Cutting Edge Retrofitting, Relighting and Redesigning*

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ABSTRACT

This article provides information on three groups of lighting strategies for typical office, school, hospital, and similar linear fluorescent applications: optimal retrofit, relight (replacing fixtures one for one, like replacing a direct troffer with an indirect basket troffer), and redesign (complete new layout, like with suspended indirects).

Since high-lumen extended-life 32W F32T8s and optimal electronic ballasts can often cost effectively replace basic grade T8 and generic electronic ballast systems, eliminating T12s and magnetic ballasts is a slam-dunk. The limitations of 28-30W F32T8s will be included.

As Willard Warren states, "Retrofitting a lousy lighting system into an energy efficient lousy lighting system is a wasted opportunity." Quality lighting is much more than proper horizontal footcandles. Light levels can often be significantly reduced in older office buildings that were originally designed for paper tasks, where computer work is now the main task. Suspended indirect fixtures usually provide much better lighting quality and can reduce wattage compared to direct troffers.

The benefits of scotopically enhanced lighting will also be discussed.

BACKGROUND

Much of this material is an evolution of my recent articles. Principal sources are *Watt's the word on T8 Retrofits*, 4/03, *Energy User News*

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*Published in modified form in *Energy & High Performance Facility Sourcebook*, proceedings of the November 12-14, 2003, World Energy Engineering Congress 12/10/03 version.

and *Retrofit/Upgrade Quarterly,* 6/03 & 9/03, *LD+A*, the monthly magazine of the IESNA.

INTENT

There is no intention to endorse any manufacturer. Websites are listed for manufacturers that are not common household names.

T12s & MAGNETIC BALLASTS

Although this is outdated technology, it is my understanding that still nearly half of the linear fluorescent fixtures sold across the country have magnetic ballasting for T12s.

CHEAP T8s & GENERIC ELECTRONIC BALLASTS

The majority of T8s and electronic ballasts used in new construction and remodels are basic-grade 700-series, 2800-2850 lumen and 15,000-20,000 hour rated lamps and generic .87-.90 BF (ballast factor) electronic ballasts. Many retrofits also use these products. Although these lamps and ballasts are the least expensive initially, they are usually not the best total value. Please see how various lamps and ballasts compare in Tables 1 and 2.

All three tables are at the end of the article.

3100+ LUMEN F32T8s & OPTIMAL BALLASTS

Over 30 percent of my retrofit/relight/redesign business involves replacing basic-grade T8s and generic electronic ballasts. When T8s are specified, the lamp of choice is what is commonly referred to as 'super,' and optimal ballasts are used with them.

The savings and financial return going from basic grade T8s and generic electronic ballasting to high lumen and extended life T8s and optimal electronic ballasts can often be as good as from going from T12s and magnetic ballasts to basic grade T8s and generic electronic ballasting.

WHAT EXACTLY IS A "SUPER" T8?

After older terms like "second generation" and "premium," and the newer term "super," many people are confused about exactly which lamps fit in what category. Some people include the 28-30W lamps as "super." Plus, what will be the term for future lamps that are better than "super?"

3100+ LUMEN 32W F32T8s

With the confusion on terms, I think it is much better to state the exact specs of F32T8s. The only F32T8s that I would consider as "super" and like to specify with instant start ballasts have 3100+ lumens, 85+ CRI (color rendition index) and 24,000+ hour rating based on the industry standard 3-hour cycles with instant start ballasts. These include the GE HL and Philips Advantage. With program start ballasts, the Sylvania XPS lamp can be included in this group.

These three lamps offer the most value and flexibility with regard to lamp life, delamping, low BF ballasts, ballast types, dimming, fewer fixtures, and temperature.

ENERGY SAVING 28-30W F32T8s

Some people are promoting the 28-30W energy saving F32T8s as the best F32T8s, but be aware of their limitations. Although they may have the best lumens per watt without including a ballast, all fluorescent lamps need a ballast.

Compare the system watts and other issues of lamps with the 32W lamps in Tables 1 and 2. Also be aware that, in general, the 28-30W F32T8s cannot be used below 60°F and they cannot be used with many rapid and program start ballasts and no dimming ballasts.

Every time I asked an end customer if they wanted to maintain two types of F32T8s, a 32W version for dimming applications, like a conference room, and unconditioned spaces, like covered garages, and a 28W version for other applications, the answer has been a resounding "NO."

Many maintenance crews have a difficult enough time keeping straight where T8 and T12 lamps with their different diameters go, let alone multiple types of T8s with the same diameter.

I have heard stories of 30W lamps installed during the warm time of the year in covered garage structures. The lamps worked great until the first cold fall night. Then the lamps had to be replaced with 32W ones.

The 28-30W lamps cost about the same or more than 3100+ lumen and 24,000+ hour rated 32W lamps.

Although the energy savings with 28-30W lamps can pay for the lamp and labor cost of a group relamping, a re-retrofit with 3100+ lumen and 24,000+ hour rated 32W lamps is usually more long-term cost effective.

As the next section describes, soon 28-30W lamps will not be the lowest wattage solution in fixtures that should not be delamped.

OPTIMAL BALLASTS

These include extra efficient instant start, the new generation of program start, upcoming extra low BF program start, and dimming ballasts. Tables 1 and 2 are pertinent to this issue.

Extra-Efficient Instant Start Ballasts

These ballasts save 3-6 watts compared to equivalent generic standard and low BF ballasts, without sacrificing light output. Although these ballasts may cost up to a few dollars more initially, they can each save $30 over its rated life.

These ballasts include in alpha order:

- Advance Optanium
- GE Ultramax
  - — Only one that also has a high BF version
- Howard Hex
- Universal ULTim8
- Sylvania is developing its version

All of these ballasts are parallel wired, so in a multi-lamp ballast, if one lamp burns out, the remaining lamp(s) keep operating normally. Except for the GE Ultramax, if one lamp lead is capped off, the BF increases. This can provide more light level options. For example, if a three-lamp .87-.88 BF ballast is used to drive just two lamps, the BF is around 1.00, which is about halfway between standard and high BF

ballasts. Always check UL listing before doing this.

Some people automatically recommend program-start ballasts when installing occupancy sensors because of short lamp life concerns. If the time delay is set for at least 12 minutes (which the major sensor manufacturers that I have talked with recommend) and if there are not excessive cycles per day, then extra-efficient instant-start ballasts with extended life T8s can be a be a better value for two reasons. One is that extra-efficient instant-start ballasts cost less than program-start ballasts. The other is that instant-start ballasts are usually more efficacious with regard to lumens per watt than program-start ballasts. So for the same amount of light, instant-start ballasts will save more energy. This means that even though the lamps do not last as long with instant-start ballasts, the extra electrical savings with instant-start ballasts often more than compensate for the extra lamp replacement costs.

New Generation of Program Ballasts

The Sylvania PSX (program start xtreme) .71 BF ballast became the first ballast in this category. Advance is in the process of introducing its program start Optanium.

With the constant lamp filament heating, program start ballasts are not as efficacious as equivalent instant-start ballasts.

Program-start ballasts also cost more, and the vast majority of program-start ballasts are series wired, not parallel wired, and the three-quarters of a second or longer delay for the lights to come on after they are turned on can be annoying.

But when lamp life is critical, program-start ballasts can be the best solution.

Upcoming Extra Low BF Program Ballasts

Currently, 28-30W lamps with extra-efficient .71-.78 BF ballasts are the lowest wattage solution in fixtures that should not be delamped. But several ballast manufacturers are developing fixed .5-.6 BF program-start ballasts. To see the advantage, let's look at 18 cell 2x4 troffers in an overlit office area that was originally designed for paper tasks, where now the main task is computer work. Three 28W F32T8s and a low BF extra-efficient ballast would consume about 65W, while three 3100+ lumen 32W F32T8s and a .55 BF program-start ballast would consume about 50W and possibly extend lamp life. It is my understanding that 28-30W lamps will not work with this low of a BF ballast, and if they

did, the light level would probably not be sufficient.

Dimming Ballasts

Dimming ballasts can provide extra low BF and flexibility, but they tend to cost about twice as much as fixed BF program start ballasts. In California, with $.15/kWh rates and good incentives, dimming ballasts can still be cost effective. In the past, when I did not need control, I specified dimming ballasts with fixed BF.

There are various types of dimming ballasts.

- 0-10V
  - — Several manufacturers
- Staged
  - — Including Universal 50/100 & 30/60/100
- Proprietary
  - — Lutron, Easylite, etc.
- DALI (digital addressable lighting interface)
  - — Nonproprietary protocol
  - — Several manufacturers

Since DALI is relatively new to this country, it deserves special attention. After being involved with some DALI projects, I am very concerned about burdening end customers with this system. Yes, DALI has a lot to offer, especially on reduced initial wiring costs. But even if everything goes well with the controls, there are two significant maintenance issues. One big issue, with at least one ballast manufacturer, is that the ballasts can permanently fail if lamps are replaced when power is on and at least one pin is still in a socket and another socket touches the metal fixture housing. This problem can really only be taken care of with a ballast redesign. Second is regular ballast replacement. Most maintenance crews are not sophisticated enough to address a new DALI ballast with the same electronic address that the failed DALI ballast had. These facilities may have to pay for a maintenance contract with a service company that has DALI expertise. As DALI evolves, I hope that easier ways to cost effectively address replacement ballasts are developed. Plus who is qualified and willing to maintain the software control system? Will the I.T. department allow it to go on the corporation's system? Is DALI really better suited for conference rooms than large office spaces?

REFLECTORS

Smoke & Mirrors—Literally & Figuratively

Sad but true, many retrofitters and others still think that reflectors are usually necessary for delamping and that specular reflectors are recommended so people would still think that the fixtures have the original number of lamps.

For anybody considering installing reflectors and delamping in troffers or wrap-arounds, please do the following test. Although it can be done with various numbers of lamps, this example is based on four lamp fixtures.

Experiment with a 2x4 troffer, 2x4 surface mount, or 4′ wrap with four F34T12 CW lamps and magnetic ballasts in a typical 8 or 9 foot ceiling.

1. Measure light levels directly below and 4′ around fixture at 30″ above floor.

2. Clean the housing and lens and install four new F34T12 CW lamps.

3. Measure light levels exactly as before. It often increases 20 to 50 percent, depending how dirty the fixture was and how depreciated the lamps were.

4. Install two 2800—2950 lumen F32T8 lamps and standard BF electronic ballast. The lamps can often go in the outboard position. If the inboard and outboard positions are too far away from center, which is unusual, the lamps should be centered.

5. Measure light levels, which are usually like original with old T12s and dirty housing & lens.

6. Install a white or specular reflector.

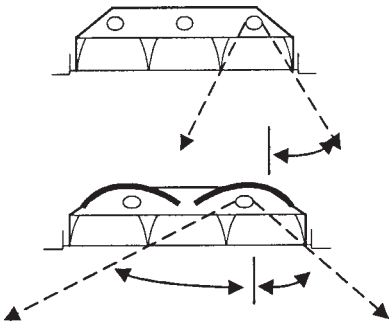
7. Measure light levels. How do you think it compares to #5?

Based on doing this many times with various fixtures, here is what I found. If the fixture has angled or sloped interior sides and cleanable good white paint with about 85 percent reflectivity, a reflector usually

provides negligible benefit, in the 5 to 15 percent average increased light range. Average is a key term, because specular reflectors tend to direct the light straight down, so although there may be more light directly underneath the fixture, there is often less light between fixtures. I have seen a confidential independent research report that shows no significant light level difference in new troffers with or without reflectors. I have found in older fixtures that if the fixture housing is white powder coat, which has up to 94 percent reflectivity, there can be a slight decrease of light with some reflectors. At least two major manufacturers use white powder coating in their interior fixtures. In these types of fixtures, the benefits are more from delamping than from the reflectors. Delamping increases luminaire efficiency, because there is less light bouncing into adjacent lamps and with fewer lamps the lamp bulb wall temperature is often closer to optimal, which results in more light coming out the lamp. Willard Warren told me that it is his understanding that T12 and T8 lamp output decreases 1 percent for every degree F that the lamp exceeds 100 degrees. He has measured over 115° in troffers with four F40T12s. A way to confirm how luminaire efficiency goes up as the number of lamps is reduced from 4 to 3 to 2, either all T12s or all T8s, in a typical type of 2 × 4, is to check it out in major fixture catalogs or websites.

Reflectors are often marketed in apples and oranges tests. Dirty fixtures with depreciated T12s are compared to clean lenses, new reflectors, and new T8 lamps. The initial result looks great: 60 percent wattage savings with about the same amount of light. But many end users that approved delamping with reflectors years ago now have too little light because the reflectors and lenses got dirty and the T8 lamps depreciated. Using high lumen F32T8s and higher BF ballasts with or without reflectors can usually solve this problem. On the other hand, less light is often an improvement. An example is an office building built before 1985 when paper tasks were the main task and 50 to 75 fc were recommended. Now, with computer tasks being predominant, 30 fc is often more appropriate. This can be achieved with delamping and/or lower BF ballasts with or without reflectors.

Additionally, if the retrofitting industry wants any respect from the general lighting community, then the practice of retrofitting 18 cell 3F34T12 2 × 4s with two repositioned T8s and a reflector should be eliminated, because it destroys proper cut-off angles, which can produce a glare bomb. The worst is with specular reflectors, which with the



parabolic louvers make the fixture look like a house of mirrors.

Facilities across the country that had these retrofits had so many complaints that they removed the reflectors and went back to three lamps. I have done some of these re-retrofits.

In addition to the above problems, this type of retrofit can also reduce switching flexibility and provide "ghost savings." There are probably millions of 18-cell 3-lamp 2 × 4s in individual offices with inboard/outboard switching in North America. Often all three lamps are on for paper tasks, two lamps are on for combination paper and computer tasks, and one lamp is on for computer tasks. Retrofitting this type of fixture with two F32T8s and one two-lamp ballast reduces switching flexibility to either both lamps on or off. Since computer-only work is so prevalent, many office workers just have one lamp on in each troffer. The ghost savings from the retrofit result, because one F34T12 driven by an energy saving magnetic ballast consumes less wattage than two F32T8s driven by electronic ballast. I know of many retrofit projects in which the actual savings were much less than the projected savings.

There are some fixtures in which reflectors are very beneficial. They include fixtures with vertical interior sides and bad paint condition. Strip fixtures that uplight are not important. Vertical interior sides allow too much light to bounce back and forth horizontally, preventing it from getting out of the fixture. Bad paint condition is often the result of cigarette smoke. Being in California for so long, I forgot about this issue until I recently audited a facility in western Illinois, my home state. As Willard Warren states "You'll scrape the paint off before you remove the products of combustion from cigarette smoke." Willard and I also agree that in areas where smoking is prevalent, an old 2 × 4 4F34T12 lensed troffer can have an "effective" luminaire efficiency half that of a new 2 × 4 2F32T8 lensed troffer before it gets an extended bombardment of smoke. Another good reason to prohibit smoking is that energy could be saved because better maintained luminaire efficiency.

Checking the cost to buy and install reflectors is really worth it for specific applications where fixtures could be delamped without reflectors.

However, reflectors can provide two other useful functions. One is centering lamps. Although it is usually okay just to use the inboard or outboard lamp holder position when delamping a four-lamp 2 × 4 to two lamps, there are some fixtures in which centering the two remaining lamps is important for appearance and performance. A reflector is often an easier solution than custom lamp holder brackets or using a Whitney punch to modify existing lamp holder brackets. The second is providing a repositioned ballast compartment and lamp socket assembly. An example is retrofitting a 9-cell 2 × 2 troffer that has two FB34T12 U-bend lamps with three F17T8s. The ballast which was in the middle of the fixture has to be moved because one of the F17T8s will go in the middle and wires and lamp holders have be on both ends of the troffers with the straight lamps. Another example is retrofitting an 8′ hooded industrial that has two F96T12 CW 60W lamps with two high lumen F32T8 lamps and 1.15 BF ballast. Although a new hooded industrial reflector kit usually does not provide that much more luminaire efficiency, it is a low parts and labor method to be able to use the 4′ lamps.

At least on the West Coast, white is much more popular than specular for reflectors mounted below 14′. White is a diffuse reflector and can provide better uniformity and comfort. At these lower mounting heights, specular reflectors can have a bad appearance. Every bend in a specular reflector can often be seen on the lens. As long as the light quantity and quality are okay, there is no need to make the fixture look like it was not delamped, so specular reflectors are not required. The two major types of white reflectors are a white powder coat and a 91 percent reflective white paint. The white powder coat is recommended because it is more reflective, and reflectivity can actually increase over time if it is kept clean, and the process is more environmentally friendly because there are no paint solvents. There is a new white paint with up to 97 percent reflectivity, which could change the balance.

For higher mounting, specular is usually better, because it is easier to direct the light where useful. Let's not even discuss the basic grade aluminum reflectors with reflectivity of 88 percent or less. The recommended specular product is enhanced aluminum with 95 percent reflectivity. Although silver film has slightly better reflectivity at 96 percent, it can be scratched easily.

Now let's go back to the point that specular reflectors help make the delamped lensed fixture look like it still has the original number of lamps. Maybe that was important for some people in the ′80s or early

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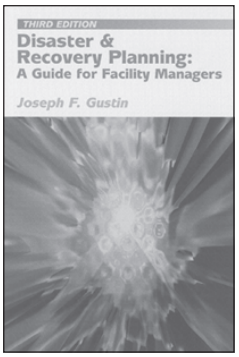

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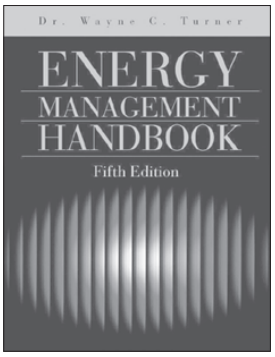

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90s, but hopefully that concern can evaporate like the concern regarding electronic ballast reliability in the early '90s. There is no valid reason why the fixture needs to look like the original number of lamps was maintained as long as the performance is there. End customers can be educated.

Regarding delamping with or without reflectors and other energy-efficient lighting measures, it is important for retrofitters and end customers to do what is best in the big picture, which is not always what gets the highest utility or other party incentive. Let's use California as an example. At least some of the utilities have offered prescriptive incentive 'rebate' programs since the '80s. Early on, there were very high rebates for reflectors in conjunction with delamping. Later reflectors and kits were not required for the delamping rebate, and the dollar amount was reduced. Now the major investor-owned utilities have a consistent prescriptive program called 'Express Efficiency,' directed by the California Public Utility Commission. The rebate is much higher to retrofit a 4F34T12 fixture with four F32T8s and low BF ballast than with two F32T8s and higher BF ballast, even though the latter is often a much better solution, including saving significantly more wattage. I have been trying to get these utilities to offer equivalent rebates for each T8 lamp installed compared to for each similar length T12 lamp removed without a replacement. That way the program would not artificially sway retrofitters and end customers one way or another.

SCOTOPICALLY ENHANCED LIGHTING

Before 1995, I was confused. Numerous times I would install samples of 35K and 41K, and neither the customers nor I understood why the 41K seemed brighter when they both had the same catalog lumens. Similarly, 400W MH seemed brighter than 400W HPS, even though the HPS has 14,000 more catalog lumens.

Around 1995 I started reading some of Dr. Sam Berman's work on scotopically enhance lightings, which states that both the cone (photopic response) and rods (scotopic response) are active during typical work light levels. Basically the higher the Kelvin, the more that rods are activated. So it started to make sense why 41K is perceived as being brighter than 35K, and MH is perceived as brighter than HPS.

Although Dr. Sam Berman and his associates have written numerous research papers, they can be too technical for many readers. On the other had, Dr. Sam Berman wrote a relatively easy to read "The Coming Revolution in Lighting Practice" in the October 2000 *Energy User News*. It is downloadable here:
www.energyusernews.com/eun/cda/articleinformation/features/bnp_Features__item/0,2584,14423,00.html

Table 3 shows that for paper tasks for the same perceived light level, 39 percent wattage can be saved with 850 compared to 735 T8s, and 20 percent using 850s compared to 835s.

Visual acuity (being able to focus) can often be more important than brightness. With smaller pupils, less aberrant rays hit the fovea, so acuity can be improved. It is like wearing pin-hole glasses. Many people, including myself, are able to read one line smaller on the common Snellen Eye Chart with 850 lamps than with 835s that provide the same light level, measured by a traditional light meter.

Solar Light Company is developing the first commercially available photopic/scotopic light meter. *www.solar.com*

PG&E (Pacific Gas and Electricity) is in the process of retrofitting, relighting, and redesigning with 5000+K T8 and T5HO lamps. The energy savings, even in facilities with T8s, and user acceptance, is very good. PG&E workers who thought that "scotopically enhanced lighting" was too long and technical, came up with their own term, "clear vision lighting."

The DOE (United States Department of Energy) is giving this lighting method a very high priority as a way to reduce energy in lighting. Preliminary results from the two DOE projects in the San Francisco area look very promising.

5000K or 6500K may be too "blue" for some applications, but proportional savings can be achieved by using 3500K instead of 3000K or 4100K instead of 3500K or 3000K

Scotopically enhanced lighting projects can backfire if not done properly. Good projects include educating the end customer and people that will work under the space, making sure that lamps are not too bright, coordination with task lights, etc. As you probably know all too well, some people do not like even the best changes, because they have to get used to them.

THINK OUT OF THE BOX

Mainly the Troffer Box

Instead of retrofitting or purchasing troffers, please consider surface-mounted or suspended indirect luminaires with T5HOs or high performance T8s and optimal ballasting.

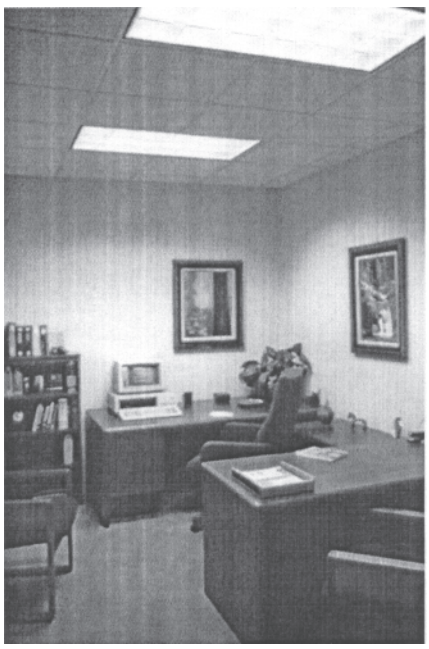
Where would you rather work?

- The picture below left, or
- The picture below right.

Be aware that the human eye is much better than cameras with regard to brightness. Actually, the picture on the right really looks better than the picture shows. The office on the left has about 70 photopic fc on the desk, while the right office has about 40 photopic fc on the desk. With indirects, frequently less light is preferred.

In addition to saving wattage, indirects can substantially improve the quality of lighting by reducing several glare issues, brightening the ceiling, improving uniformity, etc.

Although there are some studies on worker productivity increases with better lighting, the ones that I am aware of are not conclusive. More



studies are being done, but it will be some time before results are published.

What Brian Liebel, a lighting designer, and I have been doing is based on reduced negatives. We have a person or a group "experience" direct troffers and suspended indirects in an apples-to-apples comparison in a facility like the Pacific Energy Center's lighting lab. This works great if there are laptop computers and glossy paper to look at. Then we ask the person or group how much less time they think office workers would spend on breaks, with eye strain, with headaches, etc. with the suspended indirects compared to the direct lensed or parabolic troffers. Often the person or group will say 15 or 20 minutes a day.

Even just 2.5 minutes per day improvement with office workers making $50,000 per year dwarfs the installed cost of installing new indirects and makes them a much better value than just retrofitting existing troffers. This can be demonstrated using life cycle costing instead of payback, which tends to leave so many long benefits on the table.

2.5 minutes per day improvement is about 0.5 percent worker productivity improvement. 0.5 percent of $50,000 is $250 benefit per year to the company's bottom line. That is much more than most any retrofit can save in electricity in a typical office. Plus, more wattage can usually be saved with indirects than with a retrofit. So even if the parts and labor to install a suspended indirect in an individual office costs $300, the payback can be less than one year including worker productivity increases, electrical savings, and utility incentive.

One benefit of high performance T5HO suspended indirects in 11+ foot ceilings is that the row spacing can be 20'. So even if the fixtures are expensive, not many need to be purchased or installed.

Finelite has been working on its Series 15, which can provide very uniform lighting on the ceiling while being suspended 3 or 4 inches. *www.finelite.com*. Other manufacturers may offer similar fixtures.

Two good websites for comparing direct and indirect fixtures are: *www.designlights.org* and *www.lightright.org*.

ABOUT THE AUTHOR

Stan Walerczyk, CLEP and LC, has 15 years of experience in energy efficient lighting as a distributor and contractor. He is now an independent lighting consultant, including being director of lighting for Sun Energy Solutions, the largest national design and build retrofit con-

tractor. He also specializes in scotopically enhanced retrofit, relight, and redesign projects with Brian Liebel at AfterImage + Space. He is a member of IESNA's Energy Management Committee and Retrofit/Upgrade Subcommittee, which is in the process of writing a comprehensive retrofit document. He has won several IIDA EPRI awards and was Lighting Efficiency Advocate of the Year for the San Francisco Chapter of the AEE in 2001. Most of his articles and links to other lighting and related resources are downloadable at *www.sunenergysolutionsllc.com*. For questions and comments, please call him at 925-944-9481 or email him at lightingwizard@sbcglobal.net.

Table 1 - HIGH PERFORMANCE F32T8 LAMP LIFE

LAMP	WATTS	LAMP LIFE HOURS WITH VARIOUS BALLASTS & CYCLES					
		INSTANT START		RAPID START		PROGRAM START	
		3 HR	12 HR	3 HR	12 HR	3 HR	12 HR
BASIC GRADE	32	15,000	20,000	20,000	24,000	20,000	24,000
MID GRADE	32	18,000	24,000	24,000	30,000	24,000	30,000
GE HL	**32**	**24,000**	**30,000**	**24,000**	**30,000**	**30,000**	**36,000**
PHILIPS PLUS & ADV	**32**	**24,000**	**30,000**	**30,000**	**36,000**	**30,000**	**36,000**
SYLVANIA XPS	**32**	**15,000**	**24,000**	**20,000**	**28,000**	**30,000**	**34,000**
SYLVANIA XP	**32**	**18,000**	**26,000**	**24,000**	**30,000**	**24,000**	**30,000**
GE WM	**30**	**20,000**	**24,000**	**NA**	**NA**	**NA**	**NA**
GE XL WM	**30**	**24,000**	**29,000**	**NA**	**NA**	**NA**	**NA**
PHILIPS ADV EW	**30**	**15,000**	**20,000**	**NA**	**NA**	**NA**	**NA**
SYLVANIA SS	**30**	**18,000**	**26,000**	**NA**	**NA**	**24,000**	**TBD**
SLVANIA FO28	**28**	**18,000**	**26,000**	**NA**	**NA**	**24,000**	**TBD**
GE F28	**28**	**18,000**	**24,000**	**NA**	**NA**	**NA**	**NA**
F34T12 & mag ballast	34	NA	NA	20,000	27,000+	NA	NA
F28T5	28	*	*	*	*	20,000	25,000
F54T5HO	54	*	*	*	*	20,000	25,000

notes

Rated hours provided by lamp manufacturers between 12/13/02 and 12/03/03.

Lamp manufacturers may alter rated lamp life specifications, so get updates from manufacturers.

Please be aware that some manufacturers are more conservative than others on some products.

Sylvania lamp life with program start ballast is based on Sylvania PSX ballast, and may be less with other ballasts.

Program start ballasts include fixed output and most dimming ballasts.

All ballasts, except for T12, are electronic.

* is for most manufacturers do not warranty their lamps with rapid or instant start ballasts. Life significantly reduced.

Even though listed as NA (not applicable) some rapid start & program start ballasts can operate some 28-30W lamps.

Table 2 LAMP FOR LAMP TABLE (photopic lumens)

lamp & ballast type	catalog lamp lumens	EOL lumen maintenance	CRI	ballast factor	EOL lamp lumens	# of lamps	EOL lumens	EOL lumens compared to basic & standard	system wattage	wattage savings compared to basic & standard	EOL lumens per watt
F34T12CW & energy saving magnetic	2650	78%	62%	0.89	1840	1	1840	82%	44	-47%	42
						2	3680	82%	72	-24%	51
						3	5520	82%	116	-33%	48
						4	7360	82%	142	-24%	51
Basic 32W T8 & Standard	2850	90%	77%	0.88	2257	1	2257	100%	30	0%	75
						2	4514	100%	58	0%	78
						3	6771	100%	87	0%	78
						4	9028	100%	114	0%	79
Option 1 Instant Start & 32W Lamps	**3100**	**92%**	**86%**	**0.87**	**2481**	**1**	**2481**	**110%**	**28**	**9%**	**89**
						2	**4962**	**110%**	**53**	**9%**	**94**
						3	**7443**	**110%**	**80**	**9%**	**93**
						4	**9924**	**110%**	**107**	**9%**	**93**
Option 2 Instant Start & 32W Lamps	**3100**	**92%**	**86%**	**0.77**	**2196**	**1**	**2196**	**97%**	**25**	**17%**	**88**
						2	**4392**	**97%**	**48**	**17%**	**92**
						3	**6588**	**97%**	**72**	**16%**	**92**
						4	**8784**	**97%**	**96**	**15%**	**92**
Option 3 Program Start & 32W Lamps	**3100**	**92%**	**86%**	**0.71**	**2025**	**1**	**2025**	**90%**	**25**	**17%**	**81**
						2	**4050**	**90%**	**46**	**21%**	**88**
						3	**6075**	**90%**	**71**	**18%**	**86**
						4	**8100**	**90%**	**91**	**20%**	**89**
Option 4 Instant Start & 30W Lamps	**2850**	**92%**	**86%**	**0.87**	**2281**	**1**	**2281**	**101%**	**27**	**10%**	**85**
						2	**4562**	**101%**	**52**	**10%**	**88**
						3	**6843**	**101%**	**77**	**10%**	**89**
						4	**9124**	**101%**	**103**	**9%**	**90**
Option 5 Program Start & 30W Lamps	**2850**	**92%**	**82%**	**0.71**	**1862**	**1**	**1862**	**83%**	**24**	**20%**	**78**
						2	**3722**	**83%**	**43**	**26%**	**87**
						3	**5583**	**83%**	**67**	**23%**	**83**
						4	**7444**	**83%**	**86**	**25%**	**87**
Option 6 Instant Start & 28W Lamps	**2750**	**92%**	**82%**	**0.77**	**1948**	**1**	**1948**	**86%**	**22**	**23%**	**89**
						2	**3896**	**86%**	**44**	**26%**	**89**
						3	**5844**	**86%**	**65**	**25%**	**90**
						4	**7792**	**86%**	**86**	**22%**	**91**

notes:
EOL stands for end of life
Lamp life is estimated on 3 hour starts with listed ballast.
System wattages are based n 277V and may be slightly higher for 120V.
Basic and Standard has typical basic 700 series F32T8 lamps and generic standard-power electronic ballast.
All options have F32T8 lamps and optimal fixed output electronic ballasts.
The higher CRI of the options can help offset the less EOL lumens.
Many of above numbers are based on composites and extrapolations, so do not be concerned about small differences, like a difference of one or two in EOL lumens/watt.
Information on the 28W F32T8s is preliminary, and may change
It is highly recommended to do your own calculations with specific lamps and ballasts.

Table 3 - S/P Ratio Example of some 32W F32T8s

lamp	initial photopic (catalog) lumens	S/P ratio	brightness $P(S/P)^{.5}$	paper $P(S/P)^{.78}$	computer $P(S/P)^{1.0}$
735	2850	1.30	3250	3497	3705
741	2850	1.56	3560	4032	4446
835	3000	1.41	3562	3922	4230
841	3000	1.62	3818	4371	4860
850	3000	1.85	4080	4847	5550
Increase of energy efficiency of 850 when considering full field of view compared to		735	**26%**	**39%**	**48%**
		741	**15%**	**20%**	**25%**
		835	**15%**	**24%**	**31%**
		841	**7%**	**11%**	**14%**

notes
Initial lumens can range.
For example, 2950 lumen 835s & 841s and 3100 lumen 850s
S/P ratios vary among lamps and correction factor used.