand the higher temperature levels generated in the Halogen and HID families, these lamps generally have envelopes made from Quartz or similar glass[ii]. Unlike the glass normally used in GLS and Fluorescent lamps, this material does not act as a screener, allowing a larger component of Ultra Violet energy to be transmitted.

Standards (AS NZ 60598) now stipulate that lamps/luminaires have suitable UV controls in place. This is particularly important in lighting applications such as retail outlets, museums and art galleries, where UV sensitive material is displayed. Excessive exposure to UV can result in bleaching effects or material degradation resulting in discolouration or brittleness.

Lamps that do not incorporate a glass outer envelope (i.e. only use Quartz) generally now employ a special UV Filtering coat, applied during manufacture. Packaging is now generally marked to indicate this feature. Alternatively, such lamps must be used in enclosed luminaires only.

2.3 Planned Maintenance – Relamping.

The guidelines provided in the Australian "Interior Lighting" Standard suggest that all lighting design should be based on a **depreciated not initial** Lumen Output, one that takes into account the fall off over a pre-determinable lamp life span. Many recently developed lamps offer both improved Survival rates and Lumen Depreciation rates (no greater than 10% depreciation over life) so a key factor in the decision making process now becomes an understanding of the "economics" associated with "Spot" and "Bulk" lamp replacements – deciding on the number of failed lamps that one can afford to replace prior to a bulk change.

Lamp manufacturers often quoted values for "Service" life or "Economic" lamp life, which would in the past, be based on say a 20 or 30% fall off in Lumens. This figure would generally be used as a guide for lamp replacement.

Now the Survival rated becomes more important. For "Best Practice" to prevail, maintenance programs should be considered at the outset and the "economical lamp life" determined by using the Lumen Maintenance curve in combination with the Lamp Survival curve. Obviously, this point should coincide with the time of Bulk Replacement.

By applying this recommendation, lamp life may equate to a burning period well short of the "Average Rated Life" statements commonly in use.

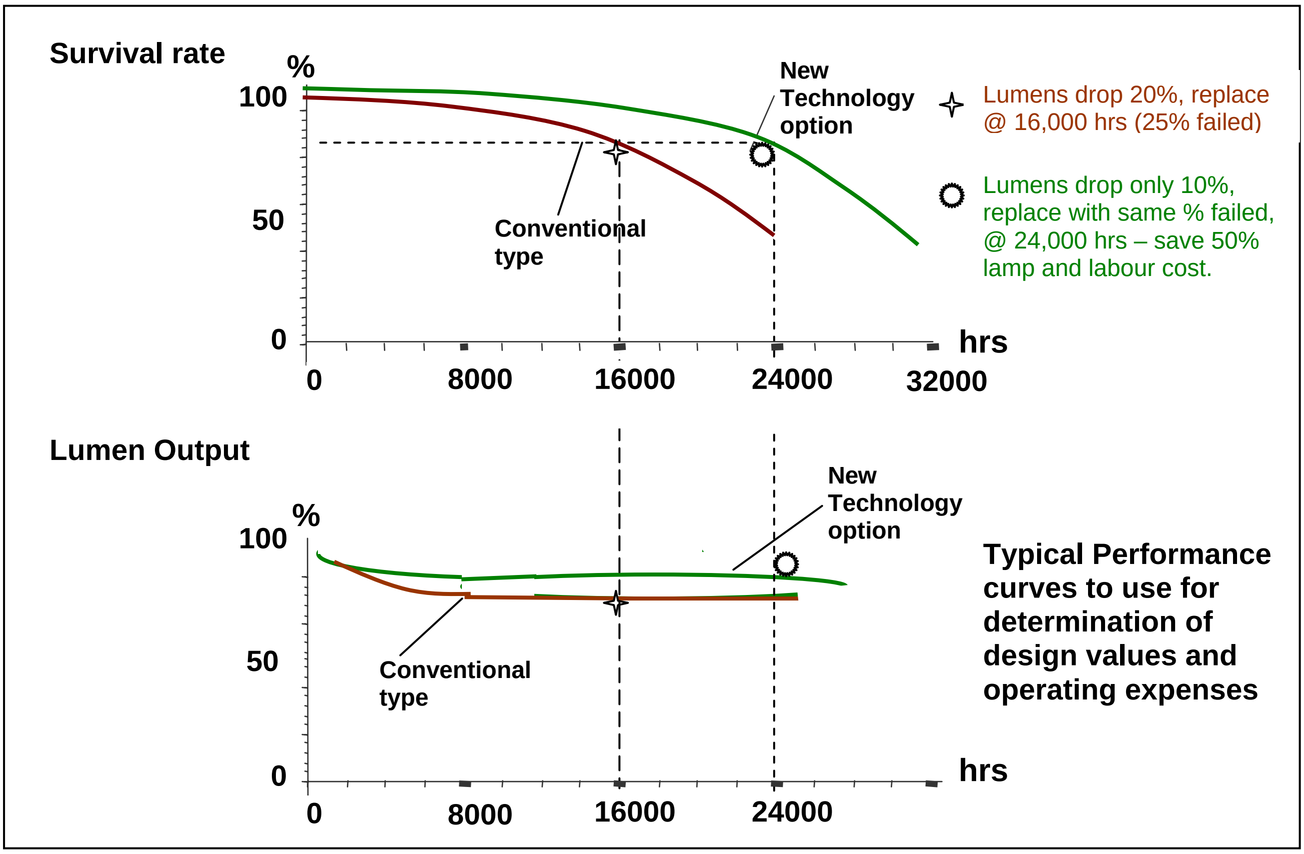


Figure 2. Comparative calculations can be done to determine (a) the best system of maintenance and (b) the time to set for a Bulk Replacement, if this is appropriate at all.

Most lamp manufacturers now offer Lighting Analysis programs (also via the Internet), linking these to data on their product. Any specification proposing new lighting schemes or refurbishment of existing installations should include an "accounting statement" to show the "pay back" to the end user.

2.4 Disposal and Recycling

In the past decade, considerable work has been done to minimise the amounts, not only of hazardous materials but also other materials such as glass, metals and plastics used in Gas Discharge lamps. In Europe and USA, Discharge lamps are however, now categorised for special monitoring, in terms of their hazardous waste content. There is also an infrastructure in place for the collection and recycling of the Mercury-reliant Gas Discharge lamps. In Europe, the "End User" is starting to pay for the collection of "Spent" Fluorescent lamps and while nearly all the bi-products of the recycling process are re-usable, they have very little value to the recycler unless there are links with lamp manufacturers.

In Australia, recycling facilities are available; however, the costs of the process would be high, as no local lamp manufacturing industry exists. Adoption of "Best Practice" would therefore tend toward use of the latest technologies where maximum effort has been made to minimise hazardous waste (Mercury) and material content. Filament lamps on their own do not contain any environmentally sensitive substances and there is no significant economic justification to recycle.

2.5 Lamp Economics - The costs of owning and operating lamps

In the example below, it will be noted that lighting equipment incorporating the newer technology is relatively expensive, essentially because of their newness and therefore at present, smaller manufacturing runs – with increase usage, this should change, to again make the electricity component a very large part of the total costs. A small additional initial investment in a more efficient system of lighting could well earn from say 50% up to even 80% saving in Operating Cost, paying for the additional outlay on original equipment and reducing maintenance expenses.

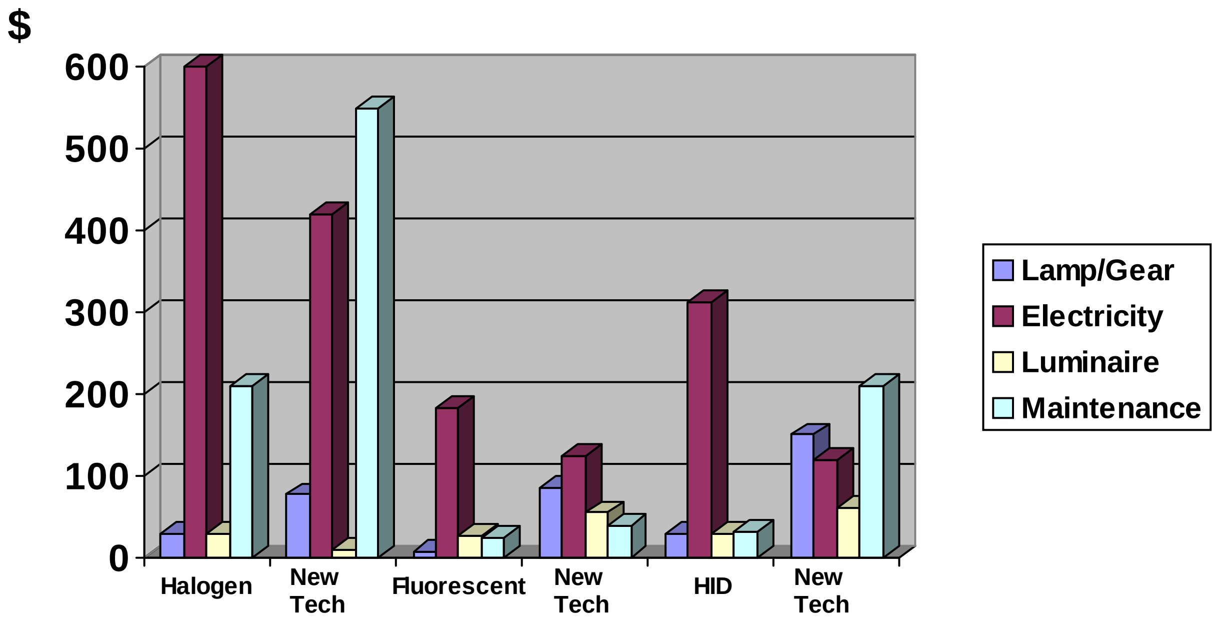


Figure 3. Comparison of typical cost components for conventional practice and the New Technology options for equal lumens over a 10 year period.

In Europe, for example, the practice of many street lighting bodies was to adopt a "Bulk Lamp Replacement" maintenance programme that scheduled a re-lamp every three years, calculated on the life expectancy of the normally available Discharge lamps. The latest technology allows a change from the "3 year schedule" to a 4-year program, introducing a 33% saving on their lamp maintenance costs, no significant impact otherwise.

Because the purchase of electric power is reasonably cheap in Australia, it is often difficult to develop a strong economic argument for changes in Interior lighting practices - the outlay on the initial costs of lighting particularly in relation to the newer technology lamps will generally require consideration of the cost of ongoing maintenance and any savings to be achieved via reductions in the air conditioning load (if any). (see Attachment 1)

Simply replacing existing 26mm (T8) lamps with Triphosphor alternatives, and operating with electronic control gear provides a 28% saving in electricity. This is not sufficient to generate a quick "pay back"; however, by including any saving from this reduction in the electricity load into the cost of providing and operating Air Conditioning, the ROI result should improve.

3. Incandescent Filament Lamps

People are now reasonably well aware that the Incandescent lamp (the long serving GLS types and the Halogen types) is produced in a range of shapes, sizes and finishes, which cater for most needs in indoor situations. Unfortunately, they let us down badly when we look for any opportunity to reduce energy usage. Efficacies up to 37 lm/W are possible, at Colour Temperatures around 3300/3400 Kelvin; however, the life expectancy of such products is very short (the melting point of Tungsten is 3383^{0}C/3550K).

With the introduction of Halogen technology, improvements in efficacies from say 7/13 lm/W (GLS) to 15/26 lm/W were achieved and life expectancy increased from 1000 hrs to at least 2000 hours and in some cases, up to 5000 or 6000 hours with present day Low Voltage product introductions.

Despite these drawbacks – poor efficiencies and short life – these lamps obviously have some usefulness. After all, to remain viable for around 120 years should say something. It would seem, however, that development in the Incandescent Filament family of lamps has now reached its limits.

Filament lamps provide the following features,

- When switched on, they light immediately
- The filament is a relatively compact source of light; easily controlled
- They can be easily dimmed.
- They give off a warm light with optimum colour rendering ability
- They are easy to install and maintain

However, for most commercial and industrial situations, wherever possible, light sources from the alternative families of lamps should be preferred.

Filament lamps, although being somewhat deficient in blue/green output, are judged to have a Colour Rendering Index of 100 – the maximum. This reflects the fact that they do emit a continuous spectrum of light, which gives them the capability of rendering all colours. We are also well acclimatised to the warm light they provide, so the filament lamp became the yardstick by which other warm coloured lamps would, in terms of their Colour Rendering abilities, be judged.

The heat generated by filament lamps is a concern (between 80% and 90% of the energy input is given off as heat). This must be considered in the design/choice of luminaires; the location of lamps/luminaires in relation to heat sensitive objects; the impact on building heat removal systems (Air Conditioning); and also by understanding the environments in which they may be operated**.**

3.0.1 Energy Usage and Lumens generated

A European study[iii] within a market segment suggests that of the total electricity load consumed by GLS lamps each year, 70% is in households. Total electricity usage on GLS lamps in businesses came in at 18 and 20% of the amount used by the Fluorescent and HID lamp types, respectively. The energy usage via GLS lamps in businesses was only assessed to be 8.5% of the total business lighting load.

This study also suggests that this GLS component only generated 4% of the light output provided by all lamps. Halogen lamps only make up 3% of Businesses Total Lighting Load and 12% of the total domestic lighting load, contributing only 1% of the lumens.

In the commercial markets in Australia, these figures may not be quite so dramatic; we are tending to employ Halogen lamps extensively, when the features provided by filament lamps are important.

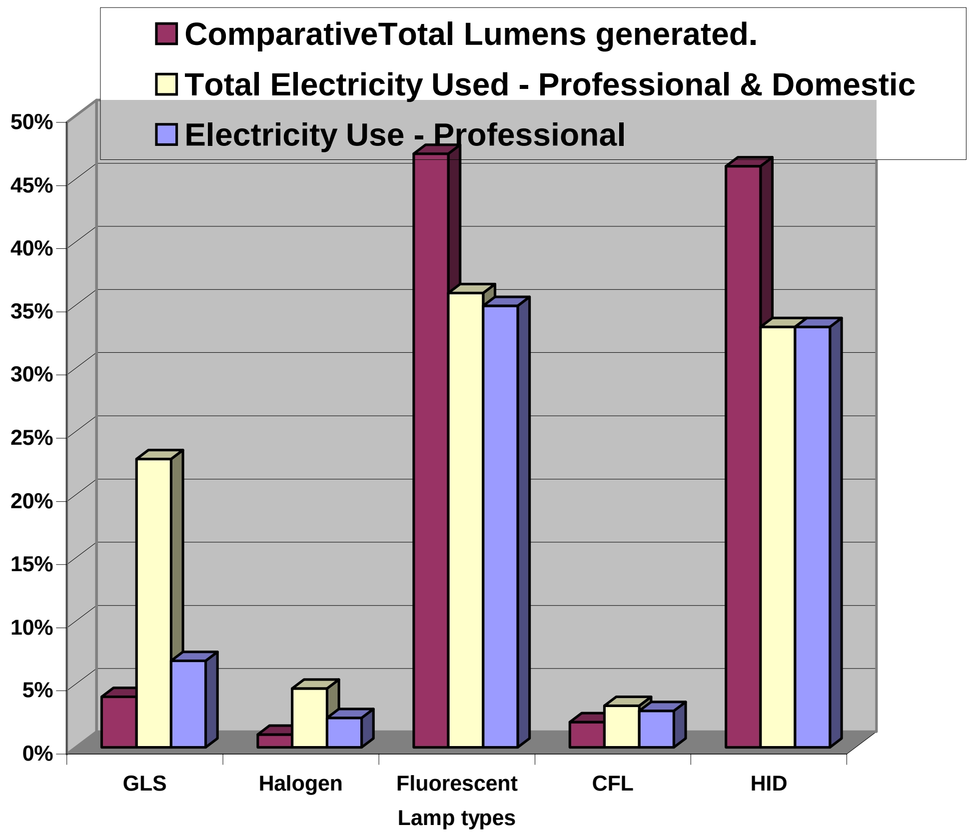


Figure 4. Comparison of electricity used per lamp type – ELC Assessment – 2001

3.1 GLS Incandescent Lamps.

Incandescent lamp (GLS) technology has not changed much over the past 50 years, some new shapes and finishes, slight improvements in lamp efficacy. These lamps are low priced products, and maintenance is generally possible without needing a tradesman. We accept the fact that they are a very inefficient producer of light and therefore poor options as conservers of electricity.

They are mainly used in domestic applications and in this situation, their short lamp life does not therefore come into consideration.

3.2 Tungsten Halogen Lamps

The tungsten halogen lamp (ILCOS type H) [iv] is an incandescent lamp with several characteristics that make it superior to the conventional filament lamps. The additional benefits of halogen lamps are:

- An improvement in efficiency by a factor of two, over GLS lamps
- Longer Life, at least doubled.
- More Compact Size and more compact filament, allowing for better control of the light
- Excellent Lumen Maintenance

They possess these enhancements because of the regenerative process known as the Tungsten Halogen Cycle, which was devised around fifty years ago. There are a number of other differences that also contribute to a reduced rate of filament vaporisation and increased light output (Efficacy). The lamp manufacturer can either use this technology to increase the lamp life, or alternately, by leaving lamp life unchanged, increase the filament temperature to produce more light.

With all this, we have some practical Tungsten Halogen lamps (generally applied in the Entertainment /Reprographics area) that achieve around 35/40 lumens/watt efficacy, current new models used in the Commercial/Industrial/Domestic areas are achieving around 25/26 lumens/watt, with longer life.

Through the Halogen process, we have a lamp that can operate at a higher temperature than GLS, so providing a slightly higher blue/green output. Hence the tag “whiter and brighter light throughout a longer life”.

If the European study mentioned above can be taken as a guide, then Halogen lamps, with only 12%% of the total domestic electricity load compare to 70% for GLS, should be utilised more often, thus opening up the potential to bring about a significant energy usage reduction, with probably a halving of the Green House gas emissions, tied to domestic lighting.

The range of Tungsten Halogen lamps is evolving to cover most applications where previously we would have used a GLS lamp, essentially, the only negative is increased initial cost. In the long term, however, lower product and operating cost benefits should generally balance out the equation. Some Halogen types operate on mains voltage (230/240V) and others, which are referred to as “Low Voltage” (ELV), usually 12 volts. Other lamps are also produced for specific tasks and voltages, e.g. 10V and 24V (ILCOS code contains 230, 12, 24 etc).

To operate the Low Voltage lamps, obviously a 240 V AC to 12V AC transformer is required.

3.2.1 Mains Voltage Lamps

Mains voltage tungsten halogen lamps are available in three main forms:

- The original **Double ended** types, commonly used for floodlighting and display work.
- **Single ended** lamps, which can be used as replacements for GLS lamps
- **Reflector** lamps, also being used to replace standard Incandescent reflector types, bringing the advantage of more compact dimensions.

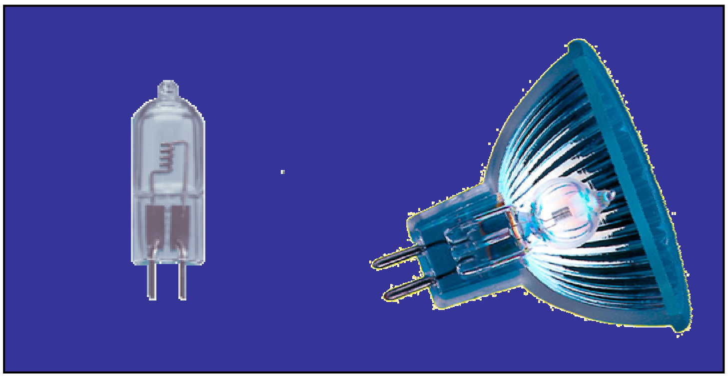
New types of 240V Single Ended Halogen lamps are emerging, which have their own unique configuration and offer even more compactness. No longer do we need to use a low voltage system to obtain minimisation. These new lamps provide double the life of the conventional filament lamp they can replace.

The newest
230V Halogen Lamp
– extremely compact

3.2.2 Low Voltage Lamps

Low voltage tungsten halogen lamps are available in a range of wattages and sizes, in two main forms:

- **'Capsule' or 'Bi-Pin'** lamps
- **'Reflector'** lamps using either aluminium or dichroic reflecting surfaces:



On right, the latest Dichroic Mirror Reflector lamp – "see thru" to show bulb with redirected energy technology.

Tungsten halogen lamps with integral reflectors are available to provide various beam angles. There are two main types of coatings used; the less expensive aluminium is used where the heating component contained within the beam of light (energy) cannot affect items within its sphere of influence.

Dichroic coated Reflector lamps are now a very popular choice; this type of reflector allows heat to pass backwards through the reflector, so reducing the amount of heat in the light beam by up to 66%.

A note of caution is relevant to the achievement of design expectations with Halogen MR16 Dichroic reflector lamp performance. Performance depends very much on the ability of the reflecting surface to stand up to its environment and as various quality finishes are now being applied, designers through to end users, should be aware that anticipated performance may be compromised by diminishing reflecting capabilities as the lamps age [v]. Packaged products do NOT clearly advise these differences, only by seeking detailed information about life expectancy and lumen maintenance, will this become obvious and even then, the outcome may still be varied by field conditions – voltage and ambient temperature. (refer to earlier comments)

3.2.2.1 Tungsten Halogen using redirected energy.

The latest technology being introduced into Halogen lamps involves reuse of the Infrared (heat) output to assist in building the energy level (temperature) within the tungsten filament itself, without using more electricity – an excellent example of conservation of energy[vi]. The resultant lamp type gives us the opportunity to replace a 50W Low Voltage lamp with the new 35W redirected IR type, with little reduction in light output.

This technology is being applied successfully across a range of LV Halogen lamps, in single ended Bi-pin Capsules, MR16 Dichroic reflector, as well as other styles of PAR reflector lamps. While in use with Mains Voltage Double Ended Linear Halogen lamps, it has been found that the benefits are not as great as when applied to low voltage lamps, as LV filaments prove more efficient than those designed for 240V.

3.2.3 Transformers to operate the Low Voltage lamps

All low voltage halogen lamps require either a dedicated low voltage electricity source (AC or DC) or if the electricity supply is 230/240V AC, a transformer to convert the mains voltage to the lower voltage required by the lamp, usually 12 volts. There are two main types of transformers, the older copper winding, iron core 50 Hertz device (Ferro-Magnetic or CCG) and the more recently released electronic component types, which converts the 240V AC into a High Frequency supply, (Electronic or ECG).

Electronic technology transformers provide at least a 50% reduction in watts consumed by this component of the lighting system and can also contribute to a longer lamp life. The initial cost of the newer technology is naturally higher at this stage however, the gap between it and the iron cored copper wound product is reducing as volume of usage increases. The acknowledged benefits of the old technology were excellent reliability under a variety of field conditions and of course, long life.

Iron cored cooper wound Transformer - CCG

Transformer using electronic technology - ECG

3.2.3.1 The Electronic Transformer for LV lamps

Electronic transformers are lighter and generally more compact than the conventional iron core transformer, other benefits are:

- Electrical and thermal overload protection (electronically reversible)
- Dimmable with either leading edge or trailing edge dimmers
- Compact size allows installation in very shallow ceiling spaces (minimum depth of 60mm) through cut-outs
- Soft start – extends lamp life
- EMC compliant (electromagnetic compatibility)

When using multiple lamps with conventional iron core transformers, generally, if one of the lamps fail, then the remaining lamps can be subjected to an over voltage; this can result in premature failure of the remaining lamps. Well-designed Electronic transformers can, to a degree, compensate for such a change in load[vii].

It is particularly important to ensure adequate ventilation around the electronic transformer because in general terms, they are less tolerant to high ambient temperatures than their magnetic iron core equivalent.

3.3 Dimming of Filament lamps

There are no major concerns about operating filament lamps on readily available suitably rated Dimmers. Incandescent lamps can be dropped to very low levels of light output and performance otherwise, is not affected. The dimmers for Halogen lamps may be designated as "leading edge" or" trailing edge" types and if they are to operate a Low Voltage lighting system, using electronic transformers, there must be compatibility between the components. The "trailing edge" technology is to be preferred.

With Halogen lamps, it should be noted that the performance is a little unpredictable when operating at settings below 10% of peak. Normal life expectancies may be affected slightly and the lamp colour tends to warm up, moving back to GLS colour.

Dimming of both these lamp types should be considered as an energy saving tool.

3.4 Why Halogen lamps may be chosen to align with "Best Practice"

Table 2.
Typical options available to provide around 1500 lumens (initial) – All Universal Burning

Characteristic	GLS	Halogen	Redirect IR Bi-pin	Internal Ballast CFL	Linear Fluor 26mm Triphos	Linear Fluor (1) 16mm Triphos
ILCOS Code	-	HSGSBT	HSGST	FBT	FD	FDH
Rating Watts	**100**	**100**	**65 + 4**	**23**	**18+5**	**24+3**
Size	105x60	105X32	**44x12**	173X58	590x26	549X16
Lumin. Flux	1360	1500	1750	1500	1350	1750
Control(Beam	Good	Good	**Best**	Fair	Asymmetric	Asymmetric
Depreciation	30%	10%	10%	20%	8%	10%
Efficacy-lm/W	13.6	15	27	75	75	74
EOS efficacy	**9.5**	**13.5**	**24**	**60**	**69**	**66**
End System lm/W	9.5	13.5	**23**	**52**	**59**	**58**
Light Colour	Warm	Warm	Warm	Warm	**>4options**	**4options**
Colour Temp.	2700K	**2900K**	**3000K**	2700K*****	30,40,60	27,30,40,
CR Index	100	**100**	**100**	80+	80+	80+
Control Gear	None 240V	**None 240V**	ECG-to 12Volts	240V Ready	Low Loss Ballast	ECG only
Dimmability	Easy	**Easy**	**Yes**	Develop	Select purpose built ballast and wiring/controls	
Start Delay	Instant	**Instant**	**Instant**	Flicker free <2s	Flickers for 3s	Flicker free<1s
Run Up time	Instant	Instant	Instant	3 min	3 min	3 min
Restrike time	Instant	**Instant**	**Instant**	< 0.5s	3 secs	< 0.5s
Service Life	1000	2000	**4000**	**12000**	**15000**	**24000**
Disposal	Usual	Usual	Usual	Usual	As per EPA	Optional
Life Cycle Cost				#		#

(1) See later comments re ambient temperature – for bare lamp i.e. @ 25°C
***** Most popular, other colours - 3000, 4000, 6500K also available.
# Orientation of lamp can affect outcome

4. Gas Discharge Lamp Technology

Discharge lamps now cover around 80% to 90% of our total artificial lighting needs, with linear low-pressure mercury discharge lamps - “fluorescent lamps” as we know them, making up the bulk of the discharge lamp family. After a relatively static period of 30 or 40 years, the last two decades has seen a concentrated effort on research, resulting in the introduction of many new and improved products.

The fluorescent lamp has seen the change from 38mm diameter (T12) to 26mm (T8), then the introduction of improved phosphors to provide greater efficacies and improved colour rendering capabilities. The fluorescent category grew to include compact versions, suggested as “energy saving” replacements for filament lamps, again in a variety of shapes and sizes, both with and without integral ballasts.

These fluorescent lamps all offered efficacies of between 60 to 100 lumens per watt, so provided the designer can deal with the larger lamp sizes, the fact that they are from four to five times more efficient than filament lamps, makes them very acceptable. With triphosphor technology now widely spread throughout the range of fluorescent lamps, Colour Rendering ratings between 80 and 95 are readily achievable, making them acceptable for most applications.

At the “powerful” end of the “Gas Discharge” lamps comes the High Intensity Discharge range, comprising elliptical or Reflector Mercury Vapour; the Metal Halide options in a variety of shapes, sizes and colours and Sodium, both Low Pressure, the achiever of maximum efficacies; and High Pressure, with its extremely long life expectancies.

Within the High Intensity Discharge family, efficacies of 150 Lumens per watt are available, while still using a lamp with tolerable colour rendering properties. The High Colour Rendering versions of these lamps are now being developed in much more compact forms, so here we have a further challenge to the Filament lamp.

One of the drawbacks of Gas Discharge technology has been that these lamps were slow to strike. Now with the increasing usage of electronic ballasts, the start up delays are considerably minimised and are virtually non-existent with Fluorescent lamps.

Most recently, to align with the push to reduce mercury in our environment, the Industry achieved lower mercury content in the 26mm fluorescent lamp (4.5mg + 0.5mg) and other newer lamps also have acceptable levels to allow normal disposal at “end of service”. With current Discharge lamp technology however, there are limits on how far the developers can move to eliminate mercury all together, without compromising the operation and performance. In High Intensity Discharge lamps, at this stage only High Pressure Sodium lamps lend themselves to mercury reduction.

The types of lamps available within the Gas Discharge lamp category are:

Fluorescent Technology - (utilising Phosphor)	-	Double Ended Linear Fluorescent; (38, 26, 16 (T5), 7 (T2) mm Diam). Compact Fluorescent, (Single, Twin, Triple, Single Ended Return tube, 2D Flat) Integrally ballasted Compact, 4 styles Induction Lamps
High Intensity Discharge - (High Pressure)	-	Mercury Vapour Metal Halide, Single and double Ended Quartz & Ceramic Arc tube Sodium, Low and High Pressure

4.0.1 Controlling Gas Discharge lamp operation

Gas Discharge lamps cannot be operated directly from the electrical supply. This is because they have a “negative” resistance characteristic – the current can continue to increase until the lamp eventually destroys itself – we need to employ a means of limiting the current. We refer to the most practical type of current limiting device as a ballast or choke. Other components can also be part of the discharge lamp’s “Control Gear”, these may be required to assist in starting, to regulate Power Factor, to allow dimming, etc.

4.0.2 Achievement of vastly improved Energy efficiency

The Gas Discharge technology is the area where most advances in energy saving light sources have emerged and there is still room for further improvements. It is envisaged that efficacies of around 250lm/W should be realisable in practical gas discharge light sources.

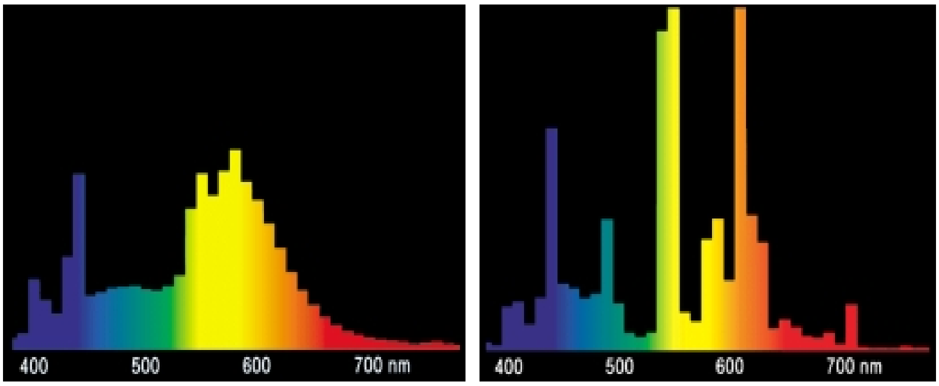
Fluorescent lighting is now the “light source of choice” for conventional office lighting and adoption of the latest technologies, with their “100 Lumens per watt” tag, has been very rapid. For industry and retail commerce, where high mounting heights and/or accenting are requirements, we now tend towards Metal Halide sources, rather than the “inefficient“ Mercury Vapour lamps.

It is interesting to note from the “European” survey that fluorescent lamp sales only accounts for 15% of the total sold and HID, around 1%, yet they apparently contribute 93% of the estimated lumens generated. This outcome from an electricity usage of only 73% of the total lighting load.

4.1 Fluorescent lamps

In fluorescent lamps (ILCOS type F), an Ultra Violet emission excites phosphors to produce light. The phosphor makeup influences the spectral output of the lamp, to produce a variety of “white light” colours, ranging commonly from 2700K through to 6500K or thereabouts.

Improvement in their quality became possible when it was discovered that certain “rare earths”, when added to the phosphor, improved the light emission. The resultant phosphors became known as “3 band” or “tri-phosphor” and these provided an increase in Lumens and improved colour rendering capabilities.



The spectral distribution of a cool white triphosphor lamp (right) is very different to that of a standard cool white lamp.

The Triphosphor has a colour rendering index of 80-89 Ra, while the standard lamp has a much lower CRI of 60-69 Ra.

Figure 5 –Spectral output of Standard Cool White (640) and Triphosphor Cool White (840)

The coating technology has improved again, to allow production of luminous efficacies in excess of 100 lumens per watt, although this is also dependent on the generation of a high frequency electric discharge, available through the use of electronic control gear. A typical example is the recently released 16mm T5 high efficiency lamp, which produces up to 104 lumens per watt.

Triphosphor lamps are more expensive to purchase than standard lamps however, their rate of luminous flux reduction or Lumen Maintenance over life is far better, offsetting the extra initial cost.

Table 3. Comparison of performance Triphosphor to Halophosphate (Cool White)

Lamp:	Colour Rendering:	Average Life - hrs	Luminous Flux:	Luminous Flux 4,000 hrs	Luminous Flux 10,000 hrs
36W-840 Triphosphor	Group 1B (80-89 RA)	15,000	3350 lm	3160 -94%	3100 - 92%
36W CW (standard)	Group 2B (60-69 Ra)	8000 to10,000	2850 lm	2280 - 80%	1995 - 70%

This new technology means fewer lamps would be required to provide the same light level as the previous lamps – 33% less or alternatively, maintenance would be greatly reduced because of the extended lamp replacement interval. (see Attachment 1)

Fluorescent lamps can be used:

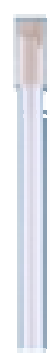
- When the electric lighting is required to operate for long periods
- When there are large areas with low mounting heights
- High luminous efficacies are required and
- Where precise optical control is NOT required.

4.1.2 Linear Fluorescent lamps.

Development over the last 10 years has seen the introduction of a number of significant changes in the Linear Fluorescent lamp technologies (ILCOS type FD, FM) and the modified options from these, (ILCOS type FC and FU). We now have a selection of fluorescent lamps to cater for a wide range of applications.

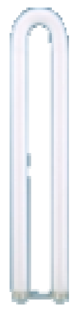
FD T8 – 26mm

FDH T5 – 16mm



FM T2 – 7mm

FC T8



FU T8

The lamp types can be summarised as follows;

- FD 38mm diam (T12) – oldest technology - Switch and Rapid/Quick Start types Standard
- FD 26mm diam (T8) – 1st phase - Switch Start Standard and Triphosphor
  2nd phase - Improved triphosphor, low Hg, HF operation
- FDM 7mm diam (T2) – Mid 90's - Cold cathode Miniature. HF operation only
- FDH 16mm diam (T5) – Developed over last 7 yrs - High Efficiency and High Output types
- 26 & 16mm Circular lamps - co-ordinated with above systems

Effectively, the 38mm diameter types are now being phased out in favour of the newer options. If necessary to use the U tube concept, the Compact Fluorescent options listed later, come into play. The FDH 16 and FDM 7mm lamps are only available with Triphosphor coatings. They also operate only on electronic control gear, while all others can be operated either on conventional control gear or electronic control gear.

The reasons for use and performance characteristics are generally covered above. In the majority of applications, linear fluorescent lamps would be housed within some form of enclosure and under these circumstances, where the heat from the lamp is contained, it is most likely that the 16mm T5 High Efficiency type becomes the lamp of first choice.

4.1.2.1 The impact of temperature on fluorescent lamp performance

When comparing 16mm T5 and 26mm T8 systems, bear in mind that their surroundings influence lumen output. Standards specify that the luminous output of fluorescent lamps be measured in ambient temperature of 25°C however, since actual temperatures around the lamp, particularly in enclosed recessed luminaires, usually exceed 25°C, compensation is necessary.

With this in mind, the FDH lamps have been designed to provide their peak luminous flux at a far more realistic 35°C. The tables below show the relationship between relative luminous flux and lamp compartment temperature for both lamps, when operating on electronic control gear.

Table 4 - Impact of ambient temperature on Fluorescent lamp lumen output

Lamp Data at 25°C (values generally published) On Electronic control gear						**Lamp data at 35°C On Electronic control gear**		
Lamp & colour	Lamp Length	System Power	Lumens	Efficacy lm/W	System lm/W	Lumens	Efficacy lm/W	System Efficiency
FD 36W T8 830, 840	1200 mm	35 W	3200	100	91	2944	92	84
FDH 28W T5 830, 840	1149 mm	31 W	2720	97	88	2900	104	94

When the FDH (T5) lamp reaches peak luminous flux at around 35°C, the FD (T8) lamp has already passed the temperature at which it peaks, and its flux has reduced to around 92% of maximum. Changes in the temperature also effect lamp voltage, so consideration should also be given to the reverse situation, mains voltage variation effecting lamp performance and here, the electronic ballast can assist, by controlling power to the lamp.

As it is often impractical to determine exactly what ambient temperature will exist within the luminaire once it has been installed, it is important that the luminaire manufacturer conducts thermal tests (as stipulated in AS/NZS 60598) and relates these to common room conditions, i.e. at ambient room temperatures of 25°C, 30°C etc. Consideration also needs to be given to the impact of air conditioning incorporated in or adjacent to luminaires and to the location of any commercial refrigeration units. FD T8 lamps should perhaps be preferred, particularly for open luminaire designs, in these circumstances.

4.1.2.2 The new 16mm T5 linear lamp technology

Although a 16mm T5 conventional technology fluorescent lamp has been available in low wattages for many years, as outlined above, this diameter tube has been adopted as part of a new concept, ILCOS family designation FDH. These new lamps, while broadly conforming to the most commonly available fluorescent lamp sizes, have really evolved as a complete lighting system [viii] rather than just an isolated lamp development. As stated, the FDH system consists of a 16mm double-ended tubular fluorescent lamp, optimised for use on a ballast that is specifically designed to run the lamp at high frequency, to enhance its efficiency.

One significant change introduced with this system is that the lamp length and wattages are different to those available with either 26 (T8) or 38mm (T12) fluorescent lamps. The lamps are approximately 50mm shorter than the most commonly used 26mm diam lamps.

The shorter length allows for easy integration into standard ceiling modules, also allowing for continuous end-to-end runs, an option that is not easily achievable with the FD systems.

To make the FDH T5 lamp even more unique, <u>two</u> quite different types have been developed:

- A high efficiency version (henceforth referred to as “HE”)
- A high lumen output type (henceforth referred to as “HO“)

Although both lamps are available in the same lengths, the HO lamps have higher wattages and therefore lumens, with a resultant increase in lamp luminance (glare).

The family of High Efficiency FDH lamps, in practice, offers efficiencies up to 104 lumens/watt - the highest of all fluorescent lamps. This increase in efficacy can be utilised via properly designed luminaires to bring about significant energy savings, even when compared to the already efficient FD 26mm triphosphor lamps. In some situations, in energy costs alone, up to 40% can be saved if the FDH High efficiency lamp with an electronic ballast replaces an existing 26mm T8 lamp, with conventional ballast. Even if the T8 lamp is used with an ECG there is still a savings potential in the region of 15-20%.

FDH lamps are not just an improvement on existing technology; they represent a radical break away from existing practice. The lamp diameter, reduced from 26mm to 16mm, permits an improvement in luminaire efficiency of around 5% over Triphosphor FD lamps. The smaller lamp diameter also helps introduce a further environmental advantage – less waste materials to dispose of.

Also, luminaires can be much smaller, thus saving on manufacturing material. As operation on electronic control gear also results in a longer lamp life than can be expected from an iron core ballast, the combination of FDH/ECG is clearly the more environmentally friendly option.

The High Output technology takes the FDH concept one step further, it is the “brightest” fluorescent lamp to come onto the market so far. It opens up a whole range of options, such as indirect lighting (up-lights), and even more compact luminaire designs.

The following table sets out the principal differences between these lamps types:

Table 5- Comparison of Lumen Outputs for the common linear fluorescent lamps

830, 840 Type	Length	**Luminous Flux at 25 °C**	**Luminous Flux at 35°C**
FDH 14W H.E. FDH 24W H.O Compared to Std18W	549 mm 549 mm 600mm	1200 lm 1750 lm 1350 lm	1350 lm 2000 lm 1215 lm
FDH 21W H.E. FDH 39W H.O	849 mm 849mm	1900 lm 3100 lm	2100 lm 3500 lm
FDH 28W H.E. FDH 54W H.O Compared to Std 36W	1149 mm 1149 mm 1200mm	2700 lm 4450 lm 3350 lm	2900 lm 5000 lm 3015 lm
FDH 35W H.E. FDH 49W HO FDH 80W H.O Compared to Std 58W	1449 mm 1449 mm 1449 mm 1500mm	3300 lm 4300 lm 6100 lm 5200 lm	3650 lm 4900 lm 7000 lm 4680 lm

Some of the best reasons for using FDH lamps include:

- They are more environmentally friendly than FD 26 or 38mm lamps, they have:
    - Reduced glass
    - Reduced gases
    - Reduced phosphor
    - Minimised Mercury content
- Luminaire costs will also benefit from the compact size with reductions in the costs of material, freight etc.
- Higher lumen output (at a realistic temperature) means fewer luminaires.
- Compact size means shallower luminaires, helping to work more effectively with building height and/or ceiling space limitations.
- The system as a whole will contribute to energy savings.
- Luminaires can be more aesthetically pleasing, while at the same time, contributing significantly to the quality of the lighting.

With FDH lamps being shorter and slimmer than FD 26mm, one other advantage is that there should not be any ‘mix-ups’ by contractors or maintenance personnel, once ongoing maintenance gets underway. A 16mm diam. T5 lamp cannot be installed in a luminaire designed for 26mm T8 lamps and vice versa.

The FDH HE lamps are also unique in regard to luminance; they display the same brightness (1.7cd/cm^2) in each wattage. This feature makes FDH HE lamps particularly suited for use in cove lighting systems, the illuminance on the ceiling, regardless of their wattage, will appear the same.

If combining different wattage 26mm lamps in a lighting cove, the appearance will vary since the luminance of the lamps are different. On the negative side, when using louvred or open luminaires with FDH HO lamps, attention needs to be paid to glare control. The HO T5 lamps have luminance levels from twice to nearly four times as high as those previously encountered with linear fluorescent lighting.

Despite these latest technology benefits, the physical size of the fluorescent lamp has always been an impediment in the quest for large lumen packages - size increasing with output. The advent of the Compact Fluorescent family and the FDH HO 16mm lamp has addressed this to some extent but even their 549 and 1449mm respective lengths for 6000/7000 lumens, is often still too long, to allow development of luminaires with better efficiencies. To achieve higher lumen packages or even greater efficiencies requires adoption of light sources that incorporate either a totally different approach, as is the case with newly developed technologies such as Induction lamp technology, or the use of different materials/technologies such as with HID lamps.

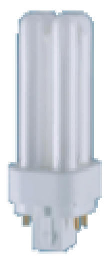
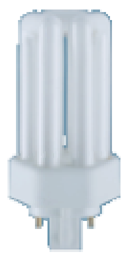
4.1.3 Miniaturisation – Compact Fluorescent lamps

This family of lamps (ILCOS types FB and FS) grew out of the need to find a system that could replace the incandescent lamp and provide improved energy efficiency. Lamp manufacturers are not quite there yet. There are some integrally ballasted models where the size has now been reduced to marry up with the incandescent lamp's envelop, however the initial cost price is still considered a little high by the target market – residential.

To provide the same light, Compact fluorescent lamps only used about 15 to 20% of the energy consumed by a GLS lamp. They only employ triphosphor technology and the colour options are similar to linear fluorescent, however, the choices have been purposely limited, tying the options to their usual applications, most Compacts for domestic use are 2700K. Like the Linear Fluorescent lamp, these lamps have a slightly lower CRI than the incandescent lamp, although this does not mean that the rendering of colours suffers greatly.

By using these lamps, one of the main features of electronically controlled fluorescent technology can be beneficially utilised – very quick start and restart in conjunction with the use of more compact, directional luminaires.


Integrally ballasted Compact Fluorescent – generic type FB

Single Ended 1, 2, 3 returned tube remotely ballasted Compact Fluorescent – generic type FS

4.1.3.1 Operating characteristics of Compact Fluorescent lamps

Compact Fluorescent lamps behave in the same manner as tubular fluorescent lamps[ix]. They are subject to variations in performance depending on voltage/current, ambient temperature as well as the burning position. They are often used in recessed downlight or enclosed luminaires, where a single lamp will tends to provide higher Light Output Ratios (LORs) than that available if two lamp lamps are used. This is largely due to the combined thermal effect of two lamps, raising the temperature inside the luminaire, which in turn results in lower light output, there is also the light loss factors associated with inter-reflection and absorption of light.

To counteract this, some types now use amalgam technology, which allow the lamps to operate at maximum output over a broader range of temperatures. The luminous flux will be at least 90% when operating in the range from 10°C to 70°C ambient temperature.

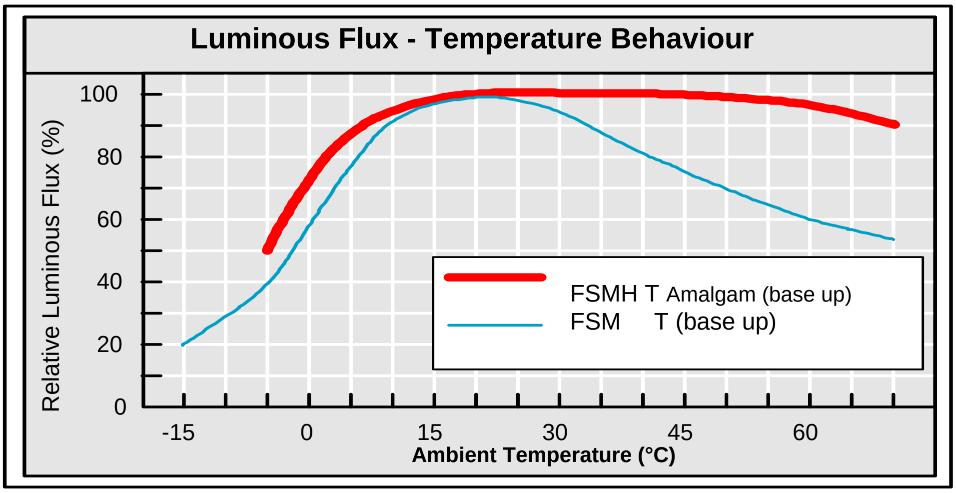


Figure 6. Comparison of CFL Lumen Output, with and without Amalgam technology.

4.1.3.2 Single ended remotely ballasted Compact Fluorescent lamps

There are various types (shapes and sizes) within the range of “remote ballast” compact fluorescent lamps. All incorporate a “returned tube” construction. A number of lamps (2 pin versions) have built-in starters, while all lamps with 4 pins are specifically designed for electronic ballasts (some may be used with a choke and a starter). Compact lamps to be used with electronic ballasts are designed with different bases so that the lamps are not interchangeable.

The higher wattage options, 42W, 57W and 70W in the triple returned tube versions, which use the amalgam technology and an 80W in the single returned tube type, have now been introduced. There is now no need to opt for the less efficient twin lamp downlights, when undertaking a design. One 70W lamp (5200 lumens) can now replace 2x32w (total 4800 lumens) and ultimately be more effective.

It is also possible to dim “Remote Ballast” Compacts designed for ECG operation.

4.1.3.3 Compact Fluorescent lamps with integrated electronic ballasts

Now commonly used as direct replacement for GLS lamps, this lamp type (ILCOS type FB) incorporates an ES (E27) or BC (B22d) base and an integral electronic ballast. It is now important to understand that the market is offering Long Life (10,000 to 15,000 hrs) and Short Life options (6000/8000 hrs). Both are Energy Savers but the short life version has been introduced to attract the domestic market.

One of the latest introductions is a version that has a sensor tuned to daylight levels. They are designed for exterior use (in enclosed luminaires) and automatically turn ON at dusk and OFF at dawn, for security lighting.

Integral Ballast CFL lamps cannot be dimmed or used on electronic switching devices, at this stage, but there are programs underway to address this deficiency.

4.1.3.4 The Induction lamp

For large packages of fluorescent light, the industry is now introducing Induction lighting[x]. These can also in a sense, claim to be "compact" fluorescent lamp. Currently there are two or three versions available on the market, with wattages ranging from 55W to 150W in two types, with higher wattages to follow and another design at 23W, colour choices are 3500K, 4100K and 5000K (all 80 CRI).

These lamps operate on high frequency with a dedicated ballast and offer an expected life of 60,000 or more hours of operation, in the larger sizes, down to 15000 hrs for the 23W. Lumen output would drop to 70% after that time. Their main application would be where maintenance work is costly i.e. complicated, requires expensive access equipment or the shutdown of a plant.

By using a 150W Induction lamp system instead of a 150W Metal Halide system (each approximately 12000 initial lumens), the Mercury to be disposed of at end of life of the induction lamp (i.e. 60,000 hour) would only be a ¼ of that in the Metal Halide lamp.

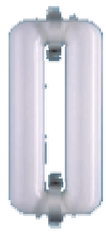


Table 6. Comparison of Fluorescent, Induction and HID lamp performance with Electronic gear

System Type	Avg. Rated Life(1) (hrs)	System Watts	EOS Lumens & System lm/W	Pass "TCLP" Test	Min. Start.Temp.
Lamp Type FDH – 80W HO	24000	86	6300, 73	Yes	5°C
Lamp type QT 70	60,000	76	4200, 55	Yes	-40°C
Lamp type QL 85	60,000	85	4200, 49	TBA	-20°C
MCS70/30/1B-H 85/S E27	12,000	74 (2)	5200, 70	No	-30°C
ST-70-H 85/E-E27	28,000 (2)	74(2)	5200, 70	Optional	-40°C

Note. (1) FDH has 80% lumen Maintenance, QT and QL - 70% lumen maintenance at 60,000 hours & 64% lumen maintenance at 100,000 hours.
(2) Electronic control gear improve efficacy of the HID lamps, MCS and ST – the Sodium lamp can also offer 50,000 hour life in some wattages.

4.1.4 Control Gear for Fluorescent lamps

Fluorescent lamps have various operating modes, depending on the method of energising the electrodes (bringing them to the required operating temperature):

- Current-controlled pre-heating via a choke/starter (conventional magnetic iron core system), preferred in countries with a high mains voltage (200V or more). The concept is also increasingly the basis for most electronic control gear (ECG) systems.
- Voltage-controlled pre-heating with additional transformer windings to provide a "rapid start". Offer slight lamp performance improvements over the conventional magnetic iron core system.
- No pre-heating (cold start). This type of starting reduces the lamp life more than any other type and is therefore not recommended for systems with frequent on/off switching.

4.1.4.1 Conventional control gear (or Ferro-magnetic - CCG or LLG)

This is a simple inductive resistor comprising an iron core around which copper wire is wound; the ballast used in the past had comparatively high power losses, along with a high thermal component. Additional components (starters or filament heating transformers) are needed to start the lamp and provide power factor correction.

Current practice has moved to regulate that if using ferro-magnetic ballasts, they will be of the reduced watts loss type (**LLG**). The basic magnetic iron cored ballast, in conjunction with a Glow Switch starter, have traditionally been the most commonly used because of low initial cost and proven long-life reliability. The Low Loss versions are a little larger and heavier and a little more expensive to manufacture.

Table 7. Typical splits in system power for various ballasts and how they are now rated

Type FSM (CFL) 26W T lamp	**CCG**	**LLG**	**ECG**
System Power:	34W	30W	28W
Ballast power Loss:	8W	4W	2W
% Ballast Power Loss:	30.8%	15.4%	7.7%
System efficiency	53 lm/W	60 lm/W	64 lm/W
Energy Efficiency Index	**B2**	**B1**	**A2**

4.1.4.2 Electronic Control Gear (ECG)

These ballasts contain all components necessary to strike and control the lamp. They can optimise lamp performance and options are available to provide "soft starting", which can assist in further extending life. They can cover the most stringent Power Factor Correction and EMC requirements.

Operating lamps at High Frequency via electronic ballasts, results in better lumen maintenance, higher light output and longer lamp life. To expand on this:

- HF operation increases light output by up to 10%
- Electrode preheat reduces consumption of emitter – longer life
- Power regulation at high ambient temperatures
- Reliable starting at lower temperatures
- Safety cut-out in case of lamp failure
- Constant, flicker-free light without stroboscopic effects

As a result of the high-frequency at around 35 to 50kHz, flickering, which can be apparent at 50Hz (and the stroboscopic effect observed with rotating machine parts), is much less noticeable or virtually invisible. Flicker via reflections off computer screens etc would also be nonexistent.

4.1.5 Dimming fluorescent lamps

With the advent of electronic ballasts, dimming of fluorescent lamps is now an easy matter, as long this requirement is specified initially. With the previous ferro-magnetic ballasts, only the T12 lamp, operated on a "Rapid Start" system (filament heating transformers included), could be dimmed, the newer T8 Standard and Tri-phosphor lamps were not generally considered to be suitable.

Dimmable ECG's assure constant electrode temperature by providing a separate filament that maintains ionisation levels while dimming is underway (reduction of lamp current). Reduced light output and lower energy consumption is achievable. Fluorescent lamps can be dimmed smoothly (flicker-free) from 100% down to around 1 to 3% of the luminous flux.
Commercially, three dimming systems are in use:

- Phase dimming
- Analogue control
- Digital – including DALI (digital addressable lighting interface)

The first two have been the most commonly used systems however, as with most things electronic, now the word is "Digital".

Digital dimming control has all the features of analogue dimming but allows an expansion of the concept. Recording of burning hours, feedback on status of dimming level and lamp operation, pre-programmed scenes, etc. are just a few examples. Like the analogue circuit, control is via a 1-10V DC signal, which when varied, is sensed by the ballast, as an instruction to vary the power to the lamp.

4.1.5.1 DALI – Digital Addressable Lighting Interface

The DALI system is capable of carrying out commands from a controller, which if desired can be a single "button". At the other end of the scale, it is compatible with most common "Bus" systems; its capabilities go far beyond that of the traditional analogue 1-10V interface.

Not all digital-ECGs or digital light control systems are based on DALI and therefore may not be compatible.

Table 8. Brief comparison of the Dimming options - Analogue vs. Digital system

Analogue 1…10V	DALI
• Floating control input • Two-wire cable • Dimming from 1 to 100%, linear characteristic • No return channel • Not addressable	• Floating control input - not polarity sensitive • Two-wire cable • Dimming from 1 to 100%, logarithmic characteristic • Individual channel return • Individual, Group and broadcast addresses • Scene control • Programmable dimming times • Integrated mains switch

4.1.5.2 Features of ECGs designed for the DALI interface system.

- ECGs are assigned to groups when the system is first started, which means the electrical wiring is independent from group arrangements
- DALI ECGs can belong to more than one group, which allows for much greater flexibility

- Scenes and group assignments are stored in the DALI ECGs, which means far fewer system components than in a comparable 1-10V system
- Feedback from ECGs on lamp status:
    - lamp on/off
    - actual light level
    - lamp fault
    - special settings, such as rate times to call up a light scene
- When a scene is called up all the DALI loads reach their setpoints at the same time.

4.1.6 Energy Efficiency Index (EEI) and Fluorescent lighting

The Energy Efficiency Index (EEI), also known as the Energy Label, is a classification system for the lamp/ECG combination (it does not relate to luminaires). In Australia, all ballasts used with linear fluorescent lamp between 15 and 70W, are required to meet a Minimum Energy Performance Standard – EEI = B2. Details of MEPS and EEI are contained in AS/NZS 4783.2

MEPs for fluorescent lamps, to be regulated October 2004, will only cover certain wattage linear types; will require initial lumen output of 85 lm/W and a minimum efficacy at 70% of life, of 75lm/W.

The EEI classification systems, set out below, are defined by certain limit values in lamp or system performance.

Rating system for Household Lamps [xi]

A Very Efficient
B >50 lm/W
C
D Mostly Halogen **-** > 16 lm/W
E Incandescent **-** GLS
F Incandescent - < 10 lm/W
G Least efficient - Coloured lamps

(Calculated according to specified formula)

Rating system for Control component.

A1: Dimmable ECGs
A2: ECGs with low loss
A3: ECGs with higher losses
B1: Good low-loss control gear
B2: Poor low-loss control gear
C: Conventional control gear

(Determined by test)

4.1.7 Where Fluorescent lamps emerge as "Best Practice"

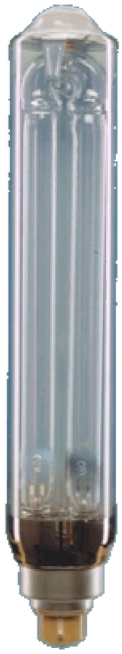
Table 9. Typical options available to provide around 3000 lumens (initial) – All Universal Burning

Characteristic	Halogen (2 req'd**)**	Compact Fluor S/E	FD T8 Triphos (1)	FDHT5HO Triphos(1)	Induction Lamp	Mercury Vapour	Metal Halide
ILCOS Code	HSGSBT	FSM	FD	FDH		QE	MT
Rating - Watts	**200**	**42+4**	**32+3**	**39+3**	**55W**	**80+14**	**39+4**
Size	105X32	168X50	1200x26	849X16		156x70	81x15
Lumin. Flux (2)	3000	3200	3350	3100	3700	3800	3300
Depreciation	10%	18%	10%	8%	30%	25%	20%
Efficacy -lm**/W**	15	70	105/94	79/90	77	48	85
EOS Efficacy	**13.5**	**50**	**94/85**	**73/83**	**54**	**36**	**68**
End System lm/W (2)	13.5	57	**86/78**	**68/77**	47	30	**61**
Light Colour	Warm	3options	**>4options**	**>4option**	2 types	2 types	Warm
Colour Temp. (2)	2900K	30,4000K	30,40,60	27,30,40,	30,4000K	40,3300	3000K
CR Index	100	80+	**80>90+**	**80>90+**	80+	50	**80>90+**
Control Gear	None 240V	ECG only	CCG/ ECG	ECG only	Special ECG	CCG only	CCG/ ECG
Dimmability	**Easy**	**Select spec. ballast and wiring/controls**			To Develop	To 50% power	Colour problem
Start Delay	**Instant**	**Flicker free <2s**	Flickers For 3s	**Flicker free<1s**	**Instant**	2 min	2-3 min
Run Up time	Instant	**1-3 min**	3 min	**3 min**	**Instant**	5 min	4 min
Restrike time	Instant	**< 0.5s**	3 secs	**< 0.5s**	**Instant**	3 min	15 min
Service Life (2)	2000	10000	**16000**	**24000**	**60000**	**16000**	9000
Disposal	Usual	Usual	As per EPA	Optional	As per EPA	As per EPA	As per EPA
Life Cycle Cost							

Note: (1) For ECG operation, 1st value calculated from lumens @ 25°C (lamp not enclosed!), 2nd @ 35°C. The "Luminous Flux" values are initial @ 25°C.
(2) Burning position can influence the outcome with Compact Fluorescent and metal Halide lamps.

4.2 The High Intensity Discharge lamps

As with the fluorescent lamp, the original High Intensity Discharge sources produce light by passing an electric current through a gas containing either Mercury (ILCOS type Q, QB) or Mercury/ Sodium (ILCOS types LS, ST and SE).



Typical of the long serving
Low Pressure Sodium – "LS"

and

Diffused Mercury Vapour Discharge
High Intensity Discharge lamps – "Q"

Unlike the Incandescent lamp, which essentially was adopted as a "perfect source" from a Colour Rendering viewpoint, the earliest Discharge Lamps did not render colour well as they were either extremely blue or extremely orange. A Blended lamp (ILCOS type QB) – Mercury Arc plus a filament which acted as a ballast, along with a coated option of the original mercury lamp, were developed and these helped to improve colour rendering. Reflector designs where also introduced (ILCOS type QR and QBR).

Some 30 years after the original developments, additional Halide combinations, which contributed to the energy level in the arc, were added to the basic Mercury Vapour lamp and the Metal Halide family of lamps (generic type M, MT, ME) evolved. These provided an increase in light output over that obtainable from the Mercury lamp and the Halide combinations were variable, to positively influence the colour rendering qualities.

The arc in these lamps operates under higher pressures and temperatures than that of the fluorescent lamp and it produces a very large amount of light from a relatively small source – hence the term High Intensity Discharge (HID) lamps.

The Low Pressure Sodium lamp (generic type LS & LSE), designed in the 1930s, is still the most efficient light producer (efficacies of 100 to 172 lm/W), as long as the light levels provided ensure continued use of "photopic" vision. ("Lumens" and therefore "lumens per watt" is accessed under this seeing condition; because the LPS lamp is virtually monochromatic, its lumen output drops significantly under "Scotopic" vision). We are also aware that colour under the LPS lamp is not all that acceptable. An "energy saving" LPS version evolved after the energy crisis of the 70s.

By raising the pressure in the Sodium discharge – a technology which became viable with the development of translucent ceramic (alumina Oxide) material; better colour was obtained but the efficacy suffered, however in producing up to 150 lumens/watt, the High Pressure Sodium (HPS) lamp (ILCOS type ST and SE) is a very useful lighting tool and an extremely good energy saver.

High Pressure Sodium – "S"

and

Metal Halide lamps – "M"

evolved from the original HID lamps – note the difference in arc tubes

Table 10. The collective merits of High Intensity Discharge lamps

HID Advantages	**HID Disadvantages**
Provide the largest Lumen packages	Most will not light instantly, slow to warm up.
Also offer the highest efficacies (lm/W).	High Initial Costs
Excellent for Energy Savings	Sensitive to unsatisfactory operating environment, including burning position.
Competitive life spans	
A range of colours for most applications	Four basic colour groups only
Good colour discernment available	
Allows good optical control	Most "useful" types need a ballast
Can operate in very cold temperatures	
Resistant to vibration and rough handling.	"Conditional" dimming of two families only – MH reacts in an "unfriendly" way

In the last decade, the emphasis has been on developing smaller HID light sources, which emulate the shapes and distribution characteristics of Tungsten Halogen lamp types. This work has now resulted in a lamp that combines a ceramic arc tube (HPS technology) and the metal halide technology. These new lamps have good colour rendering properties and improved efficacies and life.

Table 11. Comparison of technical data for various HID lamp types

Lamp Type and ILCOS Code	**Blended** QB/R	**Mercury** QE/R	**Metal Halide** M	**Ceramic MH (**MC**)**	**Sodium (H)** S	**Sodium (L)** LE
Wattage	**100- 500**	**50 -1000**	**50 - 2000**	**39 - 400**	**70 - 1000**	**18 - 180**
Lumen Output (klm)	**3 - 14**	**1.6 - 58**	**5 - 225**	**3 - 42**	**3.5 - 140**	**1.8 - 32**
Efficacy (lm/W)	**19 - 28**	**32 - 60**	**71 - 120**	**87 - 105**	**70 - 150**	**100 - 170**
Light colour	**32- 4100K**	**32- 4200K**	**30- 6000K**	**30- 4200K**	**20- 2200K**	**-**
CRI	**60 - 70**	**40 - 60**	**60 - 95**	**85 - 95**	**20**	**-**
CRI Group	**2A - 2B**	**2B- 3**	**1- 2B**	**1**	**4**	**-**

4.2.1 Metal Halide lamps

While Mercury and Sodium HID lamps have developed with essentially, universally coordinated physical, chemical and electrical characteristics, the technology and systems evolved for Metal Halide lamps has not been so regimented. There are a number of options, which employ differing electrical characteristics and use various Halide mixes, to provide a number of colour variations in the "White" light emitted. As with the colour options, efficiencies although very good, can vary considerably[xii]. Changes to enhance one parameter, often significantly impact upon another.

The different operating configurations need to be catered for within the luminaire and control gear selected. It is also important to ensure that the operating environment surrounding a Metal Halide lamp meets stated specifications otherwise poor performance results. The impact of unsuitable operating parameters will also be noticed far earlier than with either of the other two lamp categories.

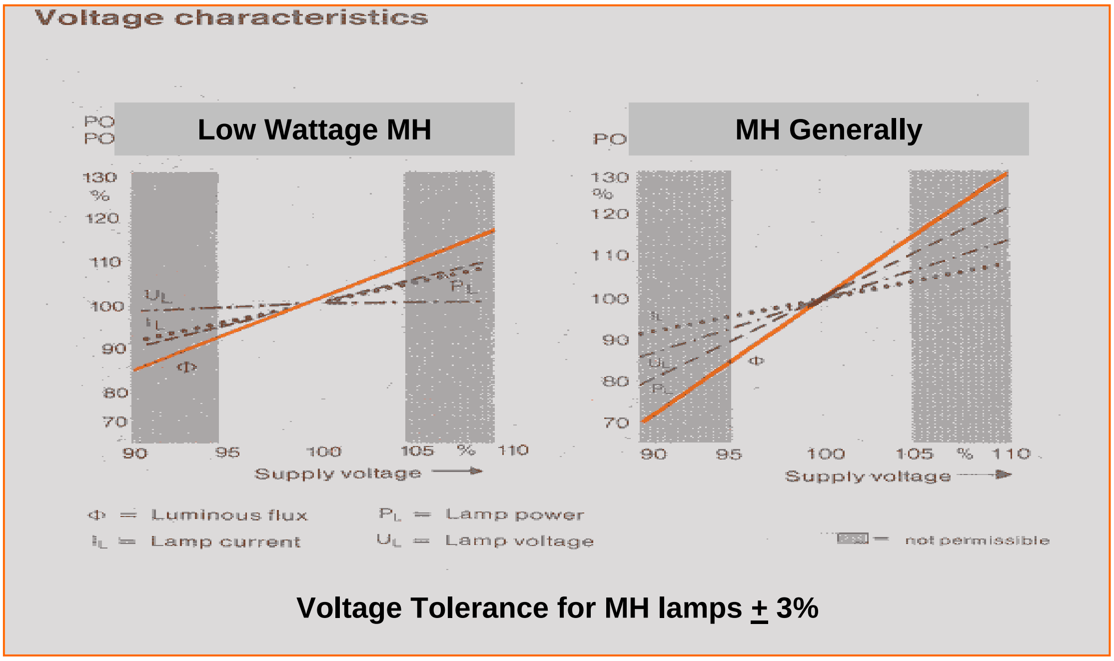


Figure 7. An indication of the variation in performance with mains voltage changes

One of the benefits of the globalisation of the lamp manufacturing industry has been to bring some standardisation into the control gear being selected to operate the more recently developed lamps. The preferred option is a system based on the High Pressure Sodium lamp's electrical parameters.

The term "Super" or "Plus" is often applied to the newer HID lamps when the lumens have been increased over that achieved from an existing type. In the mid 90's, "Super High Output" Metal Halide and High Pressure Sodium lamps started to gain prominence, offering a lift in output of around 12.5 to 15%.

The latest Metal Halide types also take advantage of improved ballast waveform technology and high voltage starting circuits or alternatively, operation at higher currents (the HPS option), to improve lumen maintenance and/or lumen output.

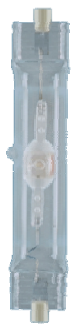
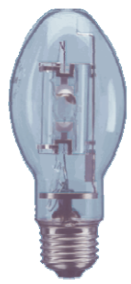
As stated, Metal Halide development work has been directed toward two key areas - reduction in size both in the glass envelope and the arc tube and improvements in the colour rendering and also in colour consistency. Even before the results of this development work were being realised, Metal Halide lamps offered the user an ability to efficiently control the light emitted and to provide the best Colour Rendering – 80 plus rating, with "Daylight" lamps (designated 950/960) offering CRI of 95.

4.2.1.1 The compact options in Metal halide lamps

The earliest examples of these very compact sources were the Double Ended Tubular Low Wattage (114mm long) (ILCOS type MD and SD) and most recently, a Bi-pin Ceramic arc tube lamp only 81 mm long (ILCOS type MC). At the opposite end of the scale, a 2000w lamp has been reduced in size by a factor of 6 or 8 so size, which was generally considered a problem in Discharge lamps, is now conforming to needs[xiii].

The Compact MH lamps have proved very successful for accent lighting in shop display work and effect floodlighting, because they allow the use of very neat luminaires while still giving the ability to provide good control.

The latest in Metal Halide lamp development incorporates "ceramic arc tube" technology, this has certainly contributed to compactness and it also allows the lamp to operate at even greater pressures. The range so far, is outlined below:

				
Double Ended	**Single Ended Tubular G12 and Bi-pin**	**Single Ended Elliptical E27**	**Single Ended Tubular E27**	**Single Ended Reflector PAR E27**
70, 150, 250W	**35, 70,150W**	**50 to 400W**	**70, 150 to 400W**	**35, 70W**
3000 – 4200K	**3000 – 4200K**	**3000, some 4200K**	**3000K,**	**3000K,**
CRI 1A, 1B	**CRI 1A, 1B**	**CRI 1A, 1B**	**CRI 1A, 1B**	**CRI 1B**
81 to 100 lm/W	**81 to 95 lm/W**	**80 to 105 lm/W**	**90 to 105 lm/W**	

The improvements can be summarised as:

- **Even higher efficacy and better lumen maintenance.**

The Ceramic arc tube technology provides the following benefits:

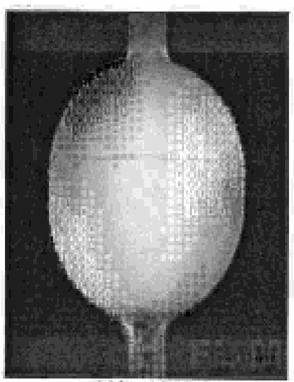
- Even Higher efficacy and better lumen maintenance.
  Lumens 15 to 20% up on the equivalent Quartz arc tube low wattage MH lamp equivalents
- A further improvement in Colour rendering abilities, with Warm White at CRI 85 and Neutral lamps at CRI 95 – enhancement of red..
- Colour stability controlled to within 200K of start point, throughout a long life.
- Life is increased over existing similar types
- Easily replaceable into existing luminaires (except for the length of the G12 lamp)

This range includes **single ended** 70W **E27 and G12** and 150W **E40 and G12 Tubular,** E27 **based** 70 to 150W **E17** and 35 to 100W **PAR 20-30** envelope products, along with the traditional **Double Ended** 70 and 150W types. Product development is now moving to include 250W and 400W E40 Elliptical and Tubular lamps, initially in 3000K colour.

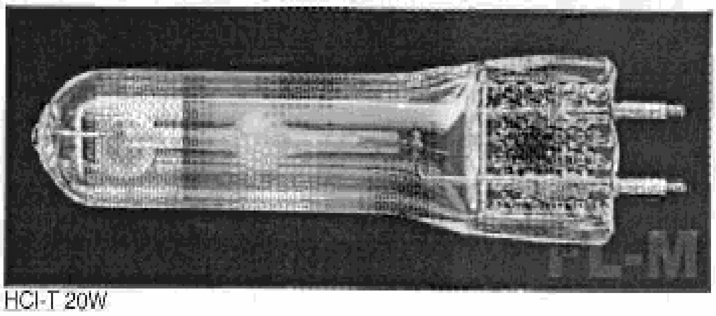
The range immediately released targeted the most popular lamp colours initially. There is a choice of Warm Deluxe (around 3000K) **- "/WDL or /830**" and Neutral Deluxe (around 4200K), - "/**NDL or /840/940**".

The Single Ended G12 types have now been followed by a "more compact" Tubular, nominally 35 and 70 watts, with a new base configuration – the lamp has a simple two-pin base (G8.5) that enables the overall length to stay within the height of the old tubular product.

Ceramic Arc Tube design is already moving to a third configuration, providing much improved arc tube stability and lamp life.



HCI-T 150W



HCI-T 20W

Typical of the latest ceramic arc tube development – a uniform oval shape

Initially, the Ceramic technology metal halide lamps were developed to retrofit pre-existing low wattage lamp types. New luminaires will however need to be designed for the PAR lamps, particularly as existing fittings may contain lamp holders with inadequate insulation to withstand the high voltage spike associated with the starting of these lamps. While a simple retrofit is tempting, it would be a good practice to check all luminaires intended for use with Ceramic technology lamps to ensure that lamp temperature limits and "Fixture Effect" comply.

4.2.1.2 Ultra Violet Control

Most HID lamps where originally designed with an outer glass envelop, which acted as a control on UV. Also, by virtue of their high light output and the nature of the lighting they perform, they were generally mounted at reasonable distances from people and objects, thus any UV output should be diffused by the time it reached areas where this may become a concern.

The applications where special attention is needed are those that have emerged since the introduction of low wattage metal halides - lighting in shops, public places and display lighting.

In striving for compactness, the outer glass envelope, which acts as a UV suppressor, is often eliminated and in open luminaries. This can expose people and products to relatively high levels of UV output. The comments at the outset are relevant to Compact Metal Halide lamps particularly; however, the luminaires for these lamps are generally provided with some form of protective glass, which also acts as a barrier in the event of non passive failure.

4.2.2 High Pressure Sodium lamps.

The High Pressure Sodium lamp is a highly efficient, long life HID source that could be produced in a variety of wattages in a very compact envelope, to enable excellent light control. The degree of control is only bettered in HID, by its contemporary, the Metal Halide lamp.

By operating Sodium filled lamps at higher pressures, the spectral output could be broadened and the colour of the light was “whitened” to the point of acceptability. Although some of the efficiency of the LPS lamp was lost, the ceramic material used to allow this change withstood higher temperatures, allowing higher wattages. The largest size LPS lamp (180W) provides 32000 lumens compared to 130,000 lumens from a 1000W HPS– 4 times the lumens from a lamp one-third the length.

One aspect of the High Pressure Sodium lamp, which impacts adversely on performance, is any inability to control excessive arc tube voltage rise during service. If arc tube operating voltage rise can be slowed, life expectancy will be improved. Recent developments aimed at reduction of arc tube blackening and Sodium leakage, two things, which, along with “fixture Effect”, influence voltage rise, have improved lumen maintenance and life expectancy. Otherwise, the basic principles of this lamp remain the same as the original design[xiv].

The recent upgrade naturally enhances the features available with HPS lamps:

- Higher Efficiencies throughout a very long life, contributing to extremely Low Operating Cost.
- Superior Lumen Maintenance – best in class
- Quickest Start/Warm Up and Restart of any Discharge source.
- Few operating restrictions

High Pressure Sodium lamps are generally applied outdoors, areas where colour discernment is not a critical issue; such as on traffic routes and in car parking lots or in industrial applications, such as High Bay lighting, Area flood lighting etc. Long lamp life makes HPS lamps the first choice for if looking at the overall costs. These lamps are generally the best for “hard to get at” installations.

4.2.3 Control gear for HID lamps

As explained earlier, all Discharge lamps need some form of current limiter, the most common practice with HID lamps, is to use an inductive Choke (ballast), which, while relatively efficient in operation, is reasonably bulky and heavy (one form of mercury lamp uses an internal resistance only and while being convenient and lightweight they are inefficient). Generally speaking, chokes add around 6 to 12.5% to the energy load represented by the lamp wattage. Where voltage fluctuations are prevalent and wattages over 150W are used, use of “Constant Wattage” ballasts are recommended, this are more costly and have very high watts loss compared to the conventional ballasts.

Even though starting aids are used, High Intensity Discharge lamps generally take from 1 to 5 minutes to start and then further time to reach full brightness. They also cannot be switched straight on again; there will be a delay in restarting. This has to be considered in their application.

Attention needs to be paid to the positioning of the control gear to ensure that the starting process is not compromised by attenuation along the connecting electric cables.

It has been a well stated requirement from manufacturers that for good lamp performance, the incoming electrical supply must match the rating (tapping) of the ballast, preferably to within plus or minus 3%. Certainly, in Australia, this has often proved to be an impractical request. The outcome of over voltage will be short life and even “non passive” lamp or ballast failures.

With low wattage lamps, particularly metal halides, which are the most vulnerable under adverse operating conditions, the use of Electronic Controls is fast gaining acceptance. They bring the same benefits as outlined earlier [xv] – including voltage control and introduce up to 50% energy savings in ballast losses.

Ballast designs utilising electronics, allow the use of higher frequencies than those available from normal ballasts. These higher frequencies and a squarer waveform in the electrical signal, act to hold the energy within the lamp at levels that contribute to improved lumen maintenance and lamp life, although with High Frequency technology there are limits to application. (Limited to 150W max. at this stage).

The use of electronics overcomes several of the commonly encountered problems that have plagued the application of low wattage Metal Halide lamps. Their adoption into a lighting installation can be well justified by examining the overall owning and operating costs associated with the installation.

- They provide around 50% increase in lamp life, via stabilisation of mains voltage variation and provision of better operating conditions.
- Improved Lumen Maintenance
- Reduced colour deviation in the lamps, by controlling variances.
- Quicker start up and achievement of full brightness
- 12 to 20% Energy Saving
- Prompt shut down in the event of a fault.
- One unit can replace three components and is compact and light in weight.

Electronic ballasts should be the only ones considered for the new ceramic technology lamps – if using a quality lamp, one should not compromise lamp performance upgrades by using other than the best in control gear packages.

Like the newer starting devices now on offer, today's electronic HID control gear can also offer "soft starting" and friendly restarting. If extinguished accidentally, the lamp is allowed to cool down sufficiently before an attempt is made to restart. If not starting within say 15/18 minutes, the system shuts down completely, so minimising "wear and tear" on the lamp. It cannot be restarted unless the main switch is activated.

4.2.4 Dimming of HID lamps

Power level switching of HID lamps has been available for some years, using ferro-magnetic based, relay operated chokes, to provide an economical and simple "stepped" system of electricity usage control. It can be used with either Mercury or High Pressure Sodium lamps, which are cable of working effectively down to 50 and 40% of power, respectively.

Electronic dimming systems are now also acknowledged as suitable for "conditional" dimming of Mercury and Sodium; however Metal Halide lamps, as a family, need to be segregated from the blanket comment. There are many field examples of "dimming" systems controlling the output of certain metal halide lamps, apparently successfully; however a review of the formal statements suggests that lamp makers in USA are more at ease with this trend than those from Europe.

Research continues in this area, tests on low wattage ceramic MH lamp types suggest that provided the user is prepared to accept that increasing degrees of colour shift may occur as the light level is lowered, along with a variable and changing lamp colour with age, there appears to be no real issues.

Position Statements are available on most manufacturers' web sites, covering their attitudes to dimming of HID. Some lamp manufactures still will not recommend dimming of their products nor will they warrant them. This stems from the "expectations' associated with their products – if you select Metal Halide, you generally do so for the "white" light and good colour rendering, dimming can alter this expectation.

4.2.5 Life of HID lamps

In the past, HID lamps from the various manufacturing centres (EC, USA, and UK, JAPAN) may have varied in the manner in which their "life" statements were expressed. In the main, the "Average rated life" approach (period through which 50% of a large batch of lamps are still burning) is now used extensively, as an indicative statement to allow comparison of HID lamp life.

In some lamp types however, particularly where Lumens depreciate quickly, life may be determined using the lamps "Lumen Maintenance Curve" i.e. the time that will elapse, before a lamp reaches a certain percentage of the initial lumens generated. This may be referred to as "Service Life". Designers and potential users should seek a full explanation of the basis for life statements (and any other judgmental performance statements) so that considerations relating to the "Total Costs" of an installation are correctly based, as mentioned earlier.

Most Discharge Lamp life statements are generally linked to a switching frequency and the burning hours per start and would generally assume the use of conventional Iron Core magnetic control gear. These aspects should form part of any life statement.

4.2.6 Risk Management and HID lamps.

Apart from the electrically related safety issues, which the luminaire designer and the people installing and maintaining HID lamps need to be trained to be aware of, as part of their "apprenticeship" into the electrical industry, there are a number of other aspects of HID lamp application that require attention, to minimise "risks" in application. Most of these concerns are brought to an installers or users notice, via the lamp's packaging.

These "warnings" relate to such things as actions to take if the outer envelope is broken; disposing of the lamp, safe practices in relation to Ultra Violet radiation and Heat and protection should a lamp fail in a non passive manner – and for that matter, even when failing in an apparently passive way.

As with the Halogen family, many High Intensity discharge lamps now have inbuilt protection to ensure that, if they are used in open luminaires, the effect of exploding lamps will be contained.

4.2.7 Where High Intensity Discharge lamps start to emerge as “Best Practice”

Where light levels of around 6000 lumens are needed and beam control is a factor.

Table 12. Typical of the options available to provide around 6000 Lumens – Between FDH HO and HID; choose the Ceramic Metal Halide, unless maintenance a real problem, then perhaps Induction.

Characteristic	**Compact Fluor S/E (2)**	**FDH T5 HO Triphos (1)**	**Induction Lamp**	**Mercury Vapour**	**Metal Halide (2)**	**Ceramic M Halide (2)**	**Sodium**
ILCOS Code	FS	FDH		QE	MT	MC	S
Rating - Watts	**80+4**	**80+6**	**75+7W**	**125+14**	***80* + 12**	**70 + 10**	**70 + 12**
Size	570X50	1449X16	313x139	156x70	81x15	**81X15**	156x37
Lumin. Flux	6000	6150	6500	6300	6400	6500	5900
Control(beam	Fair	Asymmetric	Fair	Fair	Good	**Best**	Fair
Depreciation	18%	8%	30%	25%	20%	20%	20%
Efficacy -lm/W	75	77	87	50	80	92	84
EOS Efficacy	**62**	**71**	**61**	38	**64**	**74**	**67**
End.System lm/W	**59**	**66**	**55**	34	**56**	**65**	**58**
Light Colour	3options	**4options**	2 types	2 types	3 options	2 options	Warm
Colour Temp.	30,40x2	27,30,40,	30,40	40,3300	**30,40,60**	30,4200	2000
CR Index	80+	80+	80+	50	**90**	**80 & 90+**	20
Control Gear	ECG only	ECG only	Special ECG	CCG only	CCG/ ECG	CCG/ ECG	CCG/ (ECG)
Dimmability	To Develop	**Best system**	To develop	To 50% power	Subject to lamp type, Colour a concern		To 50% power
Start Delay	**Flicker free <2s**	**Flicker free<1s**	**Instant**	2 min	1-2 min	1-2 min	**<1 min**
Run Up time	**1-3 min**	**3 min**	**Instant**	5 min	2 min	2 min	5 min
Restrike time	**< 0.5s**	**< 0.5s**	**Instant**	5 min	7-10 min	15 min	**<1min**
Life	**10000**	**24000**	**60000**	**16000**	**9000**	**12000**	**28000**
Disposal	Usual	Optional	As per EPA	As per EPA	As per EPA	Optional	As per EPA

Note: (1) For ECG operation, value calculated from lumens @ 25°C (lamp not enclosed!) The “Luminous Flux” values are initial @ 25°C.
(2) Burning position can influence the outcome with Compact Fluorescent and Metal Halide lamps.

Table 13. At 3000 lumens, the only reasons to employ HID would be continuity, size or light control.

Characteristic	**Compact Fluor S/E (2 units)**	**FD T8 Triphos**	**FDH T5 HO**	**Induction Lamp**	**Mercury Vapour**	**Ceramic MH**	**Halogen (2 units)**
Rating - Watts	**42+4**	**32+3**	**39+3**	**55W**	**80+14**	**39 + 4**	**200**
Size	168X50	1200x26	849X16		156x70	**81x15**	**105x32**
Lumin. Flux	3200	3350	3100	3700	3800	3300	3000
Efficacy -lm**/W**	70	105/94	79/9077	77	48	85	15
EOS Efficacy	**50**	**94/85**	**73/83**	**54**	36	**68**	**13.5**
End.System lm/W	57	**86/78**	**68/77**	47	30	**72**	**13.5**
CR Index	80+	**80 > 90+**	**80 > 90+**	**80+**	50	**80>90+**	**100**
Life	10000		24000	**60000**	16000	9000	2000

Table 14. Typical of the options available to provide around 12000 Lumens – use Ceramic Metal Halide or High Pressure Sodium.

Characteristic	**Compact Fluor S/E (2 units)**	**FDH T5 HO Linear Fluor (2 units)**	**Induction Lamp**	**Mercury Vapour**	**Metal Halide**	**Ceramic MH**	**Sodium Standard**
Rating - Watts	**80+4**	**160+12**	**145+7W**	**250+19**	**150 + 18**	**150 + 10**	**150 + 18**
Size	570X50	1449X16	313x139	156x70	84x25	105x23	211X46
Lumin. Flux	12000	12300	12000	13000	13000	14500	14500
Efficacy -lm**/W**	75	77	82	52	87	97	108
EOS Efficacy	**62**	**71**	**58**	39	**60**	**77**	**82**
End System lm/W	59	**68**	54	36	54	**72**	**73**
Life	10000	24000	**60000**	24000	9000	9000	**24000**

Note: In Sodium, an option to use “Super” lamps, offers even better efficiency.

Table 15. Typical options available to provide around 24000 lumens (initial) – Ceramic Metal halide or Twin Arc Sodium for long life and "100lm/W+" efficacy.

Characteristic	**FDHT5 HO Fluor (4 units)**	**Induction Lamp (2 units)**	**Mercury Vapour**	**Metal Halide Daylight**	**Ceramic MH**	**Sodium Standard Twin Arc**
Rating - Watts	**320+24**	**290+14W**	**400+25**	**400 + 18**	**250 + 19**	**250 + 18**
Size	1449X16	313x139	156x70	285x62	226x46	285X46
Lumin. Flux	24600	24000	22000	25000	25800	27000
Depreciation	8%	30%	25%	40%	20%	15%
Efficacy -lm**/W**	77	82	55	62.5	104	108
EOS Efficacy	**71**	**58**	41	37.5	**83**	**92**
End System lm/W	68?	54	39	36	**77**	**86**
CR Index	80+	80+	50	**95**	**80 & 90+**	20
Life	24000	**60000**	24000	12000	12000	**50000**

Note: In Metal Halide and Sodium, an option to use a "Super" lamp, would provide better efficiencies.

5. Concluding Comments

In presenting this review of the lamp and control gear options available, a number of aspects linked to proper application of electric lamps and lighting systems have been covered in a somewhat sketchy fashion, mainly to advise how improper use can lead to a poorer performance than expected; with a consequential unsatisfactory economic outcome.

An unsatisfactory lighting outcome is not necessarily because the lamp (and luminaire) suppliers have not presented all the information needed or are not supportive of their product, it is more to do with the fact that the most important parts of the application chain, have probably never been told exactly what they are dealing with and what is required of them – these important people are the Installers, Maintenance Contractors and the Users.

It is therefore imperative to involve these people as part of the "Information" loop (the "Best Practices in Lighting" seminars hopefully will contribute in this way). Not only the designers but the Installers, Maintenance Contractors and Owners/End Users should make themselves fully informed about the lighting products they are using. They need to:

- Maintain "Hands On" control up to the point of commissioning/application for the designer and Installer and then beyond, for the Maintenance team and Users.

  The lamp and system performance should be regularly monitored, to ensure they are meeting expectations.

- Keep abreast with and understand the changes going on.

  The future will bring many more System based lighting developments.

The Lamp/Control gear manufacturer can provide the equipment to produce "replicable" light and particularly over the last 2 decades, they have made significant technological advances. It is now up to others to ensure that the opportunities for energy saving, cost reduction and environmentally friendly outcomes are realised.

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Acknowledgements

In compiling this review, the author has drawn extensively on material prepared at Osram, associated with the release of new lamp/system technologies over the last 5 years or so. With Osram's permission, extracts have been taken from their "Product Information" presentations and particularly, the Australian "Osram Product Technical Information Course" ("OPTIC").

Attachment 1

Total Owning/Operating Costs if replacing a Standard 26mm Fluor. Lamp with Triphosphor Type.				
	FD 36W-640	**FD 36W-640**	**FD36W- 840**	**FD36W- 840**
	CCG	**CCG**	**ECG**	**ECG**
	Spot Relamping	Change @	Change @	Change@18000hr
	Light uncontrolled	30% drop in light	10% drop in light	20% drop in light
COST COMPARISON				
Total Lamps	100	100	100	100
Lamp Wattage	36	36	32	32
Lumens @ 10,000 Hrs	2850	2850	3350	3350
Average rated life	12,500	12,500	18,000	18000
Assumed Bulk replacement	0	10,000	16,000	18,000
Luminaires/Controls used	100	100	100	100
Watts loss of Unit	10	10	3	3
Cost per lamp	$3.00	$3.00	$8.00	$8.00
Installation cost -Spot Relamp	$25.00	$25.00	$25.00	$25.00
- Bulk relamp	$5.00	$5.00	$5.00	$5.00
Total lamp cost Initially	$300.00	$300.00	$800.00	$800.00
Total other cost -plus ECG install if req'd	$500.00	$500.00	$1,500.00	$1,500.00
			$300.00	$300.00
Total cost (trade):	**$800.00**	**$800.00**	**$2,600.00**	**$2,600.00**
Hours per day	12	12	12	12
Days per week	5	5	5	5
Weeks per year	52	52	52	52
Total hours per year:	**3120**	**3120**	**3120**	**3120**
Total Lamp Watts	1800	1800	1700	1700
Total Gear Watts loss	1000	1000	300	300
Total system Watts:	**2800**	**2800**	**2000**	**2000**
kWhrs (W x hrs/1000)	8736	8736	6240	6240
Electricity cost @ 10c/kWhr	**$874**	**$874**	**$624**	**$624**
Lamp replacement per year	0	250	254	225
Spot relamps per year	$349	$87	$64	$114
Capital Cost	$800	$800	$2,600	$2,600
Running Cost	$1,223	$1,211	$942	$964
TOTAL COST during the first year:	**$2,023**	**$2,011**	**$3,542**	**$3,564**
For subsequent yrs, on a per year basis.	$1,223	$1,211	$942	$964
Total over 4yrs (Approx life of Std Fluor)	**$5,692**	**$5,642**	**$6,367**	**$6,455**
if then bulk changing to restore light levels	add $800			
Total over 20 years	$19,628	$19,530	$16,070	$16,087
Approximate Savings over 20 years	**$0**	**$0**	$3,460	$3,443
Avg. Savings per lamp/year			**$1.73**	**$1.72**

List of Abbreviations used

CCG – **Conventional** (Iron Cored/Copper wound) **Control Gear**, or if you like, Coiled Copper Gear.

CFL – Compact Fluorescent lamp

ECG – **Electronic** technology **Control Gear**

ELC – European Lighting Companies Federation

EOL – End of Life – values established to reflect performance when the lamp (generally on average) dies.

EOS – End of Service – values established to reflect performance when the lamp is/will be replaced.

GLS – General Lighting Service lamp – also called a Filament lamp or "light bulb".

HID – **High Intensity Discharge lamp** – see glossary.

HO – High Output – lumens increased above a previously available product with similar characteristics.

IR – **Infra Red**, also **IRC** – **Infrared Reflective Coating** - as applied to the "Redirected Energy" lamps

K – **Kelvin,** a Unit of temperature

LLG – Low Loss Control Gear (approximately half the watts loss expected from the conventional type.

PAR – "**Parabolic Aluminium Reflector**", a generic term covering all "hard glass" two component reflector lamps, as opposed to those with soft glass blown bulbs. They are generally weather proof.

TCLP – "**Toxicity Characteristic Leaching Procedure**" - EPA (USA) SW –846 "Test Methods for evaluating Solid Waste (Physical/Chemical Methods)" Chapter 7.

*Note: A **"Glossary of Terms"** relevant to all papers in the Best Practices in Lighting Series will be provided separately.*

References

The general reference for data contained in this review, (tables, figures, etc.) unless otherwise referenced, are the catalogues produced by either

(a) The major global lamp/control gear manufacturers (Osram, Philips, GE)

or

(b) Global Control Gear manufacturers (Tridonic/ATCO, Vossloh Schwabe).

The author acknowledges that Catalogues and Technical Information would also be available from a number of other sources and these would be equally relevant in such a review.

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[i] The economical alternative to GLS – Electronic Energy- Saving Lamps
Osram Technical Guide – Page 32 Figure 19, updated by slide to suit current options.

[ii] "Tungsten Halogen Low Voltage lamps – Photo Optics – Technology and Application"
Osram Technical guide –"Spectrum" Page 24.

[iii] "Environmental Aspects of Lamps" - 1st edition 06/2001, European Lighting Companies Federation publication

[iv] AS/NZS 4293:1995 International lamp coding system (ILCOS)

[v] "Durable Cold Mirror Coatings for Lighting" – T.G.Parham & L.Auyang, GE Lighting.
Paper presented to IES USA conference, August 1993.

[vi] "Osram Product News" August 2003 – Titled "Decostar IRC" on the economics of "Redirected Energy" lamps

[vii] "Electronic transformers for Low Voltage Halogen Lamps"
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[ix] "Economical long-life light sources with plug-in bases – Compact Fluorescent lamps".
Osram Technical guide.

[x] "The electrodeless high-performance fluorescent lamp"
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[xi] AS/NZS 4782.2: 2004 & EN 50285:1999 - "Energy efficiency of electric lamps for household use"

[xii] "Powerstar (Metal Halide) Technical Information" – covers Osram European MH lamp range.
Also Osram Sylvania "Product Information and Specification guide – Metal Halide lamps" and also their "Engineering Bulletin", cover lamps available in USA (both available via Internet).

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"Metal Halide Lamps – 40years on" Paper presented by David J. Martin at IESANZ conference, April 2002.

[xiv] "High Pressure Sodium lamps" – Osram technical information booklet (available via Internet).

[xv] **"**Electronic Control gear for MH and HPS lamps" –
Osram technical guide (available via Internet).

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Reference: The economical alternative to GLS lamps - Osram technical guide
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