

Understanding Fixture Design Tools

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Teresa Bair, LC

Marketing Director, Luminaires

EYE Lighting International - Mentor, Ohio

Teresa.Bair@EYELighting.com



EYE LIGHTING
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Presentation Agenda

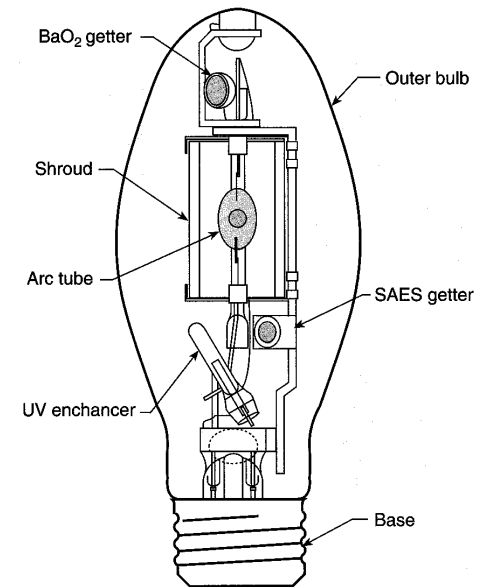
- **Uncertainties in the Use of Testing Standards: HID vs. LED**
 - Relative Photometry
 - Absolute Photometry
- **Understanding Test Reports**
 - LM-79 Photometric Data
 - In Situ Temperature Measurement
- **Applying Test Data**
 - Long Term Lumen Maintenance of LED Sources (TM-21)
 - Lighting Design
 - Luminaire Product Selection
- **Critical Product Accreditations**
- **Recommendations**

Absolute vs. Relative Photometry

- Unable to Standardize on One Method Due to Technology Differences
 - LEDs performance is vastly dependent on thermal management
 - Impossible to remove LEDs and simulate LED ‘installed’ behavior to accurately measure bare lumens
- Uncertainties Present in Both Test Methods

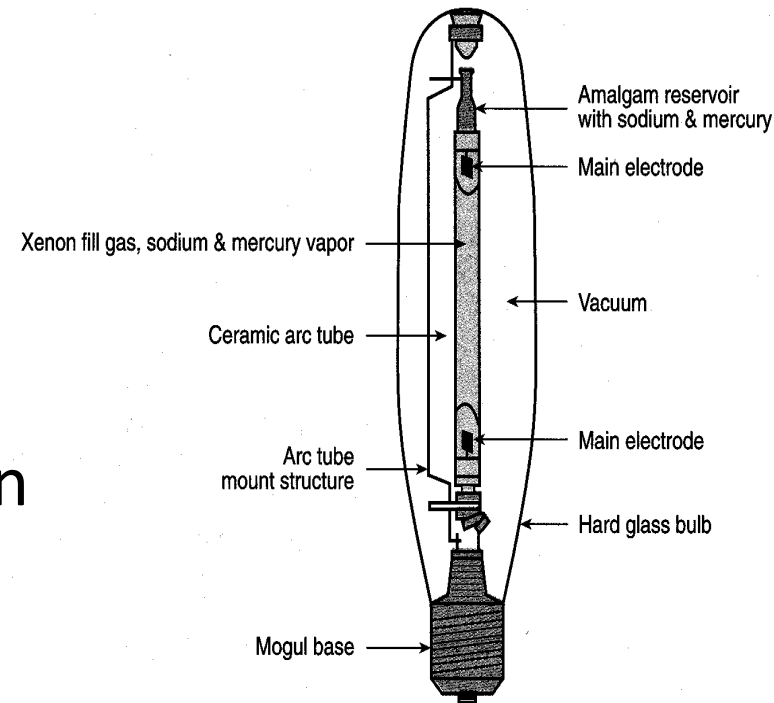
Relative Photometry Concept

1. Measure bare lamp lumens using an integrating sphere or a goniophotometer at 25°C
2. Measure lamp in luminaire and thermally stabilize at 25°C
3. Measure relative luminous intensity distribution of luminaire
4. Scale relative luminous intensity distribution according to lamp manufacturer's rated lamp lumens and ballast manufacturer's ballast factor

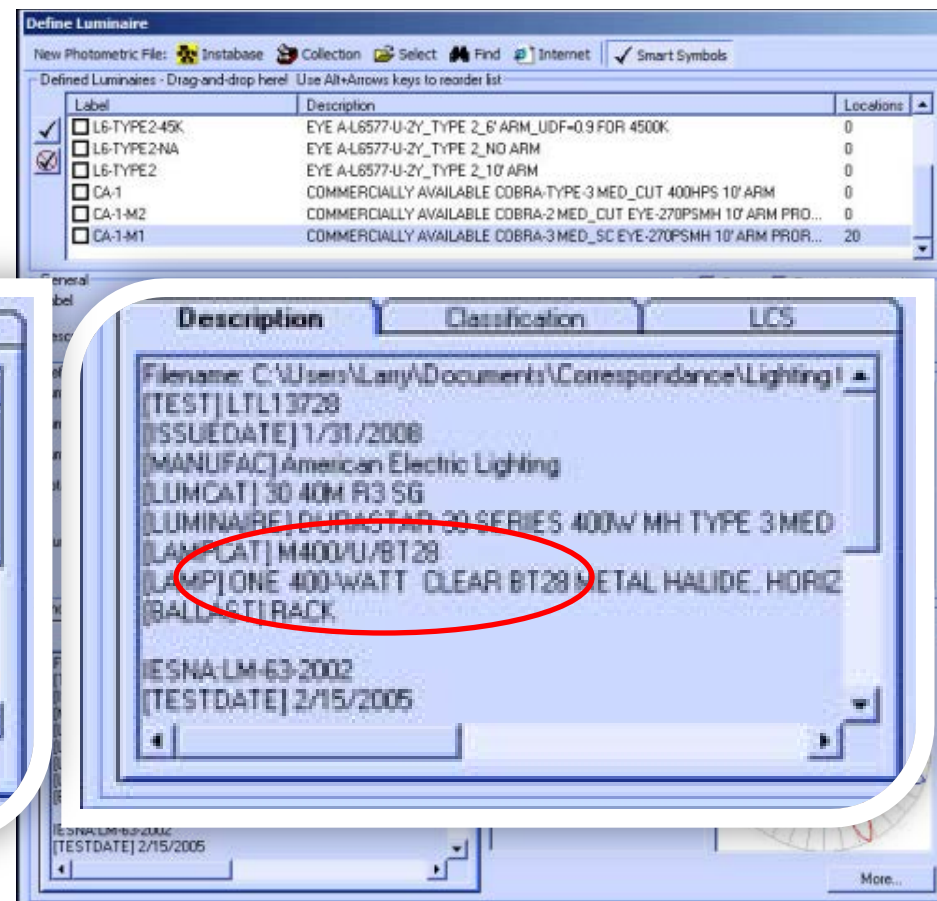
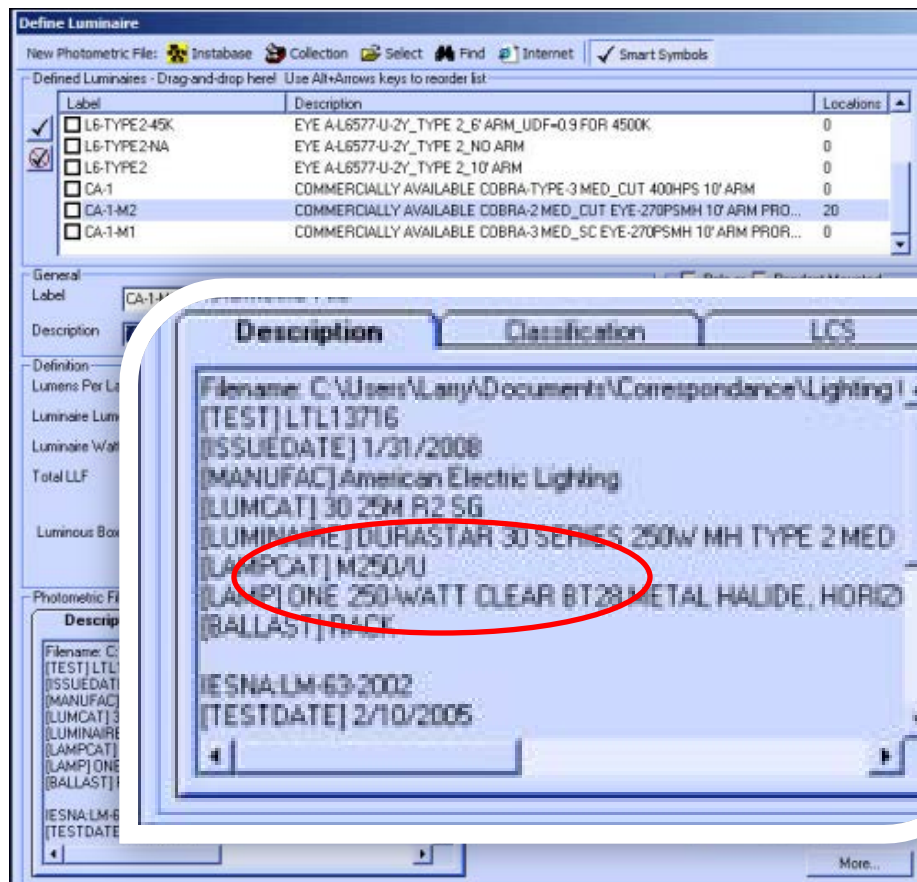


Uncertainties in the Use of Relative Photometry

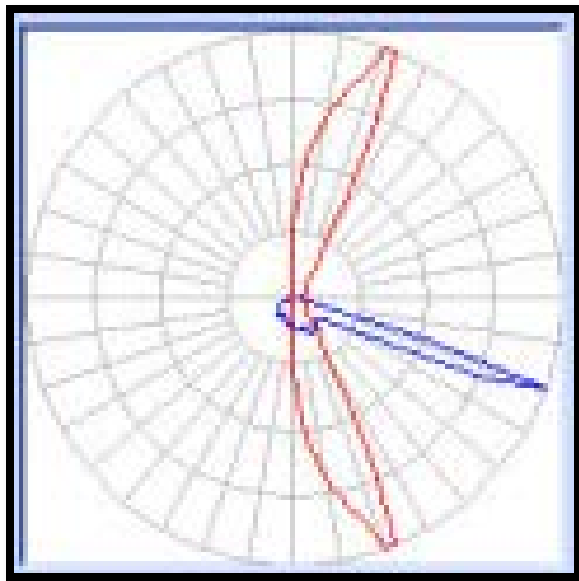
- Lamp Positioning in Fixture
- Accelerated Lamp Depreciation Due to Unexpected Lamp Operating Conditions
- Lamp Prorating Accuracy
- Luminaire and Ballast Production Variations
- Reference Lamp and Reference Ballast to Normalize Data



Uncertainties in the Use of Relative Photometry

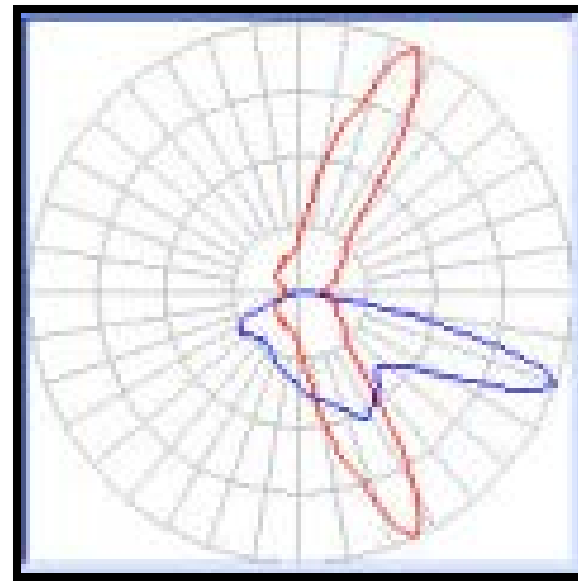


Uncertainties in the Use of Relative Photometry



Prorated from 250W

- LV Ratio: 0.89



Prorated from 400W

- Arc Tube Construction
- LV Ratio: 0.33

Absolute Photometry LM-79

Electrical & Photometric Measurements of Solid-State Lighting Products

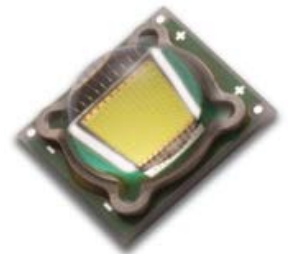
Tests

- Voltage & Current
- Luminous Flux
- Luminous Efficacy
- Intensity vs. Angle
- Color (CCT & CRI)



Uncertainties in the Use of Absolute Photometry

- LED Binning (flux, color, forward voltage)
- System Component Changes (driver, optics)
- Optics (mounting, positioning, coatings, degradation)
- Diode/Phosphor/Package Changes
- Thermal Transfer (adhesives, coating, positioning)
- Power Supply/Driver Variations (operating current, voltage)
- Limited Sample Size
- Product Evolution



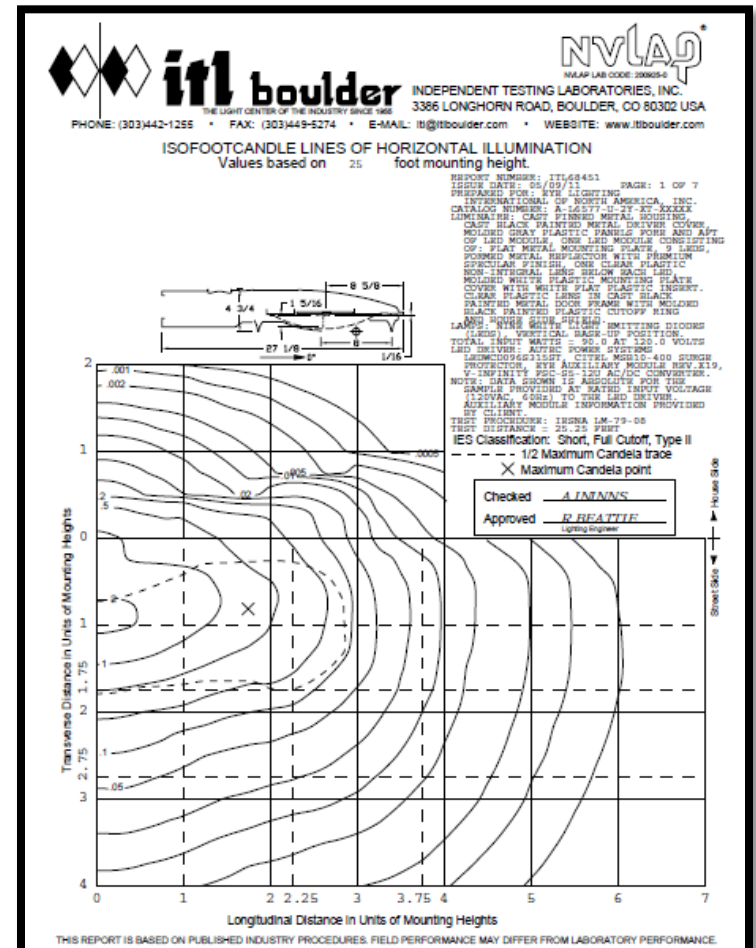
Cost of Absolute Photometry Testing

TESTING INTEGRATED LUMINAIRES (4500K)							
		LM-79	Spectral Power 1 st Luminaire	Spectral Power Additional Luminaire	Color Spatial Uniformity	In-Situ	Expected Cost
Lumen Level 1	Type II	√	√		√	√	\$2,230
	Type III	√					\$635
	Type IV	√					\$635
	Type V	√					\$635
Lumen Level 2	Type II	√		√	√	√	\$2,180
	Type III	√					\$635
	Type IV	√					\$635
	Type V	√					\$635
Lumen Level 3	Type II	√		√	√	√	\$2,180
	Type III	√					\$635
	Type IV	√					\$635
	Type V	√					\$635
Adder for Candela Tests							\$2,145
\$14,450							

*Estimate Only

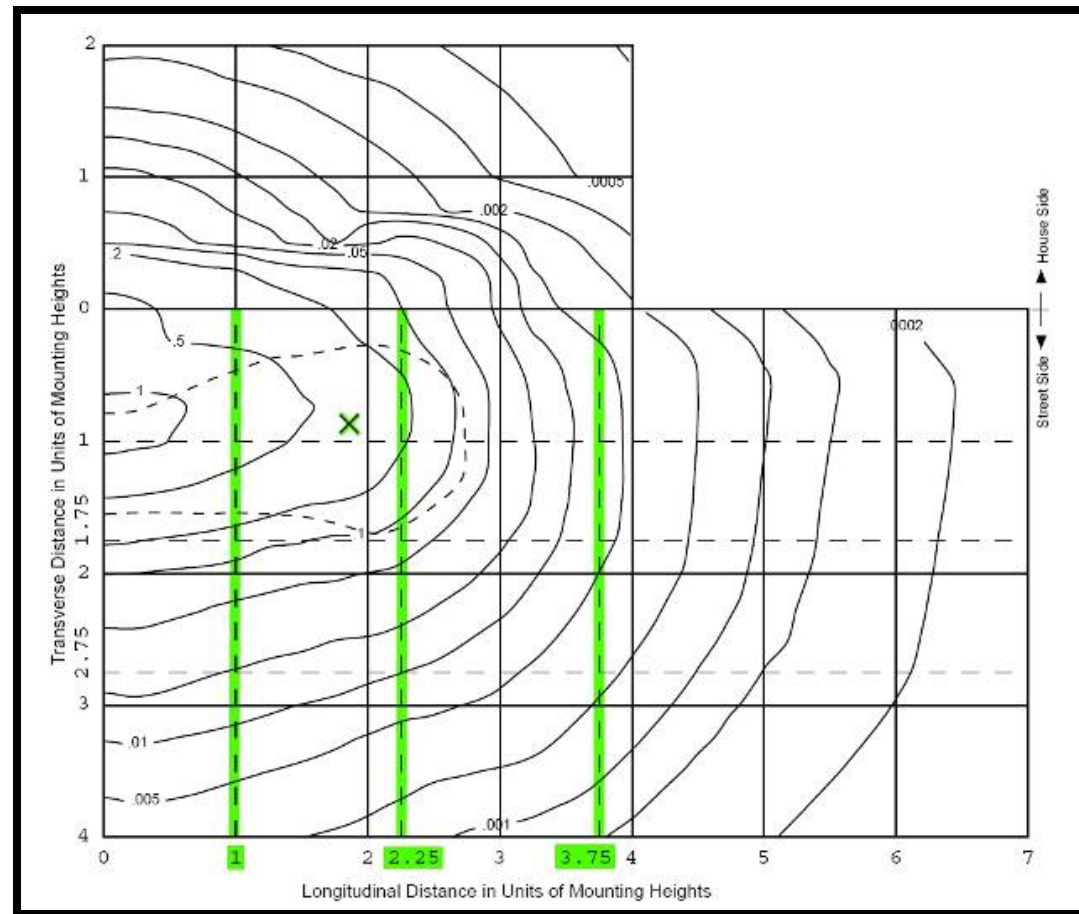
Understanding Photometric Report

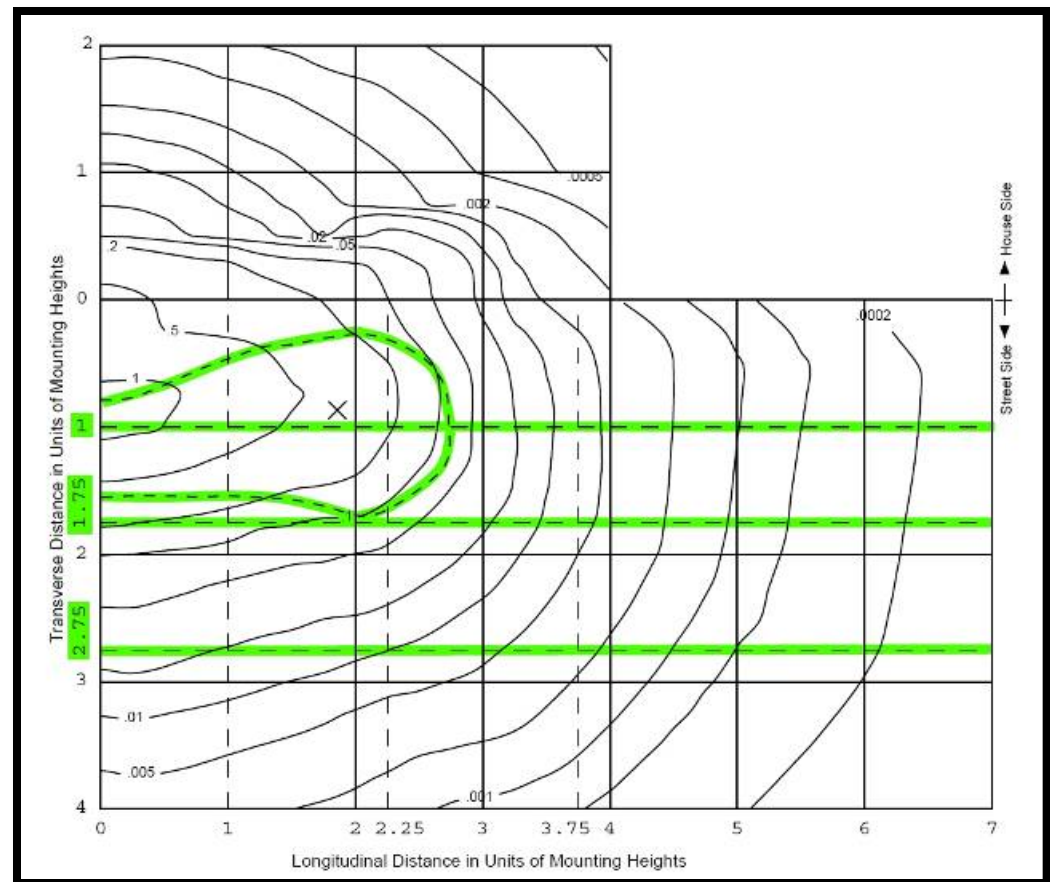
- Shows Light Distribution Pattern
- Short, Medium, Long
- Type I, II, III, IV, V



Understanding Photometric Report

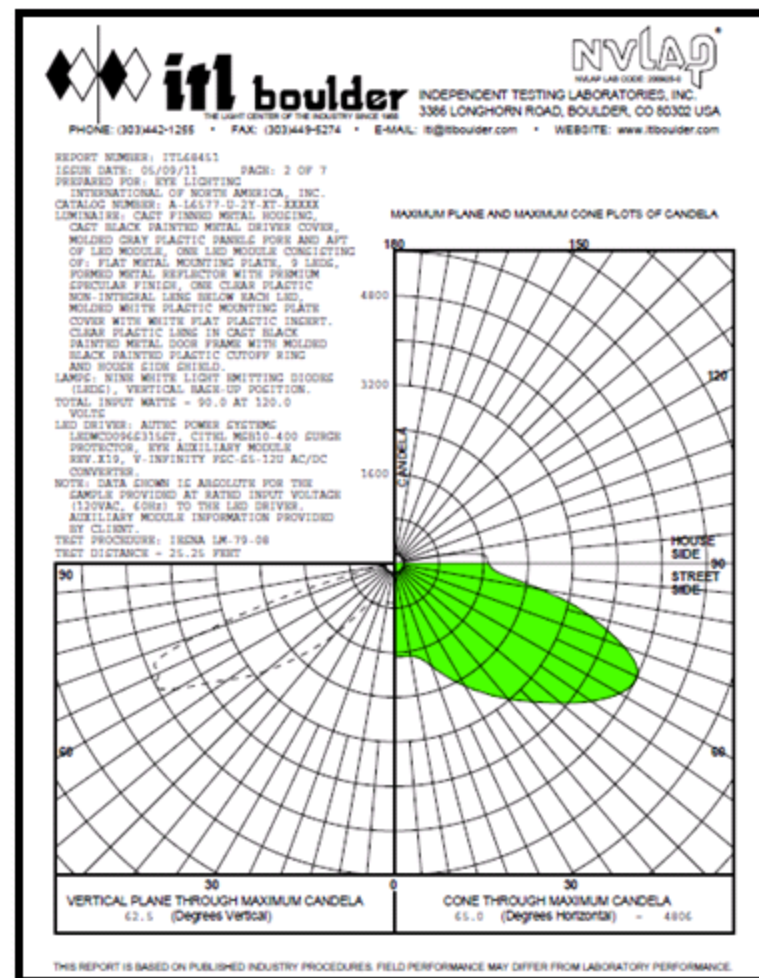
- 1 – 1.25 = Short
- 2.25 – 3.75 = Medium
- >3.75 = Long





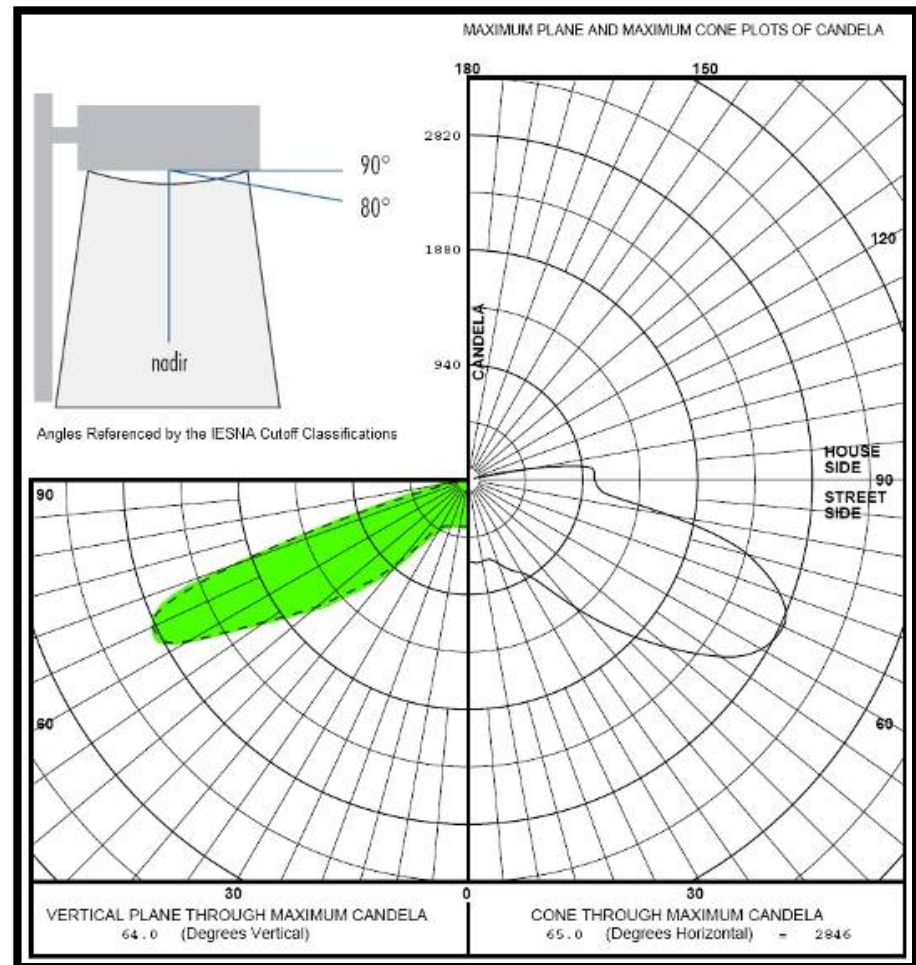
Understanding Photometric Report

- House Side/Street Side
- 11.5% Lighting Sidewalk
- 88.5% Lighting Roadway



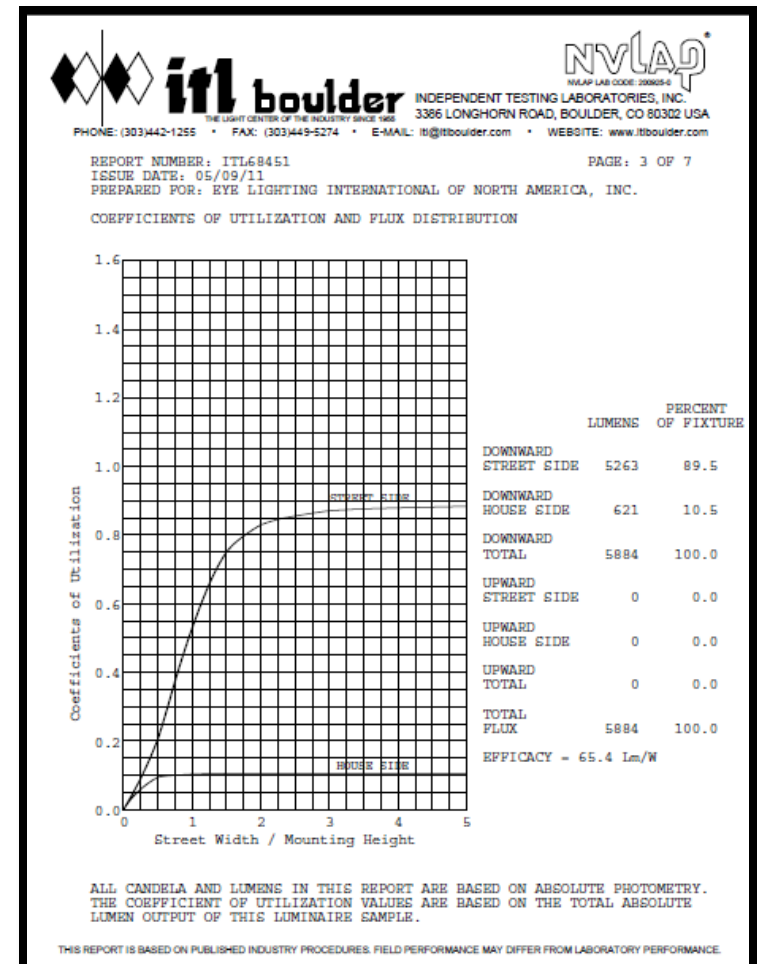
Understanding Photometric Report

- Vertical Plane
- Luminaire Classification (Uplight, Glare)



Understanding Photometric Report

- Divide the street width by the mounting height.
- Follow the ratio up from the bottom of the graph to the street-side curve
- Shows how well lumens are utilized at desired mounting height



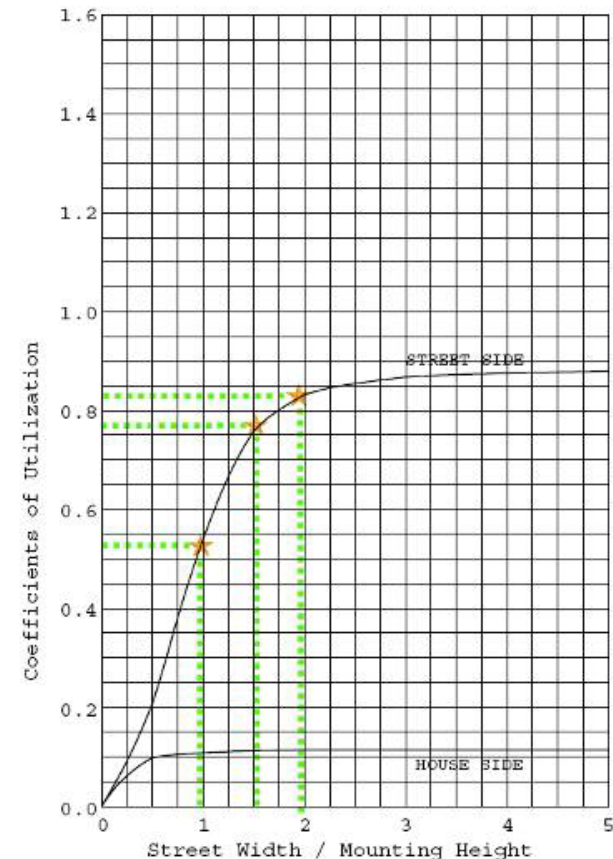
Understanding Photometric Report

Road Width Width (Feet)	Mounting Height (Feet)	Street Width / Mounting Height Ratio	CU	Lumens
48	25	1.92	.83	2,305
38	25	1.52	.76	2,111
24	25	.96	.55	1,527

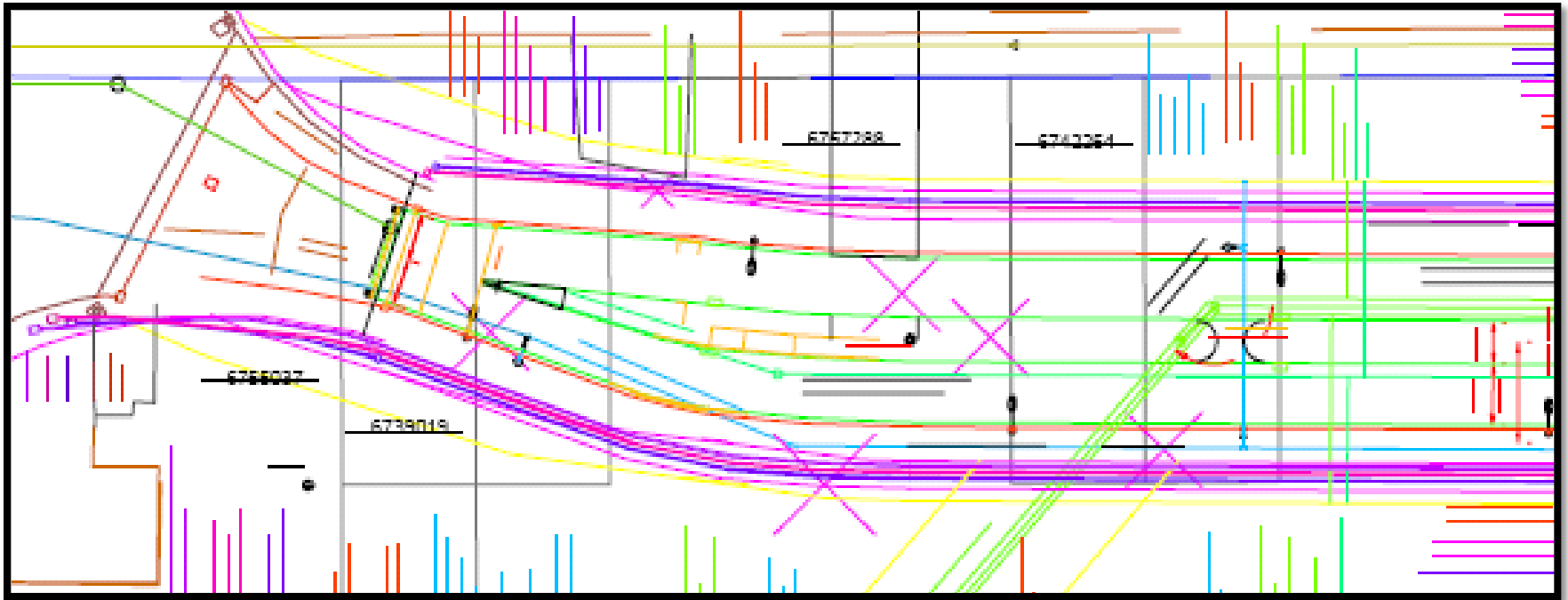
*Road Width includes Arm length, Setback, and curb to curb width

Average Illuminance Equation:

$$\frac{(\text{lumens per lamp}) \times (\text{coefficient of utilization}) \times (\text{light loss factor})}{(\text{road width}) \times (\text{pole spacing})}$$



Lighting Layout



- New Construction Roadway Lighting
 - Minimum .2 Fc criteria used
- Mounting Height of 30ft

Foot-candle comparison

Average Fc

Label	Calc Type	Units	Luminaire #1	Luminaire #2	Luminaire #3
Road Area	Illuminance	Fc	0.33	0.32	0.38
Road Only	Illuminance	Fc	1	0.77	0.78

Minimum Fc

Label	Calc Type	Units	Luminaire #1	Luminaire #2	Luminaire #3
Road Area	Illuminance	Fc	0	0	0
Road Only	Illuminance	Fc	0.3	0.2	0.3

Maximum Fc

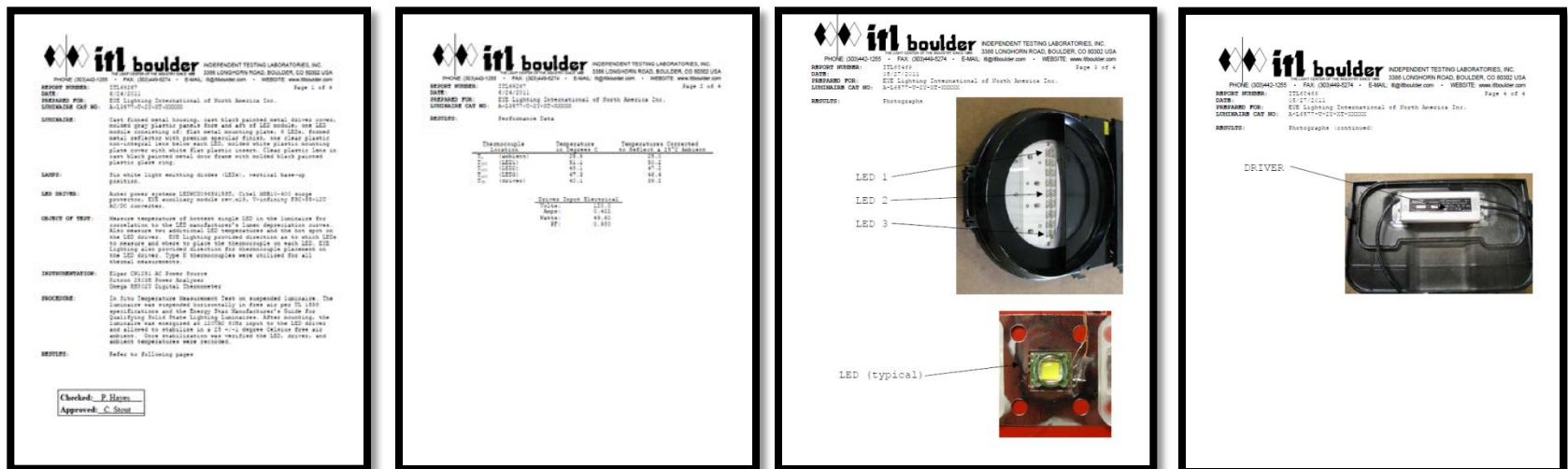
Label	Calc Type	Units	Luminaire #1	Luminaire #2	Luminaire #3
Road Area	Illuminance	Fc	1.6	1.1	1
Road Only	Illuminance	Fc	1.6	1.1	1

Luminaire Comparison

Model	Quantity	Wattage	Lumens	Cutoff	BUG Rating	LPW
Luminaire #1	10	90	5884	Full-Cutoff	B1-U0-G1	65
Luminaire #2	10	110	7236	Non-cutoff	B2-U2-G2	65
Luminaire #3	10	95	8490	Semi-Cutoff	B2-U2-G2	89

Luminaire #1 Best Choice for Application:

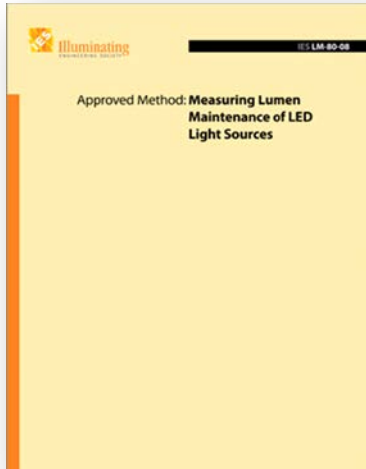
- Better Photometric Performance
- Lower Lumen Output; Achieving More Light on Task
- Lower Energy Consumption
- Less Backlight, Uplight, Glare
- Lumens-per-Watt Metric Insufficient for Product Evaluation



Projecting Long Term Lumen Maintenance of LED Light Sources TM-21

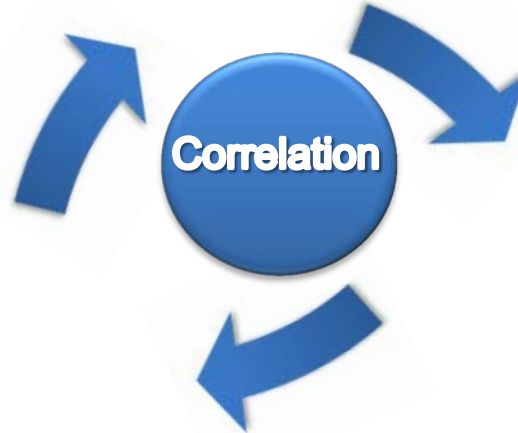
- Standardize Data Reporting Across Manufacturers
- Provides Method to Validate and Compare





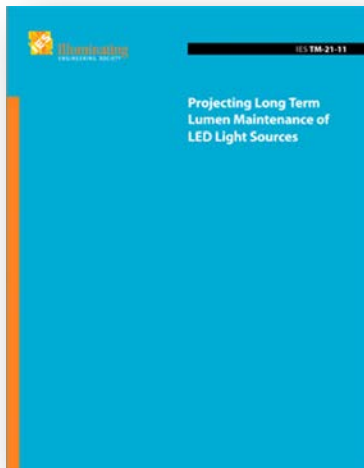
LM-80-08

- Approved Method: Measuring Lumen Maintenance of LED Light Sources



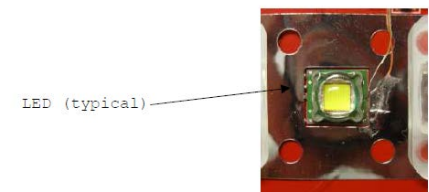
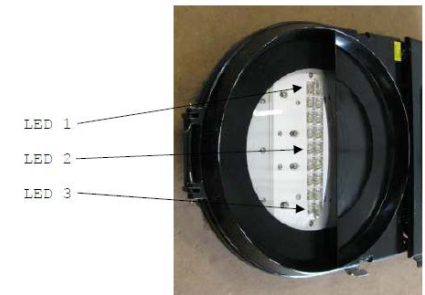
ISTMT

- In Situ Temperature Measurement Test



TM-21-11

- Projecting Long Term Lumen Maintenance of LED Light Sources



Projecting Lumen Maintenance

- TM-21 is a Standardized Reporting Method to Extrapolate Projected Lumen Maintenance
- Luminaire In Situ Temperature Correlation with LM-80 Test Temperatures
- Same LED, different results, Performance is Largely Dependent on Luminaire Design

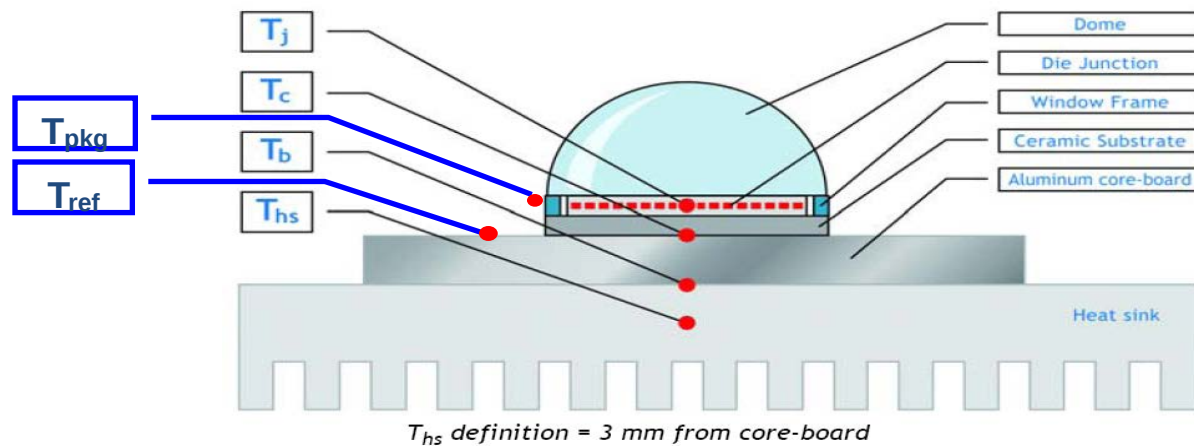
[illegible]

Sample #	Initial Lumen Flux	Initial Forward Voltage [V]	Lumen Maintenance Normalized to 1 at 0 Hours															
			0	500	1000	1500	2000	3000	4000	5000	6000	7000	8000					
1	689.4	3.24	1.000	1.005	1.007	1.009	1.010	1.011	1.012	1.013	1.023	1.028	1.022					
2	689.6	3.05	1.000	1.005	1.006	1.007	1.008	1.009	1.010	1.013	1.022	1.034	1.028					
3	724.0	3.12	1.000	1.010	1.011	1.012	1.013	1.015	1.016	1.017	1.024	1.028	1.021					
5	771.1	3.09	1.000	1.008	1.010	1.011	1.012	1.014	1.014	1.018	1.029	1.029	1.019					
6	689.9	3.10	1.000	1.010	1.011	1.012	1.013	1.014	1.015	1.024	1.044	1.041	1.028					
7	689.9	3.05	1.000	1.001	1.001	1.010	1.016	1.012	1.016	1.011	1.024	1.020	1.019					
8	701.6	3.05	1.000	0.997	1.000	0.999	0.999	0.999	0.999	1.008	1.007	1.017	1.008					
9	689.9	3.05	1.000	1.005	1.006	1.007	1.008	1.009	1.010	1.015	1.018	1.022	1.021					
10	758.0	3.13	1.000	0.989	1.007	1.005	1.003	1.006	1.007	1.001	0.916	1.020	1.005					

		1.000	1.007	1.014	1.021	1.028	1.035	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.090	1.097	1.104	1.111	1.118	1.125	1.132	1.139	1.146	1.153	1.160	1.167	1.174	1.181	1.188	1.195	1.202	1.209	1.216	1.223	1.230	1.237	1.244	1.251	1.258	1.265	1.272	1.279	1.286	1.293	1.300	1.307	1.314	1.321	1.328	1.335	1.342	1.349	1.356	1.363	1.370	1.377	1.384	1.391	1.398	1.405	1.412	1.419	1.426	1.433	1.440	1.447	1.454	1.461	1.468	1.475	1.482	1.489	1.496	1.503	1.510	1.517	1.524	1.531	1.538	1.545	1.552	1.559	1.566	1.573	1.580	1.587	1.594	1.601	1.608	1.615	1.622	1.629	1.636	1.643	1.650	1.657	1.664	1.671	1.678	1.685	1.692	1.699	1.706	1.713	1.720	1.727	1.734	1.741	1.748	1.755	1.762	1.769	1.776	1.783	1.790	1.797	1.804	1.811	1.818	1.825	1.832	1.839	1.846	1.853	1.860	1.867	1.874	1.881	1.888	1.895	1.902	1.909	1.916	1.923	1.930	1.937	1.944	1.951	1.958	1.965	1.972	1.979	1.986	1.993	2.000	2.007	2.014	2.021	2.028	2.035	2.042	2.049	2.056	2.063	2.070	2.077	2.084	2.091	2.098	2.105	2.112	2.119	2.126	2.133	2.140	2.147	2.154	2.161	2.168	2.175	2.182	2.189	2.196	2.203	2.210	2.217	2.224	2.231	2.238	2.245	2.252	2.259	2.266	2.273	2.280	2.287	2.294	2.301	2.308	2.315	2.322	2.329	2.336	2.343	2.350	2.357	2.364	2.371	2.378	2.385	2.392	2.399	2.406	2.413	2.420	2.427	2.434	2.441	2.448	2.455	2.462	2.469	2.476	2.483	2.490	2.497	2.504	2.511	2.518	2.525	2.532	2.539	2.546	2.553	2.560	2.567	2.574	2.581	2.588	2.595	2.602	2.609	2.616	2.623	2.630	2.637	2.644	2.651	2.658	2.665	2.672	2.679	2.686	2.693	2.700	2.707	2.714	2.721	2.728	2.735	2.742	2.749	2.756	2.763	2.770	2.777	2.784	2.791	2.798	2.805	2.812	2.819	2.826	2.833	2.840	2.847	2.854	2.861	2.868	2.875	2.882	2.889	2.896	2.903	2.910	2.917	2.924	2.931	2.938	2.945	2.952	2.959	2.966	2.973	2.980	2.987	2.994	3.001	3.008	3.015	3.022	3.029	3.036	3.043	3.050	3.057	3.064	3.071	3.078	3.085	3.092	3.099	3.106	3.113	3.120	3.127	3.134	3.141	3.148	3.155	3.162	3.169	3.176	3.183	3.190	3.197	3.204	3.211	3.218	3.225	3.232	3.239	3.246	3.253	3.260	3.267	3.274	3.281	3.288	3.295	3.302	3.309	3.316	3.323	3.330	3.337	3.344	3.351	3.358	3.365	3.372	3.379	3.386	3.393	3.400	3.407	3.414	3.421	3.428	3.435	3.442	3.449	3.456	3.463	3.470	3.477	3.484	3.491	3.498	3.505	3.512	3.519	3.526	3.533	3.540	3.547	3.554	3.561	3.568	3.575	3.582	3.589	3.596	3.603	3.610	3.617	3.624	3.631	3.638	3.645	3.652	3.659	3.666	3.673	3.680	3.687	3.694	3.701	3.708	3.715	3.722	3.729	3.736	3.743	3.750	3.757	3.764	3.771	3.778	3.785	3.792	3.799	3.806	3.813	3.820	3.827	3.834	3.841	3.848	3.855	3.862	3.869	3.876	3.883	3.890	3.897	3.904	3.911	3.918	3.925	3.932	3.939	3.946	3.953	3.960	3.967	3.974	3.981	3.988	3.995	4.002	4.009	4.016	4.023	4.030	4.037	4.044	4.051	4.058	4.065	4.072	4.079	4.086	4.093	4.100	4.107	4.114	4.121	4.128	4.135	4.142	4.149	4.156	4.163	4.170	4.177	4.184	4.191	4.198	4.205	4.212	4.219	4.226	4.233	4.240	4.247	4.254	4.261	4.268	4.275	4.282	4.289	4.296	4.303	4.310	4.317	4.324	4.331	4.338	4.345	4.352	4.359	4.366	4.373	4.380	4.387	4.394	4.401	4.408	4.415	4.422	4.429	4.436	4.443	4.450	4.457	4.464	4.471	4.478	4.485	4.492	4.499	4.506	4.513	4.520	4.527	4.534	4.541	4.548	4.555	4.562	4.569	4.576	4.583	4.590	4.597	4.604	4.611	4.618	4.625	4.632	4.639	4.646	4.653	4.660	4.667	4.674	4.681	4.688	4.695	4.702	4.709	4.716	4.723	4.730	4.737	4.744	4.751	4.758	4.765	4.772	4.779	4.786	4.793	4.800	4.807	4.814	4.821	4.828	4.835	4.842	4.849	4.856	4.863	4.870	4.877	4.884	4.891	4.898	4.905	4.912	4.919	4.926	4.933	4.940	4.947	4.954	4.961	4.968	4.975	4.982	4.989	4.996	5.003	5.010	5.017	5.024	5.031	5.038	5.045	5.052	5.059	5.066	5.073	5.080	5.087	5.094	5.101	5.108	5.115	5.122	5.129	5.136	5.143	5.150	5.157	5.164	5.171	5.178	5.185	5.192	5.199	5.206	5.213	5.220	5.227	5.234	5.241	5.248	5.255	5.262	5.269	5.276	5.283	5.290	5.297	5.304	5.311	5.318	5.325	5.332	5.339	5.346	5.353	5.360	5.367	5.374	5.381	5.388	5.395	5.402	5.409	5.416	5.423	5.430	5.437	5.444	5.451	5.458	5.465	5.472	5.479	5.486	5.493	5.500	5.507	5.514	5.521	5.528	5.535	5.542	5.549	5.556	5.563	5.570	5.577	5.584	5.591	5.598	5.605	5.612	5.619	5.626	5.633	5.640	5.647	5.654	5.661	5.668	5.675	5.682	5.689	5.696	5.703	5.710	5.717	5.724	5.731	5.738	5.745	5.752	5.759	5.766	5.773	5.780	5.787	5.794	5.801	5.808	5.815	5.822	5.829	5.836	5.843	5.850	5.857	5.864	5.871	5.878	5.885	5.892	5.899	5.906	5.913	5.920	5.927	5.934	5.941	5.948	5.955	5.962	5.969	5.976	5.983	5.990	5.997	6.004	6.011	6.018	6.025	6.032	6.039	6.046	6.053	6.060	6.067	6.074	6.081	6.088	6.095	6.102	6.109	6.116	6.123	6.130	6.137	6.144	6.151	6.158	6.165	6.172	6.179	6.186	6.193	6.200	6.207	6.214	6.221	6.228	6.235	6.242	6.249	6.256	6.263	6.270	6.277	6.284	6.291	6.298	6.305	6.312	6.319	6.326	6.333	6.340	6.347	6.354	6.361	6.368	6.375	6.382	6.389	6.396	6.403	6.410	6.417	6.424	6.431	6.438	6.445	6.452	6.459	6.466	6.473	6.480	6.487	6.494	6.501	6.508	6.515	6.522	6.529	6.536	6.543	6.550	6.557	6.564	6.571	6.578	6.585	6.592	6.599	6.606	6.613	6.620	6.627	6.634	6.641	6.648	6.655	6.662	6.669	6.676	6.683	6.690	6.697	6.704	6.711	6.718	6.725	6.732	6.739	6.746	6.753	6.760	6.767	6.774	6.781	6.788	6.795	6.802	6.809	6.816	6.823	6.830	6.837	6.844	6.851	6.858	6.865	6.872	6.879	6.886	6.893	6.900	6.907	6.914	6.921	6.928	6.935	6.942	6.949	6.956	6.963	6.970	6.977	6.984	6.991	6.998	7.005	7.012	7.019	7.026	7.033	7.040	7.047	7.054	7.061	7.068	7.075	7.082	7.089	7.096	7.103	7.110	7.117	7.124	7.131	7.138	7.145	7.152	7.159	7.166	7.173	7.180	7.187	7.194	7.201	7.208	7.215	7.222	7.229	7.236	7.243	7.250	7.257	7.264	7.271	7.278	7.285	7.292	7.299	7.306	7.313	7.320	7.327	7.334	7.341	7.348	7.355	7.362	7.369	7.376	7.383	7.390	7.397	7.404	7.411	7.418	7.425	7.432	7.439	7.446	7.453	7.460	7.467	7.474	7.481	7.488	7.495	7.502	7.509	7.516	7.523	7.530	7.537	7.544	7.551	7.558	7.565	7.572	7.579	7.586	7.593	7.600	7.607	7.614	7.621	7.628	7.635	7.642	7.649	7.656	7.663	7.670	7.677	7.684	7.691	7.698	7.705	7.712	7.719	7.726	7.733	7.740	7.747	7.754	7.761	7.768	7.775	7.782	7.789	7.796	7.803	7.810	7.817	7.824	7.831	7.838	7.845	7.852	7.859	7.866	7.873	7.880	7.887	7.894	7.901	7.908	7.915	7.922	7.929	7.936	7.943	7.950	7.957	7.964	7.971	7.978	7.985	7.992	7.999	8.006	8.013	8.020	8.027	8.034	8.041	8.048	8.055	8.062	8.069	8.076	8.083	8.090	8.097	8.104	8.111	8.118	8.125	8.132	8.139	8.146	8.153	8.160	8.167	8.174	8.181	8.188	8.195	8.202	8.209	8.216	8.223	8.230	8.237	8.244	8.251	8.258	8.265	8.272	8.279	8.286	8.293	8.300	8.307	8.314	8.321	8.328	8.335	8.342	8.349	8.356	8.363	8.370	8.377	8.384	8.391	8.398	8.405	8.412	8.419	8.426	8.433	8.440	8.447	8.454	8.461	8.468	8.475	8.482	8.489	8.496	8.503	8.510	8.517	8.524	8.531	8.538	8.545	8.552	8.559	8.566	8.573	8.580	8.587	8.594	8.601	8.608	8.615	8.622	8.629	8.636	8.643	8.650	8.657	8.664	8.671	8.678	8.685	8.692	8.699	8.706	8.713	8.720	8.727	8.734	8.741	8.748	8.755	8.762	8.769	8.776	8.783	8.790	8.797	8.804	8.811	8.818	8.825	8.832	8.839	8.846	8.853	8.860	8.867	8.874	8.881	8.888	8.895	8.902	8.909	8.916	8.923	8.930	8.937	8.944	8.951	8.958	8.965	8.972	8.979	8.986	8.993	9.000	9.007	9.014	9.021	9.028	9.035	9.042	9.049	9.056	9.063	9.070	9.077	9.084	9.091	9.098	9.105	9.112	9.119	9.126	9.133	9.140	9.147	9.154	9.161	9.168	9.175	9.182	9.189	9.196	9.203	9.210	9.217	9.224	9.231	9.238	9.245	9.252	9.259	9.266	9.273	9.280	9.287	9.294	9.301	9.308	9.315	9.322	9.329	9.336	9.343	9.350	9.357	9.364	9.371	9.378	9.385	9.392	9.399	9.406	9.413	9.420	9.427	9.434	9.441	9.448	9.455	9.462	9.469	9.476	9.483	9.490	9.497	9.504	9.511	9.518	9.525	9.532	9.539	9.546	9.553	9.560	9.567	9.574	9.581	9.588	9.595	9.602	9.609	9.616	9.623	9.630	9.637	9.644	9.651	9
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Projecting Lumen Maintenance (TM-21)

- LM-80 Testing Conducted by LED Manufacturers
- (2) Specified temperatures (55°C and 85°C)
- (1) Chosen temperature (70°C in this instance)
- Ambient, Physical, Electrical, and Thermal Characteristics



Projecting Lumen Maintenance

TM-21-11 Report Details	
Description of LED light source tested (manufacturer, model, catalog number)	
Sample Size	
Number of Failures	
DUT Drive Current used in the Test	mA
Test Duration	hours
Test Duration used for Projection	hour to hour
Tested Case Temperature	°C
α	
β	
Calculated $L_{70}(Dk)$	hours
Reported $L_{70}(Dk)$	hours

Projecting Lumen Maintenance (TM-21)

- Temperature measured through the TMP of the LED
- Through the use of equations, the TMP gives correlation to the junction temperature of the LED
- The actual junction is not accessible to be measured

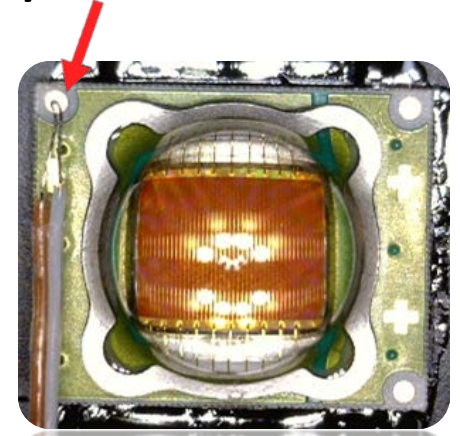
To calculate T_j from T_{pkg} , use the following formula:

$$T_j = Rth_{j-pkg} \times (P_{electrical} - P_{optical}) + T_{pkg}$$

To calculate T_j from T_{ref} , use the following formula:

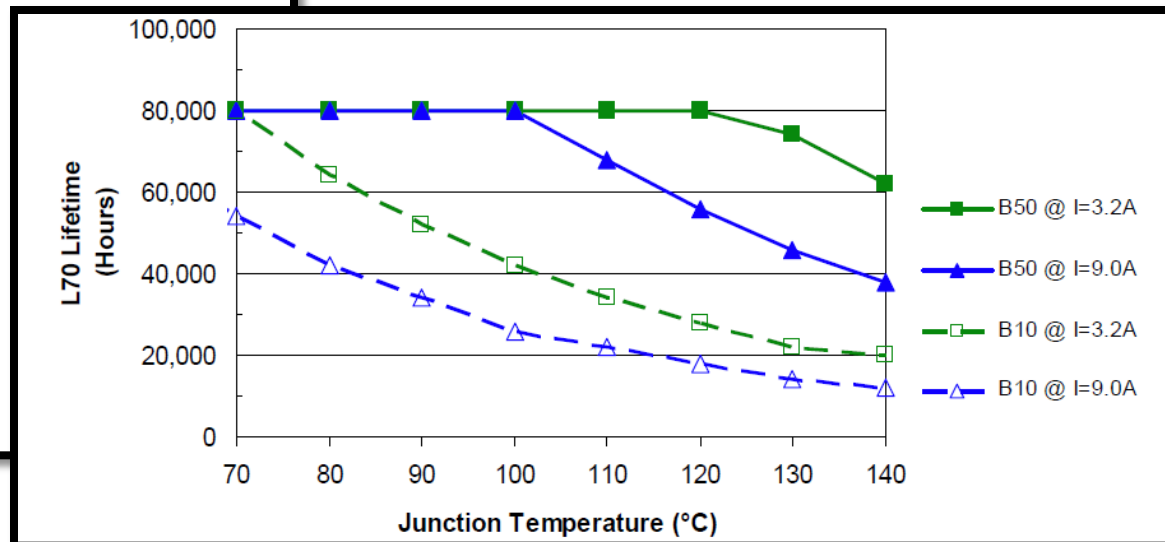
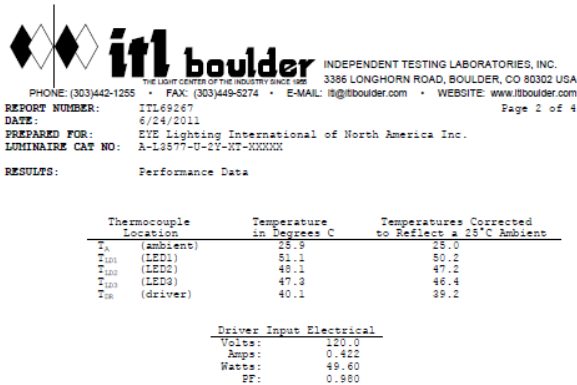
$$T_j = Rth_{j-ref} \times (P_{electrical} - P_{optical}) + T_{ref}$$

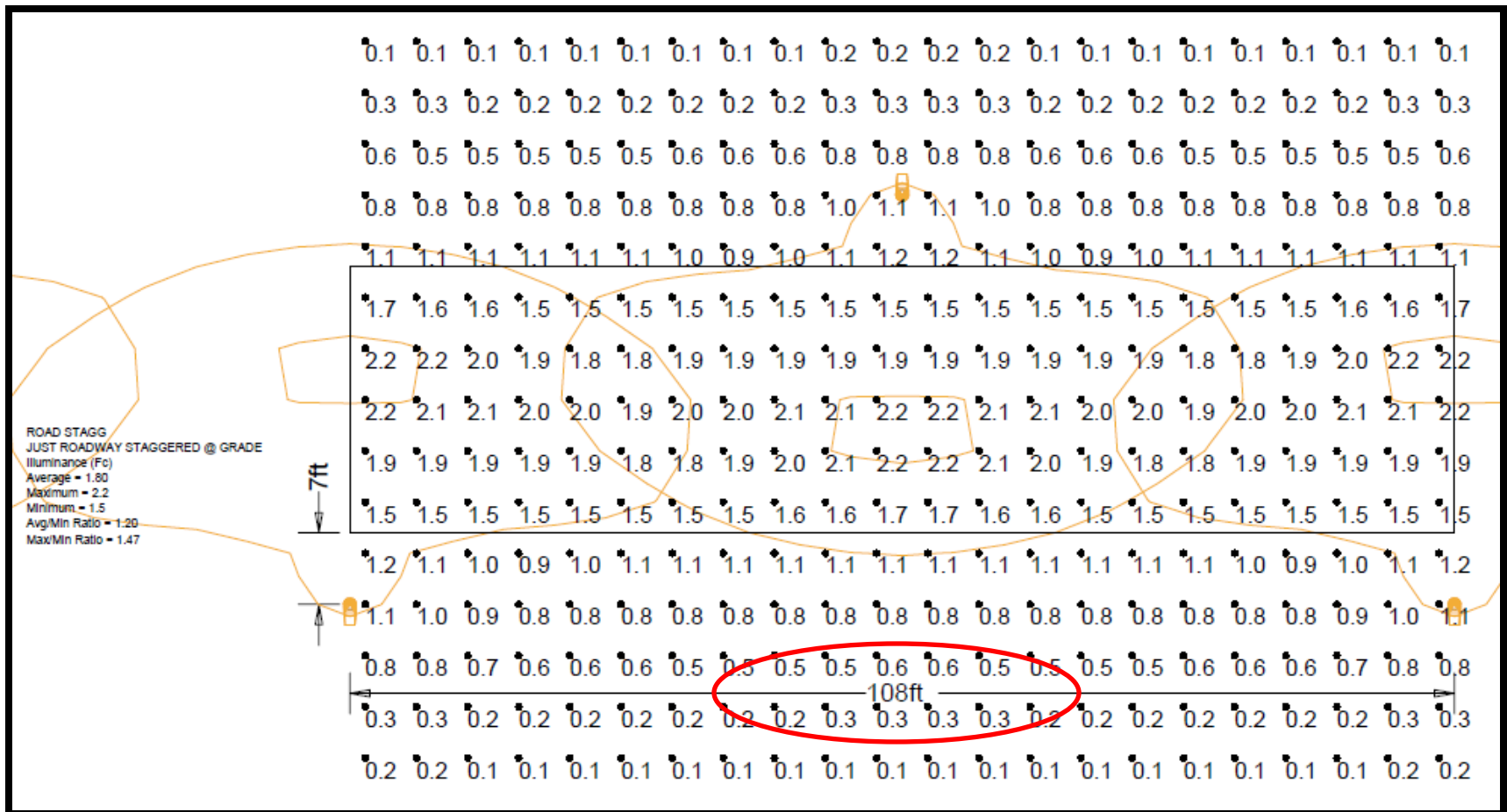
Temperature Measured



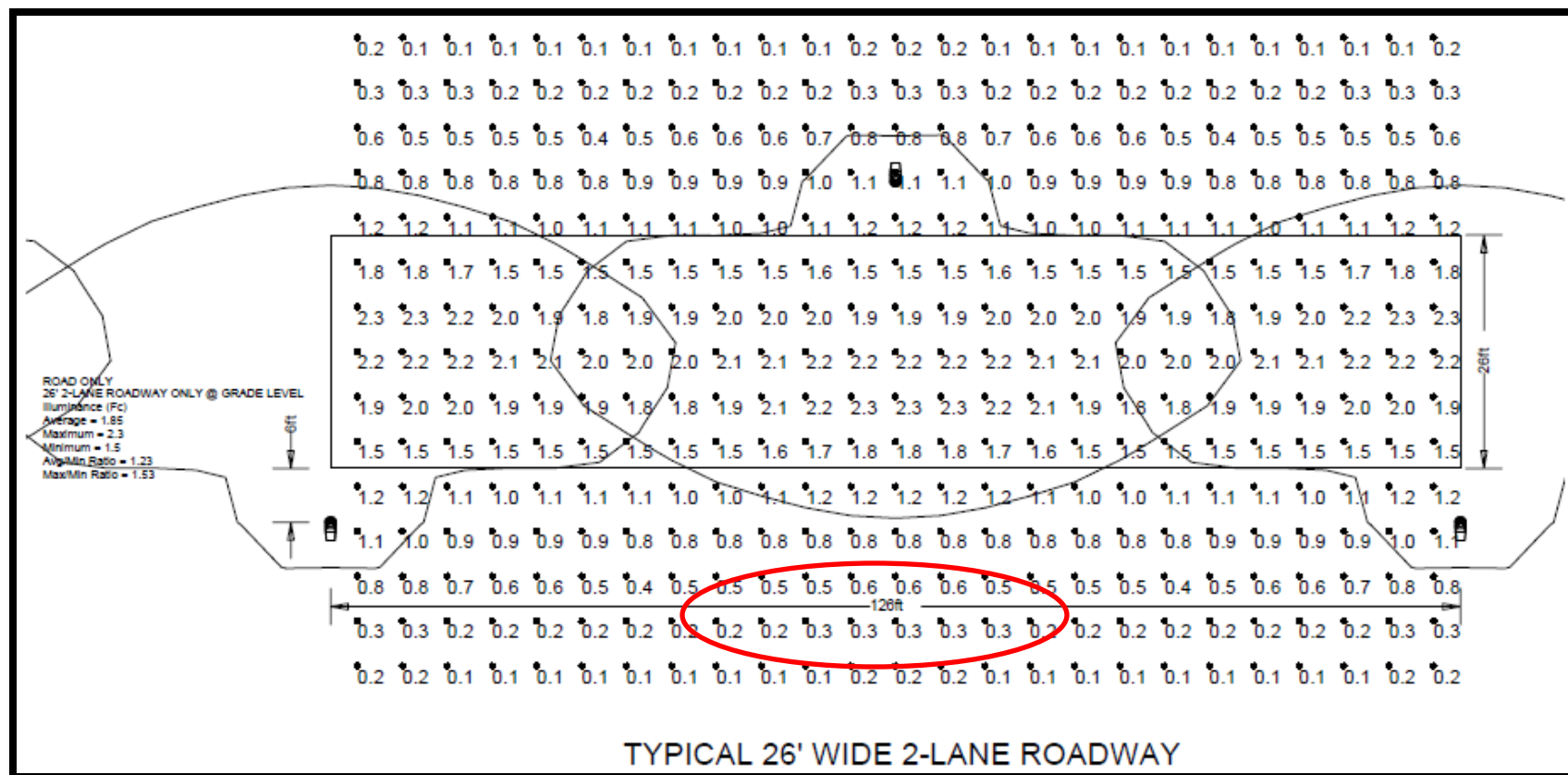
Luminaire Design Drives Reliability

- Lower Junction Temperatures = Greater Lumen Maintenance and Lower Probability of Failure





Lighting Layout with Higher LLD



18' Pole Spacing Gained by Adjusting Light Loss Factor

Outdoor Luminaire Certifications

1. Product Safety Listings / Certifications

- UL Listed, UL Recognized, UL Classified Marks
- CSA Certification Mark
- ETL Listed Mark



2. Performance Listings / Certifications

- Energy Star Listed
- DesignLights Consortium, DLC Approved
- International Dark-Sky Association, (IDA) Approved
- DOE Lighting Facts Label



3. Other Certification / Classification

- CE Mark
- IP Rated
- Vibration Tested



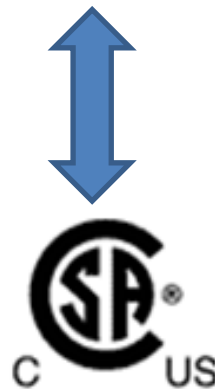
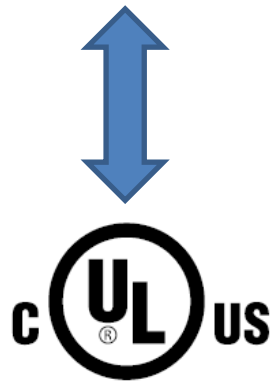
Product Listing Overview

In the United States and Canada these agencies are the ***accrediting bodies:***

- The U.S. Occupational Safety & Health Administration (OSHA)
- The American National Standards Institute (ANSI)
- The Standards Council of Canada (SCC)

Obtaining Product Listing

Obtaining a Luminaire Listing in the USA and Canada
Must Meet All NATIONAL STANDARD REQUIREMENTS
(For USA: UL Standards and for Canada: CSA Standards)



Certifying Bodies

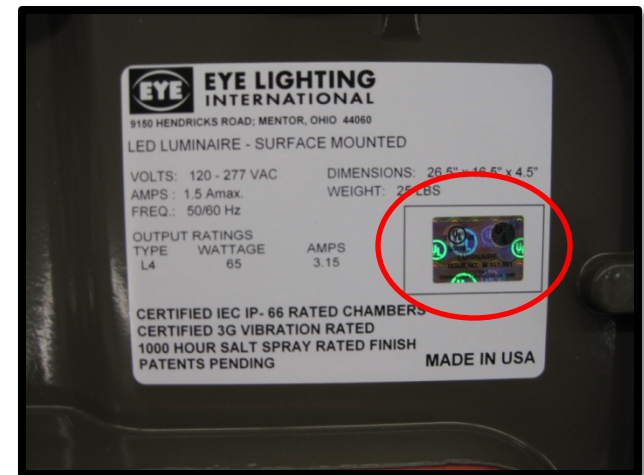
Market leaders for Luminaires in US and Canada

Electrical Safety & Compliance

- Certification Mark
- Manufacturer File Number
- Factory Audits are Periodically Completed by UL Field Representatives

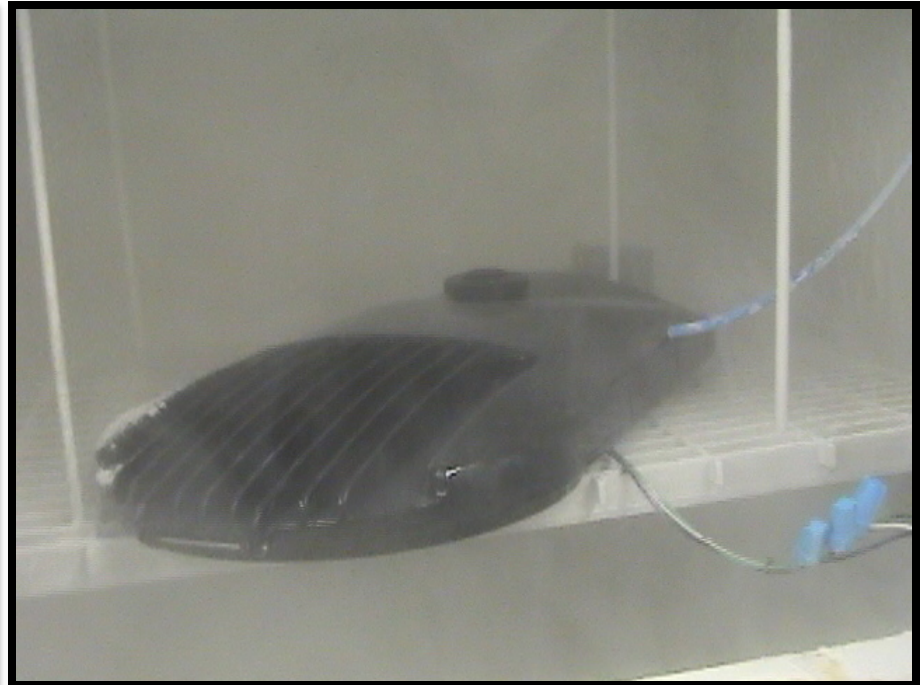
USA: UL Standards Written by Underwriters Laboratories Inc.

- *UL1598 Standard for Luminaires*
- *UL8750 LED Equipment for Use in Lighting Products*



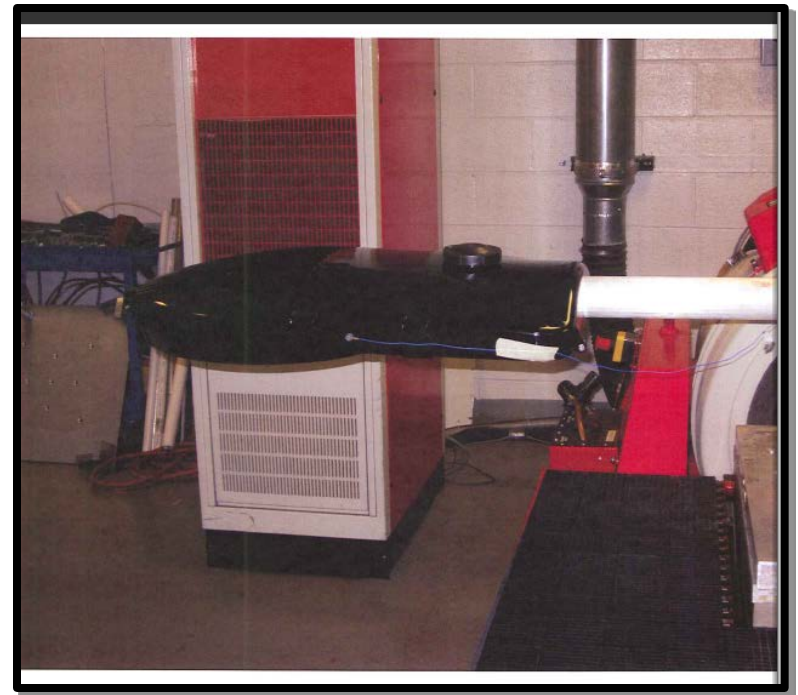
Ingress Protection

- Report showing results of IEC Luminaire test for ingress of dust, solid objects, and moisture
- IPXX Rating: Example - IP66 Rated (ANSI C136.25-2009)



Vibration Test for Roadway Luminaires

- American National Standards Institute (ANSI C136.31-2010)
- Bridge/Overpass Applications Require 3G Test Compliancy



Summary - Recommendations

- ✓ Request LM-79, In Situ Test Data from Manufacturers
- ✓ Request TM-21 Calculations from LM-80 and In Situ Results
- ✓ Compare Temperature Calculations to B50/B10 LED Curves
- ✓ Review Reports, Photos then Compare to Luminaire
- ✓ Request UL File #, Vibration Test Report, and IP Test Report
- ✓ Read all reports and make sure catalog number, drive current, energy consumption, lumen depreciation and performance data based on ambient are consistent with specification sheet
- ✓ Review Photometric Data and Perform Lighting Layout, Do NOT evaluate on Lumens-per-Watt Metric (Not Good Enough)
- ✓ Purchase from a Reputable Manufacturer (ISO, NVLAP, OSHA)

Thank you!

Teresa Bair, LC

Marketing Director, Luminares

EYE Lighting International - Mentor, Ohio

Teresa.Bair@EYELighting.com

www.eyelighting.com/LED