Tipping the balance

Total Cost of Ownership
White Paper

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Total Cost of Ownership (TCO) analysis is an invaluable technique for financial comparison of different solutions and technologies that looks beyond the initial purchase price to include future costs over the useful life of the system.
The initial digital roll out received significant financial assistance from the Virtual Print Fee (VPF) scheme. With that behind us, the full costs of projector replacement falls to the cinema operator. New projection technologies are likely to be evaluated based on their ability to either increase revenue or reduce costs. In this paper we will examine the economics of the two main contenders for delivering today’s DCI specifications or recommended practices as suggested by major content providers (DCI have not specified standards for 3D light levels besides HFR) and provide some initial thoughts on evaluating the new laser light source options.

Total Cost of Ownership (TCO) analysis is an invaluable technique for financial comparison of different solutions and technologies that looks beyond the initial purchase price to include future costs over the useful life of the system.

Total cost of ownership in the context of cinema projection can be broken down into several categories. Some are clearly quantifiable costs while others will be evaluated in different ways by different cinema operators depending on their business strategy.

The cinema industry is just about to start its first wave of digital projector upgrades and many cinema operators are planning the replacement of the very first systems installed which are often in their Premium Large Format (PLF) screens. From our own conversations we know that cinema operators are prioritising an improvement in 3D performance for these screens and reduce cost of ownership.

For example:
- Capital purchase of projection system
- Installation costs
- Lamp replacement costs
- Power consumption
- Staff costs for lamp maintenance tasks
- Extended parts warranties
- Maintenance costs
- Operational costs
- Training costs
- Downtime

The capital purchase of projection hardware is the most visible expense but lamp replacement costs and lamp power consumption costs over a period such as 5 years can represent a high percentage of the total cost of ownership. These costs are most marked at the high brightness end of the scale.
Traditional xenon lamps have dominated the industry during the life of film projectors and well into the digital age. Cinema projectors based on High Pressure Mercury (HPM) lamps have been introduced more recently and we are already seeing early adopters installing a limited number of laser light source projectors. Each technology has a different total cost of ownership profile that needs to be considered. Is there one light source technology that can tip the balance in the favour of the cinema operator?

**Lamp technologies**

The choice of lamp technology can have a significant impact on the performance and cost of ownership. Here we examine the relevant characteristics of the two main lamp technologies.

**Xenon lamps** consist of two metal electrodes, with a small gap of a few millimetres between them which are held within a quartz glass bulb filled with xenon gas at a high pressure. Light is generated by a discharge arc burning between the two electrodes. Xenon lamps have a well-known burn down curve where the brightness reduces steeply during the early section of the lamp life. This is due to the initial shape of the electrodes, most notably the cathode and how its profile changes throughout the lamp’s operational life.

The cathode shape comes to a very sharp point to achieve an initial high brightness but it gradually becomes more rounded as metal at the end of the electrode vaporises at its high operating temperature. This degradation in cathode shape is rapid during the early section of the lamp life leading to the characteristic initial steep reduction in brightness.

After a period of time, the rate of degradation of the cathode decreases and the drop off in brightness becomes slower.

High powered xenon lamps in the range 6-7kW are the most expensive to purchase. They operate with higher electrical current producing a more rapid burn down of the electrodes and steeper reduction in brightness resulting in a shorter useful life of just a few hundred hours. Naturally, higher power lamps also have the highest power consumption costs which further escalate the cost of ownership.

The xenon gas is at a high pressure of about 10 atmospheres under cold conditions and it increases significantly at the lamp’s high operating temperature. Technically competent staff are required to exchange and realign the lamps in accordance with safety procedures for such high pressure lamps.

There are a number of additional potential costs which will be familiar to cinema operators:

- Xenon lamps are a single point of failure. Lamp failure causes lost shows and loss of revenue
- When a xenon lamp explodes it destroys the lamp reflector cancelling every show until an engineer can deliver and install a new reflector. If the xenon lamp is outside warranty the cinema operator faces a large replacement bill for parts along with the loss of revenue from missed shows. Since the risk of lamp explosion increases with age because the quartz glass re-crystallizes under high temperature and pressure[1], many cinema operators prefer not run xenon lamps past their warranty hours.
The cathode shape comes to a very sharp point to achieve an initial high brightness but it gradually becomes more rounded as metal at the end of the electrode vaporises at its high operating temperature.
High Pressure Mercury lamps are alternative gas discharge lamps filled with mercury vapour. This technology offers lower costs and longer life than xenon so is the lamp of choice in general purpose projectors. HPM lamps were ruled out for cinema use for many years due to their lower brightness capability and perceived as unable to meet the demanding DCI P3 colour performance. Recent manufacturing improvements combined with modern colour management techniques have overcome these two obstacles and today, three of the four digital cinema projector manufacturers offer DCI certified models powered by HPM lamps.

HPM lamps do not have quite the same issue with burn-down in electrode shape over time so exhibit a more linear reduction in brightness throughout the life of the lamp rather than the initial steep reduction exhibited by xenon lamps.

The largest HPM lamps are currently in the order of just 450 Watts rather than the kilo Watts of power typical with xenon lamps. This restricted HPM based projectors to small screens but Sony took the unique approach of combining the light from an array of six lamps in the SRX-R515P projector to provide 15,000 lumens and address medium sized screens. These projectors in a dual configuration can be used to deliver a 30,000 lumen high brightness solution for large screens.

Two medium brightness projectors might not immediately be thought of as an attractive alternative to a single, high power xenon projector but the multiple HPM lamps used in the Sony projectors can deliver significant cost of ownership benefits over a period such as 5 years.

Key contributors to low cost of ownership are;

- **Lamp purchase costs** – the long life of HPM lamps results in fewer lamp change cycles over a period such as 5 years leading to lower lamp cost of ownership
- **Longer ‘useable lamp life’** – unlike xenon lamps, HPM lamps cause no damage to the projector in the event of a lamp explosion. Cinema operators can run the HPM lamps beyond their warranty life until they eventually fail one by one (as long as they are satisfied with the light levels) which further reduces lamp cost of ownership
- **Power consumption** – HPM lamps are very efficient at converting electrical power to light allowing a dual projection system to have a comparable, or better, power consumption compared with a single high power xenon projector
- **Simplified lamp exchange** – HPM lamps are pre-installed in disposable lamp houses so lamp exchange is a simple plug-and-play procedure with no need for a safety suit and no lamp alignment required. This has obvious cost advantages in the technical level of staff, training and time required
- **No regular lamp readjustments** – as we have seen, xenon lamp electrodes burn down over time so regular realignment of the spark gap is required to maintain optimum brightness. HPM lamp electrodes have a different burn-down profile which negates the need for spark gap realignment during the life of the lamp
The HPM multi-lamp array has the ability to protect revenues in a way not possible with a single xenon lamp:

- **Resilience to lamp failure** – if one of the HPM lamps fails or explodes, the projection continues at a slightly reduced brightness for the remainder of the show. The lamp can be quickly replaced at the end of the show to re-establish reference brightness.

- **No lost shows due to lamp explosion** – the HPM lamps are supplied as self-contained, mini lamp houses. In the event of a lamp explosion, no damage is done to the projector or nearby lamps.

### Case Study

Table 1 is based on manufacturer published specifications for two 4K projection solutions which would adequately address equivalent 3D screens: a single projector running a high powered xenon lamp that would be equipped with a 3D “light doubler” and the Sony dual projection system operating with HPM lamps and static polarising filters for 3D.

<table>
<thead>
<tr>
<th></th>
<th>Xenon</th>
<th>Sony with HPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>4K</td>
<td>4K</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>2,000:1</td>
<td>8,000:1*</td>
</tr>
<tr>
<td>Max. Lamp Power</td>
<td>7kW</td>
<td>12 x 450W = 5.4kW</td>
</tr>
<tr>
<td>Lamp Type</td>
<td>Xenon</td>
<td>HPM</td>
</tr>
<tr>
<td>Lamp Warranty Hours</td>
<td>300</td>
<td>2,000</td>
</tr>
<tr>
<td>Projector Power Consumption</td>
<td>10kW</td>
<td>8.6kW**</td>
</tr>
<tr>
<td>2D Brightness</td>
<td>33,000 lm</td>
<td>30,000 lm</td>
</tr>
<tr>
<td>2D Lumens/Watt</td>
<td>4.7 lm/W</td>
<td>5.5 lm/W</td>
</tr>
<tr>
<td>3D Brightness</td>
<td>9,240 lm***</td>
<td>9,600 lm</td>
</tr>
<tr>
<td>3D Technology</td>
<td>“Light Doubler” Unit</td>
<td>Static Polarising Filters</td>
</tr>
</tbody>
</table>

* Specification for SRX-R515 projector  
** 2 x 4.3kW per projector  
*** Based on typical 3D “light doubler” efficiency

Many of the factors contributing to total cost of ownership listed earlier in this paper are dependent on the individual installation circumstances and the cost assessment policies of individual operators. However, the projection system purchase costs, on-going lamp purchase costs and power consumption costs, which represent the greatest investment, can be compared directly.

Our studies have found that the multiple HPM lamps used in the SRX-R515DS can deliver very significant savings over a long period in terms of lamp purchase costs and lamp power consumption compared with high power xenon lamps.
A comparison of lamp purchase costs over a period of 5 years (or longer) can be calculated using the process in Table 2.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>High Power Xenon Single Projector</th>
<th>SRX-R515DS Dual System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Hours Per Day</td>
<td>10 hrs</td>
<td>10 hrs</td>
</tr>
<tr>
<td>Number of Operational Hours in 5 Years</td>
<td>10 x 364 x 5 = 18,200 hrs</td>
<td>10 x 364 x 5 = 18,200 hrs</td>
</tr>
<tr>
<td>Lamp Power, Warranty</td>
<td>7kW, 300 hrs</td>
<td>(12x) 450W, 2,000 hrs</td>
</tr>
<tr>
<td>Number of Lamp Change Cycles</td>
<td>18,200/300 hrs = 60.6 Lamp Change Cycles</td>
<td>18,200/2,000 hrs = 9.1 Lamp Change Cycles</td>
</tr>
<tr>
<td>Cost of Xenon Lamps</td>
<td>= 60.6 x € Xenon Lamp = € A</td>
<td></td>
</tr>
<tr>
<td>Calculate Cost of SRX-R515DS HPM Lamps</td>
<td>= 2 x 9.1 x € HPM Lamps = € B</td>
<td></td>
</tr>
<tr>
<td>Lamp Cost Saving</td>
<td>= € A - € B</td>
<td></td>
</tr>
</tbody>
</table>

*2 boxes of lamps, 6 lamps in a box

The savings can be even more significant when we consider operators who do not risk running their xenon lamps past the warranty life but could run HPM lamps significantly longer than the warranty period without fear of a lamp explosion damaging the projectors. HPM lamps have a ‘usable life’ beyond the basic warranty hours. Chart 1 illustrates possible lamp cost savings for HPM lamps based on warranty hours and useable life of warranty +50%.

Using typical market pricing we found that the main system costs comprising; initial system purchase (including 3D), power consumption and lamp replacement costs over 5 years; could be up to 25% lower for a HPM lamp based dual system based on lamp warranty life and up to 30% lower based on useable life.

This analysis can be repeated by cinema operators to compare their high power xenon, 3D projection system of choice with the Sony SRX-R515DS. Results will vary depending on the projection system selected and local pricing conditions.
Multiple HPM lamps used in the SRX-R515DS can deliver very significant savings over a long period.
The first laser illuminated projection systems for cinema are being deployed and as with any new technology, will undergo intensive evaluation as candidates for possible general roll out.

Looking forward to laser projection

There are two technology implementations of laser projection aimed at different applications and with different cost of ownership profiles.

• **Blue Pumped Phosphor laser projectors** are a hybrid of laser and phosphor technology. The main light source is a yellow phosphor wheel excited by a laser to generate the Red and Green light channels, the Blue channel comes directly from a laser. Maximum brightness level is limited by the phosphorescent capabilities of the wheel so this variant is only suitable for small to medium screens. Quality and specifications are in line with comparable DCI compliant lamp based projectors.

• **RGB laser projectors** use 100% laser illumination. Light is generated by arrays of Red, Green and Blue laser diodes. The number of laser sources can be stacked to achieve brightness levels above the capabilities of the largest xenon lamps with the potential to finally be able to run 3D on large screens at levels up to 14fl.
The two laser-based light sources have two advantages in common:

- **Operational Life** - Both types of laser illumination sources have very long operational life. The laser phosphor source is typically suggested to have a 20,000 hour life to decay down to 50% brightness and RGB laser sources are typically suggested to take 30,000 hours to decay down to 80% brightness. During this time a traditional projector would undergo many lamp changes.

- **Electrical Efficiency** – Lamps convert electricity into white light but the projection process only requires narrow-band light in the Red, Green and Blue regions of the spectrum, all other light energy is filtered out and wasted. Lasers are tuned to the exact colour wavelengths required thereby avoiding the wasteful generation of unwanted parts of the spectrum.

Lasers should be recognised that laser light sources are a new and expensive technology, the cost of which is added into the initial capital cost of the projector as opposed to being an ongoing operational cost as with lamps. Furthermore, if the light source represents a large percentage of the projector cost then there would be a large cost of ownership step when it is finally time to renew the light source.

When purchasing a laser projection system you are effectively “buying all of your lamps up front” and it is suggested here that Total Cost of Ownership which includes initial hardware is a more useful metric for comparison than the lamp cost of ownership. Laser illuminated projectors start to become economically viable when their total cost of ownership approaches that of equivalent lamp based projectors over the same period.

The longer term approach of TCO analysis is, again, a useful tool to compare the very different light sources of lamp technologies versus laser.

**References**

[1] XBO Theater Lamps – Technology & Application, Osram
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