CODE CHANGE PROPOSAL

Bi-Level Lighting Control Credits

JUNE 27, 2002

Overview

Description

This code and standards enhancement initiative will encourage the use of occupancy sensors, timers and specialized switching strategies in conjunction with bi-level lighting controls in intermittently occupied areas, such as hotels and motel corridors, warehouse and library stack areas and small office areas. We are proposing to introduce these new applications as control credits. The credits take the form of a Power Adjustment Factor. Power Adjustment Factors are energy neutral -- they are simply a way of encouraging application of a new technology.

The three space types identified as eligible for PAFs are corridors, library and warehouse ‘stack’ areas and small office spaces.

Corridors are typically lit at 100% levels for 24 hours per day. This credit would provide encouragement to reduce light levels by 50% when the space is unoccupied.

Lighting in library and warehouse ‘stack’ areas is typically on during normal operating hours. Yet these spaces are largely unoccupied and would benefit from reduced lighting levels during unoccupied times.

Small offices have bi-level switching and in some cases will have occupancy sensors but may not be capturing maximum energy savings. This credit would allow an automatic ON function based upon occupancy sensing for the first 50% or less of the lights. The occupant would activate the remaining 50% or more of the lights manually. The OFF function would be automatic. Manual off will also be available, to turn the lights off manually. Alternatively, the users may choose to use a Manual ON approach for the first level of lights, wherein the switch would require the occupant to turn on the lights at 50% or less level. These controls would serve to encourage lighting at the 50% level to be the default condition for a space.

Benefits

Automated bi-level control, and manual ON bi-level control in offices, will save energy and, depending on occupancy, will also reduce peak demand. Savings would be primarily for lighting systems, but there would be secondary savings in air conditioning. In small offices, the lights would be expected to operate closer to optimum conditions, because separate actions would be required to increase lighting when ambient conditions dictated the need for the light. In corridors and stack areas, savings would be achieved by automatic reductions when the space was unoccupied.

Environmental Impact

There are no adverse environmental impacts identified.

Type of Change

Prescriptive Requirement	This change would modify Power Adjustment Factors shown in section 146 Table 1-L
Compliance Option	The revised Table 1-L would provide an additional compliance credit for those using the prescriptive area category method, tailored method or the performance method.
Modeling	The performance method would need to accommodate the PAF’s.

In addition to the above, the compliance forms would need to be modified to allow for the control credit calculation. The manual would have to be modified to describe potential applications of the Power Adjustment Factors.

Technology Measures

This measure would increase the use and acceptance of specialized occupancy sensors in areas where they typically aren't yet used. This measure utilizes 'off the shelf' controls technology.

Measure Availability and Cost

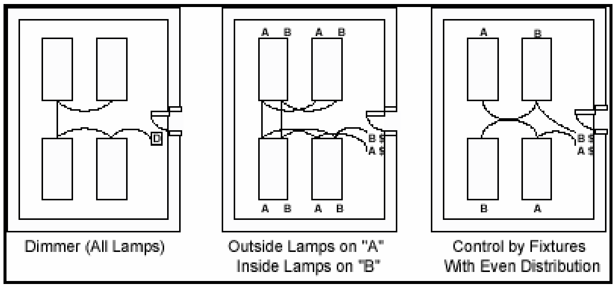
There are several control manufacturers with products available at competitive prices. Space configuration, lighting design and space type will affect design and control placement decisions. The hardware for implementing automated bi-level control exists and is readily available. The key concern is that it be implemented correctly.

Occupancy sensor – For the corridor and stack applications envisioned, the occupancy sensor must be designed to work in a long, narrow space, with a suitable sensitivity adjustment so that it turns on whenever there is movement in the space. It must also have an adjustable, relatively short off-response time delay setting suited to the lamp type controlled. The market for these types of controls is mature, and there is considerable experience in successful installations.

1) Lighting system – The type of lamp/ballast/fixture selected to work with an automated bi-level strategy must be compatible with this type of automatic control, and the fixtures must be correctly wired so that there is a reasonably uniform distribution of light when at partial lighting conditions. Fluorescent and incandescent lighting has quick start capability, and so should present few problems. HID lighting, however, has a long re-strike time; it would only be acceptable with high/low type ballasts which can switch quickly from partial to full intensity.
2) Bi-level occupancy sensing – For small office applications, the occupancy sensor must have either a automatic or manually controlled ON function, and have wiring capabilities so that each switch function activates one level of the lights. The operating sequence for the eligible control would be: 1) the first stage of the OS controls no more than 50% of the lights in a room either through an automatic action or the pressing of a switch by occupant 2) pressing another switch activates the alternate row of lamps or luminaires 3) pressing another switch would activate 100% of the lamps or luminaires. 4) Pressing another switch would turn the all the lights off. The occupant would retain control of the alternate set of luminaries or lamps and the OFF function for the entire space. The lamps are automatically turned OFF after a specified period of non-occupancy

Because bi-level control can be accomplished in many ways, costs will vary. The analysis revealed a cost between $.50 and $1.50 per square foot of area controlled. A copy of the cost assumptions can be found in Appendix A.

Figure 1 Typical Switching Strategies



Switching Strategies

For offices, The three types of switching strategies to achieve bi-level illumination are shown below (excerpted from the 2001 Nonresidential Manual):

Bi-level switching and automatic shut off is already required by code. However, the installation of the manual ON or bi-level automatic ON sensor would qualify the fixture for a Power Adjustment Factor. This factor would only apply to the last two strategies shown at right. The dimming strategy would not be eligible for the PAF because it would be eligible for the dimmable ballasts with controls credit.

For corridors, currently bi-level switching is not required. However, in many instances it makes economic sense to provide this capability, when used in conjunction with an occupancy sensor. The credit could be used with either of the two switching strategies shown. The relative difference between these three strategies is reflected in the proposed code language.

For warehouse and library stacks, bi-level switching is currently required. However, automating this function when the space is not occupied would save significant energy and should be encouraged through use of a PAF. In this situation, any of the three strategies would be eligible for this credit. It should also be an option for 100% of the lamps to be off during periods of non-occupancy. The relative difference between these three strategies is reflected in the proposed code language.

Useful Life, Persistence and Maintenance

Occupancy sensors are increasing in reliability and acceptance. The persistence of the measure would depend on how satisfactorily the controls perform. If they are badly installed or calibrated, then occupant complaints could be expected to kill the controls. If they are well installed and calibrated, then the occupants should barely be aware of them. The corridor and stack applications are not currently widespread, but they are used often enough that we believe them to be reliable. They are used in public spaces that people intermittently occupy, and so their acceptance should not be as sensitive as the acceptance in a private office or personal space. Switches recommended for private office areas would operate in a similar fashion to existing switching, allowing the occupant to tailor electric light to unique space needs.

In applications where the controls cause frequent cycling on/off of the lights, lamp life may be reduced, but it is not likely that the calendar time between lamp replacements would be shortened. This concern would be mitigated by the proposed acceptance testing requirements, where adequate time delays are mandated.

Performance Verification

Occupancy sensors require calibration to deliver savings. Recommended procedures can be found in the proposed acceptance testing criteria.

Analysis Tools

The recommendation is to provide Power Adjustment Factors. Creating these factors required no special analysis tools. Existing compliance tools can already accommodate PAFs, so there would be no change in capabilities required for them.

Relationship to Other Measures

This measure has no significant interactions with other measures, except to allow a slight increase in installed lighting power density, and would need to be coordinated with the proposed changes to other requirements for lighting control devices, such as the multi-level lighting description and the proposed credit for dimmable fluorescent ballasts and controls.

Methodology

This section describes the methodology followed in developing the proposed PAFs.

Space Type Screening

First, space type candidates were identified. Targets included all intermittently occupied spaces where lights are normally "on" 24 hours per day, spaces where occupancy is very infrequent, and where lights are controlled in large banks due to space use. Candidates included corridors, storage areas, stairways, warehouse spaces, parking garages, and library stacks. Parking garages and exteriors of hotel/motels were eliminated from consideration because these spaces are being addressed in the proposed outdoor lighting standards.

Private offices were given consideration for a special type of control because, although automatic shutoff and bi-level control is currently required, providing a switching incentive for the occupant to use no lights or 50% or less of the lights has a large energy savings potential. In addition, the presence of an occupancy sensor guarantees savings when the space is unoccupied, even during normal business hours. The manual ON or bi-level automatic ON feature prevents the automatic activation of 100% light levels.

Second, an equation was created to answer the following question: How many hours of "normally on" operation would have to be curtailed by the control in order to make the device cost effective to install? In cases where the hours were substantial, the space was dropped from consideration. Stairwells were dropped from consideration for this reason.

Although no cost-effectiveness analysis is required because the proposal is for a control credit, this simple screening was done so that only appropriate spaces would be included in the proposed code language.

Power Adjustment Factor Quantification

The proposed Power Adjustment Factors were created by estimating percentage of time the space would be unoccupied (and therefore automatically controlled), or that the space is occupied and the occupant chooses lower light levels and applying that percentage to the percentage of light controlled per luminaire. The resulting fraction represents the savings potential.

Results

The results revealed that the following space types are worthy of a PAF: interior corridors in hotels, motels and high-rise residential occupancies, library and warehouse 'stack areas' and small private offices. The space types and necessary shut-off hours are shown below. Necessary shut-off hours means the number of hours per day during which the control must shut off the lights, in order for the control to be cost effective according to CEC economic criteria.

Space type screening results

Space Type	*Shut off Hours Necessary*	*Should space be considered for PAF credit?*
Corridors	*4 – 6 hours per day*	*YES*
Library Stacks / Warehouse Stacks	*3 - 5 hours per day*	*YES*
Stairwells	*15-22 hours per day*	*NO*
Small Offices	*3 - 4 hours per day*	*YES*

Power Adjustment Factor Calculation

The Power Adjustment Factor calculations are shown for the individual spaces in the recommendations section.

Recommendations

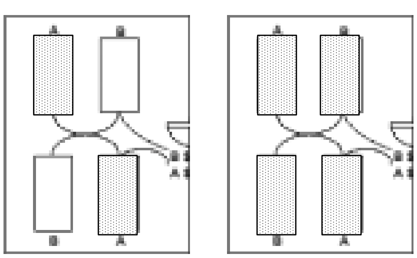
Provide a credit in the form of a Power Adjustment Factor for the following space types.

Small offices (≤250 sq. ft) and Classrooms

Recommendation: Provide a 20% Power Adjustment Factor for an occupancy sensor with bi-level "manual ON" functionality or a bi-level automatic ON functionality. The normal condition of this occupancy sensor would be no light. The switch must require separate actions in order to provide 100% light.

Rationale: This provides three distinct advantages: 1) The occupancy sensing function captures more energy savings in small rooms than large sweep automatic shut off controls do 2) the bi-level capabilities of the switch encourage 50% lighting by discouraging the behavior whereby occupants automatically flip both toggle switches up when entering the room, and 3) for those who currently use bi-level capabilities in their existing switching pattern, the manual ON or the automatic ON functions preserve this right, whereas a standard occupancy sensor may not.

Figure 2 Switching Sequence



Studies show that lighting is a matter of personal preference and when given options, people will often decrease light levels or work with their lights off when provided with good indirect light or adequate daylight. [1] In spaces with this type of control, the occupant would still have three light levels to choose from, but rather than have a readily accessible switch or an occupancy sensor that would allow the occupant to default to 100% light, achieving the 100% light level would require a separate action.

The images in Figure 2 show one of the control strategies for the recommended sensor. The first level of control ("A" fixtures or

[1] Lighting Controls Effectiveness Assessment, Draft Report on Bi-Level Lighting Study, ADM Associates for Southern California Edison, 2002

lamps), is provided by the bi-level automatic ON switch (or the manual ON occupancy sensing switch). The second level of control ("A" + "B") fixtures or lamps cannot be activated until the first level of control is activated. The occupant retains the right to use only the "B" fixtures or lamps or to turn the lights off completely.

Basis for the Credit: With the control strategy recommended above, it would take a separate action to turn all the lights on and thus more people would turn fewer lights on for a portion of the day. In addition, this credit would increase the number of occupancy sensors in small office spaces. This type of control saves more energy than does a 'sweep' control, since the automatic off features would sometimes be activated during normal business operating hours. To estimate energy savings potential, a series of assumptions are required for the following variables:

1. ***Occupancy***: The occupancy schedule for offices between 100 sq. ft and 250 sq. ft is only 67% or less during normal business hours. [2] Some assumptions must be made about the average length of each absence from a space and the delay settings for occupancy sensors. Given the expected time delays and the predicted occupancy pattern, a value of .25 is given for unoccupied periods where the control would deactivate the lights. During periods of occupancy, one of the following ambient conditions will occur.

2. ***Ambient conditions (available direct or indirect light, either daylight or electric light from a nearby source).*** The amount of ambient light varies widely in these spaces. Light needs also vary by occupant and by activity. The assumptions should not cover an individual space, but rather the average condition of all spaces when taken as a whole. Bi-level switching will only occur when ambient conditions provide adequate light to the space. Some of the time ambient conditions would provide 100% of the required light to the space. These types of conditions need only be accounted for during normal business hours when the space is occupied (75% of normal business hours). We assumed that, as a fraction of normal business hours, 8% of the time conditions would allow lighting levels to be reduced to zero, requiring no electric lighting. We also assumed that, as a fraction of normal business hours, 30% of the time conditions would allow lighting levels to be reduced by 50%. These conditions could occur when daylight was available, when another type of ambient light was available or when occupants preferred lower light levels due to space use.

The table below shows the combined effect of occupancy and assumed ambient conditions:

Table 1 Occupancy Assumptions for Small Offices

Occupancy and Required Light Condition Assumptions for Small Offices During Normal Operating Hours	*Occupancy Weighting*
Space is occupied and full light is required	0.380
Space is occupied and no electric light is needed	0.080
Space is occupied and 50% of the electric light is needed	0.300
Space is unoccupied and lights are automatically shut off	0.250

3. ***Behavior:*** There are two behavioral questions that play into the savings potential. The first question to be answered is: "What action would an occupant normally take when entering a room, given different ambient light conditions and switching options?" A recently completed study revealed that 73 percent of private office occupants never or only sometimes use their bi-level switching capability. [3] The second question then becomes "How would this behavior change with the given control? These actions do not occur outside of normal

[2] EPA study Occupancy Sensor Simulations and Energy Analysis for Commercial Buildings, Lighting Research Center Rensselaer Polytechnic Institute, 2000

[3] Lighting Controls Effectiveness Assessment, Draft Report on Bi-Level Lighting Study, ADM Associates for Southern California Edison, 2002

business operating hours. These actions also do not occur during normal business operating hours when the space is unoccupied.

It's predicted that 15% of small office spaces would normally put in an occupancy sensor to meet Section 131 (b) controls to reduce lighting. It is also predicted that, although 100% of the impacted spaces would have occupancy sensors installed, the unoccupied periods may be brief and intermittent. Therefore, we assume the light condition would only be off during 75% of the unoccupied time when these controls were present.

Table 2 shows the behavior predictions used to calculate the potential savings. The rows in the table illustrate different light conditions typically found in a small office. The first column represents the behavior for the current condition and answers the question, what percentage of people would tailor their electric lighting to the needs of the space? The second column predicts the percentage of time the light levels would adapt to the needs with the automatic control in place

As you can see from the first condition, when full light is required, no behavior change is expected. Occupants will utilize full light no matter what the control strategy. The second light condition, where the space is occupied and no light is needed to illuminate the task, the current condition assumes that 27% of the occupants will take action to turn off the light. The assumption is based on the Lighting Controls Effectiveness Assessment Report. The new type of control will not change this percentage, since the default condition will now be 50% light. The third light condition, where the space is occupied and only 50% lighting levels are required to complete a task, current conditions assumes that 27% of the occupants will take action to turn off the light. With the new control strategy, this value increases to 100%. The fourth light condition, space is unoccupied and lights are automatically shut off, would increase to 100% because all spaces would now have occupancy sensors.

Table 2 Lighting Use Predictions with Proposed Control Strategy

Time that Lighting Load Matches Lighting Requirements (in percentage)	***Under current conditions***	***With proposed control strategy***	***Resulting behavior change potential***
Space is occupied and full light is required	1.00	1.00	0.00
Space is occupied and no electric light is needed	0.27	0.27	0.00
Space is occupied and 50% of the electric light is needed	0.27	1.00	0.73
Space is unoccupied and lights are automatically shut off	0.15	1.00	0.85

4. ***Potential Savings***: Potential savings fraction for these spaces is either 100% of the light produced by a given luminaire or at least 50% of the light produced by a given luminaire (due to bi-level control). These savings rates are applied to the weighted set of assumptions based on occupancy, ambient conditions and behavior or control probability. The resulting fraction represents the savings potential of the control. Since the Power Adjustment Factor must be energy neutral, the resulting savings fraction is reduce by 50% to create a recommended Power Adjustment Factor

Table 3 Estimated Energy Savings and Recommended Power Adjustment Factor

	Occupancy Weighting	***Potential Savings Fraction***	***Potential Change Due to Control***	***Resulting Savings Fraction***
Space is occupied and full light is required	0.38	0.00	0.00	0.00
Space is occupied and no electric light is needed	0.08	1.00	0.00	0.00
Space is occupied and 50% of the electric light is needed	0.30	0.50	0.73	0.11
Space is unoccupied and lights are automatically shut off	0.25	1.00	0.85	0.21
Potential Savings Per Watt Controlled				0.32
Recommended Power Adjustment Factor				**0.20**

Interior Corridors of Hotels, Motels and High Rise Residential

Recommendation: Provide a 25% Power Adjustment Factor for automatic bi-level switching in these locations

Rationale: In these spaces, currently exempt from bi-level switching and night sweep requirements, there is a significant portion of time where the space is unoccupied. With the recommended control, when the space is occupied, full lighting is available. When the space is unoccupied, no more than 50% of the lighting is available. There are two measures of safety to preserve egress. First, there is never a circumstance where the corridor is not lit. In the event the control fails, it will fail ON. The proposed definition of multi-level lighting requires that lighting reduction be uniform. Second, the sensors will trigger full power to the system when the space is occupied.

Basis for the Credit: Our research revealed that any given corridor may be unoccupied for at least 75% of the time. During the day the corridor was assumed to be unoccupied for 25% of the time. The table below shows expected occupancy patterns and the savings fraction . The savings fraction is 1 because only the luminaries controlled are eligible for the PAF. These savings assumptions are based on the alternate luminaire type of switching. If alternate lamp switching is used, then the PAF would apply to all luminaries and therefore the savings fraction would be 50%. We accommodate this difference by first determining what the PAF would be based on luminaire switching, then note in the code that when alternate lamp or dimming is used, the PAF would be reduced by 50%.

For corridor and stack areas, the recommended PAF is 50% of the potential savings. This is recommended for three reasons: 1) Occupancy rates vary widely in these types of spaces 2) A 25% Power Adjustment Factor is sufficient to provide incentive for the desired change. 3) reducing the PAF with respect to the potential savings it may provide yields a further measure of security against the possibility of increased energy use building wide.

PAF Calculation for Corridors		Time Fraction	Savings Fraction	Weighted Savings
Day				
Occupied	75%	0.40	0.00	0.00
Unoccupied	25%	0.10	1.00	0.10
Night				0.00
Occupied	25%	0.10	0.00	0.00
Unoccupied	75%	0.40	1.00	0.40
Potential Savings per watt controlled				0.50
Recommended PAF				**0.25**

Table 4 Savings Fraction and PAF Calculation for Corridors

Commercial and Industrial Storage, Library Stacks

Recommendation: Provide a 25% Power Adjustment Factor for library spaces that utilize any type of occupancy sensor or timer when that sensor controls two or fewer rows or stacks. Provide a 15% Power Adjustment Factor for warehouse aisles that utilize any type of occupancy sensor or timer when that sensor controls two or fewer rows or stacks.

Rationale: In these spaces, providing a more flexible automatic switching scheme could save energy. Rather than sweep off entire spaces, smaller areas could benefit from the installation of an occupancy sensor or a timer. Either a 50% reduction or a 100% reduction would qualify the space for the credit.

Basis for the credit: An assumption was made that during normal hours of operation, stacks in libraries are only occupied 50% of the time. In warehouse aisles, it is assumed that they are occupied 70% of the time. The recommended PAF's provide a credit for the luminaires under control, not for the entire space. The potential savings fraction is 1, therefore, because savings are calculated using the alternate luminare strategy for control.

Table 5 Savings Fraction and PAF Calculation for Stacks

PAF Calculation for Stacks	Fraction	Savings Fraction	Weighting
Occupied	0.50	0.00	0.00
Unoccupied	0.50	1.00	0.50
Potential Savings per watt controlled			**0.50**
Recommended PAF			**0.25**

Table 6 Savings Fraction and PAF Calculation for Warehouse Spaces

PAF Calculation for Warehouse Spaces	Fraction	Savings Fraction	Weighting
Occupied	0.70	0.00	0.00
Unoccupied	0.30	1.00	0.30
Potential Savings per watt controlled			**0.30**
Recommended PAF			**0.15**

Proposed Standards Language

Section 119 (d) add

3. For Sensors used to qualify for the Power Adjustment Factor in small office spaces ≥: 250 sq ft

The occupancy sensor must have either an automatic or a manually controlled ON function, and have wiring capabilities so that each switch function activates half of the lights. The control must be capable of the following operating sequence:: a) the first stage activates no more than 50% of the lights in a room either through an automatic action or the pressing of a switch by occupant. After that event occurs any or all of the following actions may be assigned to occur when manually called to do so by the occupant: b) activating the alternate set of lights, c) activating 100% of the lights d) deactivating all lights.

The following change is recommended for Table 1-L

Table 1-L

<table>
<tr><th>TYPE OF CONTROL</th><th>TYPE OF SPACE</th><th>FACTOR</th></tr>
<tr><td>Occupant sensors

With “manual ON” or bi-level automatic ON combined with multi-level circuitry and switching from a single switch point</td><td>Any space ≤ 250 square feet enclosed by opaque floor-to-ceiling partitions; any size classroom, conference or waiting room</td><td>.2</td></tr>
<tr><td>Occupant Sensors

Used in conjunction with multi-level switching utilizing the alternate luminaire method</td><td>Hallways of hotels/motels or high rise residential spaces

Commercial and Industrial Storage stack areas

Occupancy sensor (any) or timer (controlling no more than two aisles)

Library Stacks

Occupancy sensor (any) or timer (controlling no more than two aisles)</td><td>.25

.15

.15</td></tr>
<tr><td rowspan="3">Occupant Sensors

Used in conjunction with multi-level switching utilizing the alternate lamp method.

Sensor must be wired to control 50% or more of the lamps in a luminaire</td><td>Hallways of hotels/motels or high rise residential spaces</td><td>.125</td></tr>
<tr><td>Commercial and Industrial Storage Stack Areas</td><td>.075</td></tr>
<tr><td>Library Stacks</td><td>.125</td></tr>
</table>

Occupant Sensors Used in conjunction with multi-level switching utilizing dimming technology (for HID luminaires only)	Commercial and Industrial Storage Stack Areas	.075
	Library Stacks	.125

For reference purposes, the multi-level definition is shown belowin Appendix B. This definition was taken from the skylight code change proposal and will also apply to this proposal

Proposed ACM Language

None required except to change the reference table in the standards) Table 1-L. There is currently a code application problem with high rise residential. The modeling parameters allow the corridors to be ignored. In the case where corridors are the only nonresidential occupancy, even if that occupancy represents more than 10% of the occupancy type. Typically corridors don't constitute more than 10% of the space. However, requiring input of a corridor square footage in high rise residential models would ensure that the space was calculated properly and the appropriate lighting requirements were applied.

Acknowledgments

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Appendices and Bibliography

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Appendix A Cost Effectiveness Calculations

The table below summarizes the screening process used to determine which space types should be included as PAF candidates.

Table 7: Cost effectiveness analysis for bi-level lighting controls

Table 7 explains the cost effectiveness analysis done for various spaces.

For corridors, the control variable (in column 3) is the length of the corridor analyzed, starting with 15 feet. For each successive increase in length of the corridor a cost benefit analysis is done to determine the minimum hours per day that the lights would need to be controlled by the bi-level occupancy sensor (last column – Hr/Day) to achieve a cost-benefit ratio of 1.0. The cost is based upon the difference in cost of a traditional switch(es) vs. occupancy

Lighting Type	Controller Type	Length ft.	Width ft.	LPD allowance W/sf	Total cost	Fraction Controlled	Watts Controlled kW	Hr/Yr	Hr/Wk	Hr/day
Corridor Spaces	Control variable - Corridor length									
Fluorescent	Osensor Wiring -	15	8	0.6	120	0.5	0.036	3268	63	9
	alternate lamp shut-off	15	8	0.6	160	0.5	0.036	4357	84	12
Fluorescent	Osensor Wiring -	20	8	0.6	120	0.5	0.048	2451	47	7
	alternate lamp shut-off	20	8	0.6	160	0.5	0.048	3268	63	9
Fluorescent	Osensor Wiring -	25	8	0.6	120	0.5	0.06	1961	38	5
	alternate lamp shut-off	25	8	0.6	160	0.5	0.06	2614	50	7
Fluorescent	Osensor Wiring -	30	8	0.6	120	0.5	0.072	1634	31	4
	alternate lamp shut-off	30	8	0.6	160	0.5	0.072	2179	42	6
Fluorescent	Osensor Wiring -	35	8	0.6	120	0.5	0.084	1401	27	4
	alternate lamp shut-off	35	8	0.6	160	0.5	0.084	1867	36	5
Fluorescent	Osensor Wiring -	40	8	0.6	240	0.5	0.096	2451	47	7
	alternate lamp shut-off	40	8	0.6	320	0.5	0.096	3268	63	9
Fluorescent	Osensor Wiring -	45	8	0.6	240	0.5	0.108	2179	42	6
	alternate lamp shut-off	45	8	0.6	320	0.5	0.108	2905	56	8
Fluorescent	Osensor Wiring -	50	8	0.6	240	0.5	0.12	1961	38	5
	alternate lamp shut-off	50	8	0.6	320	0.5	0.12	2614	50	7
Small Office - Bi-Level Switched										
Fluorescent	switch - alternate lamp shut-off	23	10	1.2	133.8	0.5	0.138	951	18	3
Library Stacks/ Warehouse Aisles										
Low-Bay Stacks										
Fluorescent	Osensor Wiring - alternate lamp shut-off	70	5	1.5	256	0.5	0.2625	956	18	3
Fluorescent	Osensor Wiring - alternate lamp shut-off	35	5	1.5	256	0.5	0.13125	1912	37	5
High-Bay Stacks										
Fluorescent	Osensor Wiring - alternate lamp shut-off	120	5	1.5	256	0.5	0.45	558	11	2
Fluorescent	Osensor Wiring - alternate lamp shut-off	45	5	1.5	256	0.5	0.16875	1487	29	4

Min. Hours the lamps should be controlled (turned OFF) to prove cost-effective sensor enabled bi-level controls. The sensor used for this analysis is a generic corridor occupancy sensor with a reach of 35 feet. The control strategy analyzed is one where all the lights are dimmed to 50%, or alternate lamps are switched off during unoccupied periods.

For the office occupancy, the area of the office is a control variable (as per standards this control strategy is applicable to office spaces below 250 sf in area). The sensor used is a ceiling mounted sensor for offices.

For the library stacks as well as the warehouse aisles, the area of coverage is a single aisle or bay with the length determined by the capacity of the occupancy sensor. The sensor used is are specialized sensors developed for these applications.

Appendix B Proposed Language from the Skylight Proposal

Sec 119

(e) **Automatic Multi-level Daylighting Control Devices**. Automatic multi-level daylighting control devices shall:

1. Be capable of ~~reducing the light output of the general lighting of the controlled area by at least one half while maintaining a uniform level of illuminance throughout the area~~ automatically reducing the general lighting in the controlled area in multiple steps in response to available daylight while maintaining a reasonably uniform level of illuminance. These controls shall have at least one control step that is between 50% and 70% of design illuminance and the controlled electric lighting shall consume less than 35% of rated power at minimum light output. A reasonably uniform level of illuminance in an area shall be achieved in a manner described in Section 131(b)1 through 3; and

2. If the device is a dimmer, provide electrical outputs to lamps for reduced flicker operation through the dimming range and without causing premature lamp failure; and

3. If the device is a stepped dimming system, incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes; and

4. If the device uses step switching ~~with separate on and off settings for the steps~~, the device shall have sufficient separation (deadband) of on and off points for each step of control to prevent cycling; and,

5. Have provided by the manufacturer step-by-step instructions for installation and start-up calibration to design footcandle levels; and

6. If the device uses step switching, status of each control step will be *annunciated* by an indicator light on the control device; and

7. If the device has a time delay, the time delay shall be capable of being over ridden or set to less than 5 seconds time delay for the purpose of commissioning; and

8. The light sensor shall have a linear response with 5% accuracy over the range of illuminances measured by the sensor; and

9. The light sensor shall be separate from the control device where calibrations adjustments are made; and

10. Controls for calibration adjustments to the lighting control device shall be *readily accessible* to authorized personnel, and the setpoint control have an indicator so that settings can be easily distinguished to within 10% of full scale adjustment.

This definition of automatic multi-level daylighting control devices references section 131(b) of the standard. Though the Nonresidential Manual is clear about the intent of the standard, the wording in this section was ambiguous. We recommend that the wording of Section 131(b) also be clarified as follows:

(b) Controls to Reduce Lighting. The general lighting of any enclosed space 100 square feet or larger in which the connected lighting load exceeds 0.8 watts per square foot for the space as a whole, and that has more than one light source (luminaire), shall have multi-level lighting controls that reduce lighting power in multiple steps while maintaining a reasonably uniform level of illuminance throughout the area controlled. Multilevel controls shall have at least one control step that is between 70% and 50% of design illuminance and at minimum light output consume less than 35% of rated power. ~~be controlled so that the load for the lights may be reduced by at least one half while maintaining a reasonably uniform level of illuminance throughout the area.~~ A reasonably uniform reduction of illuminance shall be achieved by:

1. Controlling all lamps or luminaires with dimmers; or

2. Dual switching of alternate rows of luminaires, alternate luminaires, or alternate lamps; or

3. Switching the middle lamps of three lamp luminaires independently of the outer lamps; or

4. Switching each luminaire or each lamp.

The parallels between this revised wording of Section 131(b) and Section 119(e) clearly defines lighting levels and power consumption at specified control steps.