CLASSROOM LIGHTING DESIGN FOR STUDENTS WITH AUTISM SPECTRUM DISORDERS

by

EMILY ANN LONG

B.S., Kansas State University, 2010

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Architectural Engineering and Construction Science
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Approved by:

Major Professor
Raphael Yunk

Abstract

Autism Spectrum Disorders, (ASD) are being diagnosed at an alarming rate. Students with ASD face many challenges in educational environments and struggle to overcome daily distractions. Students with ASD have variances in neuron connections that cause them to receive and understand their environment differently than a student without special needs. In the educational classrooms, fluorescent lighting is a significant source of extraneous stimuli that not only a source of annoyance but can also trigger common symptoms of ASD. Fluorescent fixtures economically provide an acceptable uniformity and quality of illumination, but also have disadvantages that can aggravate symptoms in students with ASD. Ballasts are required for the operation of fluorescent fixtures. These ballasts, especially if not replaced at the end of their usable life, can generate an audible hum and cyclical flickering of light. Alternative light sources, such as incandescent lamps and fixtures should be evaluated and installed not only in special needs classrooms but standard group classrooms as well. Providing additional sources or quality sources of light may help students with ASD focus on the information presented in the classroom. Traditional classroom design needs to be re-evaluated to accommodate the needs of those students with ASD to better provide a comfortable and less distracting learning environment.

It is difficult to establish rigid standards for lighting designs sensitive to individuals and special needs occupants'. By understanding the symptoms of ASD and taking into account the occupants needs lighting designers will be better able to design an environment that is both comfortable and educational. This report will address the classroom environment and student considerations in order to develop parameters and design practices that will assist new lighting designers.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I would like to acknowledge and thank my Major Professor Ray Yunk for his commitment and guidance with my research and report. I would also like to recognize the members of my committee who also positivity contributed to my work on this report, Fred Hasler and Kimberly Kramer. My parents David and Lynn Long and sister Jessica Long deserve recognition for their support and encouragement.

Research and case studies were a large portion of my report. I would like to take this opportunity to acknowledge and thank the people who allowed me to better understand the various aspects of Autism Spectrum Disorder and the application to classroom design: Tracy Anderson of Anderson-Knight Architects, Justyn Leon P.E. of LST Engineers, Dr. Pam Russell, Helen Miller, and Jessica Wilkinsen of Manhattan-Ogden School District and Amanda Arnold Elementary.

Chapter 1 - INTRODUCTION

In order to provide productive and healthier learning environments to students with Autism Spectrum Disorders (ASD), it is important to become familiar with ASD by considering the associated symptoms, the effects and connections in the brain, and how these symptoms are exhibited in the student's environment.

Autism is a medical condition that is starting to reach epidemic proportions. It is now estimated that one in one hundred children have some form of Autism Spectrum Disorder and that statistic continues to increase yearly. As of 2008, it was estimated that 1.5 million Americans are living with this condition (Autism Society, 2008). Autism Spectrum Disorder is the medical umbrella to cover all conditions and degrees of autism. The current diagnostic categories of ASD are Autism, Pervasive Developmental Disorder - Not Otherwise Specified (PDD-NOS), Asperger Syndrome, Childhood Disintegrative Disorder and Rett Syndrome. Each of the listed conditions can be specifically identified with brain scans or by the presenting symptoms, combinations of symptoms, how they are triggered and their debilitating severity (ND Autism Connection, 2010). Autism is the most common diagnosis under the umbrella of ASD. Autism typically presents itself with restrictive behaviors, deficiencies in verbal and non-verbal communication as well as mental impairments. PDD-NOS is also known as atypical autism and are categorized by more severe and pervasive mental and social handicaps. CCD is less common and exhibits a loss of social interaction, creative play and responsive behavior (Autism Society Canada, 2009). Asperger Syndrome is considered a mild condition of autism. Students with Asperger Syndrome have the mental and verbal capabilities as their peers but are handicapped in social interactions and show symptoms of poor motor skills and repetitive behavior. Students with Rett Syndrome exhibit a regression in mental and physical development. Students may stop verbally communicating or lose physical coordination and movement [National Institute of Child Health and Human Development Information Resource Center 2010]. Brain scans and diagnostic magnetic resonance imaging scans (MRIs) help doctors and researchers group patients into specific ASD categories, and also help to map out areas of the brain that are affected. By analyzing these brain abnormalities researchers are able to pin point specific areas of the brain affected and potentially help to control or minimize symptoms. There is no substantial evidence to the causes or known cure to any of the conditions under ASD, and few trial methods to managing symptoms. Further research into the causes and conditions are being conducted to compete with the growing number of cases.

One of the greatest challenges researchers and doctors are facing is that there is no strong or defining predictable pattern of symptoms or conditions between patients with ASD. Commonly, social behavior and interaction both verbal and non-verbal cues is the most prominent symptom. Other symptoms can range from something as common as allergies and asthma, to epilepsy, sensory integration dysfunction and sleeping disorders. These symptoms can appear in any combination and range in degree of severity from mild to debilitating (NDAutism Connection, 2010). The inconsistency in the presentation and severity of symptoms creates the unique problem of addressing the best way to approach and tend to the needs of students with ASD. There can be no formulaic approach to helping a student with ASD, and under the most ideal conditions each student must be attended individually depending on the severity of their condition.

Chapter 2 - THE BRAIN AND PERCEPTION

To gain a better understanding of reactions students with ASD from lighting, we need to better understand how the brain perceives and processes light. Light impacts more than just our vision. Understanding the biological and physiological impact illumination has will better identify short comings and provide methods to design an improved classroom environment. Research attributes some symptoms of ASD to abnormal neuron development and connections in the brain. These abnormal brain connections could lead to problems with visual perception.

2.1 Sensory Abnormalities in the Brain

The brain is a single organ, but can be divided into lobes, each responsible for controlling human functions and thoughts. The pre-frontal cortex is the area of the brain that helps interpret human interactions and allows empathy. Below is a graphic of the brain that highlights the pre-frontal cortex region. Because social deficiency is a common condition of ASD, researchers used MRI scans to map out activity in the brain of patients with ASD as they were presented with environmental stimuli and interactions. Researchers compared these brain scans to control scans of patients who did not have ASD. As expected the brain scans of patients with ASD showed much less activity in the pre-frontal cortex than the control scans [University of Wisconsin, 2004]. There are only vague theories of why certain areas of the brain respond with less activity or differently to stimuli, but piecing together the brain scans to create a map of how a person with ASD interprets and perceived their environment will allow for improvements and accommodations in daily life, learning environments and social interactions.

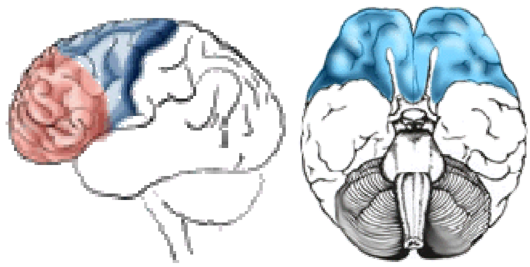


Figure 2-1 Side and bottom view of the human brain diagramming the frontal lobe highlighted in blue. The pre-frontal cortex is highlighted in pink (Johnson, Gordon S Jr. 2009).

To accurately find the environmental stimuli that enhance the symptoms of ASD, researchers have relied on brain scans and maps of the brain to determine the areas of abnormality. The intent of this type of research is to pin point the areas of concern, and then develop ways to alleviate or lessen symptoms or adverse affects in particular areas of the brain. Because the most symptoms are sensory and social cognition, most studies are focusing attention to those particular areas of the brain. A study performed in 2008 by Doctor Mustafa Sahin, MD, PhD of the Children's Department of Neurology of the Children's Hospital Boston focused on mapping the sensory and social cognition neurons in the brain in patients with Tuberous Sclerosis Complex (TSC), which is a rare and strongly connected condition to ASD. These tests and scans mapped the wiring and communication of neurons in the brain when exposed to visual or sensory stimuli. Neurons are components of the brain that send and receive electrical signals that the brain then interprets depending on the area of the brain they are sent. These neurons are a bundle of nerves that are bound together by a stem called an axon which is coated in a fatty sheath called myelin to protect the nerves and provide better transmission of signals.

Doctor Sahin and his colleagues found that the brain scans of those patients with TSC showed abnormal scattered wiring of neurons than those scans of the control patients. In was commonly seen in these scans that there were too many neuron connections and that these connections lacked a logical pattern of transmitting information to the predicted destination. This inaccurate transmission of information results in the brain's inability to accurately interpret sensory information by normal standards and creates a sensory overload for the patient [Nie, Duyu, 2010]. This study continues into the specific chemical reactions during the brain's development to define the problem, but the results of the study can help to identify problematic symptoms and possible ways to mitigate adverse effects. The study confirms that the communication in the parts of the brain that interpret light, sound and other environmental stimuli do not follow predicted paths of transmittance and therefore cannot be clearly interpretation by the brain. If the brain has a difficult time processing out extraneous stimuli from the environment, then by creating an environment that reduces these types of distractions may help students to process important and applicable information easier.

2.2 Environmental Stimuli

To further expand and generalize the results of Doctor Sahin's study, there are two main conditions to how students with ASD process information. Patients with ASD will either experience a 'hyper' or hypo' sensitivity to their environment. The prefix 'hyper' suggests an over sensitivity to stimuli. The brain picks up more information from the environment than necessary and becomes overwhelmed when processing information. The prefix 'hypo' means just the opposite; the brain cannot make the connections to correctly interpret information and it becomes lost in the brain and develops little or no reaction. As research has shown, there is no predictable pattern of which stimuli will invoke a 'hyper' or 'hypo' reaction (Autism Society, 2008). A normally developed brain is able to find a balance between information that is important and stimuli that is extraneous. The brain of an individual without ASD is dynamic and learns patterns as the neuron develop sensible paths and connections between perceiving stimuli and developing a reaction. Because the brain of a patient with ASD does not consistently have a cohesive path of neuron connections for interpretations, the information is scattered into various parts of the brain to try and formulate a reaction. The reaction is then commonly displayed as confusion, frustration, withdrawal, or repetitive behaviors. A normal brain develops these reactions depending on which area of the brain interpreted the information and the path it was transmitted to create the response. This process is dependent upon the brain development and more specifically on the paths the neurons formed during initial growth and exploration of the environment. If stimuli from the environment are intentionally limited, a student with ASD may be better able to make clearer connections between neurons in the brain.

2.3 Visual Perception of Light

There are two ways we assess our environment. The first assessment is by knowing where to look for a task or object. An example of this would be reading a book, or other tasks that have a defined visual parameter. The second way we assess the environment is by a visual search. Using this method the eyes do not have a destination to focus on but scan the surroundings to assess the environment. This happens by a succession of brief fixations. Our eyes and brains communicate quickly to assess a complete environmental picture. Our brains will predict the areas of importance and focus our attention to those areas first, before scanning the surroundings. Our eyes will also gravitate towards areas with larger objects, more light, and contrasting colors. Our eyes and brains also identify objects or tasks that are singled out and removed from distracting visual clutter. [Rea, Mark S, 2000]

Flicker is a repetitive flashing stimulus. This phenomenon is largely caused by the electrical supply. North America has established a 60 hertz (Hz) supply frequency. If the supply frequency is 60Hz the fundamental frequency or what our eyes perceive is 120Hz. The supply frequency is measured from the start and end of each wavelength, while our eyes perceive the high peak and low peak of each wavelength creating the effect of 120Hz fundamental frequency. The first figure below describes the full sine wavelength cycle created from the current of electrical supply to a lamp. The second figure describes the way the cycle appears to the occupants showing absolute values for every half cycle of the wavelength.

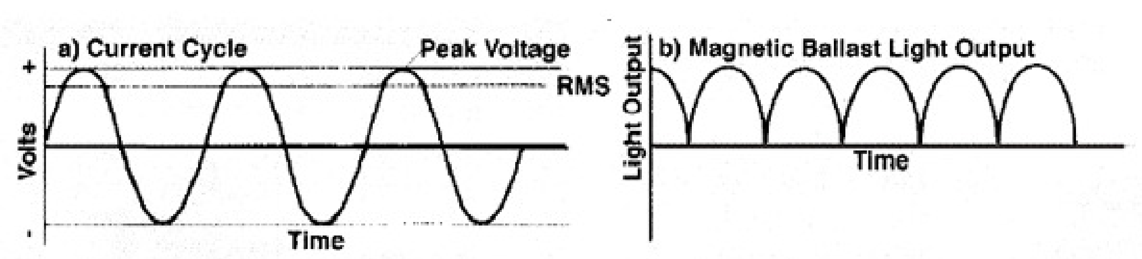


Figure 2-2: Sinusoidal graph comparing the frequency of current to perceived cycle of light

Shown is the operation of a magnetic ballast, which is the most noticeable, but the graphical representation applies to any output of light operating with a ballast (Ryan, Eileen. 2007).

Our brains can trick us into minimizing the effects of flicker. If the fundamental frequency reaches the critical flicker frequency (CFF), our brains make the light appear to be at a constant output. Higher fundamental frequencies will in effect reduce the flicker effect. The CFF varies among individuals, the task or object size, and where the flicker appears on the eye's retina. The point on the retina where the light is perceived can determine if we sense flicker. Peripheral vision can sense flickers at higher frequency than having the source directly in sight. If the flicker is wide spread in the visual field, it can lead to fatigue of the eyes and also headaches. Studies over human perception of light flicker have lead researchers to believe that even though our brains to not register a light flicker, those individuals studied were still subject to headaches and other adverse effects. It was concluded that flicker maybe be interpreted subliminally and still cause fatigue, eye strain, headaches and other negative physiological effects (Rea, Mark S, 2000).

2.4 Classroom Environment

Students with ASD face many struggles and challenges in educational environments and classrooms. Classroom and other educational facilities are designed with the intention to be bright and display a variety of objects and information to encourage interaction and learning. These stimuli can become overwhelming to a student with ASD who has difficulty focusing their attention. Students with ASD cannot always differentiate between what is socially important and something that is visually or audibly distracting. They may focus their attention to extraneous sights and sounds and be unable to engage in classroom activities and instruction. Fluorescent lighting is a common source for distracting stimuli. The construction and installation of a fluorescent lamp requires a ballast that generates an audible hum and an cyclical flicker from the electric input (Rea, Mark S, 2000). Typical students may hear a light soft hum from the lights but it quickly can be tuned out into white noise or a subtle irritation. Most often the flickering of the fluorescent lamps are invisible to a student without ASD. It should be noted that not all students with ASD notice a visible flicker in the lamps. Because of the way the brain of a student with ASD processes environmental stimuli, what seems subtle to normal students, becomes amplified to these students with ASD. A normal brain can filter out what it has learned to be unnecessary and focus the attention to the pertinent information being presented. Because of the lack of consistent wiring of neurons in the brain of students with ASD, there is essentially no method of filtering information into what is important and what is extraneous. The flickering light or hum is in equal competition with the information being presented by the instructor. This results in an overflow of information and creates a stressful learning environment for students with ASD.

Symptoms of students with ASD can be exacerbated as a result of their brain trying to process information from the environment. Some students become fixated on a flickering lamp or in severe cases, can trigger epileptic type symptoms. The occurrence of their behaviors and symptoms such as repetition of actions or words, withdrawal and physical or verbal frustration are increased when an environment seems threatening or distracting.

Many traditional schools built in previous decades or even on conservative budgets do not accommodate students by providing special needs classrooms. Most classrooms are designed based on economics and uniformity. There is a balance between efficient and cost effective classroom design and design that focuses on providing for the unique needs of special needs students and students with ASD. Many students with ASD are educated in standard classroom environments with the rest of their classmates and peers. Most students with mild cases of ASD are able to keep up with the curriculum but can find themselves struggling and lose focus when forced to ignore distractions. This fight to overlook distracting light and extraneous noise leads to a greater effort in learning the materials presented in class.

Chapter 3 - TRADITIONAL CLASSROOM DESIGN

Two of the strongest factors in design and construction of educational facilities and classrooms are consistency and cost. Most classroom type spaces constructed are similar in finishes and fixtures. The uniformity not only creates a consistency and flow through the facility, but reduces the variety of light fixture types and lamp types and results in an economical design option. Because of these driving conditions, fluorescent tube lamps in recessed troffers are the most common fixture seen in educational facilities. These fixtures provide efficient general illumination while maintaining an acceptable color rendering index (CRI). CRI refers to the accuracy the light emitted from the source compares to the perfect color proportions of the visual spectrum; day light has a CRI of 100, which is the highest value. Fluorescent fixtures are traditionally and still currently the most popular fixture in classroom design because it is able to fulfill the recommendations for quality and efficiency, while still maintaining a reasonable budget (Rea, Mark S, 2000).

3.1 Considerations for Traditional Classroom Design

Lighting design for classroom and educational facilities must take into consideration cost, flexibility and quality. Students must be easily able to read information of perform a task on a surface immediately in front of them, and also clearly be able to see a surface from a distance across the room. The Illuminating Engineering Society of North America (IESNA) provides a chart that assigns horizontal and vertical surface luminance values for specific spaces and tasks. Shown below is an adapted table listing recommended light levels for classroom and educational type spaces.

Reading Tasks	Footcandle Value Illuminance Horizontal		Illuminance Vertical	
Photocopied Tasks	30 -50	D,E	-	-
Handwritten Tasks				
Pencil	30-100	D,E,F	-	-
Pen	30	D	-	-
Computer Screens	3	A	3	A
Printed Tasks	30-50	D,E	-	-
White Boards	-	-	5	B

Notes:
A Public Spaces
B Simple Orientation, short durrations
C Working Spaces with simple visual taskts
D Visual Task with high contrast and large size
E Visual Task with high contrast and small size or low contrast and large size
F Visual Task with low contrast and small size

Table 3-1 Illuminance values for reading tasks in a classroom. Table adapted from IESNA Handbook.

A concern with high light levels is creating uniformity and minimizing shadowing and contrast ratios to reduce fatigue on the eyes. The contrast ratio is determined by comparing the measured foot candles on two surfaces or areas. tables that prescribe maximum contrast ratios for spaces based on work surface to ceiling or work surface to wall ratios. Contrast ratios are further discussed in section 6.3 of this paper. The light levels recommended by the IESNA are an average of 50 foot candles (fc) for reading and writing tasks. Glare is a concern when higher light levels are required, especially in environments with reflective surfaces such as desks or whiteboards. Room surface reflectance values are further discussed in section 6.6 of this report. To combat the distracting and debilitating effects of direct or indirect glare, shades, baffles or lenses are installed on the fixture to diffuse the light. If windows and skylights are not designed effectively, day lighting can create problematic glare (Rea, Mark S, 2000).

In addition to the quantity of light, the quality of light is an important consideration. Classroom lighting should suggest a productive and positive learning environment. Traditional design uses fixtures, color temperatures and even light distribution to encourage alertness and productivity. If illumination levels are too high and uniformity even across all planes, it may evoke the emotional feeling of something sterile or frightening to students diagnosed with ASD. Lamps with high CRI: 75 or greater should be used to imitate natural light.

Day light has been suggested to provide psychological benefits and even improve learning and testing. However, because of the natural variance in light levels with day light, supplemental electronic light fixtures and dimming controls should be utilized (Heschong, Lisa, 2003). Lighting controls should be considered to ensure flexibility in use of the space. Electronic fixtures may need to be dimmed to accommodate for video presentations or when viewing computer screens (Rea, Mark S, 2000).

The size and shape of the classroom is most often the controlling factor in fixture location and mounting height. Ideally, classrooms with high ceilings of ten to thirteen feet can utilize suspended indirect-direct fixtures. Indirect light can provide a uniform distribution and helps to reduce shadowing and glare especially on vertical surfaces. Most classrooms however, do not have the advantage of a high ceiling and recessed fluorescent troffers are most commonly used. Classroom furniture layouts are typically flexible but since the lighting fixture layout is usually permanent it should be designed around the most commonly used or predicted furniture plan. The lighting layout should take into consideration the location of the whiteboard, student desks, windows, and any exposed structure or mechanical systems. [Rea, Mark S, 2000]

With emphasis and focus shifting strongly towards sustainability, efficiency of lighting becomes a strong criteria to achieve. Lighting efficiency can be measured by several different standards. One standard measure is efficacy which compares the ratio of the output of lamp lumens to the input wattage (Stein, Benjamin, Rynolds, John S., Grondzik, Walter T., Kowk, Alison G, 2006). With the concern of saving energy and reducing electricity use, efficacy is a helpful statistic to use when selecting lamps. This second strategy to determine the efficiency is very subjective to the fixtures, fixture mounting height, materials and surfaces, lighting layout and lamp type. A second measure of efficiency is measured by the lumens a lamp or fixture will produce compared to the measurement of light read at the work surface. Lighter colored surfaces and materials with higher reflectance percentages are usually encouraged in traditional classroom design to increase the overall brightness of the classroom by reflected light.

Wiring and control of the lamps and fixtures should be addressed in order to create the most comfortable lighting environment. Classrooms need to be flexible and anticipate a variety of activities and presentations. Day-lighting controls can also be integrated with the electrical control of lights. The classroom space should be divided into lighting zones based on a level of lighting control. Areas situated near windows could be integrated with photo-cell sensors to dim electric lights when enough natural light is sensed. The front or presentation of the classroom should be well lit for general instruction but allow for dimming controls for video or computer presentations. The general work area of the classroom should be considered as a separate area or multiple areas from the rest of the classroom. The light levels should be high enough for reading and writing tasks but designed to limit eye fatigue caused from intense brightness. The light fixtures in this area should allow for the flexible arrangement of desks or other activities. Ideally in design, it is best to evenly reduce light levels when trying to achieve lower light levels. When entire fixtures are alternatively turned completely off while other are left on full, shadowing and contrast can cause uneven illumination on the work surfaces. It is better in design to control the lamps within the fixtures and reduce light levels by turning off the same number of lamps in each fixture uniformly. Dimming each lamp in the fixtures will also allow for uniform control of light levels. (Energy Effective Lighting for Classrooms: Combining Quality Design and Energy Efficiency).

3.1.1 Light Fixtures and Housing

Recessed troffers are typically measured in increments of one foot and are designed to fit conveniently into acoustical ceiling grids. The majority of the fixture housing is recessed into the ceiling plenum with the bottom edge of the fixture flush with the ceiling tiles. These fixtures house between one and four fluorescent tube lamps (t-lamps). Reflectors built into the housing will direct light down to the space while louvers or lens coverings on the bottom face of the fixture will distribute and diffuse the light. Shown below is a sketch and cross-section of a typical recessed 2 x 4 troffer.

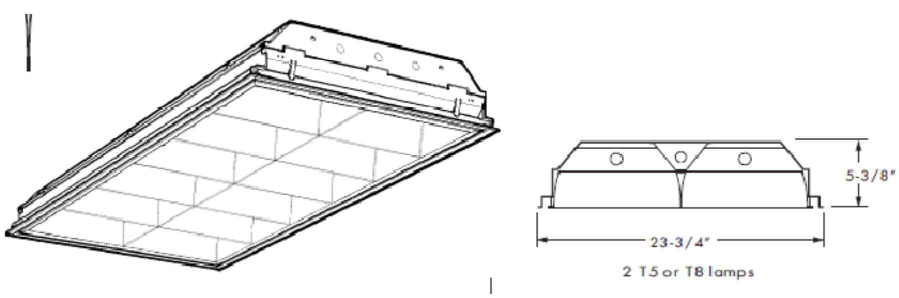


Figure 3-1: Recessed troffer parabolic with louver (H.E. Williams Inc, 2010).

Recessed troffers are commonly specified in traditional classroom environments because they are an economic fixture. These fixtures provide a high level of illumination on the work surface with an even distribution. The light output from these fixtures is completely direct; it can be practically used in installations with lower ceilings heights.

There are fixtures that provide a balance of direct and indirect light. These light fixtures are noted by percentages of light output from the top of fixture and light output from below the fixture. These fixtures are installed suspended from the ceiling structure to allow the indirect light to reflect off of the ceiling surface and down to the work plane. Fixtures can house from one to three lamps. Below is one example and style of a suspended fixture. This example exhibits sixty percent up-light and forty percent down-light with a single lamp in cross-section.

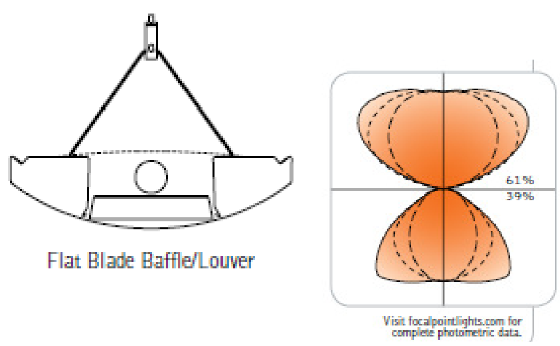


Figure 3-2: Direct/indirect suspended fixture cross section and light distribution illustration

(Focal point).

These fixtures provide less direct glare and a softer diffusion of light. Depending on fixture housing design, they can lose some efficiency compared to the recessed troffers but the quality of the lighting conditions improves. Baffles, louvers and lenses are installed on the bottom side of the fixtures to diffuse and shield direct light from the underside. Because these fixtures are suspended from the ceiling structure, they are not governed by a rigid grid layout. These fixtures can be installed linearly continuous, on diagonals or over specific classroom seating areas. For effective distribution of light, fixtures are best suspended eighteen to twenty-four inches from the ceiling.

This allows space for the light to strike the surface and distribute down and eliminates hot spots of light on the ceiling surface. Ceiling surfaces should be light colored and have a reflectance of 0.7 and greater to be effective for direct/indirect lighting.

Can lights offer a lighting solution by providing light in more concentrated areas. These fixtures are recessed in the ceiling with the majority of the fixture housing hidden in the plenum. These fixtures provide a cone shape of direct down light to the surface. Can fixtures are typically small in diameter and house compact fluorescent lamps or incandescent lamps. Below is a cross-section diagram of a compact fluorescent can light fixture. The lamp resides high in the housing above the can reflector.

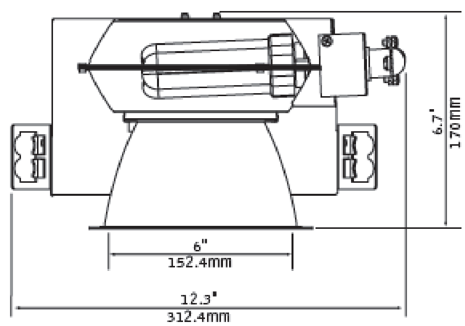


Figure 3-3: Recessed can light fixture housing and lamp [Focal Point].

Light Emitting Diodes or more commonly referred to as LEDs are a newer lighting technology in the commercial realm. LEDs have been is use in small electronic applications for close to forty years but still face limitations when used in general lighting design. LED fixtures are made up of a board or two with groups diodes on each that provide the light output for the fixture. There are tiny reflectors built into the cap of the diode as well as a larger, general reflector of the fixture. Although LED fixtures have strong advantages such as no ballast required, long lamp life and high efficiency; they are not yet well developed enough to provide uniform, general washes of illumination for larger commercial applications (*The History of LED Lights, 2010*).

3.1.2 Disadvantages to Traditional Classroom Design

As practical as fluorescent fixtures seem, they do have disadvantages. These disadvantages are presenting in studies to affect the health and wellbeing of some students and individuals. Proper maintenance, such as replacing lamps and ballasts at the end of their usable life, and keeping fixtures clean are required to ensure good light output and consistent color temperatures of the lamps. Fluorescent lamps can vary in color temperature and can also create visual distractions and inconsistency. The color temperature creates a perceived color in the blue and cool range or a warm yellow spectrum. The figure below illustrates the warm or cool appearance of lamp types. As a lamp reaches the end of the estimated lamp life, the color temperature can differ from when it was originally installed. As lamps are replaced as needed in various fixtures, the color temperature can vary in the fixtures creating a distracting spectrum.

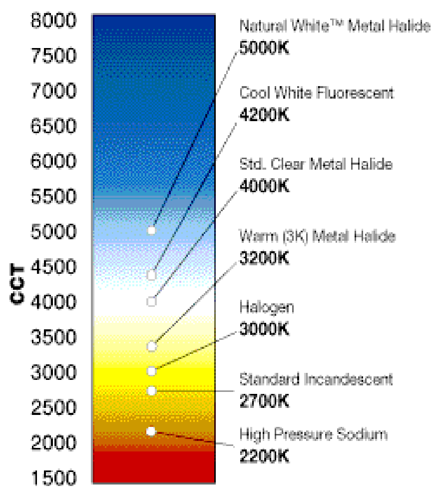


Figure 3-4: Graphic of color temperature of common light sources.
Graphic courtesy of Venture Lighting International (Venture Lighting, 2010).

Ballasts are an additional component required in the operation, and can increase the capabilities of fluorescent lamps. Ballasts have developed over time, but are still far from flawless. Ballasts are the main source and cause of hum and cause the cyclical flicker. As these components reach the end of their usable life, flicker and hum worsen and become more noticeable (Rea, Mark S, 2000).

With efficiency being a driving factor, most recessed troffer fixtures are nearly one hundred percent down light. This means that the light seen on surfaces has been emitted directly from the lamp in the fixture with little or no reflectance from the ceiling surface. This ensures that the electrical energy that has been converted into visible light is used to directly illuminate surfaces.

Even with acrylic and diffused lenses or coverings, the lamp can still be noticed (Rea, Mark S, 2000).

Chapter 4 - FIXTURES

Fluorescent lamps in fixtures have been the most commonly reported lamp type to produce light flicker and audible hum. There are many lamp types under the general category of fluorescent lamps. Theses lamps vary in size, shape, color temperature, lamp life and ballast type. As previously mentioned, fluorescent fixtures require ballasts for operation. This ballast offers the occupant control of the light in the on and off position as well as dimming capabilities. There are many types of ballasts for fluorescent fixtures that vary in frequencies. It is these operating frequencies that ultimately produce the flicker and the hum that are generated by the alternating current (AC). The following sections will discuss the most commonly used fluorescent lamp types and fixture housings, the operation of the ballast, and the noticeable disadvantages.

Fluorescent fixtures have three main components: a fluorescent lamp, the fixture housing and compatible ballast. Each of these components needs to be complementary of the others to achieve the most efficient light output while reducing any negative effects. Fixture housings not only provide a secure and mountable connection point for the lamp and ballasts but will also create a photometric web of light distribution and determine how the light is distributed and delivered to the space. The fixture housing is usually seen and because of its visibility, housings are designed also with an architectural and aesthetic intent.

4.1 Fluorescent Lamp Types

Fluorescent fixtures produce visible light by exciting phosphorus crystals on a molecular level with ultra-violet radiation (UV). The envelopes of fluorescent lamps are commonly glass or polycarbonate; the interior of the envelope is coated with phosphor powder. To initiate the molecular reaction, a given voltage is applied and two electrodes produce a mercury arc at low pressure. The result of this arc emits invisible UV radiation that reacts with the phosphorus coating. [Rea, Mark S, 2000]. The internal reaction in a fluorescent lamp requires a control to limit the current. The ballast is an essential part of the fluorescent fixture assembly to control current, adjust to lamp operating voltages and allow for user controls such as dimming.

Fluorescent lamps are specified on a variety of qualities. Lamp shape, operating voltage, color temperature and ballast type are the most influential. It is also important to know the resulting lumen output and lamp life associated with the specification qualities. The following sections will describe the most applicable and common fluorescent fixtures used in educational and classroom facilities.

4.1.1 T-8 Fluorescent Lamp

T-8 fluorescent lamps are straight tube shaped with a diameter of one inch and are available in a common length of four feet with lengths up to eight feet. Thirty-two watts is the most common operating wattage. These lamps replaced the large T-12 lamps because they are more efficient and economical. The smaller tube diameter requires less phosphorus coating and results in greater efficacy (Rea, Mark S, 2000). T-8 lamps are commonly used in two foot by 4 foot troffer type fixtures. These lamps are also used in suspended fixtures that can be direct or indirect. The length of the lamp is compatible with the fixture size and the complete fixture and lamp are able to produce sufficient light output for reading and writing tasks with a wide distribution of light. T-8 lamps can be operated from electronic or magnetic ballasts. Electronic ballasts are more universally specified because of their higher efficiency, while magnetic ballasts are now only seen in existing building or retrofits (National Lighting Product Information Program, 2010).

4.1.2T-5 Fluorescent Lamp

T-5 fluorescent lamps have diameters of 5/8th inch. These lamps have advantages over their T-8 relatives. Because of the smaller lamp diameter, T-5 lamps can be effectively used in shallow fixtures and other specific applications. They are also perceived brighter and offer improved optical control than the T-8 lamps (Rea, Mark S, 2000). Similarly to the T-8 lamps, the T-5 lamps are also seen in recessed troffers or suspended direct indirect fixtures. The smaller size and profile of T-5 lamps allow for their use in applications where fixture housings are smaller or low profile. The lamp and fixture assembly are still able to achieve an acceptable light output and even distribution good for classrooms environments. These lamps are only operated with electronic ballasts.

Although the construction and general shape of the T-5 and the T-8 lamp are similar and have similar operating characteristics, they are not interchangeable. Length measurements are provided in different standards and T-5 lamps will only operate with compatible ballasts. T-5 lamps specified in new designs and construction and are not commonly used in retrofits or minor retrofits.

4.1.3 Compact Fluorescent Lamp

Compact fluorescent lamps (CFL) are gaining popularity because of their smaller size while maintaining a high efficiency and long lamp life. These lamps can vary in wattage from five watts to fifty-five watts; with lumen outputs of 250 lumens to 4,888 lumens (Rea, Mark S, 2000). A small spike in energy is needed when the lamps are first started, but during operation of fifteen minutes or more, CFLs will use seventy-five percent less energy than a traditional incandescent lamp with a comparable output of initial lumens. The color temperature of CFLs tend on the higher color temperature. CFLs have a bluish white light output compared to a warmer, yellower output from an incandescent. Originally CFL lamps used magnetic ballasts but current lamps are using electronic ballasts. Energy Star designations are only awarded to lamps which use electronic ballasts (Energy Star, 2010).

Self-ballasted compact fluorescent lamps are filling the void created by the restrictions on incandescent lamps. These self ballasted lamps have an Edison type screw base that fits into the same connection as the incandescent lamp.

Figure 4-1: CFL with Edison screw base compared to a standard incandescent A-lamp (Philips Lighting, 2010).

These lamps are rapidly increasing in popularity in small commercial applications and residential because of the ease of interchangeability in fixtures previously designed for incandescent lamps. Although a slightly higher initial cost, these lamps have an extended lamp life, and greater energy efficiency and light output (Rea, Mark S, 2000).

CFLs are typically seen in areas where small fixtures are used or where there is a need for a smaller area of light. These lamps are used in recessed can lights or fixture housings with a smaller diameter. Self ballasted lamps were designed with the intent of replacing incandescent lamps and can be interchanged into similar fixtures. There are compact fluorescent lamps that do not have an integral ballast; and therefore, need a separate ballast for control. This eliminates the interchangeability into fixtures and will slightly increase the overall size of the fixture.

4.1.4 Energy Saving Fluorescent Lamps

Energy saving lamps achieve a standard light output while reducing the operating wattage needed. This is done by altering the gas mixture in the bulb envelope that is used to initiate the arc and maintaining the production of UV radiation to interact with the phosphor. Because the operating voltage is a crucial part of energy saving lamp operation, it is important to have ballasts that are compatible with the lamp. Ballasts of energy saving lamps reduce the starting voltage and provide less current during the operation of the lamp (Rea, Mark S, 2000).

4.1.5 High Output Lamps

High output lamps are commonly noted as HO lamps. T-5 and T-8 lamps are commonly available in a HO option. HO lamps typically provide at least forty-five to fifty percent more lumens and use slightly less than double the wattage than their standard counterpart. Comparatively, if the wattage remains the same HO lamps will provide approximately a fifteen percent increase in lumen output (1st Source Lighting, 2002). High output lamps can be practical and economic when designed in appropriate applications. HO lamps draw more current but produce more output lumens. This allows for less lamps and fixtures to be installed to achieve the same light level. HO lamps are also beneficial in indirect lighting applications. Higher light levels are naturally achieved when measured at a surface that is illuminated by a direct light source. Indirect fixtures lose a percentage of their lumen output after the light has been reflected off of a ceiling or wall surface. HO lamps provide more initial lumens at the light source and can therefore still achieve recommended light levels on the working surface even after reflection. It needs to be considered that HO lamps should be used in indirect applications or with lenses or shielding diffusers to avoid any direct sight of the lamp. Higher mounting heights also allow for a better distribution of light and reduce direct glare.

High Output lamps also have a high CRI, above 85. These lamps, along with other fluorescent lamps, are able to best imitate the color spectrum of natural daylight. It is important to consider in lighting design that the quantity of light or lumens cannot be directly compared to the quality of light output. Lamp color temperature, and the color spectrum of the light output are more important factors to human perception than a measured quantity of light.

4.2 Ballasts

Ballasts are required to operate fluorescent lamps because they have a negative incremental impedance which is not compatible with Alternating Current (AC) voltage supply. Ballasts convert the low frequency AC source and control the current supplied to the lamp for proper operation and a steady output of light (Enrico Santi, 2001). For best performance and results, ballasts are designed to be compatible with specific lamp types and to follow the labeled voltage rating. There is approximately a ten percent fluctuation in voltage allowed for ballast operation. The voltage supplied should be at the level specified or less to ensure performance and life of the ballast. Electronic ballasts are sensitive to fluctuations in voltage. It is important to regulate a steady current flow on the secondary lamp side to achieve optimum performance of the lamp (National Lighting Product Information Program, 2010).

There are standards to establish and label performance qualities of ballasts. Manufacturers will assign a percentage flicker for each type of ballast. The percentage rating is determined by the associated lamp type and the phosphorus coating inside the lamp envelope. Flickers of thirty percent or less are not perceived by the average person (Stein, Benjamin, et.al., 2006). A rating system was also developed to note the severity of an audible hum that ballasts emits. The system uses letters A, B, C, D, E and F to rate the level of hum. An A rating is the quietest ballast available while, a D rating will produce a more audible hum. Ballasts with ratings of E and F are very uncommon and seldom used. It is commonly recommended that A rated ballasts be used in commercial applications, because of the number of fixtures and the high volume of occupants in the space that may be affected by the noise (Lithonia Lighting, 2010). These ratings have been assigned ranges of average ambient sound levels measured in decibels (dB). The following table displays the ranges of decibels associated with each letter rating. To provide some perspective on the sound level, common tasks with similar decibel levels have been included.

Noise Rating	Average Ambient Sound Level in Decibles (dB)	Common Tasks with Similar dB Levels
A	20-24	Rustling Leaves
B	25-30	Watch Ticking
C	31-36	Birds Chirping
D	37-42	Refrigerator Hum
E	43-48	Dryer
F	49 and greater	Tidal Surf

Table 4-1: Ballast noise ratings.

Adapted from NLPIP Ballast Noise Rating Table 6 and *Mechanical and Electrical Equipment for Buildings.*

4.2.1 Ballast Factor

The ballast factor is measured by the ratio of the light output the ballast being rated to the light output given from a laboratory reference ballast standardized by the American National Standards Institute (ANSI), that is operating at the prescribed voltage. The value results in a percentage. Ballast factors of one indicate no loss when power is converted to visible light. It is important to select ballasts with factors near one to limit loss and improve lamp efficiency. Newer models of electronic ballasts are able to achieve ballast factors greater than one, meaning they provided more lumens than the laboratory reference ballast. This is because the laboratory ballast operates on line frequency current only; high efficiency ballast are able to alter the current to the lamp to increase operating frequency, thus achieving ballast factors ranging between 0.73 and 1.50 (National Lighting Product Information Program, 2010). It has been seen in laboratory and standards testing that higher ballast factors will reduce lamp life, and result in a faster lumen depreciation rate because of the increase in lamp current. These same adverse effects could also be seen if the ballast factor is too low. Ballasts can operate one to four lamps depending on the ballast type. More lamps operating from a single ballast will decrease the ballast factor (National Lighting Product Information Program, 2010). At the end of this section is an adapted table comparing the three ballast types that are discussed.

4.2.2 Magnetic Ballasts

Magnetic ballasts are composed of an inductor that causes an impedance of current and allows for a steady control of current to operate the lamp. The inductor is created from laminated steel plate wrapped with copper windings; this construction is referred to as core and coil (National Lighting Product Information Program, 2010). These ballasts have a larger size and are heavier than electronic ballasts, because of the components of the inductor. Magnetic ballasts only operate at low frequencies, and the same frequency as the input voltage source. The inductor naturally causes a slight lag in the sinusoidal current pattern resulting in a power factor less than one. Capacitors are sometimes included in the ballast to increase the power factor, but the extra components add to the size and weight of the ballast. Magnetic ballasts are not usually specified in new design projects and are being phased out by higher efficiency and smaller ballast. Magnetic ballasts have made improvements in component construction; but even so, these ballasts have sound rating ranging B, C and D (Enrico Santi, 2001).

4.2.3 Electromagnetic Ballasts

Electromagnetic ballasts are a hybrid of magnetic ballasts and electronic ballast by using the same core and coil, but with an electronic switch. After the lamps are started and warm, the electrode-heating circuit that was started with the electronic switch is disconnected, saving wattage. This ballast type only operates at line frequency which is 60 Hz in North America. As expected these ballasts are more expensive than the magnetic ballast but less than electronic ballasts (National Lighting Product Information Program, 2010).

4.2.4 Electronic Ballasts

Electronic ballasts eliminate the need for an induction coil and therefore significantly reduce the audible hum that is created from the induction wires in magnetic ballasts. Electronic ballasts typically have an A noise rating. These ballasts operate at a frequency of 20-60 Kilohertz which essentially eliminates any visible flicker during the lamp start up or duration of operation. These ballasts are the best option to reduce noise and flicker; however for students with ASD that show heighten sensitivity to noise and light, these ballasts do not eliminate the problem completely. These ballasts are designed to efficiently control the current to the lamp, thereby increasing lamp efficacy by ten to fifteen percent. Dimming ballasts are available for magnetic and electronic ballasts although dimming capabilities for magnetic ballasts are severely limited and perform less than electronic ballasts. Dimmers decrease the power needed to operate the lamp and thus reducing the light output levels (National Lighting Product Information Program, 2010). Electronic ballasts also provide the user with dimming controls from full brightness to theoretically one percent. These ballasts are more expensive than magnetic or electromagnetic ballasts (Stein, Benjamin, et.al. 2006). The advantages these ballast provide easily justify the difference in cost.

High frequency electronic ballasts, also known as solid state ballasts, are being developed and introduced more widely into the market. As the label implies these ballasts increase the frequency of the supply to allow the lamp to operate at a higher frequency. When applied to the knowledge of frequency and flicker described previously in this report, the eye frequency exceeds the CFF so that the eye cannot perceive the cycle as a flicker, but interprets it as a constant output of light. An important side effect to consider in applications with high frequency ballasts is the effect of electromagnetic interference (EMI) and Radio Frequency Interference (RFI). The effects of EMI and RFI become problematic in spaces with sensitive electronic equipment such as computers and communication devices (Enrico Santi, 2001). EMI increases as the frequency increases; EMI becomes problematic at ranges greater than 60 kHz. There is an optimal range between frequency and lumen output. There is not a significant increase in lumen output after the frequency reaches 60 kHz. It has been established that 60 kHz is a reasonable maximum frequency to produce the most lumen output while limiting EMI in general applications (National Lighting Product Information Program, 2010).

Comparison of Three Ballast Type*			
	Ballasts		
	Magnetic	Hybrid	Electronic
Number of lamps operated	1-4	1-3	1-4
Weight (lbs)	3.5	3.5-3.7	.4-5
Lamp operating frequency	60Hz	60Hz	20,000-60000Hz
System Efficacy	Low	High	Highest
Ballast efficacy factor	.9-1.4	1.10-1.40	1.15-1.56
Total Harmonic Distortion	20%	<20%	5-20%
Power Factor	.75-.90	>.90	.9-1.5
Lamp flicker index	.04-.07	.04-.07	<0.01
Sound Rating	A-D	A-B	A-B
Dimming	Yes	No	Yes

*Data is presented for 4' fluorescent tube lamp

Table adapted from NLPIP and information from manufactuers

Table 4-2: Magnetic, Hybrid and Electronic Ballasts criteria compared. Table adapted from NLPIP and information from manufacturers

4.3 Incandescent Lamps

Incandescent lamps emit light by using a filament that will emit electromagnetic waves in the visible range when it reaches a minimum temperature. To be effective filaments need to have a specific chemical and metal composition that makes it suitable to radiate light, and have a high melting point. Most lamps have coiled or double coiled filaments because it increases the efficacy of the lamp. The lamp envelopes are made of glass with varying compositions to create soft or hard glass that withstands a range of temperatures. The glass envelop may have a frosted coating that diffuses the light it emits without significantly reducing the lumen output. The filament burns at high temperatures by reacting with gases sealed within the envelope and the basic concept of resistance to create heat. The composition of gases varies with the filament type. Throughout the life of the lamp, particles from the burning filament collect on the inside of the lamp envelop and cause blackening. This will reduce the lumen output from the lamp throughout its life. Incandescent lamps produce light by the resistance in the filament, which is why the filament is commonly the first component to deteriorate and fail. Tungsten-halogen lamps have a regenerative cycle that minimizes the filament deposits on the lamp envelope and result in less lumen depreciation over the course of the lamp life.

There are incandescent lamps out on the market that closely mimic the color spectrum of day light. These lamps have envelopes that have a blue tint that absorb stray and strong colors in the visible spectrum to imitate the color distribution of natural light. Because of the tinted envelope, day light incandescent lamps emit approximately thirty-five percent less light than a standard incandescent lamp. Day light lamps have a high color temperature of 3500K -4000K. In general incandescent lamps tend to have high CRI rating of seventy-five to eighty-five (Rea, Mark S, 2000).

Incandescent lamps provide very flexible control to the users. No ballast is required to dim the light levels. The lamps are simply dimmed by reducing the voltage across the filament. Unlike the fluorescent lamps that operate with reactions sensitive to current and voltage, incandescent lamps do not encounter complicated effects when dimmed. When the voltage is decreased less power is drawn which results in energy conservation and a lower lamp color temperature while increasing in the life of the lamp.

Incandescent lamps are not efficient at converting power into visible light. The lumen output depends on the visible radiant energy emitted from the filament. Incandescent lamps only produce about six to twelve percent of the input wattage into visible light while the remaining energy is converted into heat and other invisible losses (Rea, Mark S, 2000). The incandescent lamps are under critical review as more stringent energy codes are passed. Fluorescent lamps have shown considerably higher energy efficiency and have been developed to be installed in applications where incandescent lamps were previously used.

Because of the current flow, incandescent lamps operating at a standard sixty Hz do not produce a flicker noticeable to humans. Trends show that the larger the filament, the higher the input wattage and higher the supply frequency, flickering effects are minimized. In cases not common in the United State of America, lamps operating at twenty-five Hz or less have been reported to have adverse flickering and stroboscopic effects. Sources operating at six Hz were not reported to have any flickering effects (Rea, Mark S, 2000).

Chapter 5 - CASE STUDY: AMANDA ARNOLD ELEMENTARY

The following case study was developed with information and resources from Anderson-Knight Architects, LST Engineers, and staff at Amanda Arnold Elementary and the Manhattan-Ogden School District. In 2002 the district completed the original Autism Suite in Amanda Arnold Elementary. This provided a usable functional space to care for and address the needs of elementary aged students with ASD and other special needs. The original space was designed and considered for special needs students and much of the design was carried over and incorporated in the design of the new suite in 2010. Fluorescent lighting was eliminated in the 2002 design and can fixtures for incandescent A-lamps were installed. There were many positive design qualities and suggested improvements that influence design decisions for the new autism suite design.

All schools in the Manhattan-Ogden district from elementary through high school level have a separate classroom for special needs and students with ASD. Many of these spaces need renovations and updated designs to better meet the needs of the students and teachers.

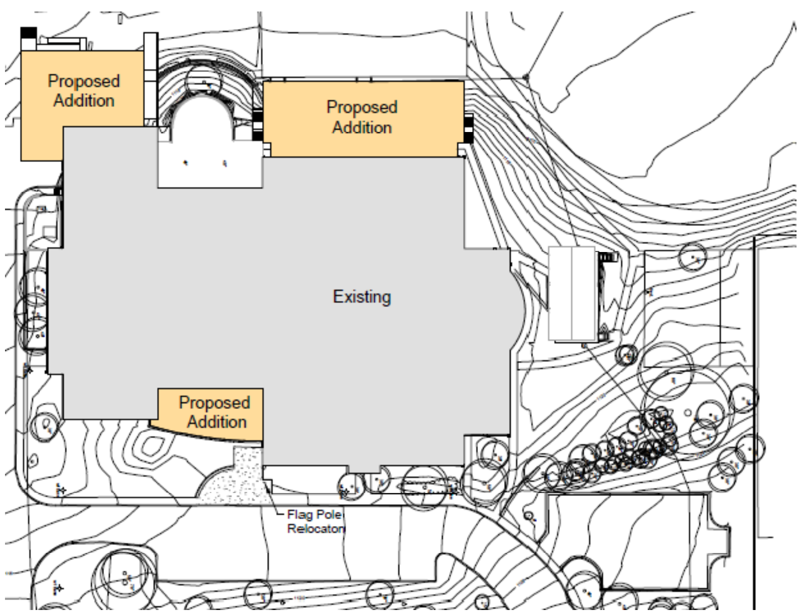


Figure 5-1 Site Plan of Amanda Arnold Elementary for Proposed Renovations Plan provided by Anderson Knight Architects (Anderson, Tracy, 2010).

Figure 5-2 2002 autism suite lighting design.

Can lights created bright scalloped patterns and contrasting shadows on the wall surface. Photos courtesy of LST Engineers (Leon, Justyn, 2010).

Figure 5-3 Reflective surfaces in the 2002 autism suite

This created problems with distracting glare. Photos courtesy of LST Engineers (Leon, Justyn, 2010).

5.1 Autism Suite Renovation

Early in 2009, the Manhattan-Ogden School District 383, in Manhattan, Kansas was approved for school construction and facility improvements. Thirteen school campuses were allocated funds for facility improvements. The concept design for the facility changes began in early April of 2009 and construction broke ground early November 2009. Amanda Arnold opened for classes August 20th, 2010 with completed renovations. For this case study, Amanda Arnold Elementary School was highlighted because of the improvements in the autism suite, specifically in regards to lighting design. Amanda Arnold Elementary was approved for seven building renovations including the addition of a full special needs and autism suite. According to the Manhattan-Ogden school district and the designers, there were no restrictions or revisions due to budget constraints.

A-lamps addressed and alleviated the problem of flickering and noise from the lamp and added user controls for dimming. To achieve uniform light throughout the space, more fixtures were integrated into the design. Maintenance and replacing burnt out lamps became costly and time consuming with the increase in fixtures. The 2010 autism suite was designed with incandescent fixtures as well, but with an incandescent PAR lamp and a deeper recessed can fixture.

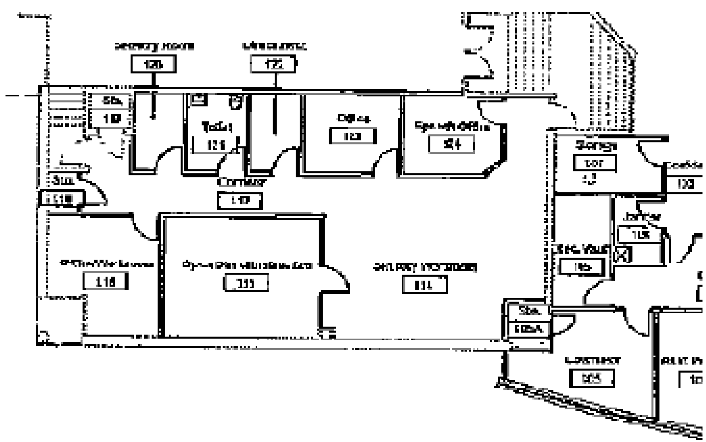


Figure 5-4 Floor plan of 2010 autism suite construction.
Image courtesy of Anderson-Knight Architects (Anderson, Tracy, 2010).

The new Autism Suite is just under 400 square feet in area and composed of eight separate spaces for students and education. Each of these spaces are partitioned with walls and doors and include: Speech Office, Direct Instruction, Sensory Room, Full Bathroom, Workroom, Open Direct Instruction and Open Sensory Workroom. It is important for students and instructors have separate enclosed rooms for smaller individualized lessons with minimal distractions. Two storage rooms provide enough space to hide and store classroom materials. There are also two egress exits provided at each end of the central corridor. The ceilings were designed high (approximately ten feet) to give the feel of open space but not an uncomfortable vastness. Most of the students with special needs that learn in this classroom have been diagnosed with a form or symptoms of ASD. Significant portions of the design were based on the needs of these students; however the suite needed to be able to accommodate the needs of all students with varying degrees of handicaps and medical diagnosis. Fortunately, in the design of the new autism suite no sacrifices in the initial design were required due to budget or other constraints. Without these limitations, the design for the new suite was able to meet the specific needs of the students and teachers.

5.1.1 Lighting Design

Lighting for the space is achieved using dimmable incandescent can fixtures with PAR lamps recessed into a high ceiling. Each individual room is equipped with a separate control for on/off and dimming. Each of the eight spaces is controlled separately by a slide dimmer switch. Most of these controls are accessible to the students. Because of the noise concerns expressed when using fluorescent ballasts, no ballasts were installed to control the light fixtures in the Autism Suite. When all lamps are on at full capacity, the light levels are approximately twenty-five foot candles which is lower than the fifty foot candles recommended by the IESNA. Day light from the windows varied the light readings in the larger Sensory Workroom depending on time of day and if there was cloud cover. Initial design calculations were based on electric lighting only and did not account for additional day light from glazing.

Figure 5-5 Office and Direct Instruction classroom lighting and student area.

The lighting design also incorporated day lighting into the space with windows. These windows are located high on the east wall of the larger Open Direct Instruction room and the Sensory Workroom space. The high windows achieve a high amount of daylight which has shown to provide emotional and mental benefits in classroom environments (Heschong, Lisa, 2003). Because of the height of the windows and operating hours of the classroom, direct glare has not been concern in the space. Automatic shades are controlled by the students and teachers to increase the level of control and comfort to the students. These blinds are dark in color but still allow a limited amount of light into the classroom. Occupants can see out but the view is blocked from the exterior looking in.

Finishes and materials in a space can be a commonly overlooked design element in lighting design. For the renovation of the Autism Suite classroom finishes, materials and colors were a high priority and integrated well with the lights. Soft, muted colors were used on the walls and neutral, calm blues were used in the carpeted areas. There were a few areas where it was practical to use linoleum but the material was limited in its use. These finishes increased the softness and distribution of the light from the fixtures and window and eliminated any problems with glare or harsh shadowing. Softer and muted colors do not possess the reflective qualities of brighter more reflective finishes, and thereby limited light levels and perceived brightness from the fixtures.

Figure 5-6: Direct Instructional Room.

The reflective flooring material can create glare and hot spots. This problem is avoided by dimming and adjusting the light level for the comfort of the user.

5.1.2 Designer Considerations

The highest consideration and priority was to create comforting, calm and peaceful environment for special needs students. The Autism Program directors and teachers requested lower light levels specifically for the autism suite. Designers at LST Engineers usedLitePro software to model and estimate light levels for each of the rooms. The main Sensory Workroom and Direct Instruction Room have average light levels estimated at twenty-seven foot candles, with a maximum calculated at fifty foot candles at points directly under the light fixtures.

Fluorescent fixtures were not considered in this design. Only dimmable incandescent fixtures were included in the design. Fixtures for incandescent lamps house a single lamp while fluorescent fixtures can house one to four lamps. This means that incandescent fixtures have lower lumen output than fluorescent fixtures and therefore more fixtures are required to achieve the desired light levels for the space. Full calculations and point by point light level values are included in Appendix B provided by LST Engineers. With consideration to the design budget, economical fixtures were selected. Designers selected seventy-five watt incandescent PAR 30 medium flood lamps, color temperature 3500K, housed in six inch diameter recessed can fixtures housing. The PAR lamps are recessed deep in the housing of the fixture to significantly reduce direct sight of the lamp. PAR 30 lamps were selected because of their efficiency in comparison to other incandescent lamps. The previous autistic suite used incandescent A-lamps in recessed can fixtures. The PAR 30 lamps has a 2,500 hour life, in comparison to a traditional incandescent A-lamp which has a life estimated at 300-700 hours (Sylvania, 2010).

Because incandescent lamps have a low light efficiency it is very difficult to meet energy standards and restrictions for watts per square foot. All spaces in the facility were considered when calculating the overall energy efficiency for the school. This allowed for some flexibility and give and take in the lighting design for some spaces to compensate with lower watts per square foot while allowing incandescent fixtures to be installed in the autism suite.

Ceiling mounted occupancy sensors are wired through wall box dimmer switches to control full on and off functions of the lamps. Each room is controlled through a separate power pack and slide dimmer to manually adjust or override the occupancy sensors. The main Open Sensory Workroom was designed with the light fixtures in that area operating on two separate areas of control. The first three rows of fixtures on the east side of the room are controlled on a separate dimmer. This allows the occupant to manually dim the light levels when day lighting provides adequate light. The two separate areas of control were also intentionally designed to break the larger space into two smaller flexible learning spaces. A single occupancy sensor in the bathroom controls both the lighting and exhaust at full or off. The corridor is controlled with a ceiling mounted occupancy sensor and three-way switching manual control.

The space for the new Autism Suite was formerly the space used for the school gymnasium, so the original ceiling was high. Once a plenum space was created, lighting designers had the advantage of a ten foot high ceiling. The higher ceiling height allowed for the light to distribute and spread before reaching the work surface and floor. The helps to eliminate the cone distribution and shadowing that can be a concern when using recessed can fixtures. The issue with conic distribution is further explained in section 6.3 of this paper.

5.2 Occupant Input

To achieve the best design in theory as well as practical usability, it is important to understand the needs and concerns of the occupants. Teachers and special needs coordinators made significant contributions to the design by expressing the concerns and needs of the instructors and students. Architects and engineers were then able to create the most user-friendly and comfortable learning environment based on these needs.

The most significant concerns that were addressed in the lighting design were the light level of the space, noise from the fixtures, and user control. The architects and designers were able to successfully address and work solutions to the restrictive criteria. Students were bothered and stressed by high light levels, hot spots created by pools of light and reflected glare from wall or desk surfaces. All light fixtures are dimmable so that a comfortable light level can be set by the student for each space. The high ceiling allows for the light to be distributed and reduces most direct lines of sight of the lamp. Special consideration was given to materials and finishes in the space to reduce reflective glare. Sensory time is an important activity for students with ASD and the controllable softer lighting creates a calming setting for students to recharge.

Occupant and individual room control were priorities in the lighting design. As budgets get tight it is common to sacrifice user and areas of control. There are individual closed rooms built into the suite and there is a personal level of dimming control for each room. This allows the student to take control and adjust the light levels to his or her comfort and reduce any distractions or anxiety from the light levels. In previous special needs classrooms small desk lamps or even decorative string lights were used to create a soft glow in a student's individual work space. In larger open areas teachers would use soft colored tissue paper to cover the light fixtures to reduce the light output and create a soft glow of color that was calming to the students. Because of the level of control in the new renovations, these adjustments were not needed.

Windows were an important part of the classroom design. Windows not only provide a natural source of illumination and excellent color rendering to a space, but also connect the occupant to nature and the environment. There are many health and educational benefits associated with day light integrated into classroom environments. Two concerns that were addressed with the window design was the glare and hot spots that could occur as well as the visual distraction they would provide to the students. Students with ASD commonly have symptoms of fixation and can be easily distracted by environmental stimuli. To balance the advantages and disadvantages of installing windows in the suite, the windows were situated high on the east wall with shades controlled by the users. This allowed for the occupants to control direct glare and hot spots in the morning hours, but to allow natural light to provide the bulk of the interior illumination during the majority of the school day. The high windows provided a way for students to view nature, and the outdoors with limitations to distractions of pedestrians or traffic.

Figure 5-7: Open Sensory Workroom with high windows and electric lights off.

Figure 5-8: Open Direct Instructional classroom with high windows and shades lowered

Chapter 6 - GOOD LIGHTING DESIGN FOR AUTISTIC CLASSROOMS

Classroom design to accommodate special needs students and students with ASD unfortunately can become an afterthought in most educational facility design. Unless there is a specific portion of the budget allocated for special needs design, many of the important design criteria that should be addressed might be overlooked or value engineered to traditional classroom standards. If we are to achieve a comfortable and effective learning environment for students with ASD, design considerations need to be proactive and integrated early in the design process. Each student that presents with ASD has a varying degree of symptoms and behavioral triggers. It is because of this uncertainty that it is important to design a flexible and calm environment. The best designs for special needs students can be developed with input and suggestions from the educational staff, and teachers who work directly with the students in the classroom environment.

6.1 Light Fixtures and Lamps

Although fluorescent fixtures are strongly encouraged for traditional classroom lighting designs, they are not recommended for autism classrooms. Fluorescent sources and fixtures have made advancements to reduce noise and flicker and other disadvantages in order to improve their overall performance and be more versatile in applications. Even with improvements to these fixtures, the brightness, flicker and hum are still strongly noticed by most students with ASD. Fluorescent lamp construction and operation is the greatest source of flickering. Students with ASD are able to perceive the cyclical flickering when other students may be unaffected. Ballasts that function with fluorescent lamps create the audible humming noise which is a distracting and frustrating stimuli to students with ASD. Even with improvements to ballast construction and operation and the common use of high frequency ballasts, it is not encouraged that any type of fluorescent fixture be installed in special needs or ASD classrooms. Fluorescent lamps are also widely used because of their efficient light output. In traditional design, high light levels and lamps that emit a cool or bluish color temperature are recommended. The cooler color in light makes the light level in the space appear brighter to the eye. Higher temperature lamp sources promote an energetic atmosphere, as well as create more of a contrast for reading tasks cool colors encourage alertness and productivity, which are helpful in a traditional classroom environment. In classrooms for students with ASD, brightness was a significant concern and one of most frustrating conditions for the students. Incandescent lamps are best used in autistic classroom design because of their warmer color temperature and a significant reduction in lumen output without the use of ballasts. The disadvantages of incandescent fixtures are a reduction in lamp life and efficiency, but they provide many benefits towards the goal of creating a comfortable space for students with ASD.

Fixtures that should be considered and installed are ones that evenly distribute and diffuse light. Fixtures that shield any direct sight of the lamp by installing recessed fixtures with deep housing cavities or by installing translucent lenses or baffles on the face of the fixture are encouraged. Indirect distribution of light allows for the source to be hidden from direct view and allows for the light to diffuse on the reflecting surface. High ceilings are best because they allow space for the light from indirect fixtures to have wider distributions when light reaches the working plane. Unfortunately, most incandescent fixtures are limited to recessed can down lights. There are a few incandescent down light fixtures with asymmetrical reflector that allow them to provide indirect light through wall washes. This specific fixture type severely limits many of the designs for special needs classrooms.

6.2 Comparison of Lighting Design

AGI32 modeling software allows us to model three typical classrooms each with a different fixture design and layout. This software will provide illumination calculations on various surfaces, lighting power densities as well as renderings to illustrate light cut off from fixtures and distribution of light. Below are the three models created in AGI32 of a typical classroom and hallway space with a ceiling height of ten feet. Room finishes for the space were designed with lower reflectance values and softer colors to represent the finishes best for a special needs classroom. The renderings have been created for six inch diameter incandescent down lights, direct recessed 2 x 4 two lamp troffers, and suspended two lamp indirect/direct fixtures. Refer to Appendix D for cut sheet data. We are able to easily compare the average light levels on the work plane, floor surface, the east wall surface, distribution of illumination levels, and contrast ratios. Full model calculations and design inputs are included in Appendix A.

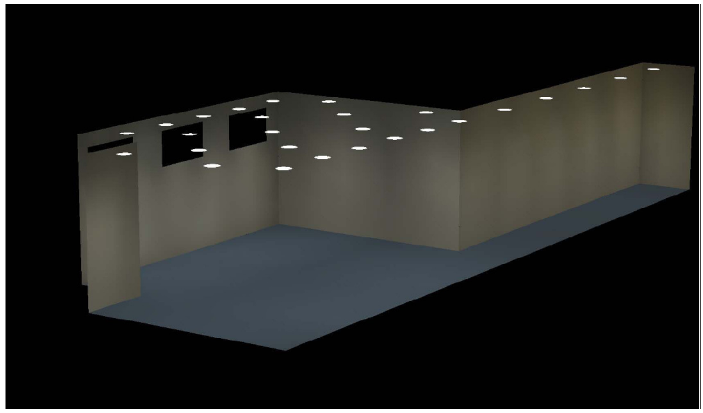


Figure 6-1: AGI32 rendering of incandescent fixture layout for a typical classroom.

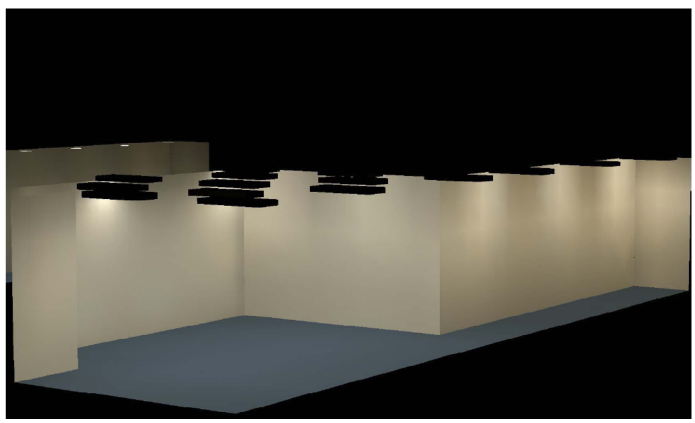


Figure 6-2: AGI32 rendering of recessed 2 x 4 troffer fixture layout for a typical classroom.

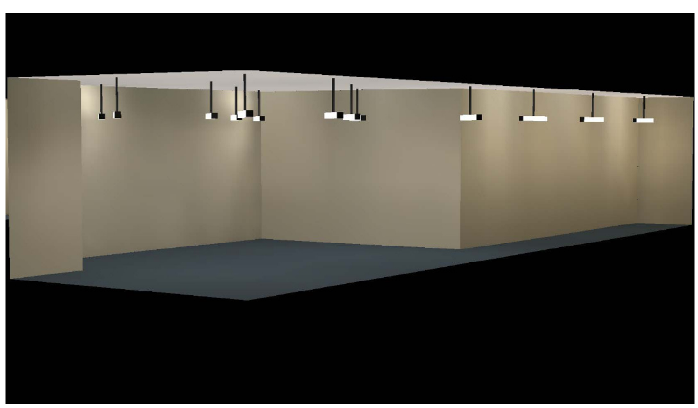


Figure 6-3: AGI32 rendering of suspended indirect/direct fixture layout for a typical classroom.

Fixtures were laid out on the reflected ceiling plan to provide the best even distribution and wash of light on the floor and minimize contrast ratios and shadows. The incandescent fixtures design was not limited by the acoustical ceiling tiles and totaled twenty-seven fixtures. Recessed 2 x 4 troffers were placed based on the layout of acoustical ceiling tiles and totaled fifteen fixtures. The design using suspended indirect/direct fixtures was not restricted by the acoustical ceiling grid and totaled thirteen fixtures in the model design.

The average light levels measured on the classroom work surface for incandescent fixtures were 71 fc at full illumination, compared to recessed fluorescent fixtures at 99 fc and suspended fluorescent fixtures at 63 fixtures. The spaces for these models were designed to achieve the most uniform light distribution, limit shadowing on vertical surfaces and to achieve appropriate contrast ratios. With those being the governing criteria for the lighting layout, the overall light levels measured on the work plane are higher than the recommended average foot candle level when the fixtures are at full lumen output. These illumination levels may seem high initially, but each of these designs have the ability to be dimmed to desired light levels. The key consideration is the incandescent fixtures do not need ballasts to achieve flexibility when dimming light levels. Illumination levels are an important consideration but there are other design criteria that must be assessed.

Calculation Summary						
Label	Units	Avg	Max	Min	Avg/Min	Max/Min
Incandescent East Wall_Wall_8	Fc	14.37	21.8	4.9	2.93	4.45
Incandescent Hallway	Fc	50.80	62.8	37.1	1.37	1.69
Incandescent Open Classroom	Fc	71.60	115	30.4	2.36	3.78
Recessed Flourescent Hallway	Fc	59.14	80.1	49.3	1.20	1.62
Recessed Fluor East Wall_Wall_8	Fc	54.09	116	24.3	2.23	4.75
Recessed Fluorescent Open Class	Fc	99.45	118	53.8	1.85	2.19
Suspended Fluor East Wall_Wall_8	Fc	42.77	120	26.3	1.63	4.55
Suspended Fluorescent Hallway	Fc	42.17	54.2	32.1	1.31	1.69
Suspended Fluorescent Open Class	Fc	63.35	72.1	35.2	1.80	2.05

Table 6-1 Calculation summary of incandescent, recessed and indirect/direct fixtures

6.2.1 Interpretation and Review of Models

From the images rendered in AGI32, it is clear that in these designs there is the concern of shadowing and hot spots on vertical wall surfaces. The recessed down light fluorescent fixtures create significant hot spots high on the wall. This effect could be reduced if the fixtures were located further away from the wall surface, but face limitations with installation because of the restriction of the acoustical ceiling grid. Hot spots and glare are reduced slightly with the use of indirect/direct suspended fluorescent fixtures but still need to be evaluated. The incandescent can light fixtures have the least problematic hot spot and glare on vertical surfaces. The light layout for the incandescent fixtures was designed to best alleviate the problem with the scalloped pattern on the vertical surfaces dues to fixture cut-off, but it is important to recognize that it is difficult to completely eliminate the shadowed effect.

The layout and design suspended indirect/direct fixtures provide the most uniform distribution of light on the vertical and floor surfaces. Recessed fluorescent troffers also provide even light distribution on the floor surface but show hot spots on vertical surfaces. Although it is subtle, slight shadowing can be seen on the floor of the model using incandescent. This is the result of the circular light distribution from the fixture not being able to provide perfect uniformity.

The modeling software provided lighting power density calculations for each of the designs. The full summary of the calculations can be referenced in Appendix A. As expected, the direct recessed troffers had the lowest value lighting power density (LPD) of 1.269 watts per square foot. The second lowest value was 1.487 watts per square foot for the indirect/direct suspended fixtures. LPD is measured in watts per square foot and is an average of the electrical consumption for a lighting design over a give area (American Society of Heating, Refrigeration , and Air-Conditioning Engineers, 2007). The model of the incandescent fixtures computed a significant value of 6.274 watts per square foot. This is a significant increase compared to the fluorescent designs.

Although the incandescent design has a significantly higher LPD value, the rendering shows that overall the can down lights provide good illumination. The incandescent fixtures are able to be dimmed to desired light levels without the need for ballasts. As seen in the rendering figure 6-1, the incandescent fixtures provide a softer atmosphere to the classroom. Even with the concern of fixture cut-off the incandescent fixtures show the least amount of shadowing and glare on the vertical surfaces. There is also greater flexibility in location of the fixtures because they are not completely restricted by the acoustical ceiling grid layout.

6.3 Vertical Illumination and Contrast Ratios

Vertical illumination, that is light levels measured on wall surfaces, must balance in contrast ratio with illumination levels on the work surface to reduce fatigue and discomfort when looking up from a task. The IESNA recommends that the light levels on vertical surfaces be no greater than five times and no less than 1/3rd the light levels on the work surface. The following table provides the measured foot candle level on both the horizontal and vertical surfaces and the resulting contrast ratios. The range for the contrast ratio is dependent on the secondary surface. Vertical surfaces parallel to eye level or in natural direct sight should have a contrast ratio closer to 1/3rd, while areas closer to the ceiling and high corners can flex towards the range of five times the light level at the work surface.

	Horizontal Surface: Work plane (fc)	Vertical Surface: East Wall (fc)	Contrast Ratio: (Horz/Vert)
Incandescent Fixtures	71.6	14.37	4.98
Recessed Fluorescent Fixtures	99.45	54.09	1.84
Suspended Fluorescent Fixtures	63.35	42.77	1.48

Table 6-2 Table comparing the results of the rendered images in AGI32. Listed is the footcandle output and the resulting contrast.

Can light fixtures tend to have sharp fixture cut-off patterns because of the conic distribution of light; this cut-off pattern is also influenced by the type of lamp. Below is the light distribution for the 75W PAR 30 wide flood lamp used in the new suite design.

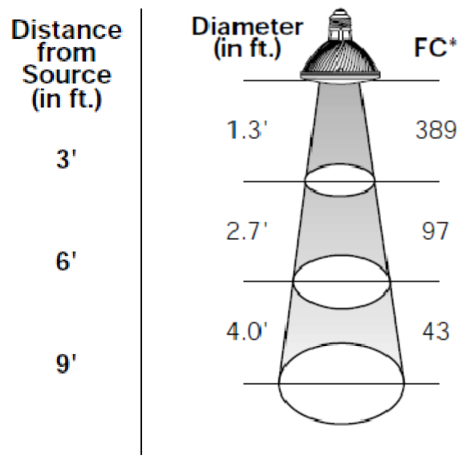


Figure 6-4 Conic distribution of light from a 60W PAR 30 normal flood lamp. (Sylvania, 2010).

This could create shadowing on high on vertical surfaces and could result in high overall contrast ratios on the vertical surface if not carefully designed. Fixtures should be spaced and laid out closer to the vertical surface as reasonable to allow for the light distribution to hit high on the wall. Fixtures laid out the second row in should be staggered to help fill in the voids in light distribution. The incandescent light fixtures in this model rendering have a very slight shadowed scalloped pattern of light on the vertical surfaces, while the fluorescent fixtures create intense hot spots in areas high on the vertical surface.

6.4 Day lighting

Lighting software is not only a helpful tool for designers to ensure that light levels are high enough in the space, but also to estimate light distribution, shadowing, and contrast ratios. Some advanced software provides designers with the ability to model the effects of day lighting into a space. Good design practice recommends that light levels are calculated without any contributions of day light to anticipate a worst case scenario. Day light modeling is very effective tool to model the effects of glare, hot spots, and light distribution. It is also allows designers to develop the most effective control strategy for day light harvesting and levels of control.

6.5 Energy Considerations

Energy standards are becoming more stringent as design stigmas focus on sustainability and energy reduction. ASD classrooms that solely use incandescent fixtures will most likely result in a LPD greater than what is suggested by current codes and standards. Values for LPD may be calculated for each space or an average of all spaces designed for. The American Society or Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have published lighting power densities in the ASHRAE Standard 90.1 -2007. This standard provides two methods to calculating the lighting power density for building interiors. The first method is the Building Area Method for which designers classify the building type and determine the gross lighted floor area of the building. Table 9.5.1 in ASHRAE 90.1 provides the lighting power density limitations for common building types. Schools and universities have a recommended LPD of 1.2 w/ft^2 under the Building Area Method. The second method is to calculate lighting power densities using the Space-by-Space Method. This method provides LPD values for specific space types within buildings. Each of the spaces must comply with the recommended values. Below is a table that shows the LPD values assigned by ASHRAE 90.1 Energy Standard for specific areas used the Space-by-Space Method.

Information adapted from ASHRAE Standard 90.1 2004 Table 9.6.1 2007 edition	
Space by Space Method	
Space Type:	LPD (w/ft^2)
Classroom Lecutre	1.4
Multi-purpose Room	1.3
Library Reading	1.2
Gym: Play Area	1.4
Storage (active)	0.8
Restrooms	0.9

Figure 6-5 Table displaying Lighting Power Densities for Space by Space Method. Table adapted from ASHRAE 90.1, 2007.

The Building Area Method allows for greater flexibility when calculating multiple spaces within a building. This would suggested that if multiple classrooms or areas of a school underwent lighting design changes, deficiencies in LPD for a special needs area may be compensated by superior efficiency in other areas. This will allow for the specific requirement and conditions to meet for special needs design and still ensure that the overall lighting design for the project meets prescribed standards (American Society of Heating, Refrigeration, and Air-Conditioning Engineers, 2007).

Computer drafting programs and calculations can provide general averages and an accurate check for the design. Software such as LitePro, Visual, and AGI32 can estimate lighting power density, as well as light levels on room surfaces and even renderings and models of light distribution. Calculations and models for day lighting consideration will help designers address concerns with glare and hot spots created from glazing. Good lighting designs for educational facilities must integrate electric lighting fixtures in with supplemental day lighting. Modeling software can assist designers in zoning lighting areas and areas of user controls. Using the output results from modeling software, designers are better able to alter their designs to best fit the application and function of the space.

6.6 Room Finishes and Reflectance Values

The architect and interior architect and designer will generally specify the room finishes for the space. It is important to coordinate with these professionals early in the lighting design to ensure that the finishes and surface in the classroom work best with lamp sources and fixture placement. In traditional classroom design it is suggested that surfaces be light colored with high reflectance values to aid in the reflectance of light distribution in the space. For special needs room, especially those designed for students with ASD, lower light levels and a warmer, softer light is recommended. Softer, more muted colors are suggested to help achieve a more calm atmosphere.

Students are often distracted by bright spots and glare. Glare is a common problem on light colored surfaces with high reflectance values. For special needs classrooms carpeted flooring is recommended over traditional tile or linoleum. Carpeted surfaces will absorb and slightly diffuse the light while the tile surfaces can have a reflectance value ranging between .70 and .90, and will create noticeable pools of light and hot spots.

Surface	Special Needs	Traditional
Ceiling	.70 - .80	.70 - .90
Wall	.30 - .50	.40 - .60
Floor	.20 - .30	.30 - .50

Table 6-3 Reflectance values for surfaces for traditional and special needs classrooms

Table adapted from the IESNA Reference Handbook and Designer input

Vertical surfaces also need to be evaluated in the design. Hot spots of light can occur on wall surfaces as the result of light cut-off from the fixture. Recessed fluorescent 2 x 4 troffer fixtures can create hot spots on vertical surfaces near the ceiling.

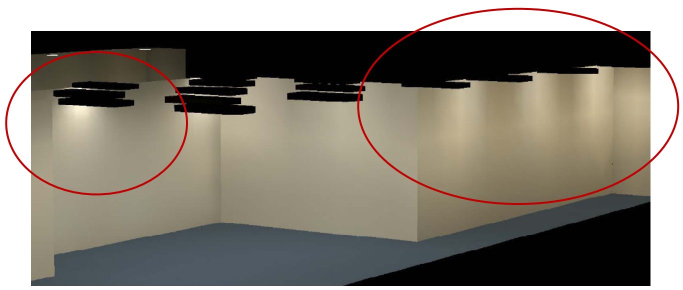


Figure 6-6 Rendering of recessed fluorescent fixtures

The image shows the problem glare and hot spots on vertical surfaces.

6.7 Occupant Input: Survey Results

A survey was conducted to gain perspective on the current classroom condition for students with ASD. The survey questionnaire is attached in Appendix C. The purpose of the survey was to assess how the classroom lighting design affects the students. Of the surveys collected, Amanda Arnold was the only school to provide education for students with ASD in a separately and specially designed classroom. In this classroom as described above, there were no fluorescent lamps installed and a considerable area of glazing on the east wall to provided daylight into the space. The lamps were recessed deep into the fixture reducing most lines of direct sight of the incandescent PAR lamp. According to the survey response, the students in the classroom environment had control over the light level with individual dimming controls for each area. In the previous design of the autism suite, instructors noticed the students getting distracted by the flickering of fluorescent lamps. Instructors rated the students' anxiety seven out of ten, with ten being the most distress, because of the brightness of the lights. The ability to adjust the light levels to achieve a comfortable brightness with the dimming controls eliminates the behavioral problems and stresses caused by high light levels. Responses on the survey reported "If the lights are too bright, they [the students] will ask for them to be dimmer." Therefore, the problem with anxiety due to brightness is alleviated because "they can adjust the brightness." It was recorded that students noticed a hum from light fixtures in other classroom and spaces with fluorescent fixtures and instructors rated the annoyance from the ballasts three out of ten, with ten being the most bothersome. Instructor Jessica Wilkinsen said that the students notice the hum "in general ed[ucation] rooms they can be distracting depending on how loud the hum is."

A few other surveys returned described the instruction for students with ASD in the traditional classroom with peers. These responses described the educational environments for kindergarten and seventh grade education levels. The classroom utilized only fluorescent fixtures with t-lamps and window glazing for daylight. At the Levy Special Education Center in Wichita, KS for elementary school level, students reported being very bothered by the fluorescent light fixtures and showed physical and behavioral aggressions because of frustration. Instructors rated the students' perception of the brightness in the classroom eight out of ten. The survey response said "Students will turn off the lights indicating they are bothering them and causing them to be upset." There are no lenses or coverings to shield the lamps from direct sight. The bright light output makes it difficult for the students to "sit, concentrate and learn." The light intensity creates a difficult environment for the students to concentrate and focus on learning material. Students also reported complaints and were bothered by the hum of the light fixtures and rated the stress a five out of ten. Because of the behavioral problems and frustration triggered by the fluorescent fixtures in the general education classrooms, instructors have tried to amend the problem by providing specific area in the classroom for students with ASD to independently work.

Lafayette CO C-1 middle school in Missouri, described full exposure of the fixture and the fluorescent tube lamp. There were no reports of students noticing the hum from the ballasts or anxiety caused from the brightness or flicker. Students rated the perceived brightness from the light source and the hum of from the fixtures a one out of ten, meaning the flicker and hum had little or no effect.

The conclusion that can be drawn from the result of these three surveys as well as interviews with school psychologists and teachers is that most students with ASD perceive flickering from fluorescent lamps and also pick up on an audible hum generate by the ballast. In classrooms where incandescent fixtures were installed and dimmable controls, students had no complaints about the light levels and did not hear a hum. Classrooms with glazing to provide day light created a positive atmosphere for students. These survey results conclude that typically fluorescent lights have hum and light flicker that increase stress in the student’s learning environment. The results also suggest that not every ASD condition or student has an adverse reaction to fluorescent fixtures.

6.8 Design Recommendations

This section of the report will address a variety of aspects of classroom design, and what lighting designers need to consider in their design. Recommendations are included based on my research to achieve the most comfortable lighting design for special needs classrooms or learning environments. The information has been developed into a table format below for easy reference.

ITEM	DESIGN CONSIDERATIONS	DESIGN RECOMMENDATIONS
Physical Layout of Space	Most special needs classroom have smaller closed classroom areas and short hallways.	Provide lighting and controls for each logically separated area of use. High ceilings 10-13' are optimal.
Room Finishes	Finishes can affect the overall brightness of the space and could have problems with glare.	Use finishes with darker and muted colors to soften the light and eliminate glare off surfaces. Select surfaces with a lower reflectance value.
Light Fixtures	Direct line of sight to the lamp should be avoided. Even light distribution to reduce shadows.	Recessed incandescent can light should have deep housings. Other incandescent fixtures should be indirect ceiling or wall fixtures. And all fixtures should have lens coverings, louvers or baffles.
Lamps	High CRI of 85 or greater, warm color temperature of 3000-3500K.	Incandescent lamps provide high CRI and warm color temperature.
Ballasts	Flicker decreases with an increase in lamp operating frequency. Noise also decreases in electronic ballasts.	Incandescent lamps do not require a ballast for operation and therefore eliminate the problems with flicker and noise.
Light Levels	Students reported visual brightness as a source of anxiety and frustration. Lower light levels best suit their needs.	Reduce light levels to an average of 25-35 fc opposed to the traditional levels of 30-50 fc.
Lighting Controls	Light levels need to be able to adjust to the intended use of the classroom or the comfort level of the students.	Dimming all lamps equally will lower the light levels, and still provide even light distribution. Controls should be available for each lighting area.
Daylighting	Provides quality light into the space and a comforting connection to the outdoor environment.	Glazing should be located high on the walls. Shades should be used to control light levels and glare. Photo sensors will integrate electric light fixtures and provide dimming.
Energy	Energy standards limit the w/ft^2 allowed. The more efficient the lamp and fixture assembly the better.	Incandescent lamps are inefficient. Calculations based on building-area method might achieve the prescribed LPD when using incandescent lamps.
Contrast Ratio	Contrast ratios should meet the recommendations prescribed in the IESNA Handbook.	From the working surface to a vertical surface in direct line of sight the contrast ratio should be limited to a difference of 1 to 3. A ratio of 1 to 5 is acceptable for vertical surfaces not immediately in the line of sight.

Maintenance	Lamps with longer lamp life and less lumen depreciation and accessible fixtures	Incandescent PAR lamp life ranges 1,200 -20,000 hrs which will require more frequent replacement. Select an incandescent lamp with a relatively longer lamp life.
Vertical Illuminance	Vertical surfaces should be as evenly illuminated as possible with limited shadowing and a contrast	Select fixtures with a wider distribution to avoid sharp light cut-offs and will also provide general illumination on wall surfaces.
Task Lighting	Students benefit from individual sources of light they can control.	Task lighting will allow the overall lower light levels to be acceptable, offer control to the student directly, efficient smaller applications, and fixtures with no ballast.

Table 6-4 Design Consideration and Recommendations.

Chapter 7 - CONCLUSION

Lighting designs for special needs students, specifically students with ASD need to be accommodating and flexible. ASD presents itself very differently in each student and it can be difficult to assess what external stimuli trigger symptoms. Some students may perceive distractions in the environment strongly and others just as mild annoyances. The severity of conditions and symptoms will vary from student to student and even daily for the same individual. It is important to create a lighting design that is accommodating towards the side of the most severe while balancing other considerations for good lighting design.

It is important to assess all the design criteria and design parameters applied to classroom lighting. Ultimately in design, compromises and trade-offs must be considered. Designers should know the advantages and disadvantages to each component of the lighting system to understand how the advantages and disadvantages contributive to the overall ideal of the design. Understanding the importance or the weight of certain design criteria over others will help to ensure that those parameters or greater importance are not sacrificed. If they are compromised, the resulting disadvantages are understood. The most helpful classroom design parameters come from the staff and students using the educational space. These educators and paras understand the students' needs and frustrations and can provide lighting designers information to help create a more comfortable classroom for the students. There is no perfect solution for classroom lighting for students with ASD, but it should be understood that the trade-offs in efficiency, lamp replacement, and cost when using incandescent lamps are necessary to avoid the distractions with noise and flicker caused by fluorescent ballasts.

Reducing distracting stimuli in the educational space is the number one priority for ASD classrooms. Distractions can be eliminated by good design of the physical layout of the space, room finishes, and good lighting design. These design conditions can be interdependent and developed to achieve a calm environment. Less reflective finishes with softer hues will reduce glare and the overall perceived brightness in the space. Incandescent lamps will emit a warm color and provide users with a high level of dimming control. Even with the limitation these fixtures present, they have been suggested to relieve many of the problems with classroom lighting fixtures most importantly ballast noise, and lamp flicker. Color temperature of the lamp source should be

3000K to 3500K to generate a warm color temperature, and finally dimmer controls to adjust light levels based on the occupants comfort or needs.

Occupancy controls offer a high level of comfort for the individual, and achieve many of the energy standards. Students will be more comfortable when given the control to adjust light levels to their personal comfort. Dimmer light levels will also shift the color temperature to a warmer appearance. Dimming the lamps will also reduce the energy draw and use less power to operate. Greater areas of control will help to break up the space into smaller working environments and anticipate the need for flexibility in the space. Integrating dimmer controls with day-light sensors will achieve a balance between electric light sources and natural day light. It is important to consider manual overrides and dimming controls to take priority over occupancy sensors or photo-cell day-lighting controls.

Discussing the concerns and behavior symptoms and triggers exhibited by students with ASD with teachers, and special education instructors will bring attention to design concerns and limitation early in the design process and allow for a better integration of systems to achieve the best learning environment and space for these students.

References

1st Source Lighting. *T-5 HO and T-8 Lighting*. http://www.1stsourcelight.com/, 2002.

American Society of Heating, Refrigeration , and Air-Conditioning Engineers. *ASHRAE Standard 90.1 -2007- Energy standard for buildings except low-rise residential buildings*. Atlanta, GA, 2007.

Anderson, Tracy. *Email Correspondence with Tracy Anderson and Emil y Long*, Anderson-Knight Architects, 2010.

Autism Society. *About Autism*. Autism Society, January 2008.

Autism Society Canada, *What are Autism Spectrum Disorders*. Autism Society Canada, 2009.

Energy Star. *Learn about CFLs*. U.S. Department of Energy. 2010.

Focal Point - The Art of Light. http://www.focalpointlights.com/. Focal Point L.L.C. 2010.

Halpin, Mark S., Bergeron, Roger, Blooming, Tom, Burch, Ruben F., Conrad, Larry E., Key, Thomas S. *Voltage and Lamp Flicker Issues: Should the IEEE Adopt the IEC Approach?*. IEEE Transactions on Power Delivery, 2003.

H.E. Williams Inc. http://www.hewilliams.com/. 2010

Heschong, Lisa, Heschong Malone Group. *Window and Classrooms: A Study of Student Performance and the Indoor Environment*. Integrated Energy Systems, California Energy Commission, October, 2003.

Johnson, Gordon S Jr. *A Guide to Brain Anatomy*. www.waiting.com, 2009.

Leon, Justyn. P.E. *Firsthand Interview with Justyn Leon P.E. by Emily Long*. October 4st, 2010.

Lithonia Lighting. *Ballast Characteristics*. Acuity Lighting Group, Inc. 2002.

Miller, Helen. *Firsthand Interview with Helen Miller by Emily Long*. October 1st, 2010.

National Institute of Child Health and Human Development Information Resource Center. *Autism Spectrum Disorders (ASDs)*. National Institutes of Health, July 28, 2010.

National Lighting Product Information Program. *Specifier Reports: Electronic Ballasts*. Lighting Research Center, 2010.

ND Autism Connection. *What is ASD*. ND Autism Connection, 2010

Nie, Duyu. *Research adds to evidence that autism is a brain ‘connectivity’ disorder*. Children’s Hospital Boston, January 10, 2010.

Northeast Energy Efficiency Partnerships, Inc. *"Energy Effective" Lighting for Classroom: Combining Quality Design and Energy Efficiency*. NEEP, 2002.

Rea, Mark S. Ph.D., Fies. *The IESNA Lighting Handbook Reference and Application 9 Ed*. Illuminating Engineering Society of North America, 2000.

Russell, Pam Dr. *Firsthand Interview with Dr. Pam Russell by Emily Long*. October 1st, 2010.

Ryan, Eileen. *How Flicker Free Ballast Work*. Red User, February 7, 2010.

Santi, Enrico. *High Frequency Electronic Ballasts Provides Live Frequency Lamp Current*, IEEE Transactions of Power Electronics, Vol 16, No. 5, September 2001.

Stein, Benjamin, Reynolds, John S., Grondzik, Walter T., Kowk, Alison G. *Mechanical and Electrical Equipment for Buildings 10th Ed*. John Wiley & Sons Inc, 2006.

Sylvania. http://www.sylvania.com/BusinessProducts/LightingForBusiness/Products/Energy EfficientProducts/Halogen/default.htm. Osram Sylvania, 2010.

"The History of LED Lights." *LEDLights.org*. LEDLights.org, 2010.

University of Wisconsin Board of Regents. *Inside Autism*. University of Wisconsin, 2004.

Veitch, J.A, &McColl, S. L. *Modulation of fluorescent light: Flicker rate and light source on visual performance and visual comfort*. Lighting and Research Technology, National Reseach Council of Canada, 1995.

Venture Lighting International. http://www.venturelighting.com/, 2010.

Wilkinson, Jessica. *Firsthand Interview with Jessica Wilkinson by Emily Long*. October 1st, 2010.

Appendix A – AGI Calculations

AGI Calculation Points and Results

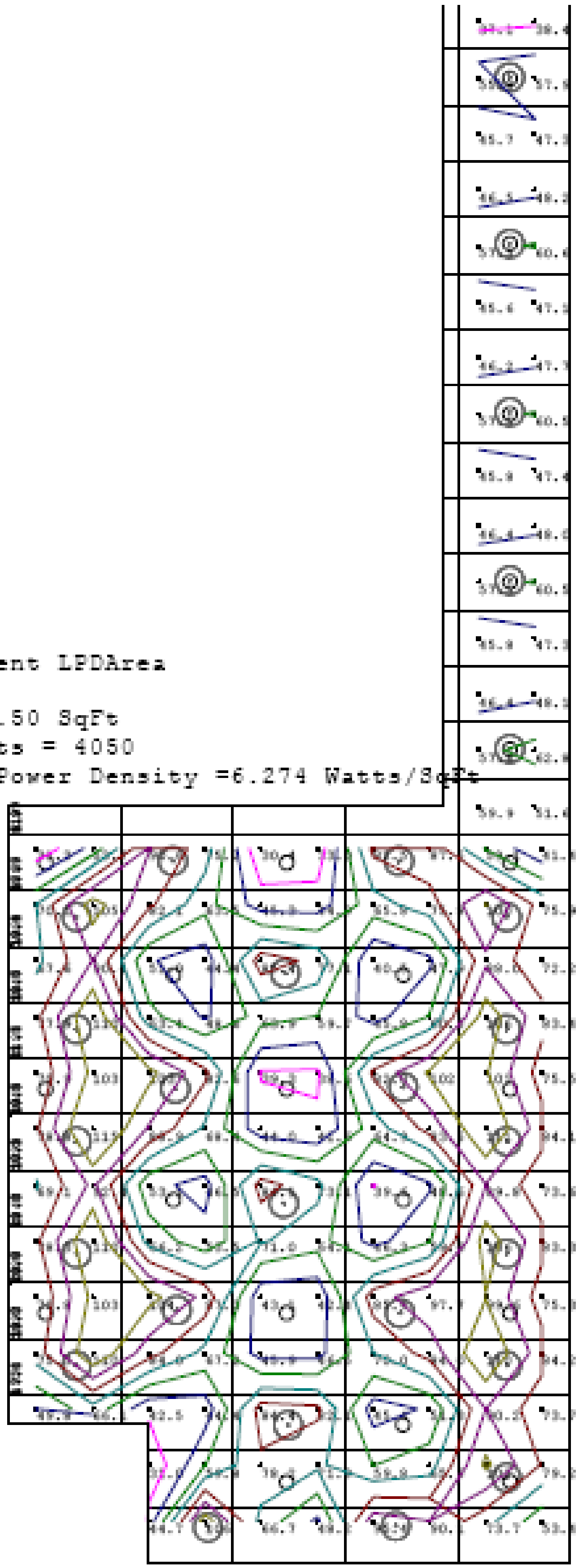
Calculation Summary						
Label	Units	Avg	Max	Min	Avg/Min	Max/Min
Incandescent East Wall_Wall_8	Fc	14.37	21.8	4.9	2.93	4.45
Incandescent Hallway	Fc	50.80	62.8	37.1	1.37	1.69
Incandescent Open Classroom	Fc	71.60	115	30.4	2.36	3.78
Recessed Flourescent Hallway	Fc	59.14	80.1	49.3	1.20	1.62
Recessed Fluor East Wall_Wall_8	Fc	54.09	116	24.3	2.23	4.75
Recessed Fluorescent Open Class	Fc	99.45	118	53.8	1.85	2.19
Suspended Fluor East Wall_Wall_8	Fc	42.77	120	26.3	1.63	4.55
Suspended Fluorescent Hallway	Fc	42.17	54.2	32.1	1.31	1.69
Suspended Fluorescent Open Class	Fc	63.35	72.1	35.2	1.80	2.05

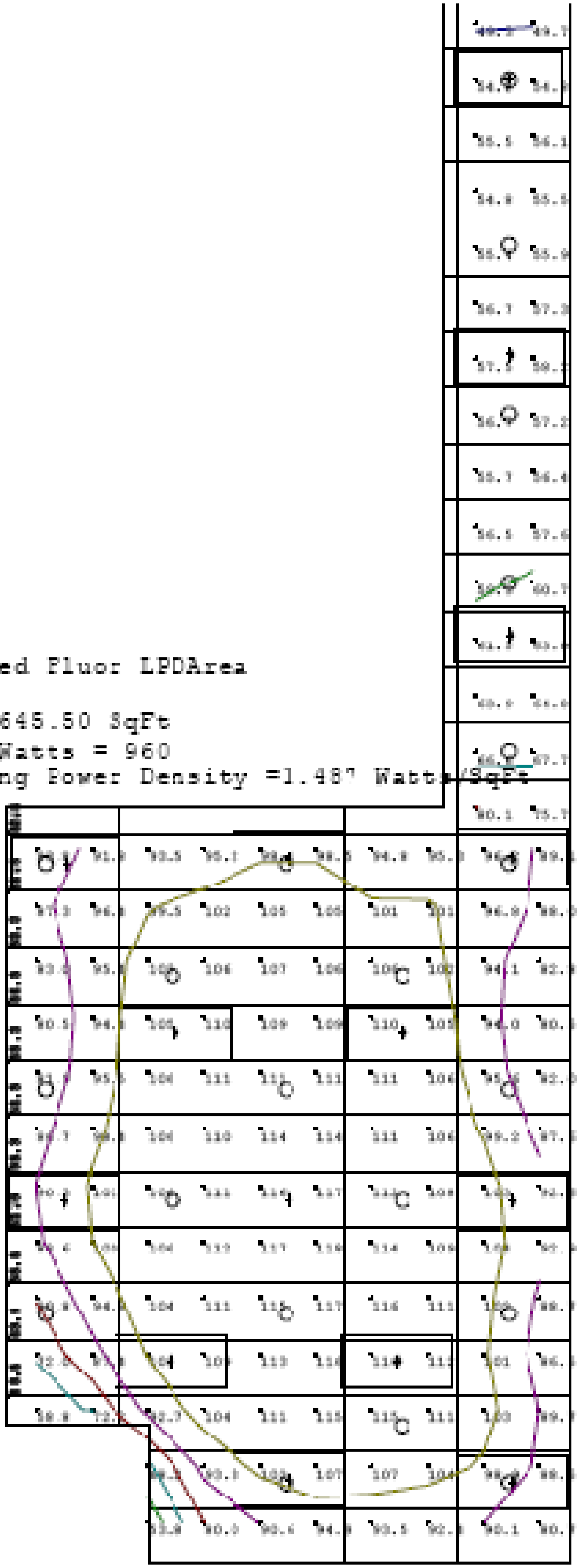
LPD Area Summary			
Label	Area	Total Watts	LPD
Incandescent LPDArea	645.5	4050	6.274
Recessed Fluor LPDArea	645.5	960	1.487
Suspended Fluor LPDArea	645.5	819	1.269

Luminaire Schedule			
Symbol	Qty	Label	Total Lamp Lumens
	27	Incandescent 6in Can Light	1700
	13	Suspended Indirect Direct	5200
	15	Recessed T5 2 lamp	5800

Incandescent LPDArea

Area =645.50 SqFt
Total Watts = 4050
Lighting Power Density =6.274 Watts/SqFt



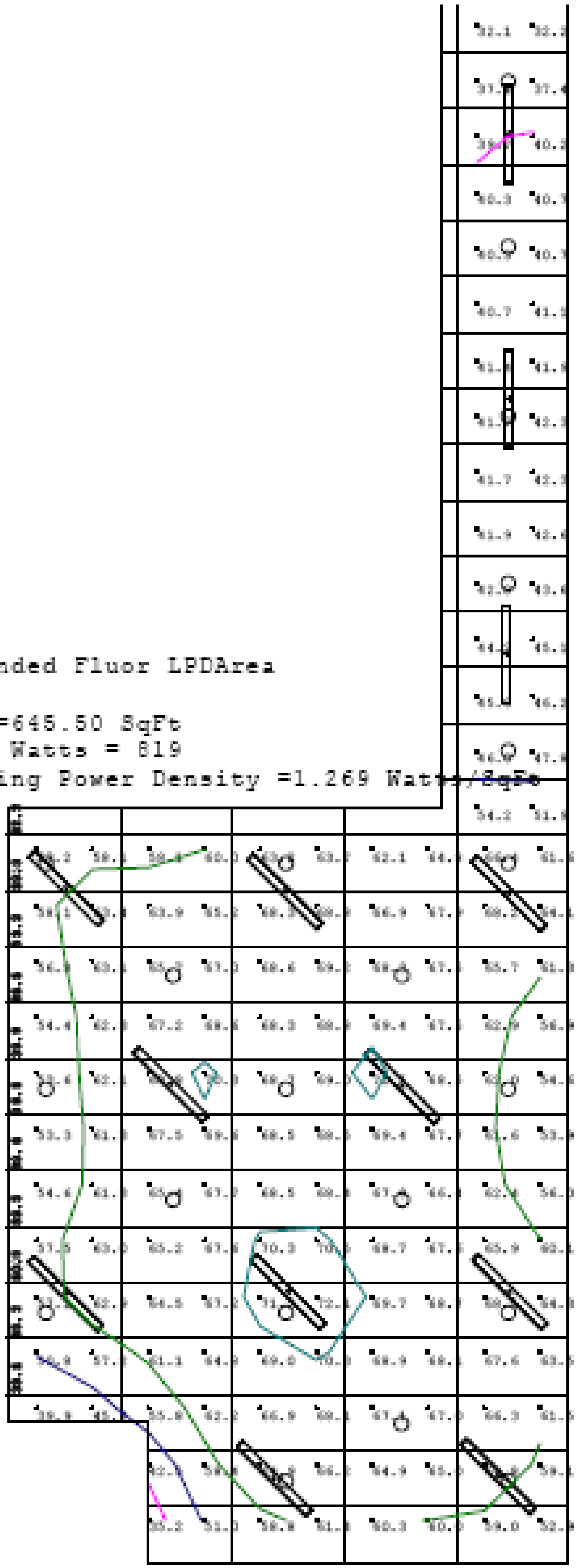


Recessed Fluor LPDArea

Area =645.50 SqFt
Total Watts = 960
Lighting Power Density =1.487 Watts/SqFt

Suspended Fluor LPDArea

Area =645.50 SqFt
Total Watts = 819
Lighting Power Density =1.269 Watts/SqFt



AGI Input Values

AGI32 MODEL INPUTS

FIXTURES		
Incandescent	R60-75W-PAR30/MED	1-Lamp
Recessed Fluorescent	HET 2x4 -28W-T5	2-Lamp
Suspended Fluorescent	FV4S-50%downlight-T5	2-Lamp
FIXTURE OUTPUT and EFFICIENCY		
Incandescent	1700 Lumens/lamp	97%
Recessed Fluorescent	2900 lumens/lamp	88%
Suspended Fluorescent	2600 lumens/lamp	97%
FIXTURE MOUNTING HEIGHT		
Incandescent	10'-0"	
Recessed Fluorescent	10'-0"	
Suspended Fluorescent	8'-0"	
ROOM PARAMETERS		
Ceiling Height	10'-0"	
Wall Reflectances	0.74 Matte Toupe	
Floor Reflectances	0.12 Blue Carpet Finish	
Ceiling Reflectacnes	0.75 Accoustical Tiles	
CALCULATION POINTS		
Spacing	2'-0" by 2'-0"	

Appendix B – Amanda Arnold Autism Suite Design and Calculations

Light Level Calculations

LitePro 2.026 Point-By-Point Results

PROJECT: Amanda Arnold Elementary/09034 GROUP: Building First Floor AREA: A-Open DI GRID: Grid 01
PREPARED BY:
VALUES ARE FC, SCALE: 1 IN= 3.0FT. HORZ GRID (U), HORZ CALC, Z= 2.5
ROOM REFLECTANCES: 30 / 50 / 20 (Ceiling/Walls/Floor)
Computed in accordance with IES recommendations

Statistics

GROUP	MIN	MAX	AVE	AVE/MIN	MAX/MIN
(+)	3.54	55.51	26.10	7.38	15.69

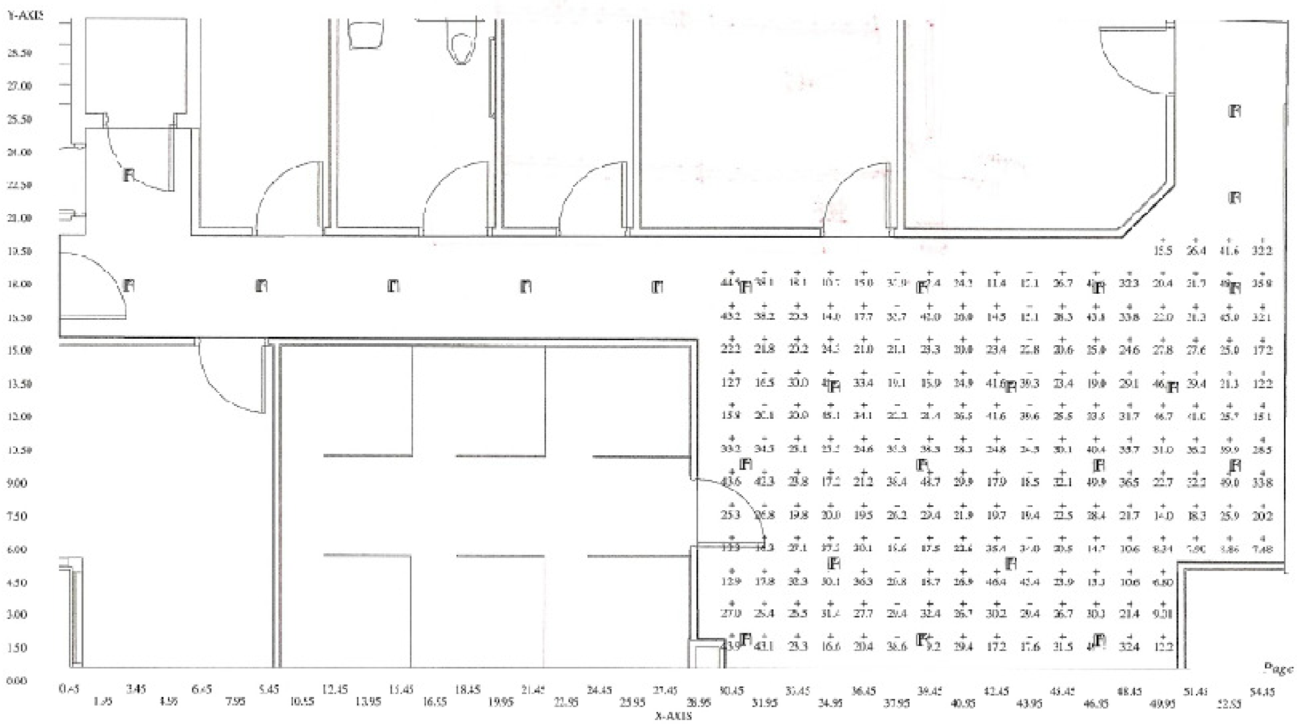
Y-AXIS \ X-AXIS	0.25	1.25	2.25	3.25	4.25	5.25	6.25	7.25	8.25	9.25	10.25	11.25	12.25	13.25	14.25	15.25	16.25	17.25	18.25
14.25	4.71	7.53	10.2	11.3	10.00	8.29	8.10	8.74	10.7	11.5	10.1	8.32	8.08	8.66	10.5	11.2	9.37	6.60	4.08
13.25	7.51	14.5	22.3	25.0	21.3	15.0	12.9	16.7	23.1	25.4	21.4	15.1	12.9	16.6	22.9	24.9	20.2	12.2	6.21
12.25	10.7	22.9	35.4	41.8	33.2	22.7	18.2	26.0	36.6	42.2	33.3	22.7	18.2	25.9	36.4	41.6	31.7	18.7	8.54
11.25	12.8	27.3	43.7	51.9	39.9	27.3	21.9	30.9	45.0	52.3	40.1	27.4	21.9	30.8	44.7	51.7	38.1	22.6	10.1
10.25	12.8	25.7	38.9	44.6	37.1	26.1	22.3	25.6	40.4	45.0	37.2	26.2	22.3	29.5	40.1	44.3	35.2	21.0	10.4
9.25	12.4	24.1	37.9	43.	35.8	25.3	21.6	28.1	39.3	43.5	36.0	25.4	21.6	28.0	39.0	42.8	33.9	20.1	10.3
8.25	13.5	27.4	41.9	49.	39.5	28.0	23.5	31.5	43.4	49.5	39.7	28.1	23.4	31.3	43.1	48.8	37.5	22.8	10.9
7.25	14.0	29.4	46.6	55.0	42.7	29.7	24.1	33.5	48.0	55.5	42.9	29.8	24.1	33.3	47.7	54.8	40.8	24.5	11.1
6.25	13.2	26.3	39.9	45.6	37.9	26.8	22.9	30.3	41.3	46.0	38.1	26.9	22.9	30.2	41.0	45.3	36.0	21.5	10.7
5.25	12.3	24.0	37.7	42.9	35.6	25.2	21.5	28.0	39.1	43.3	35.8	25.3	21.5	27.9	38.8	42.6	33.8	19.9	10.2
4.25	12.9	26.4	40.5	47.5	38.1	26.9	22.4	30.3	41.9	47.9	38.3	27.0	22.4	30.2	41.6	47.3	36.3	21.9	10.4
3.25	12.3	26.6	42.8	51.0	39.0	26.5	21.1	30.1	44.1	51.4	39.2	26.6	21.1	30.0	43.9	50.8	37.3	22.0	9.71
2.25	9.71	20.6	31.4	36.0	29.7	20.3	16.6	23.4	32.4	36.3	29.8	20.3	16.6	23.3	32.2	35.8	28.3	16.6	7.82
1.25	6.55	12.2	18.1	20.6	17.1	12.8	11.4	14.1	18.8	20.9	17.3	12.9	11.4	13.9	18.6	20.4	16.2	10.3	5.67
0.25	4.08	6.24	8.15	8.94	8.06	7.07	6.95	7.23	8.56	9.11	8.16	7.09	6.93	7.16	8.41	8.86	7.55	5.71	3.54

LitePro 2.026 Point-By-Point Results 10/4/2010

PROJECT: Amanda Arnold Elementary/09034 GROUP: Building First Floor AREA: A-Sensory/Hall GRID: Sensory
PREPARED BY:
VALUES ARE FC, SCALE: 1 IN= 6.0FT, HORZ GRID (U), HORZ CALC, Z= 2.5
ROOM REFLECTANCES: 80 / 50 / 20
Computed in accordance with IES recommendations

Statistics

GROUP	MIN	MAX	AVE	AVE/MIN	MAX/MIN
(+)	6.80	50.12	27.31	4.02	7.37



LitePro 2.026 Point-By-Point Results

PROJECT: Amanda Arnold Elementary/09034 GROUP: Building First Floor AREA: A-Sensory Room GRID: Grid 1
PREPARED BY:
VALUES ARE FC, SCALE: 1 IN= 2.0FT, HORZ GRID (U), HORZ CALC, Z= 2.5
ROOM REFLECTANCES: 80 / 50 / 20 (Ceiling/Walls/Floor)
Computed in accordance with IES recommendations

Statistics

GROUP	MIN	MAX	AVE	AVE/MIN	MAX/MIN
(+)	1.82	83.44	26.06	14.33	45.87

Y-AXIS	0.40	1.40	2.40	3.40	4.40	5.40
9.35	7.40	15.3	24.3	21.4	11.5	5.30
8.35	12.4	35.9	59.8	51.9	23.9	8.51
7.35	15.1	45.5	83.4	69.0	30.8	9.60
6.35	13.1	34.0	55.4	49.4	23.9	9.18
5.35	12.7	25.8	40.2	35.6	19.5	8.85
4.35	13.8	39.1	64.4	56.2	26.4	9.36
3.35	14.7	44.8	82.6	68.3	30.2	9.36
2.35	10.7	28.8	48.4	42.9	19.8	7.61
1.35	6.15	11.6	17.1	15.4	9.12	4.41
0.35	2.41	4.60	5.97	5.59	3.71	1.82

F

F

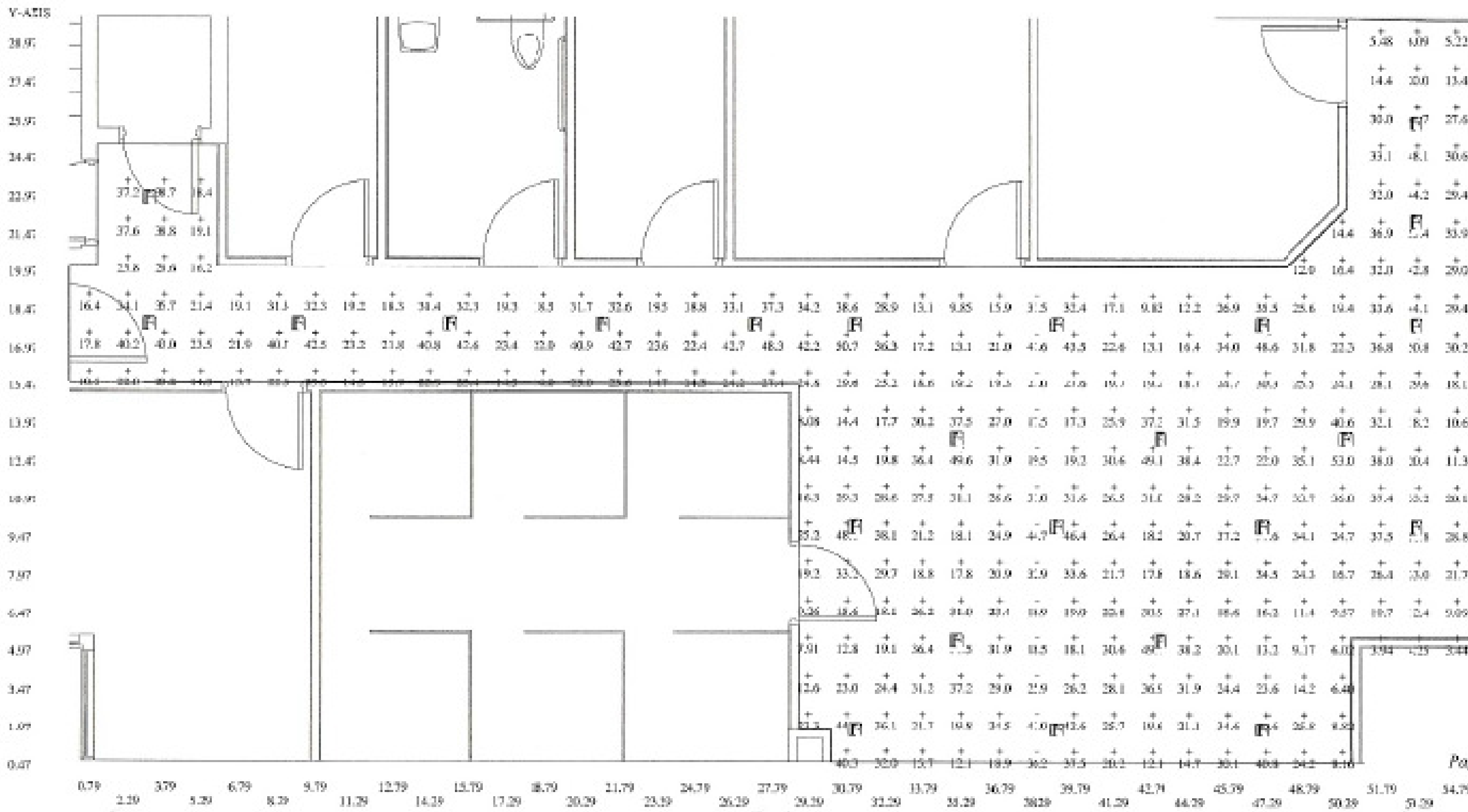
X-AXIS

LitePro 2.026 Point-By-Point Results 10/4/2010

PROJECT: Amanda Arnold Elementary/09034 GROUP: Building First Floor AREA: A-Sensory/Hall GRID: Grid 01
PREPARED BY:
VALUES ARE FC, SCALE: 1 IN=6.0FT, HORZ GRID (U), HORZ CALC, Z=2.5
ROOM REFLECTANCES: 80 / 50 / 20
Computed in accordance with IES recommendations

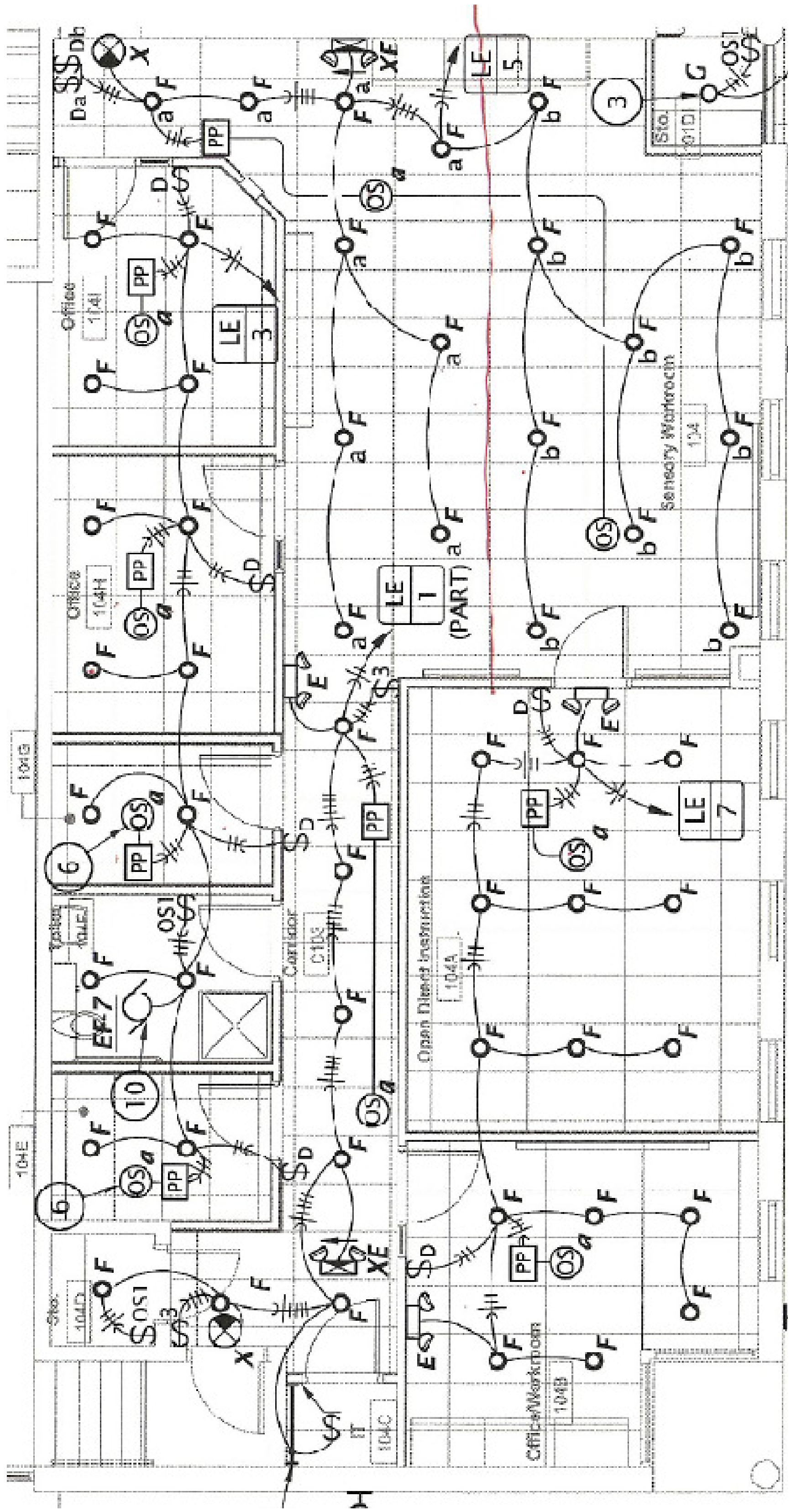
Statistics

GROUP	MIN	MAX	AVE	AVE/MIN	MAX/MIN
(+)	3.44	55.44	26.28	7.64	16.12



Page 1

Fixture Layout and Circuiting for Autism Suite



Appendix C – Classroom Lighting Surveys

Original Copy of the Survey

<u>SCHOOL INFORMATION</u>
School: ____ Year Built (if known): ________
Grade or Level: ____________________
Medical Diagnosis/Condition or Autistic Spectrum Disorder of Student(s):__________________________________
Educator or Para Position or Job Title:____

<u>CLASSROOM ENVIRONMENT</u>(Circle One and Explain as Needed)
Are classes or material taught in a separate or specially designed classroom? YES NO
Further Explanation:

Does the educational environment or space use fluorescent lights? YES NO
If Yes, are the fixtures: Fluorescent tube lamps? or Compact fluorescent lamps?
Are you able to determine the ballast type of the lamp? (Circle the most applicable if known)
(1) High Frequency Efficient Electronic (2) Electronic (3) Electromagnetic
(4) Magnetic (5) Instant Start (6) Rapid Start (7) Program Start

Is there any additional lighting or lamp types used? YESNO
(Examples could include: windows, sky lights, floor lamps, desk lamps, incandescent fixtures)
Further Explanation:

Are the fixture providing (Circle all that apply):
(1) Direct Down Light (2) Direct/Indirect (3) Completely Indirect

Are there any coverings or lenses to shields the lights? YES NO
Can the lamps in the light fixture be seen directly? YES NO

PERCEPTION OF STUDENT LEARNING AND ATTENTIVENESS:
(Scales are based on 1 being the least sensitive and 10 having the greatest affect)
Does the student(s) notice any hum or electronic noise from the light fixtures? YES NO
Further Explanation:

How do the student(s) seem to perceive the intensity or brightness of the lights on a scale of 1 to 10.
1 2 3 4 5 6 7 8 9 10

Does the brightness seem to bother the student(s), induce any problematic behavior or increase stress or anxiety? YES NO
Further Explanation:

If YES, please rate the level or stress or anxiety the student(s) seem to have caused by the brightness of the lights
1 2 3 4 5 6 7 8 9 10
Further Explanation:

Is the student(s) bothered by the brightness of the lights?
1 2 3 4 5 6 7 8 9 10
Is the student(s) bothered by the hum of the lights?
1 2 3 4 5 6 7 8 9 10

Completed Surveys

SCHOOL INFORMATION

School: Amanda Arnold

Year Built (if known): ______

Grade or Level: K-6

Medical Diagnosis/Condition or Autistic Spectrum Disorder of Student(s): ASD

Educator or Para Position or Job Title: Autism Teacher

CLASSROOM ENVIRONMENT (Circle One and Explain as Needed)

Are classes or material taught in a separate or specially designed classroom? YES NO

Further Explanation:
The autism room was just built specifically for these students
We have no-fluoresnt lights that can be dimmed.

Does the educational environment or space use fluorescent lights? YES NO

If Yes, are the fixtures: Fluorescent tube lamps? or Compact fluorescent lamps?

Are you able to determine the ballast type of the lamp? (Circle the most applicable if known)

(1) High Frequency Efficient Electronic (2) Electronic (3) Electromagnetic

(4) Magnetic (5) Instant Start (6) Rapid Start (7) Program Start

Is there any additional lighting or lamp types used? YES NO

(Examples could include: windows, sky lights, floor lamps, desk lamps, incandescent fixtures)

Further Explanation: There are windows that are always open (the shades are up)

Are the fixture providing (Circle all that apply):

(1) Direct Down Light (2) Direct/Indirect (3) Completely Indirect

Are there any coverings or lenses to shields the lights? YES NO

Can the lamps in the light fixture be seen directly? YES NO

PERCEPTION OF STUDENT LEARNING AND ATTENTIVENESS:

(Scales are based on 1 being the least sensitive and 10 having the greatest affect)

Does the student(s) notice any hum or electronic noise from the light fixtures? YES NO

Further Explanation: By having non-fluoresent lights the children are not distracted (ex. looking or staring at them) because they don't make noises.

How do the student(s) seem to perceive the intensity or brightness of the lights on a scale of 1 to 10.

1 2 3 4 5 6 7 8 9 10

I'm not for sure how to answer this ~~bot~~ because they can adjust the brightness.

Does the brightness seem to bother the student(s), induce any problematic behavior or increase stress or anxiety?

YES NO Both

Further Explanation:

If the lights are to bright then they will ask for them to be dimmer. Therefore mainly no because they can fix it.

If YES, please rate the level or stress or anxiety the student(s) seem to have caused by the brightness of the lights

1 2 3 4 5 6 7 8 9 10

Further Explanation:

Is the student(s) bothered by the brightness of the lights?

1 2 3 4 5 6 7 8 9 10 again depends on the child, and they can fix it.

Is the student(s) bothered by the hum of the lights?

1 2 3 4 5 6 7 8 9 10 Not in our room but in the general ed rooms they can be distracting depending on how loud the hum is.

SCHOOL INFORMATION

School: Lafayette CO C-1 MS → MO Year Built (if known): 1980

Grade or Level: 7th

Medical Diagnosis/Condition or Autistic Spectrum Disorder of Student(s): ______

Educator or Para Position or Job Title: Teacher – Para

CLASSROOM ENVIRONMENT (Circle One and Explain as Needed)

Are classes or material taught in a separate or specially designed classroom? YES NO

Further Explanation:

Does the educational environment or space use fluorescent lights? YES NO

If Yes, are the fixtures: Fluorescent tube lamps? or Compact fluorescent lamps?

Are you able to determine the ballast type of the lamp? (Circle the most applicable if known) ?

(1) High Frequency Efficient Electronic (2) Electronic (3) Electromagnetic

(4) Magnetic (5) Instant Start (6) Rapid Start (7) Program Start

Is there any additional lighting or lamp types used? YES NO

(Examples could include: windows, sky lights, floor lamps, desk lamps, incandescent fixtures)

Further Explanation:

Are the fixture providing (Circle all that apply):

(1) Direct Down Light (2) Direct/Indirect (3) Completely Indirect

Are there any coverings or lenses to shields the lights? YES NO

Can the lamps in the light fixture be seen directly? YES NO

PERCEPTION OF STUDENT LEARNING AND ATTENTIVENESS:

(Scales are based on 1 being the least sensitive and 10 having the greatest affect)

Does the student(s) notice any hum or electronic noise from the light fixtures? YES NO

Further Explanation:

How do the student(s) seem to perceive the intensity or brightness of the lights on a scale of 1 to 10.

1 2 3 4 5 6 7 8 9 10

Does the brightness seem to bother the student(s), induce any problematic behavior or increase stress or anxiety?

YES NO

Further Explanation:

If YES, please rate the level or stress or anxiety the student(s) seem to have caused by the brightness of the lights

1 2 3 4 5 6 7 8 9 10

Further Explanation:

Is the student(s) bothered by the brightness of the lights?

1 2 3 4 5 6 7 8 9 10

Is the student(s) bothered by the hum of the lights?

1 2 3 4 5 6 7 8 9 10

SCHOOL INFORMATION

→ Wichita

School: Levy Special Ed. Center Year Built (if known): ________

Grade or Level: K-12

Medical Diagnosis/Condition or Autistic Spectrum Disorder of Student(s): AM

Educator or Para Position or Job Title: Autism Teacher

CLASSROOM ENVIRONMENT (Circle One and Explain as Needed)

Are classes or material taught in a separate or specially designed classroom? YES NO

Further Explanation: There are two rooms for the students in class with Autism. One is an Independent work are and the other is Recreation, group, classroom work area

Does the educational environment or space use fluorescent lights? YES NO

If Yes, are the fixtures: Fluorescent tube lamps? or Compact fluorescent lamps?

Are you able to determine the ballast type of the lamp? (Circle the most applicable if known)

(1) High Frequency Efficient Electronic (2) Electronic (3) Electromagnetic

(4) Magnetic (5) Instant Start (6) Rapid Start (7) Program Start

Is there any additional lighting or lamp types used? YES NO

(Examples could include: windows, sky lights, floor lamps, desk lamps, incandescent fixtures)

Further Explanation: Windows

Are the fixture providing (Circle all that apply):

(1) Direct Down Light (2) Direct/Indirect (3) Completely Indirect

Are there any coverings or lenses to shields the lights? YES NO

Can the lamps in the light fixture be seen directly? YES NO

PERCEPTION OF STUDENT LEARNING AND ATTENTIVENESS:

(Scales are based on 1 being the least sensitive and 10 having the greatest affect)

Does the student(s) notice any hum or electronic noise from the light fixtures? YES NO

Further Explanation: Some students will turn off the lights, indicating that they are bothering them and can cause upsets

How do the student(s) seem to perceive the intensity or brightness of the lights on a scale of 1 to 10.

1 2 3 4 5 6 7 8 9 10

varies

Does the brightness seem to bother the student(s), induce any problematic behavior or increase stress or anxiety?

YES NO

Further Explanation:

Screaming, crying, noise, aggression to self or others

If YES, please rate the level or stress or anxiety the student(s) seem to have caused by the brightness of the lights

1 2 3 4 5 6 7 8 9 10

Further Explanation:

hard to sit, concentrate, Learn

Is the student(s) bothered by the brightness of the lights?

1 2 3 4 5 6 7 8 9 10

Is the student(s) bothered by the hum of the lights?

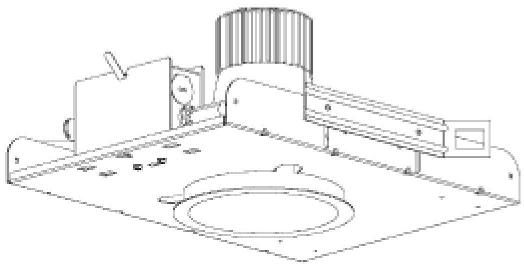
1 2 3 4 5 6 7 8 9 10

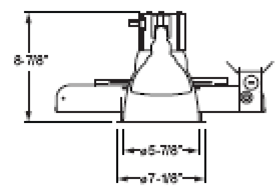
Appendix D – Cut Sheet Information

INCANDESCENT

JOB ________
TYPE ________
VOLTAGE ______

6" ROUND RECESSED DOWNLIGHT
REFLECTOR LAMP





PAN SIZE: 12" x 16-1/4"
PAN SIZE w/SCA: 12" x 16-1/4"

CEILING CUT OUT: 6-1/2"
CEILING CUT OUT w/SCA: 9-1/8"

CATALOG NUMBER

SERIES	WATTAGE	LAMP BASE	VOLTAGE	
R60	50	PAR30/MED		
R60	75	PAR30/MED		
R60	90	PAR38/MED		
R60	120	PAR38/MED		

OPTIONS & ADDERS

	SUFFIX
Clear semi-specular reflector	CS
Clear specular reflector	SPC
Straw reflector	STR
Champagne gold reflector	CG
Gold reflector	GD
Wheat reflector	WT
Pewter reflector	PW
Satin-glow reflector	SG
Fuse	F
Slope Ceiling Adaptor (Specify Degree) 5° Increments °10-30°	SCA (DEG.)
Matte white trim	MWT
277-volt	277
Micro-baffle	MB
C73 clear prismatic glass lens with accent cone (Please specify: not to exceed 100 watt)	C73/AC
C73 clear prismatic glass lens with micro-baffle (Please specify: not to exceed 100 watt)	C73/MB
Fresnel glass lens with accent cone (Please specify: not to exceed 100 watt)	FF/AC
Fresnel glass lens with micro-baffle (Please specify: not to exceed 100 watt)	FF/MB
Clear glass lens with accent cone (Please specify: not to exceed 100 watt)	CGS/AC
Clear glass lens with micro-baffle (Please specify: not to exceed 100 watt)	CGS/MB
Chicago plenum (CP)	CCEA
Yoke mount reflector	YOKE

- Standard self-flanged aluminum reflector with semi-specular, low-iridescent (CS) finish.
- Finned, extruded aluminum heat sink socket housing.
- Porcelain socket.
- Pan/plaster mounting frame: galvanized steel construction.
- Adjustable hanger brackets with bar hangers standard.
- Prewired at factory for easy field installation.
- Insulation detector.
- Lamp by others.
- Easy-access, 14-gauge galvanized steel junction box with two snap-on covers.
- UL/CUL listed for through branch circuit wiring and wet location under covered ceiling.
- Other wattages–consult factory.
- This fixture is proudly made in the USA.

FIXTURE SUBMITTED/APPROVED

Williams
DOWNLIGHTING

H.E. Williams, Inc. • Carthage, Missouri • www.hewilliams.com • 417-358-4065 • Fax: 417-358-6015
Rec. Incandescent page 10A

BUILDING ACOUSTICS & LIGHTING LABORATORIES, INC.
1618 HEADLAND DR.
FENTON, MO 63026
(314) 343-6006
(314) 343-6051 FAX

Report No: **10717.0**

Date: **6/22/00**

Description: **1/150W Par 38 Flood 6" dia Recessed Downlight Luminaire Low-Iridescent Specular Reflector w/Open Bottom**

Catalog No: **R60-150-PAR38/MED**

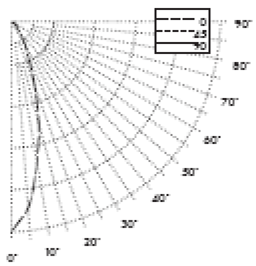
Lamp Type: **150WPAR38F**

Rated Lumens: **1700.**

No. Lamps: **1**

CANDLEPOWER DISTRIBUTION

VERT ANG	AVERAGE CANDELA	ZONAL LUMENS
0	5180.	
5	4615.	440.6
10	3485.	
15	2481.	703.4
20	1437.	
25	787.	364.3
30	469.	
35	200.	125.8
40	61.	
45	24.	18.2
50	15.	
55	10.	9.3
60	4.	
65	0.	.0
70	0.	
75	0.	.0
80	0.	
85	0.	.0
90	0.	



ZONAL CAVITY COEFFICIENTS OF UTILIZATION

EFFECTIVE FLOOR CAVITY REFLECTANCE = .20

CEILING	.80				.70				.50			.30		
WALL RCR	.70	.50	.30	.10	.70	.50	.30	.10	.50	.30	.10	.50	.30	.10
0	116	116	116	116	114	114	114	114	109	109	109	104	104	104
1	113	111	109	107	110	108	107	105	105	103	102	101	100	.99
2	108	105	101	.99	106	103	100	.98	100	.98	.96	.97	.95	.94
3	105	100	.96	.93	103	.99	.95	.92	.96	.93	.91	.94	.92	.90
4	101	.95	.91	.88	.99	.94	.90	.87	.92	.89	.86	.90	.88	.86
5	.97	.91	.87	.83	.96	.90	.86	.83	.89	.85	.82	.87	.84	.82
6	.94	.88	.83	.80	.93	.87	.83	.80	.86	.82	.79	.84	.81	.79
7	.91	.84	.80	.77	.90	.84	.80	.77	.83	.79	.76	.82	.78	.76
8	.88	.81	.77	.74	.87	.81	.76	.74	.80	.76	.73	.79	.75	.73
9	.85	.78	.73	.70	.84	.77	.73	.70	.78	.73	.70	.76	.72	.70
10	.82	.74	.70	.67	.81	.74	.70	.67	.73	.69	.67	.73	.69	.67

FIXTURE QUANTITY QUICK ESTIMATOR TABLES

REFLECTANCE: Ceiling = 80%
Walls = 50%
Floor = 20%

LIGHT LOSS FACTOR: 1.0

Room Size - 10' Ceiling	±50 ftc	±75 ftc	±100 ftc
Small - 400 Sq Ft	12	20	25
Medium - 900 Sq Ft	30	42	56
Large - 1600 Sq Ft	49	72	100

LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT	ZONE	LUMENS	%LAMP	%FIXT
0-30	1508.	88.7	90.8	90-120	0.	.0	.0
0-40	1634.	96.1	98.3	90-130	0.	.0	.0
0-60	1662.	97.7	100.0	90-150	0.	.0	.0
0-90	1662.	97.7	100.0	90-180	0.	.0	.0
			TOTAL LUMINAIRE –	0-180	1662.	97.7	100.0

IES SPACING CRITERIA: ADJACENT – .5 DIAGONAL – .3

LUMINANCES FOOT LAMBERTS

VERT ANG	HORIZ ANG
45	1886.
55	1026.
65	0.
75	0.
85	0.

MAXIMUM BRIGHTNESS NOT MEASURED

LIGHT CONE QUICK CALCULATOR TABLES

MNT HGT-FT	FC at Edge of Cone	FC at Nadir	Adjacent	Cone Dia. Diagonal
8	40.5	80.9	4.0	2.4
10	25.9	51.8	5.0	3.0
12	18.0	36.0	6.0	3.6
14	13.2	26.4	7.0	4.2
16	10.1	20.2	8.0	4.8
18	8.0	16.0	9.0	5.4
20	6.5	13.0	10.0	6.0

Williams
H.E. WILLIAMS, INC.

COLOR CONVERSION FACTORS

Straw – x .97

Champagne – x .96

Micro-baffle – x .60

Gold – x .93

Wheat – x .88

Pewter – x .86

Product Information Bulletin

CAPSYLITE® SPL™ PAR20 AND PAR30

- Totally new halogen lens/reflector system
- Superior beam control and sharp cutoff
- Improved optical system provides consistent, uniform performance from lamp to lamp
- Up to 3000-hour lamp life
- Innovative technology for high performance
- Energy efficient halogen sources
- Lens stamped with beam pattern for easy identification

ECOLOGIC® is a comprehensive program of OSRAM SYLVANIA focused on addressing environmental issues at all stages of lamp life.

ECOLOGIC®

SYLVANIA CAPSYLITE SPL PAR20 and PAR30 lamps achieve their extraordinary performance by combining a tungsten halogen capsule with a unique lens/reflector system.

CAPSYLITE SPL PAR20 and PAR30 products deliver beam patterns unlike anything else available. The smooth beam performance and compact size of these lamps result in a new level of flexibility in lighting design. They are available in 35, 50 and 75 watts and in beam angles ranging from 8° to 60°. There is a CAPSYLITE SPL PAR20 or PAR30 available to meet virtually any lighting need.

Product Availability

Product	Wattage	Beam Angle
PAR20 SPL	35	NSP 8°, NFL 30°, WFL 40°
PAR20 SPL	50	NSP 10°, NFL 30°, WFL 40°
PAR30 SPL	50	NSP 9°, NFL 25°, WFL 40°
PAR30 SPL	60	NSP 9°, NFL 25°
PAR30 SPL	75	NSP 8°, NFL 25°, WFL 40°
PAR30 Long Neck SPL	35	NSP 9°, WFL 50°
PAR30 Long Neck SPL	50	NSP 9°, NFL 30°, WFL 50°
PAR30 Long Neck SPL	75	NSP 9°, NFL 30°, WFL 50°

Application Information

Applications

Highlight merchandise
Accent / display lighting
Floor lighting
General lighting
Indoor / Outdoor
Retail
Art galleries
Hotels, restaurants
Offices
Residential

Application Notes

1. Lens stamped with beam pattern
2. Better cutoff – maximum lumens in the beam
3. Eliminates stray light at the edges of the beam pattern
4. Superior candlepower rating
5. New distinctive appearance and superior performance due to SPL optics which combines new spiral reflector and lens

SYLVANIA

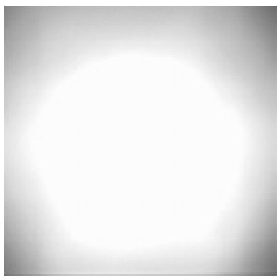
HAL015R1

Sample Specification
Lamp shall be CAPSYLITE SPL halogen (PAR20, PAR30 or PAR30LN) lamp with a (2500 or 3000) – hour average rated life, shall be diode free and employ stabilized coils. Lamp shall be energy efficient and produced to EPACT standards. Lamp base shall contain no lead solder to make the disposal of used CAPSYLITE SPL lamp easier for the end user.

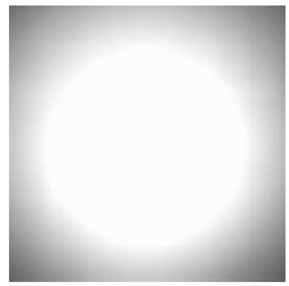
Lamp Comparison

Item No.	Lamp Type	Beam Angle	Color Temperature (K)	CBCP (cd)	Lumen (lm)	Life (hours)
14332	SYLVANIA 60PAR30/CAP/SPL/NSP9	9	2950	12,000	830	3000
	Brand X 60PAR30/H/SP10	10	2800	10,000	800	3000
14333	SYLVANIA 60PAR30/CAP/SPL/NFL25	25	2950	3500	830	3000
	Brand X 60PAR/H/FL25	25	2800	2400	800	3000
14467	SYLVANIA 35PAR20/CAP/SPL/NSP8	8	2950	3000	400	2500
	No competitive product available					
14464	SYLVANIA 35PAR20/CAP/SPL/NFL30	30	2950	900	400	2500
	No competitive product available					
14506	SYLVANIA 35PAR20/CAP/SPL/WFL40	40	2950	600	400	2500
	No competitive product available					

Optical Performance



Standard Halogen PAR



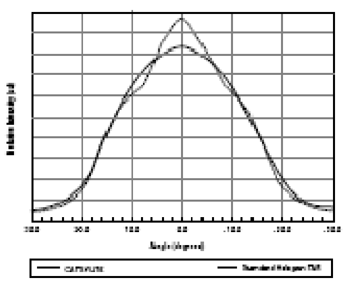
New CAPSYLITE SPL

CAPSYLITE SPL Optical System

PAR20, PAR30 and PAR30 Long Neck CAPSYLITE lamps employ a patented spiral lenticule layout on their lenses. These patterns were computer designed to deliver a smooth, round beam pattern that is free from hot spots and stray light. The new lenses, however, are only half of the story. The new spiral flat reflectors were also computer designed to work in concert with the lenses. The spiral flats on the inner surface of the reflector begin to shape and contour the light rays before they reach the lens. The reflector and the lens, therefore, share the job of controlling the light so that the resultant beam pattern is as smooth as possible. The optical system maximizes the lumens in the beam angle, while providing consistent lamp-to-lamp performance.

Beam Performance

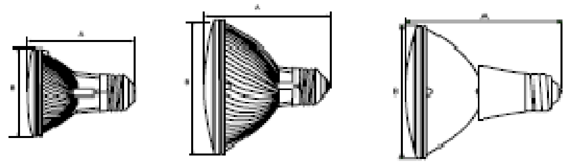
Comparison of Standard Halogen PAR to New CAPSYLITE with SPL Optics



The beam performance of the CAPSYLITE product line with SPL optics will change the way PAR lamps are specified. Traditionally, PAR lamps were designed to provide peak intensity in the center of the beam and the light level dropped rapidly from that point. In contrast, the CAPSYLITE product line is designed to give a more even distribution of high level light across as broad an area as possible with no hot spots. The result is a uniform light level on the target that maximizes the impact of the halogen source.

Dimensions

Bulb	(A) MOL	(B) Bulb Diameter
PAR20	3 1/4	2 1/2
PAR30	3 5/8	3 3/4
PAR30LN	4 11/16	3 3/4



Footcandle

Distance from Source (in ft.)	35PAR20/CAP/SPL/NSP Diameter (in ft.)	FC*	35PAR20/CAP/SPL/NFL Diameter (in ft.)	FC*	35PAR20/CAP/SPL/WFL Diameter (in ft.)	FC*	50PAR20/CAP/SPL/NSP Diameter (in ft.)	FC*	50PAR20/CAP/SPL/NFL Diameter (in ft.)	FC*
3'	0.4'	335	1.6'	100	2.2'	65	0.5'	555	1.6"	140
6'	0.8'	85	3.2'	25	4.4'	15	1.0'	140	3.2"	35
9'	1.3'	35	4.8'	10	6.6'	7	1.6'	60	4.8"	15

Distance from Source (in ft.)	50PAR20/CAP/SPL/WFL Diameter (in ft.)	FC*	35PAR30LN/CAP/NSP Diameter (in ft.)	FC*	35PAR30LN/CAP/WFL Diameter (in ft.)	FC*	50PAR30/CAP/SPL/NSP Diameter (in ft.)	FC*	50PAR30/CAP/SPL/NFL Diameter (in ft.)	FC*
3'	2.2'	89	0.5'	665	2.8'	40	0.5'	880	1.3'	289
6'	4.4'	22	0.9'	165	5.6'	10	0.9'	220	2.7'	78
9'	6.6'	10	1.4'	75	8.4'	4	1.4'	100	4.0'	35

Distance from Source (in ft.)	50PAR30/CAP/SPL/FL Diameter (in ft.)	FC*	50PAR30LN/CAP/WFL Diameter (in ft.)	FC*	60PAR30/CAP/SPL/NSP Diameter (in ft.)	FC*	60PAR30/CAP/SPL/NFL Diameter (in ft.)	FC*
3'	2.2'	145	2.8'	56	0.5'	1333	1.3'	389
6'	4.4'	35	5.6'	15	0.9'	333	2.7'	97
9'	6.6'	15	8.4'	6	1.4'	148	4.0'	43

Distance from Source (in ft.)	75PAR30/CAP/SPL/NSP Diameter (in ft.)	FC*	75PAR30/CAP/SPL/NFL Diameter (in ft.)	FC*	75PAR30/CAP/SPL/FL Diameter (in ft.)	FC*	75PAR30LN/CAP/WFL Diameter (in ft.)	FC*
3'	0.5'	1555	1.3'	489	2.2'	220	2.8'	85
6'	0.9'	390	2.7'	122	4.4'	55	5.6'	20
9'	1.4'	175	4.0'	54	6.6'	25	8.4'	9

SYLVANIA CAPSYLITE PAR lamps are available in a full range of beam angles to meet the demands of virtually any display or accent lighting application. For each available CAPSYLITE PAR lamp, this table shows how lamp output in footcandles varies as a function of distance.

Ordering and Specification Information

Item Number	Ordering Abbreviation	Watts	Base	Avg. Rated Life (hrs)	Volts	CBCP	Beam Angle	Lumens	MOL
14467	35PAR20/CAP/SPL/NSP8	35	Medium	2500	120	3000	8°	400	3 1/4
14460	35PAR20/CAP/SPL/NSP8	35	Medium	2500	130	3000	8°	400	3 1/4
14464	35PAR20/CAP/SPL/NFL30	35	Medium	2500	120	900	30°	400	3 1/4
14459	35PAR20/CAP/SPL/NFL30	35	Medium	2500	130	900	30°	400	3 1/4
14506	35PAR20/CAP/SPL/WFL40	35	Medium	2500	120	600	40°	400	3 1/4
14461	35PAR20/CAP/SPL/WFL40	35	Medium	2500	130	600	40°	400	3 1/4
14500	50PAR20/CAP/SPL/NSP10	50	Medium	2500	120	5000	10°	530	3 1/4
14528	50PAR20/CAP/SPL/NSP10	50	Medium	2500	130	5000	10°	530	3 1/4
14502	50PAR20/CAP/SPL/NFL30	50	Medium	2500	120	1450	30°	530	3 1/4
14529	50PAR20/CAP/SPL/NFL30	50	Medium	2500	130	1450	30°	530	3 1/4
14700	50PAR20/CAP/SPL/WFL40	50	Medium	2500	120	800	40°	530	3 1/4
14526	50PAR30/CAP/SPL/NSP9	50	Medium	2500	120	8000	9°	600	3 5/8
14530	50PAR30/CAP/SPL/NSP9	50	Medium	2500	130	8000	9°	600	3 5/8
14527	50PAR30/CAP/SPL/NFL25	50	Medium	2500	120	2600	25°	600	3 5/8
14531	50PAR30/CAP/SPL/NFL25	50	Medium	2500	130	2600	25°	600	3 5/8
14710	50PAR30/CAP/SPL/FL40	50	Medium	2500	120	1300	40°	600	3 5/8
14533	50PAR30/CAP/SPL/FL40	50	Medium	2500	130	1300	40°	600	3 5/8
14332	60PAR30/CAP/SPL/NSP9	60	Medium	3000	120	12,000	9°	830	3 5/8
14333	60PAR30/CAP/SPL/NFL25	60	Medium	3000	120	3500	25°	830	3 5/8
14604	75PAR30/CAP/SPL/NSP9	75	Medium	2500	120	14,000	9°	1100	3 5/8
14628	75PAR30/CAP/SPL/NSP9	75	Medium	2500	130	14,000	9°	1100	3 5/8
14603	75PAR30/CAP/SPL/NFL25	75	Medium	2500	120	4400	25°	1100	3 5/8
14627	75PAR30/CAP/SPL/NFL25	75	Medium	2500	130	4400	25°	1100	3 5/8
14606	75PAR30/CAP/SPL/FL40	75	Medium	2500	120	2000	40°	1100	3 5/8
14629	75PAR30/CAP/SPL/FL40	75	Medium	2500	130	2000	40°	1100	3 5/8
14759	35PAR30LN/CAP/NSP9	35	Medium	2500	120	6000	9°	450	4 11/16
14764	35PAR30LN/CAP/WFL50	35	Medium	2500	120	350	50°	450	4 11/16
14509	50PAR30LN/CAP/NSP9	50	Medium	2500	120	8000	9°	600	4 11/16
14482	50PAR30LN/CAP/NSP9	50	Medium	2500	130	8000	9°	600	4 11/16
14520	50PAR30LN/CAP/NFL30	50	Medium	2500	120	1850	30°	600	4 11/16
14478	50PAR30LN/CAP/NFL30	50	Medium	2500	130	1850	30°	600	4 11/16
14537	50PAR30LN/CAP/WFL50	50	Medium	2500	120	500	50°	600	4 11/16
14536	50PAR30LN/CAP/WFL/RP	50	Medium	2500	120	500	50°	600	4 11/16
14486	50PAR30LN/CAP/WFL50	50	Medium	2500	130	500	50°	600	4 11/16
14786	75PAR30LN/CAP/NSP9	75	Medium	2500	120	14,000	9°	1100	4 11/16
14777	75PAR30LN/CAP/NSP9	75	Medium	2500	130	14,000	9°	1100	4 11/16
14769	75PAR30LN/CAP/NFL30	75	Medium	2500	120	3200	30°	1100	4 11/16
14778	75PAR30LN/CAP/NFL30	75	Medium	2500	130	3200	30°	1100	4 11/16
14768	75PAR30LN/CAP/WFL50	75	Medium	2500	120	750	50°	1100	4 11/16
14785	75PAR30LN/CAP/WFL50	75	Medium	2500	130	750	50°	1100	4 11/16

Ordering Guide

50	PAR30	LN	/	CAP	/	SPL	/	NSP	10
Wattage:	Parabolic	Long Neck		CAPSYLITE				Beam Spread	9°
50	Reflector							NSP=Narrow Spot	10°
	Diameter							NFL=Narrow Flood	25°
	30=30/8							FL=Flood	30°
	20=20/8							WFL=Wide Flood	40°

OSRAM SYLVANIA
National Customer
Support Center
18725 N. Union Street
Westfield, IN 46074

Industrial & Commercial
Phone: 1-800-255-5042
Fax: 1-800-255-5043

National Accounts
Phone: 1-800-562-4671
Fax: 1-800-562-4674

Special Markets
Phone: 1-800-762-7191
Fax: 1-800-762-7192

In Canada
OSRAM SYLVANIA LTD.
Headquarters
2001 Drew Road
Mississauga, ON L5S 1S4

Industrial & Commercial
Phone: 1-800-263-2852
Fax: 1-800-667-6772

Special Markets
Phone: 1-800-265-2852
Fax: 1-800-667-6772

Visit our website: www.sylvania.com

HIGH EFFICIENCY T5 TROFFER

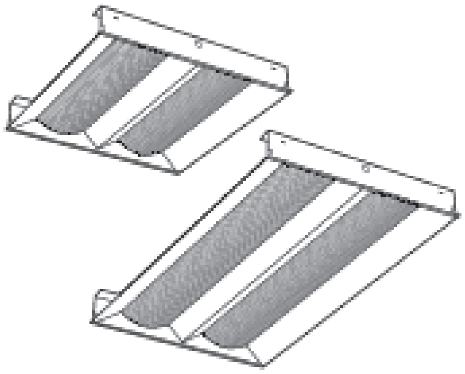
HET
2x2 & 2x4
T5

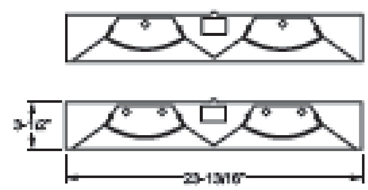
SERIES

JOB

TYPE

VOLTAGE





SPECIFICATIONS

- **Housing** – 22-gauge die-formed C.R.S.
- **Shielding** – Ribbed acrylic diffuser.
- **Finish** – Highly reflective textured matte white powder coat with multi-stage iron/phosphate prepared metal.
- **Electrical** – Electronic ballast standard, programmed start T5, rated Class P.
- **Labels** – UL/CUL listed as recessed fluorescent luminaire suitable for dry or damp locations.
- **Mounting** – NEMA Type "G" standard. For flange installations use the Drywall Flange Kit (DFK), ordered separately, see Information section.

FEATURES

- Attractive and energy efficient architectural fixture that delivers comfortable, uniform lighting.
- One-piece frosted acrylic diffuser won't become separated from fixture.
- Frosted acrylic diffusers combined with highly reflective matte white paint provide high optical efficiencies while not sacrificing visual comfort.
- Shallow fixture depth of 3-1/2" allows for use in limited plenum applications.
- Companion HET 1' x 1' recessed downlight available in Williams Downlighting Recessed Fluorescent section.
- Optional anti-microbial powder coating available to prevent the spread of dangerous micro-organisms and suppress the growth of mold and bacteria.
- Tool-less access to the electrical from the room-side of the fixture.
- Integral T-bar clips quickly secure fixture to structure.
- All parts painted after fabrication to facilitate installation, increase efficiency, and inhibit corrosion.
- This fixture is proudly made in the USA.

ORDERING INFORMATION

Submittal

	SERIES	CEILING TYPE	FIXT. STYLE	NOM W.	NOM L.	TOTAL LAMPS	WATTAGE/TYPE	SHIELDING	OPTIONS	BALLAST	VOLTAGE
EXAMPLE	HET	G	5	2	4	2	28T5S	A	OPTIONS	EB2	UNV

SERIES

HET	High Efficiency Troffer

CEILING TYPE (Must specify)

G	NEMA Type "G"

For flange installations use the Drywall Flange Kit (DFK), ordered separately, see Information section.

FIXTURE STYLE (Must specify)

5	Static, no air capability

NOMINAL WIDTH (Must specify)

2	2'

NOMINAL LENGTH (Must specify)

2	2'
4	4'

TOTAL LAMPS (Must specify)

2 or 4

2' x 2' LAMP WATTAGE/TYPE (Must specify)

14T5S	2', 14-watt T5
24T5H	2', 24-watt T5HO (2-lamp cross-section only)

2' x 4' LAMP WATTAGE/TYPE (Must specify)

28T5S	4', 28-watt T5
54T5H	4', 54-watt T5HO (2-lamp cross-section only)

SHIELDING (Must specify)

A	Acrylic lens

OPTIONS

AMW	Anti-microbial white finish

BALLAST TYPE

EB2	2-lamp electronic ballast
EBSD(95)2	2-lamp electronic ballast, step-dimming, .95 ballast factor (T5S only)

BALLAST TYPE cont'd.

EBSD(115)2	2-lamp electronic ballast; step-dimming, 1.15 ballast factor (T5S only)
EB4	4-lamp electronic ballast
EB2/2	(2) 2-lamp electronic ballasts
EBSD(95)2/2	(2) 2-lamp electronic ballasts, step-dimming, .95 ballast factor, (T5S only)
EBSD(115)2/2	(2) 2-lamp electronic ballasts, step-dimming, 1.15 ballast factor (T5S only)

VOLTAGE

120	120V	UNV	120-277V
277	277V	347	347V

Williams
FLUORESCENT LIGHTING

HET 2x2 & 2x4 T5 SERIES

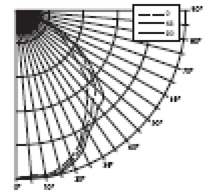
PHOTOMETRY INFORMATION

Williams Catalog #HETG-324-228T5S-A
Test Report #13351.0, Dated 12/12/06

Lamp Type: FP28T5/835
Lamp Quantity: 2

CANDLEPOWER DISTRIBUTION

VERT. ANG.	HORIZONTAL ANGLE 0	45	90	ZONAL LUMENS
0	1958.	1958.	1958.	
5	1933.	1934.	1935.	184.6
15	1925.	1940.	1957.	549.9
25	1728.	1769.	1812.	818.7
35	1431.	1510.	1583.	947.2
45	1177.	1317.	1439.	1016.1
55	778.	951.	1030.	833.2
65	471.	607.	534.	546.8
75	222.	239.	172.	236.7
85	47.	31.	27.	38.5
90	0.	0.	0.	



LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXTURE
0 - 30	1553.	26.8	30.0
0 - 40	2500.	43.1	48.3
0 - 60	4350.	75.0	84.1
0 - 90	5172.	89.2	100.0
0 - 180	5172.	89.2	100.0

TOTAL LUMINAIRE
OPTICAL **EFFICIENCY = 89.2%**

SPACING CRITERIA: END = 1.2 DIAG. = 1.4 ACROSS = 1.4

ZONAL CAVITY COEFFICIENTS

EFFECTIVE FLOOR CAVITY REFL. = .20

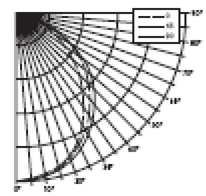
CEILING	.80			.70			.50		
WALL / RCR	.70	.50	.30	.70	.50	.30	.50	.30	.10
0	1.06	1.06	1.06	1.04	1.04	1.04	.99	.99	.99
1	.99	.95	.92	.96	.93	.90	.89	.87	.84
2	.91	.84	.79	.89	.83	.78	.80	.76	.73
3	.84	.75	.69	.82	.74	.68	.71	.66	.62
4	.77	.67	.60	.75	.66	.59	.64	.58	.53
5	.70	.60	.53	.69	.59	.53	.57	.51	.46
6	.65	.53	.46	.63	.53	.45	.51	.45	.40
7	.60	.48	.41	.58	.47	.40	.46	.40	.35
8	.55	.43	.36	.54	.42	.35	.41	.35	.30
9	.50	.39	.31	.49	.38	.31	.37	.31	.26
10	.47	.35	.28	.46	.35	.28	.34	.27	.23

Williams Catalog #HETG-322-224T5H-A-EB2
Test Report #13152.0, Dated 06/26/06

Lamp Type: FP54T5H/835
Lamp Quantity: 2

CANDLEPOWER DISTRIBUTION

VERT. ANG.	HORIZONTAL ANGLE 0	45	90	ZONAL LUMENS
0	1238.	1238.	1238.	
5	1240.	1228.	1236.	117.7
15	1189.	1190.	1203.	338.2
25	1091.	1115.	1139.	515.7
35	931.	990.	1028.	619.2
45	728.	817.	886.	629.8
55	498.	627.	698.	550.9
65	297.	411.	365.	364.0
75	130.	154.	112.	147.6
85	16.	11.	6.	12.5
90	0.	0.	0.	



LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXTURE
0 - 30	972.	25.6	29.5
0 - 40	1591.	41.9	48.3
0 - 60	2772.	72.9	84.1
0 - 90	3296.	86.7	100.0
0 - 180	3296.	86.7	100.0

TOTAL LUMINAIRE
OPTICAL **EFFICIENCY = 86.7%**

SPACING CRITERIA: END = 1.2 DIAG. = 1.2 ACROSS = 1.1

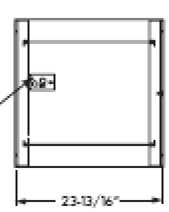
ZONAL CAVITY COEFFICIENTS

EFFECTIVE FLOOR CAVITY REFL. = .20

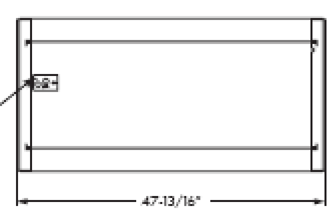
CEILING	.80			.70			.50		
WALL / RCR	.70	.50	.30	.70	.50	.10	.50	.30	.10
0	1.03	1.03	1.03	1.01	1.01	1.01	.96	.96	.96
1	.96	.92	.89	.94	.90	.88	.87	.84	.82
2	.88	.82	.77	.86	.81	.76	.78	.74	.70
3	.81	.73	.67	.79	.72	.66	.69	.64	.60
4	.75	.65	.58	.73	.64	.58	.62	.56	.52
5	.68	.58	.50	.67	.57	.50	.55	.49	.44
6	.63	.52	.44	.61	.51	.44	.49	.43	.39
7	.58	.47	.39	.56	.46	.39	.45	.38	.34
8	.53	.42	.34	.52	.41	.34	.40	.34	.29
9	.49	.37	.30	.48	.37	.30	.36	.30	.25
10	.45	.34	.27	.44	.33	.27	.33	.26	.22

BACK VIEW

1 ACCESS PLATE w/(2) 7/8" K.O.



1 ACCESS PLATE w/(2) 7/8" K.O.



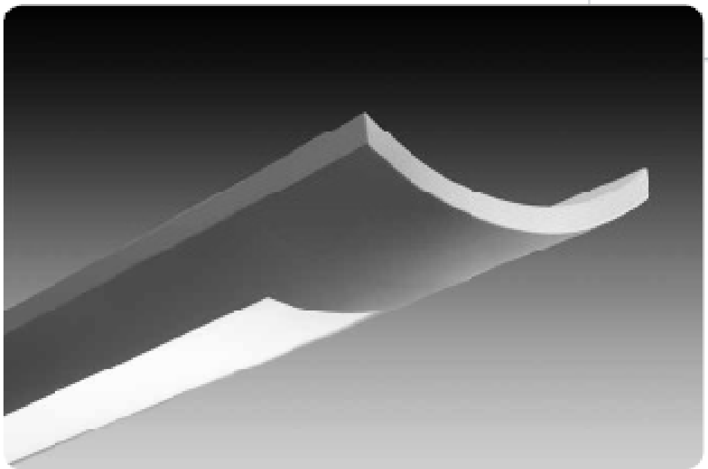
Williams
H.E. WILLIAMS, INC.
H.E. Williams, Inc. • Carthage, Missouri • www.hewilliams.com • 417-358-4065 • Fax: 417-358-6015

HEW/JF55852 10/21/10JJ

lens

verve™ IV

FOCAL POINT®



features

Suspended linear direct/indirect fluorescent with frosted acrylic, round patterned or squared patterned diffuser.

One-piece steel housing with 5" die-cast end caps.

Optional DR optics deliver light where you need it. Increased direct illumination suits ceiling heights from low to high, providing an opportunity to reduce lamps while maintaining light levels.

Internal Debris Shield keeps diffusers looking clear over the life of the project.

Practical and budget-friendly Verve™ IV is an excellent choice for commercial and educational applications.

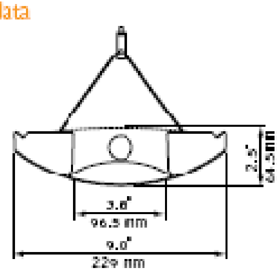
shielding options

Round Patterned Diffuser | Square Patterned Diffuser | Frosted Acrylic Diffuser

sensor option / companion luminaire

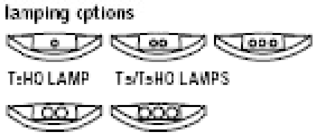
daylight/occupancy sensor | Radial or Flat Blade Baffle | Louver

dimensional data



PDR | DR0, DR1, DR2 & DR4

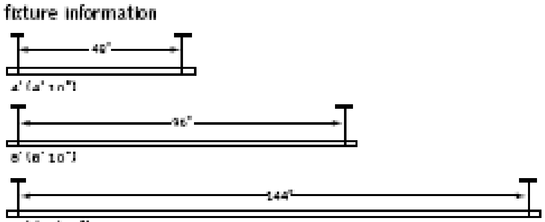
lamping options



T5HO LAMP | T5/T5HO LAMPS

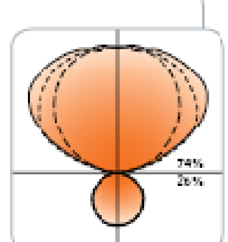
T8 LAMPS

fixture information



performance

2-Lamp T5
Frosted Acrylic Lens
96.5% Efficiency

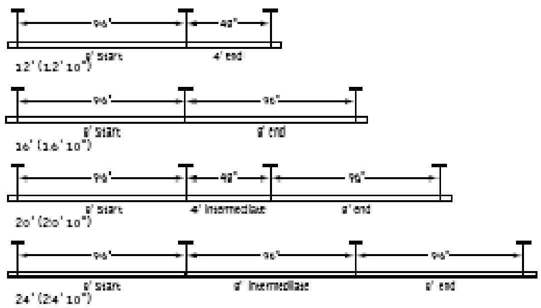


Visit focalpointlights.com for complete photometric data.

fixture:

project:

suspension information



Consult factory for additional row length information.

specifications

construction

One-piece 20 Ga. steel housing.
Die-cast 5" end cap fastened to housing.
For row installation, internal brackets form hairline joint.
Standard lengths are available in 4' and 8'.
All luminaires are provided with 'Y-cable suspension mounted on 48" or 96" centers.

4' unit weight: 20 lbs.
8' unit weight: 30 lbs.

optic

Frosted Acrylic Diffuser is 0.20" thick.
Patterned Acrylic Duffusers are 0.20" thick combined with additional 0.20" acrylic lens.
Clear acrylic internal debris shield supplied standard.
Optional Downlight Reflector optics fabricated of die-formed aluminum.
PDR reflector separates center lamp for direct distribution and two outer lamps for indirect distribution.

electrical

Luminaires are pre-wired with factory installed branch circuit wiring and over-molded quick connects.
Factory installed SJT power cord at feed location is included.
Electronic ballasts are thermally protected and have a Class "P" rating.
Optional dimming ballasts available.
UL and cUL listed.

sensors

Lutron daylight sensor is a directional sensor that operates with a Lutron EcoSystem ballast (DB). The sensor has an integrated IR receiver for EcoSystem programming.

Philips Luxsense daylight sensor measures reflected light from the surface below and dims lamp output when the light level exceeds required level. Output may be adjusted by turning the dial. A 0-10V dimming ballast is required (T5 - DS, T5HO - D7 standard).

Wattstopper daylight sensor is a closed loop system that measures total light level from daylight and electric light. A 0-10V dimming ballast is required (T5 - DS, T5HO - D7 standard).

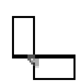
Wattstopper occupancy sensor is a passive infrared sensor designed for cubicles and small offices. It has built-in daylight sensing that will hold lights off when adequate ambient light exists. One sensor controls multiple fixtures.

finish

Polyester powder coat applied over a 5-stage pretreatment.
Canopy finished in Matte Satin White.

ordering

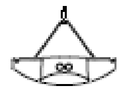
fixture series		FV4S
Verve IV	FV4S	
shielding		
Frosted Acrylic Diffuser	AC	
Round Patterned Diffuser	RA	
Square Patterned Diffuser	SA	
optional downlight accessories**		
Downlight Reflector - isolates center lamp (3-lamp & dual circuit options only)	PDR	
100% downlight	DR0	
up to 75% downlight	DR1	
up to 60% downlight	DR2	
up to 50% downlight	DR4	
lamping		
2 Lamp T5	2T5	
3 Lamp T5	3T5	
1 Lamp T5HO	1T5 HO	
2 Lamp T5HO	2T5 HO	
3 Lamp T5HO	3T5 HO	
2 Lamp T8	2T8	
3 Lamp T8	3T8	
circuit		
Single Circuit	1C	
Dual Circuit (Multiple lamp luminaires only)	2C	
voltage		
120 Volt	120	
277 Volt	277	
347 Volt	347	
ballast		
Electronic Instant Start <20% THD (T8 Only)	E	
Electronic Program Start <10% THD	S	
Electronic Dimming Ballast*	D	
mounting		
24" Cable Suspension	C24	
48" Cable Suspension	C48	
96" Cable Suspension	C96	
(Specify "J" in place of "C" for 5" dia. canopies at power feed and 2" dia. canopies at non-feed locations) (Consult factory for sloped ceiling applications)		
factory options		
Dust Cover (Consult factory for compatibility)	DC	
Emergency Circuit*	EC	
Emergency Battery Pack*	EM	
HLR/GLR Fuse	FU	
Include 3000K Lamp*	L830	
Include 3500K Lamp*	L835	
Include 4100K Lamp*	L841	
Lutron™ Daylight Sensor* (EcoSystem ballast required)	LY1	
Lutron™ Sensor Feed* (EcoSystem ballast required)	SF	
Philips™ Daylight Sensor* (0-10V dimming ballast required)	PY1	
WattStopper™ Daylight Sensor* (0-10V dimming ballast required)	WY1	
WattStopper™ Occupancy Sensor*	WO1	
finish		
Matte Satin White	WH	
Titanium Silver	TS	
luminaire length		
4'	4'	
8'	8'	
12' (8'+4')	12'	
16' (8'+8')	16'	
20' (8'+8'+4')	20'	
24' (8'+8'+8')	24'	
integrator options		
90-degree Corner	FV4-90	
remotes (specify quantity)		
WattStopper™ Daylight Setup Remote* (required for daylight programming, one included per order)	WYSR	
WattStopper™ Occupant Controller*	WOR	



* for more information see Reference section. **lamp type will effect actual percentage values. See IES file for exact uplight/downlight %.

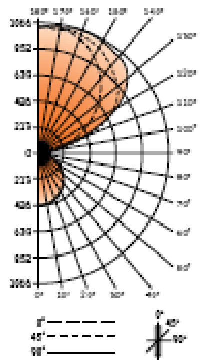
linear

frosted acrylic lens
verve™ IV



Filename:	FV4SAC2T5.IES
Catalog #:	FV4S-AC-2T5-1C-120-S-WH-4
Efficiency:	96.5%
Test #:	26371

CANDLE POWER DISTRIBUTION



Vertical Angle	Horizontal Angle 0°	22.5°	45°	67.5°	90°	Zonal Lumens
0°	433	433	433	433	433	
5°	435	432	431	432	429	42
15°	420	417	417	420	419	118
25°	390	389	390	393	393	180
35°	347	346	348	352	352	218
45°	292	292	295	299	299	228
55°	228	228	232	236	236	207
65°	159	159	164	167	168	161
75°	88	90	94	96	97	99
85°	24	25	33	38	40	36
90°	0	6	13	18	20	
95°	35	64	50	49	49	67
105°	212	328	305	374	361	301
115°	398	513	615	599	588	545
125°	567	655	797	860	873	674
135°	728	786	892	982	101	679
145°	859	898	964	1021	1044	599
155°	962	974	1018	1051	1066	468
165°	1023	1030	1043	1055	1061	294
175°	1036	1032	1044	1050	1050	101
180°	1035	1035	1035	1035	1035	

LUMEN SUMMARY

	Zone	Lumens	% Lamp	% Fixt
	0°-30°	339	6.5	6.8
	0°-90°	1288	24.8	25.7
	90°-180°	3728	71.7	74.32
Total Luminaire	0°-180°	5017	96.5	100.0

LUMINANCE DATA (CD/M²)

Vertical Angle	0°	45°	90°
45°	4044	4098	4155
55°	3890	3973	4047
65°	3669	3818	3894
75°	3322	3558	3642
85°	2638	3658	4485

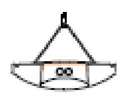
CO-EFFICIENTS OF UTILIZATION

Floor	20														
Ceiling	80				70			50		30		10		00
Wall	70	50	30	10	70	50	10	50	10	50	10	50	10	00
RCR 0	98	98	98	98	87	87	87	67	67	49	49	33	33	25
1	89	85	81	78	79	76	70	59	55	43	41	29	27	21
2	81	74	69	64	72	66	57	52	45	38	34	25	23	18
3	74	65	59	53	66	59	49	46	38	34	29	23	20	15
4	68	58	50	45	60	52	41	40	33	30	5	20	17	13
5	62	50	43	38	55	46	34	36	28	26	21	18	15	11
6	57	45	38	33	50	41	30	32	24	24	18	16	13	9
7	52	41	33	28	46	35	25	29	21	21	16	14	11	8
8	48	37	29	24	43	33	22	26	18	19	14	13	9	7
9	44	33	26	21	39	30	19	23	16	17	12	12	8	6
10	41	30	23	19	37	27	17	21	14	16	10	11	7	5

Numbers indicate percentage values of reflectivity.

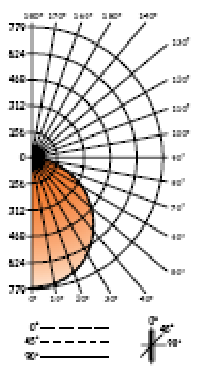
Go to www.focalpointlights.com for additional photometric data.

frosted acrylic lens
verve™ IV



Filename:	FV4SACDR02T5.IES
Catalog #:	FV4S-AC-DR0-2T5-1C-120-S-WH-4
Efficiency:	44.1%
Test #:	26372

CANDLE POWER DISTRIBUTION



Vertical Angle	Horizontal Angle 0°	22.5°	45°	67.5°	90°	Zonal Lumens
0°	775	775	775	775	775	
5°	779	772	770	771	767	74
15°	751	747	745	748	746	210
25°	697	695	693	696	695	320
35°	619	616	615	6158	617	385
45°	520	518	516	520	518	399
55°	404	401	402	405	403	359
65°	279	277	279	282	281	276
75°	151	151	156	159	161	164
85°	37	40	53	63	66	60
90°	0	9	22	32	35	
95°	2	1	6	12	14	9
105°	5	4	3	3	2	4
115°	7	6	6	5	4	5
125°	8	7	7	6	5	6
135°	8	10	9	8	7	7
145°	9	11	11	9	8	6
155°	10	13	13	12	10	5
165°	10	14	13	13	12	4
175°	10	12	13	13	13	1
180°	10	10	10	10	10	

LUMEN SUMMARY

	Zone	Lumens	% Lamp	% Fixt
	0°-30°	604	11.6	26.3
	0°-90°	2248	43.2	97.9
	90°-180°	47	0.9	2.1
Total Luminaire	0°-180°	2295	44.1	100.0

LUMINANCE DATA (CD/M²)

Vertical Angle	0°	45°	90°
45°	7187	7171	7200
55°	6882	6880	6907
65°	6450	6470	6528
75°	5726	5887	6091
85°	4153	4998	7483

CO-EFFICIENTS OF UTILIZATION

Floor	20														
Ceiling	80				70			50		30		10		00
Wall	70	50	30	10	70	50	10	50	10	50	10	50	10	00
RCR 0	52	52	52	52	51	51	51	49	49	46	46	44	44	43
1	48	46	44	42	47	45	42	43	40	41	39	39	37	37
2	44	40	37	35	43	39	34	38	34	36	33	35	32	31
3	40	36	32	29	39	35	29	33	28	32	28	31	27	26
4	37	32	28	25	36	31	25	30	24	29	24	28	24	23
5	34	28	24	21	33	27	21	26	21	25	20	25	20	19
6	31	25	21	18	30	25	18	24	18	23	18	22	17	17
7	28	22	19	16	28	22	16	21	16	21	15	20	15	14
8	26	20	16	14	26	20	14	19	14	19	13	18	13	12
9	24	18	14	12	26	18	12	17	12	17	12	16	11	11
10	22	17	13	11	22	16	10	16	10	15	10	15	10	9

Numbers indicate percentage values of reflectivity.

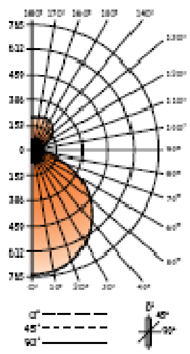
Go to www.focalpointlights.com for additional photometric data.

frosted acrylic lens

verve™ IV

Filename: FV4SACDR12T5.IES
Catalog #: FV4S-AC-DR1-2T5-1C-120-S-WH-4
Efficiency: 56.2%
Test #: 26373

CANDLEPOWER DISTRIBUTION



Vertical Angle	0°	22.5°	45°	67.5°	90°	Zonal Lumens
0°	762	762	762	762	762	
5°	765	759	757	758	755	73
15°	738	734	733	737	735	207
25°	685	683	682	686	686	315
35°	608	607	606	610	609	379
45°	511	509	510	513	513	393
55°	398	395	397	400	401	355
65°	274	273	276	278	279	273
75°	149	150	154	158	160	163
85°	37	41	53	63	66	59
90°	0	9	21	31	34	
95°	8	7	11	20	26	18
105°	44	48	42	38	43	46
115°	82	94	98	88	86	88
125°	117	134	137	138	130	118
135°	150	168	176	176	173	131
145°	177	188	201	205	204	122
155°	198	203	216	221	220	98
165°	210	211	217	220	220	61
175°	211	209	212	212	212	21
180°	210	210	210	210	210	

LUMEN SUMMARY

	Zone	Lumens	% Lamp	% Fixt.
	0°-30°	595	11.4	20.4
	0°-90°	2218	42.7	76.0
	90°-180°	702	16.5	24.0
Total Luminaire	0°-180°	2920	56.2	100.0

LUMINANCE DATA (CD/M²)

Vertical Angle	0°	45°	90°
45°	7065	7078	7123
55°	6783	6797	6861
65°	6349	6415	6493
75°	5627	5837	6073
85°	4126	5966	7448

CO-EFFICIENTS OF UTILIZATION

Floor 20

Ceiling	80				70			50		30		10		00
Wall	70	50	30	10	70	50	10	50	10	50	10	50	10	00
RCR 0	64	64	64	64	61	61	61	55	55	50	50	45	45	43
1	58	56	53	51	55	53	49	48	45	44	42	40	38	36
2	53	49	45	42	51	47	41	42	38	39	35	35	32	30
3	49	42	39	33	46	41	34	38	32	34	30	31	28	26
4	45	38	34	30	42	37	29	34	27	31	26	28	24	22
5	41	34	29	24	38	32	25	30	23	27	22	25	20	19
6	37	30	25	22	35	29	21	27	20	24	19	22	18	16
7	34	27	22	19	33	26	17	24	18	22	16	20	15	14
8	32	24	20	19	30	25	16	21	15	20	14	18	13	12
9	29	2	17	14	228	21	14	19	13	18	12	16	12	10
10	27	20	18	12	26	19	12	18	12	16	11	15	10	9

Numbers indicate percentage values of reflectivity.

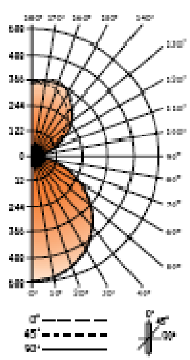
Go to www.focalpointlights.com for additional photometric data.

frosted acrylic lens

verve™ IV

Filename: FV4SACDR22T5.IES
Catalog #: FV4S-AC-DR2-2T5-1C-120-S-WH-4
Efficiency: 56.4%
Test #: 26374

CANDLEPOWER DISTRIBUTION



Vertical Angle	0°	22.5°	45°	67.5°	90°	Zonal Lumens
0°	605	605	605	605	605	
5°	608	603	601	602	599	58
15°	586	583	582	585	583	164
25°	544	542	542	545	544	250
35°	483	481	481	485	485	302
45°	406	405	406	408	409	313
55°	316	315	318	320	320	283
65°	219	218	222	224	224	219
75°	120	120	125	128	129	131
85°	30	33	42	50	53	48
90°	0	8	19	29	35	
95°	12	15	20	25	34	27
105°	67	83	74	67	79	79
115°	128	153	158	158	150	148
125°	188	220	224	224	227	195
135°	244	280	284	281	280	213
145°	291	317	334	338	327	201
155°	325	340	363	368	366	163
165°	345	353	364	371	373	102
175°	348	349	354	356	357	34
180°	347	347	347	347	347	

LUMEN SUMMARY

	Zone	Lumens	% Lamp	% Fixt.
	0°-30°	472	9.1	16.1
	0°-90°	1769	34.0	60.3
	90°-180°	1162	22.4	39.7
Total Luminaire	0°-180°	2931	56.4	100.0

LUMINANCE DATA (CD/M²)

Vertical Angle	0°	45°	90°
45°	5623	5635	5680
55°	5391	5438	5481
65°	5066	5156	5209
75°	4584	4719	4889
85°	3484	4779	5919

CO-EFFICIENTS OF UTILIZATION

Floor 20

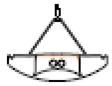
Ceiling	80				70			50		30		10		00
Wall	70	50	30	10	70	50	10	50	10	50	10	50	10	00
RCR 0	62	62	62	62	58	58	58	50	50	43	43	37	37	34
1	56	54	52	50	53	51	47	44	41	38	36	33	31	29
2	51	47	44	41	48	44	39	39	34	34	30	29	26	24
3	47	42	37	34	44	39	32	34	29	30	26	26	23	21
4	43	37	32	29	40	35	28	30	25	27	22	23	20	18
5	39	32	28	24	37	21	25	27	21	24	19	20	17	15
6	36	29	24	21	34	27	20	24	18	21	16	18	14	13
7	33	26	22	18	31	25	17	22	16	19	14	17	13	11
8	31	23	19	16	29	22	15	20	14	17	12	15	11	10
9	28	21	17	14	26	20	13	18	12	15	11	13	9	8
10	26	19	15	12	25	18	12	16	11	14	9	12	8	7

Numbers indicate percentage values of reflectivity.

Go to www.focalpointlights.com for additional photometric data.

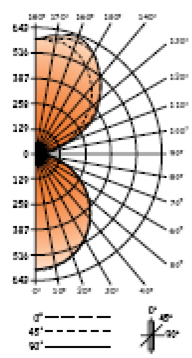
frosted acrylic lens

verve™ IV



Filename: FV4SACDR42T5.IES
Catalog #: FV4S-AC-DR4-2T5-1C-120-S-WH-4
Efficiency: 71.3%
Test #: 26375

CANDLEPOWER DISTRIBUTION



Vertical Angle	0°	22.5°	45°	67.5°	90°	Zonal Lumens
0°	600	600	600	600	600	
5°	603	598	596	598	594	58
15°	581	578	577	580	579	163
25°	540	538	538	541	541	248
35°	479	478	478	482	482	299
45°	402	402	403	406	406	311
55°	313	312	316	318	318	281
65°	217	216	220	222	223	217
75°	118	119	124	126	128	130
85°	30	33	43	50	53	47
90°	0	7	16	23	26	
95°	20	23	24	33	15	36
105°	110	139	123	104	122	129
115°	213	255	266	256	258	249
125°	311	368	373	380	389	328
135°	410	467	474	479	481	359
145°	489	532	565	564	562	341
155°	555	579	620	631	632	278
165°	593	603	623	638	643	175
175°	600	599	607	612	613	59
180°	600	600	600	600	600	

LUMEN SUMMARY

	Zone	Lumens	% Lamp	% Fixt.
	0°-30°	469	9.0	12.6
	0°-90°	1756	33.8	47.3
	90°-180°	1954	37.6	52.7
Total Luminaire	0°-180°	3710	71.3	100.0

LUMINANCE DATA (CD/M²)

Vertical Angle	0°	45°	90°
45°	5566	5595	5641
55°	5341	5403	5447
65°	5018	5121	5183
75°	4475	4695	4867
85°	3371	4784	5924

CO–EFFICIENTS OF UTILIZATION

Floor	20															
Ceiling	80				70			50		30		10		00
Wall	70	50	30	30	70	50	10	50	30	50	10	50	10	00
RCR 0	76	76	76	76	70	70	70	58	58	48	48	38	38	34
1	69	66	64	61	64	61	56	51	48	42	40	34	32	28
2	63	58	54	50	58	53	46	45	40	37	33	30	27	24
3	58	51	46	42	53	47	39	40	34	33	28	27	23	21
4	53	45	40	35	48	42	33	35	29	29	24	24	20	18
5	48	40	34	30	44	37	28	31	24	26	21	21	17	15
6	44	36	30	26	41	33	24	28	21	26	18	19	15	13
7	41	32	26	22	37	30	21	25	18	21	16	17	13	11
8	38	29	3	19	34	27	18	23	16	19	14	15	11	10
9	35	26	20	19	32	24	16	20	14	17	12	14	10	8
10	32	23	18	15	30	22	14	19	12	16	10	13	9	7

Go to www.focalpointlights.com for additional photometric data.