Cost-effective Lighting Retrofits: Lessons Learned

Mark D. Fisher
Certified Lighting Efficiency Professional
Johnson Controls
Dallas, Texas

ABSTRACT

Facility managers and energy engineers contemplating a lighting retrofit are confronted with a confusing array of product and system options. This paper presents my experience in trial and final installations. Also presented is a commonsense approach to calculating savings.

TECHNOLOGIES

Reflectors

Specular reflectors improve luminaire efficiency by minimizing the number of times light must "bounce around" within fixture recesses before exiting the fixture. Presumably, this increase in luminaire efficiency will allow delamping the fixture, while maintaining light levels. In practice, I have rarely found that light levels are maintained when delamping from four lamps to two. In fact, light levels in the critical areas between fixtures have often plummeted below the level achieved with two lamps and <u>no</u> reflector. This appears to happen as a result of the localizing effect of reflectors, e.g. the redirection, straight down, of light that was previously directed over a greater area. It is interesting to note that a delamped fixture produces about 55% of the original lumens, rather than the expected 50%. This is due to reduced surface area within the luminaire for light absorption, and reduced bulbwall temperature. Reduced bulbwall temperature, to a certain point, will result in increased light output and energy consumption. I have also found that deep, squared-off fixtures provide the greatest opportunity for reflector retrofit. A shallow fixture with gently sloping white enamel surfaces will generally provide a less drastic efficiency improvement with reflector retrofit. A trial installation in a typical area, giving due consideration to lamp aging and dirt accumulation, is the most effective way to determine what effect reflector retrofits will have on light levels. The table on the following page depicts retrofit results for a local office buiding. Fixtures were all 2' x 4' prismatic lens lay-in troffers with 4 F40CW lamps. These fixtures were retrofit with custom-designed anodized aluminum full reflectors and two T-8 lamps. Light levels were measured at the same location on the task surface (usually a desk) before and after the retrofit.

footcandles before	footcandles after	% maintained
98	83	85%
63	58	92%
65	52	80%
66	53	80%
65	47	72%
65	44	68%
75	44	59%
54	45	83%
52	43	83%
127	80	63%
132	72	55%
56	45	80%
60	39	65%
71	50	70%
72	53	74%
84	65	77%

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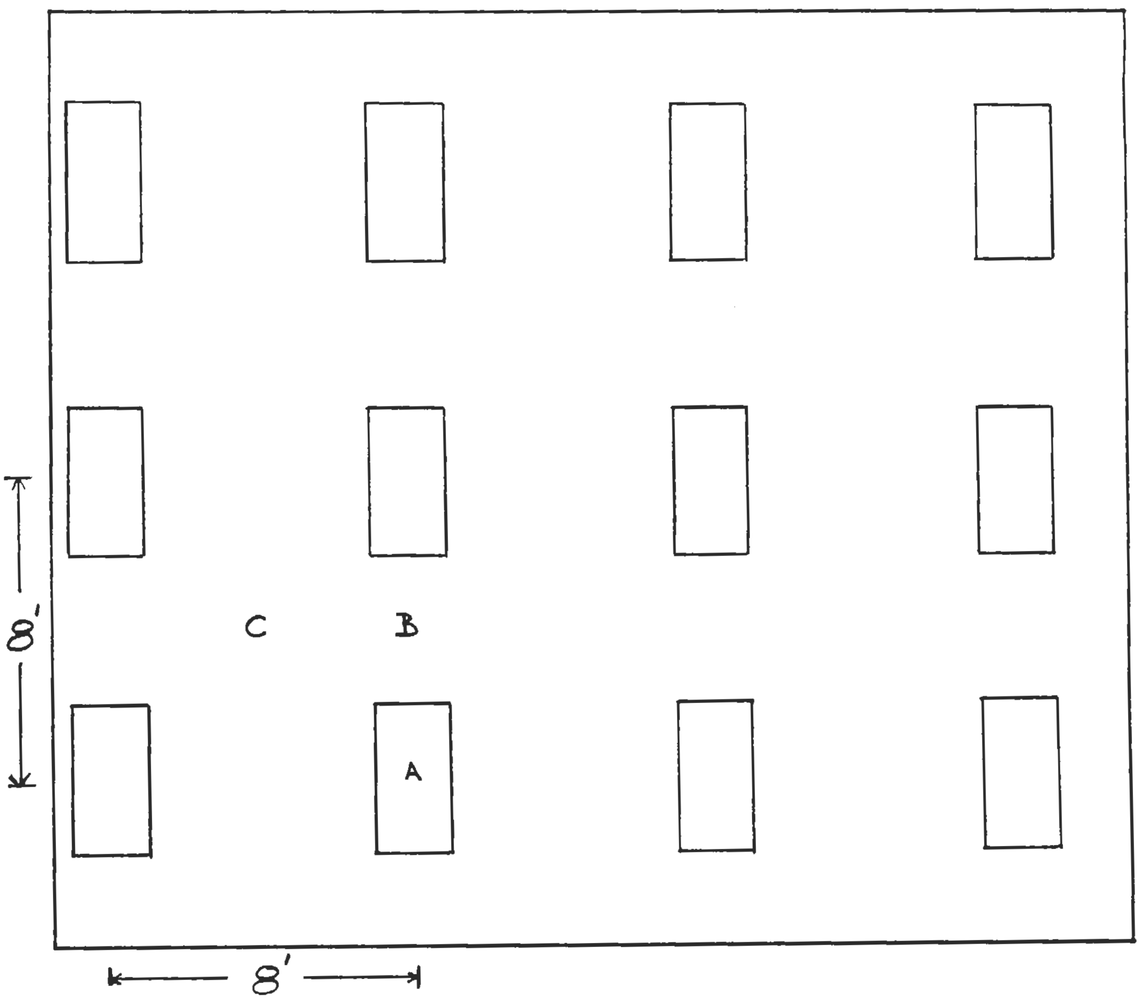
footcandles before	footcandles after	% maintained
110	99	90%
67	57	85%
59	32	54%
50	32	64%
131	78	60%
130	80	62%
85	46	54%
107	65	61%
78	54	69%
64	52	81%
79	50	63%
86	59	69%
84	68	81%
80	52	65%
77	59	77%
53	38	72%
66	47	71%
60	40	67%
121	80	66%
64	42	66%
65	41	63%
46	41	89%
63	40	63%
58	31	53%

Mean % maintained = **71%**

The wide range of % maintained performance values stems from the random placement of task surfaces beneath the lighting layout. The point which maintained 92% of pre-retrofit footcandles, for instance, was directly beneath a fixture. The point which maintained 53% was between fixtures. Please note also that existing lamps were well-seasoned (depreciated approximately 15% from new), while post-retrofit lamps had less than 50 burn hours at measurement time. Consequently, light levels could probably be expected to drop at least 10% as the fresh lamps aged and dirt accumulated within the fixture.

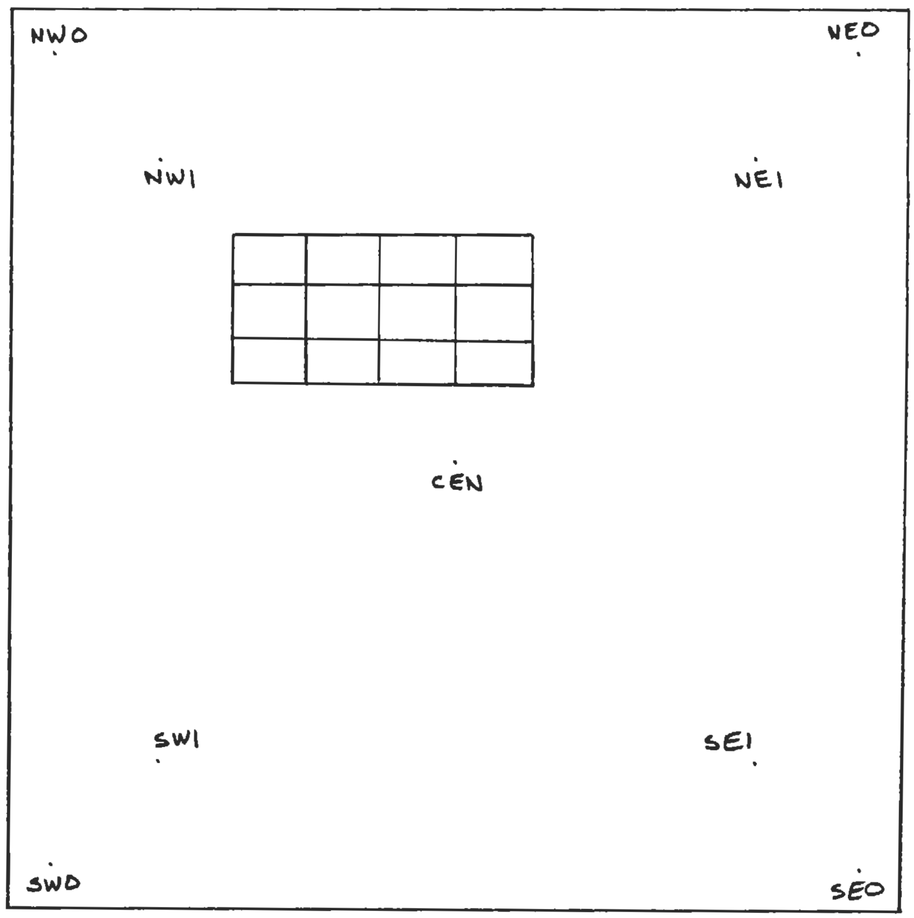
The classroom depicted below contained 2' x 4' prismatic lens lay-in troffers with 4 F34 Lite White lamps. Specular aluminum full reflectors specifically designed to distribute light as evenly as possible were installed with two of the existing lamps (in repositioned sockets).

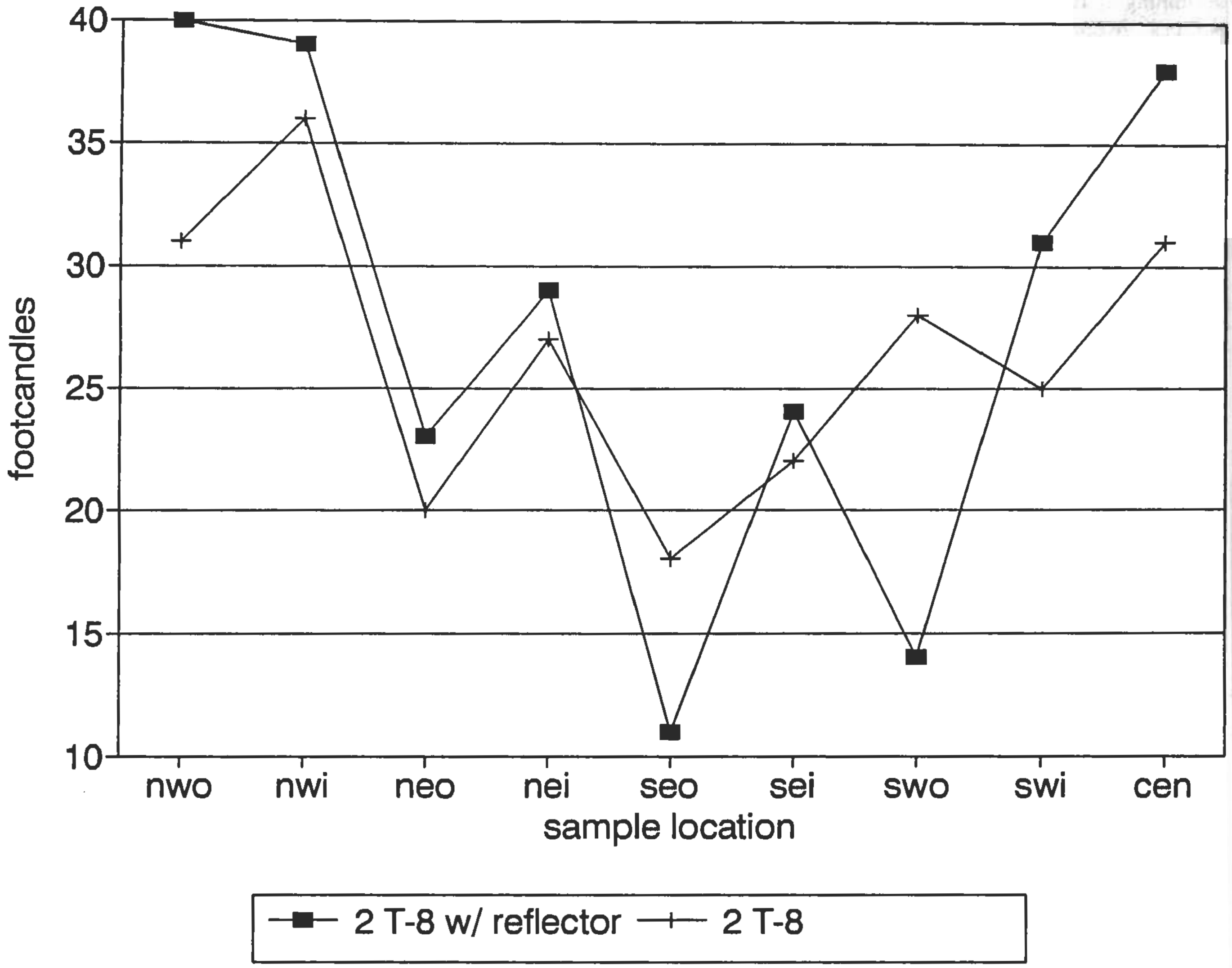


	footcandles before	footcandles after	% maintained
Point A	72	44	61%
Point B	64	37	58%
Point C	60	34	57%

Mean maintained % = 59%

The small office room depicted below contained one 2'x 4' lay-in deep cell parabolic louver fixture with 3 F34CW lamps. Prior to reflector retrofit, the fixture was converted to two T-8 lamp operation. After light levels were measured in this T-8 configuration, an anodized aluminum full reflector was installed with the same T-8 lamps. Results are presented in the graph following. As expected, the reflector raises light levels beneath the fixture, while reducing the levels to the side.




40
35
30
25
20
15
10
footcandles
nwo
nwi
neo
nei
seo
sei
swo
swi
cen
sample location
2 T-8 w/ reflector
2 T-8

T-8 Lamps and Electronic Ballasts

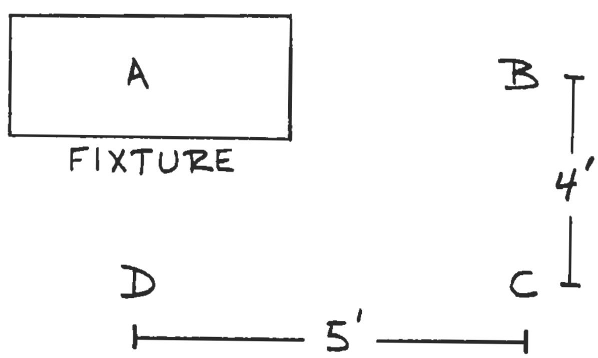
Where simple delamping or reflector installation is ruled out by light level considerations or fixture configuration, the installation of T-8 lamps and electronic ballasts has proven successful. Often, this option meets with considerably less tenant complaint, since light levels generally increase slightly, while distribution patterns and fixture appearance remain the same. On the down side, these retrofits tend to cost more than simple delamping or reflectors, and yield longer payback periods. A popular option is to utilize reflectors to enable delamping, along with T-8 lamps and electronic ballasts. Various lamp/ballast combinations can be applied as needed to maintain appropriate light levels. If T-12 lamps are replaced, one-for-one, with T-8 lamps in a fixture, one can usually apply a reduced-output electronic ballast for increased savings and similar light levels. This is due, in great part, to the minimal lumen depreciation which T-8 lamps demonstrate as they age, as compared to the T-12 lamps they replace. An additional installation cost saving and energy saving opportunity exists in the tandem wiring of 4-lamp electronic ballasts in one fixture to drive lamps in other fixtures as well.

Dimming Devices

These devices, which limit current flow from ballast to lamp, reduce light output in direct proportion to energy reduction. Little or no improvement in actual efficiency is achieved. These devices have been useful, however, where excessive light levels and unique fixture configuration mandated their use. Particular attention should be paid to the total harmonic distortion characteristics of these products.

Lenses

Various specialized lenses are available which are touted to permit delamping of fixtures with little or no light loss. The results of installing two of these products in a 2' x 4' prismatic lens troffer,without removing any lamps, are depicted below.



"dished" prismatic panel

	footcandles before	footcandles after
Point A	40	40
Point B	16	16
Point C	10	10
Point D	11	11

hex pattern panel

Point A	40	39
Point B	16	18
Point C	10	11
Point D	11	11

One exception to these generally poor results exists in retrofitting translucent, milky white lenses. By simply replacing these lenses with standard acrylic prismatic lenses, considerable light level increase can be expected, perhaps enabling delamping with or without reflector retrofit.

Incandescents

Replacement of incandescent lamps with compact fluorescents presents an unparallelled opportunity for considerable energy savings and a quick payback. Furthermore, the extended life of compact fluorescents can reduce maintenance workload significantly. The following points apply:

- Units which allow removal of lamp and reuse of ballast base can reduce replacement costs. Integral throwaway units are often smaller, and may be the only option in cramped fixtures. Those who replace lamps are often more likely to replace failed integral units with cheap incandescents again, while with component-type units they tend to replace the failed fluorescent lamp only.

- Where incandescent lamps are on a dimming circuit, compact fluorescents are inappropriate. Usually, however, significant savings can still be achieved by replacing 150R40 or 150PAR38 lamps with 60PAR38 halogen with infrared coating.

- If a compact fluorescent will not fit into a narrow-necked recessed can, an inexpensive medium-to-medium socket extender usually helps.

- Photometric characteristics of fixtures often change with compact fluorescent retrofit. Applications such as display spot lighting may not lend themselves to retrofit, except with halogen PAR lamps. Fortunately, in most general lighting, this photometric change is not critical. Individual fixture design will dictate whether a reflectorized or simple compact fluorescent unit is called for.

- For outdoor fixtures, 9 and 13 watt quad tubes may not start in freezing weather. Twin tube lamps of similar wattages may be a better choice.

- Power factor can be quite low on some magnetic ballasted products, while total harmonic distortion can be high on some electronic ballasted products.

High Intensity Discharge Lamps

Existing mercury vapor fixtures provide a good opportunity for retrofit. Where color rendition is not critical, such as warehouse space and exterior areas, high pressure sodium is preferred. Other areas should benefit from metal halide retrofit. Note, however, that metal halide lamps may require enclosed fixtures, whereas the preexisting mercury vapor lamp did not. Installation of a tempered glass lens will increase installation cost, requires more frequent cleaning, and will prevent lamp changing with an extension pole from floor level.

Exit Lights

Exit lights typically consume 40 watts continuously. For maximum brightness and visibility, compact fluorescent retrofit have proven effective. Where exit signs are flashed by the fire alarm system, a low-wattage long-life flexible incandescent retrofit is called for.

Occupant Sensors

Where tenants demonstrate a history of leaving lights on in unoccupied rooms, especially overnight and weekends, occupancy sensors can provide excellent paybacks. Careful attention must be exercised in applying them, however, as a generic approach can lead to nuisance shutoffs. Almost all occupancy sensor acceptance problems are the result of application error, rather than product deficiency. Predicting savings may be difficult, since actual and occupied burn hours are difficult to quantify, as is the overall effect on any demand portion of electric cost. Data logging tools are available to help relieve this information deficit. Note that these retrofits are especially lucrative if no other efficiency improvements are practical, and behavior patterns present significant switching-off opportunity.

Task Lighting

The proliferation of personal computers in buildings presents a unique opportunity for lighting retrofit. Monitor visibility is enhanced by general light levels of 20 to 30 footcandles. This is often achieved through delamping or reflector retrofit, yielding significant savings. Specific printed tasks may require higher levels. A relatively inexpensive task light can provide localized higher light levels at the task surface. This approach is much more energy efficient than lighting the entire area to the higher level, and serves to improve screen readability as well. Widely available compact fluorescent task lights, though more expensive first cost, are preferred for their low operating costs and extended intervals between lamp replacement.

SAVINGS CALCULATIONS

It is critical to use accurate wattage values in calculating predicted savings from a lighting retrofit. Published ANSI values are not an accurate approximation of real world fixture wattage. Field testing within a 2' x 4' lay-in deep cell parabolic louver fixture produced the results depicted in the table below.

In all cases, it is preferable to actually measure wattage consumed by specific typical fixtures on-site. At the very least, manufacturer's published fixture wattages should be used, not ANSI values. Where customers are billed for electrical power in both consumption and demand portions, it may be tempting to use an approximate consumption-only rate to simplify calculations. This will inevitably lead to inaccuracies in savings estimates. The small amount of extra effort involved in calculating demand charge savings should be well-justified. Note that, depending when the customer's peak demand is set, a retrofit may only contribute partially to demand savings. For instance, a customer who typically sets peak demand at 3:00 PM, and retrofits exterior lights which are never on during this time, can expect no savings in the demand portion of the electric bill. By the same logic, an office fixture which is on about 50% of the time when peak is set will produce only half of the demand savings that might be expected.

REVIEW

A prudent facility manager or energy engineer is wise to qualify all potential retrofits with a test installation. Savings calculations should employ measured or realistic published wattage values in equations identical to utility rate structures.

Ballast	ANSI watts	2-F40 lamps	2-F34 lamps	2-F32T8 lamps
Magnetic	96	85	78	-
ES magnetic	86	74	67	-
Electronic	62	-	-	58