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Energy and Environmental Effects of High Light Reflectance Ceilings

Engineering Study

Prepared by

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Introduction

This study investigates the effects of increasing ceiling reflectance on several typical office plans. With standards like those developed by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) and the International Energy Conservation Code (IECC) being adopted as code across the United States, there is a clear need to stretch our energy budget further than ever before. The Energy Policy Act of 2005 (EPAct 2005)1 gives tax credits for energy efficient design below ASHRAE 90.1- 20012 standards to encourage owners to reduce energy use below the code required minimum. In addition to code requirements and tax credits, many building owners are looking toward further improvements by applying the principles set forth by the United States Green Building Council (USGBC) in the Leadership in Energy and Environmental Design (LEED) programme.

With so much at stake to reduce energy use and environmental impacts, much research is being conducted into new reflector and optical designs, as well as electronics and lamp technology and methods of integrating daylight. Relatively little research has been conducted on other factors affecting lighting design, including topics such as surface reflectance effects or light loss factors. Are the standard 80-50-20 room surface reflectances that most designers assume causing over - or under-design? While more studies on light loss factor in modern environments need to be conducted, this study's focus is on the specific effects of ceiling reflectance on energy consumption.

The effects were looked at in two different comparative sets. The first investigation held all room properties, including the lighting, consistent, then looked at the effect of the ceiling reflectance on ceiling uniformity and illuminance levels at the work plane. The second investigation used the same light fixtures, lamps, and ballasts, but optimised the design for a variety of ceiling reflectances to reduce as much energy as possible while meeting the Illuminating Engineering Society of North America (IESNA) recommendations in their Recommended Practices for Office Lighting (RP-1-2004)[3].

This information was then used to compare the effects of ceiling reflectance to energy saved, energy saved as compared to ASHRAE 90.1-1999[4] and 90.1-2004[5] and its effects on the LEED Version 2.1[6] and 2.2[7] rating systems respectively, and the effects the reduced lighting load has on the HVAC system.

Throughout the following studies, a target illuminance at the task plane of 50 maintained footcandles (fc) was used, to comply with IESNA recommendations for private offices or open office plans with intermittent VDT use. Lower power densities are often achieved through lower ambient target light levels and the use of task lighting. These studies only consider the ambient lighting component.

Review of other studies

Previous studies have shown that there is a potential for significant energy savings when considering high reflectance surfaces. A recent study by Penn State University[8] showed a power density reduction in classroom spaces of 25 to 29 percent for the electric lighting when increasing the ceiling reflectance from 75% to 90%. This is also similar to the results found by the Weidt Group study[9], which found that a 25% increase in illuminance levels or an 18% decrease in operating costs could be achieved when using indirect luminaires. A study by Zhang and Ngai[10] has shown that as room reflectance increases, the ceiling uniformity also increases. Other studies that were reviewed mostly involved surface reflectance of objects within the rooms rather than the room surfaces themselves. While these studies also showed promise in energy savings for proper furniture selection, the furniture system can change numerous times in a building's lifetime. Thus, many designers use standard values for these reflectances in case the systems change in the future. Unlike furniture systems or even wall colour, ceiling systems are rarely changed unless there is a major renovation of a space. This provides a solid, reliable foundation upon which to base the lighting design. Thus any change in the ceiling system's reflectance could have long term impacts on the lighting system.

Software

Each of the studies was conducted using a minimum of three lighting software packages to verify the results. It should be noted that while the results did vary between the programmes, the variances were not statistically significant. The software packages utilised in these studies are as follows:

1. Lighting Analysts AGI32
   a. Radiosity Convergance
      i. Maximum Step size set to 1000 steps
      ii. Convergance set to 10% (0.1)

2. Luxicon 2.3.20

3. LitePro 1.02

Room Configurations:

Four room configurations were selected for being typical office spaces. Each space has a different shape and the spaces were selected to have Room Cavity Ratios (RCR) ranging from 1.0 to 7.5 in an attempt to limit any influence RCR might have on the results. The room configurations studied are as follows:

1. 10´ x 10´ Private Office (RCR = 6.0 to 7.5)

2. 100´ x 30´ Open Office (RCR = 1.3 to 1.6)

3. 60´ x 60´ Open Office (RCR = 1.0 to 1.3)

4. Irregular Open Office (RCR = 2.0 to 2.5)

While additional room configurations should be considered with future studies, this study limited the number of room configurations to four to achieve preliminary information on the effects of ceiling reflectance.

Light Fixture Selection Information:

Two different light fixtures were utilised in this study. An indirect pendant and a recessed troffer were selected to view the effects of different photometric distribution types. The fixture selections were as follows:

1. Indirect light fixture
   Single T5HO lamp in cross section 5000 initial lumens per lamp (assuming an under floor air system, which allows the room air to stratify and maintain 35 degree C ambient air temperature inside the fixture).

2. 2´ x 2´ Parabolic Troffer
   Two 32W T8 U lamps
   3150 initial lumens per lamp.

For information on the exact light fixtures and photometric files used, please see the attached appendix.

Light loss factors are as follows:

a. Room Surface Dirt Depreciation:	0.89
b. Luminaire Dirt Depreciation:	0.95
c. Ballast Factor:	1.00
d. Lamp Lumen Depreciation:	0.90
Total LLF:	**0.761**

The Studies

Workplane Illuminance and Ceiling Uniformity Study

Each room configuration was tested with 5 different ceiling heights: 10´, 9.75´, 9.5´, 9.25´, and 9´, while maintaining a luminaire height of 8.5´ from the floor plane. Work plane illuminances were calculated at 2.5´ above the floor surface. The ceiling uniformity portion of this study focuses only on the indirect fixture. Ceiling uniformity was calculated within the area above and between luminaires in compliance with IESNA RP-1-2004[3] recommendations.
The lighting layout in each room configuration was designed to meet 50 maintained fc using a 75% reflective ceiling tile. In the case of the indirect light fixture, the best possible ceiling uniformity was achieved. It should be noted that at extremely low ceiling heights, the ceiling uniformity did exceed IESNA recommendations. All variables were held constant and only the ceiling tile reflectance was varied up to 90%.
The calculations of work plane illuminance and ceiling uniformity for each fixture type were compared between the varying ceiling reflectances to determine a percentage change achieved with the higher reflectance value of the ceiling tile.

Lighting Layout 1

1. 10´ x 10´ room:
a. Indirect – 2 luminaires.

2. 100´ x 30´ room:
a. Indirect – 10 rows of 6 luminaires spaced 10 feet apart. Total of 60 luminaires.
b. Direct – A grid of 12 luminaires spaced 8 feet apart by 4 luminaires spaced 7 feet apart. Total of 48 luminaires.

3. 60´ x 60´ room:
a. Indirect – 5 rows of 14 luminaires spaced 12 feet apart. Total of 70 luminaires.
b. Direct – A grid of 7 luminaires spaced 8 feet apart by 8 luminaires spaced 7 feet apart. Total of 56 luminaires.

4. Irregular room:
a. Indirect – 8 rows of 9 luminaires spaced 10 feet apart and 4 rows of 10 luminaires spaced 10 feet apart. Total of 112 luminaires.
b. Direct – A grid of 10 luminaires spaced 8 feet apart by 5 luminaires spaced 8 feet apart, and 5 luminaires spaced 8 feet apart by 5 luminaires spaced 8 feet apart. Total of 75 luminaires.

Results:

For direct fixtures the work plane illuminance achieved modest increases ranging from 2% to 5% when increasing the ceiling reflectance from 75% to 90%.
The High Light Reflectance Ceiling (HLRC) compared to a 75% reflective ceiling achieves an average increase of approximately 22% in work plane illuminance with indirect lighting. This result was very consistent between room shapes and ceiling heights. The results are also very similar to results previously achieved in studies by Penn State University8 and by the Weidt Group study[9].

The ceiling uniformity also improved. In a few instances, calculations showed that switching to a 90% reflective ceiling enabled the ceiling uniformity to come within IESNA RP-1-20043 recommendations, whereas it did not meet the recommendations with a 75% reflective tile. In the single 10´x10´ office, an average of 3.67% improvement in ceiling uniformity was noted, whereas the open office plans had much higher average improvements of roughly 10 - 15%. Taking into account all instances where the layouts with the 90% reflectance ceiling had uniformity ratios within IESNA recommendations of 10:1, the average improvement in the uniformity ratio when switching from the 75% to the 90% reflective ceiling was 6.84%. These results are also very similar to results previously achieved in studies by Zhang & Ngai[10].

This research yields two important results:

1. HLRC ceiling systems show more improvement in larger office plans than single private offices, with ceiling uniformity ratios improving by an average of 12.58% and 3.67%, respectively.

2. HLRC ceiling systems provide an average of approximately 22% increase in work plane illuminance.

Below is a summary chart of the results found in this study.

10' Ceiling Height
Workplane illuminance increased
by an average of 22.64 %
Ceiling uniformity improved by an average of 4.51 %

9'-9" Ceiling Height
Workplane illuminance increased
by an average of 22.76 %
Ceiling uniformity improved by an average of 6.25 %

9'-6" Ceiling Height
Workplane illuminance increased
by an average of 22.54 %
Ceiling uniformity improved by an average of 9.64 %

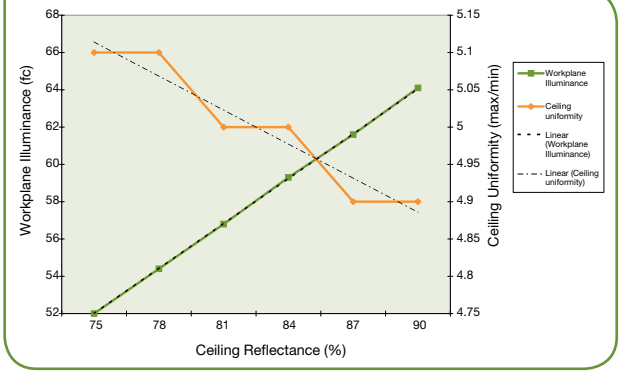
9'-3" Ceiling Height
Workplane illuminance increased
by an average of 22.87 %
Ceiling uniformity improved by an average of 13.92 %

9' Ceiling Height
Workplane illuminance increased
by an average of 22.86 %
Ceiling uniformity improved by an average of 19.45 %

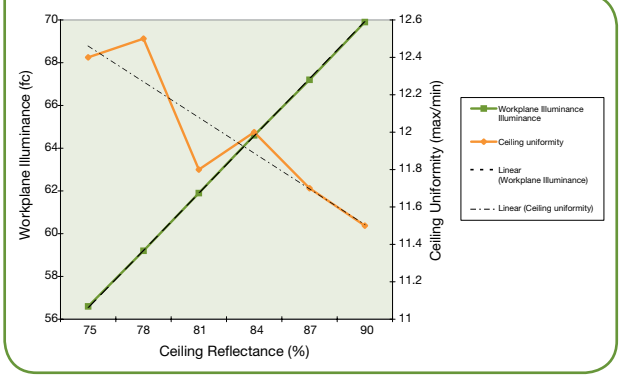
Note: Not all room and ceiling configurations met the IESNA recommended 10:1 ratio of luminance ratio (max/min). Comparing only the rooms that met 10:1 ratio, ceiling uniformity improved by an average of 6.84 %

Through analysis of the results for a variety of ceiling reflectance values, a nearly linear increase in illuminance levels was found when increasing the ceiling reflectance. This linear increase does not have a simple equation to apply to all conditions as the slope of the line is dependant on several factors including the room cavity ratio and the fixture's coefficient of utilisation. However, it is interesting to see that, given all factors remain constant within a space except the ceiling reflectance, there is a linear equation for the given room's illuminance increase. The ceiling uniformity also appears to improve in a linear fashion, although due to the decimal point limitations of the calculations the graph is not smooth. Some example graphs are included following.

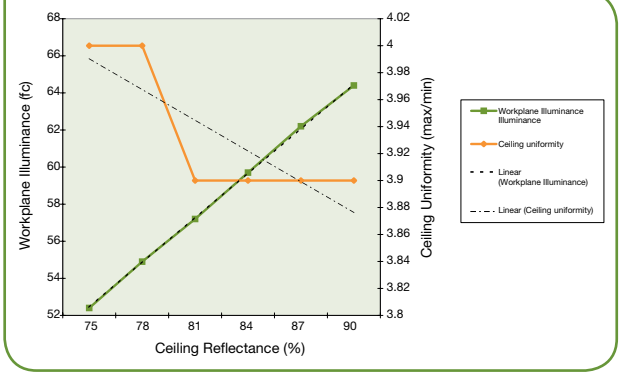
60'x60'x10 Open Office, 12' Luminaire Spacing



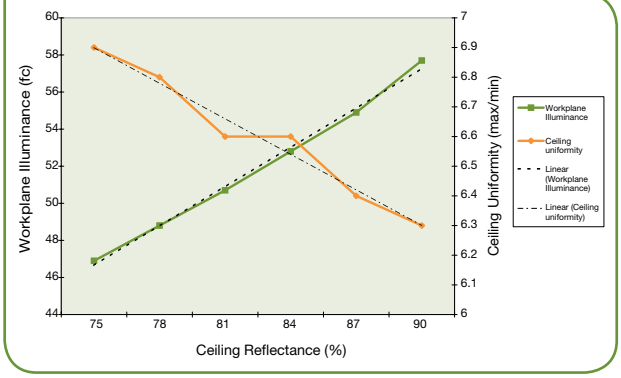
60'x60'x9.5, 12' Luminaire Spacing



100'x30'x10 Open Office, 10' Luminaire Spacing



Irregular Open Office, 10' Ceiling Height, 12' Luminaire Spacing



Energy Savings Study

Utilising the same spaces and fixtures as previously defined, a new lighting design was created for the indirect light fixtures to optimise the layout to achieve 50 maintained fc with the 90% reflective ceiling tile with the best possible ceiling uniformity. In all cases the ceiling height was held constant at 10´. Indirect luminaires were mounted at 8.5´. These results were also compared against a typical office layout of 2´ x 2´ recessed parabolic troffer style luminaires with standard spacing, as shown in the Workplane Illuminance and Ceiling Uniformity Study. All calculations were then compared against each other to determine a percentage change in energy use that was achieved with the higher value for the ceiling tile.

75% reflective ceiling tile - T5HO Indirect

1. 100´ x 30´ room:

a. Indirect – Ten rows of 24-foot sections spaced 10 feet apart for a total of 60 luminaires.

b. Direct - A grid of 12 luminaires spaced 8 feet apart by 4 luminaires spaced 7 feet apart for a total of 48 fixtures.

2. 60´ x 60´ room:

a. Indirect – Six parallel rows of three 16-foot sections spaced 10 feet apart side to side and 4 feet apart end to end for a total of 72 luminaires.

b. Direct – A uniform grid of 56 luminaires spaced on 8 foot centres in one direction and alternating 8 foot and 6 foot spacing in the other direction.

3. Irregular room:

a. Indirect - Six parallel rows of three 16-foot sections spaced 10 feet apart side to side and 4 feet apart end to end for a total of 96 luminaires total.

b. Direct – A uniform grid of 75 luminaires spaced out on 8 foot centres.

90% reflective ceiling tile - T5HO Indirect

1. 100´ x 30´ x 10´ room:

a. Eight rows of 24 foot sections spaced 12 feet apart for a total of 48 luminaires.

b. Direct - A grid of 12 luminaires spaced 8 feet apart by 4 luminaires spaced 7 feet apart for a total of 48 luminaires.

2. 60´ x 60´ x 10´ room:

a. Four parallel rows of three 16-foot sections spaced 13 feet apart side to side and 4 feet apart end to end for a total of 60 luminaires.

b. Direct – A uniform grid of 56 luminaires spaced on 8 foot centres in one direction and alternating 8 foot and 6 foot spacing in the other direction.

3. Irregular room:

a. 16-foot sections spaced 12 feet apart side to side and 4 feet apart end to end for a total of 72 luminaires.

b. Direct – A uniform grid of 75 luminaires spaced out on 8 foot centres.

Results:

Using the 90% reflective ceiling allowed the spacing between indirect luminaire sections to be increased, which reduced the total number of luminaires needed to achieve light levels similar to the 75% reflective ceiling. When changing from a 75% to 90% reflective ceiling tile utilising direct fixtures there was a slight increase in light levels, but not a large enough increase to allow for the reduction of fixtures. As such, the layouts for all ceiling reflectances remained the same for the direct fixtures.
For the 100´ x 30´ x 10´ room, utilising the HLRC allowed a reduction of the lighting power density to 0.96 watts per square foot (w/ft^2), which is 20% better than a 75% reflective ceiling. This yields a savings of 0.24 w/ft^2, or a reduction in cooling load of 20% over a standard 75% reflective ceiling. This is also a reduction of 0.16 w/ft^2 as compared to using 2´ x 2´ parabolic luminaires, which results in a reduction in cooling load by 14.29%.
The 60´ x 60´ x 10´ room shows similar results. Moving from the 75% reflective tile with a 10´ spacing to the 90% reflective tile with a 13´ spacing resulted in work plane illuminances of 52.9fc compared to 51.7fc and ceiling uniformities of 6:1 and 7.4:1 respectively, which is within the IESNA RP-1-20043 recommendation of 10:1.

Utilising a 13´ spacing allowed the deletion of one entire row of lights, dropping the power density to 1.00 w/ft^2. This yields a savings of 0.17 w/ft^2, or a reduction in cooling load due to lighting of 14.29% as compared to the 10´ spacing with 75% reflective ceiling. When compared to the 2´ x 2´ parabolic troffer, the cooling load energy savings rose to 31.43% when the recessed system achieved an average work plane illuminance of 54.3fc.
Below is a summary of the average power density reductions achieved when changing the ceiling reflectance from 75% to 90%:

The optimised layout with HLRC and indirect luminaires yielded a:

23.33% lower average power density over the standard 75% reflective ceiling layout (Layout 2).

21.14% lower average power density over the standard 2´ x 2´ parabolic troffer layout (Layout 4).

The breakdown is as follows:

100´ x 30	20.00%	better than the standard layout with 75% reflective ceiling
	14.29%	better than the 2´x 2´ layout with 75% or 90% reflective ceiling
60´ x 60´	14.29%	better than the standard layout with 75% reflective ceiling
	31.43%	better than the 2´x 2´ layout with 75% or 90% reflective ceiling
Irregular	35.71%	better than the standard layout with 75% reflective ceiling
	17.71%	better than the 2´x 2´ layout with 75% or 90% reflective ceiling

HVAC Savings Study

Using the three open office room configurations previously defined, the effects of the reduced lighting load on the HVAC system was modeled using two different computer software programs. The building was assumed to be located in Atlanta, Georgia. Each model was run once with northern facing windows and once with southern facing windows for relative heat gain and loss only, as no daylight dimming was considered. The open offices were assumed to be located on an intermediate floor, where losses and gains due to the roof or floor structure are negligible. The wall structure was assumed to have a U-value of 0.094 btu/hr/sf/oF and be of standard ASHRAE 90.1-20045 configuration. The power densities used in each iteration were developed in the previous portion of this study. A detailed occupancy schedule can be found in the attached appendix under “scheduled hours of operation.” In general the office was considered occupied from 6:00 am to 6:00 pm daily during the week and unoccupied on weekends and holidays. In the unoccupied mode some lights and equipment were considered “on” to account for late employees, cleaning or maintenance crews, security, etc.

Software Used:

1. DOE2
2. Trane Tracer

Results:

The results obtained from modeling the lighting and HVAC in Trane Tracer as it relates to heating and cooling loads showed roughly a 7% decrease in energy consumption with the indirect fixtures and 90% reflective ceiling, as compared to the 75% reflective ceiling or the 2x2 troffer layout on either ceiling. DOE2 showed similar results, although slightly lower savings. Due to the makeup of the building envelope, the internal heat gains kept the cooling system in operation year round. We predict that this is greatly dependant on climate. In cold climates, because of the decrease in watts used by the lighting system, the heating system will use more energy to compensate. For warm climates, the reduction in light power density will allow the cooling system to use less energy, holding all other variables the same.

Summary results of the study are shown below:

The reduction in lighting power density obtained by the 90% reflective ceiling enabled an average HVAC energy cost savings of:

North Facing Facade

9.10% over the layout with a 75% reflective ceiling

7.40% over the 2 x 2 troffer layout

South Facing Facade

7.80% over the layout with a 75% reflective ceiling

6.60% over the 2 x 2 troffer layout

Summary:

Based on the results of this limited study, there does appear to be a significant impact on the HVAC system from reducing the lighting load through the use of an HLRC. This impact can be positive in the form of energy savings if the building is in cooling year-round, as many large scale commercial buildings are. Even buildings that experience heating loads often only experience those loads at the perimeter and could still see overall positive impacts from the lighting savings. In buildings where the heating load is significant, the reduction of lighting will increase the HVAC system costs due to the additional heating load. It should be noted that even in this condition, the lighting savings significantly offset this additional heating cost.

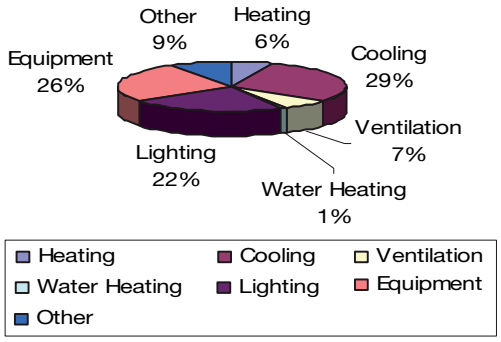
LEED Credit Analysis Version 2.1 projects registered prior to 2006:

HLRC has proven to reduce the lighting power density by over 20% as compared to a typical 75% reflective ceiling using the same lighting system, while having a positive impact on the HVAC systems in buildings that are mostly in cooling. To relate this to the LEED point system, it is necessary to look at lighting power densities rather than percentage reductions, as in previous portions of this study. LEED NC 2.16 refers to ASHRAE 90.1-19994 as the base model of energy use and then applies credits for a reduction in total building power to that specified limit.

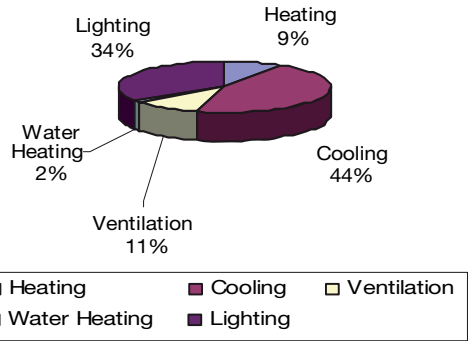
The specified lighting power density limit for open office areas is 1.3 w/ft^2. The average power densities achieved for this study are listed in the graph below and compared to the ASHRAE 90.1-19994 limit as a percentage saved.

The Energy Information Administration (EIA)11, which administers the official energy statistics for the United States Government through the Department of Energy (DOE), states that about 35% of a typical U.S. office building's energy is used in equipment and other energy using devices (see the graphs below). While these internal loads were included in the HVAC calculations for this study for heat gain purposes, they remained the same in all conditions since this study is limiting the variables to the ceiling reflectance only and associated lighting improvements only. The LEED point system is only affected by the total building energy for HVAC (heating, cooling, fans, and pumps), service hot water, and interior lighting, and thus, we can disregard the equipment and other energy users. According to the EIA11 statistics, HVAC accounts for 63% and lighting accounts for 34% of the remaining energy used in U.S. office buildings.

Percent of energy used by US office buildings according to the Energy Information Administration[11]



Percent of energy used by US office buildings related to LEED NC version 2.16 energy calculations according to the Energy Information Administration[11]



Percentage energy savings compared to ASHRAE 90.1-1999[4]

Indirect Layout with 75% Reflective Ceiling	
Percent Saving Lighting	2.3%
Percent Saving HVAC	0.9%
Total Percent Energy	1.8%
Maximized Indirect Layout with 90% Reflective Ceiling	
Percent Saving Lighting	27.4%
Percent Saving HVAC	11.0%
Total Percent Energy	21.6%
2x2 Parabolic Troffer Layout	
Percent Saving Lighting	6.9%
Percent Saving HVAC	2.8%
Total Percent Energy	5.5%

Summary:

Based on the spaces used for this study, high light reflectance ceilings do have an impact on LEED points. In this limited study, additional energy points were achieved through nothing more than increasing the ceiling reflectance. The total building energy savings as defined by LEED NC version 2.1[6] could be as high as 21.6% when optimising the lighting layout with respect to the HLRC. This savings qualifies for up to 2 points in a new building or 4 points in an existing building.

LEED Credit Analysis Version 2.2 projects registered after to 2006:

The pure energy savings in comparing LEED NC version 2.2[7] are very similar to those used in LEED NC version 2.1[6]. The biggest difference in regards to the Energy and Atmosphere credit for Optimised Energy is that version 2.2[7] refers to ASHRAE 90.1- 2004[5] whereas version 2.1[6] refers to ASHRAE 90.1-1999[4]. As a result, credits become more difficult to achieve because energy restrictions in ASHRAE 90.1-2004[4] are tighter. For example, the specified lighting power density specified limit for office areas was reduced from 1.3 to 1.1 w/ft^2. The point structure also changed slightly.

Under LEED NC version 2.1[6], a minimum reduction of 15% for new buildings and 5% for existing buildings was required to achieve the first point and then an additional point was given for every 5% additional savings beyond that. In LEED NC version 2.2[7], the first point is achieved at a reduction of 10.5% for new buildings and 3.5% for existing buildings and then an additional point is earned for each additional 3.5% savings achieved. The net result is stricter energy guidelines, but a slightly easier point system.

The average power densities achieved for this study are listed in the graph below and compared to the ASHRAE 90.1-2004[5] limit as a percentage saved.

Indirect Layout with 75% Reflective Ceiling

Percent Saving Lighting	Misses target by	5.6%
Percent Saving HVAC	Misses target by	5.6%
Total Percent Energy	Misses target by	11.8%

Maximized Indirect Layout with 90% Reflective Ceiling

Percent Saving Lighting	Beats target by	14.1%
Percent Saving HVAC	Beats target by	5.1%
Total Percent Energy	Beats target by	10.6%

2 x 2 Parabolic Troffer Layout

Percent Saving Lighting	Misses target by	10.2%
Percent Saving HVAC	Misses target by	3.6%
Total Percent Energy	Misses target by	7.7%

Percentage energy savings compared to ASHRAE 90.1-20044

Summary:

Based on the spaces used for this study, high light reflectance ceilings do have an impact on LEED points. In this limited study, additional energy points were achieved through nothing more than increasing the ceiling reflectance. The total building energy savings as defined by LEED NC version 2.2[7] could be as high as 10.6% when optimising the lighting layout with respect to the HLRC. This savings qualifies for up to 1 point in a new building or 3 points in an existing building.

Discussion:

This study focuses primarily on the effects that increasing ceiling reflectance has on illuminance levels, uniformity ratios, and building energy use. While the study attempts to take a wide variety of space configurations into account, the study is still very limited in scope and thus, only general conclusions can be drawn.

Partitions and office furniture were not included in the calculations for this study.

As shown in previous studies, such as those by Choi and Mistrick[12], office partition colour and style can have a significant impact on the lighting systems. Because this study is focused on the ceiling reflectance, the office partitions would have remained constant among all iterations and thus, the results should not be significantly different in terms of percentage increase or decrease had they been included.

As previously noted, the HVAC savings will vary considerably dependant on location. Further investigation on the impact of lighting to HVAC costs should be conducted, as this study hinted toward a decrease in lighting load having a negative impact on HVAC costs when heating loads are high, although total building energy was still decreased.

Additional energy savings could be obtained through further optimisation in the design by selecting a variety of fixtures, optics, ballast types, etc. These options were not considered, to maintain the consistency of evaluating the effects of the ceiling reflectance. Daylighting was also intentionally left out of this study but should be considered. The effects of daylight with high reflectance ceilings could add significant cost savings to the building, particularly when dimming is considered. Evaluation of these additional factors will not be easy due to the large number of variables to deal with, but initial research seems to be warranted.

As stated in the introduction, this study used 50 maintained fc average as the target work plane illuminance per IESNA recommendations for private offices or open office plans with intermittent VDT use. Additional energy reductions could be achieved through the use of a task/ambient lighting system where the ambient system only targets 30 fc. While further research is suggested, this study did not look at the effect of high reflectance ceilings at light levels other than 50 fc.

Overall Summary

In general, increasing the reflectance of the ceiling has a very positive impact on the lighting and building energy use as a whole, particularly relative to indirect lighting designs. The following conclusions can be made when increasing the ceiling reflectance from 75% to 90%:

- The illuminace levels for the same lighting design increase in a linear fashion up to 22%.
- The ceiling uniformity improves in a linear fashion.
- The ceiling uniformity improves by a greater percentage as the distance between the ceiling and the luminare is reduced.
- An average reduction in lighting energy of over 20% can be achieved, however this is widely dependant on the space configuration.
- The building's cooling system can see an average savings of 7%.
- The total building energy consumption (as calculated by LEED NC version 2.1[6]) can be reduced by 16 to 19 percent.
- 2 to 4 LEED NC version 2.16 points can be achieved for the energy reduction point for new or existing construction, respectively.
- 1 to 3 LEED NC version 2.2[7] points can be achieved for the energy reduction point for new or existing construction, respectively.

It should be recognised that each building and situation is very unique and this study in no way claims that increasing the reflectance of the ceiling system will ensure any specific energy savings or LEED points. However, the indications are that lighting designers and architects should be looking at the ceiling system as an integral portion of the building's energy reduction techniques. The overall cost impact to potential energy savings may make high reflectance ceilings a good solution for achieving energy reductions without the need for expensive new technology.

References:

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10) Zhang, J., and Ngai, P. 1998. Ceiling Luminance Ratios for Linear Fluorescent Indirect Luminaires. "Journal of the IES". 27(1):85-91.
11) Department of Energy, Energy Information Administration - Official Energy Statistics of the United States Government. Form EIA-871A-F, "Commercial Buildings Energy Consumption Survey." Found at http:\\www.eia.doe.gov\emeu\cbecs
12) Choi, A.S., and Mistrick, R.G., 1995. A Study of Lighting System Performance in Partitioned Spaces. "Journal of the IES". 24(2):50-63.

Appendix Contents

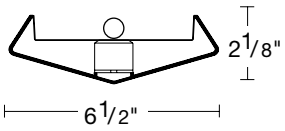
A1

LIGHTFIN® DIMINUTIVE INDIRECT

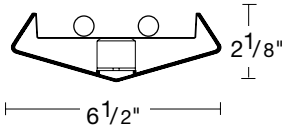
PEERLESS® 6” X 2” Angular

PENDANT MOUNT - MODULAR **SPECIFICATIONS**

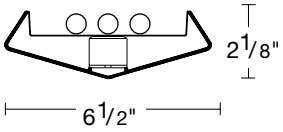
AVAILABLE FIXTURES



LFM1-1

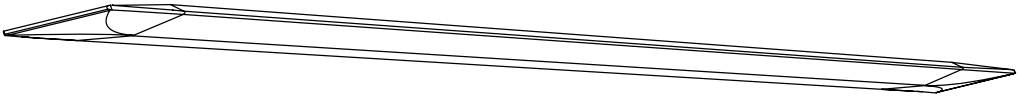


LFM1-2



LFM1- 3

SPECIFICATIONS



CONSTRUCTION

Housing AA 6063 T6 extruded aluminum forming a 6 1/2” x 2 1/8” angular channel. Die-cast end plate attaches with no exposed fasteners.

REFLECTORS

Die-formed reflectors combine hammertone specular aluminum and baked white enamel (nominal reflectance 86%).

FINISH

Satin anodised or white paint standard; custom colours available.

ELECTRICAL

Specify 120 volt or 277 volt. Pre-wired with prescribed circuits and are UL listed. Listed and labeled to comply with Canadian standards. For special circuiting, consult factory. T5 high-output lamps are included.

FIXTURE LENGTH

4’, 8’, and 12’ lengths in a single section for exact suspension spacing of 4’, 8’, and 12’. For total fixture length add 4-1/2” for each end-cap. Using internal joiners, 4’, 8’, and 12’ sections can be joined to form longer-length fixtures.

ORDERING LOGIC

Use guide below to order complete fixture runs from four feet to three-hundred feet in increments of four.

Quantity	Fixture	# of Lamps in Cross Section	Lamp Type	Nominal Row Length (Must be in 4' increments)	Maximum Section Length	Voltage	Ballast Type	# of Emergency Sections (sections per run)(Optional)**	Emergency Type (Optional)***	Switching	Lamp Colour	Mounting Type	Feed/Suspension Length	Finish	Options
	LFM1		54T5HO	FT								/			
		1 2 3			R4-4' section R8- 8' section R12- 12'section	120 277	GEB10-10% THD Ballast (consult factory)	1SE-1 section 2SE-2 sections XSE-X sections	EL-Emergency Battery Pack EC-Emergency Circuit	SCT-Single Circuit DCT-Dual Circuit	L/LP-No lamp LP830-3000K lamps LP835-3500K lamps LP841-4100K lamps	F1-T-bar Ceiling F2-Hard Ceiling Horizontal J-box	12-12" overall suspension 15-15" overall suspension 18-18" overall suspension 21-21" overall suspension 24-24" overall suspension XX-XX" overall suspension	C100-Satin Anodized Finish C200-Peerless Standard White (Low Gloss) C005-Soft White (Low Gloss) C032-White White (Gloss) C041-White White (Low Gloss) CXXX-Custom Colour (consult factory)	ACG-Adjustable Cable Grippers GLR-Fast Blow Fuse GMF-Slow Blow Fuse

** Maximum # of emergency sections per run should not exeed number of fixture sections, minus one. For additional sections, consult factory.

***EC and EL not available concurrently. EL and EC not ava ilable with DCT in 4’ sections. Separate feed required.

EXAMPLE Qty Fixture:

4 LFM1 1 54T5HO 40FT R12 120 GEB 2SE EL SCT LP 835 F1/24 C005
2 LFM1 2 54T5HO 32FT R8 120 GDIM DCT LP830 F1/12 C200 GLR

A1

LIGHTFIN® DIMINUTIVE INDIRECT

PEERLESS® **6" X 2" Angular**

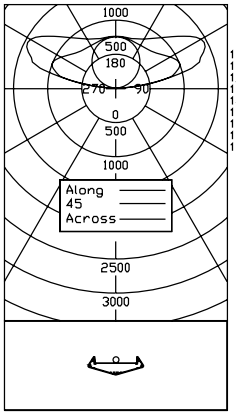
PENDANT MOUNT - MODULAR

PHOTOMETRICS

1-LAMP T5 HIGH-OUTPUT

FAR-FIELD PHOTOMETRY
DATE: 10-1-1999
REPORT NUMBER: 4507

CATALOG NUMBER: LFM1-1-54T5HO
LUMINAIRE: 6"W x 2"H EXTRUDED ALUMINUM INDIRECT LIGHT WITH WHITE PAINTED AND HAMMERTONE REFLECTOR
LAMP(S): FP54/835/HO RATED @ 5000 LUMENS
BALLAST: QT 1X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTS = 60.5 AT 120.0 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
90	0	0	0	0	0	
95	18	236	242	228	227	242
105	121	475	898	1129	1153	804
115	250	480	983	1342	1443	899
125	378	507	851	1197	1329	765
135	495	563	761	975	1065	598
145	594	630	729	844	892	464
155	671	687	729	780	799	339
165	725	732	744	756	764	211
175	755	757	758	763	762	72
180	760	760	760	760	760	

ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 90	0	0.0	0.0
90-120	1944	38.9	44.3
90-130	2709	54.2	61.7
90-150	3771	75.4	85.8
90-180	4393	87.9	100.0
0-180	4393	87.9	100.0

TOTAL LUMINAIRE EFFICIENCY = 87.9 %
CIE TYPE - INDIRECT

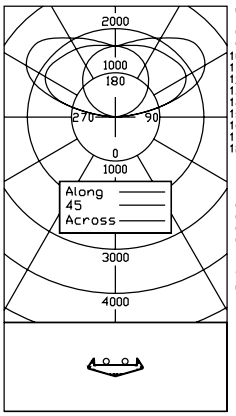
APPROVED BY:

TESTED IN ACCORDANCE WITH IES PROCEDURES, TEST DISTANCE EXCEEDS 25.0 FEET
NEAR-FIELD PHOTOMETRY AND CU TABLE AVAILABLE UPON REQUEST

2-LAMP T5 HIGH-OUTPUT

FAR-FIELD PHOTOMETRY
DATE: 10-1-1999
REPORT NUMBER: 4508

CATALOG NUMBER: LFM1-2-54T5HO
LUMINAIRE: 6"W x 2"H EXTRUDED ALUMINUM INDIRECT LIGHT WITH WHITE PAINTED AND HAMMERTONE REFLECTOR
LAMP(S): 2-FP54/835/HO RATED @ 5000 LUMENS EACH
BALLAST: QT 2X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTS =120.4 AT 120.0 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
90	0	0	0	0	0	
95	41	266	269	257	246	274
105	270	877	1238	1268	1265	1089
115	544	1087	1733	2052	2150	1533
125	809	1228	1881	2300	2426	1571
135	1054	1367	1846	2275	2424	1397
145	1260	1478	1796	2073	2187	1111
155	1419	1548	1746	1906	1970	798
165	1532	1587	1682	1757	1791	475
175	1591	1606	1618	1638	1645	155
180	1608	1608	1608	1608	1608	

ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 90	0	0.0	0.0
90-120	2896	29.0	34.5
90-130	4468	44.7	53.2
90-150	6975	69.8	83.0
90-180	8403	84.0	100.0
0-180	8403	84.0	100.0

TOTAL LUMINAIRE EFFICIENCY = 84.0 %
CIE TYPE - INDIRECT

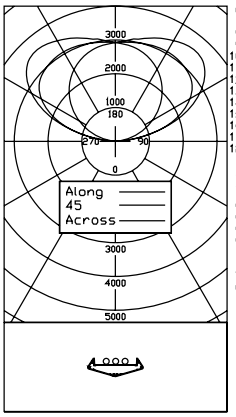
APPROVED BY:

TESTED IN ACCORDANCE WITH IES PROCEDURES, TEST DISTANCE EXCEEDS 25.0 FEET
NEAR-FIELD PHOTOMETRY AND CU TABLE AVAILABLE UPON REQUEST

3-LAMP T5-HIGH OUTPUT

FAR-FIELD PHOTOMETRY
DATE: 10-1-1999
REPORT NUMBER: 4509

CATALOG NUMBER: LFM1-3-54T5HO
LUMINAIRE: 6"W x 2"H ALUMINUM INDIRECT LIGHT WITH WHITE PAINTED AND HAMMERTONE REFLECTOR
LAMP(S): 3-FP54/835/HO RATED @ 5000 LUMENS EACH
BALLAST: QT 1X54/120PHO & 2X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTS =180.9 AT 120.0 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
90	0	0	0	0	0	
95	68	285	283	255	247	302
105	509	1152	1378	1396	1393	1284
115	1026	1715	2241	2433	2484	2008
125	1506	2080	2769	3112	3205	2303
135	1936	2379	2977	3409	3548	2222
145	2307	2619	3052	3396	3525	1879
155	2586	2782	3050	3270	3354	1396
165	2783	2873	3009	3107	3155	848
175	2891	2920	2938	2971	2982	281
180	2925	2925	2925	2925	2925	

ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 90	0	0.0	0.0
90-120	3594	24.0	28.7
90-130	5897	39.3	47.1
90-150	9999	66.7	79.8
90-180	12524	83.5	100.0
0-180	12524	83.5	100.0

TOTAL LUMINAIRE EFFICIENCY = 83.5 %
CIE TYPE - INDIRECT

APPROVED BY:

TESTED IN ACCORDANCE WITH IES PROCEDURES, TEST DISTANCE EXCEEDS 25.0 FEET
NEAR-FIELD PHOTOMETRY AND CU TABLE AVAILABLE UPON REQUEST

PERFORMANCE SUMMARIES

1-LAMP

% Luminaire Lumens from	90° - 120°	44%
	90° - 130°	61%
	90° - 150°	85%
Maximum Flux Location		110° - 120°
Luminaire Efficiency		87%

2-LAMP

% Luminaire Lumens from	90° - 120°	34%
	90° - 130°	53%
	90° - 150°	83%
Maximum Flux Location		120° - 130°
Luminaire Efficiency		84%

3-LAMP

% Luminaire Lumens from	90° - 120°	28%
	90° - 130°	47%
	90° - 150°	79%
Maximum Flux Location		120° - 130°
Luminaire Efficiency		83%

A2

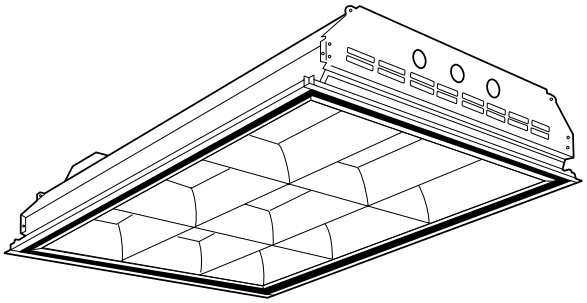
FEATURES

- Full family of parabolic luminaires with 3-inch-deep louvers.
- Models available to meet IES RP-1 minimum luminance criteria for office lighting systems in VDT applications. Optimax products are available to meet preferred criteria.
- Choice of low iridescent diffuse or specular louver finishes. Also available with new AchromaTM non-iridescent louver finish.
- Black reveal provides floating louver appearance, conceals optional air-supply slots.
- Overlapping flange and modular ceiling trims are factory-installed with standard swing-gate hangers or field-convertible with optional trim and hanger kits.
- Optional heat-removal dampers and air-pattern control blades allow airflow control.
- T-hinges are die-formed for maximum strength. Latches are spring-loaded and concealed in reveal.
- Guaranteed for one year against mechanical defects in manufacture.

PARAMAX® Parabolic Troffer

PM3 2'x2'

3" Deep Louver
6" Wide U Lamps
2 Lamps



SPECIFICATIONS

BALLAST — Thermally-protected, resetting, Class P, HPF, non-PCB, UL listed, CSA certified ballast is standard. Energy-saving and electronic ballasts are sound rated A. Standard combinations are CBM approved and conform to UL 935.

WIRING & ELECTRICAL — Fixture conforms to UL 1570 and is suitable for damp locations. AWM, TFN or THHN wire used throughout, rated for required temperatures.

MATERIALS — Housing formed from cold-rolled steel. Louvers formed from premium-grade aluminum lighting sheet. No asbestos is used in this product.

FINISH — Five-stage iron-phosphate pretreatment ensures superior paint adhesion and rust resistance. Painted parts finished with high-gloss, baked white enamel.

LISTING — UL listed and labeled. Listed and labeled to comply with Canadian and Mexican Standards (see Options).

Specifications subject to change without notice.

PHOTOMETRICS

Calculated using the zonal cavity method in accordance with IESNA LM41 procedures. Floor reflectances are 20%. Lamp configurations shown are typical. Full photometric data on these and other configurations available upon request.

2PM3 G B 2 U40 9LD
Report LTL 4452 - Lumens per lamp = 2935
S/MH (along) 1.2 (across) 1.5
Coefficient of Utilisation

Ceiling	80%			70%			50%			0%
Wall	70%	50%	30%	70%	50%	30%	50%	30%	10%	0%
0	70	70	70	69	69	69	66	66	66	59
1	66	64	62	65	63	61	60	59	58	53
2	62	58	55	60	57	54	55	52	50	47
3	57	52	48	56	51	48	50	47	44	41
4	53	47	42	51	46	42	45	41	38	36
5	48	42	37	47	41	37	40	36	33	51
6	45	38	33	44	37	33	36	32	28	27
7	41	34	29	40	33	29	32	28	25	24
8	38	30	25	37	30	25	29	25	22	20
9	35	27	22	34	26	22	26	22	19	18
10	32	24	20	31	24	20	23	19	16	15

Zonal Lumens Summary

Zone	Lumens	%Lamp	%Fixture
0-30	1098	18.7	31.6
0-40	1857	31.6	53.4
0-60	3257	55.5	93.7
0-90	3476	59.2	100.0
90-180	0	0	0
0-180	3476	59.2	100.0

2PM3 G B 2 U316 9LD
Report LTL 5466 - Lumens per lamp = 2600
S/MH (along) 1.2 (across) 1.5
Coefficient of Utilisation

Ceiling	80%			70%			50%			0%
Wall	70%	50%	30%	70%	50%	30%	50%	30%	10%	0%
0	76	76	76	75	75	75	71	71	71	64
1	71	69	67	70	68	66	65	64	62	57
2	67	62	59	65	61	58	59	57	54	51
3	62	56	52	60	55	51	54	50	47	45
4	57	51	46	56	50	45	48	44	41	39
5	52	45	40	51	45	40	43	39	36	34
6	48	41	36	47	40	35	39	35	31	30
7	45	37	31	44	36	31	35	31	27	26
8	41	33	28	40	32	27	31	27	24	22
9	38	29	24	37	29	24	28	24	21	19
10	35	27	22	34	26	21	26	21	18	17

Zonal Lumens Summary

Zone	Lumens	%Lamp	%Fixture
0-30	1077	20.7	32.3
0-40	1819	35.0	54.6
0-60	3083	59.3	92.5
0-90	3332	64.1	100.0
90-180	0	0	0
0-180	3332	64.1	100.0

LITHONIA LIGHTING
COMMERCIAL FLUORESCENT LIGHTING

A2

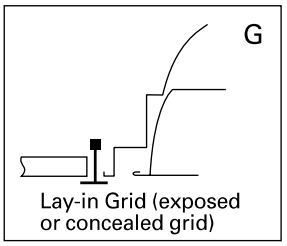
PM3 2'x2' 6" U lamps, 3" Louver Family, Paramax

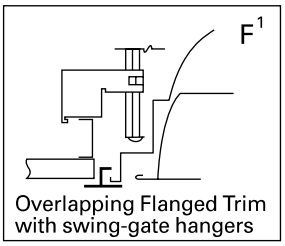
MOUNTINGDATA

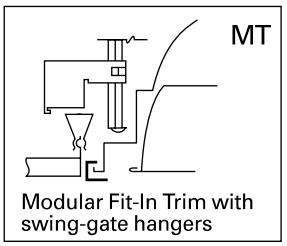
Continuous row mounting of flanged units requires CRE and CRM trim options (see Options).

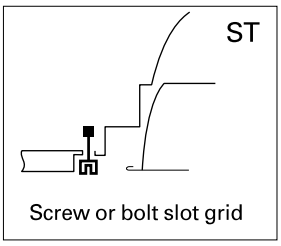
Ceiling Type	Appropriate Trim Type
Exposed grid tee	G
Concealed grid tee	G, ST
Concealed Z-spline	F, MT
Metal pan (consult factory)	MT
Screw slot (consult factory)	ST
Acoustical tile, plaster or plasterboard on rigid support parallel to lamps	F

NOTE:
1 Recommended rough-in dimensions for F trim fixtures 24" x 24" (Tolerance is +1/4", -0"). Swing-gate range 1" to 4-3/16", span 23-1/2" to 26-5/16".



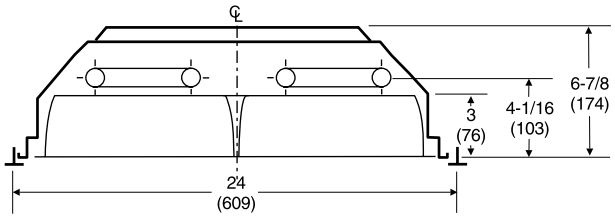






DIMENSIONS

Inches (millimeters). Subject to change without notice.



ORDERING INFORMATION

Example: **2PM3 G B 2 U316 9LD 120 GEB**

2PM3 | **Series**
- **2PM3** Paramax parabolic with 3" deep cells, 2' wide

Trim type
- **G** Grid
- **F** Overlapping flanged
- **MT** Modular fit-in
- **ST** Screw slot

Air function
- **A** Air supply/ return (slots in side trim)
- **H** Heat removal (through lamp cavity, dampers available)
- **D** Combination A & H
- **B** Static (no air function, matching appearance)

2 | **Number of lamps**
- **2** Not included.

Lamp type
- **U316** 31W T8 (6" leg spacing)
- **U40** 40W T12 (6" leg spacing)

Number of cells
- **6, 9, 12, 16**

Voltage
- **120, 277, 347, MVOLT1** Others available.

Louver finish
- **ND** Achroma™ non-iridescent diffuse silver
- **LD** Low iridescent anodized diffuse silver
- **LS** Low iridescent anodized specular silver
- **C** Diffuse gold anodized (champagne)
- **G** Specular gold anodized

Options
- **GEB** Electronic ballast, ≤20% THD
- **GEB10IS** Electronic ballast, ≤10% THD, Instant Start
- **GEB10RS** Electronic ballast, ≤10% THD, Rapid Start
- **EL** Emergency battery pack (nominal 300 lumens; see Life Safety Section); may increase fixture depth
- **LST** Tandem fixture pairs (shared ballasts)
- **PWS1836** 6' prewire, 3/8" dia., 18-gauge, 3 wires
- **GLR** Internal fast-blow fuse
- **GMF** Internal slow-blow fuse
- **LP__** Lamped (specify lamp type and colour)
- **HRD** Heat-removal dampers
- **APB** Air-pattern control blades (A & D models only)
- **ACS** Air closure strips (A & D models only)
- **PAF** Painted after fabrication (white enamel)
- **CRE** Flanged trim for continuous row mounting (end)
- **CRM** Flanged trim for continuous row mounting (middle)
- **1C** One internal channel cover[2]
- **CSA** Listed and labeled to comply with Canadian Standards
- **NOM** Listed and labeled to comply with Mexican Standards
- **JP16** Palletised and stretch-wrapped (16 per), G and MT trim only

NOTES:
1 MVOLT available with GEB10IS only.
2 Option places wireway cover between the two lamps and decreases overall fixture height by approximately1".

LITHONIA LIGHTING
COMMERCIAL FLUORESCENT LIGHTING

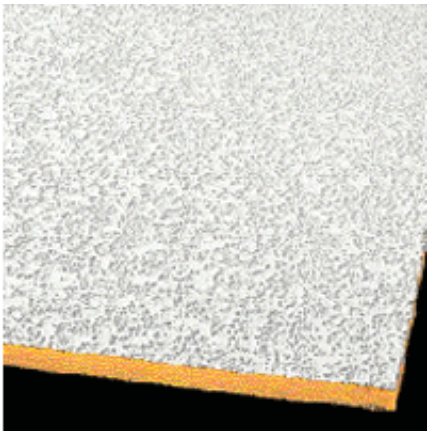
A3

Random Fissured

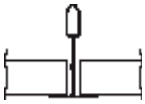
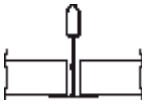
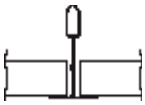
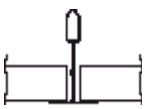
DESCRIPTION

Random Fissured is a popular vinyl faced fine-textured panel with excellent acoustical Performance (perforated).

Easy-clean surface is impact and soil resistant and scrubbable. HumiGuard Plus no sag performance.



PERFORMANCE

Item #	Edge Profile/ Grid Face	Dimensions	Colour	NRC	CAC/ AC	Fire Performance	Humidity Resist	Light Reflectance (LR)
2908 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 24 x 5 8 IN 	White	0.70	NA / NA	Class A (UL)	HumiGuard Plus	0.72
2909 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 24 x 5 8 IN 	White	0.55	NA / NA	Class A (UL)	HumiGuard Plus	0.72
2910 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 48 x 5 8 IN 	White	0.70	NA / NA	Class A (UL)	HumiGuard Plus	0.72
2911 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 48 x 5 8 IN 	White	0.55	NA / NA	Class A (UL)	HumiGuard Plus	0.72

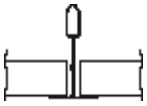
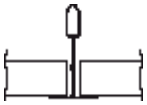
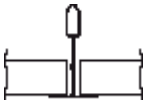
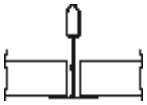
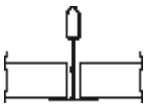
A4

Optima Open Plan

DESCRIPTION

Fine-textured Optima with nondirectional DuraBrite surface provides excellent acoustics, light reflectance and durability, including impact, scratch and soil resistance, plus washability. HumiGuard Plus no sag performance. In square and plank.

PERFORMANCE

Item #	Edge Profile/ Grid Face	Dimensions	Color	NRC	CAC/ AC	Fire Performance	Humidity Resist	Light Reflectance (LR)
3150 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 24 x 3 4 IN	White	0.90	NA /180	Class A (UL)	HumiGuard Plus	0.90
3151 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 48 x 3 4 IN	White	0.90	NA /180	Class A (UL)	HumiGuard Plus	0.90
3152 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 24 x 1 IN	White	0.95	NA /190	Class A (UL)	HumiGuard Plus	0.90
3153 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 48 x 1 IN	White	0.95	NA / 190	Class A (UL)	HumiGuard Plus	0.90
3155 SAMPLE	**Square Lay-In 15/16 IN** 	24 x 48 x 1 1/2 IN	White	1.00	NA / 200	Class A (UL)	HumiGuard Plus	0.90

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Cooper Luxicon

		Ceiling Uniformity			Work Plane Illuminance (Avg. fc)		
		75	90	% lower uniformity	75	90	% higher illuminance
10x10 Room	10	4	4	0.00	25.7	30.8	19.84
	9.75	5	5	0.00	27	32.6	20.74
	9.5	6	6	0.00	28.9	34	17.65
	9.25	11	10	10.00	31.1	37.8	21.54
	9	23	22	4.55	32.7	39.9	22.02
	Avg.			**2.91**			**20.36**
100x30 Room	10	4	3.9	2.56	52.7	64.4	22.90
	9.75	5.9	5.5	7.27	52.1	65.9	24.11
	9.5	9.7	8.9	8.99	53.8	66.4	23.42
	9.25	17.8	15.6	14.10	53.6	55.4	23.88
	9	34.8	29.7	17.17	54.3	67.3	23.94
	Avg.			**10.02**			**23.65**
60x60 Room	10	5.1	4.9	4.08	54.8	67.5	23.18
	9.75	7.9	7	12.86	55.7	68.8	23.52
	9.5	12.7	11.5	10.43	56.6	69.9	23.50
	9.25	23	20	15.00	57.8	71.7	24.05
	9	42.4	35.5	19.44	55.1	68.1	23.59
	Avg.			**12.36**			**23.57**
Irregular Room	10	4.3	4.2	2.38	62	76.3	23.06
	9.75	6	5.8	3.45	63	77.1	22.38
	9.5	9.2	8.2	12.20	64.1	78.8	22.93
	9.25	15.1	13.4	12.69	65.5	80.5	22.90
	9	30	25.2	19.05	66.6	82.4	23.72
	Avg.			**9.95**			**23.00**
	Total Avg.			**8.81**			**22.64**

Average within IESNA 10:1	5.32
Average Excluding Single Office within IESNA 10:1	6.72

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AGI 32

		Ceiling Uniformity			Work Plane Illuminance (Avg. fc)		
		75	90	% lower uniformity	75	90	% higher illuminance
10x10 Room	10	2.45	2.41	1.66	19.3	23.4	21.24
	9.75	2.75	2.71	1.48	20.37	24.75	21.50
	9.5	3.18	3.12	1.92	21.23	26.01	22.52
	9.25	4.21	4.12	2.18	21.94	26.84	22.33
	9	7.7	7.44	3.49	21.52	26.33	22.35
	Avg.			**2.15**			**21.99**
100x30 Room	10	4.71	4.34	8.53	41.7	51.73	24.05
	9.75	6.28	6.03	4.15	41.69	51.44	23.39
	9.5	9.17	8.63	6.26	41.6	50.97	22.52
	9.25	15.63	13.6	14.93	40.95	50.31	22.86
	9	27.79	23.85	16.52	39.55	48.59	22.86
	Avg.			**10.07**			**23.14**
60x60 Room	10	4.73	4.48	5.58	42.52	52.22	22.81
	9.75	6.26	5.84	7.19	42.57	52.3	22.86
	9.5	9.41	8.1	16.17	42.12	52.11	23.72
	9.25	13.72	11.6	18.28	41.78	51.77	23.91
	9	22.8	16.84	32.39	40.11	50.21	25.18
	Avg.			**16.52**			**23.70**
Irregular Room	10	3.61	3.26	10.74	52.3	64.03	22.43
	9.75	4.96	4.37	13.50	52.49	63.94	21.81
	9.5	7.82	6.31	23.93	52.59	63.77	21.26
	9.25	12.85	9.9	29.80	52.56	62.91	19.69
	9	23.68	15.86	49.31	52.54	61.13	16.35
	Avg.			**25.45**			**20.31**
	Total Avg.			**13.55**			**22.28**

Average within IESNA 10:1	9.11
Average Excluding Single Office within IESNA 10:1	12.58

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LITEPRO

		Ceiling Uniformity			Work Plane Illuminance (Avg. fc)		
		75	90	% lower uniformity	75	90	% higher illuminance
10x10 Room	10	4.12	3.99	3.18	24.7	29.9	21.01
	9.75	5.16	4.97	3.83	26.7	32.4	21.35
	9.5	7.25	6.89	5.19	28.6	34.8	21.68
	9.25	12.22	11.44	6.75	30.3	37	22.11
	9	25.45	22.96	10.86	30.7	37.6	22.48
	Avg.			**5.96**			**21.73**
100x30 Room	10	4.05	3.89	4.11	54.9	67.8	23.50
	9.75	5.91	5.57	6.16	55.4	68.5	23.65
	9.5	9.74	8.82	9.16	56.8	70.2	23.59
	9.25	17.45	15.32	13.90	57.6	71.2	23.61
	9	32.90	27.61	19.18	58.2	72.1	23.88
	Avg.			**10.50**			**23.65**
60x60 Room	10	5.18	4.88	6.15	52.5	65	23.81
	9.75	7.80	7.20	8.33	53	65.7	23.96
	9.5	12.40	11.05	12.22	53.7	66.5	23.84
	9.25	20.64	17.76	16.22	54.7	67.7	23.77
	9	37.30	30.70	21.50	55.2	68.4	23.91
	Avg.			**12.88**			**23.86**
Irregular Room	10	3.94	3.75	5.12	62.7	77.6	23.76
	9.75	5.65	5.29	6.78	63.2	78.3	23.89
	9.5	9.18	8.40	9.18	63.6	78.8	23.90
	9.25	16.09	14.21	13.21	64.3	79.6	23.79
	9	29.76	25.45	16.97	64.6	80.1	23.99
	Avg.			**10.25**			**23.87**
	Total Avg.			**9.90**			**23.28**

Average within IESNA 10:1	6.11
Average Excluding Single Office within IESNA 10:1	6,88

A8

ENERGY ANALYSIS

		Indirect Lighting 75% Ceiling	Indirect Lighting 90% Ceiling	2x2 Parabolic 75% Ceiling
100x30x10	Ceiling Uniformity	5	6.80	
	Work Plane Illuminance	55	54.50	53.6
	Power Density	1.20	0.96	1.12
	% Improvement by using Layout 3:	20.00%		14.29%

60x60x10	Ceiling Uniformity	6	7.40	
	Work Plane Illuminance	52.9	54.40	54.3
	Power Density	1.17	1.00	1.46
	% Improvement by using Layout 3:	14.29%		31.43%

Irregular	Ceiling Uniformity	4.6	8.00	
	Work Plane Illuminance	55	50.00	53.5
	Power Density	1.40	0.90	1.09
	% Improvement by using Layout 3:	35.71%		17.71%
	Avg.	**23.33%**		**21.14%**

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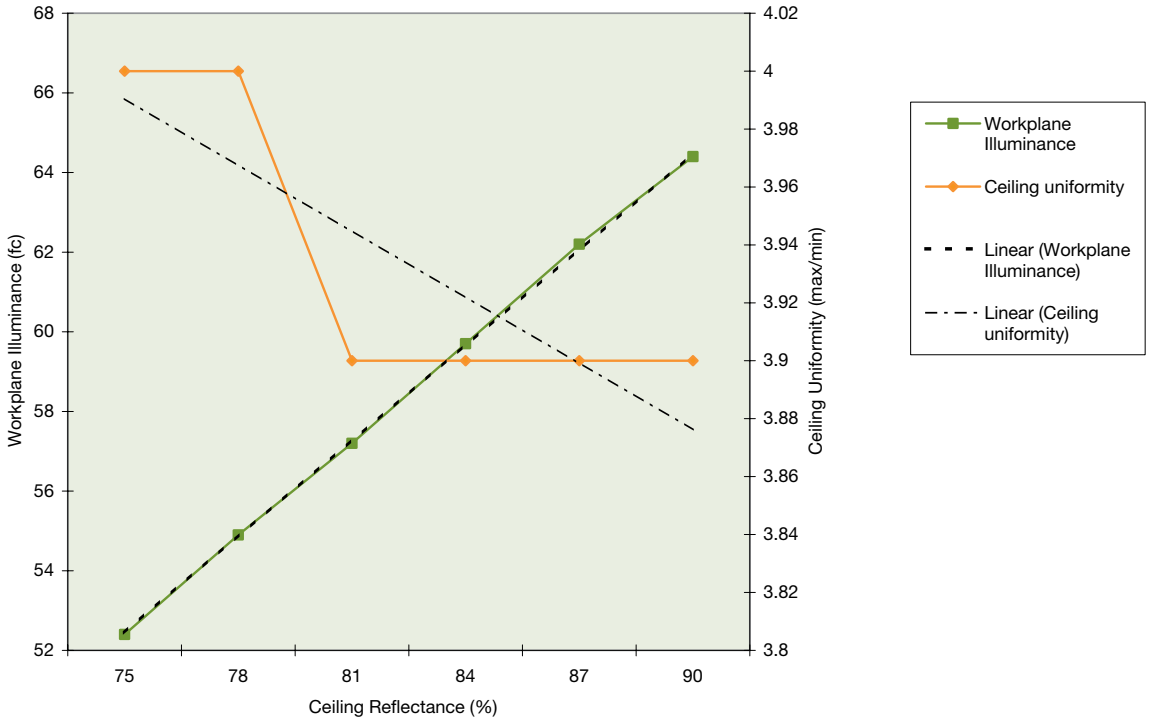
POWER DENSITY CALCULATIONS

Room	Area (ft^2)	No. of Fixtures	W/Fixture	W/ft^2
Comparison of 75% and 90% reflective ceiling				
10x10	100	2	60	1.20
100x30	3000	60	60	1.20
60x60	3600	70	60	1.17
Irregular	4800	112	60	1.40

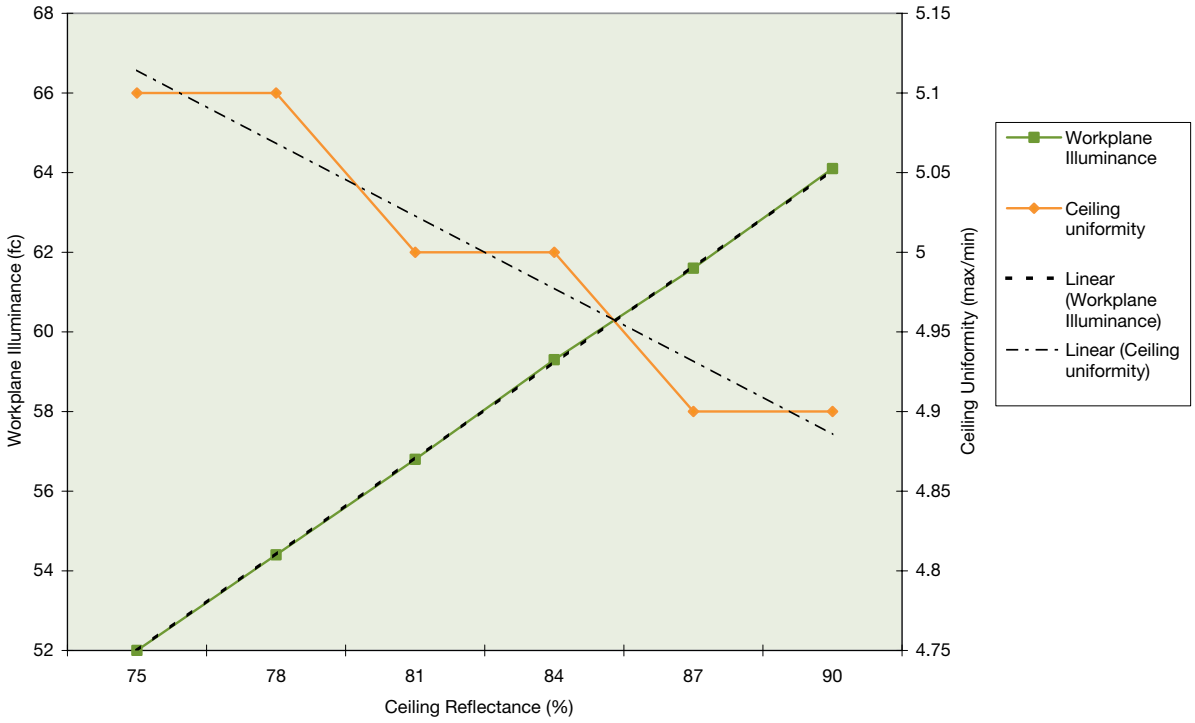
Energy Analysis				
Layout 2: Standard Layout with 75% Reflective Ceiliing				
100x30	3000	60	60	1.20
60x60	3600	70	60	1.20
Irregular	4800	96	60	1.20
Layout 3: Improved Layout with 90% Reflective Ceiliing				
100x30	3000	48	60	0.96
60x60	3600	60	60	1.00
Irregular	4800	72	60	0.90
Layout 4: 2x2 Parabolic Troffers				
100x30	3000	48	70	1.12
60x60	3600	75	70	1.46
Irregular	4800	75	70	1.09

A10

100'x30'x10' Open Office, 10' Luminaire Spacing

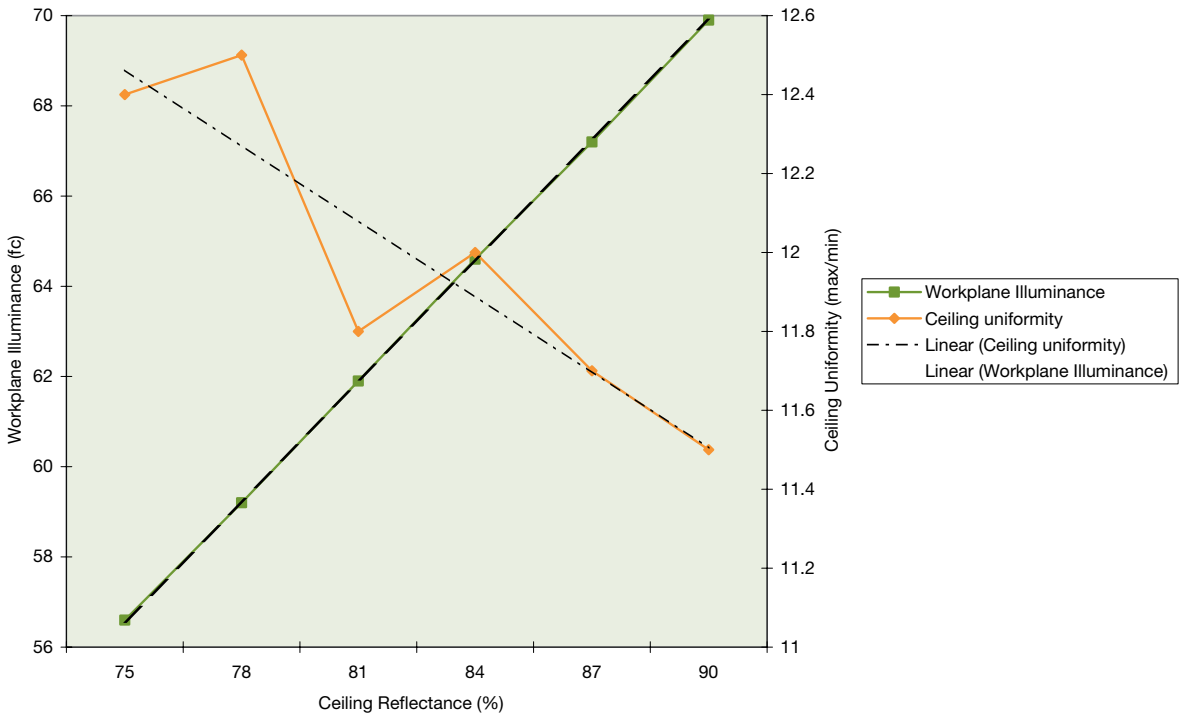


60'x60'x10' Open Office, 12' Luminaire Spacing

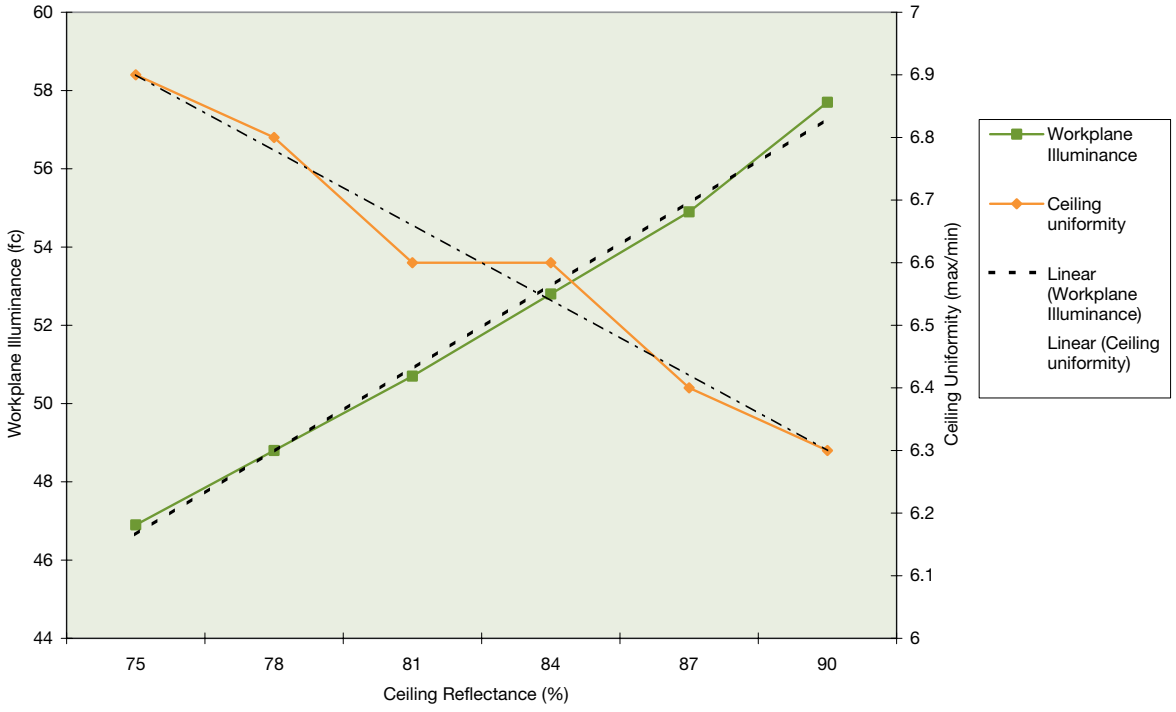


A10

60'x60'x9.5', 12' Luminaire Spacing



Irregular Open Office, 10' Ceiling Height, 12' Luminaire Spacing



High Reflectance Ceiling Tile Study
Building Energy Analysis

Model Results - Trane Tracer

Notherm Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,853	6,4	2,025	1,092	0	590	1,682	4,535
60 x 60	3600	1,17	3,305	6,9	2,046	1,196	0	667	1,863	5,168
Irregular	4800	1,4	5,157	9,0	2,646	1,603	0	9,18	2,521	7,678
Total	11400	1,27	10,458	22,3	6,717	3,444	0	2,055	5,499	15,957
90% Reflective Ceiling										
100 x 30	3000	0,96	2,305	6,1	1,891	1,039	1	542	1,582	3,887
60 x 60	3600	1	2,844	6,6	1,931	1,154	0	625	1,779	4,623
Irregular	4800	0,9	3,366	8,0	2,197	1,386	0	747	2,133	5,499
Total	11400	0,947	7,927	20,7	6,018	3,187	1	1,812	5,000	12,927
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,671	6,3	1,981	1,079	0	574	1,653	4,324
60 x 60	3600	1,46	4,088	7,3	2,241	1,313	0	741	2,054	6,142
Irregular	4800	1,09	4,050	8,4	2,367	1,468	0	812	2,280	6,330
Total	11400	1,21	10,003	22,0	6,589	3,407	0	1,995	5,402	15,405

Savings comparison with the HLRC system compared to the respective system

Lighting savings with 90% Ceiling $	HVAC savings with 90% Ceiling $	Total savings with 90% Ceiling $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
548	100	648	19,2	5,9	14,3
461	84	545	13,9	4,5	10,5
1,791	388	2,179	34,7	15,4	28,4
2,531	499	3,030	24,2	9,1	19,0
366	71	437	13,7	4,3	10,1
1,244	275	1,519	30,4	13,4	24,7
684	147	831	16,9	6,4	13,1
2,076	402	2,478	20,8	7,4	16,1

Southern Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,868	7,60	2,896	1,252	0	792	2,044	4,912
60 x 60	3600	1,17	3,316	7,60	2,556	1,318	0	810	2,128	5,444
Irregular	4800	1,4	5,169	9,50	2,910	1,668	0	998	2,666	7,835
Total	11400	1,27	10,481	24,30	8,381	3,709	0	2,423	6,132	16,613
90% Reflective Ceiling										
100 x 30	3000	0,96	2,321	7,40	2,763	1,204	0	742	1,946	4,267
60 x 60	3600	1	2,855	7,40	2,442	1,278	0	768	2,046	4,901
Irregular	4800	0,9	3,376	8,40	2,464	1,459	0	829	2,288	5,664
Total	11400	0,947	7,946	22,70	7,669	3,466	0	1,185	5,651	13,597
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,687	7,50	2,852	1,241	0	775	2,016	4,703
60 x 60	3600	1,46	4,101	8,10	2,749	1,434	0	885	2,319	6,420
Irregular	4800	1,09	4,061	8,80	2,633	1,539	0	892	2,431	6,492
Total	11400	1,21	10,024	24,00	8,234	3,680	0	2,369	6,049	16,073

Lighting savings with 90% Ceiling $	HVAC savings with 90% Ceiling $	Total savings with 90% Ceiling $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
547	98	645	19,1	4,8	13,1
461	82	543	13,9	3,9	10,0
1,793	378	2,171	34,7	14,2	27,7
2,535	481	3,016	24,2	7,8	18,2
366	70	436	13,6	3,5	9,3
1,246	273	1,519	30,4	11,8	23,7
685	143	828	16,9	5,9	12,8
2,078	398	2,476	20,7	6,6	15,4

Note 1) The individual room calculations were conducted as if the space was the complete building and applied the energy rates accordingly.

Note 2) The totals for each ceiling type assume all three spaces are added together as part of a larger building and apply the energy rates accordingly.

Note 3) The difference in lighting costs between the northern and southern exposures are related to the overall change in energy rates due to the increased amount of energy used by the HVAC system.

High Reflectance Ceiling Tile Study

LEED NC Version 2.1 Analysis

Model Results - Trane Tracer

Northern Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,853	6,4	2,025	1,092	0	590	1,682	4,535
60 x 60	3600	1,17	3,305	6,9	2,046	1,196	0	667	1,863	5,168
Irregular	4800	1,4	5,157	9,0	2,646	1,603	0	9,18	2,521	7,678
Total	**11400**	**1,27**	**10,458**	**22,3**	**6,717**	**3,444**	**0**	**2,055**	**5,499**	**15,957**
90% Reflective Ceiling										
100 x 30	3000	0,96	2,305	6,1	1,891	1,039	1	542	1,582	3,887
60 x 60	3600	1	2,844	6,6	1,931	1,154	0	625	1,779	4,623
Irregular	4800	0,9	3,366	8,0	2,197	1,386	0	747	2,133	5,499
Total	**11400**	**0,947**	**7,927**	**20,7**	**6,018**	**3,187**	**1**	**1,812**	**5,000**	**12,927**
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,671	6,3	1,981	1,079	0	574	1,653	4,324
60 x 60	3600	1,46	4,088	7,3	2,241	1,313	0	741	2,054	6,142
Irregular	4800	1,09	4,050	8,4	2,367	1,468	0	812	2,280	6,330
Total	**11400**	**1,21**	**10,003**	**22,0**	**6,589**	**3,407**	**0**	**1,995**	**5,402**	**15,405**
ASHRAE 90.1 1999										
100 x 30	3000	1,3	3,042	6,5	2080,8	1114,1	0	610,0	1,724	4,766
60 x 60	3600	1,3	3,650	7,1	2133,9	1228,1	0	699,1	1,927	5,578
Irregular	4800	1,3	4,867	8,8	2556,2	1559,6	0	883,8	2,443	7,311
Total	**11400**	**1,3**	**11,560**	**22,4**	**6781,9**	**3467,9**	**0**	**2077,6**	**5,545**	**17,105**

Savings for LEED 2.1

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
189	42	231	6,2	2,4	4,8
345	64	410	9,5	3,3	7,3
-291	-78	-367	-6,0	-3,2	-5,0
1,102	**46**	**1,148**	**9,5**	**0,8**	**6,7**
737	142	879	24,2	8,2	18,4
8,6	148	955	22,1	7,7	17,1
1,501	310	1,812	30,8	12,7	24,8
3,633	**545**	**4,178**	**31,4**	**9,8**	**24,4**
371	71	442	12,2	4,1	9,3
438	127	564	-12,0	-6,6	-10,1
817	163	981	16,8	6,7	13,4
1,557	**143**	**1,700**	**13,5**	**2,6**	**9,9**

Southern Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,868	7,60	2,896	1,252	0	792	2,044	4,912
60 x 60	3600	1,17	3,316	7,60	2,556	1,318	0	810	2,128	5,444
Irregular	4800	1,4	5,169	9,50	2,910	1,668	0	998	2,666	7,835
Total	**11400**	**1,27**	**10,481**	**24,30**	**8,381**	**3,709**	**0**	**2,423**	**6,132**	**16,613**
90% Reflective Ceiling										
100 x 30	3000	0,96	2,321	7,40	2,763	1,204	0	742	1,946	4,267
60 x 60	3600	1	2,855	7,40	2,442	1,278	0	768	2,046	4,901
Irregular	4800	0,9	3,376	8,40	2,464	1,459	0	829	2,288	5,664
Total	**11400**	**0,947**	**7,946**	**22,70**	**7,669**	**3,466**	**0**	**1,185**	**5,651**	**13,597**
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,687	7,50	2,852	1,241	0	775	2,016	4,703
60 x 60	3600	1,46	4,101	8,10	2,749	1,434	0	885	2,319	6,420
Irregular	4800	1,09	4,061	8,80	2,633	1,539	0	892	2,431	6,492
Total	**11400**	**1,21**	**10,024**	**24,00**	**8,234**	**3,680**	**0**	**2,369**	**6,049**	**16,073**
ASHRAE 90.1 1999										
100 x 30	3000	1,3	3,042	7,7	2951,4	1272,0	0	812,8	2,085	5,127
60 x 60	3600	1,3	3,650	7,8	2643,2	1348,6	0	842,1	2,191	5,841
Irregular	4800	1,3	4,867	9,3	2820,8	1626,2	0	964,2	2,590	7,458
Total	**11400**	**1,3**	**11,560**	**24,4**	**8425,3**	**3731,6**	**0**	**2445,1**	**6,177**	**17,736**

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
174	41	215	5,7	2,0	4,2
334	63	397	9,2	2,9	6,8
-302	-76	-377	-6,2	-2,9	-5,1
1,079	**45**	**1,123**	**9,3**	**0,7**	**6,3**
721	139	860	23,7	6,7	16,8
795	145	940	21,8	6,6	16,1
1,491	302	1,794	30,6	11,7	24,1
3,614	**526**	**4,139**	**31,3**	**8,5**	**23,3**
355	69	424	11,7	3,3	8,3
-451	-128	579	-12,3	-5,9	-9,9
806	159	966	16,6	6,2	12,9
1,536	**128**	**1,663**	**13,3**	**2,1**	**9,4**

High Reflectance Ceiling Tile Study

LEED NC Version 2.2 Analysis

Model Results - Trane Tracer

Northern Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,853	6,4	2,025	1,092	0	590	1,682	4,535
60 x 60	3600	1,17	3,305	6,9	2,046	1,196	0	667	1,863	5,168
Irregular	4800	1,4	5,157	9,0	2,646	1,603	0	9,18	2,521	7,678
Total	**11400**	**1,27**	**10,458**	**22,3**	**6,717**	**3,444**	**0**	**2,055**	**5,499**	**15,957**
90% Reflective Ceiling										
100 x 30	3000	0,96	2,305	6,1	1,891	1,039	1	542	1,582	3,887
60 x 60	3600	1	2,844	6,6	1,931	1,154	0	625	1,779	4,623
Irregular	4800	0,9	3,366	8,0	2,197	1,386	0	747	2,133	5,499
Total	**11400**	**0,947**	**7,927**	**20,7**	**6,018**	**3,187**	**1**	**1,812**	**5,000**	**12,927**
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,671	6,3	1,981	1,079	0	574	1,653	4,324
60 x 60	3600	1,46	4,088	7,3	2,241	1,313	0	741	2,054	6,142
Irregular	4800	1,09	4,050	8,4	2,367	1,468	0	812	2,280	6,330
Total	**11400**	**1,21**	**10,003**	**22,0**	**6,589**	**3,407**	**0**	**1,995**	**5,402**	**15,405**
ASHRAE 90.1 2004										
100 x 30	3000	1,1	2,574	6,3	1969,2	1069,9	0	570,0	16,40	4,214
60 x 60	3600	1,1	3,089	6,8	1998,6	1178,7	0	649,7	1,828	4,917
Irregular	4800	1,1	4,118	8,4	2376,6	1472,8	0	815,4	2,288	6,407
Total	**11400**	**1,1**	**9,781**	**21,5**	**6349,1**	**3308,7**	**0**	**1927,1**	**5,236**	**15,017**

Savings for LEED 2.2

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
-279	-42	-321	-10,8	-2,6	-7,6
-216	-35	-251	-7,0	-1,9	-5,1
-1,039	-233	-1,271	-25,2	-10,2	-19,8
-677	**-263**	**-940**	**-6,9**	**-5,0**	**-6,3**
269	58	327	10,5	3,5	7,8
245	49	294	7,9	2,7	6,0
752	155	908	18,3	6,8	14,2
1,8854	**236**	**2,090**	**19,0**	**4,5**	**13,9**
-97	-13	-110	-3,8	-0,8	-2,6
-999	-226	-1,225	-32,3	-12,3	-24,9
69	8	77	1,7	0,4	1,2
-222	**-166**	**-388**	**-2,3**	**-3,2**	**-2,6**

Southern Exposure	Area (SF)	Lighting Power Density	Annual Lighting Cost $	Maximum Cooling Load (Ton)	Max Block CFM	Annual Cooling Cost $	Annual Heating Cost $	Annual Fan Cost $	Total HVAC Cost $	Total Annual Cost $
75% Reflective Ceiling										
100 x 30	3000	1,2	2,868	7,60	2,896	1,252	0	792	2,044	4,912
60 x 60	3600	1,17	3,316	7,60	2,556	1,318	0	810	2,128	5,444
Irregular	4800	1,4	5,169	9,50	2,910	1,668	0	998	2,666	7,835
Total	**11400**	**1,27**	**10,481**	**24,30**	**8,381**	**3,709**	**0**	**2,423**	**6,132**	**16,613**
90% Reflective Ceiling										
100 x 30	3000	0,96	2,321	7,40	2,763	1,204	0	742	1,946	4,267
60 x 60	3600	1	2,855	7,40	2,442	1,278	0	768	2,046	4,901
Irregular	4800	0,9	3,376	8,40	2,464	1,459	0	829	2,288	5,664
Total	**11400**	**0,947**	**7,946**	**22,70**	**7,669**	**3,466**	**0**	**1,185**	**5,651**	**13,597**
2x2 Troffer Ceiling										
100 x 30	3000	1,12	2,687	7,50	2,852	1,241	0	775	2,016	4,703
60 x 60	3600	1,46	4,101	8,10	2,749	1,434	0	885	2,319	6,420
Irregular	4800	1,09	4,061	8,80	2,633	1,539	0	892	2,431	6,492
Total	**11400**	**1,21**	**10,024**	**24,00**	**8,234**	**3,680**	**0**	**2,369**	**6,049**	**16,073**
ASHRAE 90.1 2004										
100 x 30	3000	1,1	2,574	7,5	2840,6	1232,0	0	771,2	2,003	4,577
60 x 60	3600	1,1	3,089	7,5	2509,1	1301,5	0	792,7	2,094	5,183
Irregular	4800	1,1	4,118	8,8	2642,4	1542,6	0	896,6	2,439	6,558
Total	**11400**	**1,1**	**9,781**	**23,5**	**7996,8**	**3581,1**	**0**	**2297,7**	**5,879**	**15,660**

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
-294	-41	-335	-11,4	-2,0	-7,3
-227	-34	-261	-7,4	-1,6	-5,0
-1,051	-227	-1,277	-25,5	-9,3	-19,5
-700	**-253**	**-953**	**-7,2**	**-4,3**	**-6,1**
253	57	310	9,8	2,9	6,8
234	48	282	7,6	2,3	5,4
742	151	894	18,0	6,2	13,6
1,835	**228**	**2,063**	**18,8**	**3,9**	**13,2**
-113	-13	-126	-4,4	-0,6	-2,7
-1,012	-225	-1,237	-32,8	-10,7	-23,9
57	8	66	1,4	0,3	1,0
-242	**-170**	**-413**	**-2,5**	**-2,9**	**-2,6**

High Reflectance Ceiling Tile Study
Building Energy Analysis

Model Results - Trane Tracer

Notherm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,021	13,069	35,090
60 x 60	3600	1,17	25,771	14,617	40,388
Irregular	4800	1,4	41,110	20,178	61,288
Total	**11400**	**1,27**	**88,905**	**47,149**	**136,054**
90% Reflective Ceiling					
100 x 30	3000	0,96	17,620	12,179	29,799
60 x 60	3600	1	22,022	13,864	35,886
Irregular	4800	0,9	26,425	16,826	43,251
Total	**11400**	**0,947**	**66,070**	**42,095**	**108,165**
108,1652x2 Troffer Ceiling					
100 x 30	3000	1,12	20,552	12,806	33,358
60 x 60	3600	1,46	32,159	16,253	48,412
Irregular	4800	1,09	32,005	18,098	50,103
Total	**11400**	**1,21**	**84,718**	**46,158**	**130,876**

Savings comparison with the HLRC system compared to the respective system

Lighting savings with 90% Ceiling	HVAC savings with 90% Ceiling	Total savings with 90% Ceiling	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
4,402	890	5,292	20,0	6,8	15,1
3,750	753	4,503	14,5	5,2	11,1
14,685	3,352	18,037	35,7	16,6	29,4
22,835	**5,054**	**27,889**	**25,7**	**10,7**	**20,5**
2,933	627	3,560	14,3	4,9	10,7
10,137	2,389	12,526	31,5	14,7	25,9
5,581	1,272	6,853	17,4	7,0	13,7
18,647	**4,063**	**22,710**	**22,0**	**8,8**	**17,4**

Notherm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,020	15,775	37,795
60 x 60	3600	1,17	25,766	16,618	42,384
Irregular	4800	1,4	41,114	21,286	62,400
Total	**11400**	**1,27**	**88,909**	**52,417**	**141,326**
90% Reflective Ceiling					
100 x 30	3000	0,96	17,618	14,858	32,476
60 x 60	3600	1	22,026	15,869	37,895
Irregular	4800	0,9	26,430	17,987	44,417
Total	**11400**	**0,947**	**66,077**	**47,401**	**113,478**
2x2 Troffer Ceiling					
100 x 30	3000	1,12	20,558	15,507	36,065
60 x 60	3600	1,46	32,160	18,265	50,425
Irregular	4800	1,09	32,011	19,244	51,255
Total	**11400**	**1,21**	**84,718**	**51,526**	**136,244**

Lighting savings with 90% Ceiling	HVAC savings with 90% Ceiling	Total savings with 90% Ceiling	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
4,402	917	5,319	20,0	5,8	14,1
3,739	749	4,488	14,5	4,5	10,6
14,684	3,299	17,983	35,7	15,5	28,8
22,832	**5,016**	**27,848**	**25,7**	**9,6**	**19,7**
2,940	649	3,589	14,3	4,2	10,0
10,134	2,396	12,530	31,5	13,1	24,8
5,581	1,257	6,838	17,4	6,5	13,3
18,641	**4,125**	**22,766**	**22,0**	**8,0**	**16,7**

Note 1) The individual room calculations were conducted as if the space was the complete building and applied the energy rates accordingly.

Note 2) The totals for each ceiling type assume all three spaces are added together as part of a larger building and apply the energy rates accordingly.

Note 3) The difference in lighting costs between the northern and southern exposures are related to the overall change in energy rates due to the increased amount of energy used by the HVAC system.

High Reflectance Ceiling Tile Study

LEED NC Version 2.1 Analysis

Model Results - Trane Tracer

Notherm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,021	13,069	35,090
60 x 60	3600	1,17	25,771	14,617	40,388
Irregular	4800	1,4	41,110	20,178	61,288
Total	**11400**	**1,27**	**88,905**	**47,149**	**136,054**
90% Reflective Ceiling					
100 x 30	3000	0,96	17,620	12,179	29,799
60 x 60	3600	1	22,022	13,864	35,886
Irregular	4800	0,9	26,425	16,826	43,251
Total	**11400**	**0,947**	**66,070**	**42,095**	**108,165**
2x2Troffer Ceiling					
100 x 30	3000	1,12	20,552	12,806	33,358
60 x 60	3600	1,46	32,159	16,253	48,412
Irregular	4800	1,09	32,005	18,098	50,103
Total	**11400**	**1,21**	**84,718**	**46,158**	**130,876**
ASHRAE 90.1 1999					
100 x 30	3000	1,3	23,855	13,440	37,295
60 x 60	3600	1,3	28,639	15,193	43,831
Irregular	4800	1,3	38,173	19,508	57,680
Total	**11400**	**1,3**	**91,026**	**47,618**	**138,644**

Savings for LEED 2.1

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
189	371	560	7,7	2,8	5,9
345	576	921	10,0	3,8	7,9
-290	-670	-960	-7,7	-3,4	-6,3
1,102	**469**	**1,571**	**2,3**	**1,0**	**1,9**
737	1,261	1,998	26,1	9,4	20,1
8,6	1,329	2,135	23,1	8,7	18,1
1,501	2,682	4,183	30,8	13,7	25,0
3,633	**5,523**	**9,156**	**27,4**	**11,6**	**22,0**
371	634	1,005	13,8	4,7	10,6
438	-1,060	-1,498	-12,3	-7,0	-10,4
817	1,410	2,227	16,2	7,2	13,1
1,557	**1,460**	**3,017**	**6,9**	**3,1**	**5,6**

Southerm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,020	15,775	37,795
60 x 60	3600	1,17	25,766	16,618	42,384
Irregular	4800	1,4	41,114	21,286	62,400
Total	**11400**	**1,27**	**88,909**	**52,417**	**141,326**
90% Reflective Ceiling					
100 x 30	3000	0,96	17,618	14,858	32,476
60 x 60	3600	1	22,026	15,869	37,895
Irregular	4800	0,9	26,430	17,987	44,417
Total	**11400**	**0,947**	**66,077**	**47,401**	**113,478**
2x2Troffer Ceiling					
100 x 30	3000	1,12	20,558	15,507	36,065
60 x 60	3600	1,46	32,160	18,265	50,425
Irregular	4800	1,09	32,011	19,244	51,255
Total	**11400**	**1,21**	**84,718**	**51,526**	**136,244**
ASHRAE 90.1 1999					
100 x 30	3000	1,3	23,854	16,157	40,011
60 x 60	3600	1,3	28,625	17,191	45,816
Irregular	4800	1,3	38,177	20,626	58,804
Total	**11400**	**1,3**	**91,029**	**52,883**	**143,912**

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
174	382	556	7,7	2,4	5,5
334	573	907	10,0	3,3	7,5
-302	-660	-962	-7,7	-3,2	-6,1
1,079	**466**	**1,544**	**2,3**	**0,9**	**1,8**
721	1,299	2,020	26,1	8,0	18,8
795	1,322	2,117	23,1	7,7	17,3
1,491	2,639	4,130	30,8	12,8	24,5
3,614	**5,482**	**9,095**	**27,4**	**10,4**	**21,1**
355	650	1,005	13,8	4,0	9,9
-451	-1,074	-1,525	-12,3	-6,2	-10,1
806	1,382	2,188	16,2	6,7	12,8
1,536	**1,357**	**2,892**	**6,9**	**2,6**	**5,3**

High Reflectance Ceiling Tile Study

LEED NC Version 2.2 Analysis

Model Results - Trane Tracer

Notherm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,021	13,069	35,090
60 x 60	3600	1,17	25,771	14,617	40,388
Irregular	4800	1,4	41,110	20,178	61,288
Total	11400	1,27	88,905	47,149	136,054
90% Reflective Ceiling					
100 x 30	3000	0,96	17,620	12,179	29,799
60 x 60	3600	1	22,022	13,864	35,886
Irregular	4800	0,9	26,425	16,826	43,251
Total	11400	0,947	66,070	42,095	108,165
2x2 Troffer Ceiling					
100 x 30	3000	1,12	20,552	12,806	33,358
60 x 60	3600	1,46	32,159	16,253	48,412
Irregular	4800	1,09	32,005	18,098	50,103
Total	11400	1,21	84,718	46,158	130,876
ASHRAE 90.1 2004					
100 x 30	3000	1,1	20,187	12,698	32,886
60 x 60	3600	1,1	24,227	14,307	38,534
Irregular	4800	1,1	32,299	18,167	50,466
Total	11400	1,1	76,887	44,489	121,376

Savings for LEED 2.2

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
-279	-371	-650	-9,1	-2,9	-6,7
-216	-310	-526	-6,4	-2,2	-4,8
-1,039	-2,011	-3,050	-27,3	-11,1	-21,4
-677	-2,660	-3,337	-15,6	-6,0	-12,1
269	519	788	12,7	4,1	9,4
245	443	688	9,1	3,1	6,9
752	1,341	2,093	18,2	7,4	14,3
1,8854	2,394	4,248	14,1	5,4	10,9
-97	-108	-205	-1,8	-0,8	-1,4
-999	-1,946	-2,945	-32,7	-13,6	-25,6
69	69	127	0,9	0,4	0,7
-222	-1,669	-1,891	-10,2	-3,8	-7,8

Avg Savings 75% Reflective Ceiling	-15,6	-5,6	-11,8
Avg Savings 90% Reflective Ceiling	14,1	5,1	10,6
Avg Savings 2x2 Troffer Ceiling	-10,2	-3,6	-7,7

Southerm Exposure	Area (SF)	Lighting Power Density (W/SF)	Annual Lighting Energy Used KWh	Total HVAC Energy in KWh	Total Annual Energy in KWh
75% Reflective Ceiling					
100 x 30	3000	1,2	22,020	15775	37794,60331
60 x 60	3600	1,17	25,766	16618	42383,56001
Irregular	4800	1,4	41,114	21286	62400,2272
Total	11400	1,27	88,909	52417	141325,6321
90% Reflective Ceiling					
100 x 30	3000	0,96	17,618	14858	32475,71338
60 x 60	3600	1	22,026	15869	37895,28865
Irregular	4800	0,9	26,430	17987	44416,8064
Total	11400	0,947	66,077	47401	113478,0768
2x2 Troffer Ceiling					
100 x 30	3000	1,12	20,558	15507	36064,6304
60 x 60	3600	1,46	32,160	18265	50424,8939
Irregular	4800	1,09	32,011	19244	51255,06232
Total	11400	1,21	84,718	51526	136243,9793
ASHRAE 90.1 2004					
100 x 30	3000	1,1	20,185	15,393	35,578
60 x 60	3600	1,1	24,226	16,310	40,535
Irregular	4800	1,1	32,304	19,307	51,610
Total	11400	1,1	76,892	49,777	126,669

Lighting savings $	HVAC savings $	Total savings $	Percent of Lighting Savings %	Percent of HVAC Savings %	Percent of Total Savings %
-294	-382	-676	-9,1	-2,5	-6,3
-227	-308	-536	-6,4	-1,9	-4,6
-1,051	-1,979	-3,030	-27,3	-10,3	-20,9
-700	-2,640	-3,340	-15,6	-5,3	-11,6
253	535	788	12,7	3,5	8,7
234	441	674	9,1	2,7	6,5
742	1,320	2,062	18,2	6,8	13,9
1,835	2,376	4,211	14,1	4,8	10,4
-113	-114	-227	-1,8	-0,7	-1,4
-1,012	-1,955	-2,968	-32,8	-12,0	-24,4
57	63	120	0,9	0,3	0,7
-242	-1,749	-1,992	-10,2	-3,5	-7,6