STUDY OF MUSEUM LIGHTING AND DESIGN

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STUDY OF MUSEUM LIGHTING AND DESIGN

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By

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ABSTRACT

A museum is a place to discover, explore and learn about the past, present and future of creativity, as well as history. Lighting plays a significant role in developing interaction between humans and museum artifacts in one defined space. " Museums are places where lighting design is critical to the overall experience"(Lowe,43, 2009). Lighting is essential for human interaction in a space. Technical illumination research lays a foundation to conduct analysis in a variety of museums. This research component is significant to understand the complexity and various facets of overall museum lighting design. This study evaluates both the quantitative and qualitative aspects of lighting design in four museums. Psychological, physiological and experiential components are observed in these museums' environments to analyze lighting design within its exhibits. My observations and knowledge gained by studying these museums help influence and enhance the design of the Cedar Hill Museum of History.

DEDICATION

This Honor Thesis is dedicated in memory of my mother, Carolyn T. Hunt. She instilled in me the idea that we live a short time on Earth. She often said, "We are given talents that we must give back to the community and help others." The Cedar Hill Museum of History lighting design is a reflection of how she contributed to the community of Cedar Hill and helped mold the community into what is today.

My mother inspired me to explore my creativity as child. With this inspiration, I have followed my passion of designing and teaching. I would not be the outgoing person that I am without her constant love, patience and strength.

In addition to my mother, Harry Duff Hunt III and Kristofer Duff Hunt are two personal heroes who have given me endless amounts of love, support and encouragement to be the best "Busybeth" that I can be.

And, finally, I am very grateful for Dr. Asha Hegde Neizgoda. She came into my life at a critical time when I was struggling with how I fit into the "design world." She is a life-changing mentor who has given me opportunities for self discovery and personal growth. Dr. Neizgoda has challenged me to open my eyes to my passion– Lighting Design.

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Introduction

The purpose of my thesis is to study qualitative and quantitative aspects of museum lighting design in existing installations. The museum design will guide the visitors to discover, explore and learn about history in a creative environment. Lighting plays a significant role in developing interaction between humans and museum artifacts in one defined space." The goal of a museum is to create an interactive experience for the guests, as well as preserve the condition of artifacts.

Lighting is a critical component in a museum environment because the space enables visitors to see objects, experience new sights and react to the surrounding environment. Typically, environments have two types of light–natural and artificial. For a museum, the role of light is an essential part of creating an atmosphere prime for discovery, while also preserving artifacts. This can be a very difficult balancing act between meeting preservation needs and forming interactive experiences that achieve the goal of the museum–a place to discover, explore and learn. Illumination Engineering Society of North America (IESNA) provides parameters and standards for lighting design in a museum to ensure safety, preserve artifacts, and create an interactive experience for guests of all ages. A brief review of literature will help understand this thesis. The literature encompasses qualitative as well as quantitative aspects of lighting in a museum.

Daylight

Museum designs incorporate daylight because humans relate to nature. "Natural Light can be used to great effect to dramatize and enliven the design of

any building (De Chiara, 690, 2007). Light defines a space within a building's design. Daylight always fluctuates and often is fused in interactive spaces. Cloud cover, season, the time of day and a building's position are factors directly impacting lighting design and how humans experience the space. The amount of daylight penetrating the museum interior must be given serious consideration to understand how natural light impacts the space. Factors such as reflection, glare, acclimation and delineation in the space should be analyzed closely. IESNA has researched and made factors that "affect the final luminance produced by architectural surfaces and daylight" (RP-30-96, 30, 1996). Scale and proportion are important considerations. The "ceiling height and room depth" directly correlate to the amount of daylight absorbed and explore the intent of light in the space (RP-30-96, 30, 1996). Various heights and room depths also can affect human perception of space. The amount of daylight and how natural light is filtered into a space will create several different effects in a specific space. For example, if a room is small with high ceilings and a punch of daylight, it will be perceived as being larger. If a room is large with low ceilings and little daylight, the space can feel confined and stagnant. The placement of windows or glazings and the available amount of natural light gives the design variety. "Reflecting characteristics of the interior surfaces" is another factor with IESNA standards. Interior materials and finishes should be selected to contribute to the overall aesthetic of the space. When daylight is introduced in a space, interior finishes can create more reflective surfaces and cause a negative effect. Materials and finishes that are too shiny or reflective create glare. If there is glare or too much reflective light, guests may experience discomfort while interacting in the museum, and their

experience will be greatly altered. Lighting design needs to encompass the dynamics of daylight and use light properly to assist in creating an interactive and comfortable museum experience.

While daylight adds to the overall ambiance of the space, this light has negative impact on artifacts. Thus, daylight and preservation of artifacts usually conflict and must sometimes compromise for a museum design's sake. Natural light has a high light output and contains very high concentrations of Ultraviolet rays. These UV rays are known to damage textiles and artifacts. In addition, light exposure will affect artifacts. IESNA standards range from five to 30 foot-candles depending on the type of artifact (RP-30-96, 14, 1996).

In the Bob Bullock Texas State Museum of History in Austin, Texas, artifacts are all borrowed and not owned by the museum, says Mr. Lindgren, a lighting and exhibit technician. Mr. Lindgren also says that the museum is more sensitive to light levels on documents and artifacts and the museum has to be very careful with preservation. Mr. Lindgren tries to protect the museums' contents and keeps light levels closer to four to five fc because the museum does not own them (Lindgren, 2009). When artifacts are made of metal or leather, light levels can be higher. Therefore, artifacts and the museum dictate how daylight can be used in the space.

Artificial Illumination

Several types of artificial light sources are used in interior applications to provide light for visibility, tasks, accent and decoration. Typical interior artificial light sources include incandescent, fluorescent, HID, fiber optics, cold cathode and

LEDs. Incandescent lamps are generally used for ambient and accent lighting with track luminaires. In museums, incandescent, fiber optic and HID are the most common light sources.

According to IESNA standards for museums, compact fluorescents, tungsten Halogen, HID and PARs are the most common for general lighting. With indirect lighting, fluorescent lamps are used to diffuse illumination quality. Accent lighting include PAR-type incandescent and tungsten halogen. Incandescent, compact fluorescent, tungsten halogen, metal halide and fiber optic are recommended to use in case, cabinet and under-shelf lighting. Flood lighting typically consists of recessed down lights or track-mounted fixtures with incandescent, tungsten halogen and HID light sources (RP-30-96, 44, 1996). The location and purpose of the light, along with the type of light source, become crucial in providing the correct amount of light and the lamp properties for interior applications in the museum.

Light Levels

Light levels are based on the visibility as well as the accessibility in the museum space. The quantitative measurements of light in museums are determined by the exhibit type, collection, storage and handling. In the IESNA's required light levels, collection storage is five footcandles and collection handling is twenty to fifty footcandles. The type of artifacts in the museum is a significant detail in order to establish the amount of light level and light exposure to the objects. The overall objective in a museum's lighting design is to light individual objects with consideration to the sensitivity of the object and how guests will view it. If the

exhibit is very sensitive, the footcandle requirement ranges from five to ten. Sensitive objects have fifteen to twenty footcandles. Less sensitive objects can have thirty to fifty footcandles (De Chiara, 690, 2007).

Another factor in lighting a museum is the accessible light levels throughout the exhibits ranges from five to thirty footcandles. Guests' safety and preservation of artifacts are critical in an exhibit's design. (RP-30-96, 10, 1996). Ambient lighting usually consists of five to 30 footcandles. Within the interior space, ramps and stairs, visitor pathways and text panels all are required to be ten to thirty footcandles. Direct signage is twenty to thirty footcandles (RP-30-96, 11, 1996).

The age of viewers and light levels directly impact the experience of the museum. An individual less than forty years old needs five to twenty fc to adequately see details within an interior space. While older adults need a minimum of ten fc. (RP-30-96, 12, 1996).

Styles of Luminaires

Luminaires are characterized by the way light is distributed. "Light fixtures are the luminaires that are permanently attached to the building" (Karlen, 13, 2004). There are several other luminaire types including: direct, indirect, diffuse, direct/indirect, asymmetric uprights, downlights and adjustable.

> Direct luminaires emit light downward. These include most types of recessed lighting with downlights and troffers.
>
> Indirect luminaires emit light upward that bounces from the ceiling into a space. Many styles include suspended luminaires, sconces and some portable lamps.
>
> Diffuse luminaires emit light in all directions uniformly. These include most bare lamps, globes and chandeliers.

Direct/indirect luminaires emit light upward and downward, but not to the side. These include many types of suspended luminaires as well as table lamps. Direct/ indirect also can be semi-direct or semi-indirect according to the proportions of up and down light.

Asymmetric luminaires are usually designed for special applications. Asymmetric uplights are indirect luminaires with stronger distribution in one direction, such as away from a wall. Wall washers are form of direct luminaire with stronger distribution to one side so as to illuminate a wall.

Adjustable luminaires are generally direct luminaires that can be adjusted to throw light in directions other than down. These include track lights, floodlights and accent lights. (Karlen, 13, 2004).

Visual Adaptation and Accommodation

The human eye is highly adaptive. The eye has the ability to perceive things and operate under very bright lighting conditions, as well as adapt to moonlight and mid-day sunlight. This unique ability is called adaption. Visual adaption is the amount of time it takes a human eye to acclimatize to new surroundings. The eye also has the ability to change shape to focus on objects and make meaning out of the information received. This process is called accommodation. Changes from high to low luminance can affect guests in the museum depending on age and visual difficulties. In order for a human to see an object and its details, a lighting designer needs to analyze how the guests will interact with the exhibits to properly take visual adaptation into consideration. "There are limits to the range of luminance that the eye can adapt to at any one time, and areas where brightness is too high will become glare, might it difficult to see the exhibit" (Wilson, 32). This process is not instantaneous. "Adaptation is eight minutes adequate for the eye to adapt and one hours in extreme conditions between high to low light levels" (RP-30-96, 12 & 59, 1996). IESNA also suggests another criterion of observation that says the

"display of the objects should be the brightest elements in view" (RP-30-96 59, 1996). The smaller or more detailed an object is, the more light is required. Therefore, the human eye has the ability to be very receptive to light, but the amount of luminance and difference from one level to another is a significant factor in lighting of a museum.

Glare

In addition to visual adaptation, eyes can perceive conditions that are too bright and cause discomfort. "Glare is the bright light that can interfere with visual perception (Egan, 27, 2002). There are two types of glare. Direct glare is the bright light source directly impacting the field of vision. This includes a fixture aimed in direct line of sight. Reflective glare is the reflection of an image from a light source on specific shiny surfaces. An example of this would include a down light aimed on the granite floor that makes a bright spot (Egan, 27, 2002). In museums, glare can cause severe problems and interfere with the interactive experience. In the Bob Bullock Texas State Museum of History to alleviate glare problems, Mr. Lingren explained to the issue with glare and the challenge to highlight display cases without glare or shadowing. The light sources must be farther away from the case with a wide flood fixture to widely disperse the light without direct aim on the glass case (Lingren, 2009).

LIGHTING DESIGN CONSIDERATIONS

To have a successful lighting design, lighting designers have particular considerations that affect lighting on space, objects, and purpose. Color rendered, color temperature, texture, form, viewing angles, layered light and maintenance are all factors that contribute to the whole. An understanding of these factors allows the lighting designer to fuse lighting elements with an architectural designed space to create an effective and functional design for humans to interests and experience the space.

Color Rendering Index

Color Rendering Index (CRI) describes the true hue that appears from a light source. The scale is from zero to 100. Natural light is 100, which has the best color rendering properties. CRI is critical depending on the intent of the space. Retail, work spaces and museums need a high CRI for the human eye to react favorably. The Lighting Basics Design suggests 80-100 CRI for work, retail and museum spaces. In the context of interior museums, the displays and exhibits should have a high CRI and general lighting can have a lower CRI (Karlen, 4-5, 2004).

In addition to CRI, color consistency should be evaluated in interior spaces. In a museum, color consistency is very important for exhibits and displays to appear true to color. The materials and finishes will appear different under different types of artificial light sources. Within museums, the artifacts and displays are the primary focus. The background color or color surrounding the objects can alter the color viewed on the artifacts (RP-30-96, 12, 1996). "Color rendition depends on the lamp

color spectrum, reflective properties of the surface and context" (Egan, 80, 2002). The context relates to the experience and expectations of the individual with normal color vision. Museums' goals are to preserve artifacts and educate viewers about the historical past. The lighting designer must understand the intent and use of color within the space to accent or maintain the experiential effect in the exhibit (RP-30-96, 12, 1996). Incandescent lamps render red and yellow hues more truly than blue. Under an incandescent lamp, blue will appear dull blue, red will be a bright red and yellow will be a bright yellow. Fluorescent lamps have higher color rendering concentrations. Therefore, red, blue and yellow appear the same as the true hue (Egan, 80, 2002). Several lamp types can compensate for color shifting and distortion. The museum lighting designs success includes the correct use of color and how lighting can impact that use of color.

Color Temperature

Color temperature is another factor for lighting design that explains how light appears warm or cool. Kelvin is the appropriate unit for color temperature with a scale from zero to 8,000K. Warm light ranges from yellow to red-tinted light that is in the range of 2,500 to 3,500K. This color temperature is perceived as being "warm and cozy." High pressure sodium and incandescent lighting fall in the warm color temperature range, as well as lighting ranges from 2,950 to 4,100K (Karlen, 5, 2004). Cool light is observed as blue to white hues. A cold and sterile "feeling" is usually associated with 3,600 to 8,000K. The higher color temperature is suggested in special-applications lighting where color discrimination is significant (Karlen, 5, 2004).

Form, Texture, & Artifacts

Architects and Interior Designers create structures and spaces to impact buildings. Most viewers are affected by lighting in positive or negative ways, but cannot explain what made the positive or negative experience. Using the correct angles of light to highlight architectural details is essential for a lighting designer to do in order to enrich the experience. In addition to materials and finishes, ceilings, walls, floors, and other features can become surprise elements for lighting in a space. When the lighting and architecture are not compatible, the viewer feels the negative experience by noticing glare, the brightness or darkness of an exhibit and how easy it is to see artifacts.

In a museum, these forms and textures are critical to light, as well as artifacts. The angles of the luminaries and viewing angles are considered for museum lighting design. According to IENSA standards, luminaires are aimed at a steep angle, zero to twenty degrees in front of the surface to emphasize the texture or design details (RP-30-96, 12, 1996). "The two or more luminaires are aimed at 30 degree angle to highlight 3-D form of an artifact or architecture. With 2-D objects, luminaries are aimed at 30 degrees from the vertical to produce minimal shadows, glare free viewing" (RP-30-96, 12, 1996). The viewing angles are "measured from a point at the wall and 5.4 ft about the finish floor should be forty-five and seven-five degree from the horizontal to the lamp position in the light fixture" (Figure 1 and 2) (De Chiara, 690, 2007). For permanent objects or free-standing displays, the lamp position is ideally from sixty to seventy degrees (De Chiara, 690,2007) (Figure 3). Therefore, luminaire tilt, lamp position and viewing angle contribute to museum

lighting design. The IESNA standards provide standards for lighting that allow the guests to see the forms and textures.

Layering Light

Lighting design achieves composition and understanding visual aesthetics by layering light. Each layer lights certain tasks. All the layers work together to create a whole, cohesive design (Karlen, 56, 2007). In museum lighting design, the ambient, task, focal, and decorative are all layers that contribute to the overall aesthetic of a space. Ambient layering is the overall lighting of a room. This type of lighting allows one the ability to move through space and is significantly lower than task light levels. Task layer is lighting used to perform work, including reading or writing. Downlights or pendants are common forms of task lighting. With a low ambient and high task light level, the space will have a more dramatic feeling. High ambient and task light levels create a more relaxing and cheerful focus. Focal layers are primarily used for highlighting features or displays. Architecture, artwork, retail displays and signage are emphasized by focal lighting. The main idea behind focal lighting is to draw attention to the object or detail and not the light itself. Track lighting is a common type of focal lighting. Decorative layers are considered the "jewelry of architecture." This layer is ornamentation in the space and not a light source. Chandeliers, sconces, lanterns, pendants, lamps and surface lights are all decorative luminaires (Karlen, 56-57, 2007). These combinations of layers, with different light levels, create a complete lighting system. All of these layers should be in place to achieve a successful museum lighting system.

Maintenance

Lighting design is often very complex, but reducing the number of different lamps and using multipurpose luminaries assists in maintaining a successful lighting design. When selecting luminaires, Storage space and reordering costs need to be taken into account. The Bob Bullock Texas Museum of History uses track lighting with three to five different luminaries: downlights, spots and floods. This allows flexibility for aiming the light and creating adjustments for the museum. The museum also only has six different lamp types (Lindgren, 2009). In the San Antonio Museum of Art and Nasher Sculpture Center, track lighting and downlights are the only light sources. In addition to lamps and luminaires, the location of luminaires is important for replacement of lamps and re-aiming luminaires. Mr. Lindgren explained that lamps will have to be changed and luminaires may be located far from the exhibit. The distance is due to some of the exhibits being permanent or are difficult to relocate. In order to maintain the integrity of the lighting museum design, the maintenance of the luminaires and lamps must be easy to access and change.

MUSEUM ANALYSIS

Method & Procedure

Museum visitations are a critical component to the analysis of this thesis. The purpose of the museum analysis is to experience several different types of museums, observe the visual effects of lighting in interior spaces, compare lighting aesthetics and visual features, record light levels, and, finally, assess the differences and similarities that inspire the lighting design of the Cedar Hill Museum of History. Nasher Sculpture Center in Dallas, Texas; Bob Bullock Texas State Museum of History in Austin, Texas; San Antonio Museum of Art in San Antonio, Texas; and Modern Art Museum of Fort Worth in Fort Worth, Texas were visited and analyzed for this thesis. A quantitative light measurement was conducted in the Nasher Sculpture Center and Bob Bullock Texas State Museum of History as well as the display areas. The measurements were taken with a light meter model: Ideal-Sperry 61-680. Light readings were recorded in several parts of the exhibits and displays. The measurements were taken on a sketched elevation or floor plan diagram of the specific area with the type of light source, fixture type and numeric value in footcandles. In addition to the quantitative measurements, a qualitative assessment was performed in all visited museums. The qualitative criteria included: the overall aesthetic and interactive experience of the museum, psychological and physiological facets, natural and artificial light design and ambiance within each exhibit. These qualitative attributes were analyzed and contributed to the lighting design of Cedar Hill Museum of History.

Nasher Sculpture Center

Nasher Sculpture Center is a magnificent collection of sculpture and three-dimensional arts in an interior and garden gallery. The architecture and garden embrace the works. Renzo Piano designed the center, which consists of a 55,000-square foot space with four acres of garden space. The goal of the center is to have a sustainable place that will let the Nasher collection live timelessly. With the use of daylight and natural stone architectural elements, the Nasher Sculpture Center definitely achieves a contrasting Zen feeling to the "rush and bustle" of downtown Dallas. The garden also radiates calm and peacefulness, helping visitors connect with the natural space.

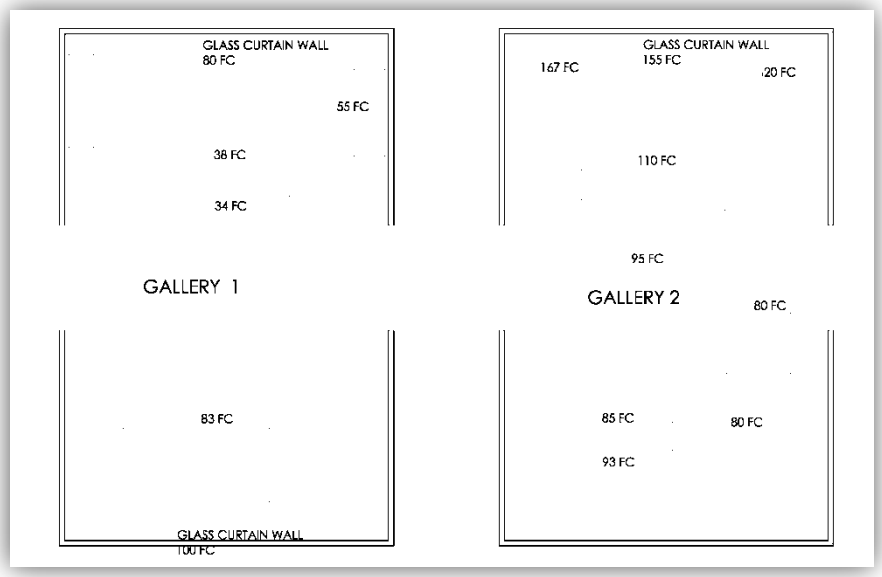
The Nasher Center's architecture and lighting elements directly invite the viewer to experience the exhibits and art. The use of daylight is the significant effect, which evokes a Zen- calming emotion in this space. Daylight is difficult to incorporate into a space because of the unpredictability of the weather and climate–winter light, summer sunlight and an overcast day all emit different color and light levels. Renzo conducted studies of daylight to assess different light levels and understand how to compensate for differences. The creation of "glass ceiling" with specialized aluminum screen is the architectural feature that influences the experience in the museum. "Building upon the concept of a 'museum without a roof,' the building's barrel-vaulted ceiling features delicate glass panes suspended atop narrow steel ribs and supported by thin, stainless steel rods. The innovative cast aluminum sunscreen device - specially designed for this project -floats above

the glass allowing controlled natural light to filter into the galleries, eliminating the need for artificial illumination much of the time" (Nasher, 2009). The glass ceiling-less permits a very even soft pool of light into in museum. Even though the light levels were very high, the feeling was not harsh or too bright. It is very soothing and relaxing for guests to interact in the space. In return, the space itself invites visitors to engage with the artwork. Due to the presence of daylight and simple décor, the sculptures are the emphasized.

In addition to the glass ceiling-less system, glass curtain walls are on the north and south side of the museum. The east and west walls are white Italian travertine with a matte finish. These galleries had a range of one hundred fifty-five footcandles to eighty footcandles (see Figure 3). The play of artificial and natural light is evident with the varying light levels in both Galleries. In Gallery 1 (figure 3), the glass ceiling and curtain walls are providing most of the light for the artwork. Depending of the location of artwork, the light levels fluctuate because the daylight is the primary source for highlighting the art. In contrast, Gallery 2 (figure 4), artificial light contributes the even light levels throughout the space and displays. The higher footcandles are directly related to eastern and western glass curtain walls that allow the daylight to pour into the space. Even though the artwork in the middle of Gallery 2 has lower light levels, the artificial light highlights the surfaces to create a visual effect for viewer to be drawn to each sculpture. In Figure 5, the vertical surfaces have very low light levels to dramatize the displays. In Display 1, a narrow spot punches the background and floods provide the ambient light. Although the range of 7.2 to 3.4 footcandles is a little variance, the background comes alive for the viewer to interact with the scene within the display. The

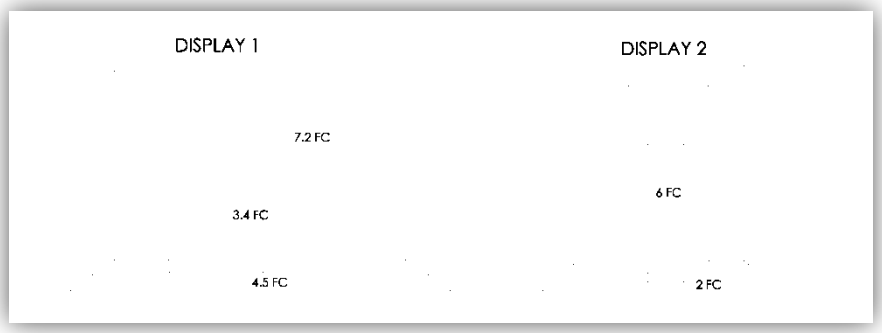
gradual differences in light levels forces eye movement throughout the art. In contrast with Display 1, the Display 2 has layered vertical surfaces with the foreground is emphasized with six footcandles compared to the background of two footcandles. Visually, the viewer is focused on the details in the foreground and this does not allow the eye to observe the entire artwork.

Figure 4



(Hunt, 2009)

Figure 5



(Hunt, 2009)

In conclusion, the Nasher Sculpture Center is a dynamic gallery space in the heart of Dallas with a subdued Zen architecture and sculpture garden. The garden is uniquely designed for interaction of nature and art. The viewer is given an information guide, which intrigues the patron to interact with art and artist's intent. The written description leads the viewers to each piece throughout the garden. The paper guide also promotes variety of options of how the viewer wants to reflect, connect and experience art. Each artist's inspiration, historical background and personal quote are elements that excite the patron about the work and enrich the experience. In the Nasher Sculpture Center, each label preserves particular elements for the art to relate to viewers in timeless place

The Bob Bullock Texas State History Museum

The Bob Bullock Texas History Museum is a museum that explains the story of Texas. E. Verner Johnson and Associates designed an interactive experiential museum that tells of the story of Texas narrative form. The museum immediately sets a dramatic, intimate tone. With three floors, the light levels are very low throughout the museum. Décor explains each exhibit while the lighting emphasizes facets

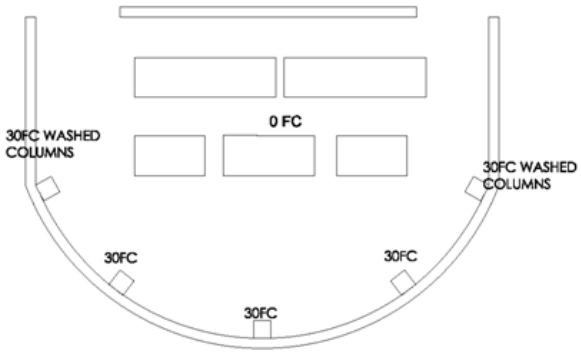
within the exhibit. The color palette is simple, natural tones of maroons, greens, dark blues and browns. The paint was eggshell with suede or linen backgrounds in the displays to the artifacts to be emphasized. The Bob Bullock Texas State History Museum targets all ages to have a unique experience through Texas history.

The first floor depicts the land before Texas as a state. Several lighting techniques provide dimension to these exhibits. Layering of light with lumanaire types is the overall striking effect is a fusion of track spots, down light cans and fiber optics for viewers to be drawn into the exhibit. The varying light levels create movement throughout the first floor. One area is thirty to forty footcandles, while the next exhibit is ten to fifteen footcandles. The cabin and teepee area had completely different color and light levels to illustrate the cozy, comforting feeling as the view was at a typical, early-Texas home. Therefore, the lighting provides a path for docents to experience each area and psychologically make a connection throughout the first floor.

"Building the Lone Star identity" is the theme for the second floor. This floor is more interactive and experiential by walking through exhibits. The "Building the Lone Star Identity" was a walk-through exhibit with soft dimmed light to feel confined and in a controlled prison environment. The lighting design creates a scary and mysterious unknown feeling. "Nation becomes a State" is an exhibit that represents a steamboat. The layering of light is contrasting with highlights and spots on elements of the steamboat. Wandering through the exhibits, the décor and lighting depicts each scene, which directly impacts visitors and indirectly forces the viewers to experience the history.

The “Centennial Theater” represents 1930’s old theater. In Figure 6, the uplight columns are washed, which is the only light in the space. The contrast of zero to thirty footcandles creates the experience as if a visitor was in a theater watching history unfold. The light adaptation is a safety concern. Once the eyes adjusted to the light level difference, the focus was on the historical information.

Figure 6



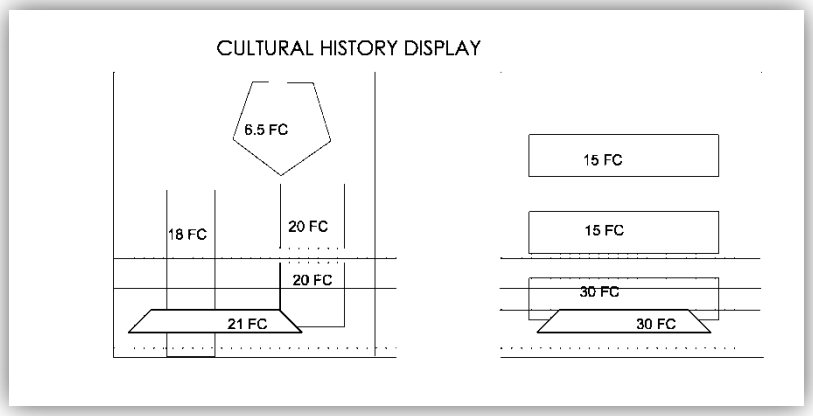
(Hunt, 2009)

Finally, the third floor is "Creating Opportunity.” These exhibits explore the different types of commerce and how cities flourished in Texas and the United States. Each area has special lighting requirement due to the variety of artifacts and displays. The variety of historical areas varies from a NASA control panel to a ranching scene to oil tanks to an airplane on the third floor. The "Oil Tank Theater" presents how the oil industry changed Texas. The theater had very low levels of light with punches of light on the signage and gas pumps to incorporate theme of history of Texas oil. Within the décor, several televisions play a movie, which

completes the experience of understanding Texas Oil. The lighting is effective because guests have to focus on the story of oil. In "Texas and Nation," the lighting is consistent and there are higher light levels of forty to fifty footcandles. The displays and artifacts were much larger in scale compared to the other areas of the museum. Safety is a significant factor in the lighting of the space. The lighting did not have glare or dramatic shadows.

Another area of the third floor is "Land of Opportunity" that displays of history of immigrants and different cultural influences in Texas. In Figure 7, this display is made of vertical, flat surfaces with narrow spots emphasizing photographs and information. The different light levels and layering of light give the display a hierarchy of importance of the information. In this display, information plaques have the highest footcandles with downlights highlighting the information for guests to read. The information at eye level is also higher light levels. The lighting design is the critical component to this display because it directs the eye to follow the main concept of the display.

Figure 7



(Hunt, 2009)

The San Antonio Museum of Art

The San Antonio Museum of Art converted the Lone Star Brewery to house a variety of artworks from all cultures from ancient to present periods. The unique collection contains Pre-Columbian to Egyptian to Asian to European artifacts. The San Antonio Museum of Art is over 55,000 square feet with four levels. The overall aesthetic of the museum was to create a unique experience combining industrial brewery with cultural and historical artifacts. The areas are divided by cultures and civilizations of the world. Each different civilization is represented by a distinctive color with historical timelines and information.

The lighting design was tailored to each area. Some exhibits feature very low levels of light for a dramatic effect inside the displays. In contrast, sunlight contributes to the feeling and mood of the area. The Pre-Colombian exhibit is similar to the calming feeling due to glass curtain walls emitting high light levels. Inside the display cases, the artifacts appear to come alive. Even though the light levels are high with daylight, the area is intriguing and inviting for viewers.

The lighting design and color palette creates movement through the exhibits in the San Antonio Museum of Art. In the entry, a long, simple barrel vault corridor connects the Egyptian area to the Greek and Roman sculpture room. A dramatic sculpture in front of a deep red wall piques interests of the guests and draws them to go through the Egyptian area to experience more. Lighting plays a critical part of the Greek and Roman sculpture room. Clerestory windows provide some daylight. Compared to the Pre-Colombian area, the Roman and Greek sculpture

area has soft, dramatic lighting with narrow spots accenting the sculptures. Glare is a negative aspect of this room due to the shiny surface on the flooring with high concentrations of spots and down lights beaming down from approximately twenty- thirty foot ceiling. The use of neutral colors in the decor contributes to the impressive glow of the sculptures within the room.

In the second floor, lighting design is the single element that directly impacts the experience of the exhibit. The light levels are very low. The décor and wood finishes are dark tones. These tones contribute to the mysterious and intriguing interaction between the displays. Once the eyes adjust to the low levels, the display cases and exhibit vignettes come alive with the punches of light in the Chinese, Japanese and South Asian areas. The eye focuses on the details of the artifacts more than the room. The lighting also creates a soothing mood with curiosity to wind through different areas. There are also many interactive vignettes, which enable the guests to relate to Asian cultures. The overall effect is successful between the floor layout, variety of displays and contrasting lighting.

The third floor has the curvilinear display elements and combination of daylight and artificial illumination. Near Eastern Oceanic area plays with form, proportions and heights within the room. The lighting design is simple with high lights inside on the artifacts. Several exhibits have curved platforms to emulate how the civilizations were connected to the water. The displays are varying heights and proportions to have visual stimulation. Compared to the second floor, the Chinese and Japanese areas are centralized by the effect of light and the Near Eastern Oceanic room is connected by color and curvilinear elements. The lighting is

critical for the Near Eastern Oceanic, but the color and curvilinear form set the tone of the area.

The San Antonio Museum of Art is "dedicated solely to furthering its mission to promote a deeper understanding of human cultures, values and traditions by displaying and interpreting art works from all cultures and periods" (SAMA, 2009). The museum is lively with artifacts and how the items are displayed. The lighting design creates each exhibit's identity and distinguishes the different area with color and light levels.

Modern Art Museum of Fort Worth

The Modern Art Museum of Fort Worth is a new icon not only for the city of Forth Worth, but the entire contemporary art community. Tadao Ando created a 53,000 square foot gallery space with modular design that connects a place for the fusion of lives with art. The mission of the museum is to "collecting, presenting, interpreting International development in post World War II art in media and creating a welcoming environment for public appreciation." The Modern Art Museum of Fort Worth stands strongly behind its mission. The museum's permanent collection contains 3,000 works. Each facet of the museum demonstrates the connection of the public with modern art.

Once inside the main lobby, a water feature surprises each guest. The water feature cannot be viewed from the exterior of the building. The architecture automatically draws the patron into space and creates a desire to know more about what the museum may contain. A long corridor separates the museum for public and private areas. The architecture and lighting direct the guests to the

public areas. The right side contains the offices and support staff for the operations for the museum. The left side of the museum is the public area. In the public area, there is gift shop, main galleries, and café. The front desk is strategically placed in the middle of the main corridor for easy access. The signs and guest services are effortlessly visible for visitors.

The architectural elements contribute to the experience of the museum. The water feature, natural light, and rich materials enhance the Zen feeling of the space. The surprise element is revealed that only surrounds exterior of the gallery areas of the museum. The water can only viewed through the large glass curtain wall from the intimate spaces created by the architecture. In addition to the water, the simple white gallery walls give contrast to the architecture and art without dominating the space. The other architectural materials, concrete, granite, wood, steel and glass, enhance the warmth and complement interaction with the art.

The museum layout is a simplified modular design where each room flows into the next space. The museum has two floors. The main corridor is similar on both floors. It also aids finding your way through the museum. The first floor is mainly reserved for the permanent collection. The second floor has a special exhibition. From the main museum entrance, there is a main corridor that connects each smaller space. The smaller spaces are darker to create a more intimate experience. The space creates a feeling or sense of peaceful journey and flow. The interior architecture divides into intimates smaller spaces for unique pieces to have personal reflection with the art. Other fascinating design aspects of the museum are the particular large lofty rooms that are double height volumes with

daylight pouring into the space. Layering natural and artificial light emphasizes the volume of the space and dramatizes the artwork. These spaces can be viewed from both the first and second floors. The double height volumes promote the dialog of people and art. The spaces also give 3D art various perspectives to observe the art.

The Modern Art Museum of Fort Worth is exclusive, unique experience to interact with a variety of media. The architecture, customer service, gallery space and patron amenities contribute distinctive successful approach to display art in a concrete modular building. The architectural design enhances the interaction with each art piece. The creative division of gallery spaces leads the patrons to have personal reflection with particular favorite masterpieces. Overall, the Modern Art Museum of Fort Worth brings a new experience to the concept of art museums and interaction with people. The architectural design and diverse art collection create an environment for art appreciation to be in everyday life.

LIGHTING DESIGN:
CEDAR HILL MUSEUM OF HISTORY

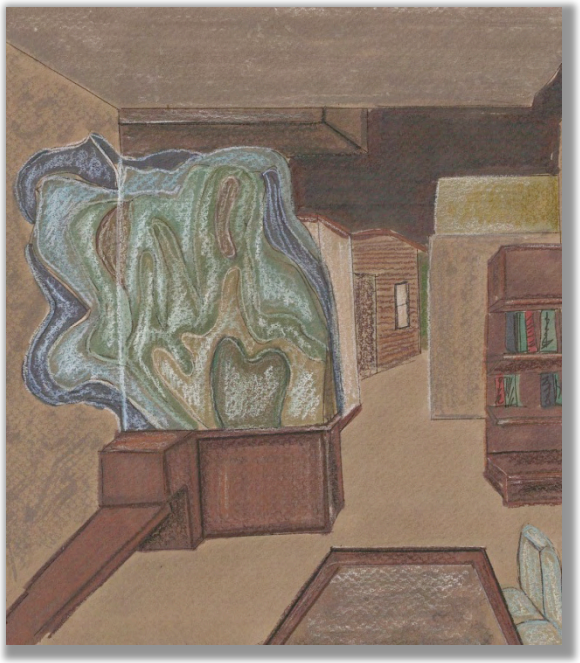
Concept

The lighting design concept of the Cedar Hill Museum of History is like a geode. A geode is a type of rock with a rough exterior that gives no indication of the beauty held within its core. Each rock is unique in composition and cannot be truly discovered until cracked open. Once a guest enters the museum, the geode-inspired lighting design is revealed. This 3,000-square-foot museum is a U-shaped building with a centralized courtyard within the museum. The designed space explains where a community meets heritage and nature. Each layer of light symbolizes a layer in the geode. The indirect, direct, downlight, uplight, spots, floods, track systems and pendants are all luminaries that contribute to the layering effect of light in the museum. The combination of metal halide, compact fluorescents, fiber optics, Gobo projectors, and linear fluorescents produce the optimal quality of light and illuminate the creative designed exhibits: Natural History, Tornado in Penn House, Railroad Depot, Commerce, Farming and Ranching, Television Towers, Oral History, and Temporary exhibit (figure 4).

Entry

The entry of the museum is the "wow" space that invites guests to experience the museum. The unique, lowered ceiling with compact fluorescent downlights emits an even pool of light in figure 9. The custom glass geode inspired topography sculpture is highlighted with metal halide PAR 20 floods and punched

with metal halide PAR 20 narrow spots lights. Behind the reception desk, the Cedar Hill Museum of History's logo is back light with downlights to welcome the guests to enter the museum.



Natural History

The Natural History exhibit is a photographic mural of Cedar Hill landscapes. Within the mural, niches display artifacts and historical information of the Cedar Hill natural history. The mural is washed by metal halide PAR 20 Floods on a track system (see figure 10). On the same track system, metal halide PAR 20 spots direct the guests to particular points of interest in this exhibit. The niches are illuminated by fiber optics with five to seven footcandles to accentuate the detail of the artifacts of the natural history.

Tornado in Penn House

The Penn family is a prominent family in Cedar Hill. In 1856, Cedar Hill was hit by two tornados at the same time that destroyed a large part of the architectural history of the town. This exhibit depicts the feeling of being in a tornado in the Penn family's home. The exterior of the house is highlighted with metal halide PAR 20 floods (see figure 11). The interior has compact fluorescent downlights to allow visitors to enter the house easily. The GOBO projector creates the lighting and series of color changes through a tornado. There are flat LCD panels in each window illustrating the effects of a tornado as a person would see from a window.

Railroad Depot and Commerce

After experiencing the 1956 tornado, guests are surprised with a lowered railroad track ceiling and a Railroad depot in the center of exhibit. The railroad ties are direct/indirect linear fluorescent pendants that are used as a feature through this exhibit to help visitors find their way. The indirect portion of light illuminates a gravel ceiling with direct light emitting on the entire area. Commerce aligns the walls with 2-D cutouts with murals of the Cedar Hill Fire Station, Straus Hotel and Mr. Payne's general store. The metal halide PAR 20 narrow spots highlight the 2-D cutouts with layering metal halide PAR 20 floods on the murals in figure 12. The highest light levels measure. The north wall is a glass curtain to emit natural light into the space. The use of daylight adds a calming component to the experience. Punches of metal halide PAR 20 narrow spots are used on the information plaques as well.

Farming and Ranching

The Farming and Ranching exhibit focuses on the "full day in Cedar Hill." The east and south wall have photographic murals of a ranching and farming scene. A track system of metal halide PAR 20 floods washes the murals (see figure 13). The ceiling has several layers to represent clouds that light effect change to emulate weather and time of day changes. A GOBO projector is used in the ceiling to create the lighting effects. The west wall is a glass curtain that allows daylight to pour into the space. Compact fluorescent downlights provide light for evening in the space. The display cases have linear fluorescents with special angular lens to distribute the light in the case for viewing and no glare.

Television Towers History

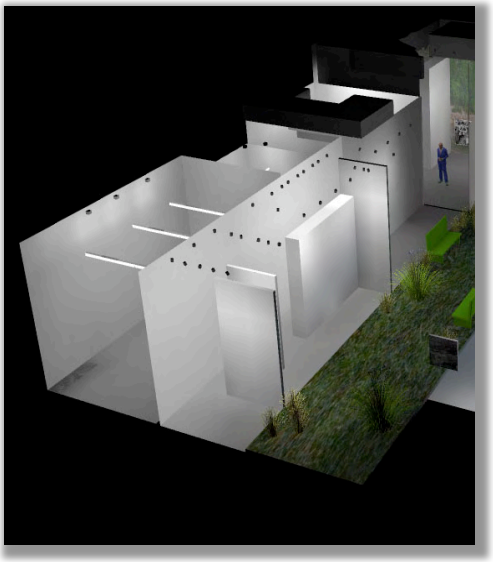
Cedar Hill is the highest point from the Red River to Houston, Texas. Over time, television towers have become an icon of the landscape of Cedar Hill. This west wall illustrates a timeline with mural photographs to the history of the towers. Similar to the farming and ranching exhibit, the metal halide PAR 20 floods emphasize the information on the wall in figure 13.

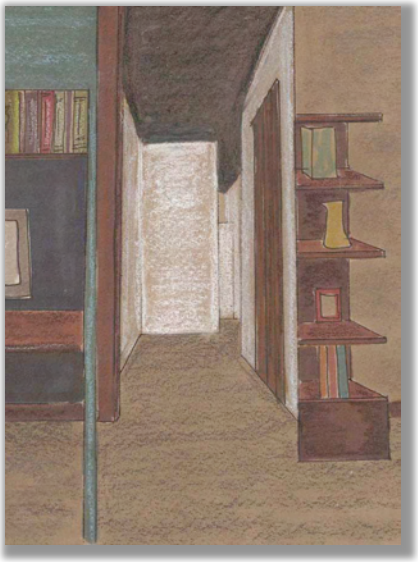
Oral History

The Oral History is a nook space within the natural history area (see figure 10). The ceilings are 12 feet with cove lighting. The space is functional with tables and a computer with which to conduct research. The lighting is even pool of indirect light for guests to research family history, learn more about Cedar Hill History, or listen to testimonials of oral history. The light levels can be adjusted for different guests and uses of the space.

Temporary Exhibit Area

The temporary exhibit area is a flexible space for different traveling exhibits. The tracking system is three feet off the walls with different light sources. In figure 14, Metal halide PAR 20 floods, PAR 20 narrow spots, and downlights are luminaries for the track system. In general, the walls are washed.



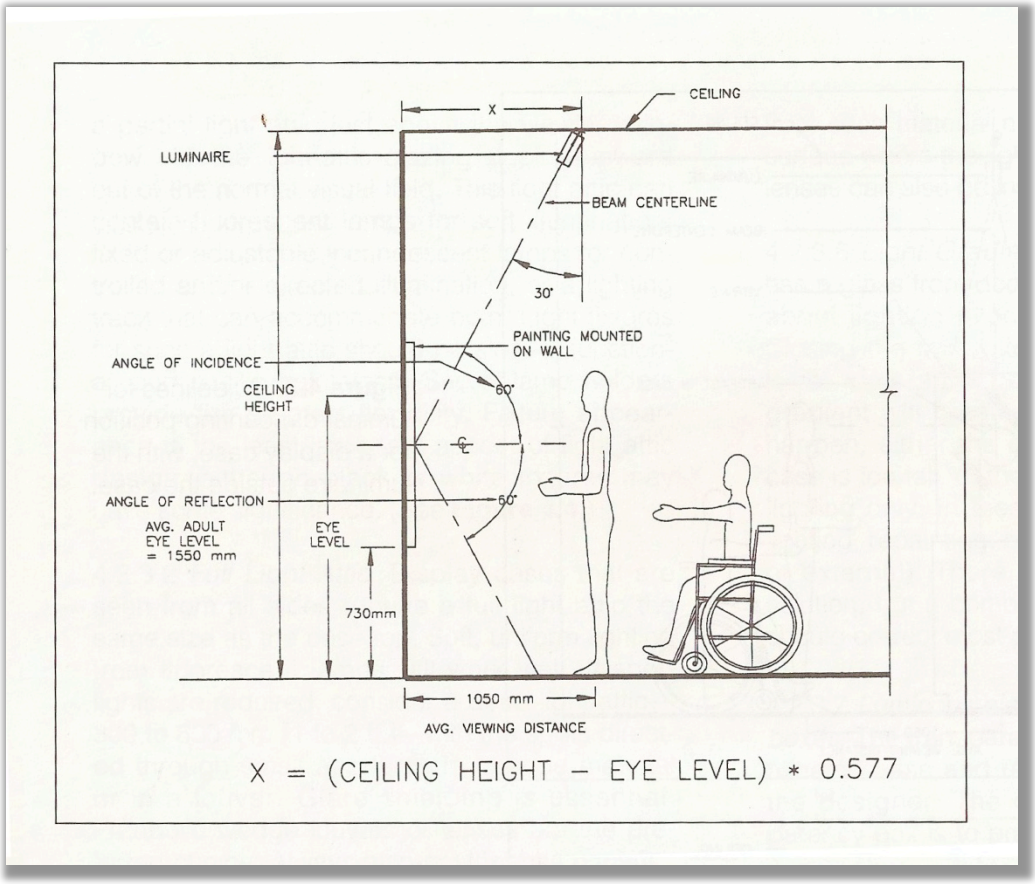


Lighting Design Considerations

In the Cedar Hill Museum of History, the lighting design has several considerations that affect the lighting and spatial concepts. Color rendered index, color temperature, texture, form, viewing angles, layered light, and maintenance are all factors that contribute to the whole. The specified lamps have high color render index and 3,500 Kelvin. The lighting maintenance is convenient because a limited number of lamp types are selected for the museum and location of luminaries are away from the exhibits. Each of exhibit area uses layers of light to attract the guests to read and learn from each historical time period. These considerations allow the lighting design to fuse lighting elements with an architectural designed space to create an effective and functional design for humans to enjoy the experiential interaction.

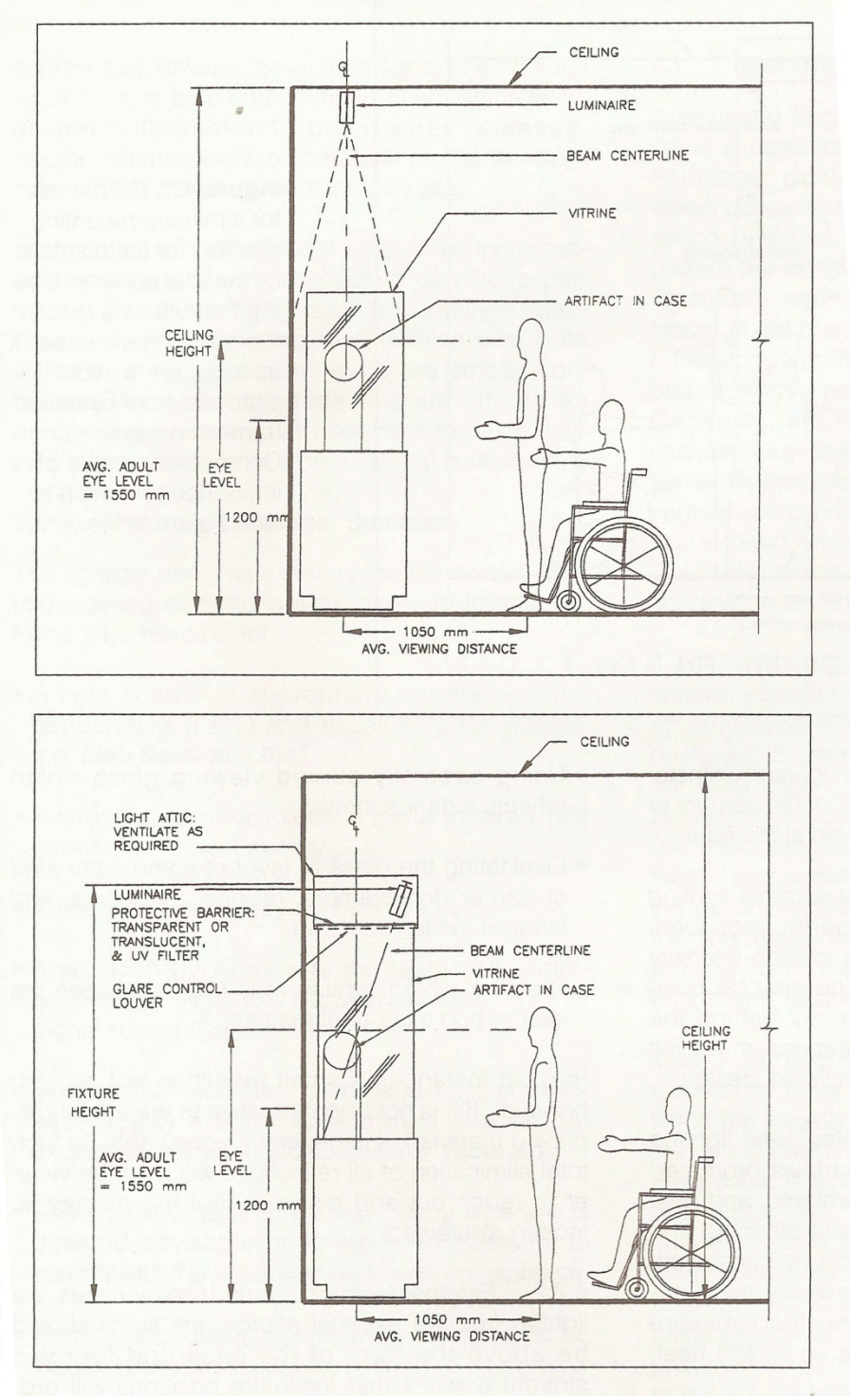
FIGURES

Figure 1



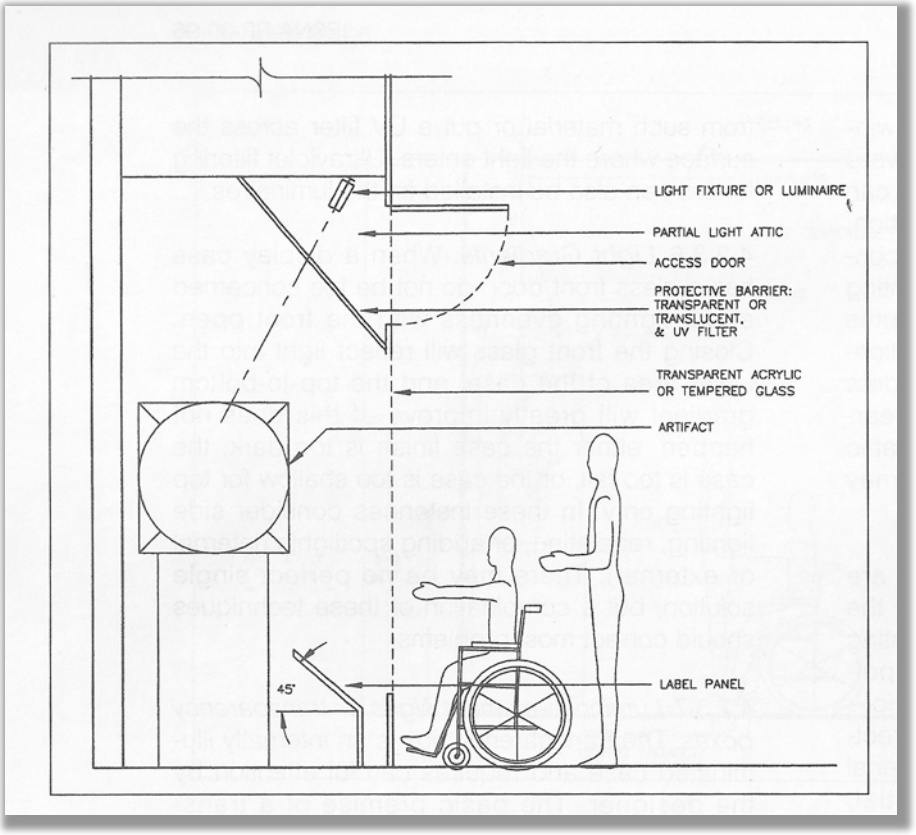
(DiChara, 690, 2007)

Figure 2



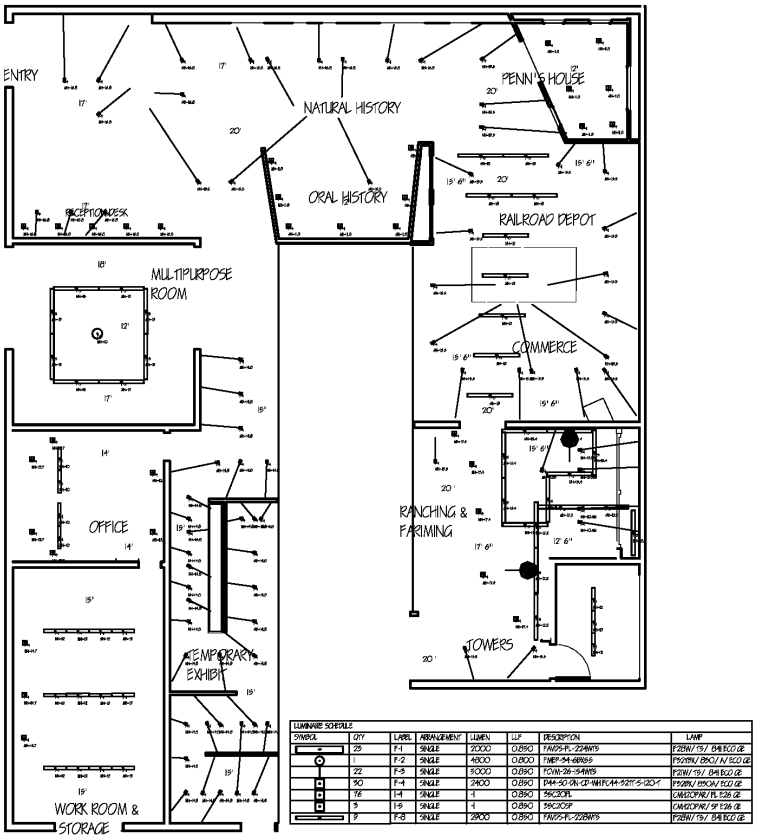
(DiChara, 690, 2007)

Figure 3



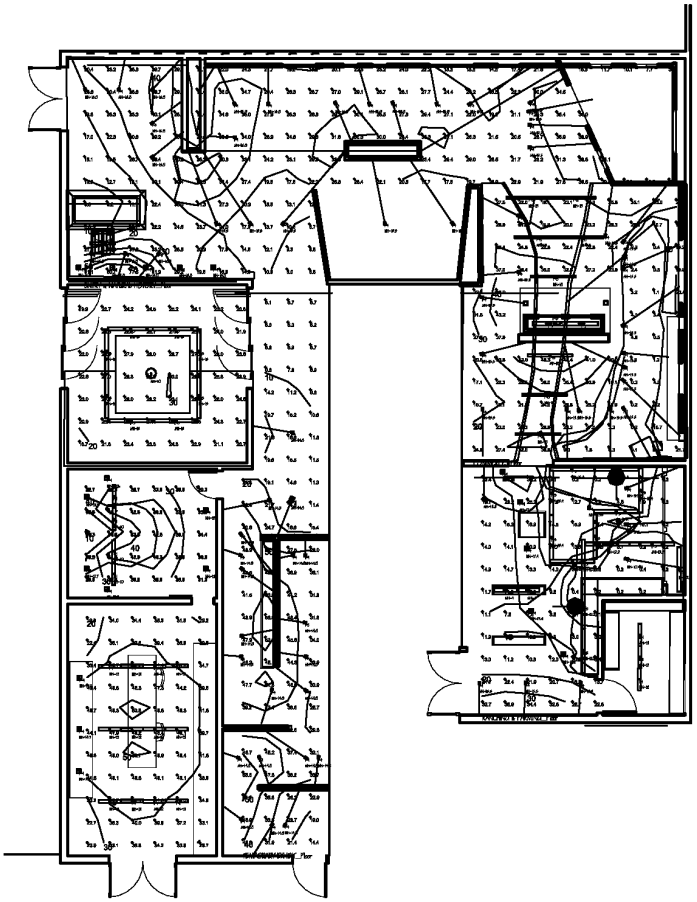
(DiChara, 690, 2007)

Figure 4



(Hunt, 2009)

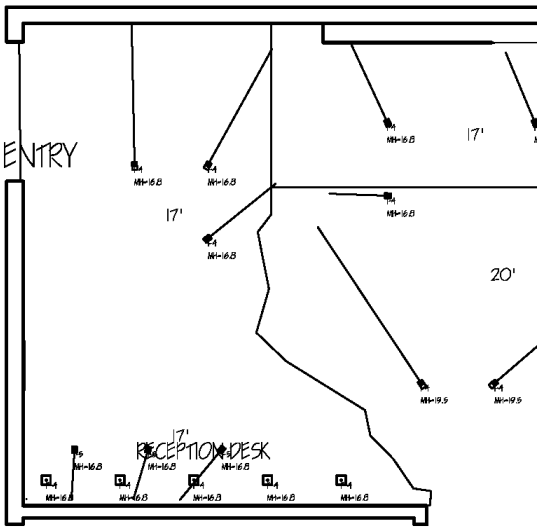
Figure 8



Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
NATURAL HISTORY DISPLAY_Wall_1	Illuminance	Fc	0.59	1.4	0.5	1.18	4.67
NATURAL HISTORY DISPLAY_Wall_3	Illuminance	Fc	0.49	1.2	0.2	2.23	6.00
NATURAL HISTORY DISPLAY_Wall_4	Illuminance	Fc	0.58	1.5	0.5	1.95	4.39
OFFICE_Workplane	Illuminance	Fc	99.56	465	20.5	1.79	2.28
NATURAL HISTORY WALL_Wall_2_1	Illuminance	Fc	7.79	28.6	0.0	N.A.	N.A.
CABIN_Wall_1	Illuminance	Fc	10.24	14.5	6.9	1.48	2.07
CABIN_Wall_5	Illuminance	Fc	9.76	13.0	5.9	1.47	1.99
DISPLAY_Wall_5	Illuminance	Fc	8.61	13.1	9.1	1.50	1.99
DISPLAY_Wall_6	Illuminance	Fc	6.09	9.8	4.9	1.60	2.28
MULTIPURPOSE ROOM_Floor	Illuminance	Fc	79.01	301	187	1.54	1.81
OFFICE_Floor	Illuminance	Fc	99.16	412.8	91	9.64	4.70
WORK & STORAGE ROOM_Floor	Illuminance	Fc	99.74	502.8	99.8	2.01	2.97
wall in_Side_1	Illuminance	Fc	9.71	24.5	4.7	2.07	5.17
wall in_Side_5	Illuminance	Fc	20.89	58.9	7.7	2.71	7.69
wall in_1_Side_1	Illuminance	Fc	27.19	79.0	9.3	2.92	7.59
wall in_1_Side_5	Illuminance	Fc	59.57	70.6	16.0	2.46	4.41
wall in_2_Side_2	Illuminance	Fc	29.19	58.7	15.4	1.79	2.28
wall in_2_Side_4	Illuminance	Fc	27.98	47.1	19.5	1.88	9.03
wall in_3_Side_2	Illuminance	Fc	21.54	47.4	9.7	2.20	4.59
wall in_3_Side_4	Illuminance	Fc	38.77	46.2	15.4	2.00	5.48
ENERGY & NATURAL HISTORY_Floor	Illuminance	Fc	29.12	80.7	5.8	6.61	2.24
ENERGY & NATURAL HISTORY_Wall_3	Illuminance	Fc	25.28	90.9	5.4	4.91	5.48
ENERGY & NATURAL HISTORY_Wall_8	Illuminance	Fc	0.00	0.0	0.0	N.A.	N.A.
ENERGY & NATURAL HISTORY_Wall_14	Illuminance	Fc	6.90	9.0	4.0	1.65	2.29
RANCHING & FARMING_Floor	Illuminance	Fc	1.58	59.2	0.1	183.80	592.00
RANCHING & FARMING_Wall_1	Illuminance	Fc	24.2	59.4	12.4	1.99	5.18
RANCHING & FARMING_Wall_4	Illuminance	Fc	40.35	98.8	1.4	25.76	68.86
RANCHING & FARMING_Wall_5	Illuminance	Fc	29.19	54.1	2.0	11.60	27.09
RANCHING & FARMING_Wall_9	Illuminance	Fc	20.56	54.5	12.0	1.70	2.86
TEMPORARY EXHIBIT_Floor	Illuminance	Fc	28.74	56.6	9.0	5.79	1.52
TEMPORARY EXHIBIT_Wall_6	Illuminance	Fc	12.92	41.4	2.0	6.38	25.70
wall in_5_Side_5	Illuminance	Fc	17.97	58.0	0.4	49.95	99.00
COMMERCE_Floor	Illuminance	Fc	2.16	49.4	0.1	28.60	494.00
wall in_A_Side_1_1	Illuminance	Fc	9.39	55.2	6.8	2.29	4.58
wall in_A_Side_5_1	Illuminance	Fc	24.91	41.9	12.1	2.01	5.46

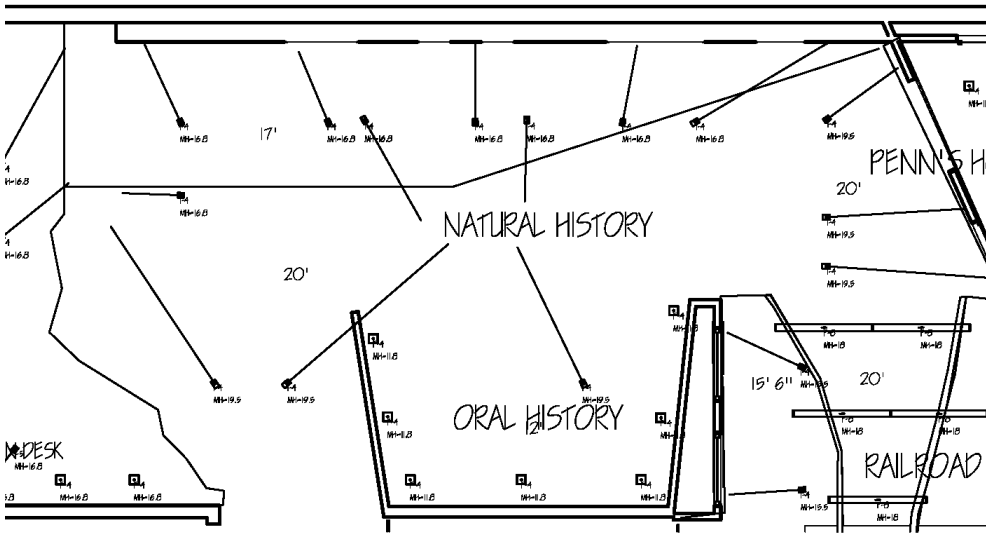
(Hunt, 2009)

Figure 9



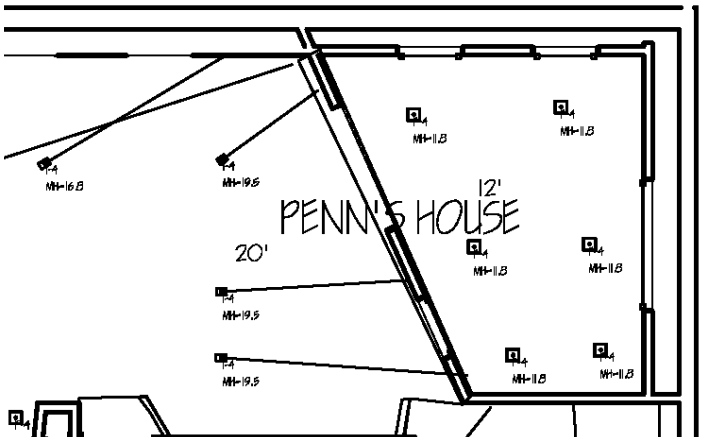
(Hunt, 2009)

Figure 10



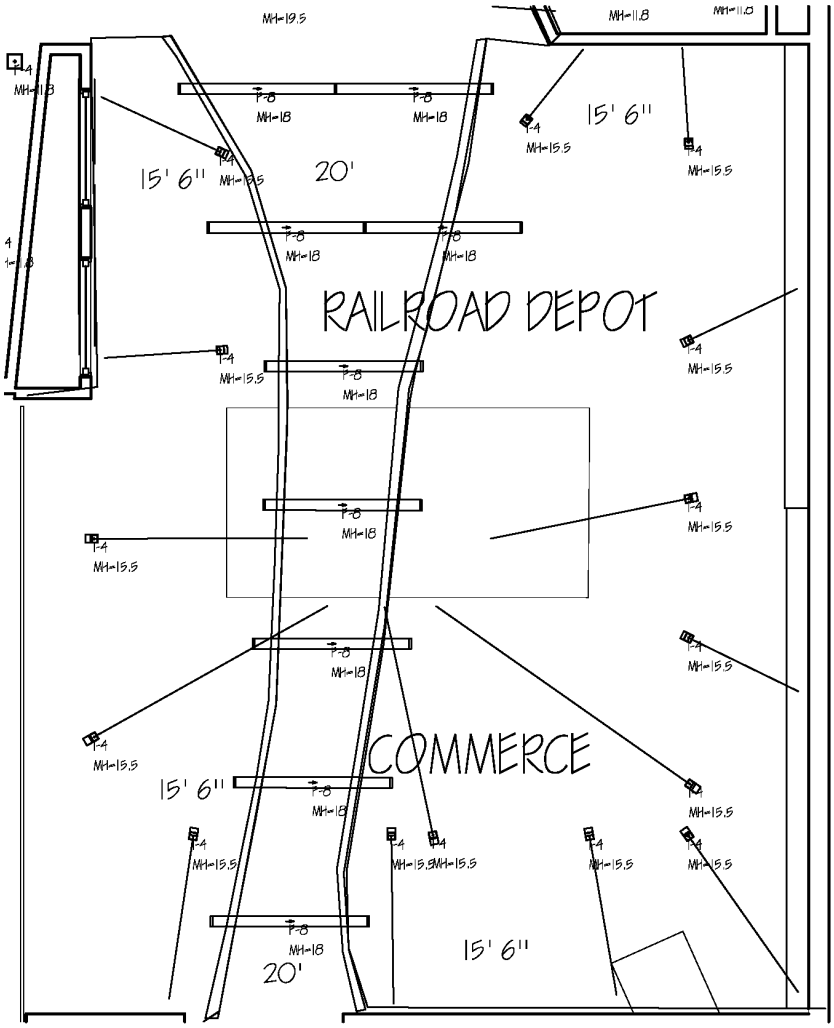
(Hunt, 2009)

Figure 11



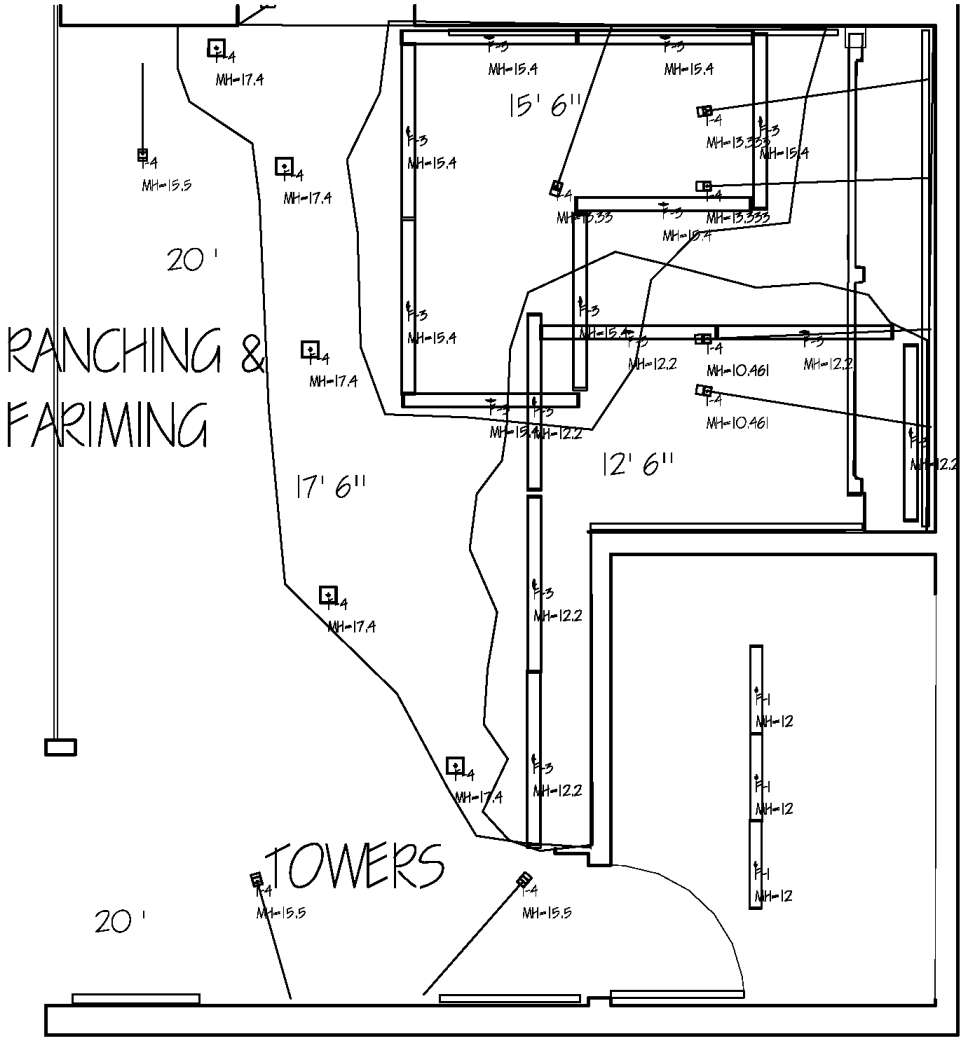
(Hunt, 2009)

Figure 12



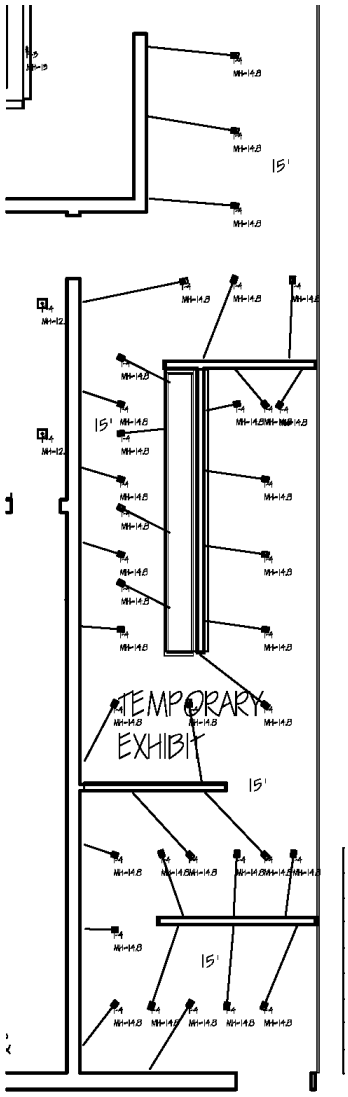
(Hunt, 2009)

Figure 13



(Hunt, 2009)

Figure 14



(Hunt, 2009)

DEFINITIONS

CRI- *Color Rendering Index* is degree of color shift objects undergo when illuminated by the light source as compared with a color of those same objects undergo when illuminated by a reference source of comparable color temperature (RP-30-96, 84, 1996).

CCT- *Correlated Color Temperature* is light source will determine whether the display takes on a "cool" or "warm" appearance, expressed in Kelvin. Higher Kelvin is a more cool appearance; lower Kelvin temperature corresponds to a warmer appearance of the light source (RP-30-96, 84, 1996).

Luminance- is the luminous intensity of a surface or object. The light can be objectively measured when reflected from or transmitted through an object. The unit of measure is expressed in footcandles? I don't know what you meant by produces footcandles. (Egan, 394, 2002).

Glare- harsh, uncomfortably bright light source or reflection that interferes with visual perception. Light from the wrong place at greater brightness than that to which eyes are adapted. (Egan, 391, 2002).

Lux- metric unit of quantity of light on 1 m squared of surface area 1 m away from light source of 1 cd(1lx equal to 0.009fc). (Egan, 394, 2002).

Foot Candle (fc) – quantity of light on 1 foot squared of surface area 1 foot away from light source of 1 cd (Egan,390, 2002).

Candelas (cd)- unit of luminous intensity equal to 1 candlepower.

LED- *Light-Emitting Diodes* – low-power, small point sources. Typically amber, orange , or red, they are used in traffic signals, commercial advertising signage and exit signs (Egan, 393, 2002).

Fluorescent lamp- discharge lam which emits electron arc stream from cathodes at ends. Fluorescent phosphor coating on inside of bulb transforms ultra-violet energy into visible light (Egan, 390, 2002).

Incandescent lamp- lamp in which light is produced by heating filament to incandescence (i. e., point of emitting light) by means of an electric current (Egan, 392, 2002).

HID- *High Intensity Discharge lamp*- discharge lamp which passes a high pressure electron arc stream through a gas vapor. Examples are mercury, metal halide, and high-pressure sodium lamps (Egan, 392, 2002).

Illuminance (E)- quantity of light (fc or lx) which reaches a surface. To convert lux to foot candles, multiply by 0.09 (Egan, 392, 2002).

Cut off-has and is being used to describe luminaries that have no direct up light (no light emitted above horizontal). However, in addition to that limitation, the Illuminating Engineering Society of North America (IESNA) definition also requires luminaries to comply with the glare requirement limiting intensity of light from the luminaire in the region between 80° and 90°.

Spill Light falls outside of the area intended to be lighted (RP-30-96, 55,1996).

Luminaire – complete lighting unit consisting of lamp or lamps together with parts to position and protect lamp, direct light , and connect lamp to a power supply. Also referred to as a fixture (RP-30-96, 84, 1996).

Diffused lighting- lighting, provided on the work-plane or on an object, that is not predominantly incident from any particular direction (RP-30-96, 83, 1996).

Fill light- supplementary illumination to reduce shadow or contrast range. (RP-30-96, 83).

Filter- a device for changing, by transmission or reflection, the magnitude or spectral composition of the flux incident upon it (RP-30-96, 84, 1996).

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