GENERAL SERVICES ADMINISTRATION

Courtroom Lighting

Criteria Evaluation and Energy Use Study

I N D E X

COURTROOM LIGHTING
CRITERIA EVALUATION & ENERGY USE STUDY

General Services Administration
Public Buildings Service
Office of Applied Science

SUMMARY OF FINDINGS

The General Services Administration (GSA) Office of Applied Science and GSA Southeast Sunbelt Region 4, in partnership with the Administrative Office of the U.S. Courts (AOUSC), and the U.S. Department of Energy Federal Energy Management Program have conducted a study of the lighting in six U.S. Federal District courtrooms to determine the source of lighting problems and energy performance.

This report is in two parts: data collection and analysis performed by Ove Arup & Partners under the auspices of the National Institute of Building Sciences, and courtroom energy performance performed by the Pacific Northwest National Laboratory (PNNL) for the U.S. Department of Energy (USDOE). Both efforts were completed under contract to GSA and co-funding for PNNL was provided by USDOE. The reports are attached within.

The following is a brief summary of the findings in the reports:

1. In sum, it appears that the source of the problems with courtroom lighting stem from inadequately defined criteria, mistakes in implementing the guidance that is available, and from a lack of understanding of the complex factors that determine how humans perceive lighting.
2. The data collection showed that there was room for improvements in the lighting design for all of the courtrooms, even in those where the lighting was considered satisfactory by the court.
3. The Energy Policy Act (EPAct) requires energy use in Federal facilities to be 30% below ANSI/ASHARE/IESNA Standard 90.1 – 2004. Standard 90.1 defines the lighting power density (LPD) that can be used in both courthouses and courtrooms which will significantly impact lighting designs. The 1999 Standard LPD for courtrooms is 1.9 watts/sf and the 30% reduction for the 2004 Standard has yet to be defined. In addition, the prescriptive performance path of Standard 90.1 - 2004 does not account for hours of use, only the connected load. *To assure that the final lighting standards are acceptable, the courts should consider actively engaging in the current code development discussions by the ASHRAE Standard 90.1 Lighting Subcommittee.*
4. Although the lighting design of the courtrooms may meet the design criteria for the *amount* of light coming from the fixtures (illuminance), the *human perception* of room brightness is dependent upon how that light is reflected from the surfaces (luminance) in the room. In other words, with the same amount of light, a room

with darker finishes will be perceived as dimmer than one with lighter finishes; hence, darker finishes require more light (and more energy) to be acceptable. It also appears that often the design of the horizontal illuminance in large courtroom spaces has not taken into account the colors of the selected finishes and is therefore under-designed. The relationships between natural and artificial lighting, color of finishes, and energy use is complicated. Development of appropriate educational tools to assist the design teams and the court should be considered to more fully help them understand this interplay of factors.

5. In general, the experience of lighting designers for courtrooms is of the highest quality. However, given the special nature of courtrooms, the courts may wish to consider providing special training and assistance (as noted above), as well as verifying the proposed lighting design through a peer review including analysis of the proposed design to increase the chances of a successful lighting design.
6. Courtroom lighting and energy use can be improved through the use of *lighting zones*, allowing for more light at the bench and courtroom well and diminishing the amount of light in those areas where the same intensity is not required, such as the jury box and spectator areas.
7. Daylighting can be used successfully in a courtroom (and is useful in reducing energy usage) if provisions are made to control sunlight. However, an analysis of the cost benefit of daylighting be should be carefully evaluated, as controls can be elaborate and expensive.

ArupLighting

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Courtroom Lighting Criteria Evaluation

Task 1 Report

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Courtroom Lighting Criteria Evaluation

Task 1 Report

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Ove Arup & Partners Consulting Engineers PC
155 Avenue of the Americas, New York NY 10013
Tel +1 212 229 2669 Fax +1 212 229 1056
www.arup.com

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Executive Summary

The US Courts have experienced some failures in lighting satisfaction within some of the recently constructed courthouses. A study by the General Services Administration's Office of Applied Sciences through the National Institute of Building Sciences was undertaken by Arup Lighting to evaluate the lighting installations with respect to the requirements of the US Courts' Design Guide. Based on these surveys, it was determined that several aspects of the Design Guide should be revised to more clearly define methods to achieve successful courtroom lighting. These include:

- More specific requirements for illuminance targets
    - Current illuminace targets are on work surface only – include vertical illuminance targets.
    - Provide more detailed illuminance targets related to specific task locations
- Discussion of surface brightnesses
    - Dark wood surfaces cause contrast problems, which need to be thoroughly studied during the design process.
    - Modern computer methods provide ways to predict surface brightnesse and should be used.
- Contrast and luminance ratios
    - Luminance ratios can vary greatly depending on lighting scheme and surface reflectences.
    - Luminance is the brightness that is seen by the eye, and hence is as important as illuminance during the design process.
- Design validation
    - Physical mock-ups in the past have not included important design considerations due to their cost.
    - Allow scope for the design team or independent third party, or both, to perform advanced computer modeling to verify the actual end result.

We recommend that the Design Guide be revised to incorporate these ideas to ensure successful lighting in future new courthouses

1 Introduction

Arup Lighting has been contracted to perform a survey of lighting installed in recently constructed courthouses, and based on the data collected, evaluate and make recommendations for the requirements of the U.S. Courts' Design Guide (Design Guide) with respect to lighting. This work was undertaken between September and December 2005, and the results of the surveys and recommendations are presented in this report.

1.1 Scope of Work

Our scope of work for the study has been defined by the GSA Scope of Work Document (PR200507070017) which describes the goals of the study. As part of this study, we have visited courthouses in the following locations:

- New York, New York (Moynihan)
- Montgomery, Alabama (Johnson)
- Central Islip, New York (D'Amato)
- Tallahassee, Florida (Annex)
- Tampa, Florida (Gibbons)
- Columbia, South Carolina (Perry)

1.2 Study Goals

The goal of this phase of the study is to present the results of the data collection for each individual courtroom and illustrate how this data relates to the requirements of the U.S. Courts Design Guide lighting criteria, as well as recommend changes to the criteria if supported by the data.

This study addresses the problem that several of the newly constructed courthouses do not have adequate lighting. This study is to determine if the source of the problem is:

- Inadequately defined standards.
- The courtroom as constructed did not meet the U.S. Courts design standards.
- A combination of the above.

2 Methodology

Our study was focused on Federal District courtrooms. In each courthouse, we visited a typical district courtroom and took the following measurements:

- Illuminance measurements (both horizontal and vertical) at key areas, including the bench, clerk's desk, witness stand, podium, jury box, tables, and gallery. These measurements were taken with a Minolta T-10 illuminance meter.
- Luminance measurements. By using a software algorithm to determine a digital camera's response to light, a series of digital photos of typical viewpoints in each courtroom were taken with a Canon EOS-20D digital camera with 28-80mm lens. These were compiled to generate a luminance map of the space. The values in the luminance map were spot checked for each viewpoint with a Minolta LS-100 luminance meter.

In each courtroom, we also noted the type of lighting control provided, as well as the type of luminaires installed if they significantly affected the quality of light (good or bad).

- Where possible, we spoke with the people that used the courtrooms to gather their opinion of the lighting. Where courtrooms have had changes to the lighting system since its initial installation, we measured both before and after scenarios. We also measured different lighting scenes where it was deemed appropriate. (*Lighting scenes* refers to the levels to which different luminaires in the courtroom are dimmed or turned on or off.)

2.1 Energy Analysis

During our study, we worked with the Pacific Northwest National Laboratory (PNNL) to determine the energy use of the lighting installation in each courtroom. The analysis of LPD for courtrooms is contained in the report by PNNL.

3 Definitions and Background

The following terms are used in this report, and may be helpful in understanding the analysis.

3.1 Lighting Units and Quantities

Illuminance is the amount of light coming from a light fixture that lands on a surface. It is measured in Footcandles (Lux in the metric system). A typical office has an illuminance of between 30 to 50 footcandles (300 to 500 lux) on desktops. Horizontal illuminance describes the amount of light landing on a horizontal surface, such a desk, and vertical illuminance describes the illuminance landing on a vertical surface, such as a wall or a face.

Luminance describes the amount of light leaving a surface in a particular direction, and can be thought of as the measured brightness of a surface as seen by the eye. Luminance is expressed in Candelas per square foot, or more commonly, Candelas per square meter (Cd/m²). A typical computer monitor has a Luminance of about 100 Cd/m².

The following two diagrams illustrate the difference between illuminance and luminance.

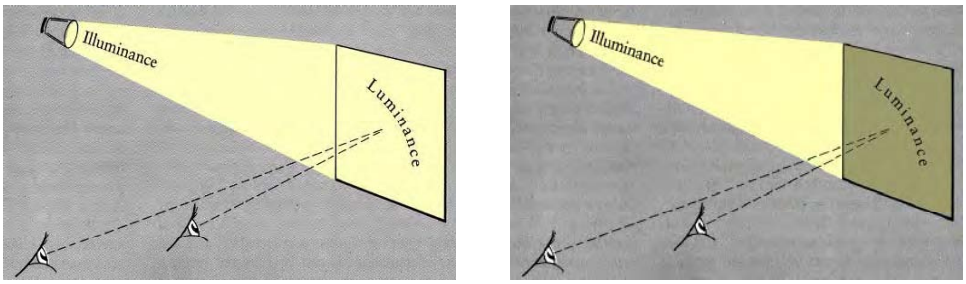


Figure 1 - Illuminance vs. Luminance

The image on the left shows a light projecting onto a light colored wall, and the image on the right shows the same light projecting onto a dark colored wall. In both cases, the measured *illuminance* on the wall is the same, since the same amount of light is landing on the surface. However, the wall in the image on the left has a higher *luminance* value than the wall in the image on the right since the measured brightness is higher.

The color rendering index of a light source is a measurement of how well a light source represents color compared to an ideal source. Color rendering index (CRI) is measured on a scale of 0 to 100. As a gauge of measure, sunlight has a CRI of 100, typical fluorescent office lighting has a CRI of 80 to 85, and parking lots vary from 20 to 65.

3.2 Key Ratios in Lighting

By measuring luminance, we can compare the brightnesses of areas in a room, and determine Luminance Ratios. Luminance ratios help quantify the relationship between lit elements in a room, and are also sometimes known as contrast ratios.

The reflectance of a surface is the percentage of light landing on a surface that is reflected outward. A typical white wall has a reflectance of around 70%, while a dark wood surface, such as cherry, has a reflectance of about 20%. Reflectance of room surfaces is critical in

lighting design, and can have a significant effect on both the physical quantity of light in a space and the subjective feeling of the light on room surfaces.

3.3 Lighting Equipment

A critical component in a lighting design is the equipment used to light a space. Luminaires, commonly known as light fixtures, contain different lamp types which have different properties of illumination.

Tungsten-Halogen and Incandescent lamps are the simplest type of lamp technology. They work by passing electricity through a filament, which glows, producing visible light. The light produced by tungsten-halogen and incandescent lamps has good color rendering (about 99). Tungsten halogen and incandescent are the least energy efficient of all typical light sources.

Fluorescent lamps produce light by passing electricity between two electrodes in a sealed tube. The resulting electrical arc produces UV light which excites phosphors on the tube, causing it to glow and produce light. Fluorescent lamps are more energy efficient than incandescent and tungsten-halogen, and are available in standard linear lengths, as well as smaller compact fluorescent sizes suitable for downlights and other smaller luminaires. Fluorescent lamps usually have a color rendering index of about 85, and are typically larger than incandescent luminaires.

Metal halide lamps are in the category of high-intensity discharge lamps, and work in a similar process to fluorescent lamps. They are the most energy efficient of the lamp types used in architectural lighting and produce a large amount of light from relatively small lamps. Newer ceramic metal halide lamps provide good color rendering (85+) and lamp sizes that are suitable for architectural lighting. However, these types of lamps require a cooling-off period of about 15 minutes after they have been turned off before they can be turned back on, which limits their use in many situations. Traditional types that were used in some of the reviewed courtroom installations have CRIs much too low, in the range of 60 to 65.

4 Current Design Guidelines

4.1 U.S. Courts' Design Guide

For reference in the survey information reported below, the following are key components of the Design Guide related to lighting:

- Recommended illuminance levels are 40 to 75 footcandles, given as a range, for all areas of the courtroom interior, except for spectator areas.
- Fluorescent lighting is allowed in indirect or direct applications.
- Incandescent lighting is allowed in direct applications.
- Metal halide lighting is allowed in indirect applications.
- Vertical footcandle level and flexibility for video and evidence display are emphasized, as well as good color rendering.
- A dimming control system is required for flexibility, allowing the judge to vary the intensity and type of lighting.

Refer to the table in section 4.3 indicating the Design Guide's illuminance recommendations for individual courtroom areas.

4.2 IESNA Lighting Handbook Guidelines (9th Edition)

Also applicable to our study are the guidelines of the *Lighting Handbook (9th Edition)* of the Illuminating Engineering Society of North America (IESNA). This comprehensive handbook serves as a standard reference and design guide for lighting in all types of interior and exterior spaces and is used by many lighting designers to help guide their designs.

The handbook indicates target illuminances for several task areas in a courtroom, which are listed in section 4.3.

The IESNA handbook also indicates important factors relating to the design of lighting in courtrooms.

- Modeling of faces and objects: this refers to the amount of definition a lighting scheme produces on a face, cause by shadows of the facial features. This is related to the ratio of horizontal to vertical illuminance on a subject.
- Appearance of the space and luminaires.
- Color appearance and contrast.
- Daylight integration and control.
- Direct glare.
- Source-task-eye geometry: this refers to the location of light sources with respect to surfaces and tasks, which sometimes can cause reflected glare.
- System control and flexibility.
- Lighting for video.

All of the key components of the IESNA Handbook's factors are mentioned by the Design Guide except for daylight integration and control.

4.3 Illuminance Recommendations

The following table indicates the illuminance target recommendations given by the U.S. Courts Design Guide and the IESNA Handbook.

Area	U.S. Courts Design Guide		IESNA Handbook	
	Horizontal Illuminance (Fc)	Vertical Illuminance (Fc)	Horizontal Illuminance (Fc)	Vertical Illuminance (Fc)
Judge(s)	40-75	NA	50	10
Courtroom Deputy Clerk	40-75	NA	50	10
Witness	40-75	NA	30	5
Interpreter	NA	NA	NA	NA
Jurors	40-75	NA	NA	NA
Court Reporter/Recorder	40-75	NA	NA	NA
Attorney and Litigants	40-75	NA	50	10
Attoney Waiting Area	40-75	NA	NA	NA
Law Clerk	40-75	NA	50	10
Baliff	40-75	NA	NA	NA
USMS Personnel	40-75	NA	NA	NA
Spectators	30-40	NA	10	3

Table 1 - U.S. Courts Design Guide Illuminance Recommendations

4.4 ASHRAE/IESNA 90.1

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in coordination with the IESNA produces standards for lighting power density in buildings. Lighting power density is the amount of installed lighting power per unit area of a building and is expressed in watts per square foot. ASHREA/IESNA Standard 90.1-2004 indicates the minimum federal requirement for energy efficiency in new federal courthouses.

The standard states that the maximum allowed lighting power density in courtrooms is 1.9 w/sf. This is lower than the previous standard of 1999, which was 2.1 w/sf.

An energy analysis of the courtrooms in this study is contained in the report by PNNL.

5 Courtrooms

A discussion of the survey findings for each courtroom is provided below.

5.1 New York, New York (Moynihan)

5.1.1 Lighting Scheme

The lighting scheme for the district courtroom in the Moynihan courthouse consists of indirect bowl pendants supplemented by tungsten-halogen downlights. Images of the typical district courtroom are below.

The indirect bowl fixtures produce an indirect glow on the ceiling, and the downlights provide supplemental directional light on the task surfaces in the courtroom. While there are more downlights at the front of the courtroom above the bench, most of the downlights are distributed evenly throughout the ceiling and not aimed or grouped for particular task areas.

5.1.2 Lighting Control Scheme

The lighting control in this courtroom is provided by a scene-set dimming system. Pre-set scenes are programmed into the control system, which can be selected by a controller at the clerk's desk.

5.1.3 Daylight

Access to daylight is provided in these courtrooms by vertical windows. Of particular note in this courthouse is that while light-reducing shades are provided, no blackout shades are provided. In the courtroom shown in the photo below, ornamental drapes are pinned together to block direct sunlight that occasionally penetrates the windows.

Since no blackout shades are provided, this makeshift solution reduces the amount of daylight in the courtroom and detracts from the architectural design. This illustrates the challenges that incorporating daylight into a courtroom presents, but could have been simply solved by adding a layer of blackout shades in the design.

5.1.4 Courtroom Photographs

Figure 2 - Looking to Bench from Podium

Figure 3 - Looking outward from bench

Figure 4 - Drapery pinned to block sunlight

5.1.5 Luminance Distribution Images

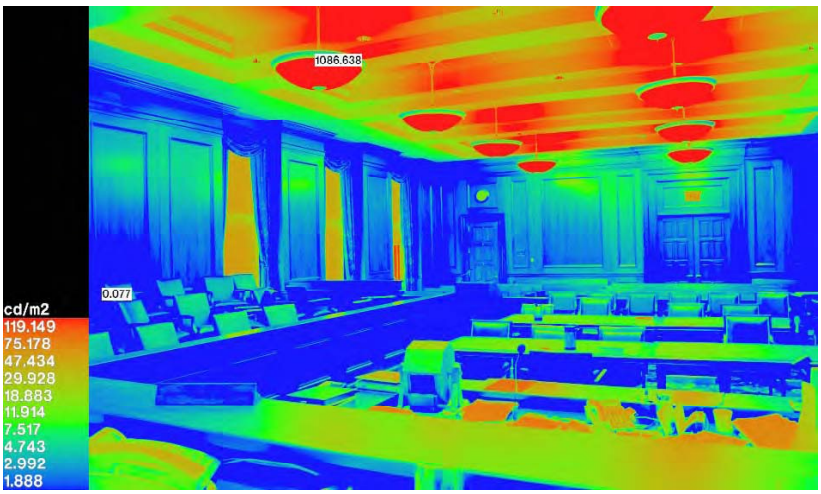


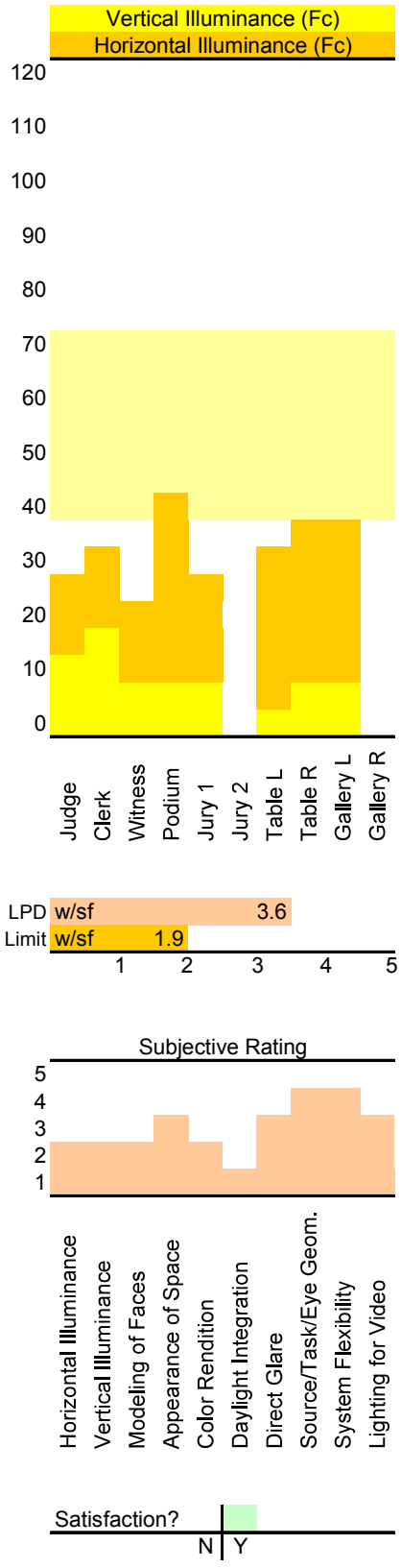
Figure 5 - Luminance distribution from bench

Figure 6 - Luminance distribution toward bench

5.1.6 Design Analysis

When compared with the other courthouses surveyed, the district courtroom at the Moynihan courthouse was a relatively successful lighting scheme. Several factors worth noting with regards to this lighting design include:

- Daylight improves the general quality of light in the space and connection to the outside, however better shading systems could have been integrated to block sunlight when it enters the room.
- There is a high amount wood wall surfaces that have a very low reflectance. These cause a high degree of contrast with the ceiling, and makes the room appear dimmer than it is due to eye adaptation. This high degree of contrast is confirmed in the luminance maps.
- The directional recessed downlights provide a significant amount of light on the task surfaces – the have a higher luminance than the walls even though they have a lower reflectance.
- Illuminance levels are slightly below the design guide and IESNA recommendations in most task areas.
- Wallwash luminaires at the front of the room over the judge are fairly ineffective due to the low reflectance and specularity of the wood panelling. This is confirmed by the minimal highlights in the luminance map image.



5.2 Montgomery, Alabama (Johnson)

5.2.1 Lighting Scheme

The lighting design for the courtroom in the Johnson courthouse, which takes design cues from the historical courtroom it is modelled after, consists mainly of indirect lighting. The pendant bowl fixtures illuminate the ceiling coffers and provide a diffuse glow. Wallwash downlights provide accents at the column details on the wall and above the judge. In the gallery area, which has a lower ceiling, downlights provide general illumination and wall sconces provide some uplight and accents.

As in the Columbia courthouse, wood wall finishes are kept at a low level, which allows the brighter wall surfaces at high level to reflect light more efficiently.

5.2.2 Lighting Control Scheme

The lighting control in this courtroom is provided by a scene-set dimming system. Pre-set scenes are programmed into the control system, which can be selected by a controller at the bench.

5.2.3 Daylight

Daylight enters the courtroom through large windows on both sides of the front of the room. The windows extend almost the full height of the wall. They are controlled with motorized with light-reducing shades. They are lowered to the position shown in the first image the majority of the time, which allows for evidence presentation. At times they are opened fully to allow in more daylight.

5.2.4 Courtroom Photographs

Figure 7 – Looking towards the bench

Figure 8 – Looking from the bench towards the jury

5.2.5 Luminance Distribution

The images below show the luminance distribution in the courtroom.

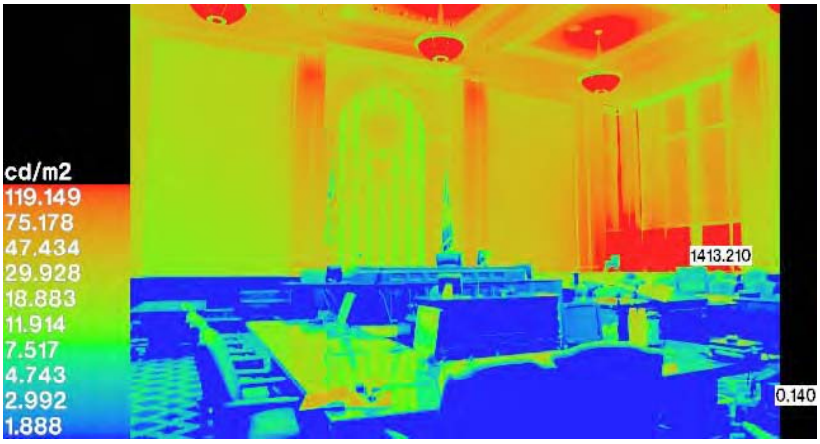


Figure 9 – Looking towards bench

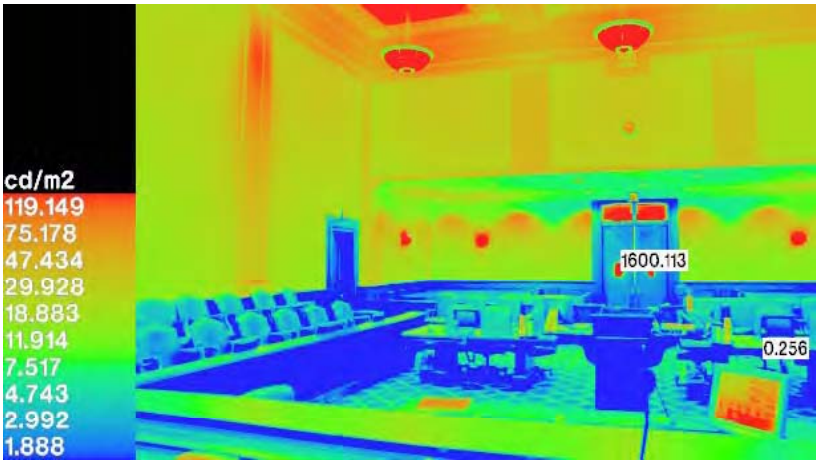


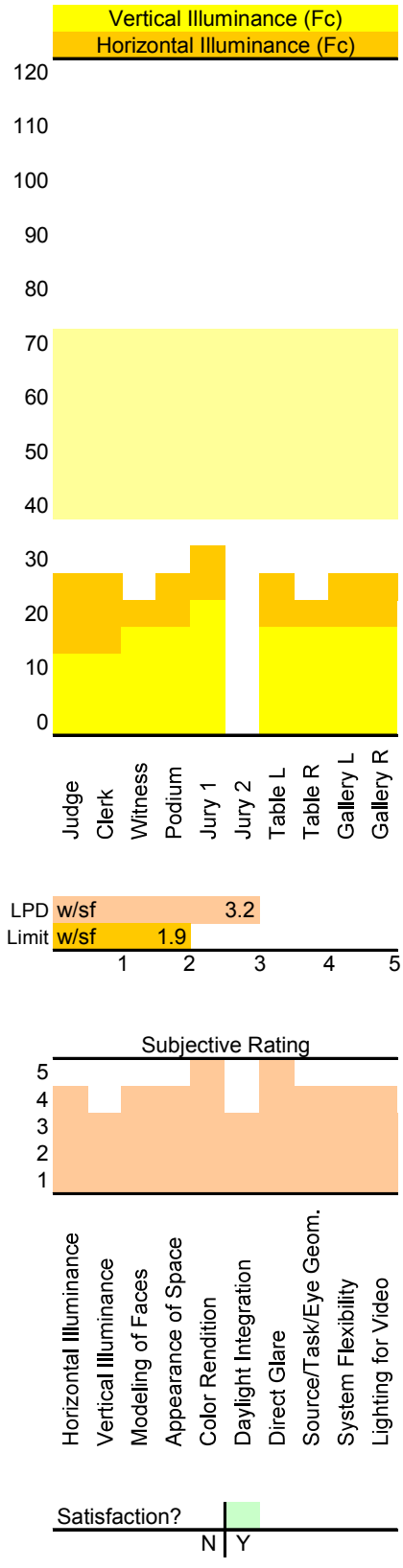
Figure 10 – Looking from bench towards jury

The luminance maps show that this courtroom had the brightest wall surfaces of all of the rooms studied, which leads to the perception of brightness in the room even though it has the lowest illuminance levels.

5.2.6 Design Analysis

The indirect approach and light colored wall surfaces in this room make it one of the best spaces of those surveyed with regards to visual perception.

- The addition of daylight into the space is well-received and appreciated by the users, and contributes to the bright feeling of the room.
- The dark colored wood panelling is kept at a low level, allowing the high reflectance wall surfaces to help light the room evenly.
- Even though this room has the lowest installed power density and lowest measured illuminance levels, it feels much brighter than the other courtrooms. This can be compared to the Islip courtroom, which has a very bright ceiling but dark walls, which contribute to the ceiling being seen as a glare source and the room feeling dim.
- The high ceilings allow the indirect pendant luminaires to be hung low enough to evenly light the ceiling, which reduces hot spots and glare.
- The plane of the bottom of the pendants is still higher than most of the other sites surveyed.
- The uniformly lit wall surface provides even reflected illumination for the courtroom.



5.3 Central Islip, New York (D'Amato)

5.3.1 Lighting Scheme

The lighting scheme for this courtroom has three components:

- A cove fluorescent wallwash at the front and back of the room.
- A large custom diffusing ceiling fluorescent luminaire system in the center of the room.
- Supplemental metal halide recessed downlights at the front of the room over the bench and the back of the room.

A key design feature of this room is the full-height wood panelled walls and high ceiling.

5.3.2 Lighting Control Scheme

The lighting in this courtroom is controlled by a set of keyed switches at the entrance and at the bench. No dimming capability is provided.

5.3.3 Daylight

No access to daylight is provided in the courtroom.

5.3.4 Courtroom Photographs

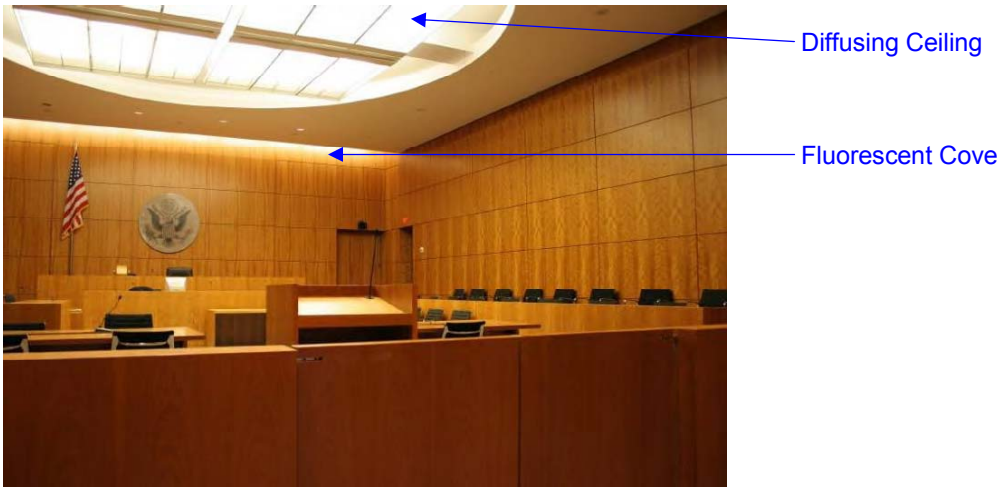


Figure 11 – Looking towards front of courtroom

Figure 12 - Looking towards the jury from the bench

5.3.5 Luminance Distribution

The image below shows the luminance distribution in the courtroom from the viewpoints in the images above.

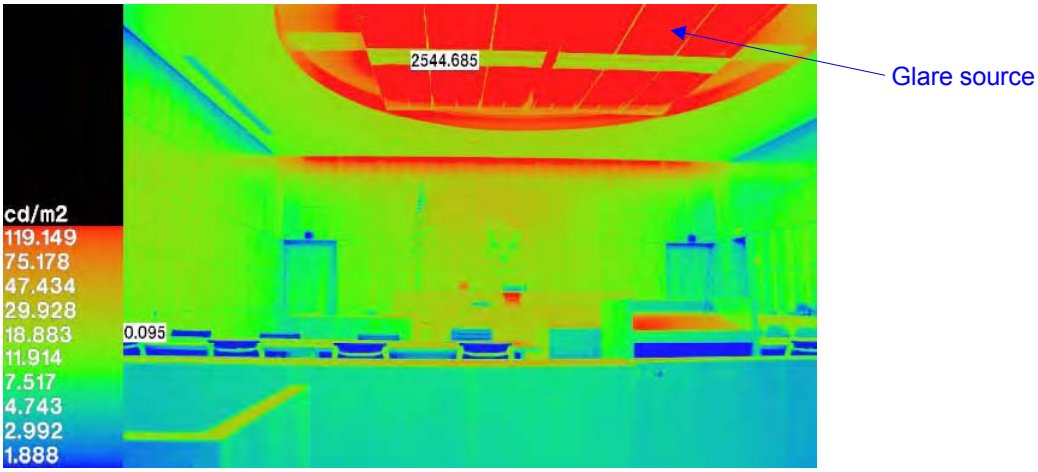


Figure 13 - Luminance map looking toward room front

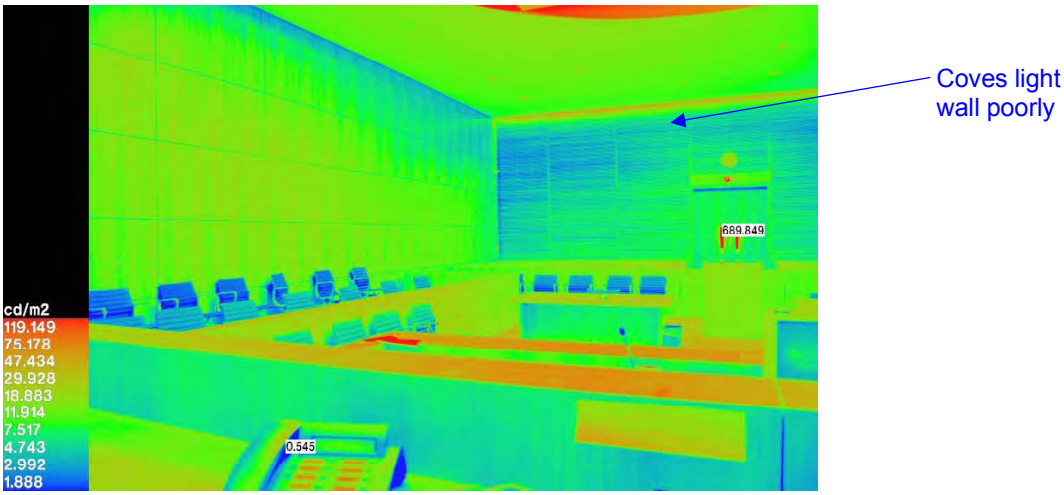


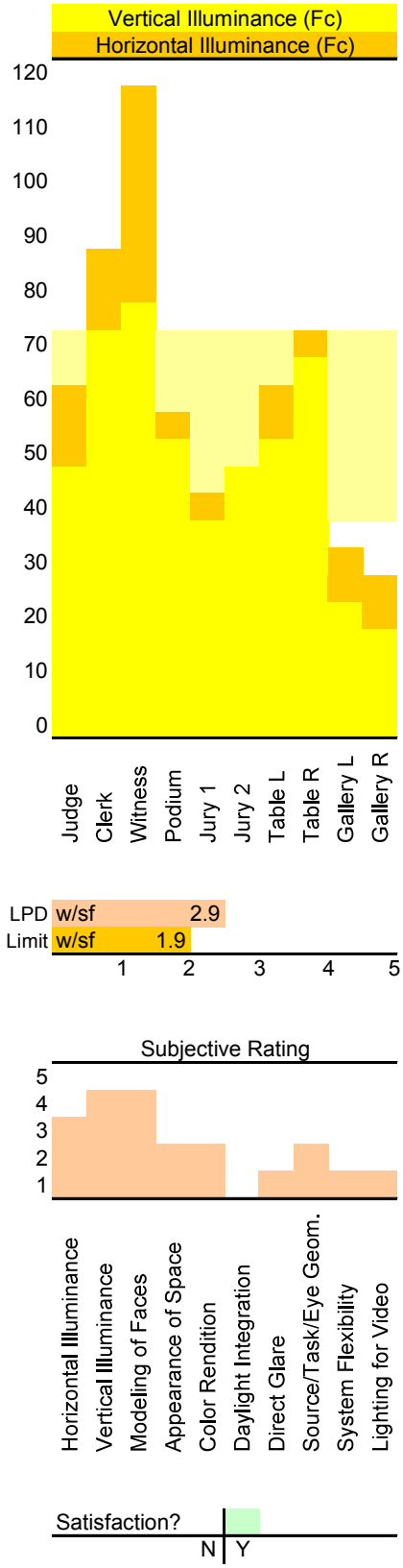
Figure 14 - Luminance map looking toward jury from bench

Other than the back wall, which has a slightly darker slatted wood cladding, almost all of the surfaces in this room are made of the same colored wood. This cladding makes different surfaces appear at very close luminance values with little contrast between surfaces, which is illustrated in the above luminance maps.

5.3.6 Design Analysis

There are several notable findings in this courtroom lighting scheme:

- Overall illuminance levels for the different task areas exceed IES recommendations significantly in almost all task areas. Illuminance levels exceed the higher Design Guide recommendations for several important areas, including the clerk's desk and the witness stand, which had an illuminance of 117 footcandles, 50% higher than the recommendation.
- Because of the relatively dark wood panelling that covers the entire wall height, the room seems dim because of the high contrast to the illuminated ceiling. The average luminance of the illuminated ceiling is around 1500 cd/m². When compared to the 30 cd/m² walls this produces a 50:1 contrast ratio, which is excessive and leads to the ceiling being seen as a glare source.
- Because of the low reflectance and specularity of the wood panelling, the cove lighting at the front and back of the room does little to light the room other than provide a visual accent at the top of the wall.
- The use of direct metal halide downlight luminaires directly contradicts the Design Guide. Users of this courtroom noted that the re-strike time for the metal halide downlights and the limited zoning severely impaired the courtrooms ability to adapt to video presentations.
- Dimming control is not provided, which is a requirement in the design guide, which further limits the flexibility of the lighting system.



5.4 Tallahassee, Florida (Annex)

5.4.1 Lighting Scheme

The Tallahassee courthouse has gone through a series of renovations to the lighting scheme after the original scheme was found as unacceptable. For this study, one of the renovated courtrooms was documented under several lighting conditions.

Based on the conversations with the users of this courtroom, the addition of an indirect linear fluorescent uplight has solved most of the courtroom's problems with regards to lighting. This condition was surveyed, as well as a condition without the uplight, which is similar to the original scheme.

5.4.1.1 Original Lighting Scheme

The original lighting scheme for this courtroom consisted mainly of an array of compact fluorescent downlights in the ceiling with supplemental wall sconces that provided uplighting. A skylight in the center of the sloped ceiling contributed daylight to the space. The density of downlights was greater over the front of the courtroom.

5.4.1.2 Revised Lighting Scheme

Several revisions were made to the original scheme before it was deemed acceptable to the users of the courtroom.

- The original compact fluorescent downlights were replaced with tungsten halogen PAR38 downlights, likely with 150W or 250W lamps.
- Downlights were added around the perimeter of the room to wash the walls
- The original uplighting sconces were replaced with more traditional diffusing sconces.
- A large square low profile linear fluorescent uplight was added to provide indirect lighting.

The key to the changes seems to have been the addition of the linear indirect uplight, since it provided a layer of diffuse indirect light that had not been present in the space before, which is desirable in a space that utilizes directional downlights so heavily.

5.4.2 Lighting Control Scheme

The lighting control in this courtroom is provided by a scene-set dimming system. Pre-set scenes are programmed into the control system, which can be selected by a controller at the bench. The fluorescent uplight component has three lamps, which are switched in sets of one and two lamps to allow different levels of lighting. It is mostly used with one lamp switched on.

5.4.3 Daylight

A square clerestory skylight system in the center of the sloped roof provides a small but significant amount of daylight to the space, allowing for the contribution of the better color spectrum of daylight and a visual connection to the outside. The skylight can be closed with motorized blackout shades. It is normally open, except when sunlight penetrates the room and causes glare, at which time it is closed.

5.4.4 Courtroom Photos

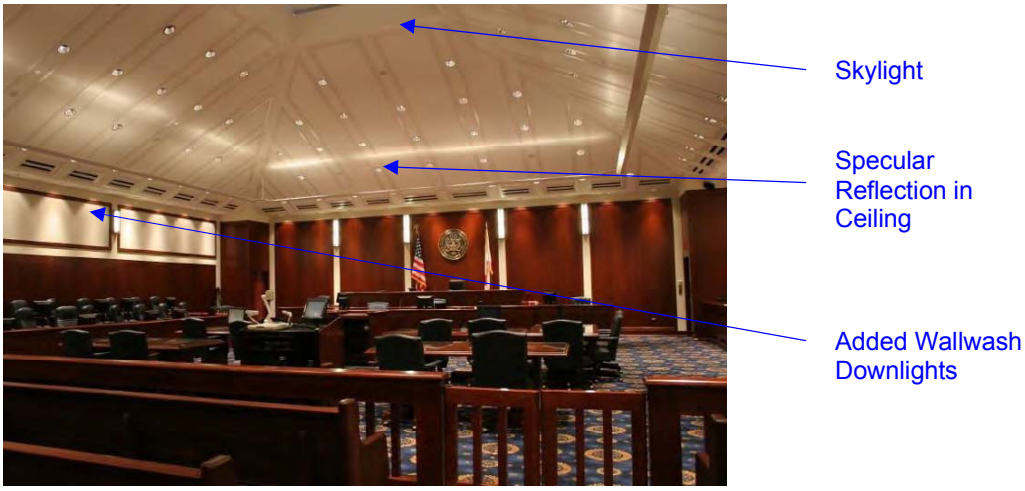


Figure 15 - Original Scheme Approximation (no daylight)

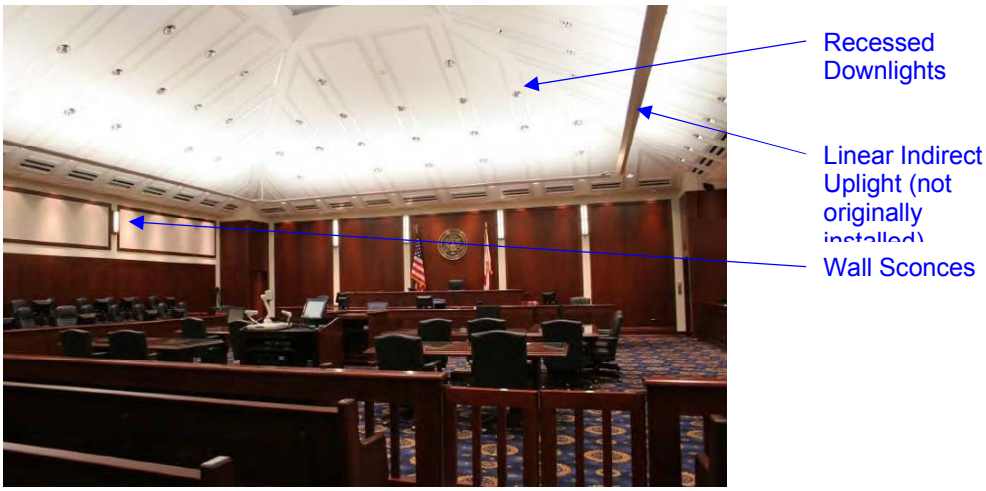


Figure 16 - Renovated Scheme (no daylight)

Note that the main differences between the original scheme and the final scheme are the uplight component lighting the ceiling and the directionality of the downlights – the original downlights likely had similar light output, but the more directional output of the tungsten PAR38 downlights contributes more light to the work surfaces.

5.4.5 Luminance Distribution

The images below show the luminance distribution in the courtroom for the final and original schemes.

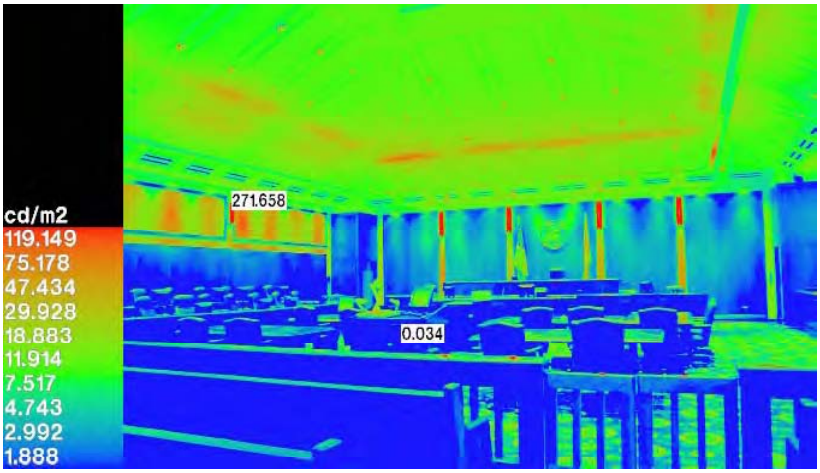


Figure 17 - Luminance map for original scheme

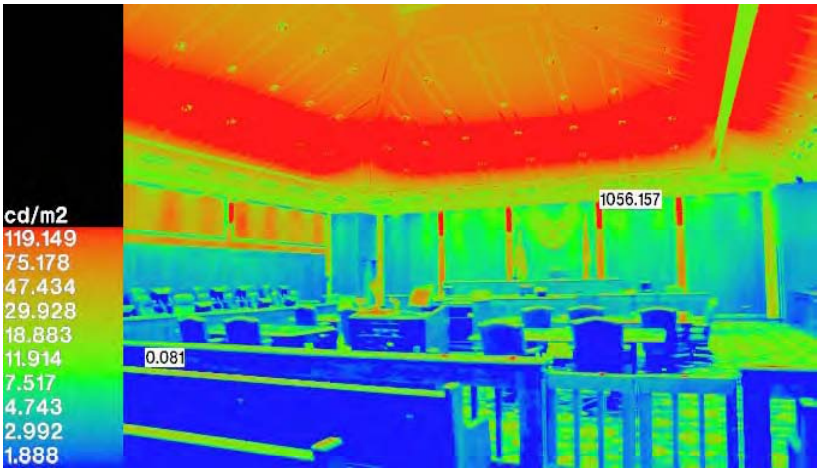


Figure 18 - Luminance map for renovated scheme

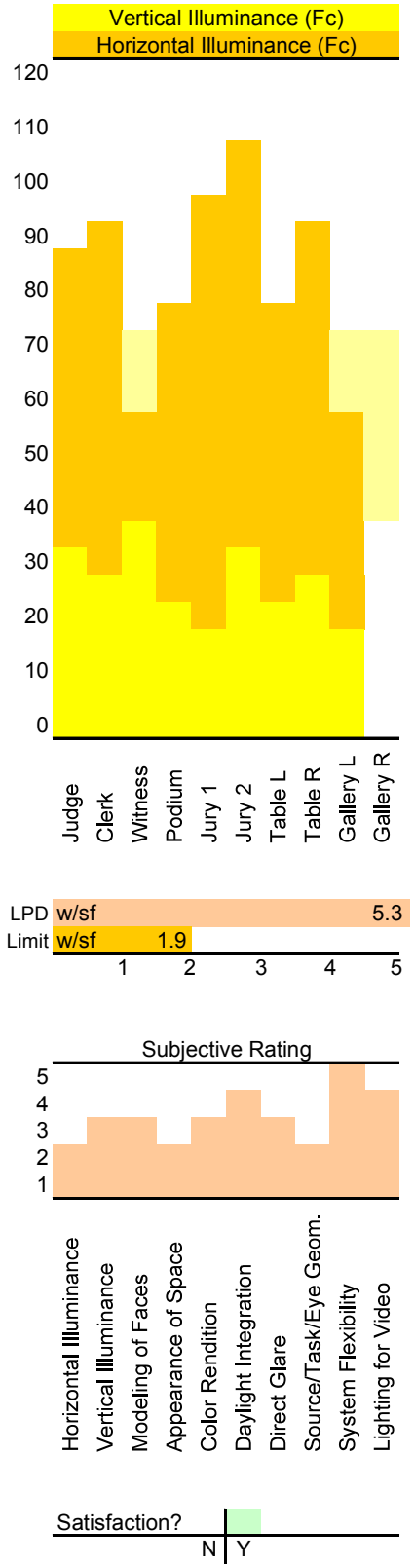
The luminance maps and images above provide a good illustration of why the revised scheme is viewed as better than the original scheme. By providing indirect uplighting for the ceiling, the room brightens when compared with the directional downlight only scheme. When compared with the Islip courthouse, the contrast ratio between the ceiling and wall surfaces is much better – less than 5:1 for most of the room. The fact that the dark wood paneling does not continue to the ceiling for the entire room also adds to the brighter feel of the room.

5.4.6 Design Analysis

Other comparisons between the original and revised scheme and other courthouses are noteable.

- The contribution of daylight with regards to overall lighting quantity is relatively small – the daylight increases the illuminance levels only 10% to 20% in most positions. However, the subjective feel of the room when there is daylight is greatly improved with even this small addition of daylight.
- This courtroom differs from several courtrooms in this report because the wood panels, even though they are dark, do not extend to the ceiling, allowing a lighter colored wall surface to help brighten the space.
- One reason the original scheme failed was the lack of diffuse light. Since all of the lighting in the space was downlighting, the ratio of horizontal to vertical light was high – over 5:1 in some cases. This can lead to shadowing on faces which can be seen as making people look worse, even more "criminal". When the uplight was added, the ratio improved.
- The addition of downlights at the perimeter provides added brightness on the walls, however there are extreme "scallops" due to the proximity of the downlights to the wall. In this situation a linear wallwash would have been more appropriate in the original design.
- The flexibility of the dimming system for downlights and bi-level switching for the fluorescent uplights allows the users of the room to tune the lighting to their needs.
- Although the final lighting solution provides a pleasing environment, it was achieved by adding many lights, and hence has the highest overall illuminance levels of any of the courtrooms surveyed – far over the recommendations of the IESNA and the design guide.
- Because of the change to tungsten-halogen lighting and addition of luminaires, this is courtroom likely has the highest installed lighting power density of the courtrooms studied.

Note: The table to the right shows data for the revised lighting scheme. Refer to the table in Section 6 for the original lighting scheme.



5.5 Tampa, Florida (Gibbons)

5.5.1 Lighting Scheme

The Gibbons courthouse in Tampa has a lighting scheme that illustrates the importance of the design guidelines. It consists mainly of downlights in an architectural slot. They are supplemented by recessed wallwashers and some tungsten halogen downlights at a floating ceiling over the bench. A fluorescent cove light runs along the higher ceiling section edge at the center of the room and provides indirect illumination to the underside of the ceiling.

The downlights originally installed in the courtroom were a set of low CRI metal halide downlights. These downlights cause significant problems because of their re-strike time and a very significant ballast hum, which is loud enough to be disruptive to proceedings in the courtroom. The metal halide downlights also provide poor color rendition. The use of direct metal halide lighting is contrary to the Design Guides recommendations.

Several courtrooms in the Tampa courthouse have had the metal halide downlights replaced with compact fluorescent (CFL) downlights of a similar type. Both types of courtrooms were surveyed.

As the photos above illustrate, the two schemes are very similar – the luminaires are in the same locations and provide similar light distributions. Despite providing acceptable light levels, the metal halide scheme proved unworkable because of the issues relating to ballast hum and restrike time. Additionally, the color rendering of metal halide lamps is not sufficient for general illumination in courtrooms, as it is used in this case.

5.5.2 Lighting Control Scheme

The lighting control in this courtroom is provided by a scene-set dimming system. Pre-set scenes are programmed into the control system, which can be selected by a controller at the bench.

5.5.3 Daylight

No access to daylight is provided in the courtroom.

5.5.4 Courtroom Photos

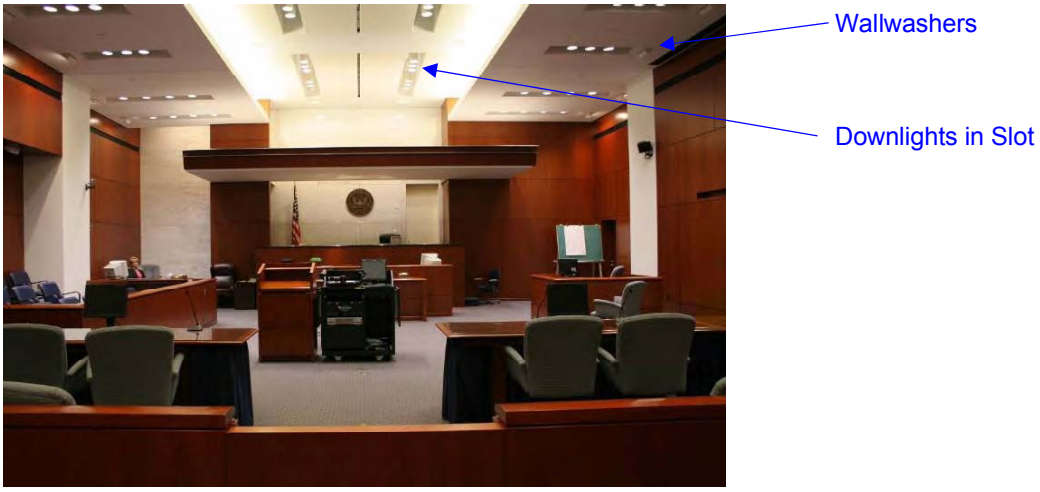


Figure 19 - Original Scheme with Metal Halide Downlights

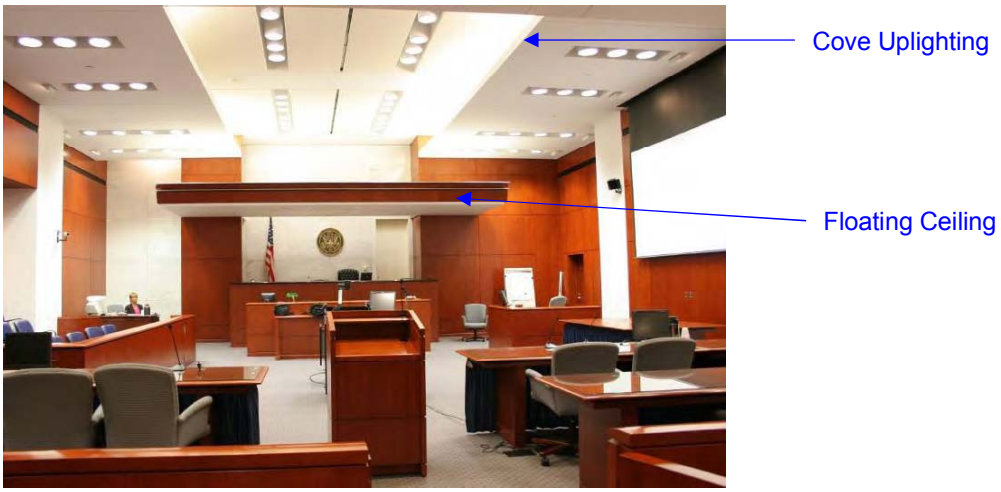


Figure 20 – Revised scheme with CFL lamps

5.5.5 Luminance Distribution

The images below show the luminance distribution in the courtroom for the final and original schemes.

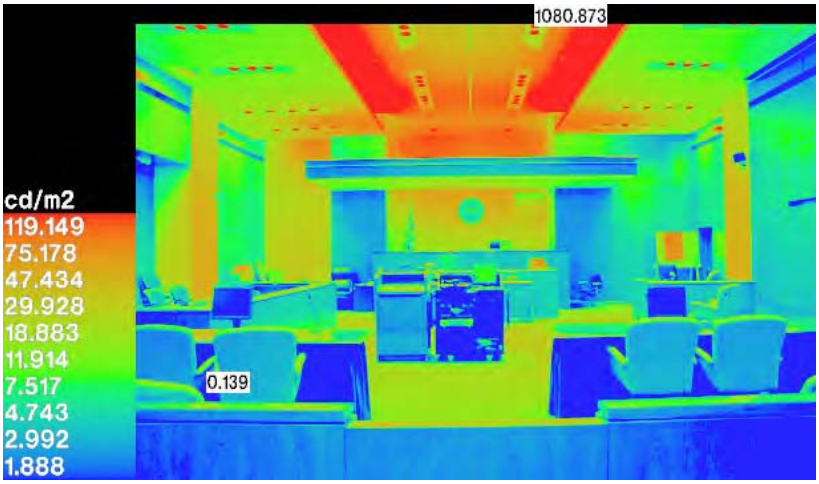


Figure 21 - Luminance map for metal halide scheme

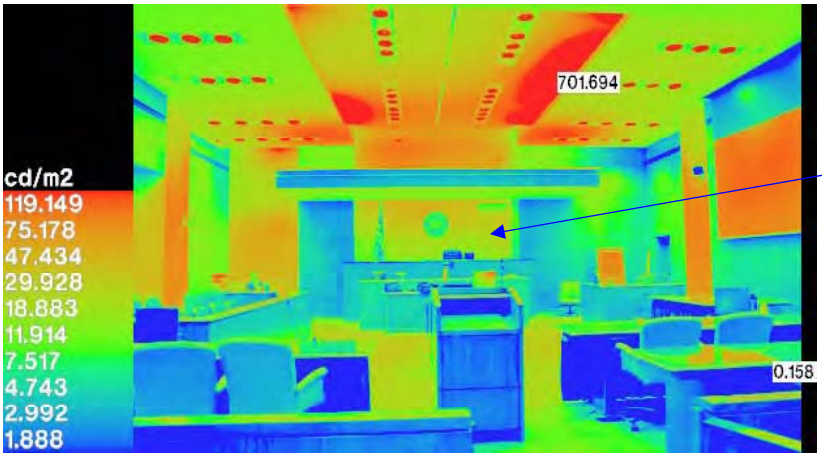


Figure 22 - Luminance map for revised compact fluorescent scheme

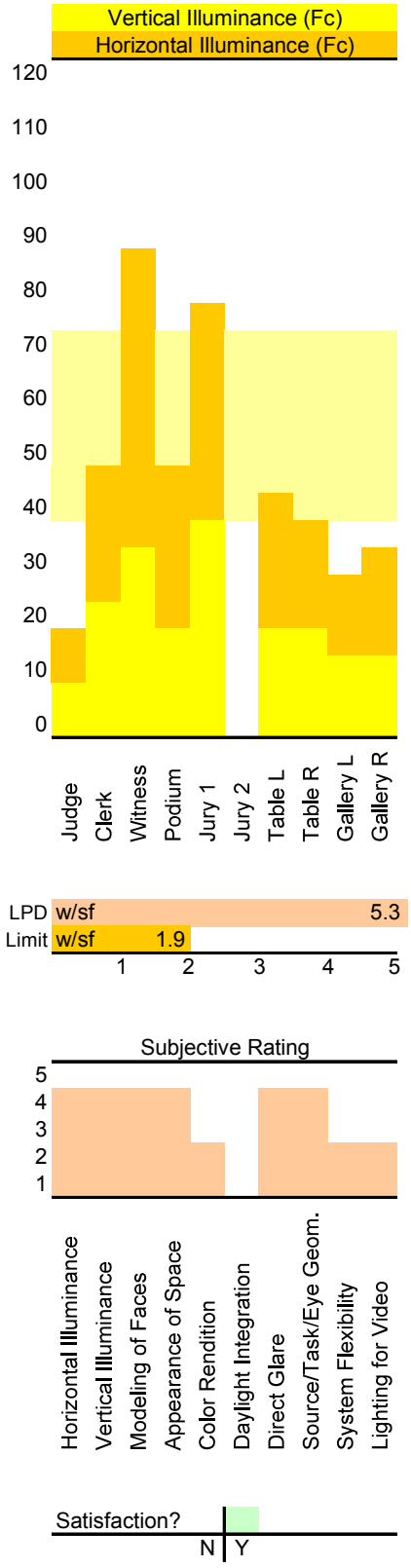
The luminance maps confirm that the lighting distribution provided by the two scenarios is indeed very similar. They both provide illumination on the ceiling to brighten the room and give a diffuse light component to the room.

5.5.6 Design Analysis

The main issue with this design was the original installation of metal halide direct downlights, contrary to the Design Guide. These downlights are problematic because of their poor color rendering, excessive ballast hum, and long re-strike time once they are turned off.

- Both the original and revised design have illuminance levels that are on the high end of the Design Guide's target ranges, with the exception of the witness and podium areas.
- Although there is a significant amount of dark wood panelling, there are parts of the walls that have lighter surfaces, which improves the overall brightness of the space.
- Although the general light levels and visual brightness in the room are relatively good for both schemes, the floating ceiling over the judge blocks a good deal of light, making that area seem darker, which can be seen in the luminance map. This area should ideally have more emphasis, not less.
- Even though the courtroom lighting is predominantly downlighting, similar to the Tallahassee courtroom, having the indirect component in the center of the room improves overall brightnesses and lightens the ceiling. This eliminates what is commonly called the "cave effect" of downlit rooms where the ceiling is dark.
- The deficiencies of the metal halide scheme were significant enough that the Tampa courthouse is revising all of the courtrooms as funds become available so that they have compact fluorescent lighting instead of metal halide.

Note: The table to the right shows data for the revised compact flourescent lighting scheme. Refer to the table in Section 6 for the original metal halide lighting scheme.



5.6 Columbia, South Carolina (Perry)

5.6.1 Lighting Scheme

The lighting design for the Perry courthouse includes a vaulted ceiling. The vaulted ceiling is uplit by linear fluorescent coves on each side. There are supplemental tungsten-halogen downlights in the vaulted ceiling that provide directional downlight on task surfaces. At the perimeter of the room, which has lower ceilings, compact fluorescent downlights supplement the scheme.

While the wood finishes in this room are one of the darkest of the courtrooms surveyed, they only cover the lower portion of the wall. This allows for better distribution of diffuse light into the room, and a transition of contrast between the walls and the ceiling.

5.6.2 Lighting Control Scheme

The lighting control in this courtroom is provided by a scene-set dimming system. Pre-set scenes are programmed into the control system, which can be selected by a controller at the bench.

5.6.3 Daylight

No access to daylight is provided in the courtroom.

5.6.4 Courtroom Photos

Figure 23 – Looking towards the bench

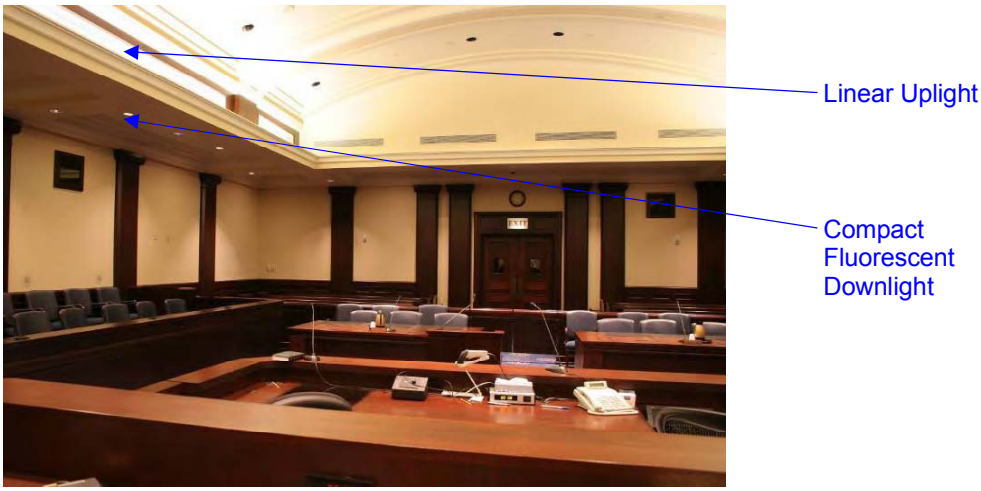


Figure 24 – Looking from the bench towards the jury

5.6.5 Luminance Distribution

The images below show the luminance distribution in the courtroom.

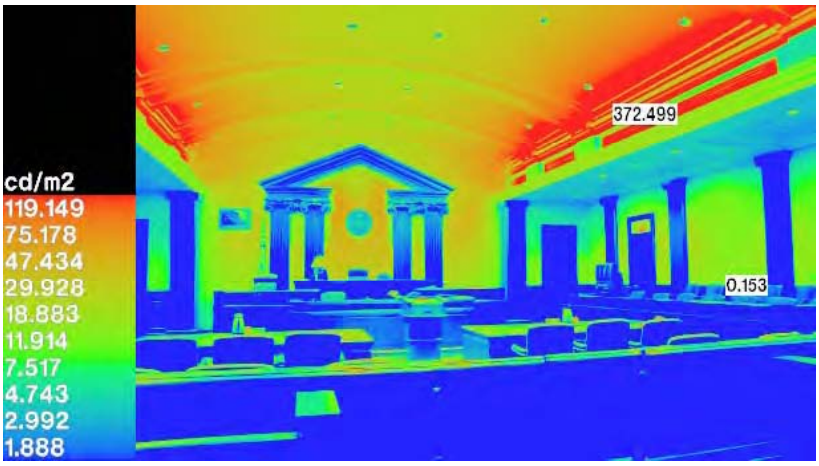


Figure 25 – Looking towards bench

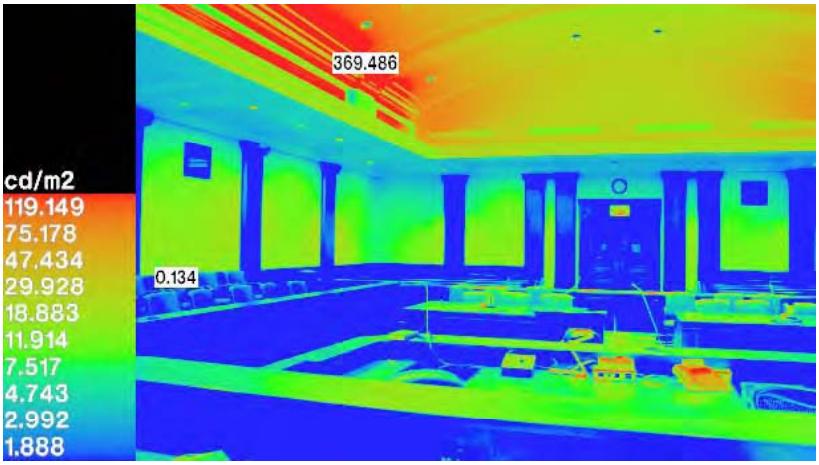


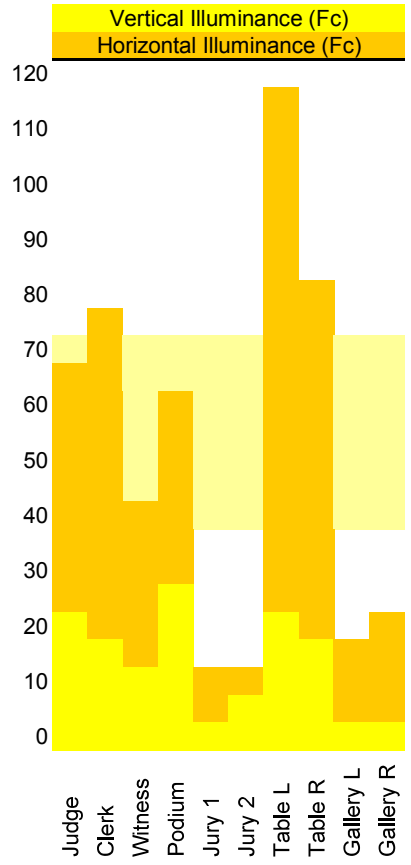
Figure 26 – Looking from bench towards jury

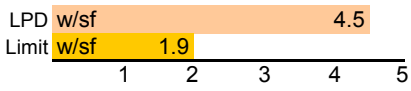
Although the wood finishes in this room are very dark, since they do not continue all the way to the ceiling, they have less of an impact on the overall brightness of the room.

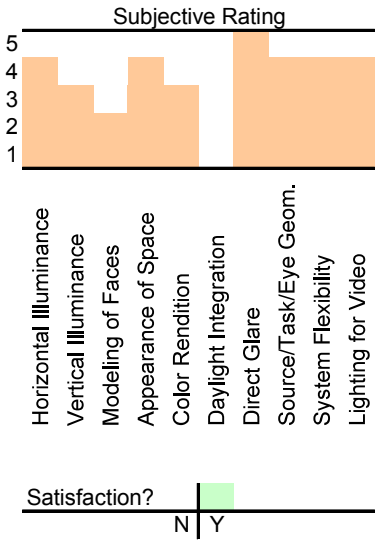
5.6.6 Design Analysis

This courtroom provided a layered approach to lighting, combining the proper equipment with lighter room finishes.

- The high lighting power density in this room is due to the tungsten-halogen downlights in the ceiling.
- The contrast ratio between the dark wood and the walls is very high.
- The linear fluorescent cove provided very soft, even illumination of the vaulted ceiling, as shown in the luminance maps. No glare or hot spots are seen on the ceiling.
- By continuing the vaulted ceiling above the bench at the front of the room rather than stopping it with a soffit, as on the other three walls, allows that area to be seen as brighter. This helps emphasize the bench as an important area of the room.
- Overall light levels are at the higher end of the Design Guide's recommendations, suggesting that the installed wattages could be slightly lower.







6 Comparative Analysis

This section of the report presents tables comparing the surveyed courtrooms. Aspects of the courtrooms that are compared are illuminance levels, lighting power density, and the subjective qualities of the Design Guide and IESNA Handbook guidelines.

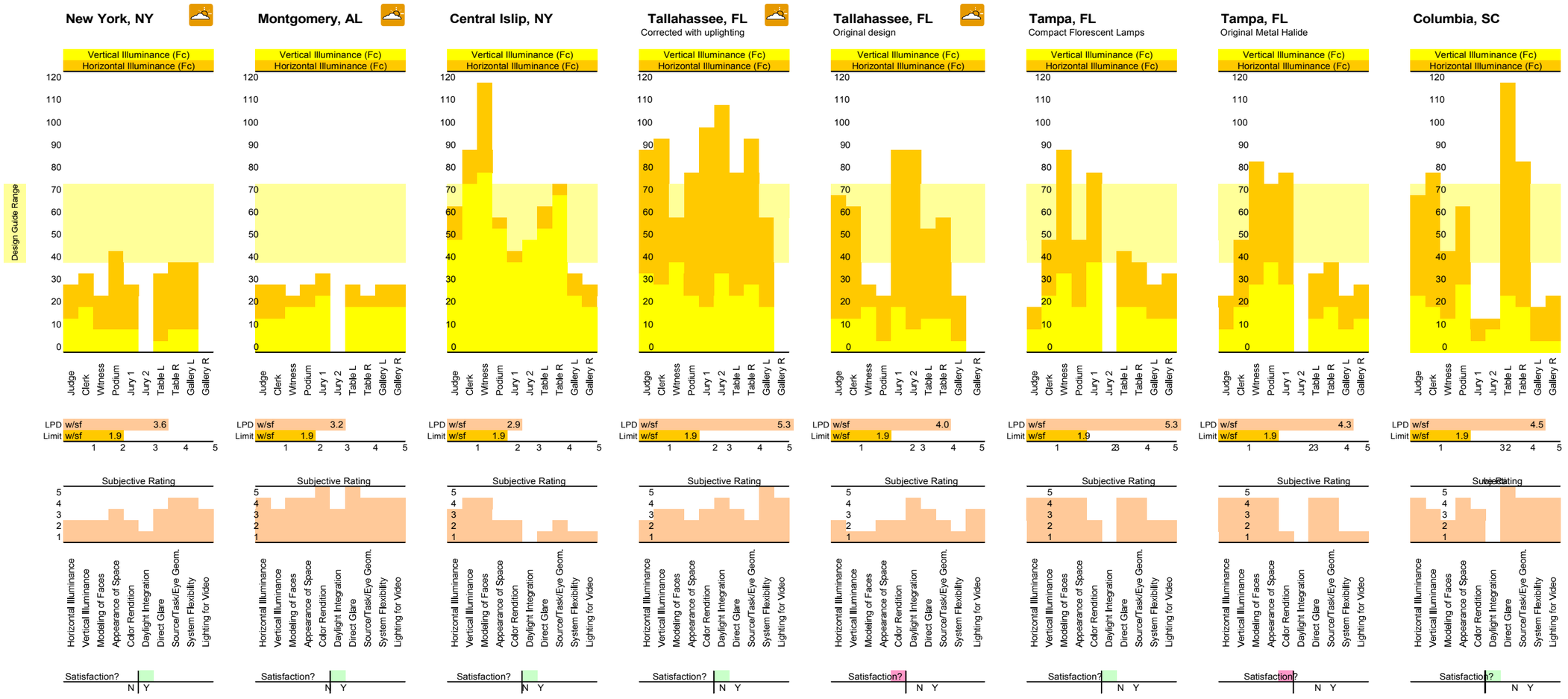


Table 2 - Comparative Analysis Chart

The subjective ratings at the bottom of the chart are on a 1 to 5 scale, with 5 being the best. The ratings are based on a comparison of the courtrooms and by looking at all of the illuminance, luminance, and LPD data to summarize the success or failure of each courtroom.

Courtroom graphs with this symbol have daylight available in the courtrooms

7 Conclusions

Based on our extensive studies, the following conclusions can be drawn:

- All of the courthouses studied exceed the allowable lighting power density. This is due to the use of incandescent tungsten-halogen lighting, which is not as efficient as other available sources.
- Using metal halide downlighting as a primary light source is undesirable, since color rendering (as observed) and control of this source is limited.
- Designing a successful lighting solution and assuring it is successfully installed during construction is critical, because revising the lighting in courtrooms once installed leads to more power use and added construction expense.
- The recommendations of the Design Guide are not always followed. This could be due to the design team not knowing or intentionally not complying with the guidelines. It may also be because of breakdowns in the construction process, perhaps in the submittal phase. The submittal phase is critical for the design team to confirm with the contractor what will be installed.
- More horizontal illuminance does not necessarily mean better performance. The best performing courtroom was the Montgomery courtroom, which had the lowest overall illuminance and power density, based on subjective ratings such as surface brightnesses, glare, and color rendition. The subjective ratings of the Montgomery and Pearl St. courtrooms show that a good lighting solution can be provided with regards to the standards in the Design Guide and IESNA Handbook using relatively low horizontal illuminances. This suggests that the illuminance recommendations in the Design Guide can be lowered if the design is geared towards these qualities, such as vertical illumination, luminance ratios, and energy use.
- Daylight is not critical, but if controlled well, it can greatly improve the perception of the courtroom. The Tallahassee courthouse has a skylight system that is easily controlled to eliminate glare due to sunlight, and the windows at the Montgomery courthouse provide a visual connection to the outside.
- Most of the courtrooms observed did not have lighting specifically designed targeted to task areas. This leads to excessive energy use because light levels remain high in areas that they are not needed.
- Most courtrooms have a significant amount of dark wood finishes, which leads to more installed lighting because the surfaces do not reflect as much light as lighter colored walls. Courtrooms that only had wood paneling at low levels generally performed better than those with full wall height wood covering. During the design process contrast must be balanced adequately.
- Providing dimming control to for lighting in courtrooms is critical for video and evidence presentation. A system that allows individual zones and types of light to be easily controlled is preferable. Links to the AV system should be provided for integrated control.

8 Recommendations

We recommend the following changes to the Design Guide to help ensure quality lighting in future courtrooms.

8.1 Illuminance Recommendations

The Design Guide should indicate more specifically illuminance targets for task areas. The current range of 40 to 75 footcandles is too broad, and leads to excessive amounts of lighting and energy use. It also does not help lead the designer towards emphasizing important areas of the courtroom with lighting, such as the bench and the witness stand.

8.2 Surface Finishes

The Design Guide should add focus on room surface finishes and contrast ratios. As indicated in the luminance maps, surface finish has a large effect on how a room is perceived. . Understanding the impact of dark colored walls and floor coverings on lighting perception is critical.

8.3 Lighting Layers

The Design Guide should require a layered approach to the lighting system. Courtrooms with predominantly directional downlighting, or only diffuse or indirect lighting performed worse than courtrooms with a good mix of direct and indirect lighting.

Specific guidelines on the use of metal halide lighting should be clearly stated, as the complexities of this lamp type (color rendering, ballast hum for some system, and restrike time) need to be carefully considered when compared to their energy saving potential.

8.4 Lighting Control

The Design Guide, in addition to requiring a dimming control system, should indicate to some level how the lighting in the courtroom should be zoned to allow for video generation, evidence presentation, and other AV uses.

8.5 Design Confirmation During Construction

One additional issue that impacts the lighting is ensuring that the intent of the design team is carried through construction. This requires the entire team to be involved in and understand any modification to the design during construction, whether they be related to value engineering, field conditions, or architectural changes.

8.6 Design Validation

The Design Guide should require the design team to verify that their design meets the requirements. This can be done using commonly used software in the lighting design field, such as AGI-32, or more detailed visualization using Radiance software, or one of several other valid software packages. The key is to recognize that courtrooms present many challenges and are more complicated than a typical building, and hence require more detailed analysis during design than a standard building project.

An example of the value of this type of analysis is shown in the following images, which are luminance maps of courtrooms. The first set of images are of the Islip courtroom,

which shows that there is very little contrast variation in the area behind the bench, which leads to a dull appearance. The second set of images is of the proposed Jackson, MS courtroom, from an earlier pilot study. These images were generated as part of a visualization of the courtroom, and show that the lighter wall behind the bench improves the visual appearance of that area and adds emphasis.

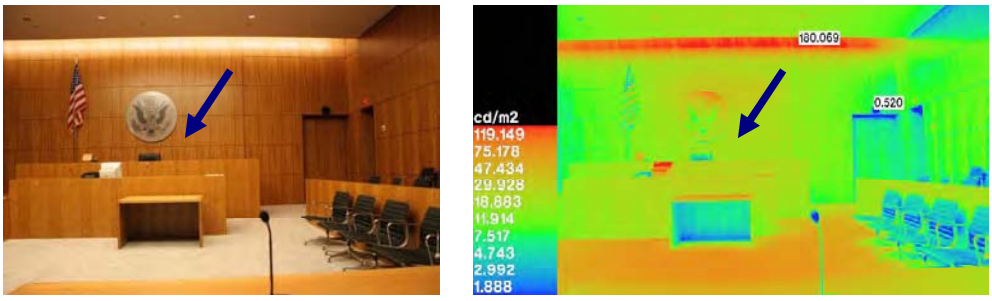


Figure 27 - Photo and Luminance Map of Islip Courtroom

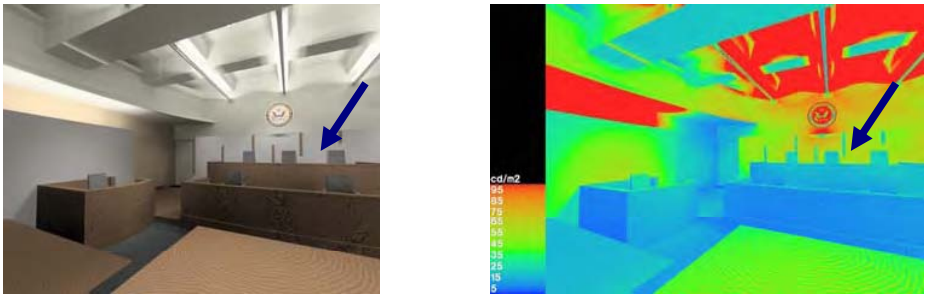


Figure 28 - Rendering and Luminance Map of Proposed Jackson Courtroom

We look forward to feedback and comments on our research and recommendations.

ArupLighting

Appendix A

Courtroom Locations

A1 Courtroom Locations

A1.1 New York, NY

Daniel Patrick Moynihan United States Courthouse

District Courtroom 15A

500 Pearl Street

New York, NY 10007-1312

A1.2 Montgomery, AL

Frank M. Johnson, Jr. Federal Courthouse Annex

District Courtroom 2B

One Church Street

Montgomery, AL 36104

A1.3 Central Islip, NY

Alfonse M. D'Amato United States Courthouse

9th Floor District Courtroom

100 Federal Plaza

Central Islip, NY 11722

A1.4 Tallahassee, FL

United States Courthouse Annex

District Courtroom

111 North Adams Street

Tallahassee, FL 32301

A1.5 Tampa, FL

Sam M. Gibbons United States Courthouse

District Courtrooms 13B and14B

801 North Florida Avenue

Tampa, FL 33602

A1.6 Columbia, SC

Matthew J Perry Jr. United States Courthouse

District Courtroom

901 Richland Street

Columbia, SC 29201

PNNL-15735

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Energy Effective Courtroom Lighting: An Analysis of Existing Conditions and Recommended Improvements

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Eric Richman, LC

March 2006

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Federal Energy Management Program
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Under Contract AGRPX0006810

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Richland, Washington 99352

Executive Summary

Providing high quality *and* energy efficient lighting in courtrooms is a complex task, and it represents a greater challenge than most other Federal space types. Energy efficient lighting in courtrooms must be accomplished with no sacrifice in quality; efficiency must be effectively invisible to the occupants. The Whole Building Design Guide (WBDG) eloquently states the architectural goals of courthouse design: "As the preeminent symbol of Federal authority in local communities, a Federal courthouse must express solemnity, stability, integrity, rigor and fairness." The courtrooms themselves must have a sense of majesty and be aesthetically inspiring. When paired with the visual needs in a courtroom—given the wide variety of tasks and the critical nature of the courtroom proceedings—one has a challenge indeed.

In consideration of these issues, this report reviews existing conditions in courtrooms and provides specific guidance about solutions that will accomplish the dual objectives of high quality and energy efficiency. The material covers all aspects of courtroom lighting, including design criteria, design and application strategies, energy efficient technologies, procurement and team selection, design process and implementation, and education.

A detailed energy analysis was performed to develop a baseline for energy consumption in courtroom lighting, and the primary root cause for excessive energy use was found to be a high incidence of incandescent technology. Incandescent lighting was responsible for 54% of the energy consumption but is the least efficient of all the technology options. Point-by-point calculations were completed to provide an energy efficient alternative to the incandescent that met the high level of criteria for performance in courtrooms. Energy modeling was completed based on redesigns that included the use of dedicated compact fluorescent downlights with dimming electronic ballasts and high performance T8 systems, resulting in an average potential savings of 27.6% and 1.2 watts per square foot. A life-cycle cost analysis was performed to provide one example of the type of energy cost savings that is available. The findings showed a Savings-to-Investment Ratio (SIR) of 5.57, and Adjusted Internal Rate of Return (AIRR) of 10.32%, and a simple payback period of four years. The national energy savings potential has been estimated at 13,328,837 kilowatt-hours.

Additional detailed design guidance has been provided in the spirit of a holistic solution. It is hoped and anticipated that the recommended solutions will transform courtroom lighting towards both energy efficiency and high quality lighting. This is more important than ever before given the passage of the Energy Policy Act of 2005, which significantly changes the energy usage requirements in Federal buildings. Ultimately it is possible to support the critical and high stakes proceedings in courtrooms while still meeting the civic duty of designing for energy efficiency and sustainability.

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Contents

Tables

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1.0 Background

This project originated from the 2005 Technical Assistance (TA) Call for Projects from the U.S. Department of Energy Federal Energy Management Program (FEMP). The General Services Administration (GSA) Sunbelt Region requested guidance on energy efficient lighting in courtrooms from a technical assistance team at the Pacific Northwest National Laboratory (PNNL). Because the GSA Public Buildings Service Office of Applied Science (OAS) and the Administrative Office of the U.S. Courts (AOUSC) were conducting similar work under a separate contract, it was later determined to align the efforts, with the lighting energy analysis conducted by PNNL and the data collection and engineering conducted by Ove Arup & Partners Consulting Engineers PC (hereafter referred to as Arup Lighting).

The impetus of the project was related to frequent problems with courtroom lighting. The question at hand was to determine the nature and source of the continuing problems and determine the best course of action to fix the root cause. Was the basis of the problems the guidance in the written criteria (or lack thereof), or the inability to apply the guidance correctly?

This report addresses these questions and provides a focus on achieving energy efficiency and high quality courtroom lighting. To this end, the focus of Arup Lighting was primarily to gather physical lighting measurements from six district courtrooms and determine what did or did not work well with respect to lighting quality and the relationship to the design criteria. The focus of the PNNL team was to perform a detailed analysis of the energy efficiency issues in consideration of the lighting quality requirements and the complexities of design criteria, procurement and construction by GSA. Arup Lighting and PNNL shared documentation and had meetings as necessary to support their mutual goals in service of GSA, AOUSC and FEMP. The revised goal of the effort was to provide guidance to GSA Public Building Service (PBS) and the AOUSC, in the hopes of improving their design criteria in both lighting quality and energy efficiency. The data collection and analysis by Arup Lighting is included in their report under separate cover.

1.1 Objectives

The objective of this work, with respect to lighting in courtrooms, is to accomplish the following:

(1) Determine the most frequent and significant lighting design problems, with respect to both energy efficiency and lighting quality.

(2) Perform an energy analysis to determine the root cause for excess energy consumption.

(3) Recommend changes to lighting criteria, and provide relevant strategies to improve lighting in courtrooms to improve energy efficiency and lighting quality.

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2.0 Analysis of Existing Conditions

The first task was to identify the design guidance provided by the two primary agencies – GSA and AOUSC – along with other relevant technical information, the existing conditions in courtrooms, and the process by which designs are developed and installed.

2.1 Relevant Design Criteria and Standards

Data was gathered to determine what the prevailing criteria and standards are for courtroom design, as well as the existing conditions in the courtroom sample set. Sources included the following list:

(1) U.S Courts Design Guide (US Courts),

(2) GSA PBS Facilities Standards for the Public Building Service (PBS P-100),

(3) IESNA[1] Lighting Handbook, 9th Edition (IESNA),

(4) Energy Policy Act of 2005 (EPACT),

(5) ANSI/ASHRAE/IESNA[2] Standard 90.1-2004 (ASHRAE),

(6) Federal commercial building energy code 10 CFR Part 434 (10 CFR Part 434).

2.1.1. U.S. Courts Design Guide

The U.S. Courts Design Guide (USCDG) provides guidance about lighting in courtrooms, summarized as follows.

- Footcandle levels range from 40 to 75 footcandles (fc) (430 to 800 lux).
- Acceptable lighting is identified by source and distribution. Fluorescent can be used for direct or indirect applications. Incandescent is only allowed in direct luminaires, while metal halide is only allowed in indirect applications.
- Specific control requirements are provided, including the minimum "scenes" that will be required of the control system.
- Additional general guidance calls for lighting that is sensitive to the needs of video display and recording, evidence display, and computer usage. Good color rendering is called for, as well as vertical footcandles. Caution is suggested with respect to bright sources because of the possibility of glare. Concerns about noise from voltage fluctuation of high wattage lamps are also raised.

2.1.2. GSA PBS P-100

The most recent update to the Facilities Standards for the Public Buildings Service (GSA P-100) was issued in March of 2005. In particular, Chapter 6, Section 6.8 on Interior Lighting has incorporated changes from the IESNA Lighting Handbook 9th edition, and has been thoughtfully updated with respect to issues related to energy efficiency, sustainability and daylighting.

[1] Illuminating Engineering Society of North America.

[2] American National Standards Institute, American Society for Heating, Refrigeration, and Air Conditioning Engineers.

However, Chapter 9, Design Standards for U.S. Court Facilities, has not been similarly updated and remains vague with respect to courtroom lighting. The guidance is consistent with the USCDG and IESNA resources, but offers little advice about how to accomplish the goals.

2.1.3. IESNA Lighting Handbook, 9th Edition

The IESNA Lighting Handbook provides the most specific guidelines for lighting in courtrooms, and does provide explanations in the handbook on strategies to achieve the criteria. A summary is provided here.

- Visual tasks are listed and include reading, audiovisual (A/V) presentations, and video and camera use.
- Special considerations include low-glare luminaires, dimming with preset levels for typical courtroom functions, and aesthetically appropriate luminaires to enhance the dignity of the courtroom.
- Color rendering is indicated as important because of evidence display.
- Horizontal and vertical illuminance levels are referenced in Chapter 10.
- Wall luminance must be reduced so it does not interfere with A/V presentations.
- Judge, jury and attorneys must still be able to take notes during the A/V presentations.
- Lighting control must be flexible and user friendly so it may easily accommodate the variety of activities in the courtroom.

Design standards for lighting are synthesized in the Lighting Handbook in the Chapter 10 Lighting Design Guide. The Guide provides a matrix that prioritizes the design issues for different spaces. Additional guidance on how to address these objectives can be found in a courtroom design example in the IESNA publication entitled "Lighting for People: A Guide to Designing Quality Lighting in the Built Environment." (IESNA DG-18) The highest design priorities for courtrooms are as follows:

(1) Appearance of Space and Luminaires
(2) Color Appearance (and Color Contrast)
(3) Daylighting Integration and Control
(4) Direct Glare
(5) Light Distribution on the Task Plane (Uniformity)
(6) Modeling of Faces or Objects
(7) Source/Task/Eye Geometry
(8) System Control and Flexibility
(9) Horizontal Illuminance
(10) Vertical Illuminance.

Further details on illuminance are also provided for the different areas of the courtroom.

Table 1. Courtroom Illuminances

Courtroom Area	Horizontal Illuminance	Vertical Illuminance
Judge and clerk	50 fc	10 fc
Litigant's table and podium	50 fc	10 fc
Witness chair	30 fc	5 fc
Spectator area	10 fc	3 fc

2.1.4. Energy Policy Act of 2005

The most significant and immediate impact of the Energy Policy Act of 2005 (EPAct) is that new Federal buildings will soon be required to achieve energy savings of at least 30%, (if cost-effective) below that required by ANSI/ASHRAE/IESNA Standard 90.1-2004. This savings has not been defined. The Department of Energy is required to issue a rule to this effect by August 2006. Stakeholders are encouraged to provide input.

It is important to note that the 30% savings requirement does not indicate a linear reduction of energy usage across the entire standard. The impact on lighting power density (LPD) numbers may be greater or lesser than the impact on the building envelope or mechanical systems, for example. If LPD's are reduced, it does not necessarily mean that the courtroom LPD will be reduced by 30%; it may be more appropriate to reduce the power allowance for other space types.

In addition to those mentioned above, there are a number of other relevant provisions.

- Sustainable design principles be applied to the siting, design, and construction of all new and replacement buildings. (Section 109)
- When newer versions of the ASHRAE Standard 90.1 or IECC (ICC) Code have been passed, EPAct 2005 encourages state and local government buildings to meet these newer versions. (Section 125)
- Technology use in Federal buildings is addressed by requiring the procurement of Energy Star® products, FEMP-designated products, and National Electrical Manufacturers Associations (NEMA) Premium® electric motors. (Section 104)
- An overarching goal for reducing energy consumption on a gross square foot basis has been set for *existing* Federal buildings. The requirement is that consumption be decreased by two percent per year, reaching a 20 percent decrease by 2015 as compared to a baseline established in 2003. (Section 102)

2.1.5. ANSI/ASHRAE/IESNA Standard 90.1-2004

ANSI/ASHRAE/IESNA Standard 90.1-2004 (ASHRAE) provides power limits for both the interior and exterior lighting of a building, along with mandatory controls requirements and some lighting source efficacy limits. Only interior lighting issues are discussed in this report.

Standard 90.1 provides lighting power density (LPD) limits in two ways. One performance path (called the "Building Area Method") is to comply with an LPD that applies to an entire building, such that average LPDs for the entire building do not exceed this number. For courthouses, the LPD limit is 1.2 watts per square foot.

Another performance path (called the "Space-by-Space" method) is to develop an "energy budget" by applying a room-specific power density for each room in the courthouse building. The LPD number for courtrooms is 1.9 watts per square foot. A variety of LPDs would apply to other areas of the courthouse. For example, the LPD number for offices is 1.1, while restrooms are 0.9, and corridors are 0.5. The room-specific power densities would be calculated for each space resulting in a power allowance for the entire building, which is likely to be different from the allowance specified under the whole building method of compliance.

The Space-by-Space method accommodates the particulars of an actual building, which would be advantageous for courthouses that have a higher density of courtrooms than is typical.

Mandatory automatic lighting controls are required. This means that the lighting controls system in the courtroom must be capable of automatically turning off the lights when the room is not in use.

2.1.6. Federal Energy Code

The current applicable rule for Federal commercial buildings (including courthouses) is entitled "10 CFR Part 434, Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings." The final rule was published on October 6, 2000 and the regulation became effective on October 8, 2001. The current Federal code is effectively superseded by the Energy Policy Act of 2005.

2.2 Design, Procurement and Construction

Information about the design, procurement and construction process was gathered. Written guidance on these topics is excellent, but practical application of the guidance cannot be reliably determined.

2.2.1. GSA Design Excellence Policies and Procedures

The GSA is deeply committed to architectural excellence, as evidenced by the Design Excellence program (GSA Design Excellence), which has been in place since 1994. This program provides explicit guidance about procurement for government design projects including courthouses, and establishes very high standards for professional expertise. The focus is primarily on architectural services and the program is mostly silent on the topic of

lighting services and energy usage. While the use of a lighting design consultant is not explicitly required, it is common practice on courthouse projects for architects to have a lighting consultant as a member of the design team.

2.2.2. Whole Building Design Guide

The Whole Building Design Guide (WBDG) is not a design guide in the traditional sense; rather it is a website that offers useful links to resources on topics related to building and construction in the Federal sector. For example, links are provided to the U.S. Courts Design Guide and relevant energy codes, but the website does not have any specific requirements per se. The web pages offer basic information about sustainability, courthouses and lighting, but there is no specific guidance about lighting in courtrooms.

2.3 Courtroom Data and Project Background

Data was collected in two ways. Information about specific courtrooms was gathered and analyzed, and GSA staff members were consulted to gain their professional experience about managing courtroom lighting projects.

2.3.1. Courtroom Data

Courtroom data collection started with a review of courthouse drawings and specifications provided by GSA, including Tampa, FL; Tallahassee, FL; Montgomery, AL; Columbia, SC; Central Islip, NY; and New York, NY.

Written documentation was supplemented with an actual lighting audit data provided by Arup Lighting. This additional data resulted in enough information to complete a reasonable energy analysis (see below). The information and results of Arup Lighting's work is published in a separate study. (Arup)

2.3.2. GSA Staff Interviews

Phone meetings were held with GSA project managers and staff to gather input on successes and failures of specific courtroom projects, as well as issues related to the process of running a courtroom lighting project. Based on these discussions, a number of issues arose as the most frequent and serious problems in courtroom lighting.

2.4 Design Problems

The most prevalent and systematic lighting problems and challenges were identified both by the audit data and by GSA project managers. The issues are listed below, and suggested solutions to these problems are found in the recommendations section of this report.

2.4.1. Synthesis of Findings from Arup Lighting Report

- Many of the courtrooms were either overlit or underlit.
- There was insufficient "bounce" light in some circumstances caused by the lack of indirect lighting, resulting in excessive shadows and poor facial modeling.
- Most courtrooms had dark wood finishes at the walls, resulting in low room surface brightness, insufficient "bounce" light, and excessive power density.

- Metal halide fixtures created problems because of color appearance, color rendering, and ballast and transformer noise.
- Insufficient daylighting control (less than optimal window shades).
- Task areas were often not treated differently than non-task (e.g., audience) areas, resulting in higher power density than is necessary.

2.4.2. Synthesis of Findings from GSA Staff Interviews

- Insufficient light at the walls (luminance), largely resulting from the use of dark finishes, primarily wood walls.
- Insufficient vertical illuminance, resulting in complaints from judges about facial modeling and evidence display.
- Spaces are *perceived* as underlit because of the low room surface brightness. This has required expensive relighting projects subsequent to initial construction, which usually increases power density.
- Control systems that are not user-friendly.
- There have been problems with ceiling plane and room geometries, where the lighting design did not respond to the architectural requirements of the space.
- Glare from lighting fixtures and occasionally windows as well.
- Color rendering issues have occurred, where finishes appear differently under the courtroom lighting than expected, resulting in changing the lighting or the wood finishes.
- Misunderstandings by the project participants can occur over design issues, often related to a lack of awareness about lighting design principles and technologies and a lack of priority for energy efficiency.

2.5 Energy Analysis

The energy analysis first focused on determining the severity of the problems related to energy usage. To do this, it was necessary to determine the power density for each of the courtrooms based on the best data available. Once this was done, possible solutions were investigated.

2.5.1. Existing Power Density Analysis

Energy data collection and analysis for the selected courtrooms involved several steps aimed at assessing the lighting characteristics. The methodology is detailed below, and the findings are compared against EPAct 2005 requirements.

2.5.1.1. Methodology

For each set of available drawings, those specific to the chosen courtroom were separated and enlarged to identify room characteristics and lighting fixture codes to match the lighting schedule where available. Audit data from Arup Lighting was applied where necessary to supplement missing information. Input wattages were multiplied by fixture quantities to get overall wattage used, which was then divided by the square footage to get the lighting power density (LPD) for each courtroom.

With a characterization of each courtroom in place, a summary of the current lighting power density was completed to represent energy use and provide a basis for potential improvements.

2.5.1.2. Summary of Lighting Power Density

Lighting power densities are listed in the table below.

Table 2. Lighting Power Densities for Selected Courtrooms

Courthouse Location & Courtroom Description	Wattage	Square Footage	ACTUAL Lighting Power Density (1, 2)	TARGET Lighting Power Density (3)
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 13B	9,896	2,287	4.3	1.9
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 14B	11,976	2,287	5.2	
Tallahassee, FL 111 North Adams St. US Courthouse- District Courtroom	12,920	2,439	5.3	
Montgomery, AL One Church Street Johnson Courthouse- District Courtroom	7,005	2,196	3.2	
Columbia, SC 901 Richland Strreet Perry Courthouse- District Courtroom 13B	17,360	3,840	4.5	
500 Pearl Street Manhattan, NY Moynihan Courthouse- Foley Square, Rm 15A	11,310	3,168	3.6	
Central Islip, NY 100 Federal Plaza Alfonz D'Amato Courthouse- 9th floor Courtroom	7,260	2,210	3.3	
Average Totals	11,104	2,632	4.2	N/A

NOTES: (1) Data was based on the most reliable information available at the time of analysis, and is subject to change should additional information become available. (2) Lighting Power Density is Watts per Square Foot. (3) The target LPD value shown here is taken from ANSI/ASHRAE/IESNA Standard 90.1-2004. Per the Energy Policy Act of 2005, a new Federal rule is due out from DOE in August 2006 requiring further energy savings of 30%, if cost effective. Impacts on individual LPD's cannot be anticipated at this time.

2.5.1.3. Energy Code Compliance

Clearly the power densities shown in Table 2 do not even approach compliance with the ASHRAE/IESNA Standard 90.1-2004 (see Sections 2.1.4 – 2.1.6). The average calculated power density is 4.2 watts per square foot (w/sf), while the target power density limit is 1.9 w/sf for courtrooms.

2.5.1.4. Energy Usage – Kilowatt-hours

It is important to note that power density is actually a limited method of determining actual energy usage because it does not assess hours of use. District courtrooms are not used as frequently as most other spaces, and so the high connected load is not likely to be as severe a problem as it could be. Unfortunately the lighting section of Standard 90.1-2004 does not have an equivalency system to determine the relative importance of different spaces with respect to energy consumption. It is important to recognize that true energy consumption is reflected in kilowatt-hours, which consider both connected load and hours of use.

The issue of energy use over time and code language related to lighting controls is being discussed in depth in the most recent ASHRAE 90.1 Lighting Subcommittee meetings. Should the U.S. Courts want to provide data about the relative energy use of courtrooms over time or have input to the code development process, feedback is always welcomed by the ASHRAE Standard 90.1 Lighting Subcommittee.[3]

2.5.2. Energy Modeling

The immediate challenge was to determine if the use of energy efficient technologies could sufficiently reduce consumption. Two methods of energy modeling were used to determine possible solutions to high energy consumption. The first method was a fairly high level and simplified investigation into the substitution of more efficient technologies. The second method was a detailed computer modeling using point-by-point ray tracing software, to provide a more focused solution to the obvious overuse of incandescent downlights.

2.5.2.1. ANSI/ASHRAE/IESNA Standard 90.1-2004 Models

The energy analysis utilized a pre-existing methodology that models different types of lighting equipment in a variety of spaces. These models form the basis for lighting power density values in the national energy standard, ANSI/ASHRAE/IESNA Standard 90.1-2004. PNNL is actively involved in supporting USDOE with respect to the development of Standard 90.1, and as such, has experience in using these models. The goal was to perform a broad strokes re-design in the courtrooms to determine how much energy could be saved.[4] The energy savings were roughly estimated by assuming a replacement of the lighting technologies.

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[3] For information on how to provide input to the ASHRAE Standard 90.1 Lighting subcommittee, email carol.jones@pnl.gov or eric.richman@pnl.gov.

[4] The modeling process is not a simple wattage reduction or replacement; rather, it requires an application of lighting equipment (using published data and coefficients of utilization) along with an IESNA approved lumen method of calculating lighting levels.

This methodology kept the existing design solutions but calculated the use of more efficient equipment. In some cases where the actual audit data revealed that the courtroom was overlit, the redesign model was able to save energy by adjusting the light output down to IESNA recommended light levels. In all but one of the courtrooms downlights and wallwashers using compact fluorescent lamps (CFL) were substituted for incandescent PAR lamps. In four of the seven courtrooms it was also possible to retrofit the linear fluorescent fixtures by replacing standard T8 electronic technology with high performance T8 systems.

Table 3 provides a summary of the initial lighting power characteristics for each courtroom location and the potential re-design power characteristics and savings. The table shows an average potential savings of 27.6% and 1.2 watts per square foot.

Table 3. Modeled Re-design Showing Savings from Efficient Technologies

Courtroom Description	Wattage	Square Footage	Lighting Power Density (1,2)	Proposed Re-Design Technlogy	Re-design wattage	Re-design Power Density	Percent Power Reduction
Tampa, FL 801 North Florida Ave (Gibbons Courthouse- District Courtroom, 13B)	9,896	2,287	4.3	CFL Wallwash (in place of Quartz wallwash) & partial retrofit to HPT8	7,006	3.1	29.2%
Tampa, FL 801 North Florida Ave (Gibbons Courthouse- District Courtroom, 14B)	11,976	2,287	5.2	CFL Wallwash (in place of Quartz wallwash) & partial retrofit to HPT8	9,086	4.0	24.1%
Tallahassee, FL 111 North Adams St. (US Courthouse- District Courtroom)	12,920	2,439	5.3	CFL Downlight Open (in place of PAR38 incandescent downlight)	8,453	3.5	34.6%
Montgomery, AL One Church Street (Johnson Courthouse- District Courtroom)	7,005	2,196	3.2	CFL Downlight Open (in place of PAR38 incandescent downlight)	6,081	2.8	13.2%
Columbia, SC 901 Richland Strreet (Perry Courthouse- District Courtroom 13B)	17,360	3,840	4.5	CFL Downlight Open (in place of PAR38 incandescent downlight) & partial retrofit to HPT8	8,273	2.2	52.3%
500 Pearl Street Manhattan, NY (Moynihan Courthouse- Foley Square, Rm 15A)	11,310	3,168	3.6	CFL Downlight Open (in place of PAR38 incandescent downlight)	7,786	2.5	31.2%
Central Islip, NY 100 Federal Plaza (Alfonz D'Amato Courthouse- 9th floor Courtroom)	7,260	2,210	3.3	Retrofit from standard T8's to High Performance T8	6,613	3.0	9%
Averages	11,104	2,632	4.2	Averages	7,614	3.0	27.6%

NOTES: (1) Data was based on the most reliable information available at the time of analysis, and is subject to change should additional information become available. (2) Lighting Power Density is Watts per Square Foot.

2.5.2.2. Defining the Gap

The most significant problem as shown above is the use of PAR lamps as a downlight solution in spaces with high ceilings. The severity of the problem is revealed in Table 3, which shows the relative energy use of incandescent as compared to the rest of the connected load in the courtrooms. On average, 54% of the total connected load is direct incandescent lighting—the most inefficient type of lighting.

Table 4. Relative Energy Use of Different Types of Light Sources.

Courthouse and Courtroom Description	% Incandescent	% Linear Fluorescent	% Compact Fluorescent	% Metal Halide
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 13B	42%	9%	49%	0%
Tampa, FL 801 North Florida Ave Gibbons Courthouse- District Courtroom, 14B	35%	7%	14%	43%
Tallahassee, FL 111 North Adams St. US Courthouse- District Courtroom	90%	0%	10%	0%
Montgomery, AL One Church Street Johnson Courthouse- District Courtroom	34%	0%	66%	0%
Columbia, SC 901 Richland Strreet Perry Courthouse- District Courtroom 13B	93%	7%	0%	0%
Central Islip, NY 100 Federal Plaza Alfonz D'Amato Courthouse- 9th floor Courtroom	0%	74%	0%	26%
500 Pearl Street Manhattan, NY Moynihan Courthouse- Foley Square, Rm 15A	81%	0%	19%	0%
Subtotal	54%	14%	23%	10%

2.5.2.3. Point-by-point Calculations

Given the results in Table 4, the first challenge was to find a substitute for incandescent lighting that would meet the strict criteria of courtroom lighting, including excellent color rendering and dimmability, while providing sufficient horizontal light levels. To identify possible solutions, point-by-point calculations were performed using five different downlight options.

In contrast to the lumen method of calculation used in the Standard 90.1 models, point-by-point calculations are a very accurate way to determine the distribution of light in a space. The target illuminance was 25 footcandles, because the direct component should contribute to roughly half of the overall illuminance in the space. The remainder of the horizontal illuminance would be provided by linear fluorescent sources or indirect metal halide. Table 4 shows the results of 15 calculations, using 5 of the most applicable types of luminaires at three different ceiling heights.

Table 5. Calculation Results using Downlight Luminaires at Three Mounting Heights

	Vertical Lamp Fixture Triple Tube CFL 42 Watt			Horizontal Lamp Fixture Triple Tube CFL 42 Watt			Horizontal Lamp Fixture Triple Tube CFLs 2 lamp-42 Watt			PAR38 HIR Halogen InfraRed (Incandescent) 100 Watt			PAR38 Metal Halide Ceramic, Pulse Start 70 Watt, electronic		
Ceiling Height: (1)	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"	12'-0"	16'-0"	20'-0"
Average Illuminance (fc)	29.7	26.6	23.9	28.6	25.3	27.9	29.2	25.7	29.9	31.1	28.8	26.6	25.5	24.3	32.5
Lighting Power Density	0.72	0.72	0.72	0.85	0.85	1.07	0.93	0.93	1.24	2.67	2.67	2.67	0.67	0.67	1.00
LPD Normalized	2.4	2.7	3.0	3.0	3.4	3.8	3.2	3.6	4.1	8.6	9.3	10.0	2.6	2.8	3.1
Maximum Illuminance	37.4	34.8	32.1	36.1	34.6	37.9	36.1	34.6	39.7	49.8	35.3	32.5	94.7	49.6	39.3
Minimum Illuminance	17.8	16.1	15.1	15.1	14.0	16.9	16.8	15.1	18.6	16.6	18.8	15.6	3.8	7.2	20.8
Max/Min Illuminance	2.1	2.2	2.1	2.4	2.5	2.2	2.1	2.3	2.1	3.0	1.9	2.1	24.7	6.8	1.9
Uniformity	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.6	0.1	0.3	0.6

NOTES: (1) Metric equivalencies for ceiling heights are as follows: 12'-0" equals 3.7 meters, 16'-0" equals 4.9 meters, 16'-0" equals 6.1 meters.

The results of these calculations show that the "Vertical Triple CFL 42 Watt" luminaire provides the best overall results, and is acceptable for each of three mounting heights. The power density is low at 0.72 watts per square foot, the fixtures do a good job of providing the target illuminance of 25 fc, and the uniformity is good at 0.6. The luminaire is a low glare fixture because the lamp sits up high in the housing of the fixture, which also results in an efficient vertical distribution. The luminaire has a dimmable electronic ballast, and the lamp is available in a variety of colors (including the popular 3000K or 3500K) and has a Color Rendering Index (CRI) of 82.

For additional background information on the calculations and the "Vertical Triple CFL" see Appendices A, B, and C.

2.5.3. Energy Cost Savings

Energy costs have escalated dramatically in the recent past, creating a renewed concern and commitment to the reduction of energy costs. Implementation of the recommendations in this report will result in lower utility bills.

Courtroom lighting design varies dramatically and it is not feasible or appropriate to provide any guarantee of energy cost savings. However, for the purposes of providing an example a life-cycle cost analysis was completed to show possible energy cost savings in a typical courtroom. District Courtroom 13B in the Perry Courthouse, Columbia, SC was considered the most typical and representative and was chosen for the analysis. For this report the estimated energy savings is based on a redesign that included the replacement of PAR incandescent downlights with dedicated dimming compact fluorescent downlights, and a retrofit of the non-dim linear fluorescent T8's to high performance T8 systems. The energy and cost savings are shown in Table 6.

Table 6. Present Value Costs and Energy Savings Summary

Description	Average Annual Consumption (kWh) and Costs ($)			Life Cycle Savings
	Base Case	Alternative Design	Savings	
Electricity	40,622 kWh 138.6 Mbtu	19,358 kWh 66.1 Mbtu	21,264 kWh 72.6 Mbtu	531, 527 kWh 1,814 Mbtu
Future Costs	$88,303	$32,838		$55,466
Present Value Life-Cycle Costs	$88,303	$42,799		$45,505
NOTES: (1) Comparative analysis was completed using Building Life-Cycle Cost (BLCC) software version 5.3-05 from the National Institute of Standards and Technology (NIST), and is consistent with Federal life-cycle cost methodology and procedures, 10CFR, Part 436, Subpart A. (2) Future Costs include energy consumption costs, and recurring and non-recurring operation, maintenance and replacement (OM&R) costs. (3) See Appendix D for the complete output of the BLCC analysis.				

Additional findings from the life-cycle cost analysis include the following:

- Savings-to-Investment Ratio (SIR) of 5.57
- Adjusted Internal Rate of Return (AIRR) of 10.32%
- Payback period of four years.

2.5.4. Energy Savings Summary

The above analysis clearly defines the nature of the energy consumption problem in typical courthouses and provides a basis for making energy efficiency improvements while meeting the strict quality criteria at the same time. To summarize the national energy savings potential an estimate is provided in Table 7.

Table 7. Summary of the Impacts of the Energy Conservation Measures

Description of Energy Conservation Measure	Energy Metric	Unit Savings / Year (Kilowatt-hours)	Unit Cost Savings ($/year) Current Dollars	O&M Cost Decrease ($/year)
(1) Replace incandescent downlights with pin-based compact fluorescent lamps and electronic ballasts, and (2) Replace non-dimmed Standard T8 fluorescent with High Performance T8 fluorescent systems.	Electric consumption	13,328,837 kWh	$1,066,307	$432,824
NOTES: (1) Typical courtroom size is 2,160 square feet, based on average of typical courtroom sizes noted in the 1997 U.S. Courts Design Guide, (2) Number of courtrooms in the U.S is 2,158, per telephone conversation with Fred Miller, GSA, 2/24/06, (3) Courtrooms usage is estimated at 9 hours per day, 5 days per week, (4) Typical power density savings is 1.22 Watts per square foot, (5) Average Federal kWh cost is applied at $0.08, (6) O&M cost is based on typical retrofits of standard T8 to High Performance T8 and incandescent PAR lamp to Triple tube CFL.				

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3.0 Recommendations

No single recommendation would be sufficient to close the gap between existing practice in courtroom lighting and energy efficient practice. The problems are systemic, and thus the solutions must also be applied systematically. The following suggestions attempt to cover additional areas critical to overall success, including: design criteria, examples of design strategies, energy efficient technology guidance, procurement and team selection, design process, implementation practices, and education.

3.1 Criteria Revisions

This section contains specific suggestions as to how the design criteria could be revised to improve both lighting quality and energy efficiency in courtroom lighting. It is important to continue the coordination between the U.S. Courts Design Guide and the GSA P-100 Chapter 9 to ensure consistency and avoid discrepancies or confusion. The technical basis for the lighting criteria should be based on the IESNA Lighting Handbook, 9th edition, per Section 2.1.3.

3.1.1. U.S. Courts Design Guide

- Table 4-4, "Heating Ventilating, and Air Conditioning (HVAC) and Lighting," should be revised to show more specific footcandle and lux requirements for the different task areas in the courtroom (see Section 2.1.3). If it is not feasible to break out the separate task areas in the existing table, provide a separate table for lighting guidance.
- As a supplement to Table 4-4, additional detail should be provided in Chapter 4 to explain more clearly the luminaire options.
- Guidance on finishes (page 4-57) should be revised to specifically *require* high wall and ceiling reflectances in courtrooms. As it stands, the guidance could be misinterpreted. While there is a mention of light reflectance ("consider acoustics and light reflectance"), there is also guidance to use hardwood veneer paneling. The interplay and relationship between lighting perception, energy efficiency and the choice of the color of wall, floor, and ceiling finishes should be more clearly defined.
- The lighting guidance on pages 4-64 and 4-65 should be revised to include IESNA design guidance. The "Lighting System" section should break out the critical issues in a bulleted or listed format as found in Section 2.1.3 (e.g., (1) Appearance of Space and Luminaires, (2) Color Appearance, (3) Daylight Integration and Control, etc.). As desired, examples of design strategies could be added.
- A commitment to energy efficiency and sustainability should be specifically called out in this section, and references to complementary sections or resources should be considered.
- The "Lighting Levels" section on page 4-64 should be revised to show more specific footcandle and lux requirements for the different task areas in the courtroom (similar to Table 4-4).
- The word "incandescent" in the "Lighting Controls" section should be replaced with the word "dimming," to allow for the use of dimming compact fluorescent fixtures. Digital controls should be added to the list of options, to allow use of the latest technology.

3.1.2. GSA P-100, Chapter 9

The guidance in the "Lighting System" section of Chapter 9 could be incrementally improved to more specifically incorporate the guidance in this section.

3.2 Design and Application Strategies

Practical application of the most appropriate energy efficient technologies in a high quality lighting design involves many variables including technology, tasks, visual performance, human preferences and comfort, costs, architecture, and implementation. This section provides specific suggestions for consideration about the art and science of energy efficient lighting in a courtroom. As a general rule, the lighting design should be responsive to the task activities in the courtroom.

3.2.1. Light for the Task

Lighting solutions should vary depending on task needs. In the case of courtroom lighting, the tasks vary significantly between the well of the courtroom where the judge, jury, and legal counsel are located, and the spectator areas.

3.2.1.1. Judge, Jury and Legal Counsel

The lighting in the well of the courtroom is where the most important and varied activity of the courtroom takes place, and the design and lighting levels should reflect this. Because the activities change throughout the courtroom proceedings and the lighting levels will need to be raised and lowered accordingly, control systems need to be adequately integrated with the lighting design. Critical tasks include viewing of witnesses, evidence, A/V presentations, paper and computers.

3.2.1.2. Spectator Areas

In most of the courtrooms reviewed for this report, the design solutions for the well and audience seating area were similar. Energy savings will be improved by lowering the lighting levels in the spectator areas, as the illuminance requirement is significantly less than in the courtroom well. If the design team wants the same "look and feel" throughout the courtroom, the luminaire can look similar while still consuming less wattage. For instance, if a suspended luminous bowl luminaire is used, the lamps and ballasts for the spectator area can be reduced from those the courtroom well, or the size of the bowl can be smaller but the style can be the same.

3.2.2. Layers of Light

To achieve better energy efficiency in the courtroom, the design strategy of using layers of light is a necessity. These different layers can be accomplished with a variety of different luminaires, but each layer has a mission-critical task. This section will cover the following types of layers: direct, indirect, wall washing, and task lighting.

In ***all cases*** the color rendering should be attractive and consistent across the different sources, with a Color Rendering Index higher than 80. The layers are comprised of several components:

- The **direct** component is necessary for the critical tasks of evidence inspection and seeing people clearly. This will generally be accomplished with recessed downlights, such as dimming compact fluorescent fixtures.
- The **indirect** component creates inter-reflections of light (also called bounce light), which are important with respect to vertical illuminance and for softening what otherwise would be harsh shadows on faces and evidence. The indirect component can be accomplished with architectural cove lighting, suspended luminous bowls, suspended architectural luminaires with an indirect element, or wall or cove mounted sconces.
- A layer of **wall washing** is necessary for acceptable room surface brightness. This is a significant factor that contributes to the impression of the majesty of the courtroom. Often the best way to accomplish wall washing is with linear fluorescent coves or linear wall wash fixtures, although it can also be accomplished with compact fluorescent downlights with a wall wash distribution.
- **Task lighting** should be provided as necessary for the attorney's tables. If there is task lighting for the attorney's tables, and dedicated recessed downlights for the jury and judge/witness areas, then it may be possible to reduce the overall direct element in a good portion of the room. In addition to saving energy, this has the added aesthetic benefit of keeping the ceiling mostly "clean," with fewer downlights.

3.2.3. Daylighting

Daylighting is consistently well-received in almost all environments, if, and only if, appropriate controls are utilized. Used well, it can dramatically improve the quality of a courtroom and truly heighten the experience of the room for all of the end users. Managed poorly, daylighting can be a problematic source of glare and thermal discomfort. In situations where windows are the primary or singular source of natural light, this usually means the use of controllable shade systems at the windows. In new construction buildings daylighting strategies may be more complex, possibly including clerestories, light shelves, and other strategies. To save energy with the use of daylight, the electric lighting must be tied into photocells that can sense the amount of daylight and adjust the electric lighting accordingly. Care should be taken to ensure that there is adequate attention to the cost benefit of the daylighting, as the costs associated with daylighting control can be significant, depending on the design. Daylighting design is considered a specialty in its own right, so it is important to look for deep and proven experience in the selection process of the lighting designer.

3.2.4. Flexibility and Control

Lighting control systems and dimming are a necessity for the courtroom well areas. Continuous dimming is preferred, but step-dimming can be sufficient in some cases. Audiovisual presentations are one of the tasks where the need for lighting control becomes most evident. For example, when a front projection system is used, it becomes important to dim the light that would otherwise wash out the screen. It is important to have a user-friendly control system with preset scenes that are easy to change. The required "scenes" are listed correctly in the USCDG. Security is important so that only the appointed

courtroom staff can have access to the lighting controls. (More detail is provided on lighting controls technology in Section 5.3.4 below.)

3.2.5. Lighting for Videoconferencing

While audiovisual presentations are quite common in courtrooms, videoconferencing and filming with the use of cameras is less common. The lighting requirements for videotaping and filming are considerably different than what is provided throughout the rest of this report. For detailed information on this topic, guidance is provided from the IESNA in their newly completed design guide entitled "Lighting for Videoconferencing" (IESNA DG-17). Basic guidance is outlined here.

Vertical illumination is the most important lighting element for videoconferencing. 30-50 fc of vertical illuminance is necessary for videoconferencing. Keep in mind that there is a ratio of approximately 2:1 between horizontal and vertical illuminance. This means that 50 vertical footcandles is often equivalent to 100 horizontal footcandles (the exact ratio depends on the lighting design and photometric distribution of the fixtures). This would double the energy consumption in these areas.

Contrast ratios are very important in lighting for cameras. Cameras will exaggerate contrast, so it becomes important to ensure that the perimeter walls are dimmable, and to minimize scallops on the walls by using linear fluorescent wall washing.

Lighting for videoconferencing would impact all aspects of the lighting design—including increased costs for the equipment, the look and feel of the courtroom, and the energy consumption. Therefore, permanently installed lighting for videoconferencing should only be provided if it's deemed truly necessary based on the intended use of a particular courtroom.

For infrequent videoconferencing or occasions when camera filming is necessary, consider the option of using portable equipment that is employed only for the duration of the proceedings. Television crews often provide their own lighting, but it will be necessary to plan access to a large enough power supply. Another solution would be to install powered track in the courtroom so that theatrical lighting fixtures could be added as necessary.

3.2.6. Courtroom Finishes

The reflectances of the surfaces in the courtroom are integrally related to the aesthetic success of the courtroom and the energy efficiency issues as well. It is important to understand the relationships between the variables to make informed decisions.

- Lighter finishes allow for improved inter-reflection, which improves the visibility of faces and evidence.
- Darker finishes require more lighting and thus more wattage, which will make it difficult (if not impossible) to meet energy code limits and will also add to the lighting equipment costs.
- The use of wood finishes is traditional in courtrooms and contributes to the ambiance and majesty of the space.

- The use of wood must be considered in the context of sustainable design, which becomes more relevant given the new requirements in EPAct 2005.

One approach that has been applied with success in recently built courtrooms is to use less wood in the upper portions of the walls, and more wood toward the lower portions of the room. Well-designed accents and details in wood can contribute significantly to the ambience and quality of the courtroom.

3.3 Energy Efficient Lighting Technologies

One of the ways to close the gap between the audited energy consumption and the connected load required by code is to use the most advanced energy efficient equipment available. A few possibilities are mentioned below, along with some caveats and cautions.

3.3.1. Compact Fluorescent Lamps

Compact fluorescent lamps come in larger lumen packages than when they were first introduced, and often use amalgam technology to help with heat and durability. As of February 2006, 70- and 80-watt compact fluorescent lamps have become available; however, the heat of these lamps may prove to be a durability issue and it is best to wait to ensure that they are reliable in the marketplace before applying them in a courtroom. The highest wattage lamp recommended is the 42-watt triple tube to be used with a dimmable electronic ballast.

3.3.2. High Performance T8 Systems

For areas where dimming is not required (e.g., spectator areas), high performance T8 lamp and electronic ballast systems (HPT8) provide approximately 23% savings as compared to the commodity T8 lamp and ballast system. (ESource) The best performing luminaire components should be specified as part of an energy efficiency strategy. DOE FEMP has guidance on HPT8 technologies on their website at www.eere.energy.gov/femp, and the Consortium for Energy Efficiency has performance specifications listed on their website at www.cee1.org.

3.3.3. Ceramic and Pulse Start Metal Halide

Metal halide in direct applications in courtrooms is not recommended primarily because of dimming constraints and the potential for color shifting in dimming applications. However, consideration should be given to metal halide in indirect applications. The newest metal halide technologies are vastly improved from prior generations of this technology. The quality of the lamps (specifically ceramic and pulse start lamps) have improved with respect to Color Rendering Index (greater than 80 CRI), color temperature (available down to 3000K), and color consistency between lamps and across life. Lamp life is long and lumen depreciation has been reduced. Electronic ballasts are also currently available. Metal halide is a very energy efficient light source and comes in a variety of wattages that can be helpful in the large spaces of a courtroom.

3.3.4. Lighting Controls

The newest lighting controls are digital, which provide for almost any type of control arrangement. Lighting controls with continuous or step dimming should be applied in the

front areas of the courtroom. When specifying lighting controls, focus should be on system integration between ballasts, controllers, and any central energy management systems that may be planned for the whole building. It is advisable to verify that the software protocols communicate reliably between the different components, especially if different manufacturers are being used. The lighting specifier should have extensive experience with the use of control systems and should have high confidence in their recommended solution. Experienced commissioning services are also critical to success.

3.4 Credentials, Certifications, Experience Review

The GSA Design Excellence program requires an LC certification (an LC indicates Lighting Certified through the National Council for Certifying the Lighting Professions), which should indeed be required and is useful as a minimum credential. The IALD (International Association of Lighting Designers) appellation should also be considered, along with a portfolio of successful lighting design applicable to courtrooms when choosing the design team. Look for extensive and proven experience with respect to daylighting and advanced lighting control systems.

3.5 Design Process and Implementation Practices

The design process is an integral element of a successful project, and even more so in sustainable design. A few suggestions will ratchet up the chance of success on a courthouse project.

- Engage lighting design services early, and have them involved as a primary team contributor to the integrated design process.
- Lighting calculations should be required, for both horizontal and vertical illuminance and the luminances of all surfaces. Calculations should be performed with the different layers of the lighting system "turned off" so that it is clear exactly how much each layer is contributing to the overall design.
- Serious consideration should be given to a virtual mock-up of the courtroom to evaluate lighting design. With the software and virtual rendering tools that are now available, it is possible to cost effectively preview the visual experience of the courtroom from all visual perspectives.
- Carefully consider any adjustments to courtroom lighting that are considered during value engineering or from contractor requests for substitutions. Substitutions to the original lighting design are risky and are not advised unless thoroughly reviewed and approved by the lighting designer. To avoid diminishing the effectiveness of the lighting design during the construction phase, proposed substitutions should be accompanied by lighting calculations that meet the original design intent.
- Commissioning services to assure compliance with the design intent should be required in the contract documents. Operations and maintenance manuals to train and educate the staff are recommended and are essential for the ongoing success of the lighting design. Where possible, try to keep lamp types to a minimum, and keep the location of the luminaires accessible for servicing by the maintenance staff. Remember that the post-installation phase is also a mission-critical part of the success of the project.

3.6 Education and Communication

To help facilitate understanding by the participants in the design process, consideration should be given to creating educational tools targeted to the needs of specific groups.

3.6.1. The Design Team

Consider a new technical report geared toward the design team, to capture many of the points found in this report and to help educate the lead architectural designer and lighting designer on the interplay and relationship between finishes and high quality, energy efficient courtroom lighting. The product should highlight successes in courtroom lighting and provide enough detail to add value to future projects.

3.6.2. The Judges

A different type of educational tool is merited for judges and other occupants of the courtroom. This document would be less technical in nature, and would address some of the most common mythologies about lighting. The information should focus on explaining the interplay between finish colors, perceived lighting, and the energy efficiency requirements of the building. The text should also explain the changes and improvements that have occurred in lighting technology, both in fixture and lamp improvements (color rendition, flicker, energy efficiency) and controls.

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4.0 Conclusion

In summary, this report has shown the need for improvements to courtroom lighting with respect to both lighting quality and energy efficiency. Newer technologies in lighting and software will provide improvements, but the human element is key. Lighting should not be considered simple, or easy, or the last thing to do on a project. Given proper respect and the right level of expertise and focus, courtroom lighting can obtain the highest quality and efficiency at the same time. Implementing the recommendations in this report will yield significant national energy savings while supporting critical courtroom tasks, reducing energy costs, and furthering compliance with the Energy Policy Act of 2005.

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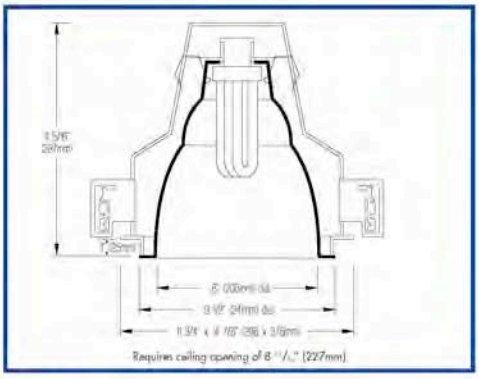
Appendix A: Example Lighting Fixture Cut

The following technical specification is presented as a sample of an appropriate energy efficient technology for use in high ceilings, and was utilized in point-by-point calculations shown in Appendix B. The product shown here is the "Triples-V 42/8" by Edison Price Lighting. Pacific Northwest National Laboratory, the General Services Administration and the U.S. Department of Energy do not specifically endorse this, or any specific product. ***This is intended as an example for illustration purposes only.***

recessed compact fluorescent downlight/wallwasher



PHOTOMETRIC REPORT

IES *Report No. 44962. Original Independent Testing Laboratories, Inc. (ITL) test report furnished upon request.*

Luminaire ..... recessed compact fluorescent downlight with spun aluminum reflector, specular finish
Lamp ..... Philips 42-watt triple-tube compact fluorescent, 4-pin GX24q-4 base, 3200 lumens
Efficiency 69.2%
Spacing Criteria ..... 0°-1.1, 90°-1.1

BALLAST INFORMATION

Voltage	*120*	*277*
Input Watts	48	48
Line Current (A)	.42	.18
Power Factor (%)	>98	>98
THD (%)	<10	<10
Min. Starting Temp* (°F)	0	0

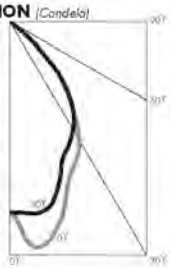
*Consult lamp manufacturers for specific temperatures.

ZONAL LUMEN SUMMARY

Zone	*Lumens*	*% Lamp*	*% Fixture*
0 - 30°	1222	38.2	55.2
0 - 40°	1831	57.2	82.7
0 - 60°	2214	69.2	100.0
0 - 90°	2214	69.2	100.0
90 -180°	0	0.0	0.0
0 -180°	2214	69.2	100.0

CANDLEPOWER DISTRIBUTION *(Candela)*

Vertical Angle	*Horizontal Angle* 0.0	45.0	90.0
0	1659	1659	1659
5	1922	1788	1672
15	1759	1676	1560
25	1357	1278	1209
35	983	978	973
45	537	503	559
55	2	2	2
65	0	0	0
75	0	0	0
85	0	0	0
90	0	0	0



LUMINANCE DATA
(Candela/m²)

Vertical Angle	*Average 0° Longitude*	*Average 90° Longitude*
45	22012	22914
55	101	101
65	0	0
75	0	0
85	0	0

To convert cd/m² to footlamberts, multiply by 0.2919.

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD
Effective Floor Cavity Reflectance 20%

Ceiling Reflectance (%)	80				70				50			30			10			0
Wall Reflectance (%)	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
Room Cavity Ratio																		
0	82	82	82	82	80	80	80	80	77	77	77	74	74	74	71	71	71	69
1	78	76	74	73	77	75	73	72	72	71	69	69	68	67	67	66	65	64
2	74	70	67	65	72	69	66	64	67	65	63	65	63	61	63	61	60	59
3	70	65	61	58	68	64	60	58	62	59	57	60	58	56	59	57	55	54
4	66	60	56	53	64	59	55	52	58	54	52	56	53	51	55	52	50	49
5	62	55	51	48	61	55	51	48	53	50	47	52	49	47	51	48	46	45
6	58	51	47	44	57	51	47	43	50	46	43	49	45	43	48	45	43	41
7	55	48	43	40	54	47	43	40	46	42	40	46	42	39	45	42	39	38
8	52	45	40	37	51	44	40	37	43	39	37	43	39	36	42	39	36	35
9	49	42	37	34	48	41	37	34	41	37	34	40	36	34	39	36	34	33
10	46	39	35	32	46	39	34	32	38	34	31	37	34	31	37	34	31	30

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Appendix B: Point-by-Point Calculations

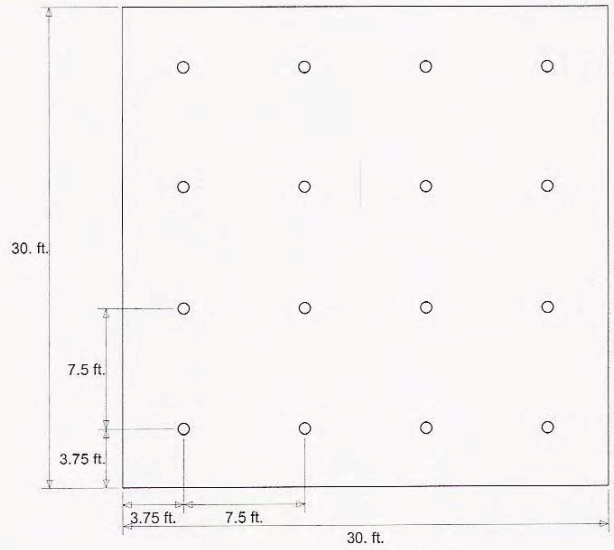
Edison Price Triples-V 42/8, at **12'-0"** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	30 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 30 fc maintained.



Reflected Ceiling Plan
Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:		2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:		
	Z: 12. ft.		Floor:	0.2	Target Illuminance:		25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:			40.5W (connected)
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

Lighting Technologies, Inc.
5171 Eldorado Spgs Dr. Boulder, CO 80303

Page 1

Calculation Grid: Workplane (Layout #1)

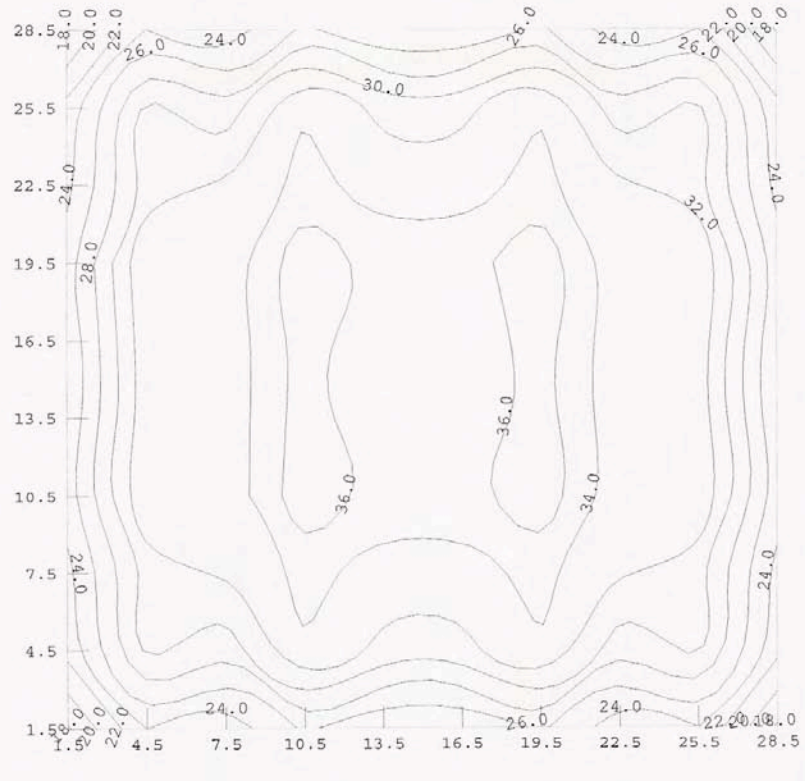
Grid Summary

Grid Properties		Statistics			
Grid Type:	Illuminance	Average:	29.7	Max/Min:	2.1
Grid Height:	2.50 ft.	Max:	37.4	Ave/Min:	1.7
Units:	English	Min:	17.8	Uniformity:	0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	18	24	23	26	24	24	26	23	24	18
25.5	23	30	29	34	31	31	34	29	30	23
22.5	23	31	32	35	33	33	35	32	31	23
19.5	25	34	33	37	35	35	37	33	34	25
16.5	24	33	33	37	34	34	37	33	33	24
13.5	24	33	33	37	34	34	37	33	33	24
10.5	25	34	33	37	35	35	37	33	34	25
7.5	23	31	32	35	33	33	35	32	31	23
4.5	23	30	29	34	31	31	34	29	30	23
1.5	18	24	23	26	24	24	26	23	24	18

Calculation Grid: Workplane (Layout #1)



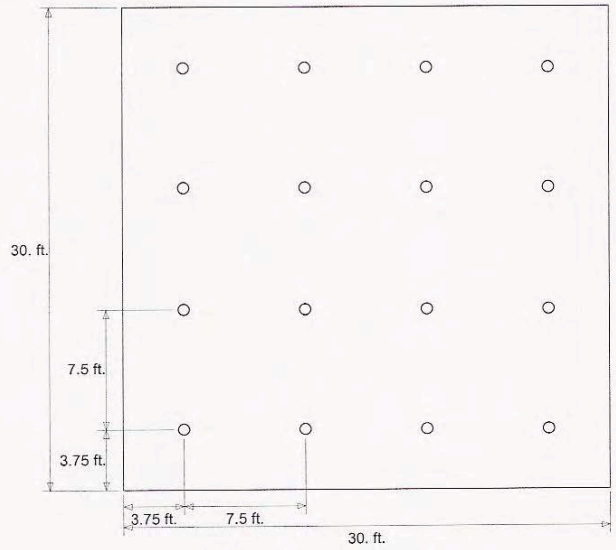
Edison Price Triples-V 42/8, **at 16'-0"** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	27 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 27 fc maintained.



Reflected Ceiling Plan
Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:	2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:	
	Z: 16. ft.		Floor:	0.2	Target Illuminance:	25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:			40.5W (connected)
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

Page 1

Calculation Grid: Workplane (Layout #1)

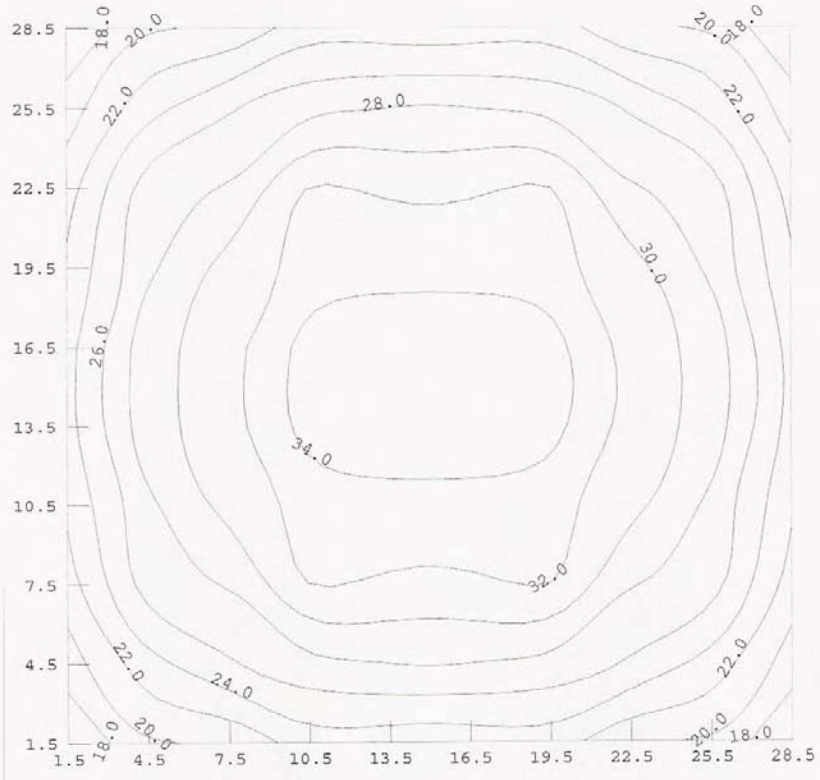
Grid Summary

Grid Properties		Statistics			
Grid Type:	Illuminance	Average:	26.6	Max/Min:	2.2
Grid Height:	2.50 ft.	Max:	34.8	Ave/Min:	1.7
Units:	English	Min:	16.1	Uniformity:	0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	16	20	20	23	23	23	23	20	20	16
25.5	19	23	26	27	28	28	27	26	23	19
22.5	21	27	28	32	32	32	32	28	27	21
19.5	22	28	31	33	34	34	33	31	28	22
16.5	23	29	31	35	35	35	35	31	29	23
13.5	23	29	31	35	35	35	35	31	29	23
10.5	22	28	31	33	34	34	33	31	28	22
7.5	21	27	28	32	32	32	32	28	27	21
4.5	19	23	26	27	28	28	27	26	23	19
1.5	16	20	20	23	23	23	23	20	20	16

Calculation Grid: Workplane (Layout #1)



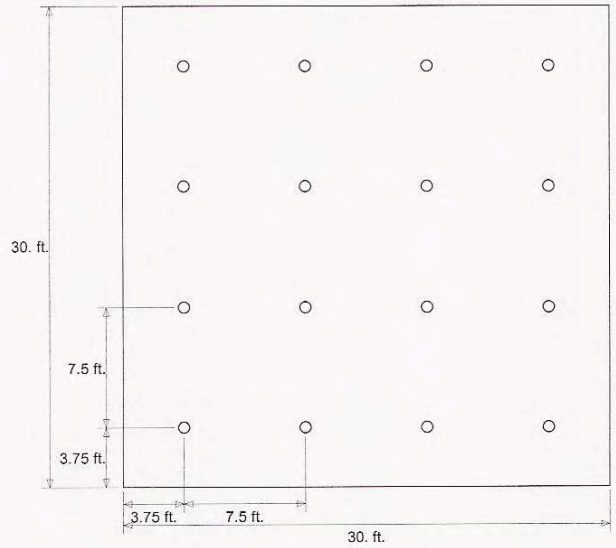
Edison Price Triples-V 42/8, **at 20'-0"** Above Finished Floor

Summary for Layout #1: Ttt842.ies

Results

Average Illuminance:	24 fc	# of Rows:	4
Unit Power Density (UPD):	0.72 W/ft²	Row Spacing:	7.5 ft.
Spacing Criteria:	Acceptable	# of Cols:	4
		Col. Spacing:	7.5 ft.

16 luminaires provide 24 fc maintained.



Reflected Ceiling Plan
Scale: 0.12 in. = 1 ft.

Room Characteristics

Dimensions:	X: 30. ft.	Reflectances:	Ceiling:	0.8	Work Plane Height:	2.5 ft.
	Y: 30. ft.		Walls:	0.5	Target UPD:	
	Z: 20. ft.		Floor:	0.2	Target Illuminance:	25 fc

Luminaire Characteristics

Luminaire Description: Ttt842.ies

Suspension Length:	0.000 ft.	Wattage:		40.5W (connected)	
Total Light Loss Factor:	0.77	Aiming:	O: 0°	T: 0°	S: 0°
Efficiency:	69.2 %				

Lamp Description: One 42W triple-tube 4-pin

Lamps Per Luminaire:	1	Lamp Lumens:	3,200

Page 1

Calculation Grid: Workplane (Layout #1)

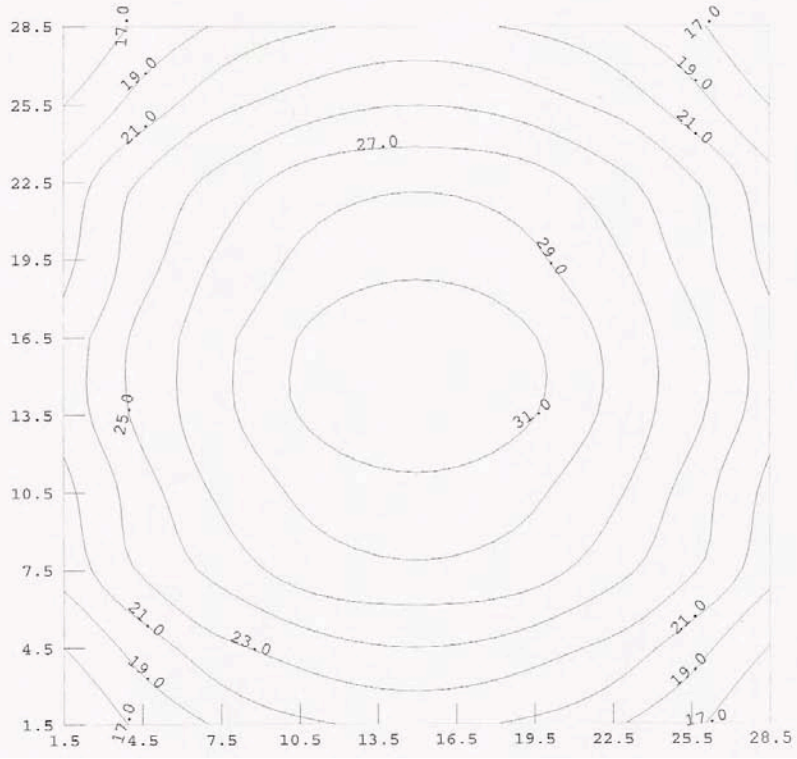
Grid Summary

Grid Properties		Statistics			
Grid Type:	Illuminance	Average:	23.9	Max/Min:	2.1
Grid Height:	2.50 ft.	Max:	32.1	Ave/Min:	1.6
Units:	English	Min:	15.1	Uniformity:	0.6

Grid Values

	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5	28.5
28.5	15	17	19	21	21	21	21	19	17	15
25.5	17	20	23	24	25	25	24	23	20	17
22.5	20	23	26	28	29	29	28	26	23	20
19.5	20	24	27	29	30	30	29	27	24	20
16.5	22	26	28	31	32	32	31	28	26	22
13.5	22	26	28	31	32	32	31	28	26	22
10.5	20	24	27	29	30	30	29	27	24	20
7.5	20	23	26	28	29	29	28	26	23	20
4.5	17	20	23	24	25	25	24	23	20	17
1.5	15	17	19	21	21	21	21	19	17	15

Calculation Grid: Workplane (Layout #1)



Appendix C: Comparison of Component vs. System Efficiencies

	Edison Price Triples-V 42/8 Vertical Triple 42 Watt CFL	Edison Price Triples-H 142/8 Horizontal Triple 42 Watt CFL	Edison Price Triples-H 242/8 Horizontal Double 42 Watt CFL	Edison Price Darklite 38/7 PAR38 100 Watt HIR	Edison Price Arclite 38/7 PAR38 70 Watt MH
Lamp lumens	3,200	3,200	6,400	2,070	6,700
Mean lumens	2,752	2,752	5,504	N/A	N/A
Lamp Lumen Depreciation	0.86	0.86	0.86	1.00	1.00
Ballast Factor	1.00	1.00	1.00	1.00	1.00
Lamp Lumen Factor	1.00	1.00	1.00	1.19	0.78
Luminaire Dirt Depreciation	0.89	0.89	0.89	0.89	0.89
LIGHT LOSS FACTORS	0.77	0.77	0.77	1.06	0.70
Center Beam Candlepower	N/A	N/A	N/A	6,300	16,000
CRI	82	82	82	100	85
CCT	3000-3500	3000-3500	3000-3500	2700-3000	3000
Lamp Life	12,000	12,000	12,000	3,000	10,000
Input watts	49	49	92	100	79
Lamp-Ballast Efficiency, lumens/watt	65	65	69	100	88
Fixture Efficiency (FE)	69.2	69.0	60.9	82.3	88.2
System Efficiency (FE+LLD+BF+LDD)	53.0	52.8	46.6	73.2	78.5
Fixture Zonal Lumens 0-30 degrees	38	29	27	79	84
Fixture Zonal Lumens 0-40 degrees	57	51	45	81	87
Fixture Zonal Lumens 0-60 degrees	69	69	61	82	88
Candlepower Distribution					
at Vertical Angle... 0	1659	934	1865	6338	10006
5	1922	902	1824	5374	8753
15	1759	839	1863	3298	6803
25	1357	963	1874	579	1969
35	983	836	1535	57	238
45	537	506	1031	6	31
55	2	7	21	2	0
65	0	0	2	0	0
75	0	0	0	0	0
85	0	0	0	0	0
90	0	0	0	0	0
Total	8219	4987	10015	15654	27801

Notes

(1)The cut sheet for Darklite 38/7 shows candlepower values for a 100-watt HIR, but the photometric report uses an old Q150 lamp with 1735 lumens. We used a Lamp Lumen Factor of 1.19 to bring the lamp lumens up to 2,070 lumens for the 100 HIR.

(2) The ballast for the 42-watt triple tube lamp is Sylvania Quicktronic Electronic CF DALI 51384, QTP 1x42CF/UNV DALI, 120-277, 42W DT/E, 3200 lumens, 1 lamp, 49 input watts, 65 lumens/watt..

(3) The ballast for the (2) 42-watt triple tube lamps is Sylvania Quicktronic Electronic CF DALI 51386, QTP 2x42CF/UNV DALI, 120-277, 42W DT/E, 3200 lumens, 2 lamp, 6400 lumens, 92 input watts, 69 lumens/watt.

(4) The ballast for the 70-watt PAR 38 Metal Halide lamp is Sylvania Quicktronic MH, 51913, QTP 1x70MH/UNV-J, 120-277, 70W T6, 6700 lumens, BF 1.0, 79 input watts, 88 lumens/watt.

(5) The candlepower values shown for the 70-watt metal halide are adjusted for accuracy using a Lamp Lumen Factor. The photometric report is for a 100 watt lamp, so we used a factor of .78 to take the candlepower values down to a 70-watt lamp.

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Appendix D: Building Life-Cycle Cost Comparative Analysis

NIST BLCC 5.3-05: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: existing

Alternative: Lighting Retrofit

General Information

File Name:	C:\Program Files\BLCC5\projects\Courtroom lighting-2.xml
Date of Study:	Mon Mar 06 16:32:56 PST 2006
Project Name:	Courtroom Lighting
Project Location:	U.S. Average
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	EER
Base Date:	January 1, 2006
Service Date:	January 1, 2006
Study Period:	25 years 0 months(January 1, 2006 through December 31, 2030)
Discount Rate:	3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$9,961	-$9,961
Future Costs:			
Energy Consumption Costs	$54,236	$25,846	$28,390
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$34,068	$6,992	$27,076
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0

Subtotal (for Future Cost Items)	$88,303	$32,838	$55,466
Total PV Life-Cycle Cost	$88,303	$42,799	$45,505

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$55,466
- Increased Total Investment	$9,961
Net Savings	$45,505

Savings-to-Investment Ratio (SIR)

SIR = 5.57

Adjusted Internal Rate of Return

AIRR = 10.32%

Payback Period

Estimated Years to Payback (from beginning of Service Period)

Simple Payback occurs in year	4
Discounted Payback occurs in year	4

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	Average Annual Consumption			Life-Cycle Savings
	Base Case	Alternative	Savings	
Electricity	40,622.0 kWh	19,358.0 kWh	21,264.0 kWh	531,527.2 kWh

Energy Savings Summary (in MBtu)

Energy Type	Average Annual Consumption			Life-Cycle Savings
	Base Case	Alternative	Savings	

Electricity	138.6 MBtu	66.1 MBtu	72.6 MBtu	1,813.6 MBtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO2	35,958.27 kg	17,135.55 kg	18,822.72 kg	470,503.64 kg
SO2	93.12 kg	44.38 kg	48.75 kg	1,218.48 kg
NOx	75.47 kg	35.96 kg	39.51 kg	987.50 kg
Total:				
CO2	35,958.27 kg	17,135.55 kg	18,822.72 kg	470,503.64 kg
SO2	93.12 kg	44.38 kg	48.75 kg	1,218.48 kg
NOx	75.47 kg	35.96 kg	39.51 kg	987.50 kg

U.S. General Services Administration
Public Buildings Service
Office of Applied Science
1800 F Street, NW
Washington. DC 20405