HIBAYS, HIBAYS, HIBAYS

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Introduction

When Brooks Sheifer, Robert Ofsevit and I wrote 'Essay By Invitation' (a.k.a. The Case for T5HO Hibays), June 2001, LD+A, one of the main reasons was that we saw way too many hibays installed with HPS, standard (a.k.a. probe start) metal halide (MH) and eight 42W compact fluorescents. It is quite apparent that T5HOs and pulse start metal halide have made their mark. Since the text was submitted last March for June publication, much has been learned. Although I still specify hibays with T5HOs a majority of the time, the pendulum is starting to swing toward electronically ballasted ceramic MH. Since technology and experience are advancing so rapidly, this article should be taken as a stop in the road on an endless trip, instead of a final destination.

Perspective

The majority of our company's hibay work is one-for-one replacement of existing 400W standard MH and HPS hibays. So we focus on more efficient and effective one-for-one replacements. Repositioning hibay locations and using fewer higher lumen hibays is usually less effective and less cost efficient. We have done some total redesigns including controls.

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 footcandles 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 also highly recommend reading the new IESNA Recommended Practices For Lighting Industrial Facilities and Sports & Recreational Area Lighting.

Although fluorescents 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 pulse start MH lamps, which have 90 - 95 CRI without sacrificing light output.

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 come to you, would you prefer having to look up into a point source HID hibays or 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.

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 Sam Berman's and others' work. I believe that the latter is more based on how the human eye perceives light at normal 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 when using high S/P general lighting, and that the gain in visual acuity can result in faster reading time. After closely examining these and Sam Berman's studies, ask yourself if the scotopic/photopic ratio research is really that controversial on a scientific level. Or is most of the controversy political?

Whichever camp that you are in, the 'how can fluorescents with half the initial lumens replace HID' table provides some useful information based on photopic lumens and Sam Berman's 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.

It is important to be aware that the IESNA does 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. The downside is that any tube guard or lens will block some of the light. 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 hibay options section. When the ambient temperature frequently reaches 49 degrees C (120 degrees F) at mounting height, which is not that uncommon in warehouses that do not have adequate venting or air conditioning, pulse start metal halide is probably 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 manufactures. In areas with skylights, the daylight contribution can often mitigate the reduced light output from fluorescents when they are the hottest.

Temperature - Ballasts

Temperature is usually not a factor with HID magnetic and HID electronic ballast life for hibays.

According to several electronic ballast manufacturers, hot temperatures can dramatically reduce the life of many electronic fluorescent ballasts. A typical maximum ballast case temperature rating is 70 degrees C (158 degrees F), which can often be reached in the fixture when the ambient temperature is 57 to 60 degrees C (135 to 140 degrees F). At these temperatures the rated ballast life is often listed at 60,000 hours. At 10 degrees C (18 degrees F) higher temperature, ballast life could be reduced to 30,000 hours. If the ambient temperature does not usually exceed 49 degrees C (120 degrees F) then ballast life can be increased to 90,000 hours. I highly recommend fluorescent hibay manufacturers that have good heat sinks and venting in the ballast compartment. There is at least one manufacturer, which has a ballast case temperature rating of up to 90 degrees C (194 degrees F), and others are developing their own, which would eliminate this potential problem.

Lamp Lumen Maintenance

Although lumen maintenance is better with pulse start MH than regular MH, it is still not very good in comparison to good fluorescents. Using mean lumen maintenance for 400W pulse start MH lamps and magnetic ballasts is insufficient, because the mean lumen maintenance may be 80%, the end of life lumen maintenance is about 60%. (End of life is rated life, when 50% of the lamps have burned out and 50% are still operating.) I have never known anybody that replaces pulse start MH lamps at 40% of rated lamp life, when mean lumens are calculated. Mean lumens are also called maintained or design lumens. The term 'maintained' does not work very well for MH, because there is so much light loss after 40% of rated life. Although some facilities group relamp, most of the time lamps are replaced when they are burned out or after a bunch have burned out, so end of life lumen maintenance is the most important number. This is especially the case in one-lamp fixtures. Be aware that lumen maintenance percentages are often lower for 300, 320 and 350W pulse start metal halide lamps than 400W pulse start MH. Ceramic MH lamps have about 65% end of life lumen maintenance. Tri-phosphor fluorescents have much better lumen maintenance. T5HOs have 95% end of life lumen maintenance and 800 series T8s have about 92% end of life lumen maintenance.

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 75% 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 85 to 94%.

Glass Lined Domes
They are also available with additional inner reflector. Luminaire efficiencies can range from 85 to 94%. Luminaire efficiencies can range from 85 to 94%.

Prismatic Reflectors
These dome shaped reflectors are available in glass and acrylic. These cost more than metal domes, but provide higher luminaire efficiency, mainly because some of the light is refracted instead of reflected. 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.
There are at least two manufacturers that have high performance systems with outer prismatic reflector and inner metal reflector. Luminaire

efficiency can be up to 95% with more of the light directed down.

Metal Linear Reflectors

Most manufacturers use 95% reflective enhanced aluminum, which is very scratch resistant. Some may use 96% silver film. 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 hibays with metal reflectors that we have seen in the current practical world is about 92%. 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. They presented this paper at the 2001 IES Annual Conference and hopefully it will soon be 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 degrees C (77 degrees F), while T5HO lamps provide optimal light output at 35 degrees C (95 degrees 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 an enclosed luminaire or luminaire that the heat cannot easily escape from close to the lamps, so although the true ambient temperature is still 25 degrees C, the modified ambient temperature by the lamps is 35 degrees C. Another way to supposedly get over 100% luminaire efficiency is to do the testing at 25 degrees C and use a multiplier for the lamps.

Luminaire Dirt Depreciation (LDD)

LDD is not included in the examples 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. The IESNA informed me that they are working on this subject, but reports will take some time.

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. This is much less of a problem with 5/8" diameter T5HOs than 1 1/2" diameter T12s.

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. Usually none of the hibay is cleaned when pole changers are used. If a person gets to the hibay to change a lamp, it is a crap shoot if he or she cleans the inside and the odds are that he or she will probably not clean the outside of the dome.
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 is also grimy and electrostatic 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 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, 1.18 to 1.20 BF ballasts are required, and the only ballasts available with this high ballast factors are instant start, which reduce T8 lamp life. For example, most T8s that are rated for 24,000 at three hour starts on rapid start ballasts will only have a 18,000 - 20,000 hour rating at three hour starts on instant start ballasts. At 12 hour starts, the life will be slightly over 24,000 hours and near 30,000 hours at 24 hour cycles with instant start ballasts.
T5HO lamp life is based on program start ballasts, so rated lamp life is fairly constant with short to long cycles.
No matter the lamp type, it is highly recommended to require at least 20,000 hour rated lamp life for hibay applications.

Lamp Maintenance
Standard and pulse start MH lamps should be turned off at least once every two weeks, or nonpassive failures can occur. I like the irony in the term 'nonpassive failure', after seeing the damage done to fixtures from this. It is anything but passive.
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

Controls are 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 warm up and restrike times. High/low control systems can save some energy, but it is not linear between wattage and light output. If the light level is at 50%, the wattage will be about 65% of maximum. 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 high/low capability is more linear. 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. 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.

DALI, which is digital addressable logic interface, could revolutionize the dimming electronic ballast industry as it becomes more popular in North America. Each ballast has its own address, so could it could be controlled independently or with interchangeable other ballasts. This

system also has two-way communication, which can allow facility managers to check out on their computers, which lamps and ballasts have burned out.
Other proprietary fluorescent dimming control systems are also making their way into the industry, however, the competition among the manufacturers makes it actually more costly to install some of these systems. Once a standard program language is adopted, the use of dimming technology should be much lower and more widely accepted.

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 warehouse type of applications a photocell can be attached to each fluorescent hibay close to large roll up doors to turn off power when there is sufficient day lighting.

Miscellaneous
Electronic ballasts can only be mounted up to 25 feet from lamps. Many magnetic ballasts can be remote mounted 100+ feet from lamps, as long the proper gauge wire is used.
Lamps, driven by magnetic ballasts, flicker, which can be a problem. There is no flicker with electronic ballasts.
Magnetic ballasts can cause stroboscopic effects, like making a working circular saw or drill press look like they are turned off. 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 ballasts that drive two MH lamps, which saves about 7% of electricity.
If the line voltage is 480, using electronic ballasts requires splitting existing circuits or running new wiring, because electronic ballasts are not available in 480V.
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. When we replaced HPS hibays with T8s in one high school gym, the varsity basketball coach told us that he loved the new lighting, but that his team lost the home court advantage, because none of the visiting teams were used to HPS's yellow light. It looks like most California utility incentive programs will finally eliminate incentives in 2002 for interior HPS applications.
Although they do 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. The other is the new 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, even though these lamps are not cheap.

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.
We have considered replacing 400W standard MH lamps with 360W energy saving standard MH lamps, but, so far, have always determined a better solution.

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. 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. If the line voltage is 277 and if power quality is decent, 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 paying the extra money for a high performance pulse start MH hibay, because basic grade spun aluminum ones can cost less than $120 and with specials at 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 hibay will be required.

Pulse Start MH with Dimming Electronic Ballast Option
Dimming electronic ballasts make this type of pulse start MH a much better option. But this is still a relatively new, limited and expensive technology. By 2002 there may be more than one manufacturer. A good hibay with electronic ballast and pulse start MH lamp may cost $400, and hopefully will come down in price. Based on information provided by one manufacturer, it is attaining: full light output within one minute with cold start (cold start is defined if off for more than two minutes), less than three minute hot restrike time, 13-15W ballast loss for 350, 400 and 450W lamp systems, 25% longer lamp life, 85% end of life lumen maintenance, and 0-10V controls, dimming from 100% full light output down to 9%, and 121W at maximum dimming. This manufacturer reports over 42,000,000 machine/lamp hours of operation over the last five years. Based on my information from lamp manufacturers, most of the testing has been done at full output and some down to, but not below, 50% dimming.

Ceramic MH with Magnetic or Dimming Electronic Ballast Option
High wattage ceramic MH lamps are a brand new technology with

promising specifications. These lamps can be considered upgrades of pulse start MH lamps and use the same ballasts. These lamps provide better CRI than commonly used fluorescents while providing about the same initial light output, lumen maintenance and lamp life as regular pulse start MH lamps. Most fluorescents used in hibay applications have 85 - 86 CRI. Although there are fluorescents with 95 CRI, the lumens drop by about one third. The ceramic versions use the same magnetic and electronic ballasts as regular pulse start lamps. Just don't get sticker shock with the pricing of these lamps.

CFL Option

There are usually 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.

With amalgam, light output is fairly even from 10 degrees C (60 degrees F) to 70 degrees C (140 degrees F) ambient temperature.

There are new CFLs with up to 70W and 5200 initial lumens, which may be a better option, because fewer lamps would be required in each open dome, which would improve luminaire efficiency and relamping costs. But their rated life is still a concern for hibay applications.

F32T8 Option

Below 20 feet mounting height, 3100 - 3200 lumen, extended life, F32T8s can work very well. There are several manufacturers that make high performance 4' long hibays for 6 F32T8s. Above 25 feet a T8 solution gets tricky with more lamps per hibay or more hibays. When minimizing lamp types is important (and it often is), we always consider the T8 option. An example is a facility or campus that uses or will be using mostly F32T8s and has a solitary small gym or warehouse. 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 a ballast manufacturer will develop overdrive program start ballasts, which would remedy this problem. F32T8s can often be a better solution than F54T5HOs in colder applications, because F32T8s provide optimal light output at 25 degrees C (77 degrees F) compared to F54T5HOs, which provide optimal light output at 35 degrees C (95 degrees C). 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.

Induction Option

Cost effective when maintenance costs are very high. Examples are erecting a special scaffold to reach hard to reach fixtures, renting an expensive lift, and spending $200 to do the paperwork to get access into a room that has low-level radiation waste material. For these types of applications it is 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.

Induction lamps can start at temperatures as low as -40 degrees C and F, but light output will be low unless bulb wall temperature or amalgam tip temperature significantly increases. For cold or hot applications, we recommend working with luminaire manufacturers that have experience with the intricacies of induction systems. Hopefully there will soon be higher lumen and more U.S. voltage systems.

Biaxial Option

40, 50 and 55 watt T5 biaxial 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 biaxial lamp. A 55W biaxial 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%. Biaxial lamps are not cheap and are rated for only 12,000 hours for the 55W, up to 20,000 hours for the 40W.

Biaxial lamps are very temperature sensitive with regard to light output. In a horizontal position the optimal ambient temperature is about 30 degrees C (86 degrees F) with fairly steep fall off both above and below. Earlier this year we looked at a cold storage area that had some 40W biaxial hibays with no bottom lens. The ambient temperature was about 5 degrees C (41 degrees 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.

We recently talked to one fluorescent hibay manufacturer who basically stopped using high wattage biaxial lamps, except when a customer requires a 2 ft. long fixture.

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

F54T5HO Option

F54T5HOs have enough punch for high mountings. They are thin enough to be considered almost a line source, so luminaire efficiency can be very high. These linear sources in well designed hibays provide excellent vertical footcandles, which is much more important than horizontal footcandles in applications like warehouse rack aisles. For forklift operators loading or unloading pallets in high warehouse racks, there is lot less glare and shadowing with 4 foot or longer fluorescent hibays than with point source HID hibays. A hibay with 4-F54T5HOs, consuming about 235 maximum watts, can usually replace a 400W standard or a 300 or 320W pulse start MH hibay. With program start ballasts, the rated lamp life is 20,000 hours, even when controlled by occupancy sensors. Installation labor can be quite low, since hook, cord & plug suspended mounting is available. Hibays with F54T5HOs do not have to look like 4 ft. hooded industrials. The luminaires can have horizontal triangle, square or cross configuration. They can have direct, indirect or direct/indirect distribution.
Care should be taken using F54T5HOs in direct applications below 16 feet mountings, so glare is not a problem.
If a 2' long fixture is required, F24T5HO lamps may be an option.

Compare Options
Make your own comparisons. Include quality of light, S/P ratio (if you want to), end-of-life horizontal & vertical footcandles, 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.
It may also be wise to test various lamps for a specific option. Although a specific lamp type from one manufacturer may state higher lumens than from another manufacturer, that is not always the case in the real world. Be cautious of supposedly rated 3200 lumen F32T8s. Lamps should be burned in for 100 hours before they are compared.
Whatever you do, please help stamp out standard MH, standard HPS and basic-grade domes.

T5HO Applications
Pacific Gas & Electric Distribution Center
Fremont, CA
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 optibrite (Mirro4™) 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 over-ride button was installed to control burn time. Previously, fixtures in this area were often left on all night long and most weekends.

Gymnasiums

California high school gyms in Manteca, Galt and San Lorenzo School Districts had mostly 400W MH high bays, which were replaced one-for-one with 4 ft. fluorescent hibays with 4-F54THOs and two program-start electronic ballasts. Fixture wattage was reduced from 450 to 234. With the warm-up and restrike time of the old MH 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. We worked with one manufacturer to design a hibay that is strong with steep angled sides so badminton birdies and balls easily roll off. (Developing trouble-free fluorescent hibays has definitely involved a learning curve!) Galt Gym had 2x2 surface mounted box hibays. To avoid patching and painting we used 2x4 surface mount hibays.

The Solano Junior College Gym 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.
Strong wire cages were used for all of these gym applications.

General Considerations Regarding F54T5HO Hibay Technology
As you probably know all too well, F54T5HO lamps and ballasts now cost way more than premium grade F32T8 lamps and ballasts. Within two years (much less time for existing T5HO lamps to burn out), T5 lamps and ballasts should be considerably less expensive, as the size of production runs increase, higher speed equipment is used and lamps are manufactured in North America instead of just in Europe. There is nothing that is inherently more expensive manufacturing a T5HO lamp than a top of the line F32T8 lamp.
Hopefully lamp manufactures will offer these lamps with a 50K CCT. We greatly appreciate that one manufacturer made a special batch of 50K F54T5HOs in Europe and shipped them to us so we could use them in a showcase test project.
Check with the lamp manufacturer to confirm they will warranty their lamps with a specific ballast.
There are some instant start ballasts for F54T5HOs, which cost significantly less than the program start models. The instant start ballasts shorten lamp life considerably, but may be okay for applications with burn cycles greater than 12 hours. We prefer program start ballasts which work in all applications. Although most ballasts have a 1.0 BF, some have less. We look forward to the opportunity to install and evaluate the upcoming 4-6 lamp dimming ballasts. They may work out very well for general and for daylight harvesting.
Distributor/contractor cost for high quality and well designed 4' warehouse hibays, including name brand ballasts with 4 name brand F54T5HOs, can be under $175. Similar hibays for gyms can cost more because of heavier duty metal and strong wire cage.
The twenty or so manufacturers have helpful product/application information. Just in California I know of six manufacturers. It would be nice to see LD+A add a category for fluorescent hibays in their annual Lighting Equipment & Accessories Directory.

Pulse Start and Ceramic Pulse Start MH Applications
We have installed numerous hibays with pulse start MH lamps and magnetic ballasts, because we could not convince the customers otherwise. Although they are working well, we think that T5HOs would have worked better for these applications. We have done several exterior projects with pulse start MH lamps and magnetic ballast kits, floods and

shoe boxes. I look forward to evaluate existing projects and design & install hibay projects with pulse start and ceramic MH lamps with dimmable electronic ballasts.
General Considerations Regarding Pulse Start and Ceramic MH Lamps and HID Electronic Ballasts
Some of the lamp manufacturers do not have pulse start MH lamps available in horizontal or vertical base down position yet.
250W and 400W ceramic pulse start MH lamps are very new. Although the manufacturer's specifications look very good, it will take some time to determine how these lamps perform in the long term in numerous real life applications.
It will be interesting to see what happens as dimming electronic ballasts become more prevalent.
What may really improve this technology is if lamp manufacturers make lamps that are specifically designed to be driven by electronic ballasts.

Afterword

As always, I thank Sam Berman and colleagues for their continued work on the benefits of scotopically enhanced light sources. It is a shame that some lighting companies try to sell overpriced and misapplied product based on Sam's research.
I also appreciate the help of Barbara Erwine, Bill Dillon, Brian Liebel, Brooks Sheifer, Dennis Beasley, Dennis Spaulding, Doug Foley, Ed Hammer, Jean Marc, Jonathan Baty, Ken Patterson, Mark Thorpe, Peter Brown, Robert Ofsevit, Tom Barnes, and Willard Warren.
It is important to be cautious of people that are only aware of limited technologies or sell only one product type. I highly respect manufacturer reps, who do what is best for the end customer, even though they can lose out on sales.
Hope to see you at 2002 Lightfair in San Francisco. Brian Liebel and I will present a half day workshop, 'Cutting Edge Retrofitting and Relighting'.

About the Author

Stan Walerczyk LC, participates in consulting to turn-key design & build retrofit/upgrade projects for Sun Industries, the largest design and build lighting retrofit contracting firm in California, and is currently expanding nationally. He is a member of IESNA's National Energy Management Committee and chair of its Retrofit/Upgrade Subcommittee. For questions, comments and updates, contact swalerczyk@sunindustriesinc.com.

Hibays

lamp & hibay fixture type	initial lamp lumens	BF	actual initial lamp lumens	EOL lamp lumen depreciation	EOL lamp lumens	luminaire efficiency	EOL lamp luminaire lumens	system 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	42%	22,250	75%	16,530	455	36	1.49	22,561	50
spun aluminum reflector with 400W 22-CRI standard HPS	50,000	1.00	50,000	30%	35,000	75%	26,250	465	56	0.62	18,080	39
enhanced aluminum reflector with (4) 841 85-CRI F54T5HOs	20,000	1.00	20,000	10%	18,000	92%	16,560	235	70	1.62	24,126	103
enhanced aluminum reflector with (6) 3100 lumen 841 85-CRI F32T8s	18,600	1.18	21,948	8%	20,192	90%	18,173	226	80	1.62	26,476	117