

DEPARTMENT OF VETERANS AFFAIRS

**OFFICE OF CONSTRUCTION AND
FACILITIES MANAGEMENT (00CFM)**

**LED & CONVENTIONAL
LIGHTING SYSTEMS
COMPARISON STUDY**



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1 EXECUTIVE SUMMARY

This study compares LED lighting to conventional fluorescent and high-intensity discharge (HID) lighting within the VA healthcare environment. It calculates the luminous performance and life cycle costs of these lighting systems.

Lighting calculations were performed in typical VA functional areas which account for the majority of the luminaires used in healthcare construction: office and exam rooms, corridors, nurse stations, parking lots and garages, and warehouses and energy centers. The calculations are based on readily-available lighting systems and technologies from multiple manufacturers, and underlying assumptions for hours of use, color temperature, energy cost, optic types, etc., were made such that the calculations were performed to enable direct performance comparison.

- Conventional lighting systems are significantly less expensive in a life cycle analysis.
- Interior LED luminaires are currently best suited for applications which require 30 footcandles of illumination or less in applications that require long hours of operation, and also at mounting heights such that maintenance access is costly.
- LED lighting is currently not well suited for interior applications that require more than 30 footcandles of illumination. More LED fixtures are required to achieve the luminous and life cycle cost performance demonstrated by fluorescent lighting.
- Exterior LED luminaires are currently suited for parking lots and garages, and exterior egress lighting.
- LED luminous efficacy is improving rapidly. Fluorescent and HID luminous efficacy appear to have reached a plateau.
- The largest challenge currently faced by LED lighting technology is the management of produced heat. Between 60% and 80% of the energy supplied to an LED light source is dissipated as heat.
- While fluorescent and HID lighting technologies are mature, LED lighting technology is developing quickly. The information and conclusions regarding LED lighting in this study will be out of date within 12 months following publication.

2 INTRODUCTION

2.0 Acknowledgments

This study was performed by GLHN Architects & Engineers, Inc. for the National Institute of Building Sciences and the Department of Veterans Affairs, Office of Construction and Facilities Management.

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2.1 Study Scope

The goal of this study was to calculate, examine, and compare the luminous performance and cost of LED and conventional (linear fluorescent, compact fluorescent, and high-intensity discharge) lighting systems in the context of the most common luminaire uses in the VA healthcare environment.

2.2 Study Conditions

The luminaire types examined in this study account for the majority of the luminaires used in VA medical facilities:

- Troffers
- Downlight Cans
- Exterior Egress Lights
- High-Bays
- Parking Lot Pole Lights
- Parking Garage Lights

These luminaire types, with LED and conventional sources, were applied in the spaces that account for the majority of the space program in VA medical facilities:

- Offices
- Exam Rooms
- Procedure Rooms
- Corridors
- Exterior Egress
- Reception Areas, Waiting Rooms, and Television Lounges
- Nurse stations
- Warehouses
- Energy Centers
- Parking Lots and Garages

This study uses a common set of calculation assumptions for lamp color temperature, length of luminaire 'on' time, energy costs, etc., in order that the most realistic comparison is obtained. For example, it was found that the underlying assumptions commonly used by luminaire manufacturers to obtain rated lamp life were chosen to most advantageously present the lighting technology used, i.e. 3 hours of 'on' time per start for linear fluorescent, and 10 hours of 'on' time per start for HID, and 12 hours of on time per start for LED. As much as possible, this study uses a normalized set of assumptions.

The luminaires selected for this study are typical application products for use in typical environments.

Each space was lit in calculation, using manufacturer's photometry, to the light levels specified in the VA Electrical Design Manual. Sufficient LED and conventional luminaires were used to achieve the specified light level. The luminaire counts thus obtained were carried to the life cycle cost comparison, where the luminaire first cost, cost of energy, and cost of maintenance were compared over a 15-year life cycle.

The final goal of this study was to make recommendations on the most advantageous lighting technologies for VA use.

3 METHOD OF APPROACH

3.0 Selection of Spaces

This study compares LED and conventional lighting technologies in the following spaces:

- Offices
- Exam Rooms
- Procedure Rooms
- Corridors
- Exterior Egress
- Reception Areas, Waiting Rooms, and Television Lounges
- Nurse stations
- Warehouses
- Energy Centers
- Parking Lots and Garages

These spaces are typically illuminated with what, on a set of construction documents, are termed 'commodity' luminaires for general illumination: those that account for the majority of the luminaires used, and therefore those that account for the largest share of the lighting budget on a construction project. These spaces account for much of the floor plate area in a wide cross-section of VA facilities: hospitals, ambulatory care centers, and administrative, support, utility, and parking areas.

Spaces that use more specialized luminaire applications – for example, patient bed wards, operating suites, radiology, etc. – are not examined in this study.

The results obtained for the spaces selected for this study can easily be extended to similar spaces with similar luminous criteria. There are many additional VA spaces, for example, that use the ubiquitous ceiling troffer luminaire: laboratories, pharmacies, SPD, research, dietetics, etc.

3.1 Selection of Luminaire Manufacturers

The luminaires used in this study's calculations were chosen with the following criteria:

- Produced by manufacturers with a minimum of three years lighting manufacturing experience.

- Produced by manufacturers having an above average reputation for manufacturing quality, product reliability, and ongoing research and development.
- Compliance with the Buy American Act (BAA).
- Conformance with national and international standards for light sources.

3.2 Lighting Calculations Assumptions

The study uses a common set of assumptions to perform lighting calculations.

- **Light Levels:** As required by the VA Electrical Design Manual.
- **Photometry:** Relative Photometry IES files are acceptable for conventional sources because they have standardized lamps. For LED sources, Absolute Photometry IES files are necessary because of LED lighting systems variability, per IESNA LM-79.
- **Light Loss Factors:** Includes dirt depreciation, lumen depreciation, and ballast factor. Refer to Section 5, Results for the light loss factors used.
- **Color Rendering Index (CRI):** All sources used in this have CRI values between 80 and 90, assuring appropriate color quality of light. The current VA standard is for sources with a CRI >70.
- **Color Temperature:** Sources with a color temperature of 4000K were used for both interior and exterior applications. Note that LEDs are most efficient at 5000-6000K; however this is not a desirable color temperature.
- **Luminaire 'On' Time per Start:** 12 hours per start was used for fluorescent and LED sources, and 10 hours per start for HID sources, per manufacturers published data.

Note that T5HO lamps were not evaluated despite their high lumen output and performance in high bay applications. T5HO lamps are not listed as an acceptable lamp in the VA Master Electrical Specifications (Section 26 51 00) or the VA Electrical Design Manual.

3.3 Life Cycle Calculation Assumptions

The following life cycle costing assumptions were used:

- **Energy Cost, Escalation, and Discount Rate:** Refer to the Life Cycle Analysis.
- **Time:** 15 years was used for the useful lifespan of a luminaire. This encompasses the lifecycle of one LED and driver system, and is a common assumed lifespan of a building space before renovation that will affect the lighting system.

4 DEFINITIONS & BACKGROUND

4.0 Definitions

Absolute Photometry: Involves luminous measurements made with detectors calibrated to provide direct assessment in absolute units. Used for conventional lamps and luminaires with solid-state light sources (in which the source and luminaire are inseparable), produces light intensity values for a given luminaire under specific conditions (time, location, temperature, etc.) See *Relative Photometry*.

Color Rendering Index (CRI): Expressed as a rating from 0 to 100 on the Color Rendering Index, the CRI describes how a light source makes the color of an object appear to human eyes. The higher the CRI rating, the better its color rendering ability. The International Commission on Illumination (CIE) does not recommend its use with white light LEDs. A new metric for white light LEDs is under development.

Color Temperature: A specification of the apparent color of a light source relative to the color appearance of an ideal incandescent source held at a particular temperature and measured on the Kelvin (K) scale. The color temperature of a light source is a general indication of the warmth or coolness of its appearance.

Driver: The power supply that provides constant current and constant voltage to the light-emitting diode in order to maintain a constant luminous output.

Fluorescent: A gas-discharge lamp that uses electricity to produce visible light by exciting mercury vapor within a phosphor-lined tube.

High-Intensity Discharge: A gas-discharge lamp that uses electricity to produce visible light by an electric arc inside a tube filled with gas and metal salts.

Light-Emitting Diode (LED): Diodes that emit visible light when electricity is applied.

Luminous Efficacy: A measure of light produced per unit of power, expressed in lumens/watt.

Relative Photometry: Provides an intensity distribution on a per unit basis. The basis is an assumed total lumen output of the lamp or lamps usually used in the luminaire. Equivalent luminous intensities are determined from measurements made with detectors that are not absolutely calibrated. This system relies on standardized light sources and is not appropriate for LEDs.

4.1 Background

This section contains additional technical material of interest in the comparison between LED and conventional lighting technologies.

Compliance with Buy American Act: The cutsheets for luminaires used in this study usually do not indicate country of manufacturing origin. The manufacturers are reputable and typically US-based.

Dimming: Until national standards are in place to measure dimming performance, dimming LEDs is generally not recommended. However, dimming technology for fluorescents sources is more mature.

Electromagnetic and Radio Frequency Interference (EMI/RFI): In general, LED drivers and controls and conventional ballasts produced by reputable manufacturers will exhibit similar levels of EMI/RFI. These levels are typically acceptable in most power distribution environments.

Environmental Impact: Fluorescent and HID sources contain mercury, and are generally classified as hazardous waste. Although LED lighting systems typically contain no mercury, they have their own environmental impacts, which are governed by the 2006 RoHS directive in the European Economic Community, which restricts six hazardous substances in the manufacture of electronic equipment. It is anticipated that RoHS compliance will become an increasingly important criterion for specifying LED lighting.

Organic LED (OLED): Organic LEDs are an emerging technology, for which standard luminaires do not yet exist. OLED sources are physically flexible and very thin, but luminous efficacies are currently much lower than silicon-based LEDs. This study does not consider OLED technology.

Performance Testing for LED Technology: The US Department of Energy is a recommended resource for the evaluation of LED lighting technology, under the CALiPER program (<http://www1.eere.energy.gov/buildings/ssl/index.html>).

Photometry: Conventional lighting products are tested using relative photometry, where actual test data is adjusted to the light output of a standardized lamp. This is not possible with LED products, so absolute photometry is used, reflecting actual light from the test source without adjustment. The calculations performed in this study use IES files with absolute photometry for all LED products in accordance with IESNA LM-79 recommendations.

Warranty: LED luminaires typically carry a five year warranty. Conventional lighting system warranties vary, with one year for the fixtures and three to five years for the lamp & ballast combination being typical.

5 RESULTS

5.0 Lighting Calculations & Drawings

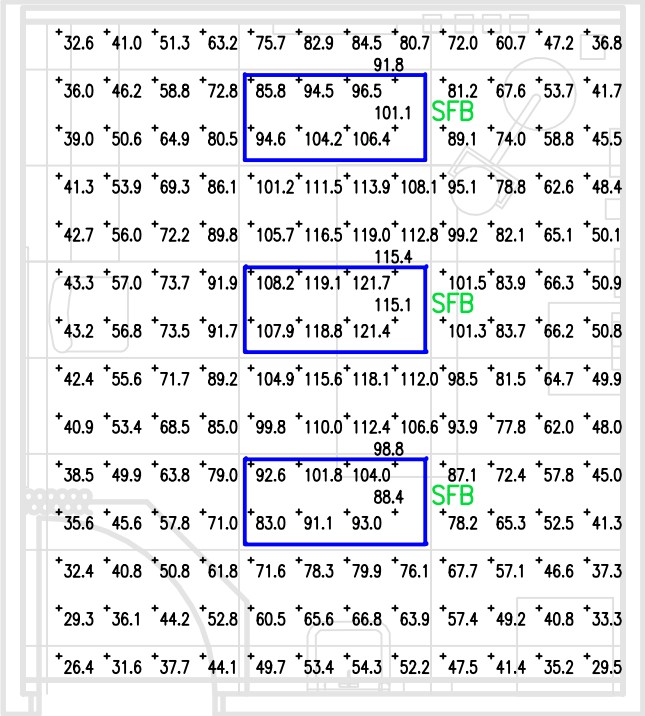
The lighting calculations that follow were performed with Lithonia Visual.

The input data and assumptions, and the calculation results, are on each drawing.

The result of the calculations is the quantity of luminaires necessary to achieve similar luminous performance in a given space with a specified light level and uniformity. The quantity of luminaires is a data input for the life cycle cost analysis.

LUMINAIRE SCHEDULE (FLUORESCENT)									
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS	
SFB	3	2SP8 3 32 A12125 GEB10RS LP841	SP8 SPECIFICATION PREMIUM T8 TROFFER 2'X4' 3 LAMP T8 #A12125 LENS ELEC	(3) 32W T8 LINEAR FLUORESCENT	2SP8_332_A121 25_1_3_ADDE. IES	2850	.75	88.0	

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
PROCEDURE ROOM	+	71.2 FC	121.7 FC	26.4 FC	4.6:1	2.7:1

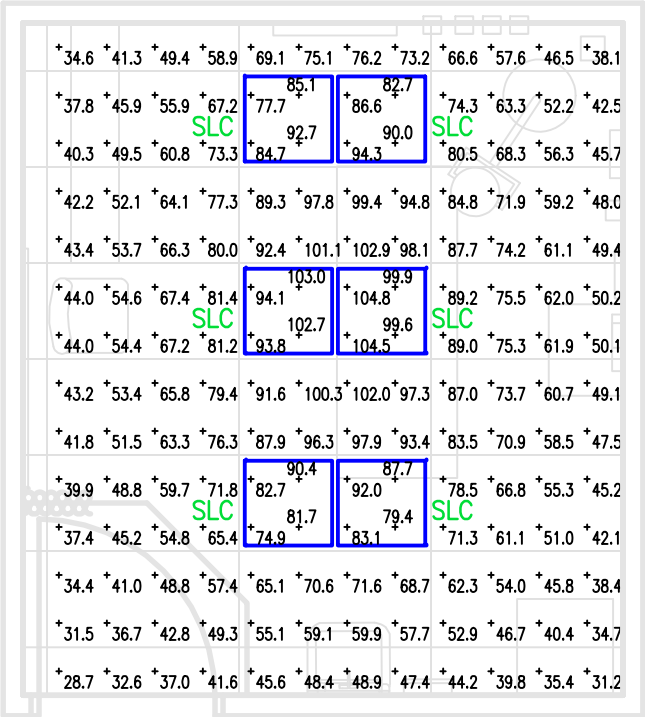


PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

NOTES (FLUORESCENT):
 ROOM SQUARE FOOTAGE – 175
 TOTAL WATTS – 264
 VA EDM LIGHTING LEVEL (FC) –100
 CALC. LIGHTING LEVEL (FC) – 71.2
 ASHRAE 90.1 LTG. POWER DEN. – 1.5
 CALC. LTG. POWER DENSITY – 1.5
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 36"

LUMINAIRE SCHEDULE (LED)									
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS	
SLC	6	1200 DR W 4000 MV 050 SS IN 3500 AA	2X2 RECESSED TROFFER WHITE INTERIOR AND FROSTED FLAT PLASTIC LENS.	320 LEDS. LUMINAIRE OUTPUT: 3488 LMS	IES-1200-4000 K.IES	ABSOLUTE	0.75	50.5	

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
PROCEDURE ROOM	+	65.4 FC	104.8 FC	28.7 FC	3.7:1	2.3:1



PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

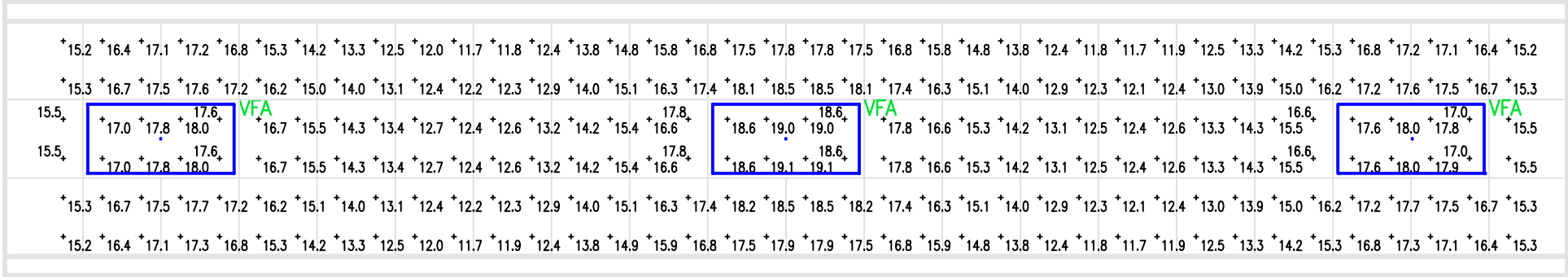
NOTES (LED):
 ROOM SQUARE FOOTAGE – 175
 TOTAL WATTS – 303
 VA EDM LIGHTING LEVEL (FC) –100
 CALC. LIGHTING LEVEL (FC) – 65.4
 ASHRAE 90.1 LTG. POWER DEN. – 1.5
 CALC. LTG. POWER DENSITY – 1.7
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 36"

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VFA	3	2RT8S 2 32 MVOLT GEB10RS LP841	VOLUMETRIC LIGHTING, RT5, 2X4, 2 LAMP	(2) 32W T8 LINEAR FLUORESCENT, HORIZ. POS.	2RT8S_2_32.IES	2800	.75	54.8

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
CORRIDOR	+	15.3 FC	19.1 FC	11.7 FC	1.6:1	1.3:1

NOTES (FLUORESCENT):

ROOM SQUARE FOOTAGE - 240 REFLECTANCE: CEILING 80%
TOTAL WATTS - 164.4 WALLS 50%
VA EDM LIGHTING LEVEL (FC) -20 FLOOR 20%
CALC. LIGHTING LEVEL (FC) - 15.3 CALCULATION LEVEL - 0"
ASHRAE 90.1 LTG. POWER DEN. - 1.0
CALC. LTG. POWER DENSITY - 0.7



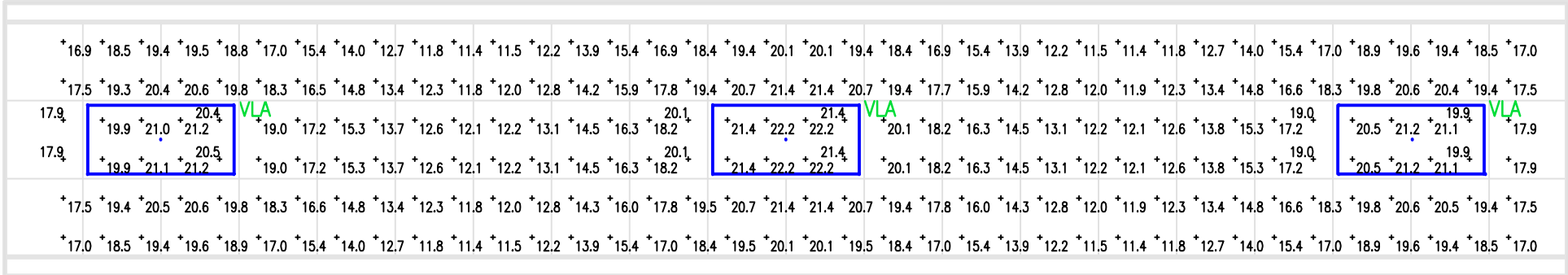
PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VLA	3	2RTLED 4600L D50 LP835	2RTLED 2X4, 4573 LUMEN, 50W, 3500K LAMP	(1) 50W LED UNIT, DOWNLIGHT POS.	2RTLED_4600L_D50_LP835.IES	ABSOLUTE	.75	50.0

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
CORRIDOR	+	16.7 FC	22.2 FC	11.4 FC	1.9:1	1.5:1

NOTES (LED):

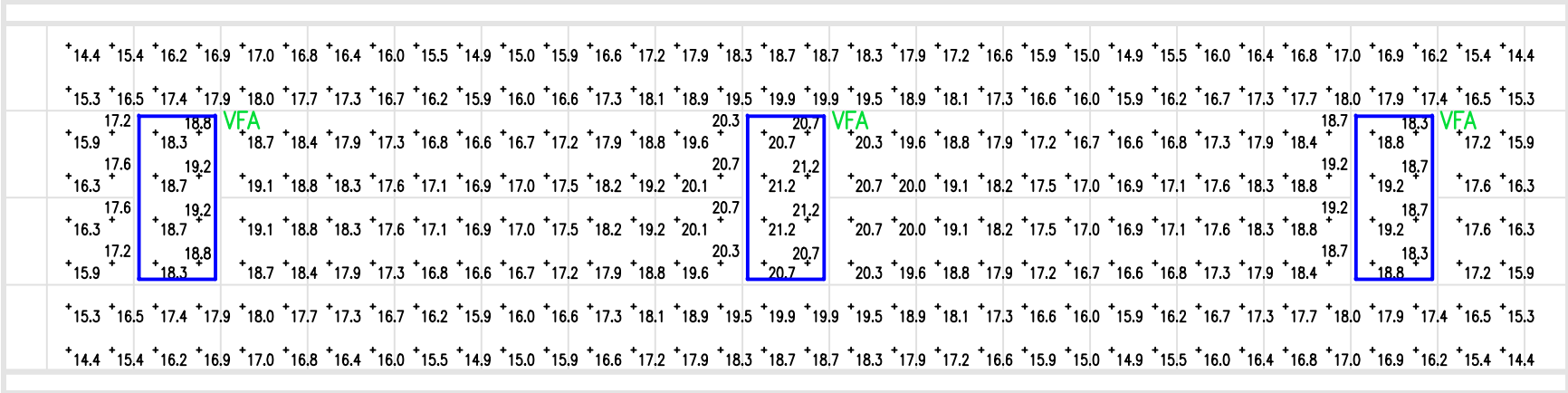
ROOM SQUARE FOOTAGE - 240 REFLECTANCE: CEILING 80%
TOTAL WATTS - 150 WALLS 50%
VA EDM LIGHTING LEVEL (FC) -20 FLOOR 20%
CALC. LIGHTING LEVEL (FC) - 16.7 CALCULATION LEVEL - 0"
ASHRAE 90.1 LTG. POWER DEN. - 1.0
CALC. LTG. POWER DENSITY - 0.6



PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VFA	3	2RT8S 2 32 MVOLT GEB10RS LP841	VOLUMETRIC LIGHTING, RT5, 2X4, 2 LAMP	(2) 32W T8 LINEAR FLUORESCENT, HORIZ. POS.	2RT8S_2_32.IES	2800	.75	54.8

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
CORRIDOR	+	17.6 FC	21.2 FC	14.4 FC	1.5:1	1.2:1



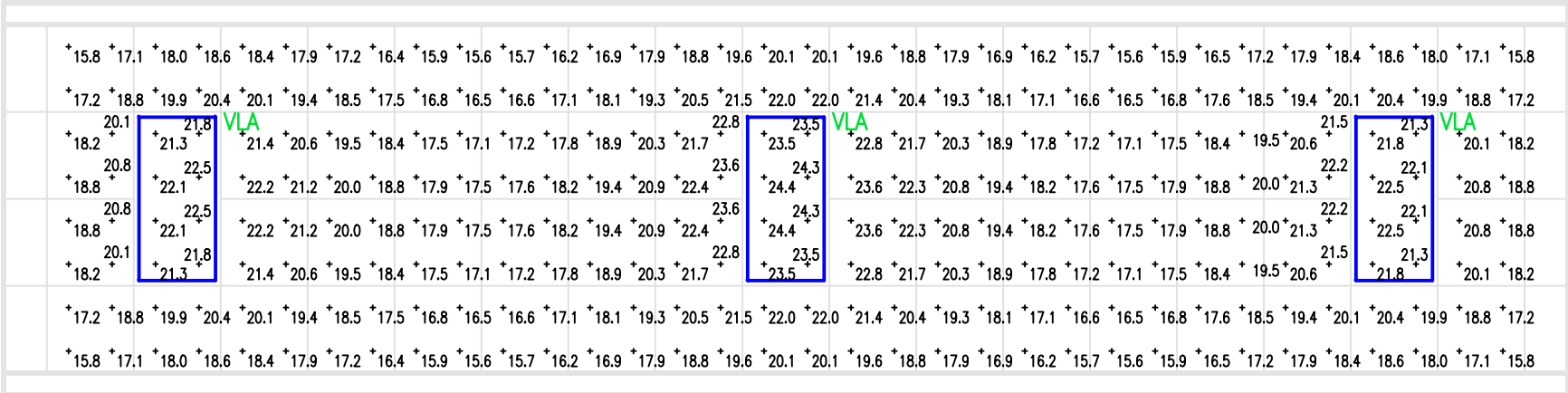
PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

NOTES (FLUORESCENT):

- ROOM SQUARE FOOTAGE – 288
 - TOTAL WATTS – 164.4
 - VA EDM LIGHTING LEVEL (FC) –20
 - CALC. LIGHTING LEVEL (FC) – 17.6
 - ASHRAE 90.1 LTG. POWER DEN. – 1.0
 - CALC. LTG. POWER DENSITY – 0.6
- REFLECTANCE: CEILING 80%
 - WALLS 50%
 - FLOOR 20%
 - CALCULATION LEVEL – 0"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VLA	3	2RTLED 4600L D50 LP835	2RTLED 2X4, 4573 LUMEN, 50W, 3500K LAMP	(1) 50W LED UNIT, DOWNLIGHT POS.	2RTLED_4600L_D50_LP835.IES	ABSOLUTE	.75	50.0

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
CORRIDOR	+	19.2 FC	24.4 FC	15.6 FC	1.6:1	1.2:1



PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

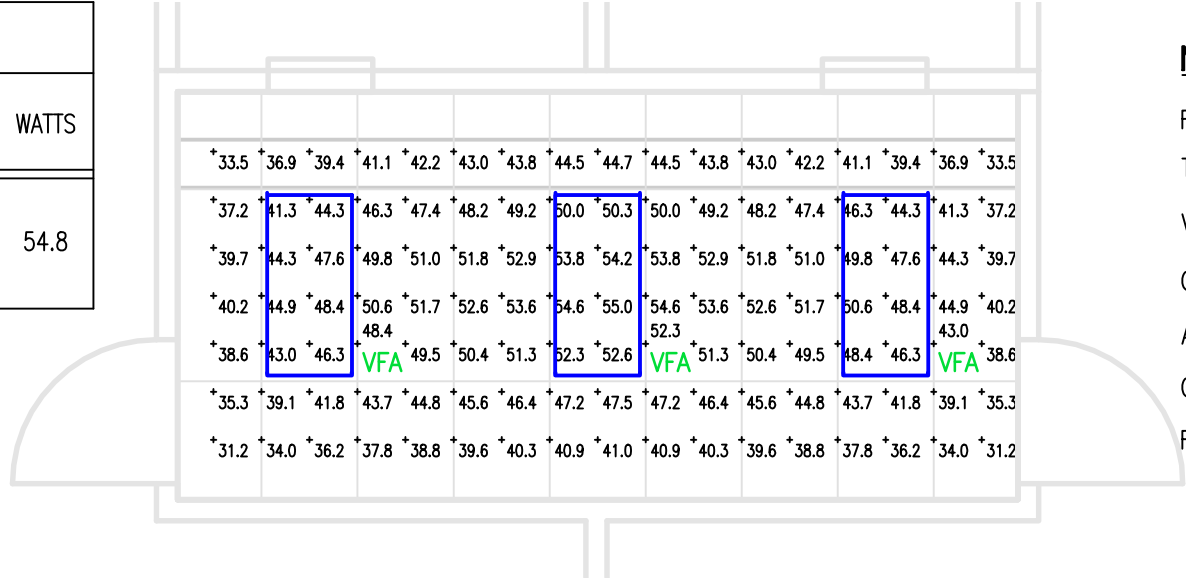
NOTES (LED):

- ROOM SQUARE FOOTAGE – 288
 - TOTAL WATTS – 150
 - VA EDM LIGHTING LEVEL (FC) –20
 - CALC. LIGHTING LEVEL (FC) – 19.2
 - ASHRAE 90.1 LTG. POWER DEN. – 1.0
 - CALC. LTG. POWER DENSITY – 0.5
- REFLECTANCE: CEILING 80%
 - WALLS 50%
 - FLOOR 20%
 - CALCULATION LEVEL – 0"

NURSE STATION	
LAMP SOURCE: FL/LED	DRAWING NO: 5.15

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VFA	3	2RT8S 2 32	VOLUMETRIC LIGHTING, RT5, 2X4, 2 LAMP	(2) 32W T8 LINEAR FLUORESCENT, HORIZ. POS.	2RT8S_2_32.IES	2800	.75	54.8

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
NURSE STATION	+	44.9 FC	55.0 FC	31.2 FC	1.8:1	1.4:1

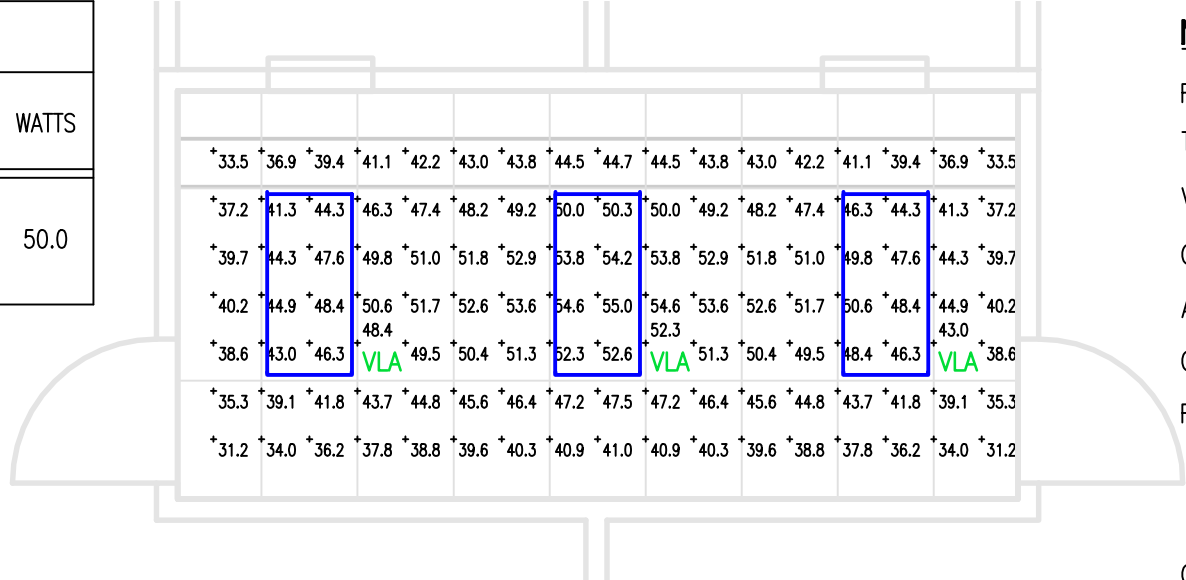


PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

NOTES (FLUORESCENT):
 ROOM SQUARE FOOTAGE – 150
 TOTAL WATTS – 164.4
 VA EDM LIGHTING LEVEL (FC) –50
 CALC. LIGHTING LEVEL (FC) – 44.9
 ASHRAE 90.1 LTG. POWER DEN. – 1.0
 CALC. LTG. POWER DENSITY – 1.1
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 36"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
VLA	3	2RTLED 4600L D50 LP835	2RTLED 2X4, 4573 LUMEN 50W, 3500K LAMP	(1) 50W LED UNIT, DOWNLIGHT POS.	2RTLED_4600L_D50_LP835.IES	ABSOLUTE	.75	50.0

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
NURSE STATION	+	48.6 FC	61.3 FC	32 FC	1.9:1	1.5:1



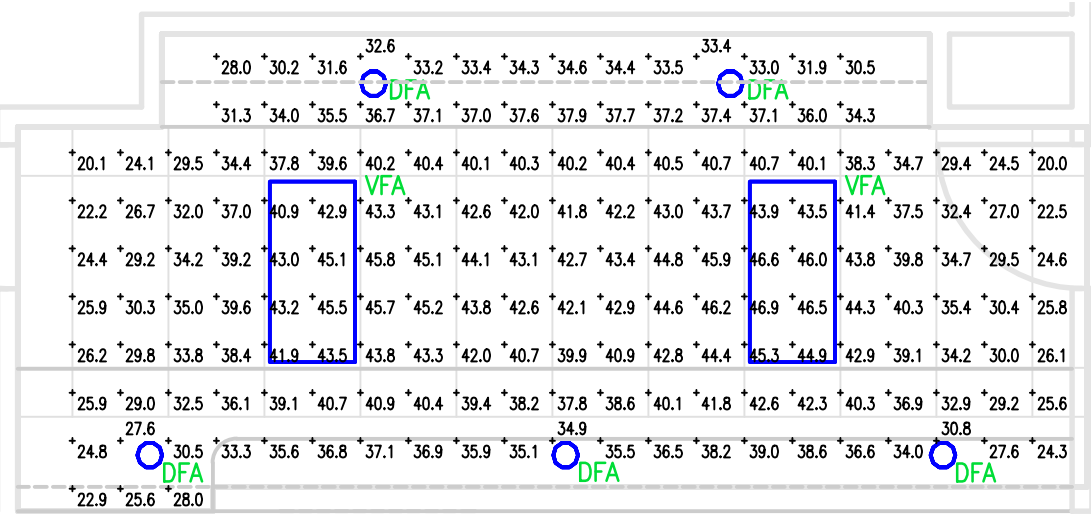
PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

NOTES (LED):
 ROOM SQUARE FOOTAGE – 150
 TOTAL WATTS – 150
 VA EDM LIGHTING LEVEL (FC) –50
 CALC. LIGHTING LEVEL (FC) – 48.6
 ASHRAE 90.1 LTG. POWER DEN. – 1.0
 CALC. LTG. POWER DENSITY – 1.0
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 36"

RECEPTION	
LAMP SOURCE: CFL/FL/LED	DRAWING NO: 5.16

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DFA	5	8031CCLW	CALCULITE 6" APERTURE CFL RECESSED DOWNLIGHT COMFORT CLEAR FINISH TRIM, HORZ. LAMP	(1) 26W PLT CFL LAMP	8031CCLW-26W.IES	1800	.67	28.6
VFA	2	2RT8S 2 32 MVOLT GEB10RS LP841	VOLUMETRIC LIGHTING, RT5, 2X4, 2 LAMP	(2) 32W T8 LINEAR FLUORESCENT, HORIZ. POS.	2RT8S_2_32.IES	2800	.75	54.8

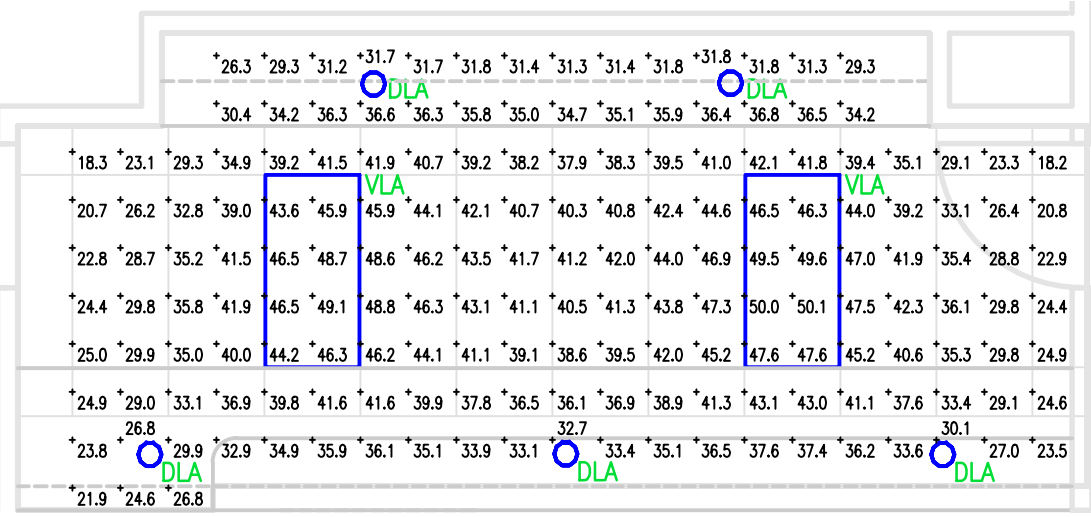
STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
RECEPTION	+	36.7 FC	46.9 FC	20.0 FC	2.3:1	1.8:1



NOTES (FLUORESCENT):
 ROOM SQUARE FOOTAGE – 200
 TOTAL WATTS – 252.6
 VA EDM LIGHTING LEVEL (FC) –30
 CALC. LIGHTING LEVEL (FC) – 36.7
 ASHRAE 90.1 LTG. POWER DEN. – 1.1
 CALC. LTG. POWER DENSITY – 1.3
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 30"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DLA	5	LF6LED 6LFLED5 40K	6" LITEFRAME LED DOWNLIGHT SEMI-DIFFUSE ALZAK REFLECTOR	PHILIPS FORTIMO DLM 1100	3333.IES	ABSOLUTE	.67	16.3
VLA	2	2RTLLED 4600L D50 LP835	2RTLLED 2X4, 4573 LUMEN, 50W, 3500K LAMP	(1) 50W LED UNIT, DOWNLIGHT POS.	2RTLLED_4600L_D50_LP835.IES	ABSOLUTE	.75	50.0

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
RECEPTION	+	36.7 FC	50.1 FC	18.2 FC	2.8:1	2.0:1

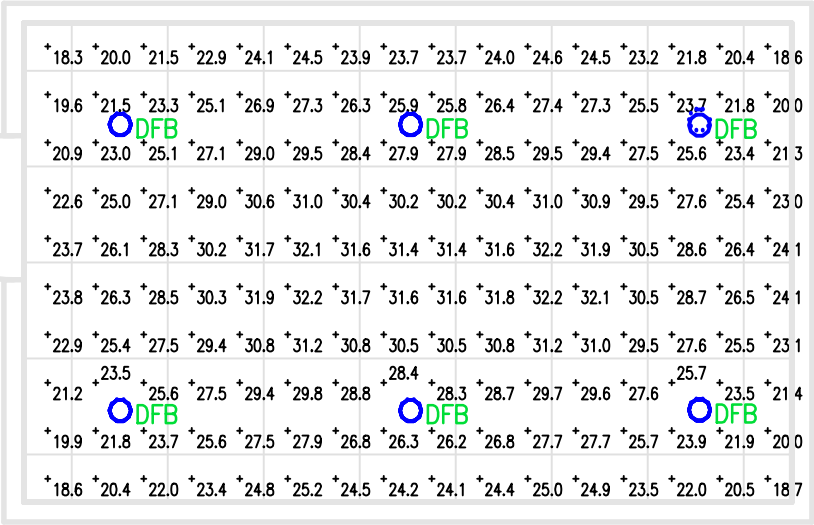


NOTES (LED):
 ROOM SQUARE FOOTAGE – 200
 TOTAL WATTS – 181.5
 VA EDM LIGHTING LEVEL (FC) –30
 CALC. LIGHTING LEVEL (FC) – 36.7
 ASHRAE 90.1 LTG. POWER DEN. – 1.1
 CALC. LTG. POWER DENSITY – 0.9
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 30"

WAITING ROOM	
LAMP SOURCE: CFL/LED	DRAWING NO: 5.17

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DFB	6	8031CCLW	CALCULITE 6" APERTURE CFL RECESSED DOWNLIGHT COMFORT CLEAR FINISH TRIM, HORZ. LAMP	(1) 32W PLT CFL LAMP, GX24Q-4 BASE	8031CCLW-32W. IES	2400	.67	36

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
WAITING ROOM	+	26.4 FC	32.2 FC	18.3 FC	1.8:1	1.4:1

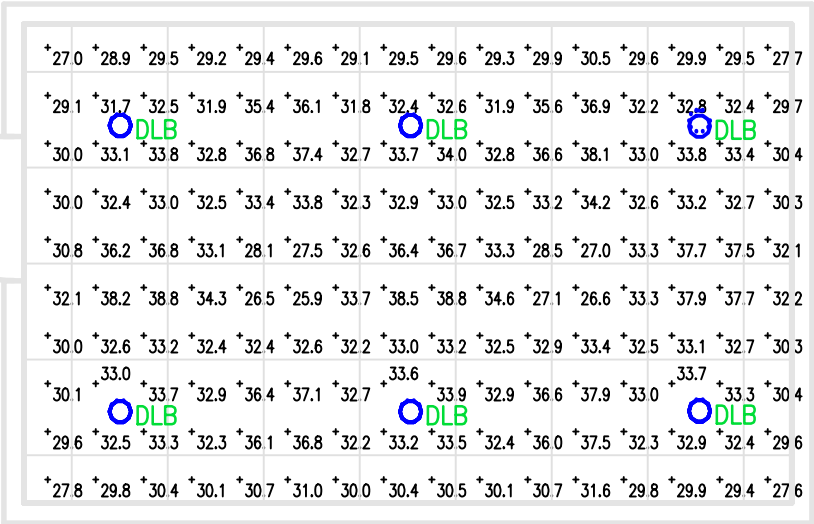


PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

NOTES (FLUORESCENT):
 ROOM SQUARE FOOTAGE – 160
 TOTAL WATTS – 216
 VA EDM LIGHTING LEVEL (FC) –30
 CALC. LIGHTING LEVEL (FC) – 36.7
 ASHRAE 90.1 LTG. POWER DEN. – 1.3
 CALC. LTG. POWER DENSITY – 1.4
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 30"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DLB	6	OM6LED27U-R6 LED40KMDCS	6" RECESSED LED DOWNLIGHT FORMED WHITE ENAMEL PLASTIC UPPER "MIXING CHAMBER", CLEAR GLASS ENCLOSURE WITH PHOSPHOR OVERLAY, SPUN SPECULAR ALUMINUM LOWER REFLECTOR.	22 BLUE LEDS	28993.IES	ABSOLUTE	.67	26.9

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
WAITING ROOM	+	32.5 FC	38.8 FC	25.9 FC	1.5:1	1.3:1

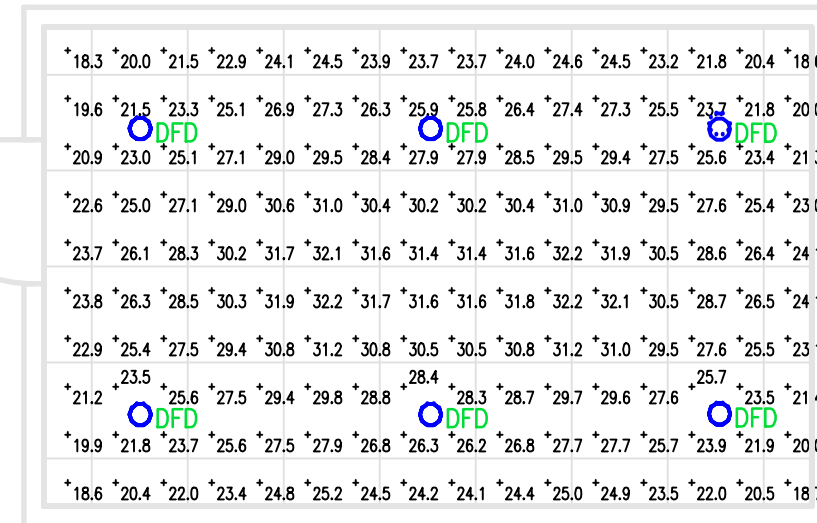


PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

NOTES (LED):
 ROOM SQUARE FOOTAGE – 160
 TOTAL WATTS – 161.4
 VA EDM LIGHTING LEVEL (FC) –30
 CALC. LIGHTING LEVEL (FC) – 32.5
 ASHRAE 90.1 LTG. POWER DEN. – 1.3
 CALC. LTG. POWER DENSITY – 1.0
 REFLECTANCE: CEILING 80%
 WALLS 50%
 FLOOR 20%
 CALCULATION LEVEL – 30"

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DFD	6	8031CCLW S6132BCU3	CALCULITE 6" APERTURE CFL RECESSED DOWNLIGHT COMFORT CLEAR FINISH TRIM, HORZ. LAMP	(1) 32W PLT CFL LAMP, GX24Q-4 BASE	8031CCLW-32W. IES	2400	.67	36

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
TV LOUNGE	+	26.4 FC	32.2 FC	18.3 FC	1.8:1	1.4:1



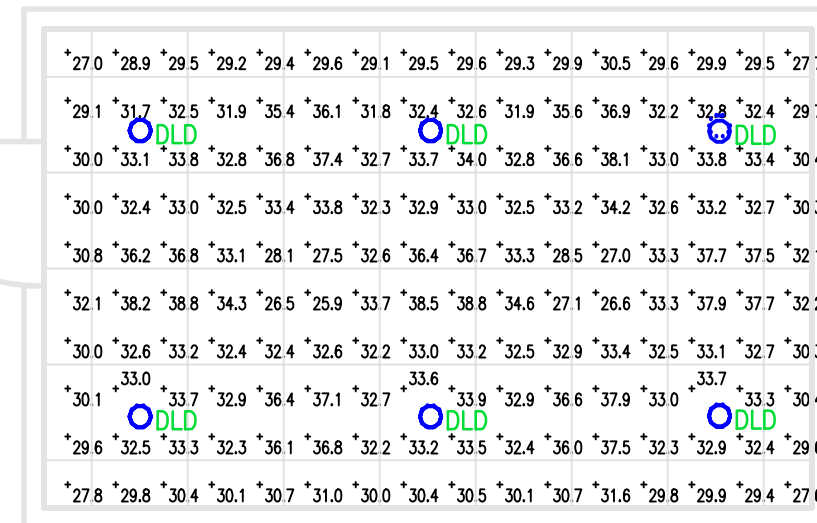
PLAN VIEW (FLUORESCENT)
SCALE: 1/4" = 1'-0"

NOTES (FLUORESCENT):

- ROOM SQUARE FOOTAGE – 160
- TOTAL WATTS – 216
- VA EDM LIGHTING LEVEL (FC) –30
- CALC. LIGHTING LEVEL (FC) – 36.7
- ASHRAE 90.1 LTG. POWER DEN. – 1.3
- CALC. LTG. POWER DENSITY – 1.4
- REFLECTANCE: CEILING 80%
- WALLS 50%
- FLOOR 20%
- CALCULATION LEVEL – 30"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
DLD	6	OM6LED27U-R6 LED40KMDCS	6" RECESSED LED DOWNLIGHT FORMED WHITE ENAMEL PLASTIC UPPER "MIXING CHAMBER", CLEAR GLASS ENCLOSURE WITH PHOSPHOR OVERLAY, SPUN SPECULAR ALUMINUM LOWER REFLECTOR.	22 BLUE LEDS	28993.IES	ABSOLUTE	.67	26.9

STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
TV LOUNGE	+	32.5 FC	38.8 FC	25.9 FC	1.5:1	1.3:1



PLAN VIEW (LED)
SCALE: 1/4" = 1'-0"

NOTES (LED):

- ROOM SQUARE FOOTAGE – 160
- TOTAL WATTS – 161.4
- VA EDM LIGHTING LEVEL (FC) –30
- CALC. LIGHTING LEVEL (FC) – 32.5
- ASHRAE 90.1 LTG. POWER DEN. – 1.3
- CALC. LTG. POWER DENSITY – 1.0
- REFLECTANCE: CEILING 80%
- WALLS 50%
- FLOOR 20%
- CALCULATION LEVEL – 30"

LUMINAIRE SCHEDULE (HID)

LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
HMA	12	TH 400MP A16GL PS(LEG 3, SC= 1.7)	STANDARD ALUMINUM OPTICAL, 400 MH W/ GLASS LENS	(1)400W CLEAR BT-37 PULSE START METAL HALIDE, VERT. BASE-UP POS.	TH_400M_A16G L_(LEG_3,_SC= _1.7).IES	42000	0.55	458

STATISTICS (HID)

DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
WAREHOUSE STORAGE	+	21.1 FC	25.1 FC	11.6 FC	2.2:1	1.8:1

NOTES (HID):

ROOM SQUARE FOOTAGE – 6847 REFLECTANCE: CEILING 80%
 TOTAL WATTS – 5496 WALLS 50%
 VA EDM LIGHTING LEVEL (FC) –20 FLOOR 20%
 CALC. LIGHTING LEVEL (FC) – 21.1 CALCULATION LEVEL – 30”
 ASHRAE 90.1 LTG. POWER DEN. – 0.9
 CALC. LTG. POWER DENSITY – 0.8

LUMINAIRE SCHEDULE (LED)

LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
HLA	15	HBL128GL70NW- UNV-MC-WT	PHILIPS DAY-BRITE LED HIBAY 4-POD (PRODUCTION MODEL) HIBAY MEDIUM DISTRIBUTION CLEAR GLASS LENS	LEDGINE 4X32 CREE XPG NW 4000K (LED#46/47/48/49) LUMINAIRE OUTPUT=22234 LM	29362.IES	ABSOLUTE	0.68	286.5

STATISTICS (LED)

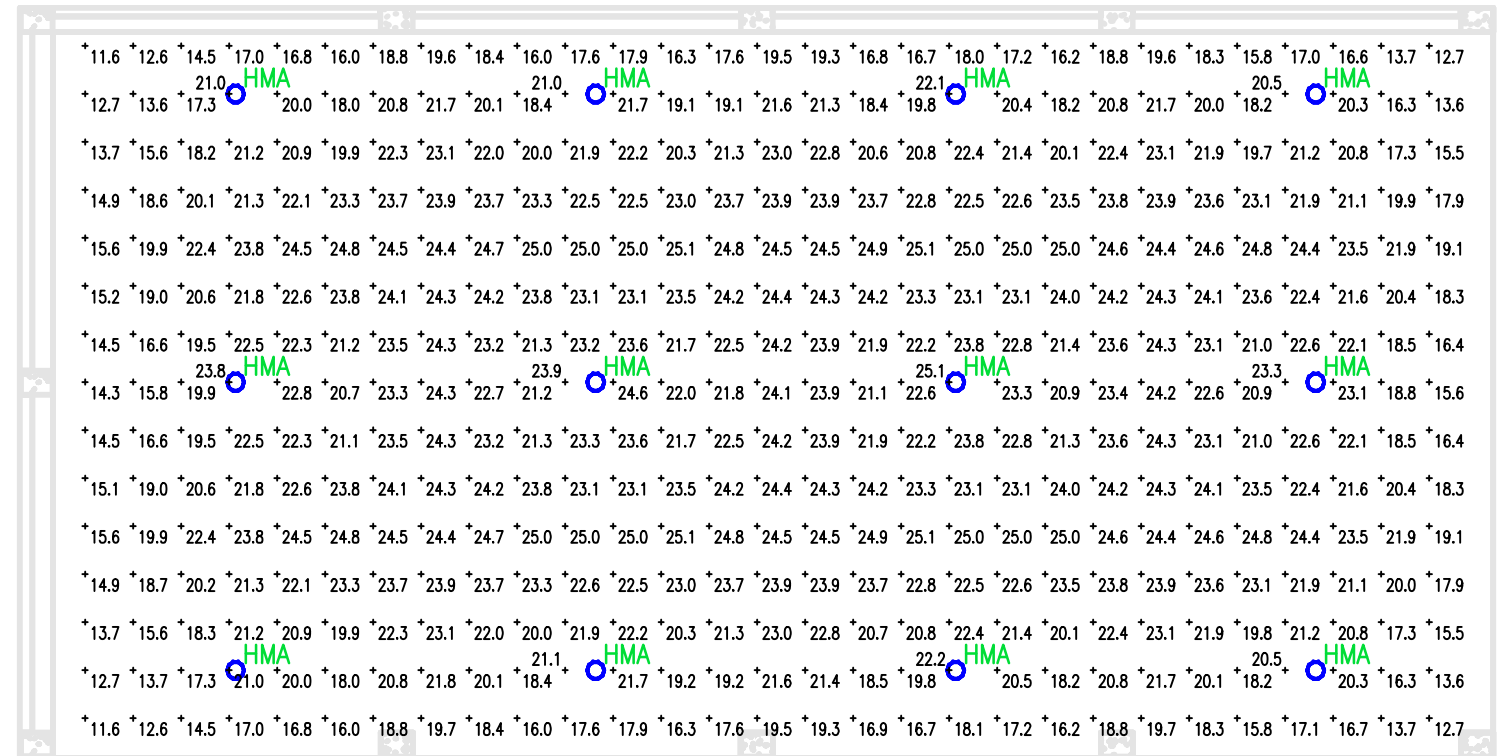
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
WAREHOUSE STORAGE	+	24.2 FC	28.5 FC	19.3 FC	1.5:1	1.3:1

NOTES (LED):

ROOM SQUARE FOOTAGE – 6847 REFLECTANCE: CEILING 80%
 TOTAL WATTS – 4298 WALLS 50%
 VA EDM LIGHTING LEVEL (FC) –20 FLOOR 20%
 CALC. LIGHTING LEVEL (FC) – 24.2 CALCULATION LEVEL – 30”
 ASHRAE 90.1 LTG. POWER DEN. – 0.9
 CALC. LTG. POWER DENSITY – 0.6

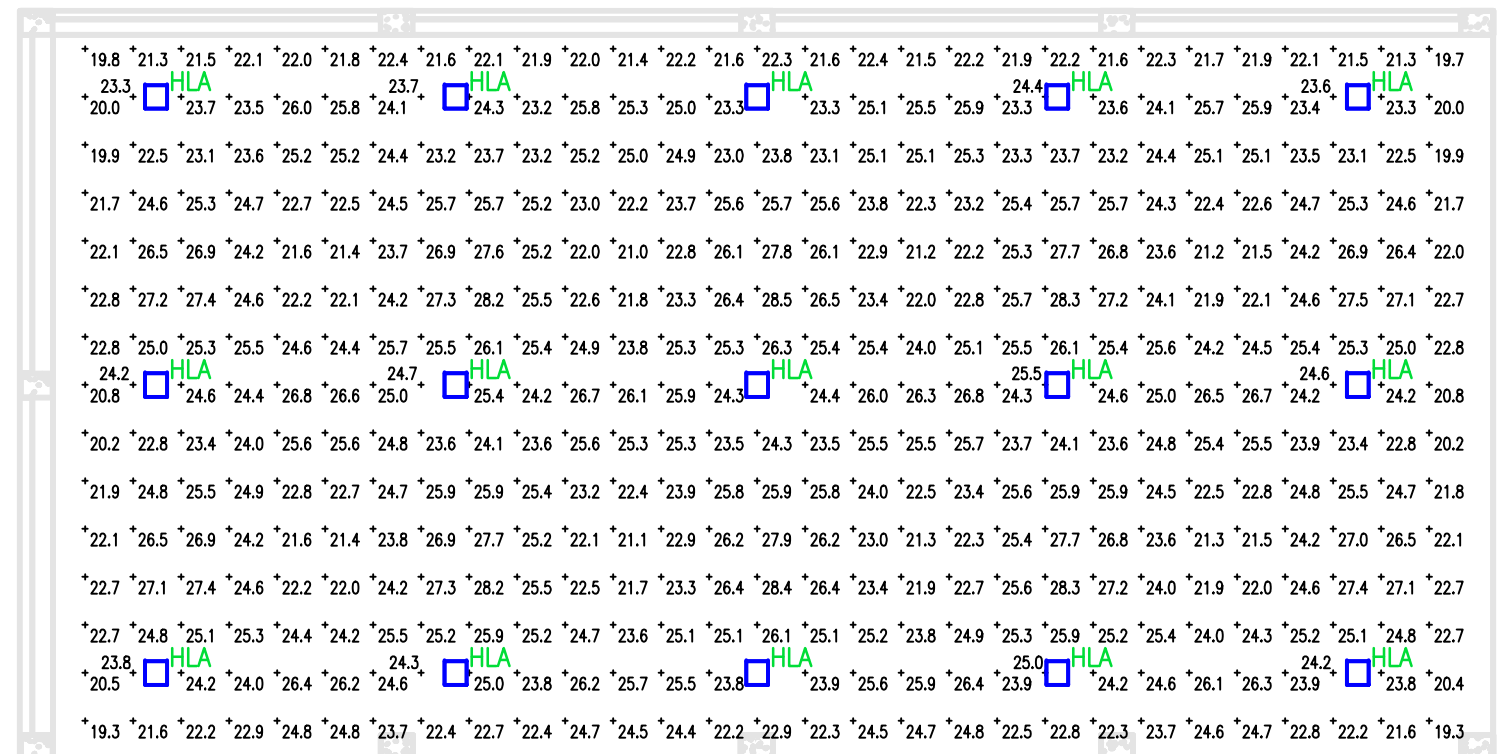
WAREHOUSE STORAGE

LAMP SOURCE: HID/LED	DRAWING NO: 5.19
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PLAN VIEW (HID)

SCALE: 1/16" = 1'-0"



PLAN VIEW (LED)

SCALE: 1/16" = 1'-0"

LED & Conventional Lighting
Systems Comparison Study

LUMINAIRE SCHEDULE (HID)

LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
HMA	15	TH 400MP A16GL PS (LEG 3, SC= 1.7)	STANDARD ALUMINUM OPTICAL, 400 MH W/ GLASS LENS	(1)400W CLEAR BT-37 PULSE START METAL HALIDE, VERT. BASE-UP POS.	TH_400M_A16G L_(LEG_3,_SC= _1.7).IES	42000	0.55	458

STATISTICS (HID)

DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
ENERGY CENTER	+	27.6 FC	37.9 FC	13.2 FC	2.9:1	2.1:1

NOTES (HID):

ROOM SQUARE FOOTAGE – 6847 REFLECTANCE: CEILING 80%
 TOTAL WATTS – 6870 WALLS 50%
 VA EDM LIGHTING LEVEL (FC) –30 FLOOR 20%
 CALC. LIGHTING LEVEL (FC) – 27.6 CALCULATION LEVEL – 30”
 ASHRAE 90.1 LTG. POWER DEN. – 1.5
 CALC. LTG. POWER DENSITY – 1.0

LUMINAIRE SCHEDULE (LED)

LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
HLA	18	HBL128GL70NW- UNV-MC-WT	PHILIPS DAY-BRITE LED HIBAY 4-POD (PRODUCTION MODEL) HIBAY MEDIUM DISTRIBUTION CLEAR GLASS LENS	LEDGINE 4X32 CREE XPG NW 4000K (LED#46/47/48/49) LUMINAIRE OUTPUT=22234 LM	29362.IES	ABSOLUTE	0.68	286.5

STATISTICS (LED)

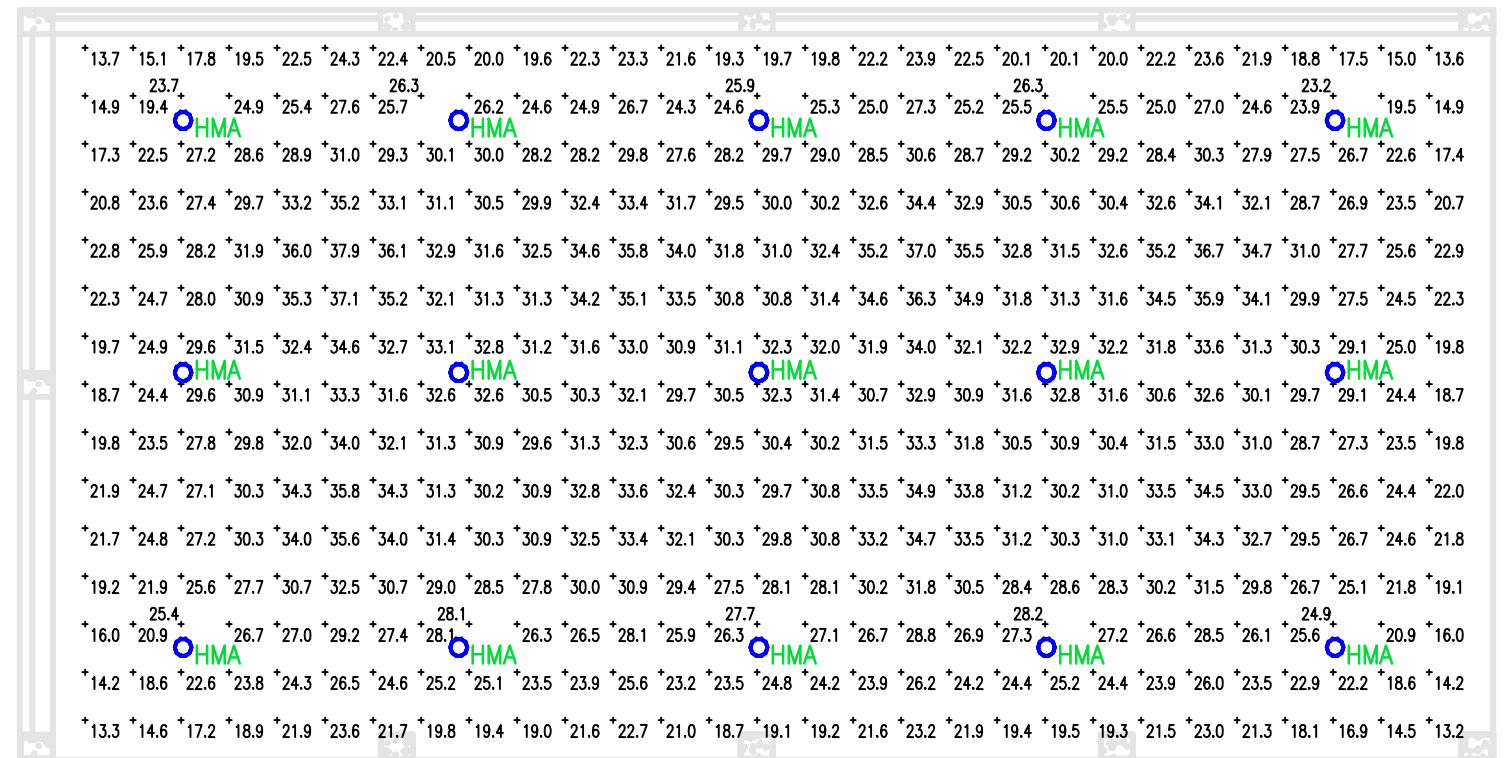
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
ENERGY CENTER	+	29.3 FC	34.3 FC	20.3 FC	1.7:1	1.4:1

NOTES (LED):

ROOM SQUARE FOOTAGE – 6847 REFLECTANCE: CEILING 80%
 TOTAL WATTS – 5157 WALLS 50%
 VA EDM LIGHTING LEVEL (FC) –30 FLOOR 20%
 CALC. LIGHTING LEVEL (FC) – 29.3 CALCULATION LEVEL – 30”
 ASHRAE 90.1 LTG. POWER DEN. – 1.5
 CALC. LTG. POWER DENSITY – 0.8

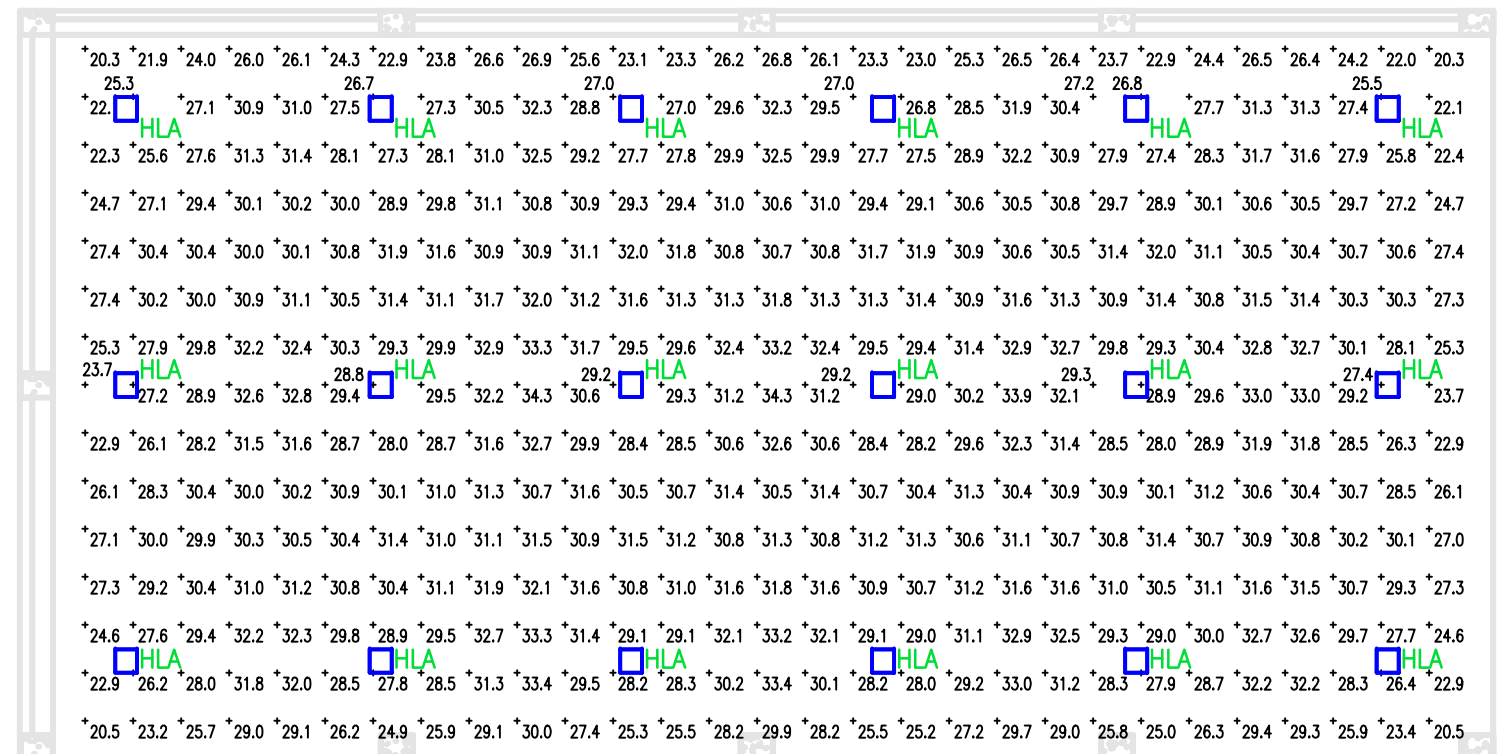
ENERGY CENTER

LAMP SOURCE: **FL/LED** DRAWING NO: **5.110**



PLAN VIEW (HID)

SCALE: 1/16" = 1'-0"



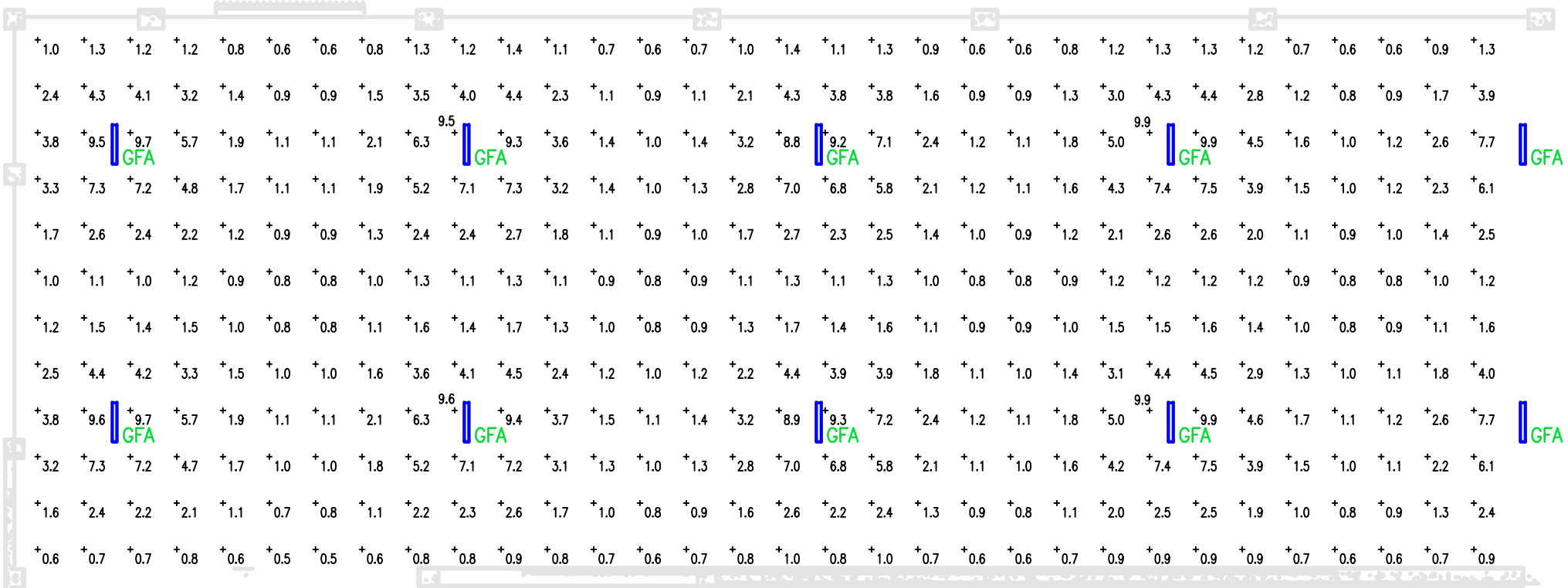
PLAN VIEW (LED)

SCALE: 1/16" = 1'-0"

LED & Conventional Lighting
Systems Comparison Study

LUMINAIRE SCHEDULE (FLUORESCENT)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
GFA	10	FEM4 2 32 BMPCL MVOLT GEB10IS LP841	4' ENCLOSED & GASKETED LUMINAIRE, W/MIRO 4 SPECULAR BALLAST COVER AND POLYCARBONATE LENS	(2) 32W SYLVANIA LAMP	FEM4_2_32_X3 2_BMPCL.IES	2950	0.67	55.2

STATISTICS (FLUORESCENT)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
TYPICAL 5 BAY PARKING AREA	+	2.4 FC	9.9 FC	0.5 FC	19.8:1	4.8:1

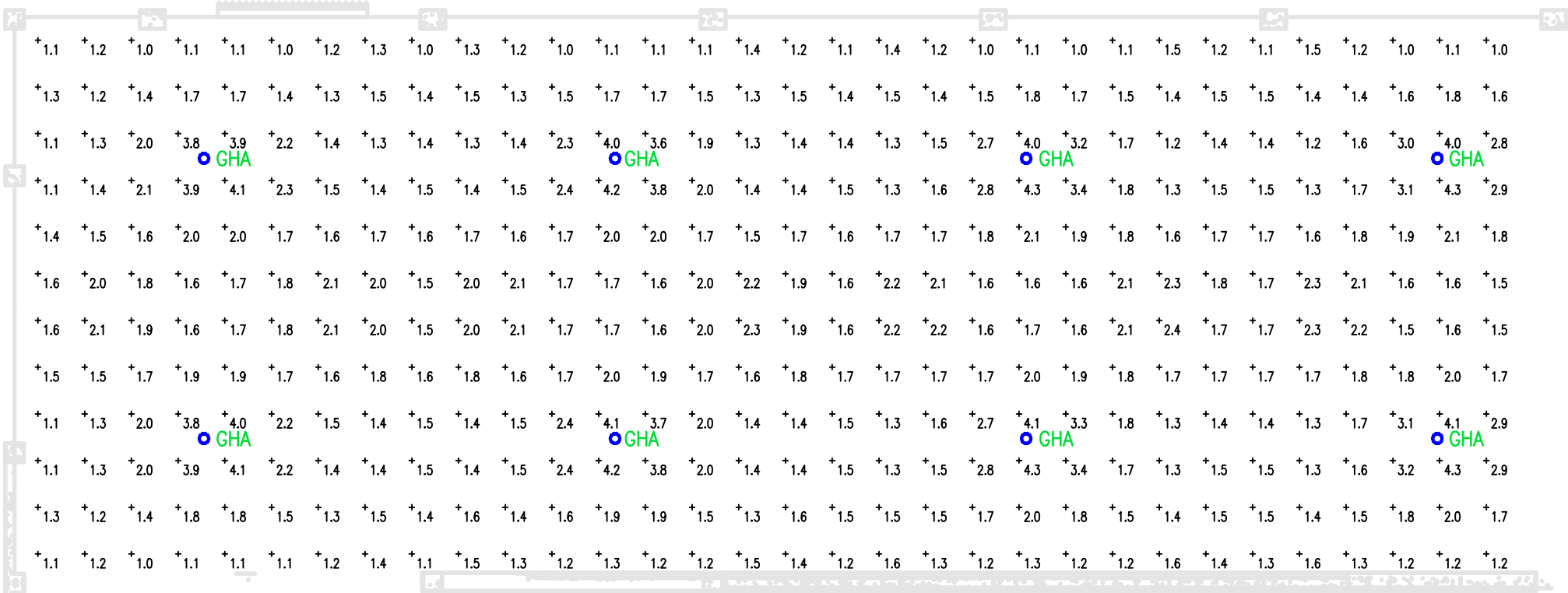


PLAN VIEW (FLUORESCENT)
SCALE: 1/16" = 1'-0"

- NOTES (FLUORESCENT):**
- ROOM SQUARE FOOTAGE – 9345
 - TOTAL WATTS – 552
 - VA EDM LIGHTING LEVEL (FC) – 2
 - CALC. LIGHTING LEVEL (FC) – 2.4
 - ASHRAE 90.1 LTG. POWER DEN. – 0.2
 - CALC. LTG. POWER DENSITY – 0.1
 - REFLECTANCE: CEILING 80%
 - WALLS 50%
 - FLOOR 20%
 - CALCULATION LEVEL – 0"

LUMINAIRE SCHEDULE (HID)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
GHA	9	PGR 70MHC MVOLT HEB LPI	PARKING GARAGE LUMINAIRE WITH RECTANGULAR, CUTOFF DISTRIBUTION	(1) 70W CLEAR ED-17 CERAMIC METAL HALIDE, VERT. BASE-UP POS.	PGR_100M.IES	5900	0.63	79

STATISTICS (HID)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
TYPICAL 5 BAY PARKING AREA	+	1.8 FC	4.3 FC	1.0 FC	4.3:1	1.8:1

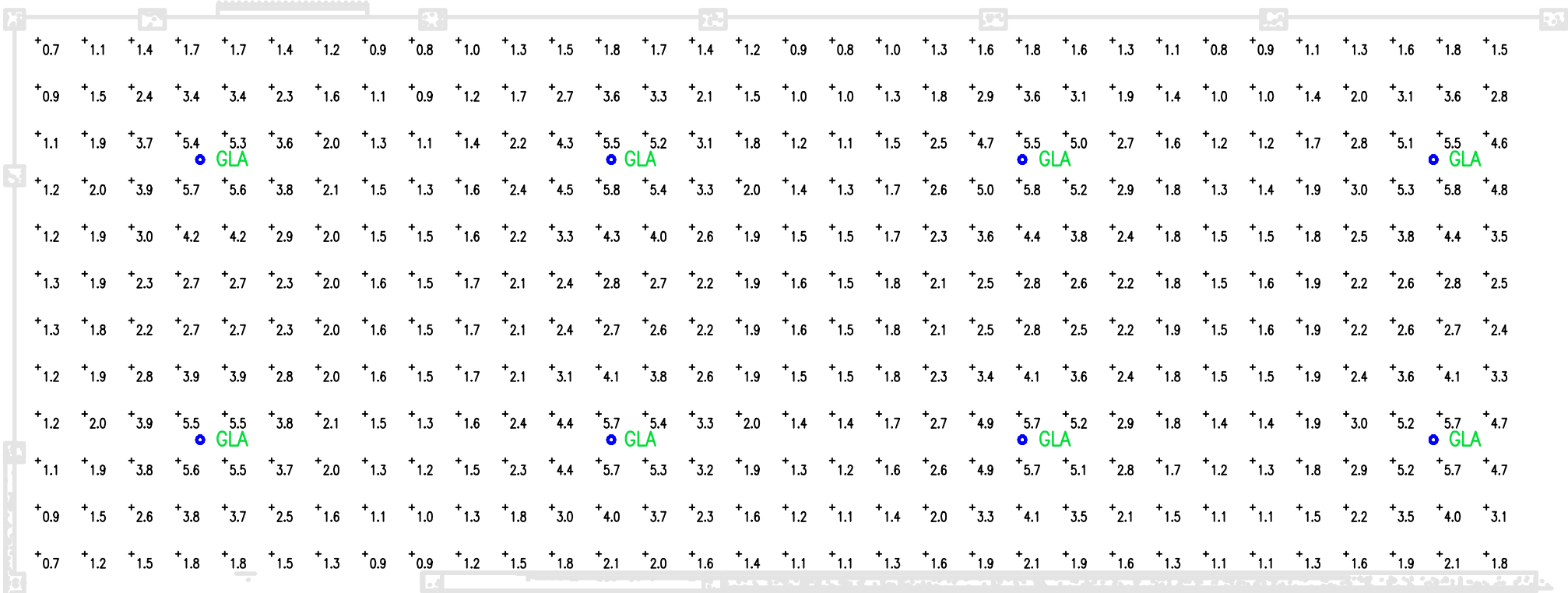


PLAN VIEW (HID)
SCALE: 1/16" = 1'-0"

- NOTES (HID):**
- ROOM SQUARE FOOTAGE – 9345
 - TOTAL WATTS – 711
 - VA EDM LIGHTING LEVEL (FC) – 2
 - CALC. LIGHTING LEVEL (FC) – 1.8
 - ASHRAE 90.1 LTG. POWER DEN. – 0.2
 - CALC. LTG. POWER DENSITY – 0.1
 - REFLECTANCE: CEILING 80%
 - WALLS 50%
 - FLOOR 20%
 - CALCULATION LEVEL – 0"

LUMINAIRE SCHEDULE (LED)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
GLA	8	QLP-32G2-700-S-UNV-EZ-TSA	QUALITY LED PARKING GARAGE LIGHT	CREE XPG ON 32 LEDGINE BOARD	QLP-32G2-700-S.IES	ABSOLUTE	0.69	72.4

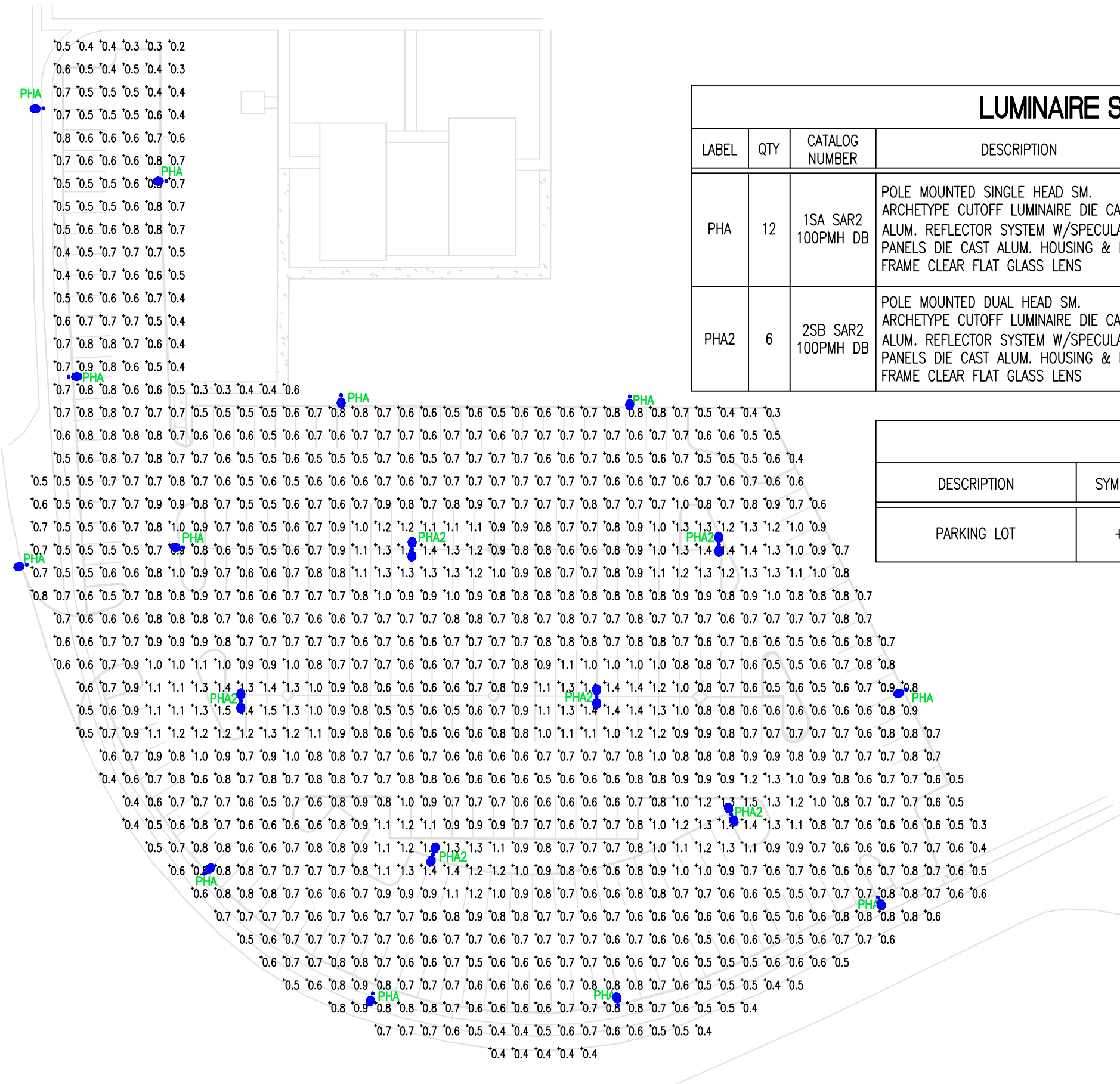
STATISTICS (LED)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
TYPICAL 5 BAY PARKING AREA	+	2.4 FC	5.8 FC	0.7 FC	8.3:1	3.4:1



PLAN VIEW (LED)
SCALE: 1/16" = 1'-0"

- NOTES (LED):**
- ROOM SQUARE FOOTAGE – 9345
 - TOTAL WATTS – 579.2
 - VA EDM LIGHTING LEVEL (FC) – 2
 - CALC. LIGHTING LEVEL (FC) – 2.4
 - ASHRAE 90.1 LTG. POWER DEN. – 0.2
 - CALC. LTG. POWER DENSITY – 0.1
 - REFLECTANCE: CEILING 80%
 - WALLS 50%
 - FLOOR 20%
 - CALCULATION LEVEL – 0"

PARKING LOT	
LAMP SOURCE: HID	DRAWING NO: 5.114

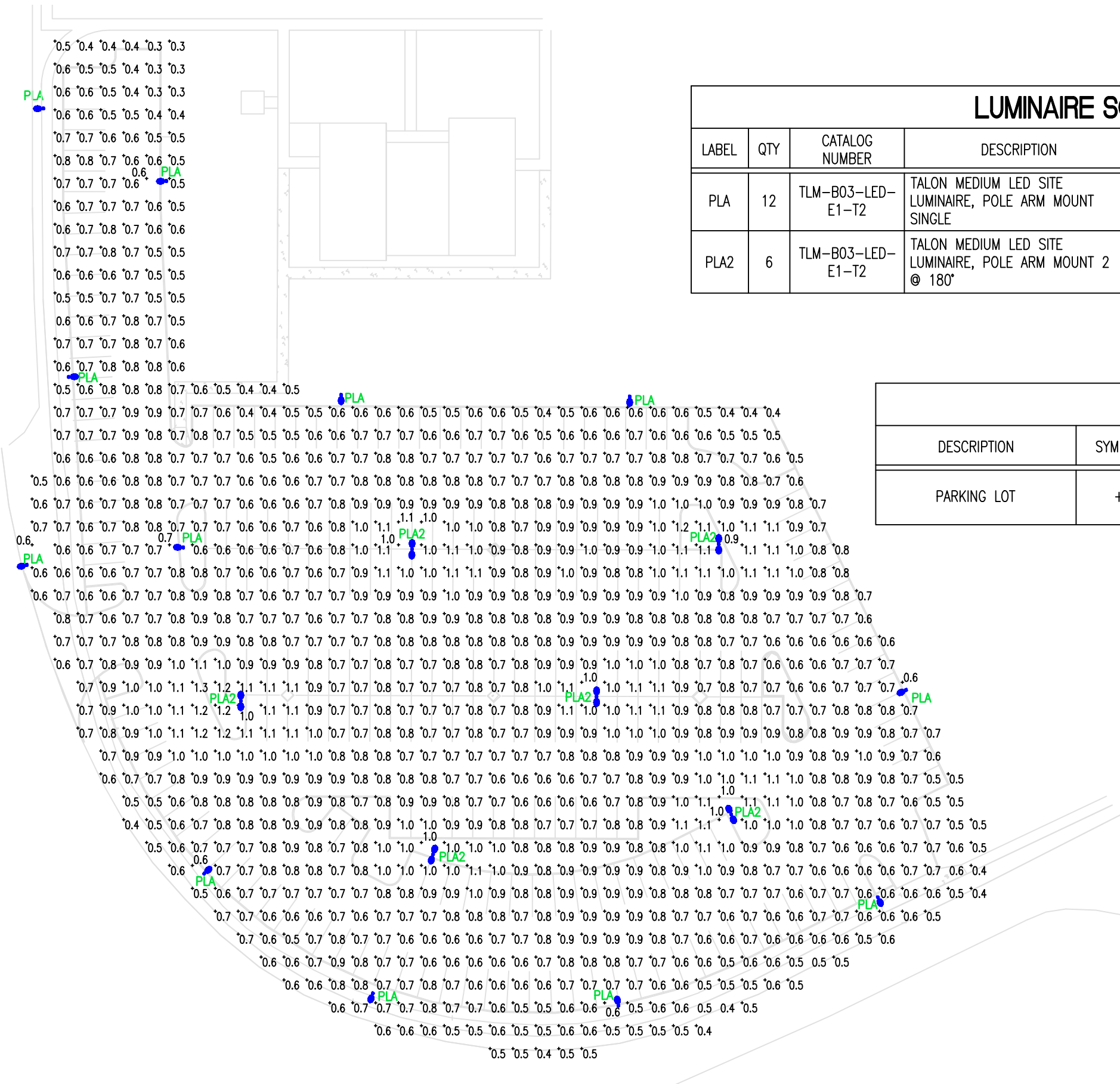


LUMINAIRE SCHEDULE (HID)								
LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
PHA	12	1SA SAR2 100PMH DB	POLE MOUNTED SINGLE HEAD SM. ARCHETYPE CUTOFF LUMINAIRE DIE CAST ALUM. REFLECTOR SYSTEM W/SPECULAR PANELS DIE CAST ALUM. HOUSING & LENS FRAME CLEAR FLAT GLASS LENS	(1) 100W CLEAR, CMH 4000K, ED17 MEDIUM BASE LAMP, HORIZ. POS.	SAR2-100P.IES	9000	0.64	138
PHA2	6	2SB SAR2 100PMH DB	POLE MOUNTED DUAL HEAD SM. ARCHETYPE CUTOFF LUMINAIRE DIE CAST ALUM. REFLECTOR SYSTEM W/SPECULAR PANELS DIE CAST ALUM. HOUSING & LENS FRAME CLEAR FLAT GLASS LENS	(1) 100W CLEAR, CMH 4000K, ED17 MEDIUM BASE LAMP, HORIZ. POS. EACH HEAD	SAR2-100P.IES	9000	0.64	276

STATISTICS (HID)						
DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
PARKING LOT	+	0.7 FC	1.5 FC	0.2 FC	7.5:1	3.5:1

- NOTES (HID):**
- ROOM SQUARE FOOTAGE – 91977
 - TOTAL WATTS – 3312
 - VA EDM LIGHTING LEVEL (FC) – 1
 - CALC. LIGHTING LEVEL (FC) – 0.7
 - ASHRAE 90.1 LTG. POWER DEN. – 0.2
 - CALC. LTG. POWER DENSITY – 0.04
 - CALCULATION LEVEL – 0"

PLAN VIEW (HID)
SCALE: 1" = 50'



LUMINAIRE SCHEDULE (LED)

LABEL	QTY	CATALOG NUMBER	DESCRIPTION	LAMP	FILE	LAMP LUMENS	LLF	WATTS
PLA	12	TLM-B03-LED-E1-T2	TALON MEDIUM LED SITE LUMINAIRE, POLE ARM MOUNT SINGLE	(3) LED LIGHTBARS, 4000K - TYPE 2	TLM-B03-LED-E1-T2.IES	ABSOLUTE	0.64	73
PLA2	6	TLM-B03-LED-E1-T2	TALON MEDIUM LED SITE LUMINAIRE, POLE ARM MOUNT 2 @ 180°	(3) LED LIGHTBARS, 4000K - TYPE 2. EACH HEAD	TLM-B03-LED-E1-T2.IES	ABSOLUTE	0.64	146

STATISTICS (LED)

DESCRIPTION	SYMBOL	AVERAGE	MAXIMUM	MINIMUM	MAX/MIN	AVG/MIN
PARKING LOT	+	0.7 FC	1.3 FC	0.3 FC	4.3:1	2.3:1

NOTES (LED):

- ROOM SQUARE FOOTAGE - 91977
- TOTAL WATTS - 1752
- VA EDM LIGHTING LEVEL (FC) - 1
- CALC. LIGHTING LEVEL (FC) - 0.7
- ASHRAE 90.1 LTG. POWER DEN. - 0.2
- CALC. LTG. POWER DENSITY - 0.02
- CALCULATION LEVEL - 0"

PLAN VIEW (LED)
SCALE: 1" = 50'

5.1 Life Cycle Analysis

The following table compares the life cycle cost of LED and conventional lighting systems when applied to the given spaces under the stated assumptions. Refer to Appendix A for cutsheets of the luminaires used, and to Section 3, METHOD OF APPROACH, for more information on underlying assumptions of these calculations, and to the table of assumptions following the life cycle cost analysis.

LIFE CYCLE ANALYSIS																																
Space (Illumination Level); Conventional or LED Lighting Technology	Luminaire Type	Luminaire Description	Drawing	Luminaires to Meet Specified Illumination level	Luminaire Price	Lamps per Luminaire	Lamp price	System Input Watts per Luminaire	System Luminous Efficacy, lumens per watt	Lamp life @ 10-12 hr starts	Weekly Hours of Operation: Annual kWh	Hours of Operation/15 yrs	kWh in 15 yrs	Number of lamp changes in 15 yrs	INITIAL COSTS:	Luminaires	Installation	OPERATION COSTS:	Lamp Replacement Cost (present value)	Ballast Replacement Cost (present value)	Energy Cost (present value)	Lamp Disposal Cost (present value)	15 YR TOTAL COST (net present value, calculation not shown)									
Exam/Treatment Room (50 fc)											40																					
Conventional	SFA	2x4 Fluorescent Troffer	5.1.1	1	85.33	2	3.21	58	98	30,000	121	31,200	1,810	1		\$85	\$80		\$18	\$115	\$161	\$0.80										
	SFB	2x4 Fluorescent Troffer		1	108.00	3	3.21	88	98	30,000	183	31,200	2,746	1		\$108	\$80		\$22	\$115	\$244	\$1.20	\$966									
LED	SLC	2x2 LED Troffer		4	277.00	1	138.50	50.5	69	50,000	420	31,200	6,302	0		\$1,108	\$320		\$0	n/a	\$561	\$0.00	\$2,026									
Procedure Room (100 fc)											40																					
Conventional	SFB	2x4 Fluorescent Troffer	5.1.2	3	108.00	3	3.21	88	98	30,000	549	31,200	8,237	1		\$324	\$240		\$65	\$345	\$733	\$3.60	\$1,620									
LED	SLC	2x2 LED Troffer		6	277.00	1	138.50	50.5	69	50,000	630	31,200	9,454	0		\$1,662	\$480		\$0	n/a	\$841	\$0.00	\$3,039									
Corridors (20 fc)											126																					
Conventional	VFA	2x4 Fluorescent Troffer	5.1.3 5.1.4	3	122.33	2	3.21	54.8	108	30,000	1,077	98,280	16,157	3		\$367	\$240		\$165	\$345	\$1,438	\$2.40	\$2,481									
Conventional (ext. life T8)	VFA	2x4 Fluorescent Troffer		3	122.33	2	3.21	54.8	111	40,000	1,077	98,280	16,157	2		\$367	\$240		\$110	\$345	\$1,438	\$2.40	\$2,445									
LED	VLA	2x4 LED Troffer		3	438.67	1	219.33	50	91	50,000	983	98,280	14,742	1		\$1,316	\$240		\$670	n/a	\$1,312	\$0.00	\$2,956									
Nurse Station (50 fc)											126																					
Conventional	VFA	2x4 Fluorescent Troffer	5.1.5	3	122.33	2	3.21	54.8	108	30,000	1,077	98,280	16,157	3		\$367	\$240		\$165	\$345	\$1,438	\$2.40	\$2,481									
LED	VLA	2x4 LED Troffer		3	438.67	2	219.33	50	91	50,000	983	98,280	14,742	1		\$1,316	\$240		\$670	n/a	\$1,312	\$0.00	\$2,956									
Reception (50 fc)											84																					
Conventional	VFA	2x4 Fluorescent Troffer	5.1.6	2	122.33	2	3.21	54.8	108	30,000	479	65,520	7,181	2		\$245	\$160		\$73	\$230	\$639	\$1.60										
	DFA	Downlight Compact Fluorescent Can		5	142.00	1	7.74	28.6	63	12,000	625	65,520	9,369	5		\$710	\$300		\$492	\$575	\$834	\$3.75	\$7,775									
LED	VLA	2x4 LED Troffer		2	438.67	2	219.33	50	91	50,000	437	65,520	6,552	1		\$877	\$160		\$451	n/a	\$583											
	DLA	Downlight LED Can	3	297.00	1	148.50	16.3	67	50,000	214	65,520	3,204	1		\$891	\$180		\$457	n/a	\$285	\$0.00	\$3,657										
Waiting Rooms (30 fc)											84																					
Conventional	DFB	Downlight Compact Fluorescent Can	5.1.7	6	185.00	1	7.35	36	67	12,000	943	65,520	14,152	5		\$1,110	\$360		\$579	\$690	\$1,260	\$4.50	\$7,661									
LED	DLB	Downlight LED Can		6	331.00	1	165.50	26.9	56	50,000	705	65,520	10,575	1		\$1,986	\$360		\$1,005	n/a	\$941	\$0.00	\$4,017									
Television Lounge (30 fc) Dimmed											84																					
Conventional	DFD	Downlight Compact Fluorescent Can	5.1.8	6	185.00	1	7.35	36	67	12,000	943	65,520	14,152	5		\$1,110	\$360		\$579	\$690	\$1,260	\$4.50	\$7,636									
LED	DLD	Downlight LED Can		6	331.00	1	165.50	26.9	56	50,000	705	65,520	10,575	1		\$1,986	\$360		\$1,005	n/a	\$941	\$0.00	\$4,017									

continued

LIFE CYCLE ANALYSIS																																
Space (Illumination Level); Conventional or LED Lighting Technology	Luminaire Type	Luminaire Description	Drawing	Luminaires to Meet Specified Illumination level	Luminaire Price	Lamps per Luminaire	Lamp price	System Input Watts per Luminaire	System Luminous Efficacy, lumens per watt	Lamp life @ 10-12 hr starts	Weekly Hours of Operation: Annual kWh	Hours of Operation/15 yrs	kWh in 15 yrs	Number of lamp changes in 15 yrs	INITIAL COSTS:	Luminaires	Installation	OPERATION COSTS:	Lamp Replacement Cost (present value)	Ballast Replacement Cost (present value)	Energy Cost (present value)	Lamp Disposal Cost (present value)	15 YR TOTAL COST (net present value, calculation not shown)									
Exam/Treatment Room (50 fc)											40																					
Conventional	SFA	2x4 Fluorescent Troffer	5.1.1	1	85.33	2	3.21	58	98	30,000	121	31,200	1,810	1		\$85	\$80		\$18	\$115	\$161	\$0.80										
	SFB	2x4 Fluorescent Troffer		1	108.00	3	3.21	88	98	30,000	183	31,200	2,746	1		\$108	\$80		\$22	\$115	\$244	\$1.20	\$966									
LED	SLC	2x2 LED Troffer		4	277.00	1	138.50	50.5	69	50,000	420	31,200	6,302	0		\$1,108	\$320		\$0	n/a	\$561	\$0.00	\$2,026									
Warehouse Storage (20 fc)											70																					
Conventional	HMA	HID High Bay	5.1.9	12	230.00	1	20.38	458	92	20,000	20,005	54,600	300,082	2		\$2,760	\$2,100		\$4,569	\$3,720	\$26,707	\$30.00	\$45,908									
LED	HLA	LED High Bay		15	1,140.50	1	570.25	286.5	78	50,000	15,643	54,600	234,644	1		\$17,108	\$2,625		\$8,724	n/a	\$20,883	\$0.00	\$47,801									
Energy Center (30 fc)											168																					
Conventional	HMA	HID High Bay	5.1.10	15	230.00	1	20.38	458	92	20,000	60,016	131,040	900,245	6		\$3,450	\$2,625		\$17,135	\$4,650	\$80,122	\$37.50	\$197,013									
LED	HLA	LED High Bay		18	1,140.50	1	570.25	286.5	78	50,000	45,052	131,040	675,773	2		\$20,529	\$3,150		\$20,869	n/a	\$60,144	\$0.00	\$118,965									
Exterior Egress Exit (10 fc)											96																					
Conventional	WFA	Compact Fluorescent Wall Pack	none	1	282.00	1	7.35	36	67	12,000	180	74,880	2,696	6		\$282	\$60		\$116	\$115	\$240	\$0.75	\$1,710									
LED	WLA	LED Wall Pack		1	491.00	1	245.50	27	66	50,000	135	74,880	2,022	1		\$491	\$60		\$257	n/a	\$180	\$0.00	\$937									
Parking Garage (2 fc)											134																					
Conventional	GFA	Fluorescent Vapor-Tight	5.1.11	10	106.33	2	3.21	55	107	30,000	3,832	104,520	57,486	3		\$1,063	\$1,250		\$551	\$1,150	\$5,116	\$8.00	\$11,726									
Conventional	GHA	HID Garage Lighter	5.1.12	8	275.00	2	7.35	80	75	20,000	4,460	104,520	66,893	5		\$2,200	\$1,008		\$1,065	\$1,712	\$5,953	\$40.00	\$20,111									
LED	GLA	LED Garage Lighter	5.1.13	8	466.60	1	233.30	73	70	100,000	4,069	104,520	61,040	1		\$3,733	\$1,008		\$1,878	n/a	\$5,433	\$0.00	\$11,744									
Parking Lot (1 fc)											96																					
Conventional	PHA	HID Pole Light	5.1.14	24	608.67	1	30.44	138	65	20,000	16,534	74,880	248,003	3		\$14,608	\$4,200		\$14,432	\$5,136	\$22,072	\$60.00	\$88,258									
LED	PLA	LED Pole Light	5.1.15	24	1,175.00	1	587.50	73	73	50,000	8,746	74,880	131,190	1		\$28,200	\$4,200		\$14,270	n/a	\$11,676	\$0.00	\$55,602									

Assumptions

Source

General

Energy Cost	\$0.089	per kWh	US Energy Information Administration; www.eia.gov
System Life	15	years	assumed; no data available
Discount Rate	3.2%		
Financing Period (Years)			
% yearly increase for electricity	3.2%		

Installation

Troffer, fluorescent & LED	\$80.00	each	per 2011 RS Means Electrical Cost Data
Vaportight linear fluorescent	\$125.00	each	"
High bay, pole	\$175.00	each	"
Garage Lighter (low bay)	\$126.00	each	"
Can, wall pack, CFL & LED	\$60.00	each	"

Disposal Cost

	Average Cost		per Environment, Health and Safety Online
4' fluorescent	\$0.40	each	"
CFL	\$0.75	each	"
HID	\$2.50	each	"
LED	\$0.00	each	"

Lamp Cost

	Average Cost	Sylvania	G.E.	Philips	
4' T8 835	\$3.21	each	\$3.80	\$3.28	\$2.55
400W pulse start metal halide	\$20.38	each	\$20.66	\$22.90	\$17.59
100W ceramic metal halide	\$30.44	each	\$26.75	\$38.86	\$25.71
70W ceramic metal halide	\$29.83	each	\$26.75	\$38.86	\$23.89
32W compact fluorescent	\$7.35	each	\$6.21	\$6.79	\$9.06
26W compact fluorescent	\$7.74	each	\$7.36	\$6.79	\$9.06
LED assembly	50%	of luminaire	assumed; no data available		

Lamp Replacement Labor Cost

Troffers, Downlight, garage	\$11.93	per luminaire	per 2011 RS Means Electrical Cost Data
High Bay, pole	\$170.00	"	per Lighting Research Center, Parking Lot Luminaire Calculator

Ballast Replacement Cost, Material & Labor

Fluorescent	\$115.00	each	per 2011 RS Means Electrical Cost Data
400W HID	\$310.00	"	"
100W ceramic metal halide	\$214.00	"	"
70W ceramic metal halide	\$214.00	"	"
32W compact fluorescent	\$115.00	"	"
26W compact fluorescent	\$115.00	"	"
Compact fluorescent wallpack	\$115.00	"	"

Notes:

1. Pole lights costs do not include pole, base, and excavation
2. HVAC loads added by luminaires are assumed to be equal, and are not included in the calculations.

6 CONCLUSIONS

6.0 Luminous Performance

- Interior LED luminaires are currently best suited for applications which require 30 footcandles of illumination or less in applications that require long hours of operation, and also at mounting heights such that maintenance access is costly.
- LED lighting is currently not well suited for interior applications that require more than 30 footcandles of illumination. More LED fixtures are required to achieve the luminous and life cycle cost performance demonstrated by fluorescent lighting.
- Exterior LED luminaires are currently suited for parking lots and garages, and exterior egress lighting.
- LED luminous efficacy is improving rapidly. Fluorescent and HID luminous efficacy appear to have reached a plateau.
- The largest challenge currently faced by LED lighting technology is the management of produced heat. Between 60% and 80% of the energy supplied to an LED light source is dissipated as heat.
- While fluorescent and HID lighting technologies are mature, LED lighting technology is developing quickly. The information and conclusions regarding LED lighting in this study will be out of date within 12 months following publication.
- LED sources are most efficient at cooler color temperatures, e.g. 6000K, which is inappropriate for most applications. This study used 3500 - 4500K sources to balance energy efficiency with color rendering needs.

6.1 Life Cycle Performance

The life cycle analysis shows that the comparison between LED and conventional lighting systems is most sensitive to the differences in first cost between systems, and least sensitive to the cost of energy. In between is the cost of maintenance; and it is to be noted that the labor costs of maintenance outweigh the material cost of replacement lamps, ballasts, or LED modules.

6.2 Future Trends

- LED luminous efficacy is improving rapidly. Fluorescent and HID luminous efficacies appear to have reached a plateau.
- Rated lamp life for conventional lighting technologies is increasing.

- The single largest challenge faced by LED lighting technology is the management of produced heat, which affects LED life and luminous efficacy.
- While fluorescent and HID lighting technologies are mature, LED lighting technology is relatively new and is developing quickly. The information and conclusions regarding LED lighting in this study will be out of date within 12 months following publication.
- Testing, manufacturing, safety, controls, and measurements standards for conventional light sources have been established for many years. Similar standards for LED lighting are relatively new or still under development, and are likely to change as the technology develops.
- At the current time, dimming of LED luminaires requires very careful component matching and slow fade rates for the LED module, the dimming driver, and the dimming controls. This technology is expected to improve.
- It is expected that the LED modules will become easily replaceable, and will be electrically, physically, and optically interchangeable between manufacturers, similar to present-day incandescent or HID lamps which can be interchanged between luminaires by different manufacturers.
- If the recent trend of limited availability and steep cost increases for phosphors continues, the price difference between fluorescent and LED lighting systems will diminish rapidly. Both technologies use phosphors, but fluorescent lamps use a higher quality of phosphors, and in greater quantities than LED.

7 RECOMMENDATIONS

Based on the results of this study, the following recommendations are made:

- Linear fluorescent sources and HID sources are currently superior to LED sources for interior general illumination luminaires at typical office and healthcare ceiling heights where more than 30 footcandles are needed. More LED fixtures at greater cost are needed to perform the same luminous task as conventional sources in these applications:
 - Exam/Treatment rooms, and other similar spaces, such as offices
 - Procedure Rooms
 - Nurse Stations
- LED is recommended for:
 - Reception Areas, Waiting Rooms, Television Lounges, and other areas where downlight can luminaires are used at 30 footcandles and less
 - Energy centers, where the illumination level and the cost of maintenance are relatively high
 - Parking lots and garages
- Steady increases in LED luminous efficacy are projected to one day make LED sources the preferred source. At this time and at desired VA color temperatures, conventional sources are more efficacious than LED sources.
- LED technology is not currently recommended for general-illumination areas requiring high light levels with high color rendering, such as medical diagnostics. LED technology cannot yet equal the luminous and life cycle cost performance of fluorescent lighting in these applications.
- When relamping linear fluorescent luminaires, use extended-life lamps. The life of such lamps can be rated as high as 40,000 hours, based on a 12-hour start.
- T8 to LED retrofits (changing lamp/ballast for LED/driver) are not recommended. DOE CALiPER testing has shown that LED retrofits have low lumen outputs compared to the fluorescent lamps they replace. For any LED retrofit product, it is recommended that end users refer to CALiPER product test results.

APPENDIX A LUMINAIRE COSTS & CUTSHEETS

Each luminaire cutsheet is keyed to the luminaire type used in the calculations in Section 5, Results.

Up to three cutsheets for each luminaire type are provided, when 'or equal' luminaire types were found. When fewer than three cutsheets are provided for a luminaire type, it indicates that three equivalent luminaires were not available that met the criteria of this study.

TYPE	AVG COST	RC LURIE	AZ LTG	INVERSE	LOL AZ	DESERT	TOTAL L&C
DFA	\$142.00	\$185.00	\$152.00		\$89.00		
DFB	\$142.00	\$185.00	\$152.00		\$89.00		
DFC	\$234.33	\$300.00	\$248.00		\$155.00		
DLA	\$297.00	\$390.00	\$203.00	\$348.00	\$247.00		
DLB	\$331.00	\$395.00	\$351.00		\$247.00		
DLD	\$331.00	\$395.00	\$351.00		\$247.00		
GFA	\$106.33	\$105.00	\$124.00		\$90.00		
GHA	\$275.00	\$280.00	\$350.00	\$195.00			
GLA	\$466.60	\$500.00		\$575.00	\$348.00	\$480.00	\$430.00
HLA	\$1,140.50				\$1,075.00		\$1,206.00
HMA	\$230.00	\$210.00		\$250.00			
SFA	\$85.33	\$85.00	\$81.00	\$90.00			
SFB	\$108.00	\$116.00	\$103.00	\$105.00			
SLC	\$277.00	\$332.00				\$222.00	
PHA	\$608.67	\$485.00	\$416.00	\$925.00			
PLA	\$1,175.00	\$455.00	\$1,620.00	\$1,450.00			
VFA	\$122.33	\$116.00	\$121.00	\$130.00			
VLA	\$438.67	\$335.00	\$546.00	\$435.00			
WFA	\$282.00	\$310.00	\$241.00	\$295.00			
WLA	\$491.00	\$500.00	\$588.00	\$385.00			