PHOTOMETRIC ANALYSIS OF LED LIGHTING SYSTEMS FOR LOW-TEMPERATURE, REACH-IN, REFRIGERATED DISPLAY CASES

ET 08.14 Report

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What's Inside...

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Southern California Edison's Design & Engineering Services (D&ES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program under internal project number ET 08.14. D&ES project manager Scott Mitchell conducted this technology evaluation with assistance from Vireak Ly and Nam Phan. For more information on this project, contact *Scott.Mitchell@sce.com*.

Disclaimer

ABBREVIATIONS AND ACRONYMS

AC	Alternating current
CCT	Correlated color temperature
CRI	Color rendering index
DC	Direct current
LED	Light emitting diode
RTTC	Refrigeration and Thermal Test Center
SCLTC	Southern California Lighting Technology Center
THD	Total harmonic distortion

EXECUTIVE SUMMARY

Seven different LED lighting systems were tested to determine how viable they are as energy efficient refrigerated display case lighting options. Color rendering index (CRI), correlated color temperature (CCT), luminous flux, lumen output, power consumption, power factor, and total harmonic distortion (THD) were examined in a laboratory setting. The goal was to verify manufacturers' stated product claims. The systems came from six different manufacturers and it was determined that half of all the manufacturers' product specifications and performance claims were inaccurate, with results varying by 10% or greater.

INTRODUCTION

A laboratory evaluation of three lighting technologies (T8 fluorescent, LED, fiber optic lighting) for low temperature refrigerated display cases was conducted at Southern California Edison's (SCEs) Refrigeration and Thermal Test Center (RTTC) in 2006. The test results were intended to be used to create a new rebate program for refrigerated display case lighting options. Since the time of the 2006 evaluations, many more manufacturers have entered the market with a wide range of claimed performance achievements.

In an effort to offer the same rebate program statewide, discussions were started with Pacific Gas & Electric and San Diego Gas & Electric to define qualifications for a rebateable LED product. Concerns were raised about the validity of product specifications provided by LED manufacturers, because many of their claims appeared to be based on performance of the LED chips rather than on the particular product configuration offered for sale. Additionally, there was a suspicion that some products were achieving low wattage operation by operating at a low power factor or high harmonic distortion.

This project verified the performance of several manufacturers' products through laboratory tests and compared the resulting data to the manufacturers' product specifications. The main areas of interest were color temperature, color rendering index lumen output, power consumption, power factor, and total harmonic distortion.

PRODUCTS TESTED

To ensure a proper comparison, 5-foot long LED systems intended for use in a three-door, reach-in, low temperature display case were purchased from six manufacturers. One manufacturer supplied its current offering plus a new product that was just being rolled out to market. A total of seven systems were tested.

All systems were comprised of two end fixtures and two center fixtures, see Figure 1. The lone exception was the Product B system, which used the same fixture in both the center and end positions. Product A was the only manufacturer driving the LEDs off direct AC power. All other systems used a driver that converted the AC line voltage to lower voltage DC for the LED fixtures. The product designations, system configurations, and power type are shown in Table 1.

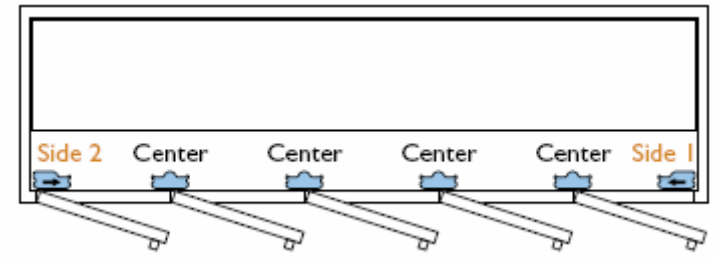

FIGURE 1. EXAMPLE OF MODULES PLACED IN A FIVE-DOOR FREEZER (TOP VIEW)

TABLE 1. TESTED PRODUCTS

PRODUCT	CONFIGURATION	POWER DELIVERED TO LED
A	2 End, 2 Center	AC
B	4 End/Center	DC
C	2 End, 2 Center	DC
D	2 End, 2 Center	DC
E	2 End, 2 Center	DC
F	2 End, 2 Center	DC
G	2 End, 2 Center	DC

For testing purposes, only half of each system was used (i.e., two fixtures for the Product B system and 1 End and 1 Center fixture for all other systems) and was connected as instructed to LED drivers, see Figure 2, provided by each manufacturer. This was the "test system."

FIGURE 2. LED POWER DRIVER 100W, 24VDC

TEST SETUP

Each test system was installed inside the SCLTC's light integrating sphere. While there is no industry standard test method for LED refrigerated display case fixtures, there are accepted best practices for evaluating specific parameters. The integrating sphere and peripheral equipment are capable of measuring all of the desired parameters mentioned below.

The integrating sphere measures the total light output of a fixture. The fixture under test is placed in the center of the integrating sphere. At one side of the sphere is a light meter that measures the light output of the lamp. A baffle is directly between the fixture and the light meter to prevent the meter from seeing any direct light from the lamp.

The entire inside of the sphere (including the baffle and mounting for the fixture) is coated with a highly reflective white paint that reflects all wavelengths equally. This allows for accurate measurements. Readings from the optical sensor are processed with the integrated software and displayed on the monitor.

FIGURE 3. PICTURE OF INTEGRATING SPHERE

The sphere was used to take spectral intensity measurements at intervals over the first 15 minutes of operation after the test system was powered on. The CRI, color temperature, and luminous flux at the end of the 15-minute period were recorded. The test system was powered through a power data logger that recorded instantaneous power, power factor, and THD in 1-second intervals for the duration of the 15-minute period.

Note: Fixtures were tested in the sphere at room temperature, not in a refrigerated environment.

RESULTS

Table 2 compares the manufacturer's claimed lumen output, color temperature, and CRI against those actually measured in the tests. Test results varying more than 10% from the manufacturer's claimed values are highlighted below. Lumen output was lower than claimed for all manufacturers. Color temperatures and CRIs varied slightly from claimed values, but for the most part deviations were within reason.

TABLE 2. COMPARISON OF TEST RESULTS WITH MANUFACTURER-CLAIMED PHOTOMETRIC PROPERTIES

PRODUCT	LUMINOUS FLUX (LUMENS)		COLOR TEMP (K)		COLOR RENDERING INDEX	
	MFR. CLAIM	TEST RESULTS	MFR. CLAIM	TEST RESULTS	MFR. CLAIM	TEST RESULTS
A	1478	1346	4200	3946	71	67.89
B	2400	2008	4100 ± 300	3964	75	67.46
C	---	2106	4200	4206	---	75.12
D	---	1737	4950-6250	4698	70	70.93
E	2070	1779	4100	4090	---	78.61
F	1920	1669	4800	5002	72	69.10
G	2250	1511	4100	4254	70	76.90

Table 3 presents test results of power factor, power, THD, and efficacy along with manufacturer's claimed values for power and efficacy. Test results varying more than 10% from the manufacturer's claimed values are highlighted below. Electric utilities prefer technologies with high power factors and low THD because low power factors and high THD can negatively affect electric transmission on the grid and may require more power production at the generating station to satisfy the load. The Product A system, which used AC power, showed the lowest power factor and highest THD. However, the DC Product B and Product C systems had significantly higher THD than the remaining four systems. Power measurements for three systems were actually lower than those claimed by the manufacturers by 1 to 2 W. On the other hand, those that understated their power demand did so by 2.5-9 W. All of the efficacy values were overstated by manufacturers. In most cases the discrepancy was greater than 10%, rising to a maximum of 31% for the Product G system.

TABLE 3. COMPARISON OF TEST RESULTS WITH MANUFACTURER-CLAIMED ELECTRICAL PROPERTIES

MANUFACTURER	POWER FACTOR	POWER (W)		THD (%)	EFFICACY (LUMEN/W)	
	TEST RESULTS	MFR. CLAIM	TEST RESULTS	TEST RESULTS	MFR. CLAIM	TEST RESULTS
A	0.9	16+8 = 24	23	42	61.6	58.5
B	0.95	*19+19 = 38*	*43*	22	*63.2*	*46.7*
C	0.93	29+17 = 46	49	34	---	43.0
D	0.99	*36+18 = 54*	*63*	11	---	27.6
E	0.98	35+17.5 = 52.5	51	11.6	*39.4*	*34.9*
F	0.98	41+20.5 = 61.5	64	13	*31.2*	*26.1*
G	0.99	29+14.5 = 43.5	42.5	12	*51.7*	*35.6*

CONCLUSION

These test results show that manufacturer's specifications for LED lighting systems in general, and for refrigerated display cases in particular, must be carefully scrutinized. Significant variations from claimed values were observed for some of the most critical performance metrics. Before any utility rebate programs are initiated for these products, performance specifications must be created and independent testing or another means of verification must be carried out to ensure that specific products meet the specifications. Additionally, program staff must evaluate all aspects of product performance (i.e., power factor and THD), not just reductions in power consumption to ensure that negative impacts aren't created at the grid level.

RECOMMENDATIONS

For inclusion in SCE's Energy Efficiency rebate programs, it is recommended that LED refrigerated display case products satisfy the minimum requirements set forth in Table 4.

Note: Some of the CRI and CCT requirements are subjective and may serve a particular need of the customer. As such, products that do not meet these requirements should be evaluated on a case-by-case basis.

TABLE 4. PROPOSED EE PROGRAM REQUIREMENTS FOR LED LIGHTING IN REFRIGERATED DISPLAY CASE

CATEGORY	REQUIREMENT
Application	Refrigerated Display Cases
Min Light Output	850 Lumen/door
Zonal Lumen Density	100% 0-90 deg
Minimum Luminaire Efficacy	30 L/W
Allowable CCTs	< 6500K
Min CRI	75
Minimum L70 Lifetime	35,000 hrs
Mfr Warranty	5 yrs
Off State Power	0 W
Power Factor	> 0.9
THD	< 20%

APPENDIX A. SPECTRAL DISTRIBUTION PLOTS FOR ALL SYSTEMS

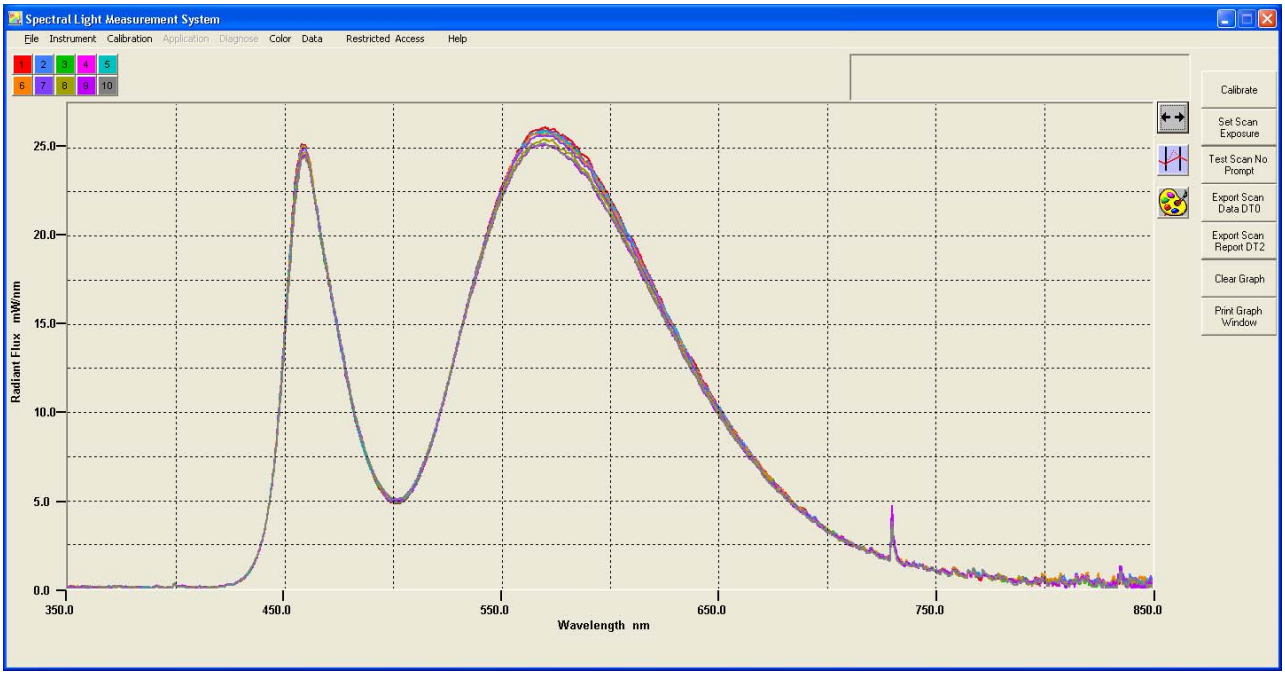

FIGURE 4. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT A

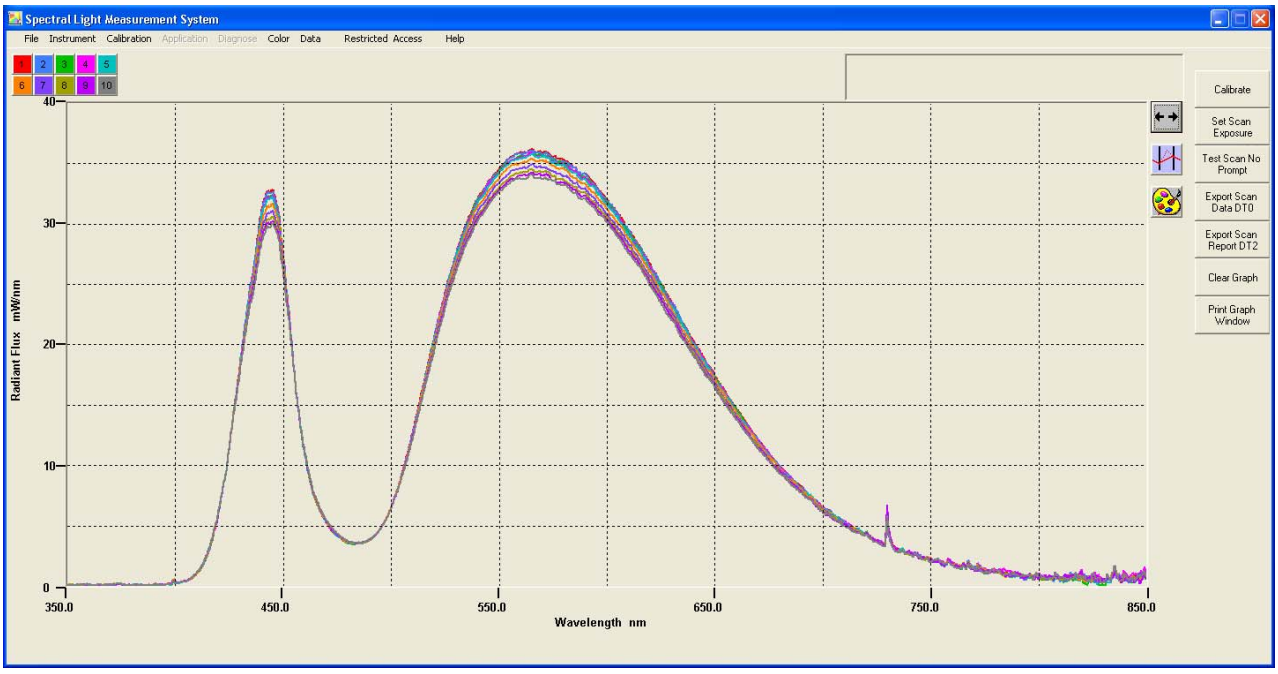

FIGURE 5. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT B

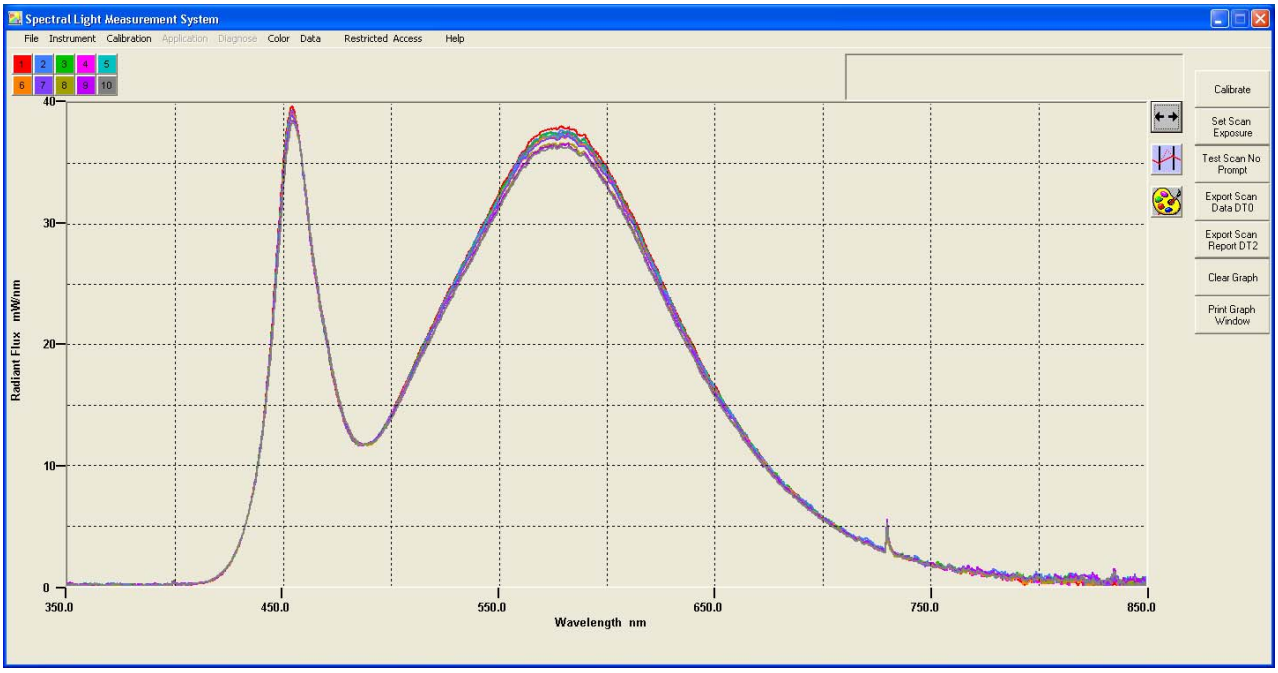

FIGURE 6. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT C

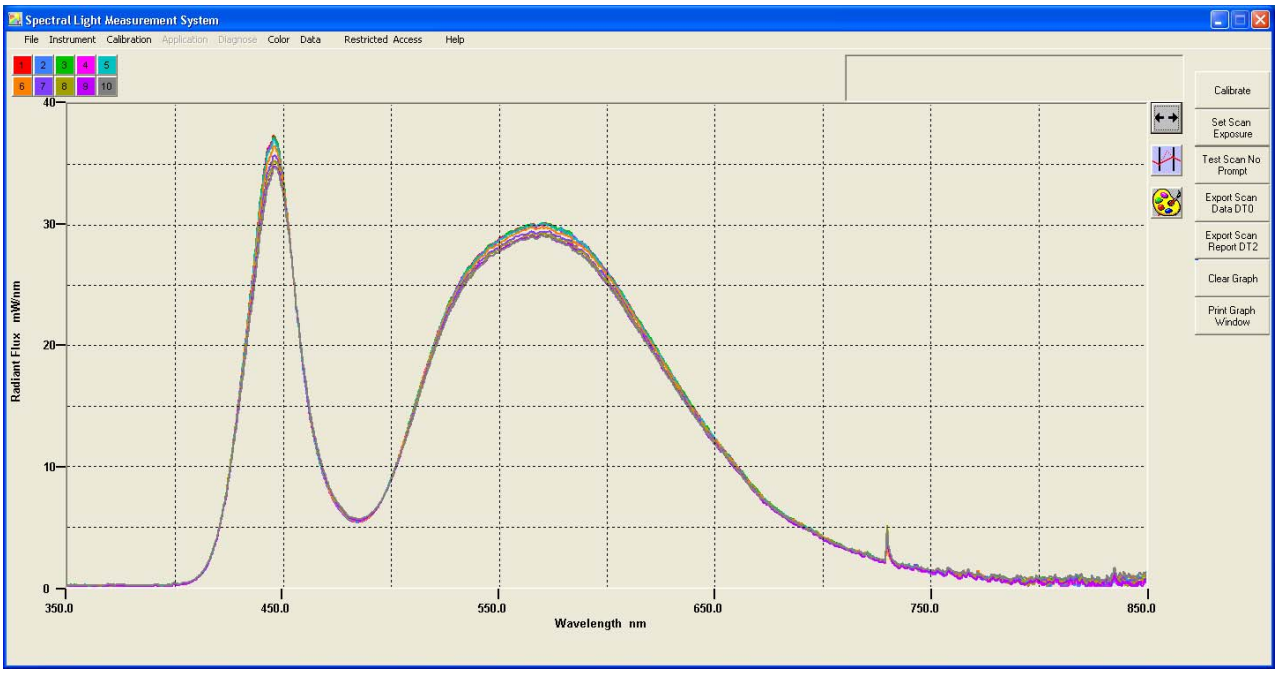

FIGURE 7. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT D

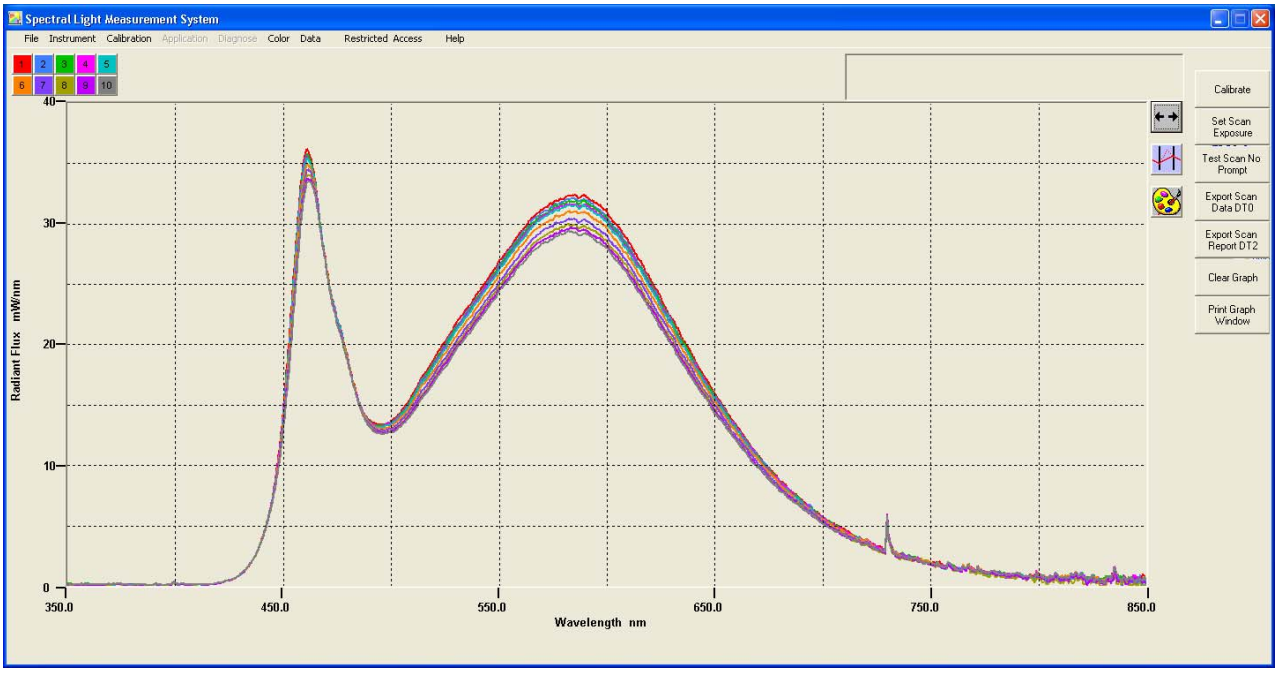

FIGURE 8. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT E

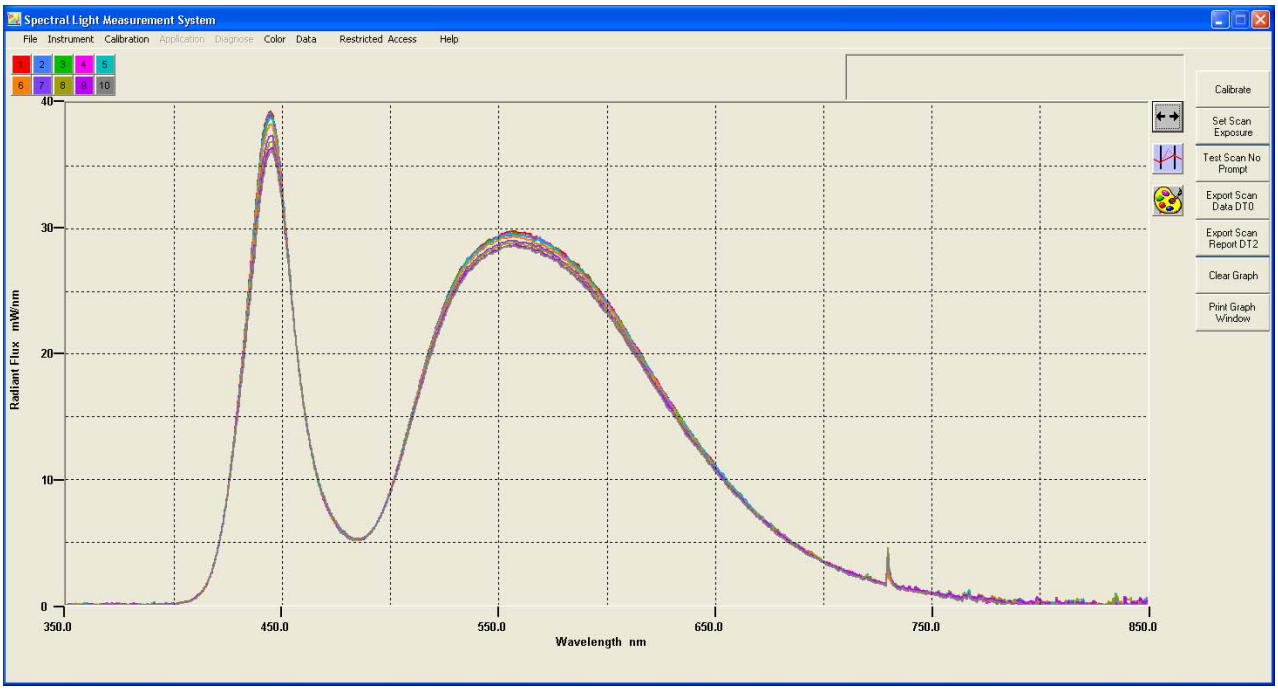

FIGURE 9. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT F

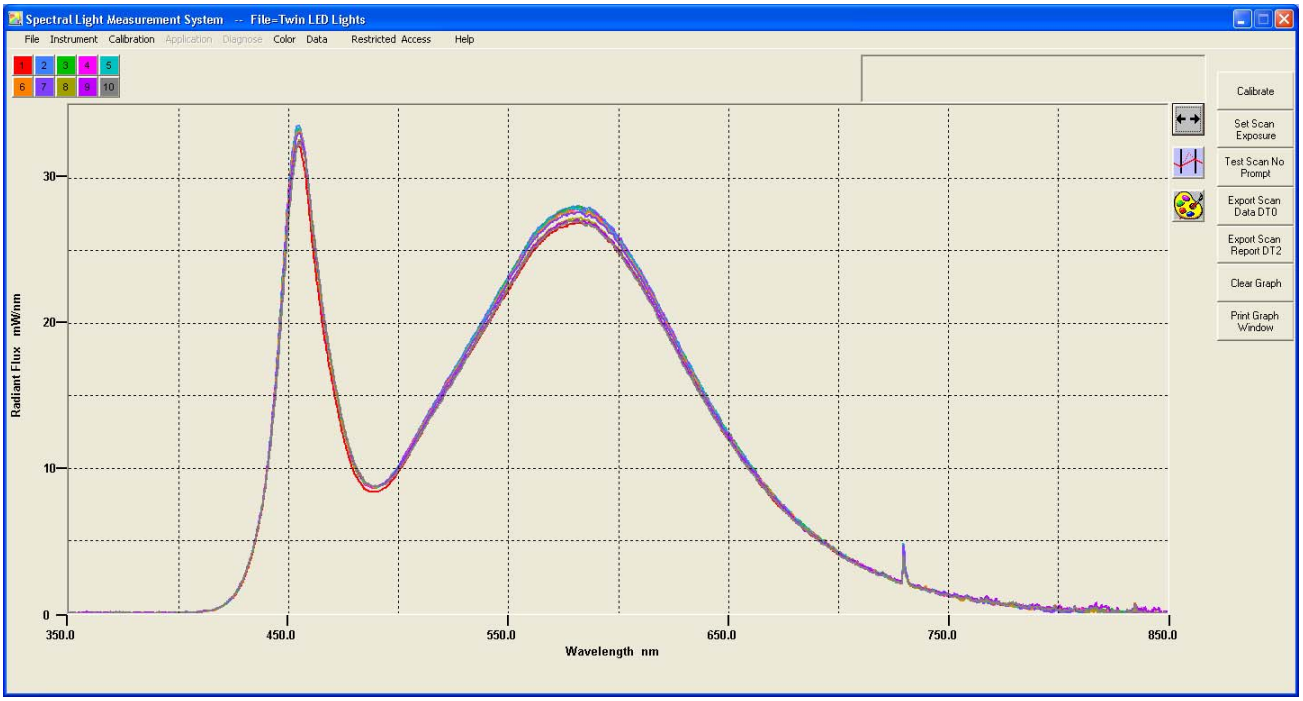

FIGURE 10. SPECTRAL DISTRIBUTION PLOT FOR PRODUCT G

APPENDIX B. PRODUCT SPECIFICATION SHEETS


Adobe Acrobat Document

Simple Tube Specification – Revision 4


Adobe Acrobat Document

LED Display Light Specifications


Adobe Acrobat Document

True Color Freezer Case Brochure


Adobe Acrobat Document

Affinium LED Freezer Lighting


Adobe Acrobat Document

LED Power – Refrigerator & Freezer Case Lighting


Adobe Acrobat Document

GE Lumination RDL Gen2 Series


Adobe Acrobat Document

GE Lumination RV30 Series