HIBAYS
It's All About The Details

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Introduction

With technology and experience advancing so rapidly, this is my fifth article on this subject. It started with 'Comparing Fluorescents and HID', 9/98, *Energy User News,* then came 'Essay By Invitation', 4/99, *LD+A*, followed by 'Essay By Invitation', 6/01, *LD+A* and 'Essay By Invitation', 2/02, *LD+A*. Like the previous articles, this one should be taken as a stop in the road on an endless trip, instead of a final destination.

Intent

Customers deserve more than what is really marketing hype from hibay manufacturers and sales people. Several T5HO and T8 hibay manufacturers have marketing literature that tries to show that their products are the best thing since sliced bread. There are also HID manufacturers that do basically the same for what they sell; for example you do not need 10 F54T5HOs to be the equivalent of magnetically ballasted 450W PS MH. I do not like to do business with any party that does not provide accurate and balanced information.

In reality, the footcandles per watt performance of PS or ceramic MH with high performance dome and electronic ballast is very similar to T5HOs or T8s with electronic ballasting and good reflectors. Because MH electronic ballast pricing is significantly coming down T5, T5HO and electronically ballasted PS MH hibays may cost nearly the same. Although some of the dimming electronic MH ballasts do cost significantly more, their flexibility and performance can often provide the best total solution in some applications. Don't automatically jump on the T5HO bandwagon, like so many have.

Any of these advanced lighting technologies - T8s, T5HOs, extra-long life CFLs (compact fluorescent lamps), induction, PS (pulse start) MH (metal halide) or ceramic MH may be the best solution for specific applications. The intent of this article is to provide information so you can decide the best technology for various applications.

Definition of Hibay

Although some people call it a hibay if mounted over 25 feet high and a lowbay if less than 25 feet high, I do not make that distinction. I often see typical HID lowbays, the ones with large diameter relatively flat dome and large drop lens, in 'hibay' applications and typical HID hibays in 'lowbay' applications (often because hibays cost less than lowbays). I am not making a firm distinction between hibays and lowbays.

Quality of Light

In the past horizontal footcandle measurement was the most common way to evaluate if the lighting was adequate or not. The Ninth Edition of The IESNA Lighting Handbook has made big strides to expand what constitutes good lighting. This includes glare, contrast ratios, shadows, color appearance, vertical footcandles and horizontal footcandles. I highly recommend reading chapters 10, 19 and 20 of the IESNA Handbook as well as the new IESNA Recommended Practices For Lighting Industrial Facilities and Sports & Recreational Area Lighting. www.iesna.org

Although fluorescent lamps are available with up to 95 CRI, the lumens are much less than for 85-86 CRI fluorescents. Most fluorescent hibays have 85 – 86 CRI lamps, which have better color rendering than all HID, except the new ceramic MH lamps, which have 90 – 96 CRI without sacrificing light output. There are also 5000K 90 CRI PS MH lamps that have slightly less photopic lumens per watt than lower Kelvin and lower CRI PS MH lamps, but the higher scotopic/photopic ratio, described in the next section, can compensate for the lower photopic lumens.

For some applications, well designed linear fluorescent hibays are better than well designed HID hibays with regard to glare, contrast ratios and vertical footcandles. Following are two application examples. Imagine yourself playing volleyball. As you follow the high arching ball coming towards you, would you prefer having to look up into a point source HID hibay or a 4' or 8' long fluorescent hibay with four F54T5HOs or six F32T8s? Imagine yourself as a forklift driver having to deal with vertical surfaces and load and unload pallets in high warehouse racks. Compare vertical footcandles with well designed 4', 8' or extended row linear fluorescent hibays mounted in the middle of rack aisle row parallel to the racks with well designed HID hibays mounted in the middle of rack aisle row. Envision how easily a loaded pallet can block the light from the point source HID lamp.

For other some applications, like retail, PS or ceramic MH in clear prismatic hibay domes provide more uniform uplight, can be considered more aesthetically pleasing, and maintain the traditional hibay look, compared to most fluorescent hibays with or without uplight.

There often needs to be more than just hibays for good lighting. Lower mounted hooded industrials or other task lights are often required in industrial settings. Dimmable PAR-halogens are very helpful for dances, plays and presentations in gymnasiums. Emergency lighting is usually required.

Two Ways to Measure Light

The long established way of measuring the amount of light has been with photopic lumens, which are the lumens listed in lamp catalogs. Another way is combining photopic and scotopic lumens, based on Dr. Sam Berman's and others' work. I believe that the latter is more based on how the human eye really perceives light at common interior light levels. The various lighting studies by Berman, et. al. over the last 15 years have concluded that general lighting with high scotopic to photopic ratios (S/P), typically characterized by high color temperature lamps, provide better visual acuity. 'Visual Acuity Depends on the Color Temperature of the Surround Lighting' by Mojtaba Navvab, which was published in Summer 2001 *Journal of the IES* and 'Using Visual Acuity to Measure Display Legibility' by Sheedy and Bailey, *Work With Display Units 94*, Creico et-al. Elsevier, Amsterdam, 1995, show significant visual acuity gains and faster reading times when using high S/P general lighting. The easiest to read is Berman's 'The Coming Lighting Revolution in Lighting Practice' in October 2000 *Energy User News*, which is downloadable at http://www.energyusernews.com/eun/cda/articleinformation/features/bnp__features__item/0,,14423,00+en-uss_01dbc.htm.

Personal experience can be more relevant than research. What do you think is brighter in an apples to apples comparison, a new 38,000 photopic lumen 400W MH or a new 50,000 photopic lumen 400W HPS? People that I have talked with that have seen this comparison have said the MH, even though it has 24% less photopic lumens. You can do the same exercise with 5000K and 3500K F32T8s that have the same CRI and photopic lumens. Guess what the answer is -- the scotopically enhanced 5000K.

In the past fluorescents had the edge regarding availability of high scotopic/photopic ratios. But 5000K PS MH lamps are being introduced.

Whichever camp you are in, the two tables in the Table Time section provide useful information based on photopic lumens and also task modified lumens.

It requires experience and expertise to properly design lighting systems based on S/P ratios, because color tone preferences and ambiance issues can be very important.

Hopefully lamp manufacturers will provide more S/P ratios in their catalogs, websites or spec sheets.

Be aware that the IESNA does yet not accept the principle that light levels can be reduced below IESNA's existing illuminance recommendations by the use of scotopic enriched lighting.

Temperature - Lamps

The light output of HID lamps is relatively constant with relationship to temperature. On the other hand the light output of most fluorescents is very dependant on ambient temperature. If the ambient temperature is cold or ranges from cold to normal, the problem can usually be taken care of with tube guards, lenses and/or enclosed fixtures, because they can raise the 'ambient temperature' right next to the lamps. With certain ballasts, sealed fixtures and tube guards, T8s and T5HOs can be operated slightly below –18^{o} C (0^{o} F). The downside is that any tube guard or lens will block some of the light. For fairly hot applications, vents in the reflectors, which also provide some uplight, and no cover over the reflectors can dissipate heat from near lamps. If the ambient temperature is too hot or ranges from cold to hot, there is no easy solution.

Optimal ambient temperatures are listed for specific fluorescent lamp type in the Hibay Options Section. When the ambient temperature frequently reaches 49^{o} C (120^{o} F) at mounting height, which is not that uncommon in warehouses that do not have adequate venting or air conditioning, PS or ceramic MH may be a better option than fluorescent. For the majority of applications temperature is not a major concern for fluorescent lamps in hibays, except for biaxial lamps. The table's light output quantities are based on optimal temperatures and can be easily modified for other temperatures. You can get lumen and temperature tables from the lamp manufacturers. However, this does not accurately predict how lamps will perform in specific hibays under various ambient temperatures. Hibay manufacturers should be able to provide this data.

The major lamp manufacturers are working on adding amalgam or using some other technology so T5HOs will be able to provide more light at cold and maybe also hot temperatures. Some fixture manufacturers are working on heating or cooling the 'cold spots' of T8 and T5HO lamps to increase light output.

In areas with skylights, the daylight contribution can often mitigate the reduced light output from fluorescents when they are the hottest.

Don't base your decision solely on point-by-point computer layouts when comparing, for example, T8 vs. T5HO. What looks best that way is often not reality. At certain temperatures a specific T5HO hibay outperforms a specific T8 hibay and at another temperature the same T8 hibay outperforms the same T5HO hibay. Some manufacturers have less concern for thermals than others. Bottom lenses, uplight vents in reflectors, etc, can complicate the basic rule that T8s provide more light when it is cooler and T5HOs provide more light when it is hotter.

Temperature – Ballasts

Temperature is usually not a concern with HID magnetic ballasts, but may be one with at least some HID electronic ballasts. Even if the HID electronic ballast is rated for 90^{o} C (194^{o} F), one ballast manufacturer recommends a maximum ambient temperature of 40^{o} C (104^{o} F), and another one recommends 55^{o} C (131^{o} F). If heat sinking in ballast compartments improves, then electronic HID ballasts will be able to be used in higher ambient temperatures.

Temperature is definitely a concern with fluorescent electronic ballasts.

Hot temperatures can dramatically reduce the life of many electronic fluorescent ballasts. A typical maximum ballast case temperature rating is 70° C (158° F), which can often be reached when the ambient temperature is 57° to 60° C (135° to 140° F). It really depends on how the fixture dissipates heat. At 70° C (158° F) ballast case temperature the rated ballast life is often listed at 60,000 hours. At about 10° C (18° F) higher ballast case temperature, ballast life may be reduced to 30,000 hours. At about 10° C (18° F) lower ballast case temperature, ballast life may be increased to 90,000 hours.

I highly recommend fluorescent hibay manufacturers that have good heat sinks and venting in the ballast compartment. Several companies have introduced 90° C T5HO ballasts, which help reduce this potential problem. But the 90° C ballasts only have a 3 year warranty when the case temperature is between 70° and 90° C, and do not yet have a proven track record.

Ballast temperature tends to be more problematic in T5HO than T8 hibays, because T5HO hibays are narrower so the heat is condensed from the lamps and ballasting. The heat has caused many T5HO ballasts to fail prematurely. There are several large national companies that have had so many problems with poorly designed T5HO hibays that they do not want to consider them in any new projects.

One ballast manufacturer began including a strip of mylar in a percentage of their T5HO ballasts. If the film shows that the maximum ballast case temperature rating was exceeded, the manufacturer does not have to replace the ballasts during the warranty period. This is fair, because ballast manufacturers should not have to replace ballasts that were not operated according to guidelines. Other ballast manufacturers are considering similar measures.

In unconditioned spaces that can get hot, I typically specify that fluorescent hibay manufacturers need to guarantee that at an ambient temperature of 52° C (125° F) the maximum electronic ballast case temperature will not exceed 70° C (158° F). Many fluorescent manufacturers, that do not provide large ballast compartments or ballast compartment venting and use steel instead of much better heat sinking aluminum, cannot honor that guarantee. Ideally their design should prevent ballast case temperature from exceeding 60° C (140° F), for extra ballast life.

Lamp Lumen Maintenance

The amount of light that a lamp provides as it ages is much more important than when it is brand new. Many people use mean or design lumens, which is the percentage of light measured at 40% of rated life compared to initial light output. This is usually listed in lamp catalogs. I prefer end of rated life lumen maintenance, which provides worst-case information (I know of very few facilities that group relamp, which is typically recommended at 70 – 80% of rated lamp life). End of life lumen maintenance is usually not listed in lamp catalogs but can be obtained from lamp manufacturers.

Yes, PS and ceramic MH have much better lumen maintenance than standard MH. But with typical magnetic lead ballasts, which are also called CWA (constant wattage autotransformer) ballasts, the lumen maintenance of PS and ceramic MH still pales in comparison to high performance fluorescents. With magnetic lag ballasts, which include reactor and modified reactor (HX) types, PS and ceramic MH's lumen maintenance is substantially improved, because the current waveform is much more sinusoidal. Up another notch to electronic ballasts that have avalanche enhanced starting and high frequency current waveforms, the lumen maintenance of PS and ceramic MH get closer to the lumen maintenance of high performance fluorescent. It appears that the more dimming with electronic ballasts, lumen maintenance can near 80% at end of life for PS MH lamps. So be leery of comparisons from fluorescent hibay manufacturers that only use the worst case 65% mean or 45% end of life lumen maintenance for standard MH and 75% mean or 65% end of life for PS MH.

Dimming electronic ballasts for PS and ceramic MH allow for a good lumen maintenance system. A closed loop photocontrol system can be placed in each hibay, so a new lamp will be under-driven and as the lamp ages, it is driven harder.

T5HOs and high performance T8s have mean and end of life lumen maintenance from 90 to 95%.

Luminaire Efficiency

Higher luminaire efficiency is not always better. A bare lamp fixture has 100% luminaire efficiency, but only 50% of that light may actually be useable. Although lowering HID lamps or having slanted biaxial lamps extending down below the bottom of the hibay improves luminaire efficiency it may reduce the amount of light that hits the target area.

No matter what type of hibay, a bottom lens will reduce luminaire efficiency about 10 percentage points. So if a hibay without a lens has a 75% luminaire efficiency, adding a lens would bring it down to about 67%. All listed luminaire efficiencies in this article are with open bottom - without a lens.

Metal Domes

Most generic round metal dome hibays provide 70 to 80% luminaire efficiency. Either all of the light can be directed down or there can be some slats, which provide some direct uplight.

Faceted Metal Domes

These provide higher luminaire efficiencies than basic spun aluminum domes. They are also available with additional inner reflector. Luminaire efficiencies can range from 80 to 94%.

Glass Lined Domes

They are also available with additional inner reflector. Luminaire efficiencies can range 80 to 94%.

Prismatic Reflectors

These dome shaped reflectors are available in glass and acrylic. Both have pros and cons. For example, plastic costs less and may have more downlight. Glass can be better for high temperatures and is chemical resistant. Both cost more than metal domes, but provide higher luminaire efficiency, mainly because some of the light is prismatically reflected instead of surface reflected, and a small portion of the light passes through the dome to provide side and up lighting. Luminaire efficiency can be around 93%, but how much of the side and uplight is really useful for specific applications?

Clear ribbed or prismatic reflectors can often help eliminate the ‘cave effect’ by brightening the ceiling and upper walls, which can be very important in numerous applications. But the uplight is often wasted with dark colored ceilings. Contrast ratios are really only improved with white ceilings. Ceilings can often be quite well lit without any direct uplight. An example are highly polished or waxed gym floors, which reflect a lot of downlight up to the ceiling and upper walls.

Excessive dirt depreciation in dirty environments is a definite possibility. Also the lower wattage pulse start MH lamps are only rated for 15,000 hours, so having to replace lamps more often may not be cost effective. However, dimming electronic ballasts could be used with a higher wattage 20,000 hour rated lamps, consuming the same wattage as lower wattage lamps

Several manufacturers provide outer prismatic reflector and inner metal reflector systems. Luminaire efficiency can exceed 93% with more of the light directed down.

Metal Linear Reflectors

Most manufacturers use 95% reflective enhanced aluminum, which is very scratch resistant. There is also a new 98% reflective silver, not film, which may cost 20 to 40% higher to end customer. 90 – 94% reflective white reflectors are often a good option for low mounted hibays to reduce glare. Based on physics, higher luminaire efficiencies are possible with reflectors with 5/8” diameter linear T5HO lamps than 1” diameter T8s, biaxial lamps or triple loop CFLs. T5HOs are the closest to a line source or linear point source.

Without playing games, the best luminaire efficiency for T5HO and T8 hibays with metal reflectors that I seen is about 93%. Luminaire efficiencies are typically lower for other fluorescent hibays with metal reflectors.

I strongly agree with 'Photometry for T5 High-Output Lamps and Luminaires' by John Zhang and Peter Ngai at Peerless/Lithonia. It was published in the Journal of the IES. It promotes a new protocol for T5HO luminaire efficiency. It is foolish for luminaire manufacturers to state over 100% luminaire efficiency, because luminaires are tested at 25^{o} C (77^{o} F), while T5HO lamps provide optimal light output at 35^{o} C (95^{o} F). One way to supposedly get over 100% luminaire efficiency is to allow the heat of the T5HO lamps to increase the temperature next to the lamps in a luminaire that the heat cannot easily escape from close to the lamps, so although the true ambient temperature is still 25^{o} C, the modified ambient temperature by the lamps is 35^{o} C. Another way to supposedly get over 100% luminaire efficiency is to do the testing at 25^{o} C and use a multiplier for the lamps.

Luminaire Dirt Depreciation (LDD)

LDD is not included in the table, because I have not seen substantial information on this. In dirty environments, LDD can be more significant than lamp lumen maintenance, but the jury is out on how various lamp types and mounting are specifically affected. .

An advantage of horizontal fluorescent lamps is that about 40% of the light comes from the bottom half of the lamps without having to bounce off a reflector or refractor like a vertical HID lamp has to. A negative of horizontal fluorescent lamps is that dirt can land and stay on the top of them more easily than on vertical HID lamps. Also, since there is more surface area, it can take more time to clean a linear fluorescent than an HID hibay.

LDD can be very significant with clear ribbed or prismatic domes, and over time can block most of the side and uplight in dirty applications. Where pole changers are used, hibays are not usually cleaned. If a person gets to the hibay to change a lamp, it is maybe 50/50 if he or she cleans the inside and the odds are high that outside of the dome will not be cleaned.

Glass reflectors may get less of a static charge than various plastics and metals, which may result in less dirt accumulation.

Dirt may affect specular surfaces more, because, both optical control and reflectivity decrease.

I have not seen any thing definitive on how HID and linear fluorescent hibays compare with regard to LDD. If anybody knows of good documentation on this subject, please send it to me.

No matter what type of hibay, it is important to be aware of various types of dirt. There is dust type of dirt that mainly adheres when it fall on top of a surface. There are also oily, grimy and electrostatic types of dirt that can easily adhere to vertical as well as horizontal surfaces.

The lamp compartments in both fluorescent and HID hibays can be sealed, have filtered air vents, have chimneys and incorporate other ways to reduce LDD.

Lamp Life

HID lamps are rated at 10 hour cycles and fluorescents are typically rated for 3 hour cycles. A majority of hibay applications have at least 10 hour cycles. Running many fluorescents at 10 hour cycles will significantly increase rated lamp life. But there is a catch to this.

Most T8 lamp life is based on being driven with rapid start ballasts. For hibay applications, 1.14 to 1.20 BF (ballast factor) ballasts are usually the most appropriate, and the only ballasts currently available with this high BF are instant start, which can greatly reduce T8 lamp life in short cycles, which can often occur with occupancy sensors. For T8 hibay applications with instant start ballasts, it is highly recommended to use high lumen F32T8s that are rated for at least 24,000 hours at 3 hour cycles and 30,000 hours at 12 hour cycles, both with instant start ballasts. Don't just look in a lamp catalog. For example, one lamp manufacturer listed 30,000 hour rated life for one of their F32T8 lamp types in their 2002 catalog, but that lamp life rating is based on using a specific program start ballast. That lamp only has a 15,000 hour rating with instant start ballasts. You can get accurate lamp life ratings based on specific ballast types from various manufacturer's websites, headquarters and local reps. A number of ballast manufacturers are developing high BF program start ballasts for T8s, which could work out great for occupancy sensor applications, but consume slightly more wattage.

T5HO lamp life is based on program start ballasts, so lamp life does not degrade that much with short cycles. Be careful, because there are some instant start ballasts for T5HOs, which cost less and use less wattage, but lamp life can go down the tubes. It is my understanding that the major lamp manufacturers may not warranty their lamps with instant or rapid start ballasts.

Some ballast experts say that PS MH lamp life can be increased 25% with electronic ballasts that have avalanche starting, but we will have to wait for lamp manufacturers to make that claim. Lumen maintenance is still good at end of life, and extended lamp warranties have been provided.

The old workhorse, 400W standard MH lamps can often last 30,000 hours, but are only rated for 20,000 hours because lumen maintenance gets very low past 20,000 hours.

No matter the lamp type, at least 20,000 hour rated lamps are recommended for hibay applications.

Lamp Maintenance

Standard and pulse start MH lamps should be turned off at least once every week to reduce the risk of nonpassive failures in lamps which are not containment 'O' rated. I like the 'spin' in the term 'nonpassive failure', after seeing the damage done to fixtures from this. It is surely not passive. It is worth noting that the number of MH lamps with the 'O' rating are increasing, which encourages the use of open luminaires.

HID people often state 'why would you want to buy and replace all of those fluorescent lamps in each fixture?'. Fluorescent people tend to often reply 'with only one lamp in a hibay, when that lamp burns out, you need to replace it ASAP, because with the one lamp out, there is one big dark space' unless the system was designed for significant lighting overlap. For some applications it is a big plus to use a pole changer to replace HID lamps. If a pole changer can not be used, like when there is a bottom lens or wire cage, then maintenance is often better (a.k.a. less urgent) with multiple T8s and T5HOs than with single HID lamps.

When maintenance costs are very high, induction systems may be the best option.

Controls

Historically controls have been very limited with HID lamps and magnetic ballasts, because of lamp warm up and restrike times. For example, in most gyms, the HID hibays are turned on at the beginning of the day and left on until closing, because of the long warm up and restrike times. High/low control systems can save some energy, but it is not one-to-one between wattage and light output. For example, if the light level is at 40%, the wattage may be about 60% of maximum, only saving 40%. HID lamp life can suffer with high/low magnetic systems. In many applications the high-low feature simply masks the fact that you have to run the system at 50% load, even when the lights aren't needed at all. The low wattage of most high/low control systems is usually higher than the maximum wattage of the equivalent F54T5HO or F32T8 system.

HID dimmable electronic ballasts are much more control friendly. The relationship between light output and wattage can be much more linear and efficacy and lamp life may be improved. But the restrike and warm up times are often still too long for turning completely on and off with occupancy sensors. Gyms are a very good application. For activities such as conference basketball games, the light levels can be set at max overhaul or just over court area. For activities such as PE classes, the lights could be dimmed significantly, which saves considerable electricity.

Because fluorescents are instant on, they are the most suitable for controls. In gyms, we have found that the burn time is often reduced 20% replacing HID with fluorescent, because the staff can turn the lights off when the gym is not used and turn them back on when it is used. Switches and occupancy sensors can be used to turn on and off all of the lamps. Although fluorescents have instant on, it takes a short time to reach full brightness, especially in cold environments. In order to provide sufficient light right after a sensor turns on a single or bank of fluorescent hibays, it is often recommended to include more lamps in each hibay in warehouse rack aisles.

An example is to use 6-F54THOs instead of 4-F54THOs to replace a 400W MH or HPS hibay. Since the burn time is usually greatly reduced, there are usually substantial KWH savings to offset the use of the two additional lamps to attain sufficient instant light levels.

There are many dimming ballasts for various fluorescent lamps. Some are proprietary, which only work on one company's system and others are nonproprietary, such as 0 – 10V. But if you are not aware, all 0-10V systems don't work the same way.

Digital addressable logic interface (DALI) may revolutionize the dimming electronic ballast industry. Each ballast can be controlled independently or with multiple groups. This system also has two-way communication, which can allow facility managers to identify on their computers, burned out lamps and ballasts. DALI is not proprietary, so several manufacturers are making interchangeable ballasts and controllers. But until addressing and commissioning become much more simplified and pricing comes down, I do not think that DALI is ready for prime time.

Regarding fluorescent ballasts, dimming does not always save as much as you may think. Dimming ballasts are typically program start, which maintains lamp cathode heating, and as dimming brings down the light level, cathode heating increases. Both dimming and non-dimming program start ballasts have a significantly lower BEF (ballast efficacy factor) than extra-efficient instant start T8 ballasts.

$$BEF = (\text{ballast factor} \times 100) / \text{system wattage}$$

This is one reason why instant start T8 systems can save more wattage than program start T5HO systems.

Daylight Harvesting

Although this could be part of the controls section, this subject deserves more. Warehouses, big box retail, industrial facilities and gyms are great applications for skylights, which can save KWH and more important – peak load. I hate to see hibays fully on during the middle of the day that are underneath or right next to skylights. What a waste!

A photoswitch that has sufficient dead band can work even with a regular magnetic ballasted HID hibay. Performance is better with a magnetic high/low HID hibay and dual stage photoswitch. Dimming electronic ballasted HID and a continuous photocontrol is even better.

Daylight harvesting is very easy with fluorescents, because they have instant on with no restrike time. Fluorescent hibays can be staged dimmed (step controlled) with multiple fixed output ballasts and continuously dimmed with dimming ballasts. In addition to windows and skylights another good application is installing a photocell to fluorescent hibays close to large roll up doors to turn off power when there is sufficient day lighting.

It is critical to budget sufficient time and money to properly commission occupancy sensors, photocontrols and other controls.

Sustainability

Sustainability is very important and comprehensive. A very good book is 'Cradle to Cradle' by William McDonnaugh and Michael Braungart. This article limits the scope to color coating, mercury and lead.

Powder coating is recommended over paint for reflectors and fixture housings, because there are no solvents. Plus powder coat tends to hold up better to rust and salt air.

People are becoming aware that mercury is a bigger problem than was thought of in the past. Even in states, like California, that have mandatory recycling rules for lamps that have mercury, not all lamps get recycled. It is important to be aware that recycling is not a perfect, because significant mercury can be embedded in the lamp glass, and when that glass is re-melted to be re-used, that mercury can be released into the environment. So it is also important to reduce mercury at the source. Following is a table on mercury.

MERCURY CONTENT						
lamp type	mg per lamp	lamps per fixture	mg per fixture	EOL fixture 10K lumens	rated 10K hours	mg of Hg per (10K-EOL-lumen x 10K-hour)
160W induction	**8 -- 18**	**2**	**16 -- 36**	**1.440**	**10.0**	**1.11 - 2.49**
F54T5HO	**1.4 -- 5**	**4**	**5.6 -- 20**	**1.860**	**2.4**	**1.25 - 4.48**
400W ceramic PS MH	**12 -- 35**	**1**	**12 -- 35**	**3.200**	**2.0**	**1.88 - 5.47**
F32T8 (long life)	**3.5 -- 8**	**6**	**21 -- 48**	**1.968**	**2.8**	**3.81 - 8.71**
250W ceramic PS MH	**15 -- 25**	**1**	**15 -- 25**	**1.920**	**1.5**	**5.21 - 8.68**
42W CFL	**2.7 -- 5**	**8**	**21.6 -- 40**	**2.560**	**1.4**	**6.03 - 11.16**
400W quartz PS MH	**50 -- 70**	**1**	**50 -- 70**	**2.975**	**2.0**	**8.40 - 11.76**
250W quartz PS MH	**34 -- 41**	**1**	**34 -- 41**	**1.645**	**1.5**	**13.78 - 16.61**
400W standard MH	**50 -- 70**	**1**	**50 -- 70**	**1.710**	**2.0**	**14.62 - 20.47**
250W standard MH	**34 -- 41**	**1**	**34 -- 41**	**0.950**	**1.0**	**35.79 - 43.18**
notes:						
Check with specific lamp manufacturers about specific lamps regarding mercury content.						
Fluorescents are low mercury types. T8s are 3100 lumen and rated for 24,000 hours at 3 hour cycles.						
All MH lamps are clear. Electronic ballasts drive all PS MH lamps. Magnetic ballasts drive standard MH.						
160W induction is a composite of actual lamps.						
EOL stands for end of life for all lamps in fixture. 10K means 10,000.						
Rated hours are based on 10 hour cycles. This is apples to apples comparing fluorescent and HID						
Luminaire efficiency, which is not included, is much lower with basic grade spun aluminum domes.						
BFs are 1.0 except for F32T8s, which is 1.15.						
Standard MH lamps should not be used because of high mercury and low efficacy.						
Prepared by Stan Walerczyk. 10/16/04 version						

Linear fluorescent lamps do not have lead. Although the lamp manufacturers are switching to leadless soldier, some manufacturers still make some HID lamps with lead solder. I recommend that you only purchase HID lamps that are lead free.

Miscellaneous

While electronic ballasts can only be mounted up to 12 or 25 feet from lamps, many magnetic ballasts can be remote mounted 100+ feet from lamps, as long the proper gauge wire is used. In the case of pulse starting HID lamps, a remote ignitor is used.

Lamps, driven by magnetic ballasts, will flicker (due to re-ignition every half line cycle), which can be a problem. There is no 120 Hz flicker with electronic ballasts. Some electronic ballasts can be operated by DC.

Magnetic ballasts can cause stroboscopic effects, like making a working circular saw or drill press look like they are turned off. HPS provides more stroboscopic effect than MH. This potential danger can be reduced by having close-by hibays on different input power phases or having electronically ballasted task lights. Because electronic ballasts operate at such high frequencies, there are no stroboscopic effects.

For emergency lighting and instant on, most HID hibays require an additional high wattage quartz lamp. Since fluorescents are instant on, back-up quartz lamps are not necessary.

Magnetic ballasts are much more prone to obnoxious buzzing than electronic ones.

There are some magnetic and magnetic ballasts that drive two MH lamps, which saves some wattage.

Several manufacturers have or will have 480V T5HO and T8 ballasts.

Lamp holders deserve mention. European twist lock sockets are highly recommended for both T8s and T5HOs. For T5HOs make sure that the lamp holders are rated for the heat. I have seen some that were not and melted. When retrofit standard MH with PS or ceramic MH, new high voltage pulse rated sockets may be required. Sometimes mounting the new lamp holder is so much of a problem, that replacing the entire fixture is less expensive.

Benchmark for Hibay Options

Let's use the old workhorses, the 400W standard MH and HPS with metal reflector dome that has less than 80% luminaire efficiency. If you want to consider mercury vapor, 1000W mercury vapor provides about as much light as 400W standard MH and HPS. Mercury vapor usually does not die, just gets dimmer and dimmer over the years.

HPS Option

With its terrible CRI and S/P (scotopic/photopic) ratio, HPS should be avoided for interior applications. Who wants to hang around under ugly yellow light?

In the early to mid 90s some of the California incentive programs basically covered the parts cost of HPS hibays to replace mercury vapor and old style HO and VHO T12 fluorescents. So many gyms and warehouses got new HPS hibays. Hopefully utility incentive programs will finally eliminate incentives interior HPS applications some time.

Although it does not save any electricity, there are two ways to greatly improve the typical 22 CRI of regular HPS lamps. One is the color enhanced HPS lamps, which have 65 to 70 CRI, though life and lumen ratings are greatly reduced, and the color temperature is still only 2200K. The other is the quartz and ceramic MH retro lamps which are designed to be driven by HPS ballasts and provide a CRI up to 90. The benefits are often worth the cost.

Standard MH Option

Pulse start MH has so many advantages over standard MH, that the latter should get a fond farewell and gracefully retire. It is a shame how many new standard MH hibays are still being installed.

Some lamp manufacturer sales people try to push the 360W energy saving standard MH lamps to replace 400W standard MH lamps on existing ballasts, because it can be quick sale, and a contractor is not necessary. Except for short term leases, I usually find better solutions.

Pulse Start MH with Magnetic Ballast Option

Moving the starter from the lamp to the ballast allows for a higher performance arc tube in pulse start MH lamps. From the design standpoint, 300, 320 or 350W pulse-start MH can replace 400W standard MH one-for-one, or fewer 400 or 450W pulse start MH fixtures will be required in a redesign. It is important to determine the exact type of existing 400W standard MH lamps. If they are basic grade universal mount lamps that are only rated for about 36,000 initial lumens, then 300 or 320W pulse start lamps and ballasts may work very well. If the existing 400W lamps are vertical base up with 43,000+ initial lumens, then it may require a 350W pulse start replacement to match the desired lumen package.

As stated previously there are several types of PS MH magnetic ballasts, which vary in lamp lumen depreciation and cost. If the line voltage is 277 and if power quality is good, 277V reactor ballasts are recommended, because they save wattage compared to multi-tap CWA ballasts.

Existing hibays can be replaced or retrofitted with ballast, socket and lamp kits. Especially with hook, cord and plug units, it is often more cost effective to go with new hibays.

With a high performance dome and reflector, a 250W pulse start MH lamp could maybe replace a generic hibay with 400W standard MH and magnetic ballast, but the 250W lamps only have a 15,000 hour rated lamp life.

Sometimes it is difficult justifying the extra money for a high performance pulse start MH hibay, because basic grade spun aluminum ones can often cost less than $100. Usually a lighting system with low-cost basic-grade hibays will cost more than a lighting system with high performance hibays, because either fewer or lower wattage high performance hibays will be required.

Pulse Start MH with Electronic Ballast Option

In many applications the only way that PS MH can really compete with fluorescent is if electronic ballasts are used with PS MH.

Most of the electronic PS MH ballasts are also dimming, some down to 35%, which can save considerable energy. But in many applications, dimming is not necessary or cost effective.

Electronic ballasts for 250 to 450W PS MH have logged millions of machine/lamp hours. More manufacturers are coming out with their own ballasts, which validates that these ballasts really do work. With higher volumes and competition, pricing is dropping.

Not all PS MH electronic ballasts are created equally. At least one manufacturer has avalanche enhanced ignition, which uses a special wave shape to reduce the energy flow during the starting impulse. The wave shape and lower energy availability while the electronics are not thermionic means reduced loss of electrode material during the starting sequence. This may help on lumen maintenance and lamp life.

Lamp replacement duration may be able to be doubled in a yoked pair of fixtures with one ballast and two lamps. The ballast will always start the lamp with the least resistance, so as the lamps age each one will get about equal burn time.

Dimming electronic ballasts can also help minimize lamp types and help prevent maintenance people putting the wrong wattage lamp in certain fixtures. For example, instead of using 175, 250 and 400W lamps, just the longer life 400W ones can be used through out the facility with dimming and wattage set for areas that require less light.

At least one lamp manufacturer makes PS MH lamps that are specifically designed for electronic ballasts.

Ceramic MH with Magnetic or Dimming Electronic Ballast Option

Ceramic MH may be the future of metal halide.

320 – 400W ceramic MH lamps are becoming more popular in retail and other applications where very high color rendering is important. With the 92+ CRI, products may be more 'sellable' and artwork may look better.

Although there are fluorescents that have CRI in the nineties, the lumens drop about one third compared to ones with CRI in the 80s. Ceramic MH does not sacrifice light output for CRI. Lumens per watt for ceramic MH is almost as good it is for PS MH.

Ceramic MH lamps use the same magnetic and electronic ballasts that PS MH lamps use.

Don't get sticker shock with ceramic MH lamps; pricing should come down over time. A less expensive alternative to ceramic MH lamps may be the 90 CRI 5000K PS MH lamps.

CFL Option

CFLs have much lower lumens/watt than T8s and T5HOs. There are often eight 42W triple-loop CFLs in one cavity, so 'how good can luminaire efficiency really be?'. Don't be surprised if maintenance costs end up devouring most of the electricity savings. At 80% of rated lamp life, which is 6,000 to 14,000 hours depending on lamp manufacturer, cycle length and ballast type, it can cost $60 to $80 per fixture to group relamp. Plus there's labor and often lift rental costs, which can be substantial.

One advantage of this option is that because most CFLs have amalgam, light output is fairly even from 10^{o} C (60^{o} F) to 70^{o} C (140^{o} F) ambient temperature.

There are new high wattage and extended life CFLs that can make this option a lot better. These lamps provide up to 9,000 lumens at 120W, which is still not that great of an efficacy. They are rated at 18,000 hours at 3 hour cycles and 20,000 hours at 12,000 hour cycles.

Biax Option

40, 50 and 55 watt T5 biax lamps used to be a good option before the straight F54T5HO lamp evolved. Reflectors can be designed much more efficiently for a straight lamp than for a biax lamp. A 55W biax lamp has about the same catalog lumens as an F54T5HO. They even use the same ballast. But a well designed hibay with four F54T5HOs outshines a well designed hibay with 4–55W biaxial lamps by about 10%. Biax lamps are not cheap and are rated for only 12,000 hours for the 55W, up to 20,000 hours for the 40W. At least on lamp manufacturer may increase life on their 40W biax lamps from 20,000 to 25,000 hours, if program start ballasts are used.

Biax lamps are very temperature sensitive with regard to light output. In a horizontal position the optimal ambient temperature is about 30^{o} C (86^{o} F) with fairly steep fall off both above and below. A couple of years ago, I looked at a cold storage area that had some 40W biax hibays with no bottom lens. The ambient temperature was about 5^{o} C (41^{o} F), so the light output was only about 50%. Because of this misapplication, the end customer did not want to even consider other fluorescent options.

Several manufacturers that used to make biax hibays have switched over to linear fluorescent hibays.

The new 80W 6000 lumen T5 biaxial lamp could be useful for some applications, but it is only rated for 10,000 hours.

Induction Option

Induction systems are considerably less efficacious than other high performance systems, but induction can reduce maintenance costs more than any other system.

When maintenance costs are very high, induction systems can be cost effective. Examples are erecting a special scaffold for hard to reach fixtures, renting an expensive lift, and draining a swimming pool. For these types of applications it can be worth paying up to $800 for a hibay that the lamp(s) and ballast(s) are rated for 100,000 hours.

Induction systems are a classic *Catch 22*. They cost so much because volume is low and volume is low because the cost is so high. But volume is increasing and pricing is dropping. Additional manufacturers are helping bring the pricing down.

Induction lamps can start at temperatures as low as -40^{o} C and F, but light output will be low unless bulb wall temperature or amalgam tip temperature significantly increase. For cold or hot applications, we recommend working with luminaire manufacturers that have experience with the intricacies of induction systems.

F54T5HO Option

You probably already know that you can usually replace a 400W standard MH that has a spun aluminum dome with a 4-F54T5HO hibay, reducing wattage from about 458 to 234, but there is a lot more to be aware of.

Some T5HO hibay manufacturers also state that 4 F54T5HOs can also replace 350W PS MH, which is true if the dome is spun aluminum, but not if there is a high performance dome.

As stated earlier, heat can be a big problem with T5HO ballasts and lamps. Also make sure you are getting program start ballasts unless you do not care about lamp warranties and lamp life. With program start ballasts, lamp life rating is 20,000 hours at 3 hour cycles and 25,000 hours at 12 hour cycles.

Until there are good program start high BF ballasts for T8s, T5HOs with program start ballasts can be a better solution for occupancy sensor applications where the average cycle length is less than 2 hours.

But be careful with T5HOs and occupancy sensors in cool and cold applications. It takes T5HOs quite a while to get to near full brightness after they are turned on. To make sure there is enough light for people, especially fast forklift drivers, extra lamps in hibays or some lamps always on, not controlled by sensors, are recommended.

In properly designed enclosed fixtures, T5HOs can be used in freezer applications down to below 0^o F (-18^o C). But be cautious of using T5HO fixtures in blast freezers, which are typically colder and have a serious 'wind'.

I highly recommend that designers and customers require that T5HO hibay manufacturers provide accurate ballast case temperature and percentage of light output at cold to hot temperatures for specific hibay models with and without bottom lens, tube guards and uplight vents.

T5HOs provide maximum light output at ambient 35^o C (95^o F) in an open lamp test. This is really an indirect reference, because maximum light output is really based on the lamp's cold spot. For a T5HO it is on the glass close to the end cap on one side of the lamp.

T5HO lamp pricing is coming down, but until the three major manufacturers start making the lamps here instead of shipping from Europe, they will still be considerably higher than the best T8s. A number of Chinese and other Pacific Rim companies are shipping T5HOs to North America at quite low prices, but quality and warranty issues are big question marks.

As stated previously, be cautious of non-program start ballasts. Some fixture manufacturers may try to save a few bucks getting instant start ones, but lamp life could be much less than expected especially in occupancy sensor and other short cycle applications.

It will be interesting to see what the major lamp manufacturers come up with to make light output more consistent across the temperature range. At least one major manufacturer is developing a T5VHO lamp, which would provide more lumens than T5HOs.

At least one fixture manufacturer offers different reflector designs for low, medium and high mounting heights.

T5HO and T8 hibays do not have to look like hooded industrials. The luminaires can have horizontal triangle, square or cross configuration. They can have direct, indirect or direct/indirect distribution. Four foot long clear prismatic domes are also becoming available.

F32T8 Option

In many applications I prefer F32T8 compared to F54T5HO hibays for the following reasons:

- T8 systems typically use less wattage for the same amount of light
- Ballast case temperature is not such a concern, because T8 hibays tend to be larger, which facilities heat dissipation
    - But it still can be an issue
- High performance T8s last longer with 3+ hour cycles
    - After high BF program start ballasts for T8s become available, this will also be the case for occupancy sensor applications.
- High performance T8s cost about half as much as name brand T5HOs
    - So 6 F32T8s will cost less than 4 F54T5HOs in an apples to apples comparison
- T8s often allow for lamp minimization in same building and facility
    - Can use the same lamp type in hibays as in other applications

I used to think that T8 hibays were only good up to 25 or 30 feet high. Then I increased it to 40 feet. Recently I heard about one project they worked well at 85 feet. Maybe T5HO hibays are not better at high heights, like was supposed.

As stated previously, the F32T8s that should be used are the ones with 3100+ catalog or photopic lumens, although if they are 5000K, 3000 catalog or photopic lumens are okay. One concern with T8 hibays is that after the original high lumen lamps burn out, some people replace them with lower lumen lamps, because they cost less. This can result in insufficient light levels.

Ballasts with 1.14 to 1.20 BF are usually required, and since the only overdrive ballasts are instant start, lamp life and maintenance can be a problem when controlled by occupancy sensors or manually switched too frequently. Hopefully during 2004 there will be some overdrive program start ballasts, which would remedy this problem. But be aware that with program start ballasts, T8 system efficacy will probably be less than with instant start ballasts.

F32T8s can often be a better solution than F54T5HOs in colder applications, because F32T8s provide optimal light output at 25^{o} C (77^{o} F), compared the 10^{o} degree C higher optimal for T5HOs.

Just like for T5HOs, I highly recommend that designers and customers require that T8 hibay manufacturers provide accurate ballast case temperature and percentage of light output at cold to hot temperatures for specific hibay models with and without bottom lens, tube guards and uplight vents.

At least one lamp manufacturer will honor warranty with up to a 1.32 BF. A 3100 lumen F32T8 with a 1.32 BF ballast provides 4092 lumens, which is not that far away from 5000 lumen F54T5HOs. Other manufacturers are considering this at least on a specific project basis.

At least one fixture manufacturer is having good success with T8s in freezer applications below –18^{o} C (0^{o} F). There are also T8HOs that work well in cold applications.

Recently I have become aware of several problems with tube guards on T8s. It is very important to make sure that the tube guard end caps allow for proper electrical connection and that either instant start ballasts with arc protection or program start ballasts are used. NEMA has a good document on this. www.nema.org

T8 hibays, like their T5HO cousins do not have to look like hooded industrials. They can be designed to have an architectural flair.

Compare Options

Make your own comparisons. Include quality of light, S/P ratio (if you want to), end-of-life horizontal & vertical footcandles, dirt depreciation, glare, distribution, shadowing, spacing criteria, system wattage, initial parts and installation costs, ambient temperature range, ballast case temperature ratings, warm up and restrike times, control flexibility, lamp life, replacement lamp cost, labor cost for maintenance and lift rental costs. Also compare options within options, like apples to apples comparisons of various T8 hibays.

WHATEVER YOU DO, PLEASE HELP STAMP OUT

- Standard MH
- Standard HPS
- Basic-grade domes.

Table Time

There are three useful tables in this section. The numbers and rankings in these tables are not set in stone. I encourage you to use these tables as templates based on specific lamps, ballasts and fixtures that you are considering. The first one shows how fluorescent with half the initial catalog lumens can replace basic grade MH and HPS systems. Lamp lumens, BF, luminaire efficiency, etc. can vary among manufacturers and models, so you could do your own specific comparisons.

HOW CAN FLUORESCENTS WITH HALF THE INITIAL LUMENS REPLACE HID?

Following are some examples

lamp & hibay fixture type	initial lamp lumens	BF	actual initial lamp lumens	EOL lamp lumen maint-enance	EOL lamp lumens	lumin-aire effic-iency	EOL lamp luminaire lumens	sys-tem watts	EOL lamp luminaire lumens per watt	S/P ratio	EOL lamp luminaire task modified lumens	EOL lamp luminaire task modified lumens per watt
spun aluminum reflector with 400W 41K 65-CRI standard MH	38,000	1.00	38,000	45%	17,100	75%	12,825	458	28	1.65	18,953	41
spun aluminum reflector with 400W 22-CRI standard HPS	50,000	1.00	50,000	72%	36,000	75%	27,000	465	58	0.62	18,596	40
enhanced aluminum reflector with (4) 850 85-CRI F54T5HOs	20,000	1.00	20,000	93%	18,600	92%	17,112	234	73	1.90	28,231	121
enhanced aluminum reflector with (6) 3100 lumen 850 85-CRI F32T8s	18,600	1.15	21,390	92%	19,680	91%	17,909	220	81	1.90	29,546	134

Notes
BF stands for ballast factor and EOL stands for end of life.
Fluorescent lamp lumens are based on optimal temperatures & can be adjusted with lumen/temp tables provided by manufacturers.
Luminaire dirt depreciation could be included if you know it.
HID have magnetic ballasts.
Fluorescents have electronic ballasts.
End of life luminaire task modified lumens = end of life lamp luminaire lumens x $(S/P)^{.78}$ [.78 exponent]

The High Performance Hibay Comparison Table shows how generic high performance PS and ceramic MH systems compare with T5HO and T8 systems. You can do your own comparisons with specific lamps, ballasts, luminaire efficiency and distribution, and temperature. S/P ratio can vary within each lamp type. At optimal temperatures, T5HO and T8 systems do have better performance than PS and ceramic MH ones, but often the air temperature by the fluorescent lamps and the fluorescent lamps' cold spots are not at optimal temperature. The Temperature/Light Output Table, and similar ones from other manufacturers, is based on lamps operated in the open air at various ambient temperatures. But the same information directly applies to the air near the lamp in the lamp compartment. The lamp compartment can be much hotter than the ambient temperature. A T5HO will lose about 20% of its light when temperature near lamp is 26^{o} C (79^{o} F) and 55^{o} C (131^{o} F). A T8 will lose about 20% of its light when temperature near lamp is 13^{o} C (55^{o} F) and 46^{o} C (115^{o} F). At higher and lower temperatures, the reductions are greater for both T5HOs and T8s. For example, at 16^{o} C (60^{o} F) near lamp, a T5HO will lose about half of its light, which could be very important with occupancy sensors in cold applications. The 90+ CRI MH lamps can also be an advantage compared to fluorescent is some applications. If somebody would make a 5000K ceramic PS MH lamps, the task modified lumens per watt would be awesome. Although listed luminaire efficiencies are very similar, some fixtures aim light differently, which can be very important for some applications.

HIGH PERFORMANCE MH, T5HO & T8 HIBAY COMPARISON

Following are some examples

lamp, ballast & dome/reflector type	lamp life hours at 10 hour cycles	CRI	initial total lamp lumens	BF	actual initial total lamp lumens	EOL lamp lumen maint-enance	EOL total lamp lumens	lumin-aire effic-iency	EOL lamp luminaire lumens	sys-tem watts	EOL lamp luminaire lumens per watt	Kelvin	S/P ratio	EOL lamp luminaire task modified lumens	EOL lamp luminaire task modified lumens per watt
320W quartz PS MH lamp, magnetic reactor ballast, high performance dome	20,000	65	32,000	1.00	32,000	65%	20,800	92%	19,136	345	55	4000	1.65	28,280	82
320W quartz PS MH lamp, electronic ballast, high performance dome	20,000+	65	32,000	1.00	32,000	70%	22,400	92%	20,608	333	62	4000	1.65	30,456	91
high Kelvin quartz 375W PS MH lamp, electronic ballast, high performance dome	20,000+	90+	28,000	1.00	28,000	80%	22,400	92%	22,608	391	58	5000	2.10	36,759	94
400W quartz PS MH lamp, electronic ballast, high performance dome	20,000+	65	43,000	1.00	43,000	70%	30,100	92%	27,692	413	67	4000	1.65	40,925	99
250W ceramic MH lamp, electronic ballast, high performance dome	15,000+	94	24,000	1.00	24,000	80%	19,200	92%	17,664	260	68	4200	1.86	28,662	110
400W ceramic MH lamp, electronic ballast, high performance dome	20,000+	92	34,000	1.00	40,000	80%	32,000	92%	29,440	413	71	3700	1.82	46,967	114
4 F54T5HO lamps, electronic ballasts, enhanced aluminum reflector	24,000	85	20,000	1.00	20,000	93%	18,600	92%	17,112	234	73	5000	1.90	28,231	121
6 F32T8 lamps, electronic ballasts, enhanced aluminum reflector	28,000	85	18,600	1.15	21,390	92%	19,680	91%	17,909	220	81	5000	1.90	29,546	134

Notes

BF stands for ballast factor and EOL stands for end of life.

High performance domes include clear prismatic, metal faceted or glass lined metal faceted.

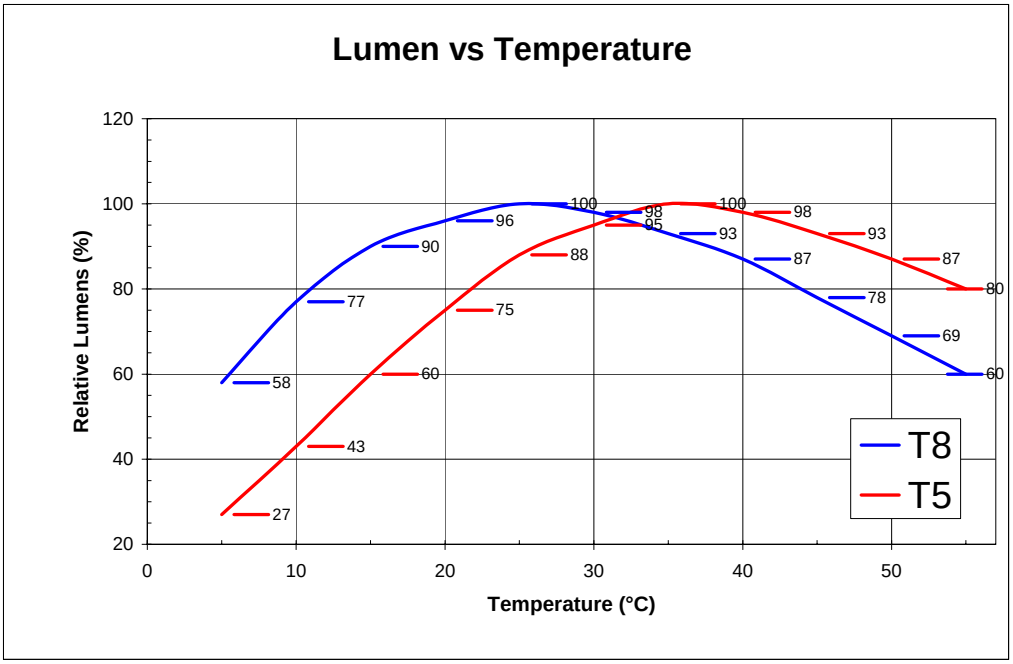
IMPORTANT! Fluorescent lamp lumens are based on optimal temperatures & can be adjusted with lumen/temp tables provided by manufacturers.

Luminaire dirt depreciation could be included if you know it.

All line voltages considered to be 277V.

End of life luminaire task modified lumens = end of life lamp luminaire lumens x $(S/P)^{.78}$ [.78 exponent]

Prepared by Stan Walerczyk for 'Hibays -It's All About The Details'. 10/10/04 version.



The bottom line is that no one technology is superior for all applications.

Case Studies

Pacific Gas & Electric Distribution Center
Fremont, CA

This was one of the early T5HO projects, and it is holding up quite well. This project demonstrates how installation of F54T5HO reduced load, but really set the table for a major controls implementation. The warehouse had mainly 400W HPS high bays mounted at 35 feet height with hook, cord and plug. In the rack aisles, minor hallway and back open areas, each 400W HPS hibay was replaced with an 8 ft. hooded industrial hibay that used a cord and plug and was easily chain-mounted. Each new luminaire has 6–F54T5HO lamps, three program start (1.0 BF) electronic ballasts, 95% reflective specular reflectors, a power pack, and occupancy sensor. With power feeds running perpendicular to rack aisles, it was more practical for each hibay to have its own sensor and power pack than to run low voltage wires among fixtures. We specified hibays with 6–T5HOs instead of 4–T5HOs, so forklift drivers would have sufficient light as soon as fixtures turned on, especially on cold days. 8 ft. hibays were chosen over less expensive 4 ft. luminaires to reduce shadowing. Wattage was reduced from 450 to 351. Obviously the majority of savings is attributed to burn-time reduction from occupancy sensors that totally switch off fixtures in occasionally occupied areas. Sensor time delay was set for 10 minutes in rack aisles and 30 minutes in minor halls and back open areas. In a similar manner, 1000W MH high bays were replaced with 8' hooded industrials with 8 T5HOs, ballasts, sensors, etc. In addition to the 610 watt per fixture reduction there is again significant KWH savings from the sensors, which are set at 30 minute delay. In the front open area and major hall shadowing was not a factor, and traffic is higher during normal operating hours. Here the 400W HPS high bays were replaced with 4' hooded industrials with four T5HOs and no sensors. Wattage was reduced almost 50%. A programmable time clock with digital time switch override was installed to control burn time. Previously, fixtures in this area were often left on all night long and most weekends.

Big Box Retail

It seems that all of the big box chain stores are switching from standard MH to T5HO, T8, PS MH or ceramic MH both for new stores and retrofits. Some of these chains prefer the traditional HID hibay 'look', instead of linear fluorescent.

Plus the round clear prismatic domes provide more uniform uplight than linear fluorescent.

Gymnasiums

I have specified replacing HPS and standard MH hibays with T8 and T5HO hibays in numerous K-12 and college gyms. Typically the wattage was cut in half. With the warm-up and restrike time of the old HID hibays, the lights had been left on all day, even when not being used for substantial periods of time. Now teachers, coaches and maintenance folks can turn the lights off and back on when needed.

One San Jose, CA high school gym had HPS hibays. After they were replaced with T8s, the varsity basketball coach told me that he and team loves the new lighting, but they lost their home court advantage. Before his team was used to the yellow and low color rendering lighting and the visiting teams were not.

The Solano Junior College Gym in Northern California had end to end 8' hooded industrials with two F96T12 VHO lamps. To avoid expensive inside wireman wages we retrofitted a portion of these fixtures with specular hood kits and combinations of either 4 or 6 F54T5HOs. The remaining fixtures were gutted and used as power channels with new ballast covers. Occupancy sensors were also installed in non-emergency fixtures.

Strong wire cages were used for all of these gym applications.

Airplane Hangar with 1000W MH hibays mounted at 85'

This is a high security facility that will remain nameless. Maintenance costs are very high, so the original main concern was to provide long group relamping intervals in addition to reducing wattage. Before the retrofit, the group relamping schedule was about 9,000 hours, which is 75% of the 12,000 hour rated life of the lamps they were using. Some 1000W MH lamps are rated for 15,000 – 18,000 hours.

I considered the pros and cons of three options - induction, T5HOs and PS MH with electronic ballasting. (T8s were not considered because fixtures would be too large to deal with at this height)

Induction

Since higher wattage lamps are not available yet, it would take at least four of 150 or 165W lamps and ballasts to replace 1000W MH. The fixture system wattage would be about 660 watts. Contractor cost would be about $1500. With mark up and installation this would be quite expensive. Although induction lamps and ballasts have a rated life of 100,000 hours, which seems very appealing, there are downsides. With lamp lumen and dirt depreciation, the lamps and reflective surfaces would probably have to be cleaned every 40,000 or so hours of operation, unless a six lamp system would be used and that would be more expensive and consume more than 900 watts.

T5HOs

It would require a fixture with at least 8 F54T5HO lamps to replace a 1000W MH hibay. The wattage would be about 468, which is good, but the group relamping duration would not be. T5HOs are rated for 20,000 hours, which at 75% of that, it would be a 15,000 hour group relamping interval. Relamping duration could be doubled, but it would require a pair of 8 lamp fixtures with a programmable time clock that would switch power from one fixture to the other after 15,000 hours, which would increase relamping duration to 30,000 hours. This would also be expensive.

Pulse Start MH with electronic ballasting

A yoked pair of hibays with one electronic ballast looked like the best total value. Each hibay would have one 450W pulse start MH lamp, glass lined faceted metal dome and inner reflector. The luminaire efficiency would be over 90%. The single ballast will drive the lamp of least resistance at any time. So as the lamps age and the fixtures are turned on and off, the lamps will get about equal burn time. With this electronic ballast, rated lamp life may be increased from 20,000 hours to 25,000 hours. So rated life per yoked pair may be up to 50,000 hours. Based on group relamping at 75% of rated life, the useable life may be 37,500 hours. Going this or any longer in calendar days would probably result in unacceptable low light levels due to dirt depreciation. The wattage would be about 465. Each yoked pair would cost about half as much as a quad set of four 150 or 165W induction lamps and ballasts. The installed cost for this option would be significantly less than for the 16 T5HO lamp fixture array.

….then the facility changed priorities

More light became more important than maintenance concerns. We decided on replacing each 1000W MH hibay with a yoked pair of glass lined metal faceted hibays having two 400W PS MH lamps, two electronic ballasts and two glass lined metal faceted domes, each with its own inner reflector. Both lamps are on at the same time. Wattage was reduced from about 1100 to 830 and light levels were significantly increased. The group relamping schedule will still be greatly improved.

Lamp minimization was another benefit. These dimming electronic ballasts also allowed us to minimize lamp types. We replaced 1000 MV, 400W MH and 250MH lamps with the same 400W PS MH lamps with the ballasts dimmed down to appropriate light and wattage levels.

Industrial Facility

This facility now has primarily 250W HPS low bays. Areas keep changing. What is production now, may turn into a storage area in a month, which may become an aisle in a year. So design flexibility is very important. I specified 4' low bays with 4 F32T8s, 1.15 BF extra efficient instant start ballast and exposed reflectors to dissipate heat. Replacing 250W HPS and standard MH with 4 T8s works out better than with T5HOs, because 2 F54T5HOs is not quite enough light and 3 F54T5HOs is too much wattage. Each T8 hibay is specified to have a plug-in occupancy sensor port, lens door receptacle, and 12' power cord so mounting positions can be easily changed. Occupancy sensors should be originally provided for 75% of the fixtures. Lens doors should be provided for 20% of the fixtures.

Four For Induction

7Up / RC Cola in Vernon, CA had 35 mostly 400W HPS hibays over a production area with serpentine conveyor belts. Access to the hibays was so difficult that many of the hibays were left burned out. It cost approximately $30,000 to erect custom scaffolds and planking in this 24/7 operation. To significantly reduce lighting maintenance costs, each HID hibay was replaced with a dual 150W induction lamp hibay. Lamp life is more than quadrupled, but fixtures may have to be cleaned before lamps burn out. If that is necessary, hopefully a pole will work. In other areas HID hibays were replaced with T5HO ones.

Several food companies have converted to induction in their large freezers in distribution centers and in grocery stores. If you have ever had to replace lamps and ballasts in a heavy parka with thin gloves on a lift above food, you would want to do it as infrequently as possible. Just dropping a lamp, which breaks, can mean tossing out pallets of food.

The Waste Isolation Pilot Plant (WIPP) is a DOE low level radioactive waste disposal facility near Carlsbad, NM. It had 400W HPS hibays. Light quality was not good. With the warm up and restrike times the lights were left on from Monday morning to Friday night. Having to shut down areas to allow lamps and ballasts to be replaced is very expensive. Plus expensive boom lifts are required for some locations that do not allow straight up access. Most of these HPS hibays have been replaced one for one with new hibays that have two 150W induction lamps and ballasts. The three major benefits are fixture wattage reduction from about 465 to 314, burn time significantly reduced because of instant on, and probably most important, minimum projected maintenance for next 10 to 15 years. Lawrence Berkeley National Laboratory provided additional design/feedback/assistance and pre and post metering. The simple payback is 3.1 years including maintenance savings.

A multi-level parking garage for a hospital had 175W standard MH ceiling cone fixtures. The hospital would test its back up generator once a week. The MH's long warm and restrike times caused problems because of darkness. Not enough of the fixtures had quartz back ups, plus they seemed to keep burning out. The MH lamps were rated for 10,000 hours. The labor rate is quite high, because it is union. Including improving the lighting, energy savings and reduced maintenance costs, it was cost effective to replace these fixtures with similar ones that have 165W induction. Now there is instant on. The wattage was reduced from 210 to 165, and lamp life was increased ten fold. Since induction lasts so long, if the fixtures are not designed properly, they will need to be cleaned every 25,000 or 50,000 hours, which defeats one of the main benefits of induction. There are sealed fixtures designed specifically for induction that are more than sealed and gasketed. They really do not let dirt in.

Moscone Convention Center

San Francisco, CA

The best solution does not have to be either HID or fluorescent. The best solution can incorporate the advantages of both.

A very good example is the south hall of this convention center. It had fixture arrays consisting of a 400W standard MH hibay, 1000W standard MH hibay, and two 500W incandescents. The 400 watter was mainly used for show set ups and tear downs and self illuminated shows, like when Lightfair was there. Both the 1000 and 400 watters were used for many shows. The incandescents were also used for many shows, because of the much better CRI. The incandescents were also used for emergency lighting, because of instant on. Each of these fixture arrays were replaced with a rectangular assembly that has one 400W PS MH lamp in a high performance dome and twelve F54T5HOs with specular reflectors. These fixture assemblies look quite good. The three circuits still allow for three levels of lighting. The T5HOs have instant on and good enough color rendering, so incandescents are not needed.

Wrap Up

An appropriate 'follow the money' question for this article follows. Does the hibay fixture manufacturer try to recommend the best solution or just what it has and can sell? I highly respect manufacturers and rep agencies that recommend other firms' products when they know they are better. Although they maybe lost a few sales, I have given them more total sales over the years because of their and honesty and knowledge. Some of these manufacturers have expanded their product lines to include different lighting technologies in order to provide more best solutions.

I am trying to get at least one independent test lab to set up a good procedure and set up to measure ballast case temperature and light output from cold to hot ambient temperatures. That would provide fixture manufacturers and customers invaluable information on the lighting strategies and options, including up vents and lenses, for specific applications.

The research for this article taught me some very good lessons, including do not get lamp life information from ballast companies. It would be helpful if lamp manufacturers and ballast manufacturers worked closer together.

A final note is that I thank all of the lamp, ballast and fixture manufacturers, lighting designers and retrofitters that helped me with this article. If all of the names were listed, it would be a long paragraph, and this article is already too long.

About the Author

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