DOT/FAA/TC-17/69

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Development of Infrared Specifications for Night Vision Goggle-Compatible Light-Emitting Diode L-810 and L-864 Obstruction Light Fixtures

December 2017

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.
DOT/FAA/TC-17/69

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
DEVELOPMENT OF INFRARED SPECIFICATIONS FOR NIGHT VISION GOGGLE-COMPATIBLE LIGHT-EMITTING DIODE L-810 AND L-864 OBSTRUCTION LIGHT FIXTURES

5. Report Date
December 2017

6. Performing Organization Code
ANG-E261

7. Author(s)
*Canter, Garrison; **Freyssinier, Jean Paul; ***DiPilato, Michael; ***Gallagher, Donald

8. Performing Organization Report No.

9. Performing Organization Name and Address

*CSRA
1201 New Road
Suite 242
Linwood, NJ 08221

**Rensselaer Polytechnic Institute
Lighting Research Center
21 Union Street
Troy, NY 12180

***Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Airport Technology R&D Branch
Atlantic City International Airport
Atlantic City, NJ 08405

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFACT-15-D-00007

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Aviation Administration
Airport Engineering Division
800 Independence Ave. SW
Washington, DC 20591

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code
AAS-100

15. Supplementary Notes
The FAA Airport Technology Research & Development Branch COR was Michael DiPilato and Donald Gallagher.

16. Abstract

After extensive use by military aviators, night vision goggles (NVG) are now increasingly utilized by civilian pilots to conduct search-and-rescue, emergency medical transport, and other flight operations. However, with the use of light-emitting diodes (LED) in place of incandescent fixtures for obstruction lighting, the Federal Aviation Administration (FAA) has found that some pilots using NVGs are unable to see red LED obstruction lights because the light generated falls outside the visible spectrum of certain classes of NVG lens filters.

In response, the FAA Office of Airport Safety and Standards–Airport Engineering Division tasked the FAA's Airport Technology Research and Development Branch (ATR) with conducting research to determine performance specifications (output wavelength, minimum vertical beam spread, and minimum radiant intensity) for infrared (IR) emitters to be incorporated into L-810 and L-864 LED obstruction light fixtures to ensure compatibility with NVGs currently in use.

Researchers from ATR, Rensselaer Polytechnic Institute, and CSRA Inc. conducted this research effort in three phases. Phase 1 consisted of a literature review to determine suitable IR wavelength and minimum vertical beam spread specifications. Phase 2 consisted of conducting laboratory testing of commercially available incandescent and LEDs with IR L-810 and L-864 fixtures. Phase 3 consisted of conducting flight evaluations to determine the minimum level of radiant intensity needed for pilots to acquire the obstruction lights.

Based on the research conducted, the following specifications are recommended for the L-810 and L-864 fixtures:

1) L-810: A nominal IR output wavelength of 800-900 nanometers (nm); a minimum vertical beam spread of 10° with a center between +4° and +20° at all radials throughout 360° (same as the FAA requirements for visible light); and a minimum IR radiant intensity of 4 milliwatt per steradian (mW/sr).

2) L-864: A nominal IR output wavelength of 800-900 nm; a minimum vertical beam spread of 3° at all radials throughout 360° (same as the FAA requirements for visible light); and a minimum IR radiant intensity of 246 mW/sr.

17. Key Words
Night vision goggle, Obstruction lighting, L-810, L-864, Infrared

18. Distribution Statement
This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
114

22. Price

ACKNOWLEDGEMENTS

The authors of this report would like to thank personnel from CSRA Inc. and Rensselaer Polytechnic Institute's (RPI) Lighting Research Center (LRC) for providing technical support during this research effort.

Jim Newman of CSRA Inc. provided technical support during all phases of this research effort (literature review, laboratory testing, and flight evaluations).

The following individuals from RPI's LRC provided technical support during phase 2 of this research effort (laboratory testing): Nadarajah Narendran (Principle Investigator), Jean Paul Freyssinier, Andrew Bierman, Martin Overington, Yi-wei Liu, and Howard Ohlhous.

The authors would also like to thank the Delaware River and Bay Authority and personnel from Cape May County Airport for providing a test location and coordinating the closure of the FAA's Research Taxiway (Taxiway C) for this research effort.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AC	Advisory Circular
AGL	Above ground level
ANVIS	Aviator's Night Vision Imaging System
ATR	Airport Technology Research and Development Branch
cd	Candela
CFR	Code of Federal Regulations
DUT	Device under test
F	Flashing
FAA	Federal Aviation Administration
FPM	Flashes per minute
InFO	Information for Operators
IR	Infrared
LED	Light-emitting diode
LRC	Lighting Research Center
MCP	Microchannel plate
MOD	Ministry of Defense
mW/sr	Milliwatt per steradian
nm	Nanometers
NVG	Night vision goggle
NVIS	Night vision imaging system
RPI	Rensselaer Polytechnic Institute
SAFO	Safety Alert for Operators
SM	Statute miles
SPD	Spectral power distribution
SRA	Safety risk assessment
SSI	Significant safety issue
UK	United Kingdom
U.S.	United States
VFR	Visual flight rules
VIS	Visible (pertaining to spectral range)
VMC	Visual meteorological conditions
WWD	Cape May County Airport

EXECUTIVE SUMMARY

After extensive use by military aviators, night vision goggles (NVG) are now increasingly utilized by civilian pilots to conduct search-and-rescue, emergency medical transport, and other flight operations. However, the Federal Aviation Administration (FAA) has found that with the gradual replacement of incandescent obstruction light fixtures with light-emitting diode (LED) light fixtures, some pilots using NVGs are unable to see red LED obstruction lights because the light generated falls outside the visible spectrum of certain classes of NVG lens filters.

In response, the FAA Office of Airport Safety and Standards–Airport Engineering Division tasked the FAA's Airport Technology Research and Development Branch (ATR) with conducting research to determine performance specifications (output wavelength, minimum vertical beam spread, and minimum radiant intensity) for infrared (IR) emitters to be incorporated into L-810 and L-864 LED obstruction light fixtures to ensure compatibility with NVGs currently in use.

Researchers from ATR, Rensselaer Polytechnic Institute, and CSRA Inc. conducted this research effort in three phases. Phase 1 consisted of a literature review to determine suitable IR wavelength and minimum vertical beam spread specifications. Phase 2 consisted of conducting laboratory testing on a variety of commercially available incandescent and LED with IR L-810 and L-864 fixtures. Phase 3 consisted of conducting flight evaluations to determine the minimum level of radiant intensity needed for pilots to acquire the obstruction lights when using NVGs at the distance required with the unaided eye.

Based on the research conducted, a nominal IR output wavelength range of 800-900 nanometers is recommended. This range coincides with the peak spectral response range of NVGs, ensuring the fixtures will be visible by all current NVGs regardless of the class of objective lens filter used.

For LED versions of both the L-810 and L-864 IR fixtures, it is recommended that the minimum vertical beam spread of the IR emissions meet the existing FAA requirements in Advisory Circular (AC) 150/5345-43, "Specification for Obstruction Lighting Equipment," for the photometric beam spread and distribution of the visible light. Therefore, it is recommended that the L-810 (L) IR fixture have a minimum 10° IR vertical beam spread, with the center between +4° and +20° at all radials throughout 360°. Likewise, it is recommended that the L-864 (L) have a 3° minimum vertical IR beam spread at all radials throughout 360°.

A minimum IR radiant intensity of 4 milliwatt per steradian (mW/sr) is recommended for L-810 (L) IR fixtures and 246 mW/sr for the L-864 (L) IR fixtures. Based on the results of the flight evaluations conducted, it was determined that an L-810(L) IR fixture with a radiant intensity of 4 mW/sr could be acquired by a pilot at the minimum acquisition distance of 1.4 statute miles. To produce a sufficiently differentiated visual appearance between the L-810 and L-864 fixtures when viewed with NVGs, the proportional difference between the minimum candela (cd) requirements for the L-810 and the L-864 was used. The L-810 minimum is 32.5 cd

and the L-864 peak effective intensity is 2000 cd, which is equivalent to what would be seen with the unaided eye. Therefore, the L-864 intensity equates to approximately 61.5 times the intensity of the L-810. Based on an L-810 intensity of 4 mW/sr, a proportional IR intensity for the L-864 would equate to 246 mW/sr.

1. INTRODUCTION.

The Federal Aviation Administration (FAA) Office of Airport Safety and Standards–Airport Engineering Division tasked the FAA's Airport Technology Research and Development Branch (ATR) to determine performance specifications (output wavelength, minimum vertical beam spread, and minimum infrared (IR) radiant intensity) for IR emitters to be incorporated into L-810 and L-864 light-emitting diode (LED) obstruction light fixtures, to ensure compatibility with night vision goggles (NVG) currently in use. This report details the results of this research effort.

1.1 BACKGROUND.

After extensive use by military aviators, NVGs are now increasingly utilized by civilian pilots to conduct search-and-rescue, emergency medical transport, and other flight operations. NVGs function by amplifying ambient light, allowing the pilot (wearer) to better view objects and terrain in dark or overcast conditions. NVGs can enhance the safety of flights at night by allowing the pilot to see terrain and other potential hazards and helping pilots maintain spatial orientation and general situational awareness [1].

In 2009, the FAA issued Safety Alert for Operators (SAFO) 09007 [2]. This SAFO notified pilots that some red LED obstruction lights may not be visible when using NVGs. According to this alert, some NVG filters can prevent a visual response to the limited visual emissions of these lights. Therefore, SAFO 09007 advised the following: "Crews that fly using NVGs are warned to use extra caution when flying near obstacle areas and to report any hazardous sites to the nearest Flight Standards District Office (FSDO) or the appropriate military Safety Officer." [2]

In 2011, the FAA issued Information for Operators (InFO) 11004 [3]. This document informed pilots that certain LED lighting could not be less visible to pilots using NVG. It warned that, "Random installations of LED lights are occurring at airports and on obstacles worldwide. Certain LED lights fall outside the combined visible and near-infrared spectrum of NVG." [3] Furthermore, InFO 110004 states, "Dramatic image changes may occur when maneuvering from a surface marked with incandescent lights to a surface marked with LED lights, additionally, LED obstacle beacons may be more difficult to identify." [3]

In December 2015, an FAA safety risk assessment (SRA) panel met to conduct a preliminary hazard analysis of potential hazards related to the use of LED lighting technology across the National Airspace System [4]. Based on the risk assessment, obstruction lighting incompatibility with NVGs was identified as a Significant Safety Issue (SSI), because the worst possible outcome would be a collision with an obstacle and loss of aircraft. The SRA team recommended conducting further research to investigate and resolve this SSI [4].

1.2 PURPOSE.

The purpose of this research effort was to investigate IR spectrum issues preventing the acquisition of LED obstruction light fixtures by pilots using NVGs and to recommend appropriate IR specifications to resolve these issues.

1.3 OBJECTIVES.

The objectives of this report are to describe and summarize findings from this research effort and recommend the following IR performance specifications for use in the LED obstruction light fixtures:

- Output wavelength for the IR emitters
- Minimum vertical beam spread
- Minimum IR radiant intensity output

1.4 RELATED DOCUMENTATION.

The following documents are related to this research effort:

- Engineering Brief (EB) 67, "Light Sources Other Than Incandescent and Xenon for Airport and Obstruction Lighting Fixtures"

- Title 14 Code of Federal Regulations (CFR) Part 91.155, "Basic Visual Flight Rules (VFR) Weather Minimums"

1.5 RESEARCH APPROACH.

A team of researchers from ATR, Rensselaer Polytechnic Institute (RPI), and CSRA Inc. was assembled to conduct this research, which was performed in three phases. Phase 1 consisted of a literature review to determine suitable IR wavelength and minimum vertical beam spread specifications. Phase 2 consisted of conducting laboratory testing of a variety of commercially available incandescent and LED with IR L-810 and L-864 fixtures. Phase 3 consisted of conducting flight evaluations using ATR subjects to determine the minimum level of radiant intensity needed for pilots to acquire the obstruction lights.

This research effort was led by ATR researchers, who were supported by subject matter experts (researchers) from RPI and CSRA. CSRA researchers supported all three phases of this effort, and RPI researchers supported Phase 2.

2. PHASE 1: LITERATURE REVIEW.

For the first phase of this research effort, ATR researchers conducted a review of literature relevant to the subject matter. ATR researchers examined existing FAA standards and specifications for obstruction light fixtures, as well as technical documentation regarding the underlying functional principles of NVGs and the effects of NVG filters on visibility of lighting. Finally, to gain a better understanding of the approaches taken by other governments to ensure obstruction light compatibility with NVGs, ATR researchers reviewed current international specifications for IR obstruction lights.

Sections 2.1 through 2.4 contain the results and findings of this literature review.

2.1 CURRENT FAA OBSTRUCTION LIGHTING SPECIFICATIONS.

The FAA currently has in place extensive standards and recommended practices for the marking and lighting of obstructions. Generally, obstructions include structures with heights of 200 ft above ground level (AGL) or greater, and structures on, or in the vicinity of, airports. These standards, which are based on decades of safety research conducted by the FAA, can be found in two primary documents:

- Advisory Circular (AC) 150/5345-43, "Specification for Obstruction Lighting Equipment" [5]: This document specifies the lighting equipment and fixtures that should be used for lighting obstructions. The color of the light, flash rate, intensity, and various electrical and performance requirements are addressed in this document.

- AC 70/7460-1, "Obstruction Marking and Lighting" [6]: This document provides FAA requirements for lighting and marking man-made structures as obstructions.

AC 150/5345-43 identifies obstruction light types with "L" number designations, as shown in table 1. Because pilots have reported issues with viewing these fixtures through NVGs, this report will focus on the L-810, L-810 flashing (F), and L-864, which are marked red in table 1. These three red fixtures are used for nighttime lighting of obstructions. Although the L-885 fixture is also a red light fixture, it was not included in the research scope. LED versions of these fixtures are denoted by an "L" in parentheses following the fixture type (e.g., L-864 (L)).

Table 1. The FAA Obstruction Fixture Light Fixture Types [5]

Type	Description
L-810	Steady-burning red obstruction light
L-810 (F)	Flashing red obstruction light, 30 flashes per minute (FPM)
L-856	High-intensity flashing white obstruction light, 40 FPM
L-857	High-intensity flashing white obstruction light, 60 FPM
L-864	Flashing red obstruction light, 30 FPM
L-865	Medium-intensity flashing white obstruction light, 40 FPM
L-866	Medium-intensity flashing white obstruction light, 60 FPM
L-885	Flashing red obstruction light, 60 FPM

2.1.1 The L-810 and L-864 Fixture Specifications.

Red aviation obstruction lights are used to increase conspicuity of obstructions during nighttime. The red obstruction light system for non-catenary structures is composed of flashing omnidirectional lights (L-864) and/or steady-burning or flashing (L-810) lights. Recommendations on lighting structures can vary, depending on the obstruction height, as specified in AC 70/7460-1.

Section 3.4.1.2 of AC 150/5345-43 specifies the minimum beam spread and intensity specifications for the L-810 obstruction light fixture, as described below. Note that no certified L-810 (F) fixtures are currently offered by the industry at this time.

The center of the vertical beam spread must be between +4 and +20 degrees. With a minimum vertical beam spread of 10 degrees and at all radials throughout 360 degrees, there must be a minimum intensity of 32.5 candela.

Flashing L-810 (F) Light Unit.

1. The light unit must flash simultaneously with the L-864 flashing light at a rate of 30 flashes per minute (FPM) (± 3 FPM).
2. The center of the vertical beam spread must be between +4 and +20 degrees.

With a minimum vertical beam spread of 10 degrees and at all radials throughout 360 degrees, there must be a minimum intensity of 32.5 candelas equivalent to steady burning mode. The minimum effective intensity will be half of this value, but is not calculated for this application. [5]

The L-864 is a flashing, omnidirectional light fixture used to light a variety of obstructions, such as towers, chimneys, and wind turbines. The L-864 is required to be installed at heights above 150 ft AGL. The beam spread and intensity specifications for the L-864 red flashing obstruction light fixture are as follows:

> At all radials throughout the omnidirectional 360 degrees, there must be a peak effective intensity of 2,000 ±25% candela. There must also be a minimum effective intensity of 750 candela throughout a minimum vertical beam spread of 3 degrees. Multiple light units may be used to achieve a horizontal coverage of 360 degrees. [5]

As shown in table 1, the flash rate for the L-864 fixture is required to be 30 FPM.

2.1.2 Obstruction Light Fixture Visibility Requirements.

Appendix B of AC 70/7460-1 outlines the rationale determining the current fixture intensity specifications [6]. As stated in this AC, the guidelines are based on "Title 14 Code of Federal Regulations (CFR) Part 91, General Operating and Flight Rules, sections 91.117 (Aircraft speed), 91.119 (Minimum safe altitudes: General), and 91.155 (Basic VFR weather minimums). These specify contain aircraft speed restrictions, minimum safe altitudes, and basic VFR weather minimums for governing the operation of aircraft, including helicopters, within the United States." [6]

AC 70/7460-1 states the following with respect to obstruction avoidance safety margins:

> A pilot in an aircraft flying at a speed of 165 kt (190 mph/306 kph) or less should be able to see obstruction lights in sufficient time to avoid the structure by at least 2,000 feet (610 m) horizontally under all conditions of operation, provided the pilot is operating in accordance with 14 CFR Part 91. Pilots operating 250 kt (288 mph/463 kph) aircraft should be able to see the obstruction lights unless the weather deteriorates to 1 statute mile (1.6 km) visibility at night, during which

time period 2,000 candelas enables the light to be seen at 1.2 statute miles (SM) (1.9 km). [6]

AC 70/7460-1 notes that the 2000-ft avoidance distance was intended to protect aircraft collision with guy wires utilized on 2000-ft structures:

> The guy wires at a 45-degree angle would be at a distance of 1,500 feet from the structure at a 500-foot elevation. Since the aircraft is to be 500 feet clear of obstacles (the guy wire), the distance of avoidance from the structure is 1,500 + 500 = 2,000 feet. [6]

Figure 1 shows an illustration of this obstruction light acquisition scenario.

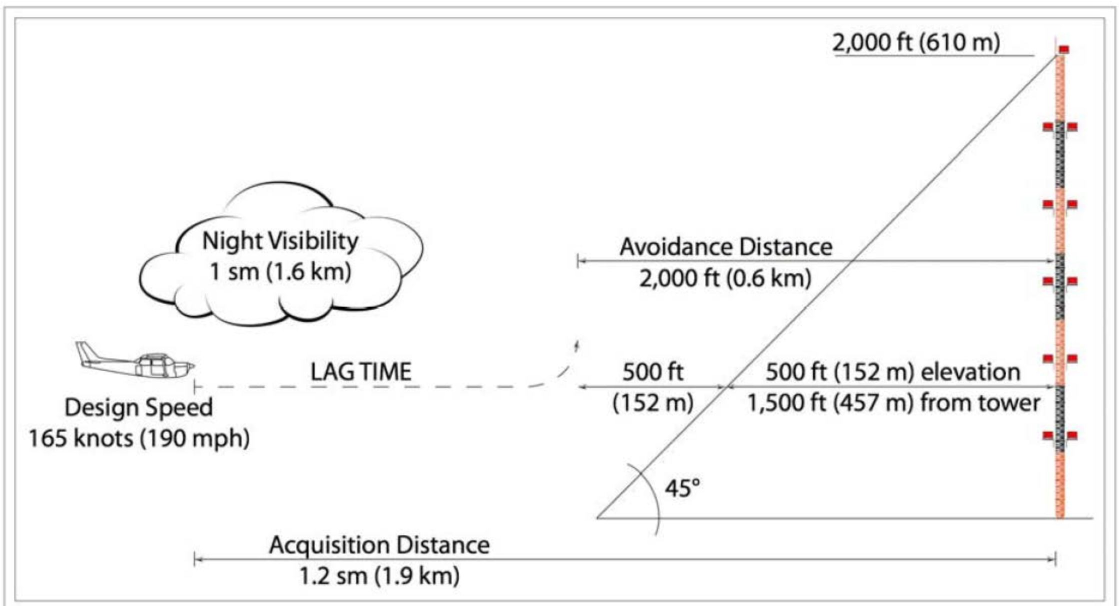


Figure 1. Acquisition Distance Calculation [6]

Table 2, which is excerpted from AC 70/7460-1 [6], shows the distances that various intensity lights are visible under 1 and 3 SM meteorological visibilities. It was determined that the LED-IR obstruction light acquisition and avoidance distances for pilots using NVG should meet or exceed the nighttime acquisition distances of pilots without the aid of NVG. The L-810 light fixture has an intensity of 32.5 cd, and the L-864 has a peak intensity 2000 cd. Thus, as shown in red in table 2, an L-810 fixture with an IR emitter should be acquired at a minimum distance of 1.4 SM, and an L-864 fixture should be acquired at a minimum distance of 3.1 SM with meteorological visibility of 3 SM.

Table 2. Light Fixture Acquisition Ranges and Intensities [6]

Time Period	Meteorological Visibility Statute Miles	Distance Statute Miles	Intensity Candelas
Night		2.9 (4.7 km)	1,500 (±25%)
	3 (4.8 km)	3.1 (4.9 km)	2,000 (±25%)
		1.4 (2.2 km)	32
Day		1.5 (2.4 km)	200,000
	1 (1.6 km)	1.4 (2.2 km)	100,000
		1.0 (1.6 km)	20,000 (±25%)
Day		3.0 (4.8 km)	200,000
	3 (4.8 km)	2.7 (4.3 km)	100,000
		1.8 (2.9 km)	20,000 (±25%)
Twilight	1 (1.6 km)	1.0 (1.6 km) to 1.5 (2.4 km)	20,000 (±25%)
Twilight	3 (4.8 km)	1.8 (2.9 km) to 4.2 (6.7 km)	20,000 (±25%)

2.2 OVERVIEW OF NVG TECHNOLOGY.

NVGs are devices that can provide pilots assistance to identify visual cues at night and to maintain situational awareness. NVGs are one component of a night vision imaging system (NVIS). A complete NVIS consists of an NVG-compatible lighting system, trained flight and maintenance crews, and an FAA-approved maintenance program [1]. NVGs in aviation are designed to be used for night flying, primarily during visual meteorological conditions (VMC). They are mounted in a binocular form on a pilot's helmet.

2.2.1 Principles of NVG Operation.

NVGs amplify ambient light through a process of image intensification, allowing the wearer to better view objects and terrain in dark or overcast conditions [7]. The resulting image that the pilot sees is a monochromatic view of the outside environment, as shown in figure 2.

Figure 2. View From an NVG

NVGs consist of three main components: the eyepiece lenses, the objective lenses, and the image intensifier tubes, as shown in figure 3 [7]. T he design and configuration of these components determine the overall performance of the NVGs. T he image intensifier tubes generally are the most critical component determining image clarity, though the eyepiece and objective lenses can also affect performance [8].

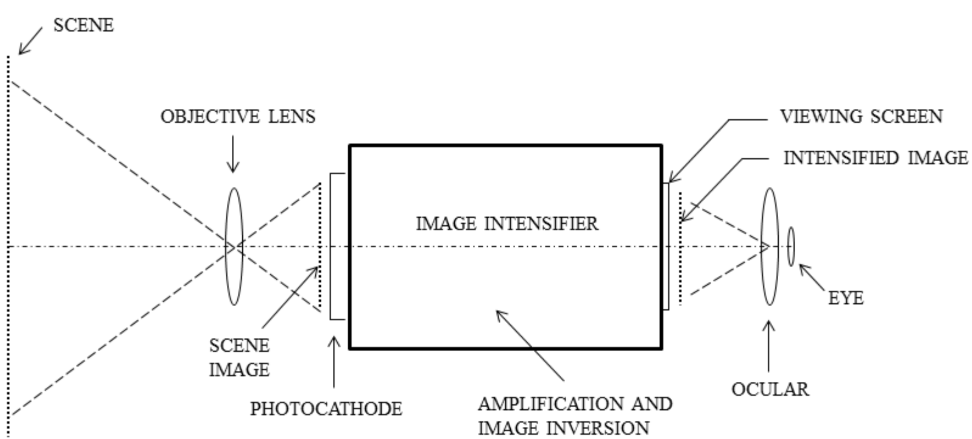


Figure 3. The NVG Image Intensifier and Optical Components [7]

In chapter 7 of the technical guide *The Avionics Handbook*, Mr. Dennis Schmickley describes the image intensification process of NVGs in the following manner:

> An image intensifier is an electronic device that amplifies light energy. Light energy, photons, enter into the device through the objective lens and are focused onto a photocathode detector that is receptive to both visible and near-infrared radiation. Generation III devices use gallium arsenide as the detector. Due to the photoelectric effect, the photons striking the photocathode emit a current of electrons. Because the emitted electrons scatter in random directions, a myriad of parallel tubes (channels) is required to provide separation and direction of the electron current to assure that the final image will have sharp resolution. Each channel amplifier is microscopic — about 15 μm in diameter. A million or so microchannels are bundled in a wafer-shaped array about the diameter of a quarter. The wafer is called a microchannel plate (MCP). The thickness of the MCP, which is the length of the channels, is about 0.25 in. Each channel is an electric amplifier. A bias potential of about 1000 V is established along the tube, and each electron produced by the photoelectric effect accelerates through the tube toward the anode. When an electron strikes other electrons in the coated channel, they are knocked free and continue down the tube hitting other electrons in a cascade effect. The result of this multiplication of electrons is a greatly amplified signal. The amplified stream of electrons finally hits a phosphor-type fluorescent screen which, in turn, emits a large number of photons creating an image. [7]

It is required that NVGs used by pilots must have a one-to-one (1x) image magnification [6]. As noted by Mr. Schmickley: "The pilot's perceived NVG image of the outside world must be equal to the actual size of the unaided-eye image of the outside real world to provide natural motion and depth perception." [7] A diagram of the image amplification process is shown in figure 4.

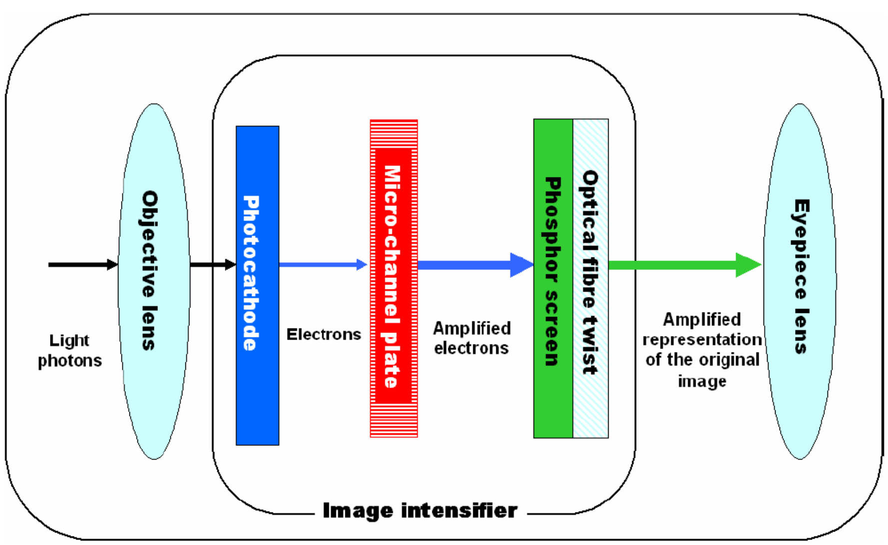


Figure 4. The NVG Image Amplification Process [1]

2.2.2 Development of NVG Technology.

NVGs are classified broadly into three development generations: Generation 1, 2, and 3. The primary difference among these generations is the technology utilized in the image intensifier tubes [7].

Generation 1 NVG tubes were developed in the 1960s. These NVGs were large and could not be head-mounted for aviation use [7].

Later in the 1960s, Generation 2 NVGs were developed. These featured the addition of MCP technology, which allowed NVGs to be miniaturized and mounted on helmets for the first time. Generation 2 NVGs contained image intensifiers with multi-alkali photocathodes, which were sensitive to wavelengths of approximately 400–900 nanometers (nm) [7]. An enhanced version of Generation 2 NVGs with improved gain was developed in the 1970s and was distinguished with a +, as shown in figure 5 [9].

Generation 3 NVGs were introduced in the early 1980s. These NVGs featured image intensifiers containing galium arsenide (GaAs) photocathodes and an ion-barrier film on the MCP [7]. Generation 3 NVGs are most sensitive to bandwidths of approximately 600–900 nm [8]. Generation 3 NVGs have continued to improve in terms of factors such as reliability, image resolution, signal-to-noise ratio, photocathode sensitivity, and luminance gain, with Generation 3+ NVGs being introduced in the 1990s. Generation 3+ NVGs, also unofficially referred to by the NVG industry as Generation 4, are the generation of NVGs currently in use by pilots [9].

Generations of Image Intensification Tubes

Generation (GEN)	Characteristics
GEN I	Introduced in mid-1960s. Oldest technology; considerable distortion, short tube life.
GEN II	Introduced in late 1960s. Incorporated microchannel plate (MCP) , provided improved gain, smaller size.
GEN II+	Introduced in 1970s. Improvements in gain, resolution. (+ indicates enhanced.)
GEN III	Introduced in 1980s. Significantly improved gain and spectral sensitivity in the near-infrared region; improved MCP; improved photocathode.
GEN III+	Introduced in 1990s. Slight improvements in photocathode; improved gain, resolution. (+ indicates enhanced.)

Figure 5. The NVG Generations [9]

As shown in figure 6, the photocathode responsivity of Generation 3 NVGs to light in this spectrum is much greater than Generation 2+ NVGs. The responsivity, shown on the Y-axis in figure 6, is measured in milliAmperes per Watt (ma/w).

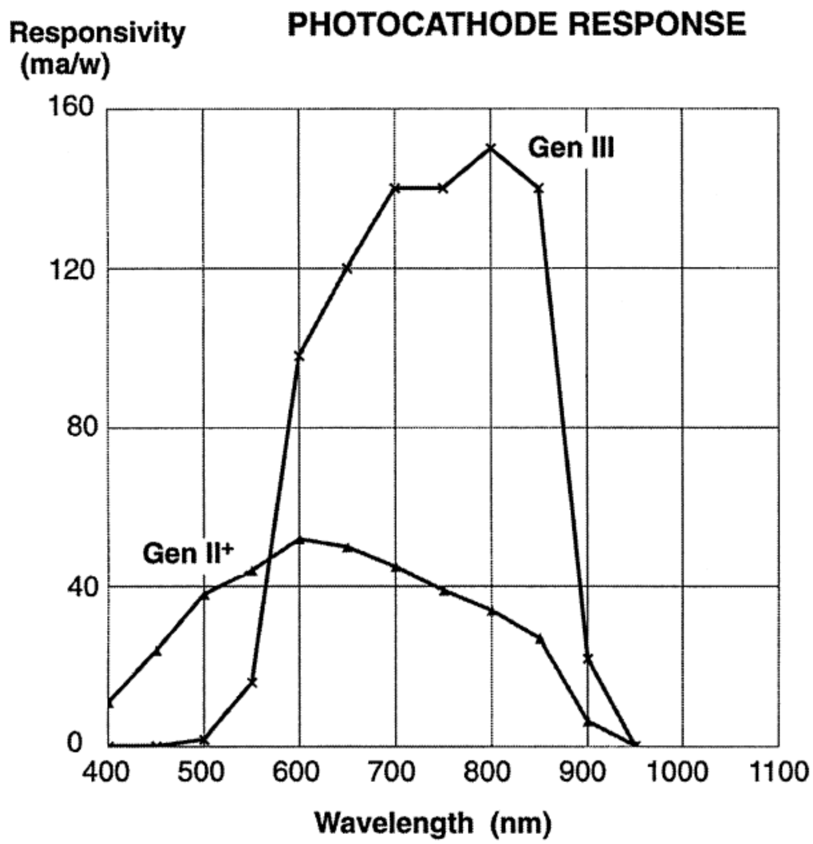


Figure 6. Photocathode Response Comparison: Generation 2 and 3 NVGs [7]

The performance level of Generation 3 NVGs has progressively increased over time. For example, current models of Generation NVGs have significantly improved photocathode performance, resolution, and signal-to-noise ratios compared to early Generation 3 m odels. Newer NVGs contain additional features such as improved automatic brightness controls to protect the image intensifier tube and autogating power supplies to better handle transitions between very light and very dark environments [7].

Model numbers of NVGs used in aviation originate from United States (U.S.) military specifications and are designated as Aviator's Night Vision Imaging Systems (ANVIS)-6 and ANVIS-9. The ANVIS-6 and ANVIS-9 mainly differ based on form factor rather than visual performance (e.g., different helmet mounts, objective lenses focusing method, battery packs, etc.) [8]. The ANVIS-6 specification was developed first by the U.S. Army and was used for rotorcraft. The ANVIS-9 designation was developed based on the needs of the U.S. Air Force due to incompatibility of the ANVIS-6 for use in fixed-wing aircraft [8].

2.2.3 Civil Use of NVG in the National Airspace System.

Based on the success experienced by the military, civil operators such as emergency medical service operators, pipeline and powerline surveillance crews, and news teams began to request to utilize NVGs for increased situational awareness in flight in the 1990s [10]. The FAA conducted several research studies in this decade regarding the risks and benefits of NVG use, such as the study DOT/FAA/RD-94/21, “Night Vision Goggles in Emergency Medical Service (EMS) Helicopters,” published in 1994 [10]. Eventually, the FAA issued FAA Order 8900.1, Volume 4—Aircraft Equipment and Operational Authorization, Chapter 7—Rotorcraft Authorizations and Limitations, Section 4—Night Vision Imaging Systems, providing guidance for civil aircraft operators to incorporate NVGs [11].

Due to improvements and availability of NVG technology, an increasing number of 14 CFR Part 135 (charter and on-demand) operators have requested to use NVGs for additional commercial operations. For approval to use NVGs, 14 CFR Part 135 operators must demonstrate they have in place FAA-approved maintenance, training, and other FAA safety programs [11]. As noted in FAA Order 8900.1, NVGs can only be used during VMCs, and operators “are not to use NVGs during inadvertent instrument meteorological conditions (IIMC).” [11] Order 8900.1 also emphasizes that, “The use of NVGs does not change or modify any of the existing regulations pertaining to operational limitations.” [11]

2.3 THE LED OBSTRUCTION LIGHT VISIBILITY ISSUES WITH NVG.

Past FAA research has shown that NVG objective lens filters, which are used to ensure compatibility of NVGs with cockpit lighting, are the primary cause of LED lighting visibility issues [12]. Current NVGs are sensitive to light with wavelengths between approximately 450 nm and 920 nm [12]. This range overlaps the visible spectrum of light (approximately 390 nm to 700 nm) [13], which is the cause of potential incompatibility. If visible light in the cockpit is not effectively filtered by NVGs, the automatic gain control of the NVGs to be activated and potentially reduce the visual acuity for the pilot [8].

MIL-STD-3009, “Lighting, Aircraft, Night Vision Imaging Systems (NVIS) Compatible,” contains specifications for chromaticity and radiance requirements for cockpit lighting compatibility with NVGs [14]. The filters are installed on the objective lenses of the NVGs. NVG filters currently in use include Class A, Class B, and Class C [14]. Corresponding types of cockpit lighting are also identified by classes (e.g., Class A and Class B).

Class A filters restrict wavelengths below 625 nm from being viewed by the NVG, allowing the use of blue, green, and yellow lighting to be used in the cockpit (specified as Class A cockpit lighting) [14]. Class B filters restrict lighting with wavelengths below 665 nm from being viewed by NVG, allowing the use of some red lighting in cockpit displays and other Class B lighted instrumentation [14]. Class C filters also restrict light wavelengths below 665 nm, with the exception of a limited amount of green for a heads-up display [8]. The Class B objective lens filter is currently the standard filter used by civilian NVG operators to be compliant with FAA-certification requirements. The use of Class A and C filters is generally limited to military operations.

As shown in figure 7, Class A NVG filters can view colors with wavelengths 625 nm and above, and Class B filters can view colors with wavelengths of 665 nm and above [13]. However, because red LED obstruction lights have a limited emission range (approximately 620 nm to 645 nm), some red LEDs may have limited visibility using Class A filters and no visibility using Class B filters. Because the Class B filter is the most restrictive in terms of wavelengths that are visible, lights that are visible using a Class B filter will also be visible to Class A and C filters.

Therefore, to be compatible with Class A, B, and C filters, obstruction lighting would to need have IR emissions above the wavelength above 665 nm.

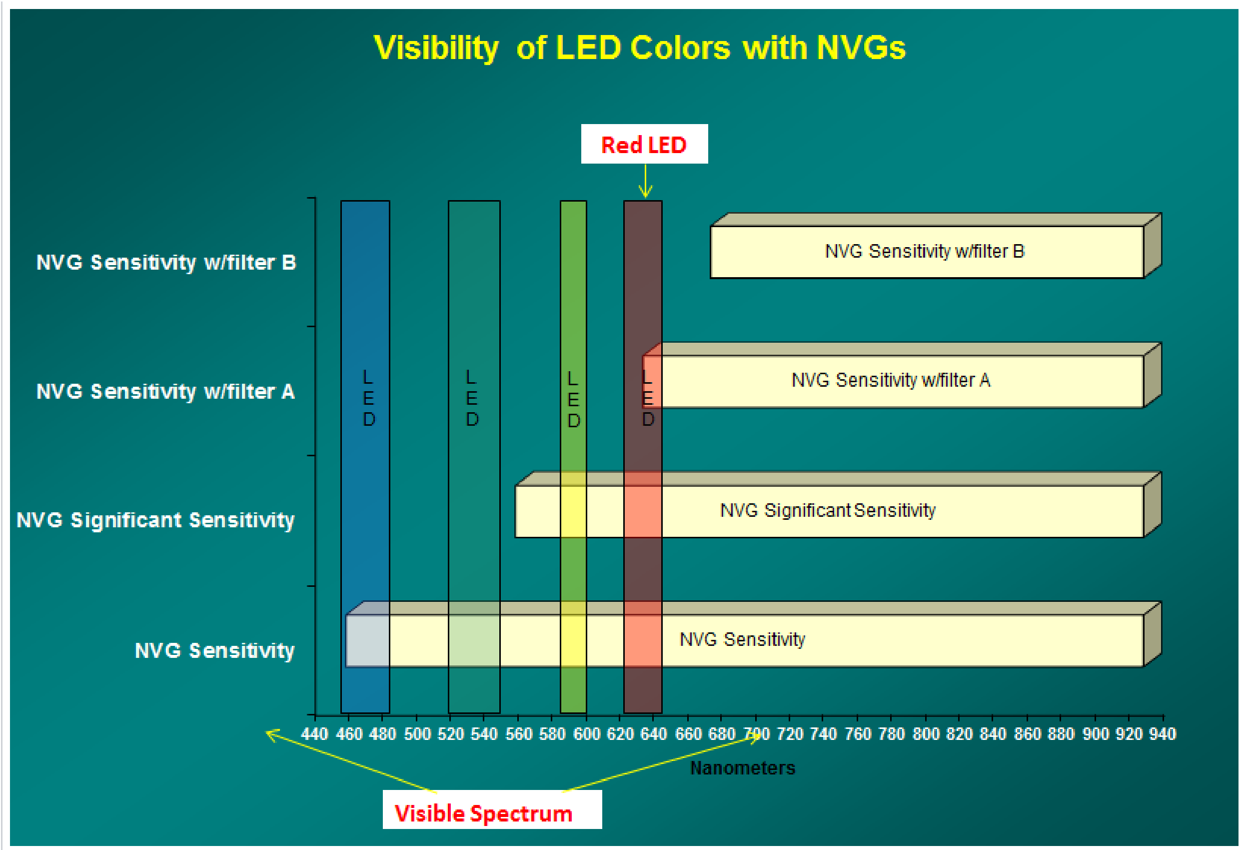


Figure 7. Visibility of LED Colors With NVG [13]

In 2011, ATR researchers conducted a study at Atlantic City International Airport to further explore this LED visibility issue [15]. As shown in figure 8, researchers first confirmed the spectral sensitivity range for both Class A NVG and Class B NVG on a logarithmic scale, confirming limited sensitivity below 625 nm and 665 nm for each of these respectively, and showing the spectral sensitivity for these NVG peaked at 850 nm.

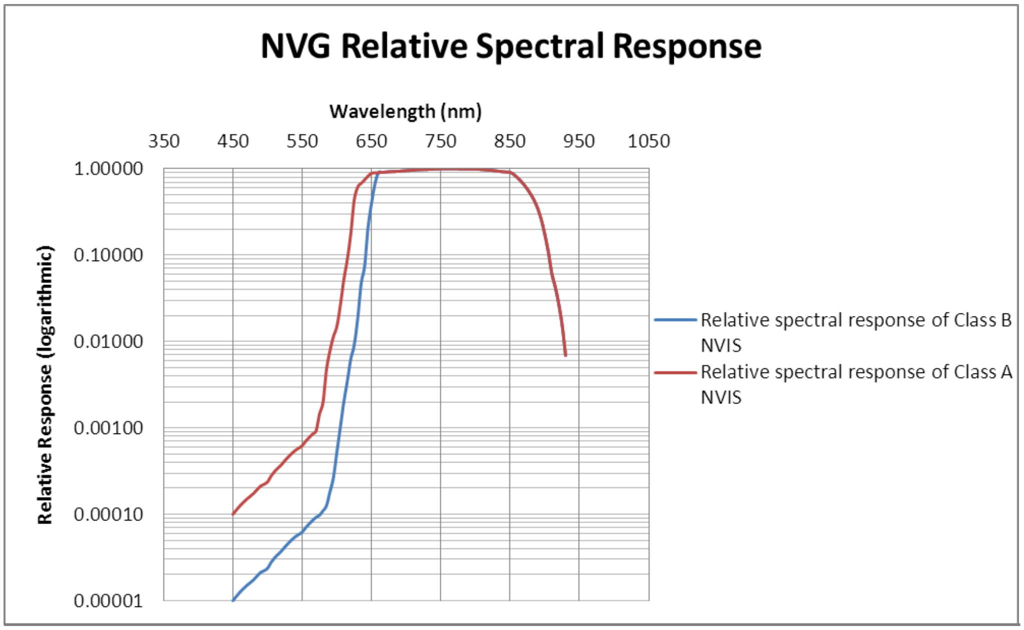


Figure 8. Relative Spectral Sensitivity Range for Both Class A NVG and Class B NVG on a Logarithmic Scale [15]

The researchers then conducted ground testing with ATR subjects and flight tests with subject pilots from the U.S. Coast Guard. The results demonstrated that red LEDs can be visible using NVGs as long as the wavelengths of the fixtures are within the NVG filter sensitivity range. For example, figure 9 shows an example of a red LED obstruction light visible through a Class A filter.

Figure 9. Red LED Obstruction Light Viewed Through Class A NVG [15]

2.4 INTERNATIONAL RESEARCH AND STANDARDS.

Governments of other nations have also researched the issue of red LED obstruction lights not being visible to pilots using NVG. For instance, the Finnish and the United Kingdom (UK) governments have adopted specifications for LED IR based on the findings of their research into published standards for obstruction lights. These standards are summarized in table 3. The researchers are aware that other nations, such as Canada and Australia, are also currently developing standards; however, these standards have not yet been published.

Table 3. Finnish and UK Government IR Specifications

Regulatory Authority	IR Wavelength (nm)	Applicability	IR Radiant Intensities and Vertical Beam Spread(s) (mW/sr)
Finnish Transport Safety Agency	800-940	Low intensity (L-810 equivalent)	Minimum: 3 (+5° - <+90°) Minimum: 25 (>0° - <+5°) Maximum: 60 (-90° - +90°)
		Medium intensity (L-864 equivalent)	Minimum: 500 (>0° - <+2°) Maximum: 1000 (-90 - +90°)
UK Ministry of Defense (MOD)	750-900	General IR specification for wind turbine lighting	Minimum: 600 (-15° - +30°) Maximum: 1200 (-15° - +30°)

2.4.1 Finland.

The Finnish Transport Safety Agency has created IR specifications for low- and medium-intensity, red, LED obstruction lights used on wind turbines after receiving requests by military and rescue pilots for standards to be put in place [16]. These specifications were based on the results of testing by the Finnish military [17]. For flashing lights, the Finnish government requires that the IR light flash at the same rate as the visible obstruction light. As shown in table 3, the L-810 equivalent fixture has two beam spread requirements related to minimum intensity. These include a 0-5° main beam with a minimum radiant intensity of 25 mW/sr (0-5°) and a secondary beam encompassing 5-90° with a minimum radiant intensity of 3 mW/sr. The L-864 equivalent fixture is required to have a 2° beam spread with a minimum radiant intensity of 500 mW/sr. The Finnish government also has defined maximum IR radiant intensities of 60 mW/sr and 1000 mW/sr for the L-810 and L-864 equivalent fixtures, respectively.

2.4.2 United Kingdom.

To increase the conspicuity of wind turbines to military pilots without increasing the amount of visible light, the UK Ministry of Defense (MOD) has defined IR specifications for LED lighting used on wind turbines in its "Normal MOD requirement." This specification requires IR emitters to be used on obstructions in locations where low-flying military aircraft may be at increased risk of collision with the obstructions, such as wind farms [18]. The UK MOD states that its research showed that these specifications will generate "a 7-8 nm NVG pick-up range - remaining above 5 nm as the light ages" [18]. As shown in table 3, the vertical beam requirement is a 600 mW/sr radiant intensity between -15° and 30°. Similar to the Finnish government, the UK MOD has defined a maximum IR radiant intensity, which is 1200 mW/sr.

3. PHASE 2: LABORATORY TESTING.

Due to the lack of existing research regarding the amount of IR emissions necessary for fixtures to be conspicuous to pilots using NVGs, a specification for IR intensity could not be determined during Phase 1. Phase 2 was launched to obtain a variety of incandescent and LED with IR L-810 and L-864 fixtures and conduct laboratory testing on these fixtures to determine their IR intensities.

3.1 OBSTRUCTION LIGHT FIXTURES TESTED.

A variety of L-810 and L-864 fixtures were obtained from nine different manufacturers. As shown in tables 4 and 5, these primarily consisted of FAA-certified, commercially-available LED fixtures with IR emitters. In addition, one incandescent L-810 and one incandescent L-864 fixture were obtained for baseline comparison purposes. As shown in table 6, ATR researchers also obtained two nonconventional fixtures, which included an IR retrofit unit and a prototype obstruction light from with adjustable IR intensity. The FAA does not currently have in place "L" numbers or certification standards for these fixtures. For data collection purposes, RPI assigned each fixture the unique sample numbers shown in tables 4-6. Due to technical difficulties and schedule limitations, IR measurements for two L-864 fixtures and the retrofit IR unit could not be collected by RPI.

Table 4. The L-810 Fixtures Obtained for Testing

RPI Sample Number	Description	FAA Certified*
110155	Single head L-810 (L) + IR	Yes
110157	Single head L-810 (L) + IR	Yes
110158	Single head L-810 (L) + IR	Yes
110159	Single head L-810 (L) + IR	Yes
110164	Single head L-810 (L) + IR	Yes
110165	Incandescent single head L-810	Yes
110166	Single head L-810 (L) + IR	Yes

* FAA certification is in reference to the visible light output of these fixtures.

Table 5. The L-864 Fixtures Obtained for Testing

RPI Sample Number	Description	FAA Certified*
110154	L-864 (L) + IR	Yes
110162	L-864 (L) + IR	Yes
110167	Incandescent L-864	Yes
110168	L-864 (L) + IR	Yes
N/A	L-864 (L) + IR	Yes

* FAA certification is in reference to the visible light output of these fixtures.

Table 6. Other Fixtures Obtained for Testing

RPI Sample Number	Description	FAA Certified*
N/A	IR retrofit unit	N/A
110156	IR-only single head	N/A
110169	Adjustable-intensity IR prototype	N/A

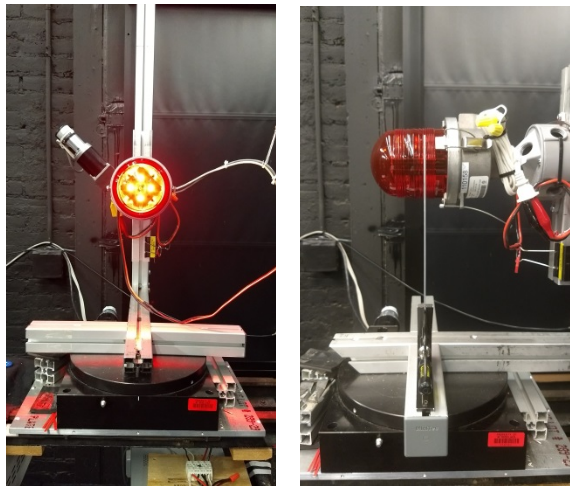
* FAA certification is in reference to the visible light output of these fixtures.

3.2 LABORATORY TESTING PROCEDURES.

Eight L-810 and five L-864 fixtures were tested at RPI's Lighting Research Center (LRC) for angular luminous and infrared (IR) radiant intensity distributions. As part of the tests, the spectral power distribution (SPD) of each device under test (DUT) was also measured. This section summarizes the procedures and the results of the laboratory tests.

The angular intensity distributions of each fixture were tested in the visible (VIS, 380 nm to 780 nm) and the infrared (IR, 800 nm to 900 nm) spectral ranges. The main interest of these tests was the radiant intensity (in units of mW/sr) in the range from 800 nm to 900 nm, due to this range coinciding with the peak sensitivity range for NVGs. The angular range of interest is in the vertical region from 0° to 20° for the L-810 type fixtures and in the 0° to 3° vertical region for the L-864 type fixtures, which include the FAA-required beam spreads for visible light from these fixture types. Both fixture types were scanned in the horizontal angles from 0° to 360° in different angular increments.

The RPI's LRC researchers measured the DUTs using the custom bar-goniophotometer apparatus. The goniophotometer consists of two motorized rotary stages configured as a type B goniophotometer controlled with a custom National Instruments™ LabVIEW program. The L-810 samples were positioned and held in place on the vertical rotary stage by a junction box with a suitable threaded couple that matched the existing thread in the fixture. The L-864 samples were positioned and held in place by bolts directly or suitable means to the horizontal rotary stage. Figure 10 shows two fixtures under test in the bar goniophotometer setup used for measuring the angular intensity distributions of the DUTs. Note that the DUTs in figures 10(a) and (b) are not the same.



(a) (b)

Figure 10. Goniophotometer Setup Example

The DUTs were aligned using their mechanical and optical centers, as appropriate depending on the fixture type. For the L-810 samples, the goniophotometer was programmed to scan from 180° to -180° horizontal angle in 5° i ncrements, and from -5° to 90° vertical angle in 1° increments. Because of the generally larger size and weight of the L-864 samples, only the rotary stage to control the horizontal angle positioning was used. For the L-864 samples, the goniophotometer was programed to scan from 180° t o -180° horizontal angle in 22.5° increments. To measure the distribution at different vertical angles, the sensors were moved vertically to reflect the desired vertical angle position from -2.5° to 5° in 0.5° increments.

The setup consisted of two detectors, one photometrically calibrated illuminance sensor for the visible part of the spectrum[1], and a silicon photodiode fitted with a bandpass filter[2] for the infrared part of the spectrum. Figure 11 shows the manufacturer spectral specifications of the bandpass filter.

---

[1] LMT illuminance sensor, photometrically corrected (calibration factor -1.869×10^{-8} A/lx)

[2] Edmund Optics (part number 86958) hard coated broadband bandpass interference filter (peak = 875 nm, full-width half-maximum = 50 nm; OD >4.0)

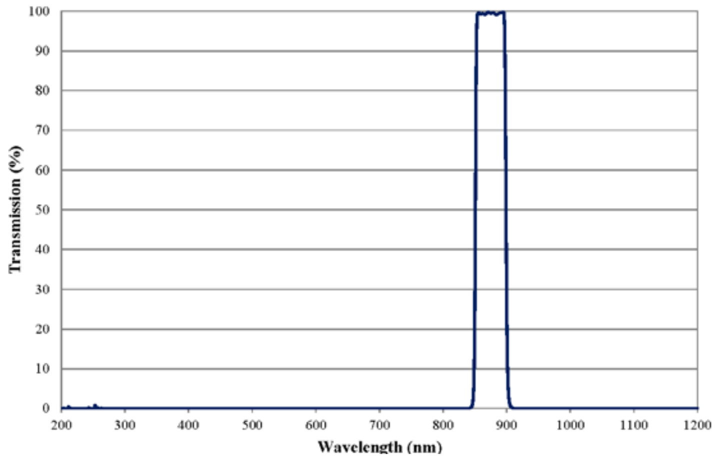


Figure 11. Spectral Transmission Properties of the Bandpass Filter Used for Testing

The candela unit was used to measure the intensity of the visible light output, or luminous intensity. Candela measurements include a weighting of the radiant power by the photopic luminous efficacy function. This function corresponds to the wavelengths of light most visible to the human eye. Because light in the IR part of the spectrum is not visible to the human eye, the candela unit does not effectively describe the intensity of IR light. Therefore, to measure the IR radiant intensity of each fixture, the unit milliwatts per steradian (mW/sr) was used.

The luminous intensity (in units of candela, cd) of the fixtures is related to the illuminance at a known distance by the inverse square law. The two sensors were located[3] 5.639 meters down range from the goniophotometer axis center and aligned so that their surface normal intersected the light fixtures axis. Since the illuminance sensor has a known absolute calibration, the luminous intensity can be derived simply from the illuminance measurements (in units of lux, lx) at each angle and the square of the distance from the light source to the sensor.

To obtain the IR radiant intensity (in units of mW/sr), an intermediate calibration step was necessary for each fixture to first determine the absolute irradiance at the face of the silicon photodiode. For this step, a double monochromator[4] spectrometer was put in line between the light source and the silicon photodiode. To obtain the calibration factor for each fixture, an absolute spectral power distribution[5] (SPD) was measured at a known distance after the DUT was considered stable. In all cases, the DUTs were turned on for at least one hour before a measurement was taken.

---

[3] This distance was fixed in the setup; however, depending on the dimensions of the DUTs, the distance used in the calculation of luminous intensity (or irradiance) was adjusted if needed to compensate for the distance from the center of rotation to the light-emitting surface of the fixture.
[4] Princeton Instruments, model Acton SpectraPro® 2300i.
[5] SPDs were measured in the range from 380 nm to 1000 nm in 1-nm increments. The integration time was adjusted as needed depending on the IR output of the samples and ranged from 1 s to 4 s per nm.

The distance[6] from the center of rotation of the goniophotometer to the entrance slit of the spectrometer was 3.38 m (133 in.). Once the SPD was measured, the spectrometer was removed and the reading from the filtered silicon photodiode was recorded. These three factors (SPD[7], distance, and photodiode reading) were used to derive a calibration factor in units of [mW/sr·A] that was applied to the angular measurements. This procedure was repeated for all fixtures tested. Figure 12 shows a schematic drawing of the general setup.

Because of the size and weight of sample 110167, it was not possible to use the motorized rotary stage. In this case, a manually operated rotary stage was setup at a longer test distance (10.14 m) between the fixture and the sensors. The calibration and test procedure for this sample was otherwise as described. LED samples were not seasoned before testing, but incandescent samples were seasoned for 10 hours at their rated voltage. During the tests, all samples were powered at nominal voltage from a regulated power supply.

Figure 12 shows a schematic of the setup used showing the location of the VIS and IR sensors, the double monochromator spectrometer, and the goniophotometer for a typical L-810 test. The L-864 samples were mounted to motorized stage 1, and the vertical position of the sensors was adjusted manually for each vertical angle measured. Note that figure 12 is not to scale.

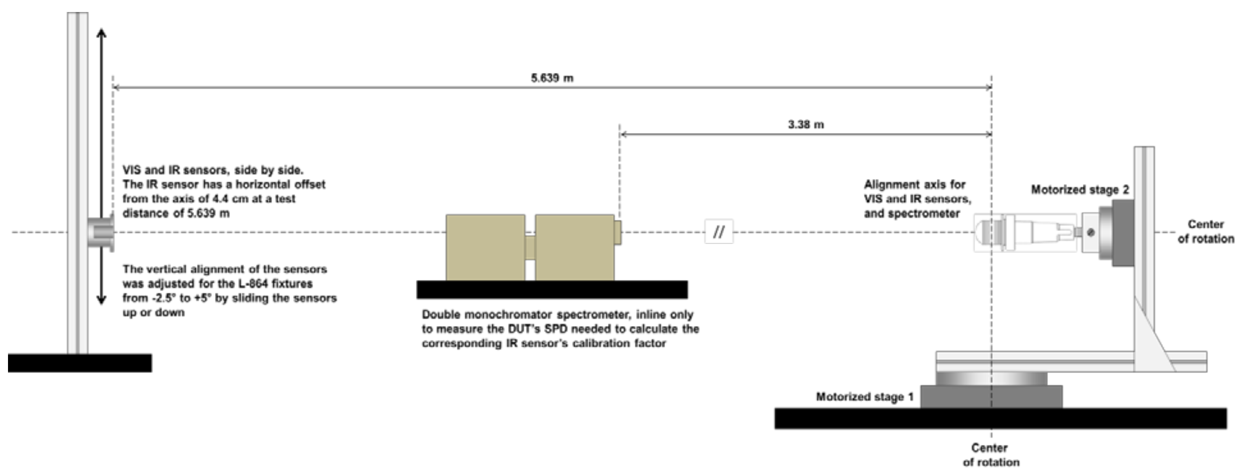


Figure 12. Test Setup Schematic

3.3 LABORATORY TESTING RESULTS.

Because of the limitations in the availability of a longer test distance for the type of fixtures, and the low IR output of certain samples, the overall uncertainty in the following results is estimated to be approximately 5 percent. These results should not be considered for certification of any type.

[6] Same as footnote 4.
[7] For the calculation of the calibration factor for the filtered silicon photodiode, only the range from 800 nm to 900 nm was used, taking into account the corresponding integration time (see footnotes 6 and 4).

Table 7 contains a summary of the luminous intensity and IR radiant intensity within the 0° to 20° vertical region of the beam for the eight L-810 samples. Table 8 contains a summary of these values within the 0° to 3° vertical region of the beam for the five L-864 samples. It was found for each fixture that there was not a uniform IR intensity across the horizontal plane; therefore, the minimum (Min), average (Avg), maximum (Max) and standard (Std) deviation values shown in the tables were determined from the full intensity distributions across the different horizontal angle cuts.

Tables 9 and 10 summarize the peak wavelength in the visible and IR regions for the samples tested. Detailed luminous and radiant intensity measurement data can be found in appendices A through M.

Table 7. Summary of L-810 Luminous Intensity and IR Radiant Intensity

Sample Number	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
110155	3.6	23.0	48.9	12.4	4.4	11.9	20.3	4.0
110156	No output in the visible range				8.5	69.7	155.2	37.8
110157	3.0	37.8	83.1	21.6	19.5	87.3	337.1	69.2
110158	6.7	49.2	96.5	24.2	24.4	209.6	398.1	111.0
110159	11.3	47.8	81.2	22.0	2.2	6.7	17.0	3.1
110164	29.8	54.6	96.9	17.9	53.4	136.0	231.5	42.4
110165	10.8	39.1	66.4	17.4	220.0	800.3	1415.9	371.3
110166	5.2	45.9	83.9	17.8	7.7	89.3	210.9	68.2

*Broadband spectrum emission from an incandescent light source.

Table 8. Summary of L-864 Luminous Intensity and IR Radiant Intensity

Sample Number	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
110154	36.7	714.1	1,454.6	434.7	527.8	600.5	693.0	33.6
110162	363.1	1,733.2	2,563.7	626.5	1,735.1	5,006.5	7,042.9	1,510.8
110167	1,122.7	1,583.0	2,077.7	192.8	17,582.4	24,828.8	33,436.2	3,522.7
110168	302.8	1,432.8	2,604.4	678.2	414.2	687.0	1,048.8	136.4
110169	14.7	32.3	39.5	6.7	253.6	1,546.6	2,525.2	602.9

* Broadband spectrum emission from an incandescent light source.

Table 9. Summary of L-810 Peak Wavelengths in the Visible and IR Spectral Regions

Sample Number	Visible Region (nm)	IR Region (nm)
110155	626	870
110156	No output in the visible range	869
110157	625	862
110158	635	861
110159	619	856
110164	636	861
110165*	780	1000
110166	635	864

* Broadband spectrum emission from an incandescent light source.

Table 10. Summary of L-864 Peak Wavelengths in the Visible and IR Spectral Regions

Sample Number	Visible Region (nm)	IR Region (nm)
110154	643	867
110162	634	861
110167*	780	850
110168	620	857
110169	631	856

*Broadband spectrum emission from an incandescent light source.

4. PHASE 3: FLIGHT EVALUATIONS.

To determine an appropriate minimum IR radiant intensity for the L-810 and L-864 fixtures, three rounds of flight evaluations were conducted over multiple nights. The initial flight evaluations consisted of subjects being flown directly towards the test fixture location to determine the baseline acquisition distance for each fixture. The second and third evaluations consisted of subjects orbiting the fixture location at set distances to confirm the findings from the initial evaluation. Nine individuals with aviation-related backgrounds and experience were subjects in the evaluations.

4.1 METHODOLOGY.

Based on the literature review results and findings, it was determined that the minimum IR radiant intensities for L-810 (L) and L-864 (L) IR fixtures should be based on the existing visibility requirements under AC 70/7460-1. Therefore, it was decided that the L-810 (L) IR fixtures should have a radiant intensity sufficient for this fixture to be acquired by pilots at a minimum distance of 1.4 SM. The L-864 (L) IR should have a radiant intensity sufficient for pilots to acquire this fixture at a minimum distance of 3.1 SM. These distances were based on FAA research showing these distances are necessary to provide pilots with adequate distance to see the obstruction and take evasive action to avoid coming within 2000 ft of an obstruction.

It was also decided that the visual appearance of L-864 fixtures should be sufficiently differentiated from that of L-810 fixtures when viewed with NVGs as they are when viewed with the unaided eye. Therefore, it was decided that the current ratio between the L-810 and L-864 minimum intensities for visible light should also be applied to IR light. The nominal L-864 peak effective intensity (2000 cd) is approximately 61.5 times the minimum intensity of the L-810 (32.5 cd); thus, it was proposed that the minimum IR intensity for the L-864 should be 61.5 times the IR minimum established for the L-810, contingent on the resulting intensity for the L-864 allowing the fixture to be acquired at a distance of 3.1 SM during flight evaluations.

4.2 FLIGHT EVALUATION PROCEDURES.

All evaluation flights were conducted in VMC, with meteorological visibility of at least 3 SM. Evaluation flights were scheduled to begin no earlier than one hour after sundown to provide adequately dark conditions. ATR personnel coordinated with the airport operator to temporarily close this taxiway during testing. The NVG model used for this assessment was the ITT 4944 Gen III+ with a Class B objective lens filter. The Class B filter was selected since it caused LED visibility issues for pilots. These NVGs were professionally calibrated prior to the evaluations.

The aircraft used for the evaluations was a rented Cessna 172 flown by a hired commercial pilot. The location for the flight evaluations was the FAA Research Taxiway (Taxiway C) at Cape May County Airport (WWD), located in Rio Grande, New Jersey. This location provided several advantages for the flight evaluations, such as easily accessible electrical power, controllable LED lighting, and airport access without an airport escort. (FAA personnel acted as escorts.)

Figures 13 and 14 show the L-810 and L-864 fixtures evaluated, which were the same units that had undergone laboratory testing at the LRC. Figure 15 shows the fixture location at WWD.

Figure 13. The L-810 Fixtures Evaluated at WWD

Figure 14. The L-864 Fixtures Evaluated at WWD

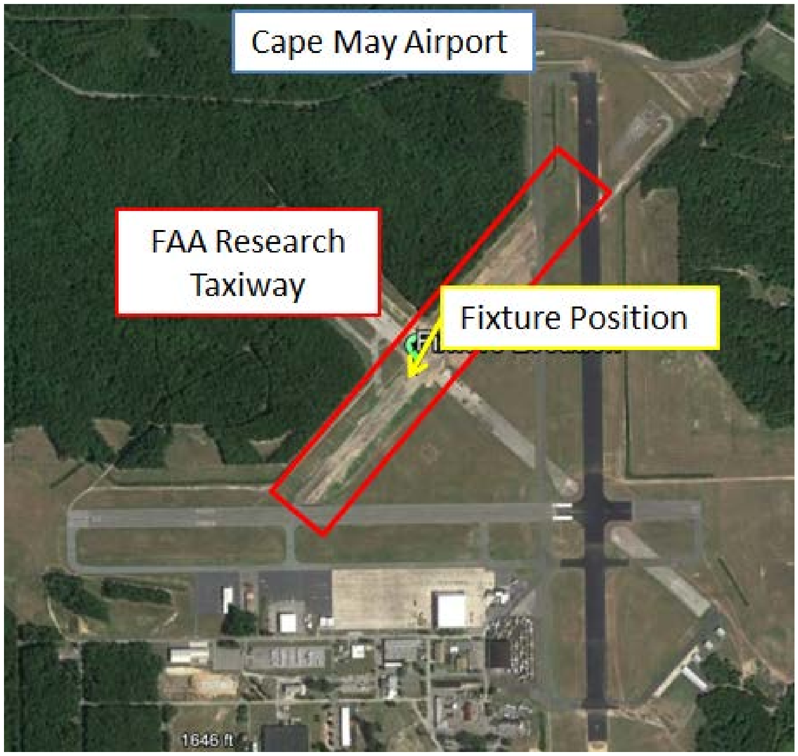


Figure 15. Fixture Position at WWD

4.2.1 Initial Flight Evaluation.

For the initial flight evaluation, ATR personnel were divided into two teams: a ground team and a flight team. The ground team positioned and powered on the obstruction light fixture prior to each run. The flight team, which was onboard the aircraft with the subject, communicated with the ground team via radio and recorded data on behalf of the subject.

Each fixture was evaluated individually by subjects. Prior to beginning the evaluation, subjects were briefed on the evaluation procedures and general location of the fixture being evaluated to distinguish it from other lights in the area. The data collected from these evaluations consisted of the distance that each fixture became conspicuous. Subjects were instructed to report when the fixture was conspicuous, which was defined as the subject being able to "confidently identify the fixture." A flight team member obtained visual range data using a portable aviation global positioning system (GPS). A sample pilot data sheet is shown in appendix N.

The ground team set up the fixtures at the approximate midpoint of the FAA research taxiway adjacent to the centerline, as shown in figure 16. This position provided a relatively dark location that was an adequate distance from surrounding runways and a clear line of sight for the aircraft flight path.

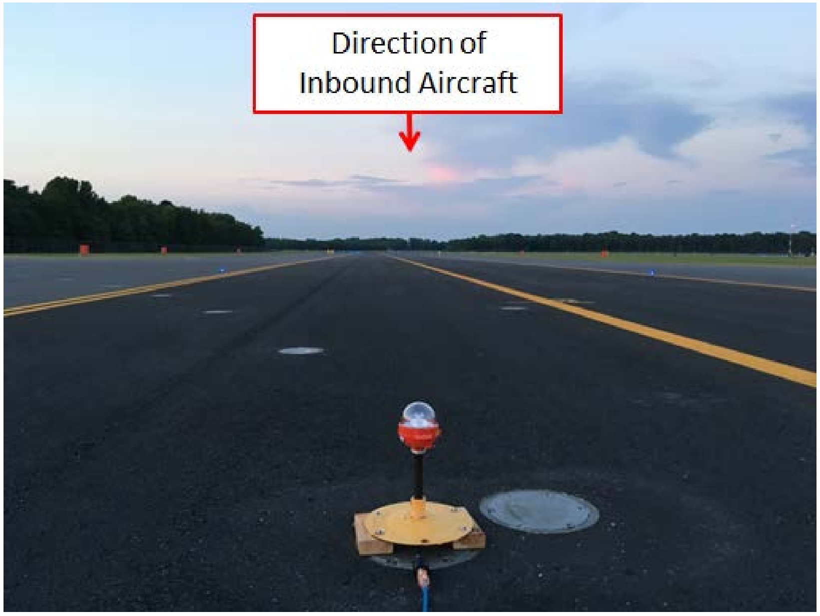


Figure 16. Fixture Position on WWD Taxiway for Initial Flight Evaluation

To assist the pilot in locating and aligning with the fixture location, red LED lead-in lights were installed adjacent to the taxiway centerline at 200-ft increments, as shown in figure 17. These centerline lights, as well as the blue taxiway edge lights, were not visible to the subjects wearing NVGs due to the Class B objective lens filter.

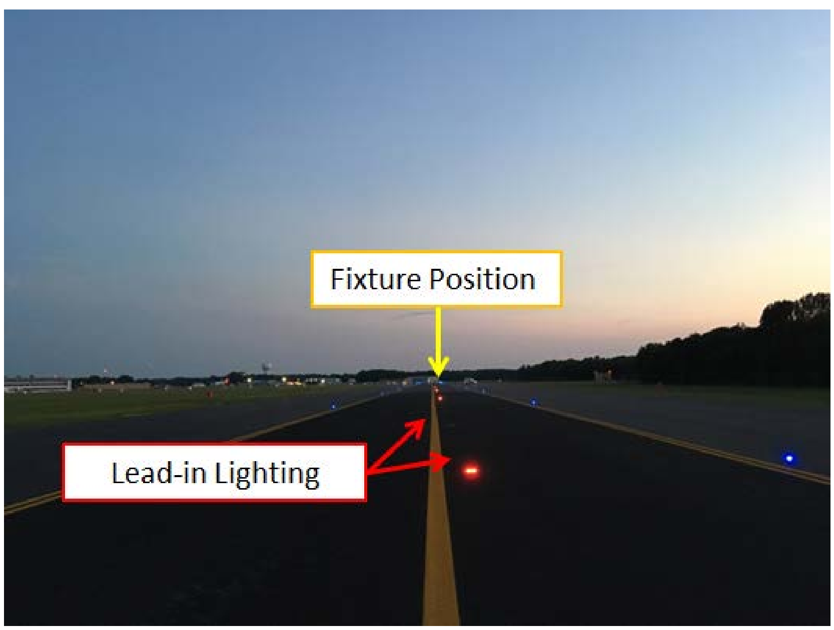


Figure 17. Lead-in Lights on WWD Taxiway for Initial Flight Evaluation

During each evaluation run, the pilot flew a standard flight profile, while the subject scanned the area with NVGs for the obstruction fixture being evaluated. The airfield lighting was turned on during each run. The ground team reported via radio when each fixture was ready to view. The pilot then conducted a preplanned approach towards the fixture location. As shown in figure 18, runs approaching the L-810s began from a waypoint that was 5 SM from the fixture location, and L-864 fixtures began from a waypoint that was 6 SM away. The heading flown was approximately 230°, which aligned the aircraft with the taxiway.

Figure 18. Flight Approach Diagram for Initial Flight Evaluation

The L-864 fixtures were evaluated at an altitude of 700 ft AGL. This altitude had been selected to allow the aircraft to be within the vertical beam of the L-864 fixture. The L-810 fixtures were evaluated at an altitude of 1500 ft AGL. This altitude had been selected to allow the aircraft to be within the vertical beam of the L-810.

4.2.2 Second Flight Evaluation.

Following the initial flight evaluations, a second flight evaluation was conducted using select L-810 and L-864 fixtures in an effort to validate data that was collected during previous flights and to identify a minimum intensity (mW/sr) for both fixtures. As shown in figure 19, the aircraft orbited the fixtures at predetermined and constant altitudes and distances: 1.4 SM and 3.1 SM for the L-810 and L-864 fixtures, respectively. The purpose of these orbits was to allow the specific minimum intensities for each fixture to be evaluated by subjects in both vertical and horizontal orientations with different background illumination. This evaluation also provided an opportunity for subjects to view intensity levels not observed in the initial flight evaluations.

Figure 19. Orbit Distances for Second Flight Evaluation

During this flight, subjects initially viewed two L-810 fixtures, as shown in table 11. The radiant intensity values of the L-810 fixtures ranged from a minimum of 4 to a maximum of 118 mW/sr. Subjects acquired both L-810 fixtures at the minimum acquisition distance of 1.4 SM.

Table 11. The L-810 Obstruction Lights Evaluated During Second Flight

Sample Number	Radiant Intensity (mW/sr)			Altitude (ft)	Viewing Angle (Degrees)	Viewing Distance (SM)
	Minimum	Average	Maximum			
110159: LED+IR L-810	4	5	6	780	6°	1.4
110157: LED+IR L-810	48	76	118	900	7°	1.4

Subjects then evaluated one L-864 fixture and four L-810 fixtures that were set to flashing mode to simulate an L-864, as shown in table 12. The measured radiant intensities of these fixtures ranged from a minimum of 4 mW/sr to a maximum of 683 mW/sr. The purpose was to allow the subjects to view the simulated L-864 fixtures at intensity values significantly lower than the L-864 fixtures evaluated in previous evaluation flights.

Table 12. The Obstruction Lights Evaluated as L-864s During Second Flight

Sample Number	Radiant Intensity (mW/sr)			Altitude (ft)	Viewing Angle (Degrees)	Viewing Distance (SM)
	Minimum	Average	Maximum			
110159: LED+IR L-810(F)	4	5	6	1700	6°	3.1
110157: LED+IR L-810(F)	48	76	118	2000	7°	3.1
110164: LED+IR L-810(F)	113	145	192	1700	6°	3.1
110158: LED+IR L-810(F)	296	315	356	1700	6°	3.1
110154: LED+IR L-864	566	615	683	1100	4°	3.1

4.2.3 Third Flight Evaluation.

A third and final flight evaluation was conducted to validate the 246 mW/sr IR radiant intensity value recommended for the L-864 fixture. As shown in table 13, the fixture selected for this evaluation was sample 110158. Although sample 110158 was an L-810 fixture rather than an L-864 fixture, it was selected based on its measured IR intensity range of 215-294 mW/sr. Similar to the second flight evaluation, the aircraft orbited the fixture at a specified altitude and distance. In this case, the radius of the orbit was 3.1 SM, which was the minimum distance that an L-864 is expected to be acquired. The altitude selected was 1200 ft AGL that was selected to ensure a 4° vertical viewing angle, which would provide the desired intensity range. The subjects observing the fixture were three experienced aviation researchers.

Table 13. Obstruction Fixture Observed on Third Flight Evaluation

Sample Number	Radiant Intensity (mW/sr)			Altitude (ft)	Viewing Angle (Degrees)	Viewing Distance (SM)
	Minimum	Average	Maximum			
110158: L-810	215	259	294	1200	4	3.1

4.3 FLIGHT EVALUATION RESULTS.

Following the flight evaluations, the data collected were compiled and analyzed. For the initial flight evaluation, researchers used the known distances and altitudes the fixtures were reported to be conspicuous. The vertical angles at which each subject observed the fixture were determined and cross-referenced with the angular measurements measured by RPI's LRC personnel to determine the approximate level of intensity observed by each subject. Due to variation in radiant intensity across the horizontal plane of the fixtures, the exact intensity viewed by the subjects was unknown; therefore, the minimum, average, and maximum values are included.

Tables 14 and 15 contain the data collected from the evaluation flights. These data included the distance at which each subject acquired the fixture and the IR intensity value at the angle the subject acquired the fixture. It should be noted that the acquisition distances reflect ranges that the fixtures were conspicuous to the subjects. However, these distances were limited to variation in the length of the runs conducted and do not represent the maximum distances these fixtures may be acquired.

Due to schedule limitations and other constraints, not all subjects viewed every fixture. For example, ATR researchers eliminated some fixtures from additional evaluation after initial data showed the fixtures were conspicuous at distances greatly exceeding the critical distances (1.4 SM for L-810s and 3.1 SM for L-864s).

As shown in table 14, all L-810 fixtures evaluated were acquired by subjects at distances greater than 1.4 SM. All subjects were able to acquire the sample 110159 L-810, at radiant intensities ranging from 3-6 mW/sr at distances of 2.7 SM or greater. As shown in table 15, the results showed all L-864 (L) IR fixtures were acquired at distances greater than 3.1 SM. It was found that these fixtures, which had IR radiant intensity values of 499 mW/sr and above, were acquired at ranges of 5 SM or more by all subjects.

Table 14. The L-810 Flight Evaluation Results

Sample Number	Radiant Intensity (mW/sr)			Distance Acquired (SM)
	Minimum	Average	Maximum	
110159: LED+IR	3	4	5	5.5
	4	4	5	5
	4	4	6	3.8
	4	4	6	3.8
	4	4	5	3.9
	4	4	5	4
	4	5	6	2.7
110155: LED+IR	4	6	7	5.6
	5	7	11	4.8
	5	7	11	4.4
	5	7	11	4.8
	5	7	11	5
	5	7	11	4.5
	5	8	14	3.9
	7	10	15	3.5
	14	15	17	2.5
110156: IR-only	25	42	52	3.2
	25	42	52	5.2
	25	42	52	5.7
	25	42	52	5.4
	25	42	52	5.6
	25	42	52	5.8
	27	45	58	4.8
	28	49	65	4.3
	28	49	65	4.2
110157: LED+IR	34	46	64	3.8
	37	51	79	3.4

Table 14. The L-810 Flight Evaluation Results (Continued)

Sample Number	Radiant Intensity (mW/sr)			Distance Acquired (SM)
	Minimum	Average	Maximum	
110164: LED+IR	69	111	166	5.3
	69	111	166	5.4
	69	111	166	5.6
	69	111	166	5.7
	70	107	162	6.1
	77	113	164	4.6
	77	113	164	4.4
	77	113	164	4.9
	77	113	164	5.0
110166: LED+IR	118	164	205	5.6
	118	164	205	5.5
	118	164	205	5.5
	118	164	205	5.8
	118	164	205	5.6
110158: LED+IR	215	259	294	4.2
	215	259	294	4.3
110165: Incandescent	1153	1293	1372	5.5
	1153	1293	1372	5.5
	1153	1293	1372	5.6
	1153	1293	1372	5.7
	1153	1293	1372	5.6
	1153	1293	1372	5.2
	1315	1330	1338	4.2
	1315	1330	1338	4.2
	1315	1330	1338	4.2

Table 15. The L-864 Flight Evaluation Results

Sample Number	Radiant Intensity (mW/sr)			Distance Acquired (SM)
	Minimum	Average	Maximum	
110168: LED+IR	499	678	876	5.2
	499	678	876	5.1
	502	690	899	5.5
	502	690	899	5.5
	502	690	899	5.5
	506	701	922	5.7
	509	713	946	6.1
	509	713	946	6.1
110154: LED+IR	538	597	676	6.1
	538	597	676	6.1
	538	597	676	6.2
	538	597	676	6.3
	539	598	678	5.9
	540	599	681	5.4
	540	599	681	5.3
	541	600	683	5.1
110162: LED+IR	5224	5792	6354	5.5
	5392	5911	6464	6.0
	5392	5911	6464	5.8
	5392	5911	6464	6.0
	5392	5911	6464	6.0
	5560	6029	6573	6.2
	5560	6029	6573	6.2
	5560	6029	6573	6.3
110167: Incandescent	21137	25370	30543	5.8
	21575	25749	31413	6.1
	21575	25749	31413	6.4
	21575	25749	31413	6.1
	21575	25749	31413	6.3
	21575	25749	31413	6.1
	21575	25749	31413	6.4
	21575	25749	31413	6.2

On the second flight, subjects validated the data collected from previous flights, confirming that a "simulated L-864 fixture" with a minimum intensity of 4 mW/sr could be acquired at a minimum distance of 3.1 SM. This intensity value was used as a baseline for determining the L-864 minimum intensity using the methodology described in section 4.1.

On the third flight, subjects evaluated a fixture with an IR intensity range of 215-294 mW/sr to validate the proposed L-864 minimum radiant intensity of 246 mW/sr was observed. Subjects found that this IR intensity level provided an acceptable intensity level for observing the fixture and was sufficiently visually differentiated in appearance from L-810 fixtures with a 4 mW/sr intensity.

5. RECOMMENDATIONS.

This research effort showed that all fixtures with IR radiant intensities of 4 mW/sr or more were able to be acquired by subjects wearing NVGs with Class B objective lens filters at distances greater than 3.1 SM. Sections 5.1.1 through 5.1.3 present IR specifications for the output wavelength, minimum vertical beam spread, and minimum IR radiant intensity recommended for L-810 (L) and L-864 (L) fixtures incorporating IR emitters.

5.1 OUTPUT WAVELENGTH.

Based on this research effort, a nominal IR output wavelength of 800-900 nm is proposed. This range coincides with the nominal spectral response range of NVGs, ensuring the fixtures will be visible by all current NVGs regardless of the class of objective lens filter used.

5.2 MINIMUM VERTICAL BEAM SPREAD.

For LED versions of both the L-810 and L-864 IR fixtures, the minimum vertical beam spreads of the IR emissions should meet the existing FAA requirements in AC 150/5345-43H [5] for the photometric beam spread and distribution of the visible light. T herefore, ATR researchers recommend that the L-810 (L) IR fixture have a minimum 10° IR vertical beam spread with the center between +4° and +20° at all radials throughout 360°. The ATR researchers also recommend that the L-864 (L) have a 3° minimum vertical IR beam spread at all radials throughout 360°.

5.3 MINIMUM IR RADIANT INTENSITY.

Based on the results of the flight evaluations conducted, ATR researchers determined that an IR radiant intensity of 4 mW/sr could be acquired by all subjects outside of the minimum L-810 and L-864 acquisition distances listed in AC 70/7460-1 [6] during nighttime VMC.

A minimum radiant intensity of 4 m W/sr is recommended for L-810 (L) IR fixtures. ATR researchers concluded it was desirable to produce a sufficiently differentiated appearance between the L-810 and L-864 fixtures when viewed with NVGs. Therefore, a minimum radiant intensity of 246 mW/sr is recommended for L-864 (L) IR fixtures.

Table 16 shows the minimum intensities for the L-810 and L-864 fixtures.

Table 16. Minimum Intensities for L-810 and L-864 Fixtures

Obstruction Light Fixture	Time Period	Meteorological Conditions (SM)	Acquisition Distance (SM)	Minimum cd	Minimum mW/sr
L-810	Night	3	1.4	32.5	4
L-864			3.1	2000 (±25%)	246

6. REFERENCES.

1. Australian Government, Australian Transport Safety Bureau, "Night Vision Goggles in Civil Helicopter Operations," Aviation Research Report B2004/0152, April 2005.

2. Federal Aviation Administration (FAA), "Night Vision Goggle (NVG) Advisory Pertaining to Certain Red Color Light Emitting Diodes (LED)," Safety Alert for Operators (SAFO) 09007, March 6, 2009.

3. FAA, "Enhanced Flight Vision System (EFVS), Enhanced Vision Systems (EVS), and Night Vision Goggles (NVG) compatibility with Light-Emitting Diodes (LED) at airports and on obstacles," Information for Operators (InFO) 11004, February 15, 2011.

4. FAA, "Safety Risk Assessment of Light Emitting Diode (LED) Lighting in Aircraft Operations Addendum," FAA internal report, September 30, 2016.

5. Federal Aviation Administration, "Specification for Obstruction Lighting Equipment," Advisory Circular (AC) 150/5345-43H, September 28, 2016.

6. FAA, "Obstruction Marking and Lighting," AC 70/7460-1L, December 4, 2015.

7. Schmickley, D.L., *The Avionics Handbook*, CRC Press, C. R. Spitzer, ed., Virginia, 2001, Chapter 7, "Night Vision Goggles," http://nvgsafety.com/NVG_Support/Night_Vision_Goggles/Night_Vision_Goggles_Chap7.pdf (date last visited 12/12/17).

8. Aldous, A. and Luke, D., "Night Vision: Defining the Differences," March 2011, available at http://nvgsafety.com/Articles_n_Publications/Night_Vision-Defining-the-Differences.pdf (date last visited 5/8/2017).

9. Rash, C.E., "Use of Night Vision Goggles Increases in Civilian Helicopter Operations," *Flight Safety Foundation—Helicopter Safety*, Vol. 30, No. 6, November-December 2004.

10. Salazar, G., Temme, L., and Antonio, J.C., "Civilian Use of Night Vision Goggles," Association of Air Medical Services Position Paper, January 2003.

11. FAA, Flight Standards Information Management System, "Aircraft Equipment and Operational Authorization," FAA Order 8900.1, Vol. 4, June 23, 2014.

12. Mai, T., Federal Aviation Administration Office of Airport Safety and Standards, "Airport Visual Aids Update," *Illuminating Engineering Society of North America Aviation Lighting Committee (IESALC) Government Contract Meeting*, May 10, 2012.

13. Gallagher, D., FAA, Microsoft® Excel® spreadsheet: NVG LED, internal communication, 2012.

14. U.S. Department of Defense, "Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible," Interface Standard MIL-STD-3009, February 2, 2001.

15. Bassey, R. and Gallagher, D., "Visibility of Light Emitting Diodes With Night Vision Goggles," *International Civil Aviation Organization Aerodromes Panel, Visual Aids Working Group (8th Meeting)*, June 16, 2011.

16. Finnish Transport Safety Agency, "Frequently asked questions/Wind turbines and wind parks," April 4, 2014 , https://www.trafi.fi/filebank/a/1398325294/8c76ffa4719ef2b49b5de75832e19ab3/14618-Trafi_FAQ_wind_turbines_and_wind_parks.pdf (date last visited 12/01/17).

17. Finnish Transport Safety Agency, "Instructions for daytime signaling of wind turbines, aircraft warning lights and the grouping of lights," December 11, 2013, https://www.trafi.fi/filebank/a/1398325231/5f0bd97a9f10b3607113b514a1d630a0/14617-Trafi__windturbines_daymarkings_and_obstacle_lights_12112013.pdf (date last visited 12/01/17).

18. United Kingdom Ministry of Defense, Royal Air Force, Low Flying Operations Squadron, "MOD Specification for IR and Low Intensity Red Vertical Obstruction Lighting (AL 3)," Reference: W ITT/605/LFOPS, November 22, 2012, http://planning.allerdale.gov.uk/portal/servlets/AttachmentShowServlet?ImageName=250651 (date last visited 12/01/17).

APPENDIX A—DETAILED TESTING RESULTS FOR SAMPLE 110155:
L-810 (L) FIXTURE WITH INFRARED EMITTER

Figures A-1 through A-4 and tables A-1 through A-3 provide detailed testing results for sample 110155: L-810 fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

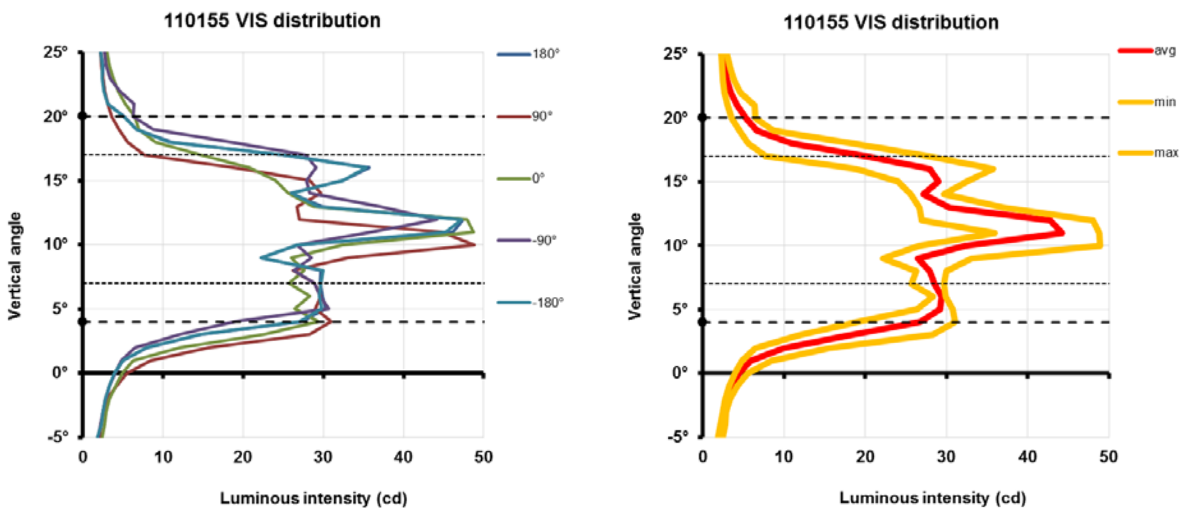


Figure A-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110155

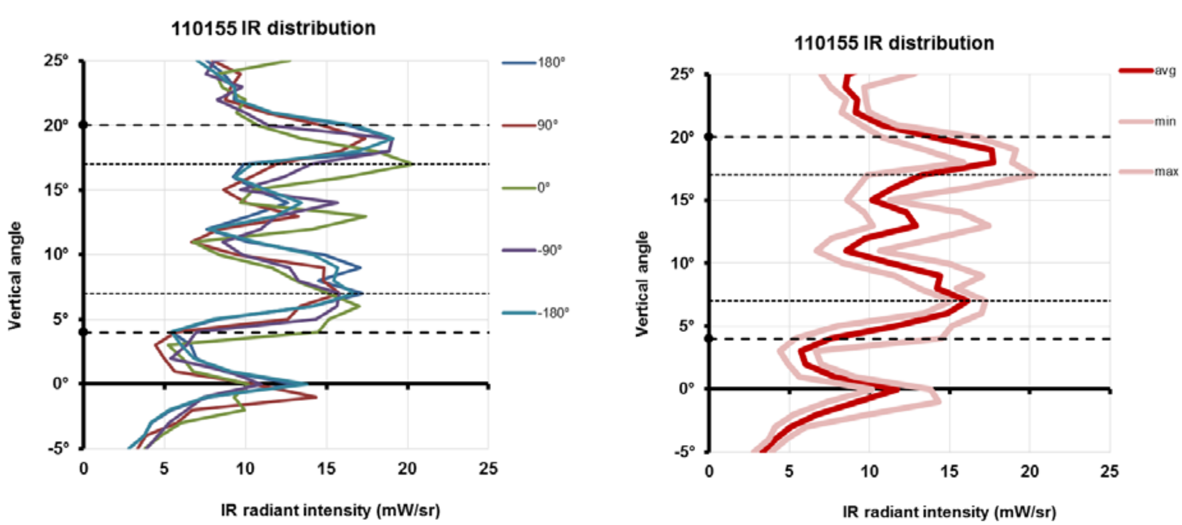


Figure A-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110155

Table A-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110155

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	3.6	23.0	48.9	12.4	4.4	11.9	20.3	4.0
4° to 20° Beam	3.6	26.2	48.9	11.3	5.4	12.8	20.3	3.7
7° to 17° Beam	7.7	30.6	48.9	8.6	6.7	12.2	20.3	3.1

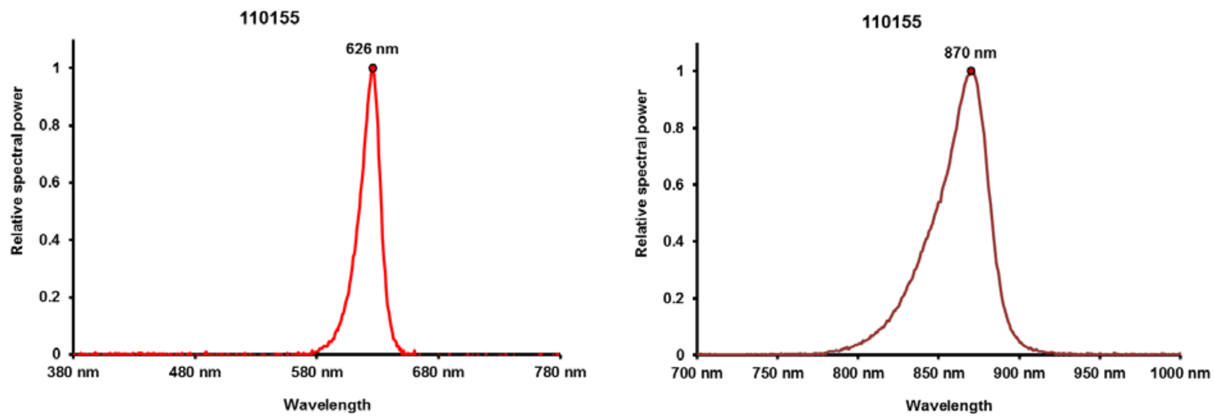


Figure A-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110155
(The peak wavelength in each region is also shown.)

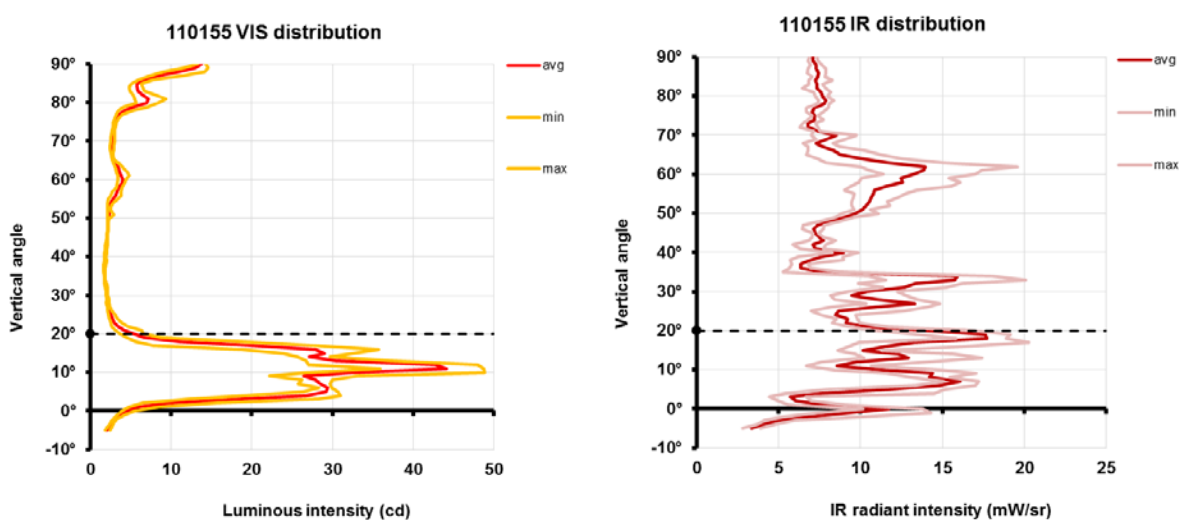


Figure A-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110155

Table A-2. Luminous intensity (cd) distribution of sample 110155 VIS

Vertical angles	180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
	Horizontal angles								
-5°	2	2	2	2	2	2	2	2	0
-4°	2	2	3	2	2	2	2	3	0
-3°	3	3	3	3	2	2	3	3	0
-2°	3	3	3	3	3	3	3	3	0
-1°	3	4	4	3	3	3	4	4	0
0°	4	5	5	4	4	4	4	5	1
1°	5	8	6	5	5	5	6	8	2
2°	8	16	12	6	8	6	10	16	4
3°	15	28	23	12	15	12	18	28	7
4°	27	31	29	19	27	19	27	31	5
5°	30	29	26	31	30	26	29	31	2
6°	30	30	28	30	29	28	29	30	1
7°	30	29	26	29	30	26	29	30	2
8°	30	26	28	26	30	26	28	30	2
9°	22	33	26	29	22	22	26	33	5
10°	27	49	32	27	27	27	32	49	10
11°	46	45	49	36	45	36	44	49	5
12°	47	27	48	44	47	27	43	48	9
13°	30	27	29	37	29	27	30	37	4
14°	26	30	26	28	26	26	27	30	2
15°	32	28	24	28	32	24	29	32	4
16°	36	19	21	29	35	19	28	36	8
17°	25	8	15	28	25	8	20	28	8
18°	11	6	9	18	11	6	11	18	5
19°	7	5	7	9	7	5	7	9	1
20°	5	4	6	6	5	4	5	6	1
21°	3	3	5	6	3	3	4	6	2
22°	3	3	4	5	3	3	3	5	1
23°	2	2	4	3	2	2	3	4	1
24°	2	2	3	3	2	2	3	3	0
25°	2	2	3	3	2	2	2	3	0
26°	2	2	3	3	2	2	2	3	0
27°	2	2	2	2	2	2	2	2	0
28°	2	2	2	2	2	2	2	2	0
29°	2	2	2	2	2	2	2	2	0
30°	2	2	2	2	2	2	2	2	0
31°	2	2	2	2	2	2	2	2	0
32°	2	2	2	2	2	2	2	2	0
33°	2	2	2	2	2	2	2	2	0
34°	2	2	2	2	2	2	2	2	0
35°	2	2	2	2	2	2	2	2	0
36°	2	2	2	2	2	2	2	2	0
37°	2	2	2	2	2	2	2	2	0
38°	2	2	2	2	2	2	2	2	0
39°	2	2	2	2	2	2	2	2	0
40°	2	2	2	2	2	2	2	2	0
41°	2	2	2	2	2	2	2	2	0
42°	2	2	2	2	2	2	2	2	0
43°	2	2	2	2	2	2	2	2	0
44°	2	2	2	2	2	2	2	2	0
45°	2	2	2	2	2	2	2	2	0
46°	2	2	2	2	2	2	2	2	0

47°	2	2	2	2	2	2	2	2	0
48°	2	2	2	2	2	2	2	2	0
49°	2	2	2	2	2	2	2	2	0
50°	2	2	2	2	2	2	2	2	0
51°	2	2	2	3	2	2	2	3	0
52°	2	2	2	3	2	2	2	3	0
53°	2	2	2	2	2	2	2	2	0
54°	3	3	2	2	3	2	3	3	0
55°	3	3	3	2	3	2	3	3	1
56°	4	3	3	3	4	3	3	4	1
57°	4	3	3	3	4	3	3	4	0
58°	4	3	4	3	4	3	4	4	0
59°	4	3	4	4	4	3	4	4	0
60°	4	3	4	4	4	3	4	4	0
61°	3	3	4	5	3	3	4	5	1
62°	3	3	4	5	3	3	4	5	1
63°	3	3	4	4	3	3	3	4	1
64°	3	3	4	3	3	3	3	4	0
65°	3	3	3	3	3	3	3	3	0
66°	3	3	3	3	3	3	3	3	0
67°	3	3	2	3	3	2	3	3	0
68°	3	3	2	3	3	2	3	3	0
69°	3	3	2	3	3	2	3	3	0
70°	3	3	2	3	3	2	3	3	0
71°	3	3	3	3	3	3	3	3	0
72°	3	3	3	3	3	3	3	3	0
73°	3	3	3	3	3	3	3	3	0
74°	3	3	3	3	3	3	3	3	0
75°	3	3	3	3	3	3	3	3	0
76°	3	3	4	3	3	3	3	4	0
77°	4	4	4	3	4	3	4	4	0
78°	4	5	5	3	4	3	4	5	1
79°	5	7	5	4	5	4	5	7	1
80°	8	7	6	6	8	6	7	8	1
81°	7	6	6	9	7	6	7	9	1
82°	7	5	5	8	7	5	6	8	1
83°	7	5	5	6	7	5	6	7	1
84°	6	5	5	6	6	5	6	6	1
85°	6	6	5	6	6	5	6	6	0
86°	6	8	6	7	6	6	7	8	1
87°	7	11	8	8	7	7	8	11	2
88°	10	14	12	9	10	9	11	14	2
89°	12	15	14	12	12	12	13	15	1
90°	14	14	14	13	14	13	14	14	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***3.6***	***23.0***	***48.9***	***12.4***
4° to 20° beam	3.6	26.2	48.9	11.3
7° to 17° beam	7.7	30.6	48.9	8.6

Table A-3. Radiant intensity (mW/sr) distribution of sample 110155 IR

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	3	3	4	4	3	3	3	4	1
-4°	4	4	5	5	4	4	4	5	1
-3°	4	6	6	5	4	4	5	6	1
-2°	5	7	10	6	5	5	7	10	2
-1°	8	14	9	7	8	7	9	14	3
0°	13	10	10	11	14	10	12	14	2
1°	9	6	7	9	9	6	8	9	2
2°	7	5	6	5	7	5	6	7	1
3°	7	4	5	6	6	4	6	7	1
4°	5	6	14	7	5	5	8	14	4
5°	8	13	15	14	8	8	12	15	3
6°	14	13	17	16	14	13	15	17	1
7°	17	16	15	16	17	15	16	17	1
8°	14	15	13	13	15	13	14	15	1
9°	17	15	12	13	16	12	14	17	2
10°	15	10	8	10	14	8	11	15	3
11°	10	7	7	9	11	7	9	11	2
12°	8	8	14	11	8	8	10	14	3
13°	10	13	17	12	12	10	13	17	3
14°	13	10	10	16	13	10	12	16	2
15°	11	9	10	10	11	9	10	11	1
16°	9	10	16	12	9	9	12	16	3
17°	10	12	20	14	10	10	13	20	4
18°	19	16	18	19	17	16	18	19	1
19°	19	17	13	19	19	13	18	19	2
20°	16	15	11	11	17	11	14	17	3
21°	11	11	9	10	12	9	11	12	1
22°	9	9	10	8	9	8	9	10	1
23°	9	9	9	10	9	9	9	10	0
24°	9	10	8	8	8	8	8	10	1
25°	8	8	13	8	7	7	9	13	2
26°	8	11	13	14	8	8	11	14	3
27°	15	14	10	13	14	10	13	15	2
28°	12	13	8	9	12	8	11	13	2
29°	9	9	13	8	9	8	9	13	2
30°	9	10	12	11	9	9	10	12	1
31°	12	13	11	15	12	11	13	15	2
32°	14	16	10	12	15	10	13	16	3
33°	14	19	20	12	14	12	16	20	4
34°	18	17	11	17	17	11	16	18	3
35°	9	7	5	8	9	5	8	9	1
36°	7	6	6	6	7	6	6	7	1
37°	7	6	7	6	6	6	6	7	0
38°	7	6	9	6	7	6	7	9	1
39°	8	6	9	8	7	6	8	9	1
40°	9	10	8	8	9	8	9	10	1
41°	8	7	8	6	7	6	7	8	1
42°	8	7	8	6	7	6	7	8	1
43°	8	8	8	7	8	7	8	8	1
44°	8	8	7	7	8	7	7	8	0
45°	7	7	7	7	7	7	7	7	0
46°	7	7	6	8	7	6	7	8	0

47°	8	8	7	8	8	7	7	8	1
48°	9	8	8	8	9	8	8	9	1
49°	9	9	9	9	10	9	9	10	0
50°	9	11	10	9	9	9	10	11	1
51°	10	11	10	10	10	10	10	11	0
52°	9	12	10	10	10	9	10	12	1
53°	9	12	12	10	10	9	11	12	1
54°	10	12	12	10	10	10	11	12	1
55°	10	13	10	12	10	10	11	13	1
56°	9	13	10	12	10	9	11	13	2
57°	9	16	13	10	9	9	12	16	3
58°	10	15	16	12	10	10	13	16	3
59°	10	12	15	14	11	10	12	15	2
60°	12	12	14	17	11	11	13	17	2
61°	16	11	10	17	15	10	14	17	3
62°	17	10	11	13	20	10	14	20	4
63°	14	8	11	11	15	8	12	15	3
64°	12	7	9	9	13	7	10	13	2
65°	10	7	7	8	11	7	9	11	2
66°	10	7	7	8	10	7	8	10	2
67°	9	8	7	7	8	7	8	9	1
68°	7	8	8	7	6	6	7	8	1
69°	8	9	8	7	7	7	8	9	1
70°	9	9	7	10	8	7	9	10	1
71°	8	8	7	8	7	7	7	8	0
72°	7	7	7	6	7	6	7	7	0
73°	7	7	7	7	7	7	7	7	0
74°	8	7	7	7	8	7	7	8	0
75°	7	7	7	7	7	7	7	7	0
76°	7	7	8	7	7	7	7	8	0
77°	7	7	8	7	7	7	7	8	1
78°	8	7	8	8	8	7	8	8	0
79°	8	8	8	7	8	7	8	8	0
80°	8	8	7	8	7	7	8	8	0
81°	8	7	7	8	8	7	8	8	0
82°	8	6	8	7	8	6	7	8	1
83°	8	7	8	7	7	7	7	8	0
84°	7	7	8	7	7	7	7	8	1
85°	8	7	7	7	8	7	7	8	0
86°	8	7	8	7	8	7	7	8	1
87°	7	8	7	7	7	7	7	8	0
88°	8	7	7	7	8	7	7	8	0
89°	7	7	7	7	7	7	7	7	0
90°	7	7	7	7	7	7	7	7	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***4.4***	***11.9***	***20.3***	***4.0***
4° to 20° beam	5.4	12.8	20.3	3.7
7° to 17° beam	6.7	12.2	20.3	3.1

APPENDIX B—DETAILED TESTING RESULTS FOR SAMPLE 110156:
L-810 INFRARED-ONLY FIXTURE

Figures B-1 through B-3 and tables B-1 and B-2 provide detailed testing results for sample 110156: L-810 infrared (IR)-only fixture. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

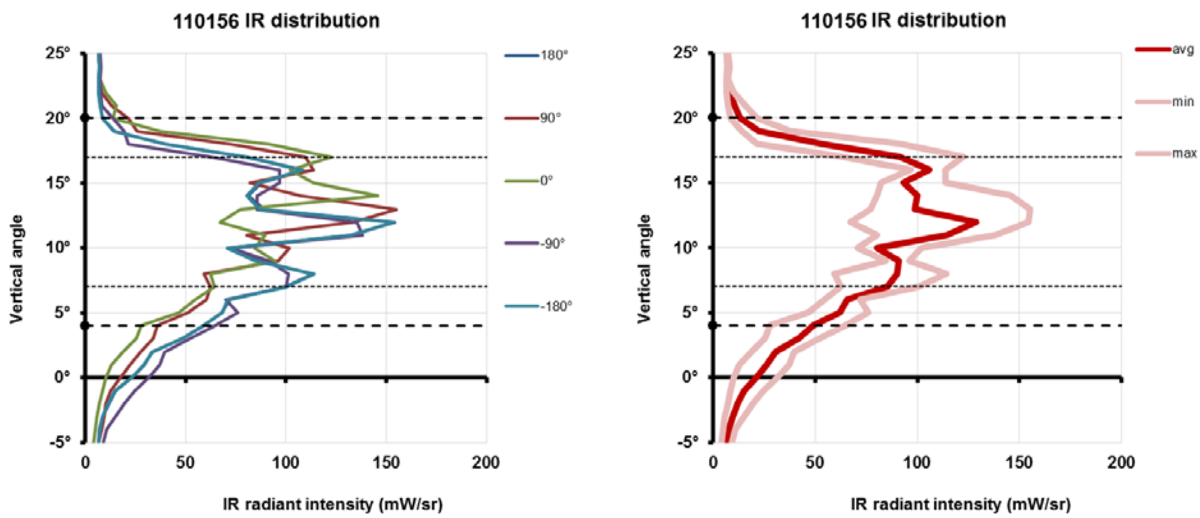


Figure B-1. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110156

Table B-1. Summary of Radiant Intensity Across Different Beam Regions for Sample 110156 (This sample does not have a visible red light source.)

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	N/A	N/A	N/A	N/A	8.5	69.7	155.2	37.8
4° to 20° Beam	N/A	N/A	N/A	N/A	8.5	79.1	155.2	35.7
7° to 17° Beam	N/A	N/A	N/A	N/A	59.2	98.1	155.2	24.9

N/A=Not applicable

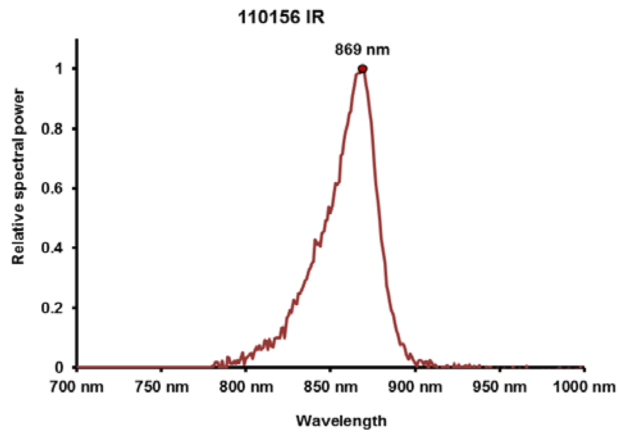


Figure B-2. Relative Spectral Power Distribution in the IR Region for Sample 110156 (The peak wavelength is also shown.)

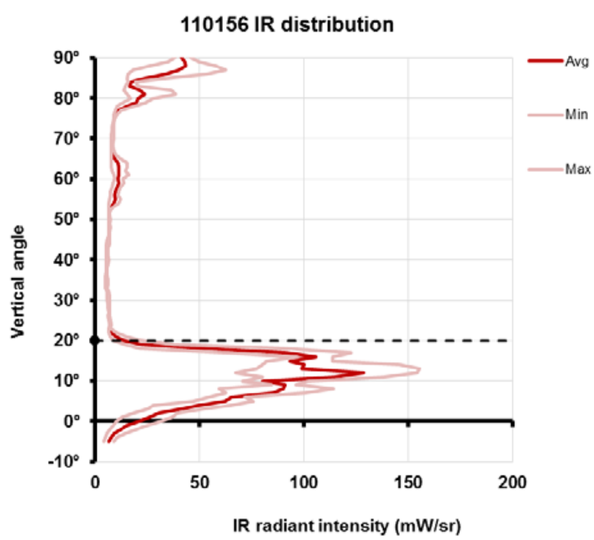


Figure B-3. Average, Minimum, and Maximum Radiant Intensity as a Function of Vertical Angle From -5° to 90° for Sample 110156

Table B-2. Radiant intensity (mW/sr) distribution of sample 110156 IR

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	6	7	4	9	6	4	7	9	2
-4°	7	8	5	11	7	5	8	11	2
-3°	8	9	6	15	9	6	9	15	3
-2°	12	10	7	19	11	7	12	19	4
-1°	15	13	9	25	15	9	15	25	6
0°	23	17	10	31	23	10	21	31	8
1°	30	22	13	37	29	13	26	37	9
2°	33	27	19	39	34	19	30	39	8
3°	49	34	25	52	48	25	42	52	12
4°	59	36	28	65	59	28	49	65	16
5°	68	51	47	76	68	47	62	76	12
6°	72	60	55	70	71	55	66	72	8
7°	100	63	64	100	101	63	85	101	20
8°	113	59	62	101	114	59	90	114	27
9°	87	96	95	92	85	85	91	96	5
10°	71	102	84	73	71	71	80	102	13
11°	132	80	90	138	133	80	114	138	27
12°	154	133	67	135	153	67	129	154	36
13°	89	155	77	86	87	77	99	155	32
14°	81	107	146	86	80	80	100	146	28
15°	87	82	114	97	86	82	93	114	13
16°	108	114	102	97	108	97	106	114	7
17°	81	110	123	63	80	63	91	123	24
18°	40	72	92	21	40	21	53	92	28
19°	15	26	37	19	14	14	22	37	10
20°	9	21	14	14	8	8	13	21	5
21°	7	13	15	8	7	7	10	15	4
22°	7	8	10	8	7	7	8	10	1
23°	7	7	7	7	7	7	7	7	0
24°	7	7	7	8	7	7	7	8	0
25°	7	7	7	7	7	7	7	7	0
26°	6	7	7	7	6	6	6	7	0
27°	7	6	7	7	7	6	7	7	0
28°	6	7	7	7	6	6	6	7	0
29°	6	7	6	7	6	6	7	7	0
30°	6	7	6	7	6	6	6	7	0
31°	6	6	6	7	6	6	6	7	0
32°	6	6	6	7	6	6	6	7	0
33°	5	6	6	6	5	5	5	6	0
34°	5	5	6	5	5	5	5	6	0
35°	5	5	6	5	5	5	5	6	0
36°	5	5	6	5	5	5	5	6	0
37°	5	5	6	6	5	5	5	6	0
38°	5	5	6	6	5	5	6	6	0
39°	6	5	6	6	6	5	6	6	0
40°	5	7	6	6	5	5	6	7	0
41°	5	6	6	6	5	5	6	6	0
42°	6	6	5	6	6	5	6	6	0
43°	6	6	5	6	6	5	6	6	0
44°	6	6	5	7	6	5	6	7	1
45°	6	6	6	7	6	6	6	7	1
46°	7	7	7	7	6	6	7	7	0

47°	7	7	7	7	7	7	7	7	0
48°	7	7	7	7	7	7	7	7	0
49°	7	7	7	6	7	6	7	7	0
50°	7	7	7	6	7	6	7	7	0
51°	7	7	7	7	7	7	7	7	0
52°	7	7	6	7	7	6	7	7	0
53°	8	7	7	8	8	7	8	8	1
54°	11	8	7	9	11	7	9	11	2
55°	12	9	7	9	12	7	10	12	2
56°	11	9	7	10	11	7	9	11	2
57°	11	9	7	10	11	7	10	11	2
58°	12	9	8	11	12	8	11	12	2
59°	12	10	9	14	12	9	11	14	2
60°	11	9	10	13	11	9	11	13	2
61°	9	11	11	16	9	9	11	16	3
62°	8	14	13	15	8	8	11	15	3
63°	8	15	14	12	8	8	11	15	4
64°	8	14	15	10	8	8	11	15	4
65°	8	12	11	9	8	8	9	12	2
66°	8	10	8	9	8	8	8	10	1
67°	8	9	8	9	8	8	8	9	1
68°	8	9	8	9	8	8	8	9	1
69°	8	8	8	9	8	8	8	9	0
70°	8	8	8	9	8	8	8	9	0
71°	8	8	8	9	8	8	8	9	0
72°	8	8	8	9	8	8	8	9	0
73°	8	9	8	9	8	8	9	9	0
74°	9	9	9	9	9	9	9	9	0
75°	9	9	9	9	9	9	9	9	0
76°	10	9	9	11	10	9	10	11	1
77°	12	10	10	13	12	10	11	13	1
78°	19	11	11	18	19	11	16	19	4
79°	24	14	13	24	24	13	20	24	6
80°	17	19	22	28	17	17	21	28	5
81°	15	31	38	19	15	15	24	38	10
82°	14	27	37	17	14	14	22	37	10
83°	15	18	21	15	15	15	17	21	3
84°	19	16	17	16	19	16	18	19	2
85°	33	15	16	21	33	15	24	33	9
86°	53	16	16	31	53	16	34	53	19
87°	63	20	18	39	62	18	40	63	22
88°	57	33	26	42	58	26	43	58	14
89°	50	39	35	42	49	35	43	50	6
90°	38	40	43	46	38	38	41	46	3

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***8.5***	***69.7***	***155.2***	***37.8***
4° to 20° beam	8.5	79.1	155.2	35.7
7° to 17° beam	59.2	98.1	155.2	24.9

APPENDIX C—DETAILED TESTING RESULTS FOR SAMPLE 110157:
L-810 (L) FIXTURE WITH INFRARED EMITTER

Figures C-1 through C-4 and tables C-1 through C-3 provide detailed testing results for sample 110157: L-810 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

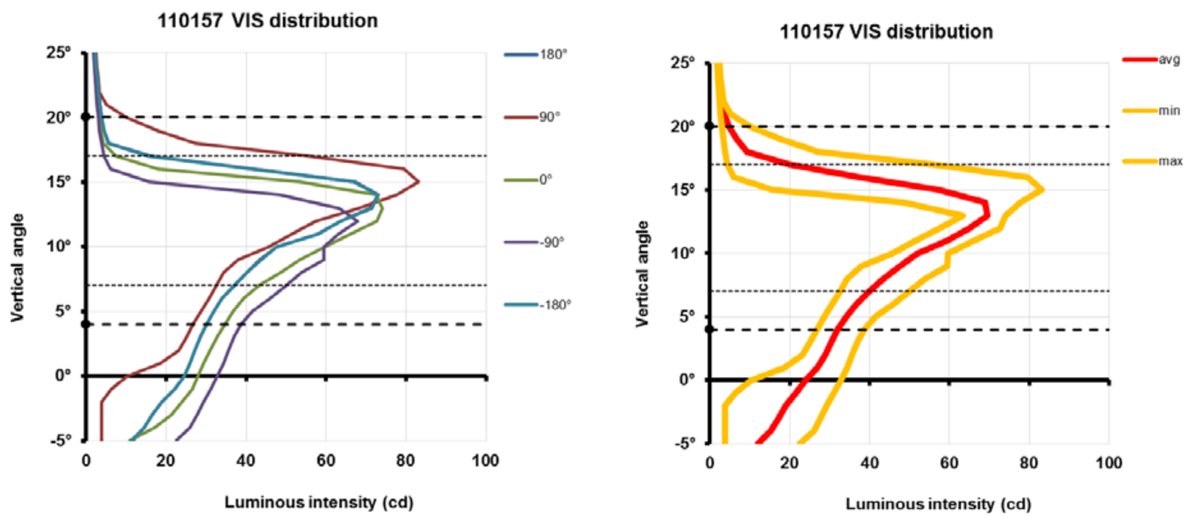


Figure C-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110157

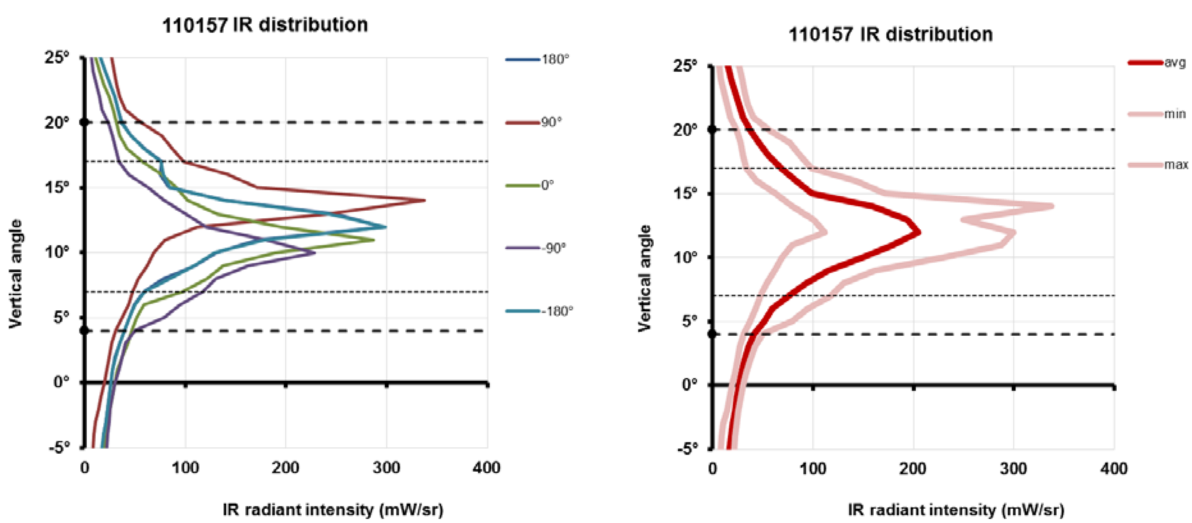


Figure C-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110157

Table C-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110157

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	3.0	37.8	83.1	21.6	19.5	87.3	337.1	69.2
4° to 20° Beam	3.0	40.3	83.1	23.2	23.5	100.7	337.1	70.6
7° to 17° Beam	4.4	50.9	83.1	19.7	33.6	129.2	337.1	72.4

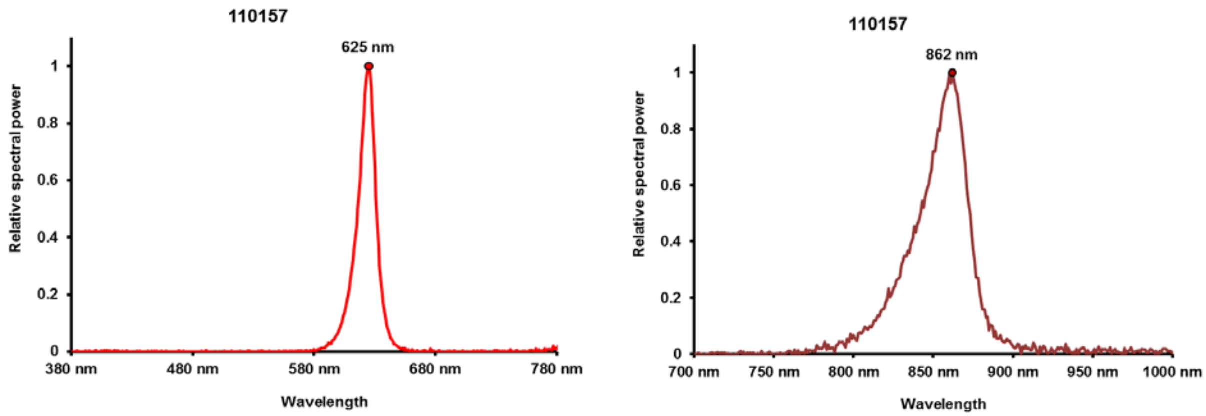


Figure C-3. Relative Spectral Power Distributions in the Visible (Left) and IR (Right) Regions for Sample 110157
(The peak wavelength in each region is also shown.)

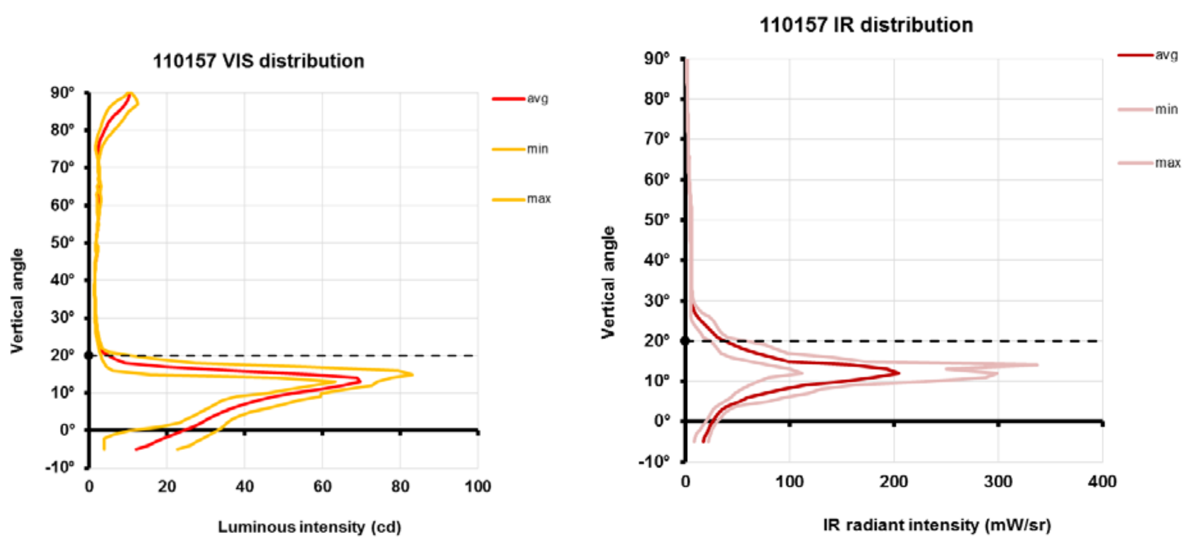


Figure C-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110157

Table C-2. Luminous intensity (cd) distribution of sample 110157 VIS

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	12	4	11	23	11	4	12	23	7
-4°	15	4	17	26	15	4	15	26	8
-3°	17	4	21	28	17	4	17	28	9
-2°	19	4	24	29	19	4	19	29	9
-1°	22	6	26	31	22	6	22	31	9
0°	24	10	28	33	25	10	24	33	8
1°	26	19	29	34	26	19	27	34	6
2°	27	23	31	35	27	23	29	35	5
3°	29	25	33	37	29	25	30	37	5
4°	30	27	35	39	30	27	32	39	5
5°	32	29	37	42	32	29	34	42	5
6°	34	31	39	46	34	31	37	46	6
7°	37	33	43	50	37	33	40	50	7
8°	40	34	49	54	40	34	43	54	8
9°	43	38	53	59	44	38	48	59	9
10°	48	46	60	60	48	46	52	60	7
11°	58	51	66	63	58	51	59	66	6
12°	64	57	73	68	64	57	65	73	6
13°	71	68	74	63	71	63	70	74	4
14°	73	78	73	48	73	48	69	78	12
15°	67	83	53	16	67	16	57	83	26
16°	42	80	18	6	41	6	37	80	28
17°	16	56	8	4	16	4	20	56	21
18°	6	27	4	4	6	4	9	27	10
19°	4	18	4	3	4	3	7	18	6
20°	4	10	3	3	4	3	5	10	3
21°	3	5	3	3	3	3	4	5	1
22°	3	3	3	2	3	2	3	3	0
23°	3	3	2	2	3	2	3	3	0
24°	3	3	2	2	3	2	2	3	0
25°	2	2	2	2	2	2	2	2	0
26°	2	2	2	2	2	2	2	2	0
27°	2	2	2	2	2	2	2	2	0
28°	2	2	2	2	2	2	2	2	0
29°	2	2	2	2	2	2	2	2	0
30°	2	2	2	1	2	1	2	2	0
31°	2	2	2	1	2	1	2	2	0
32°	2	2	1	1	2	1	2	2	0
33°	2	2	1	1	2	1	2	2	0
34°	2	2	1	1	2	1	2	2	0
35°	2	2	1	1	2	1	1	2	0
36°	1	2	1	1	1	1	1	2	0
37°	1	2	1	1	1	1	1	2	0
38°	1	2	1	1	1	1	1	2	0
39°	1	2	1	1	1	1	1	2	0
40°	1	2	1	1	1	1	1	2	0
41°	1	2	1	1	1	1	1	2	0
42°	1	2	1	1	1	1	1	2	0
43°	2	2	1	2	2	1	2	2	0
44°	2	2	1	2	2	1	2	2	0
45°	2	2	2	2	2	2	2	2	0
46°	2	2	2	2	2	2	2	2	0

47°	2	2	2	2	2	2	2	2	0
48°	2	2	2	2	2	2	2	2	0
49°	2	2	2	2	2	2	2	2	0
50°	2	2	2	2	2	2	2	2	0
51°	2	2	2	2	2	2	2	2	0
52°	2	2	2	2	2	2	2	2	0
53°	2	2	2	2	2	2	2	2	0
54°	2	2	2	2	2	2	2	2	0
55°	2	2	2	2	2	2	2	2	0
56°	2	2	2	2	2	2	2	2	0
57°	2	2	2	2	2	2	2	2	0
58°	3	3	3	2	3	2	2	3	0
59°	3	3	3	2	3	2	3	3	0
60°	2	3	3	2	2	2	2	3	0
61°	2	3	3	2	2	2	3	3	0
62°	2	3	3	2	2	2	2	3	0
63°	2	3	2	2	2	2	2	3	0
64°	2	3	2	2	2	2	2	3	0
65°	2	3	2	2	2	2	2	3	0
66°	2	3	2	3	2	2	3	3	0
67°	3	3	2	3	3	2	3	3	0
68°	3	3	2	2	3	2	3	3	0
69°	2	3	2	3	3	2	2	3	0
70°	2	3	2	3	2	2	2	3	0
71°	2	2	2	3	2	2	2	3	0
72°	3	2	2	3	3	2	2	3	0
73°	2	2	3	3	2	2	2	3	0
74°	2	2	3	3	2	2	2	3	0
75°	2	2	3	3	2	2	2	3	1
76°	2	2	3	3	2	2	3	3	1
77°	2	2	4	3	2	2	3	4	1
78°	3	2	5	4	3	2	3	5	1
79°	3	2	5	4	3	2	4	5	1
80°	3	3	6	4	3	3	4	6	1
81°	4	3	7	5	4	3	4	7	2
82°	4	3	8	5	4	3	5	8	2
83°	5	4	9	6	5	4	6	9	2
84°	6	4	10	7	6	4	7	10	2
85°	7	5	10	9	7	5	8	10	2
86°	8	5	11	11	8	5	8	11	3
87°	8	6	11	12	8	6	9	12	2
88°	9	7	11	12	9	7	10	12	2
89°	10	9	11	12	10	9	10	12	1
90°	10	10	11	11	10	10	10	11	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***3.0***	***37.8***	***83.1***	***21.6***
4° to 20° beam	3.0	40.3	83.1	23.2
7° to 17° beam	4.4	50.9	83.1	19.7

Table C-3. Radiant intensity (mW/sr) distribution of sample 110157 IR

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	19	8	20	22	17	8	17	22	5
-4°	19	9	22	23	19	9	18	23	6
-3°	21	10	24	24	21	10	20	24	6
-2°	23	14	25	25	23	14	22	25	5
-1°	24	17	27	27	24	17	24	27	4
0°	26	20	30	30	26	20	26	30	4
1°	27	22	33	34	27	22	29	34	5
2°	30	24	37	37	30	24	32	37	5
3°	34	27	42	40	35	27	36	42	6
4°	40	31	47	50	40	31	41	50	7
5°	44	37	52	79	44	37	51	79	16
6°	50	43	59	95	50	43	59	95	21
7°	59	48	97	118	59	48	76	118	30
8°	78	54	122	130	84	54	94	130	32
9°	109	62	137	162	108	62	116	162	37
10°	131	69	189	229	128	69	149	229	61
11°	171	79	287	180	179	79	179	287	74
12°	297	112	195	121	299	112	205	299	91
13°	250	240	132	100	243	100	193	250	71
14°	140	337	102	79	138	79	159	337	103
15°	84	171	91	63	84	63	99	171	42
16°	75	142	76	44	78	44	83	142	36
17°	76	98	57	34	75	34	68	98	24
18°	60	87	42	30	59	30	56	87	21
19°	46	77	35	28	46	28	46	77	19
20°	37	56	31	24	37	24	37	56	12
21°	33	40	28	17	33	17	30	40	9
22°	30	35	24	14	30	14	27	35	8
23°	25	32	19	11	25	11	23	32	8
24°	20	29	14	8	20	8	18	29	8
25°	16	26	11	6	15	6	15	26	7
26°	12	22	8	5	12	5	12	22	6
27°	9	16	7	5	9	5	9	16	4
28°	7	13	6	5	7	5	8	13	3
29°	6	9	6	5	6	5	7	9	2
30°	6	8	6	5	6	5	6	8	1
31°	6	7	6	5	6	5	6	7	1
32°	6	6	6	5	6	5	6	6	1
33°	6	6	6	5	6	5	6	6	1
34°	6	6	6	5	6	5	6	6	1
35°	6	6	6	5	6	5	5	6	1
36°	5	6	6	5	5	5	5	6	1
37°	5	6	6	5	5	5	5	6	0
38°	6	6	6	5	6	5	5	6	0
39°	6	6	6	5	6	5	6	6	0
40°	5	6	6	5	5	5	6	6	0
41°	6	6	6	5	6	5	6	6	0
42°	6	6	6	5	6	5	6	6	0
43°	6	6	6	5	6	5	6	6	1
44°	6	6	6	5	6	5	6	6	1
45°	6	6	6	5	6	5	6	6	1
46°	6	6	6	5	6	5	5	6	1

47°	5	6	6	5	5	5	5	6	0
48°	5	6	6	5	5	5	5	6	0
49°	5	6	6	4	5	4	5	6	1
50°	5	6	6	4	5	4	5	6	1
51°	5	6	5	4	5	4	5	6	1
52°	5	6	5	4	5	4	5	6	1
53°	5	6	5	4	5	4	5	6	0
54°	5	5	5	4	5	4	5	5	0
55°	5	5	5	4	5	4	5	5	0
56°	4	5	4	4	4	4	4	5	0
57°	4	5	4	4	4	4	4	5	0
58°	4	4	4	4	4	4	4	4	0
59°	4	4	4	3	4	3	4	4	0
60°	4	4	4	3	4	3	4	4	0
61°	3	4	3	3	3	3	3	4	0
62°	3	3	3	3	3	3	3	3	0
63°	3	3	3	3	3	3	3	3	0
64°	3	3	3	3	3	3	3	3	0
65°	3	4	3	3	3	3	3	4	0
66°	3	3	3	3	3	3	3	3	0
67°	3	3	3	3	3	3	3	3	0
68°	3	3	3	3	3	3	3	3	0
69°	3	3	3	3	3	3	3	3	0
70°	3	3	3	3	3	3	3	3	0
71°	3	3	3	3	3	3	3	3	0
72°	2	3	3	2	2	2	3	3	0
73°	2	3	3	2	2	2	2	3	0
74°	2	3	2	2	2	2	2	3	0
75°	2	3	2	2	2	2	2	3	0
76°	2	2	2	2	2	2	2	2	0
77°	2	2	2	2	2	2	2	2	0
78°	2	2	2	2	2	2	2	2	0
79°	2	2	2	2	2	2	2	2	0
80°	2	2	2	2	2	2	2	2	0
81°	2	2	2	2	2	2	2	2	0
82°	2	2	2	2	2	2	2	2	0
83°	2	2	2	2	2	2	2	2	0
84°	2	2	2	2	2	2	2	2	0
85°	2	2	2	2	2	2	2	2	0
86°	1	2	2	2	1	1	2	2	0
87°	1	2	2	2	1	1	2	2	0
88°	1	2	2	2	1	1	2	2	0
89°	1	2	2	2	1	1	2	2	0
90°	1	2	2	2	1	1	2	2	0

Summary

Luminous intensity (cd)	**Min**	**Avg**	**Max**	**Std**
0° to 20° beam	***19.5***	***87.3***	***337.1***	***69.2***
4° to 20° beam	23.5	100.7	337.1	70.6
7° to 17° beam	33.6	129.2	337.1	72.4

APPENDIX D—DETAILED TESTING RESULTS FOR SAMPLE 110158:
L-810 (L) FIXTURE WITH INFRARED EMITTER

Figures D-1 through D-4 and tables D-1 through D-3 provide detailed testing results for sample 110158: L-810 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

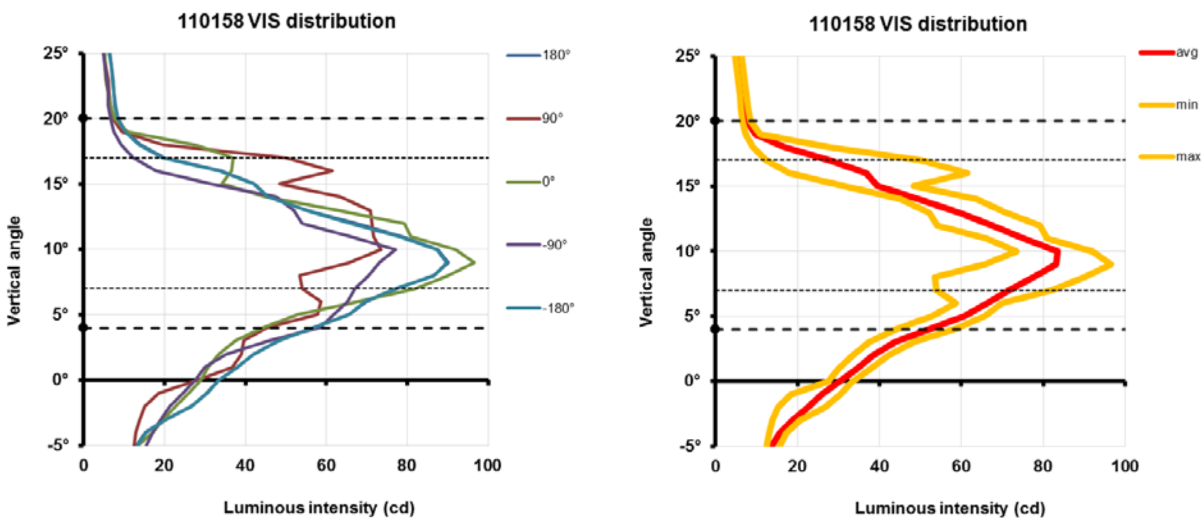


Figure D-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110158

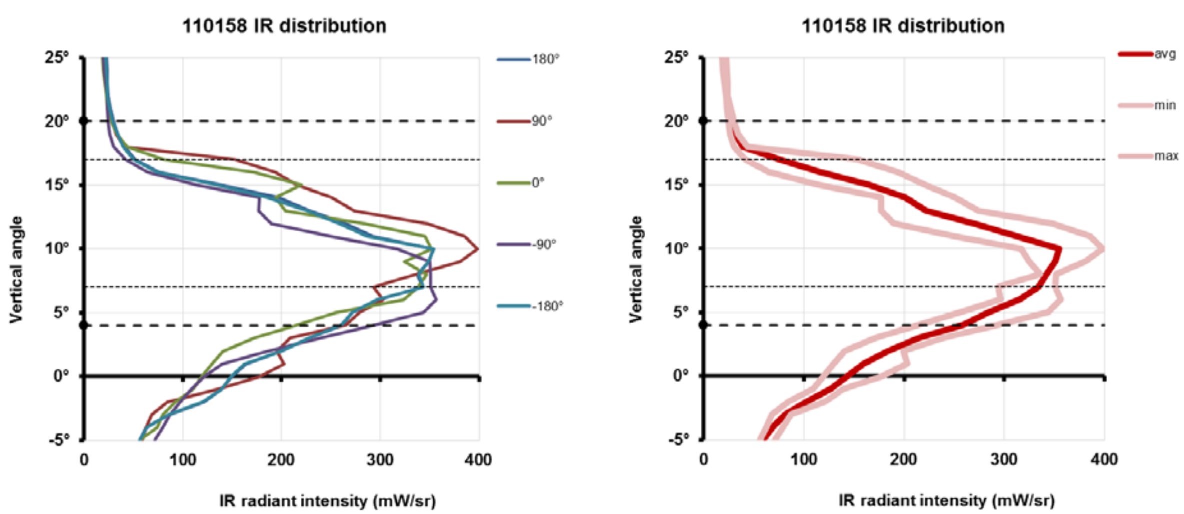


Figure D-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110158

Table D-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110158

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	6.7	49.2	96.5	24.2	24.4	209.6	398.1	111.0
4° to 20° Beam	6.7	52.1	96.5	25.9	24.4	217.6	398.1	120.9
7° to 17° Beam	12.2	61.0	96.5	21.5	41.7	249.2	398.1	103.0

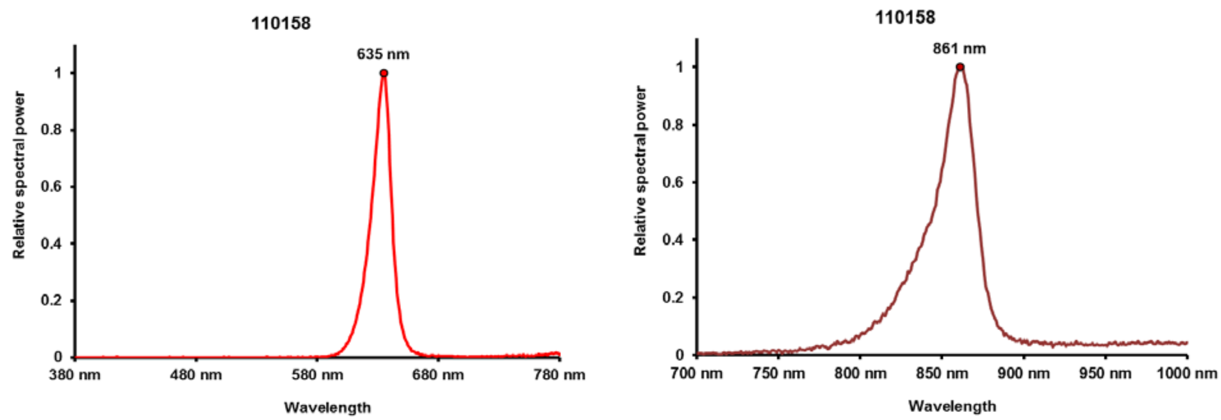


Figure D-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110158
(The peak wavelength in each region is also shown.)

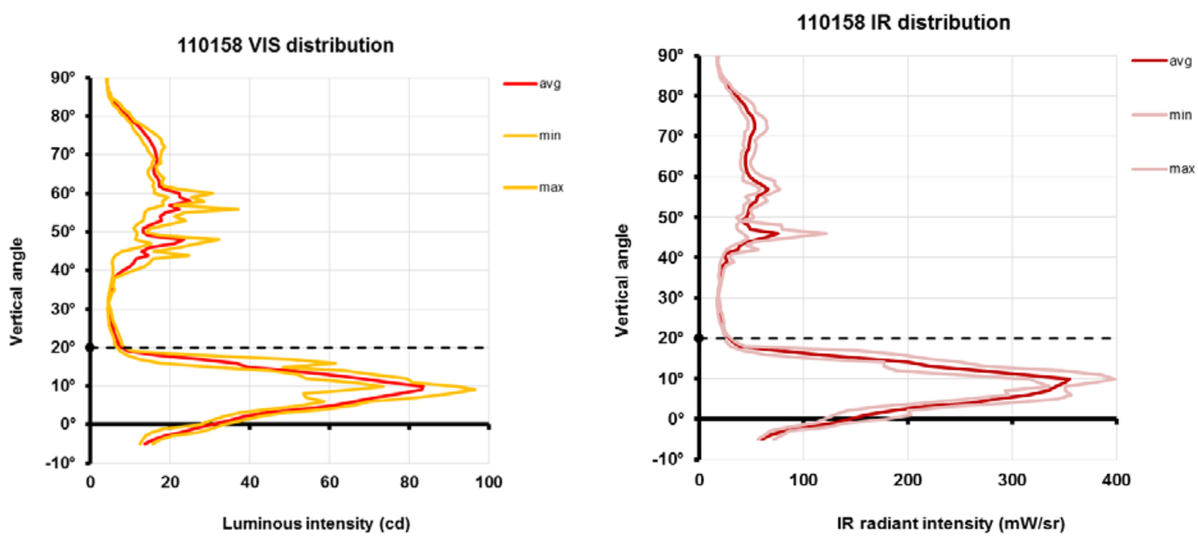


Figure D-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110158

Table D-2. Luminous intensity (cd) distribution of sample 110158 VIS

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	13	12	14	16	13	12	14	16	1
-4°	15	13	17	17	15	13	16	17	2
-3°	20	14	20	19	21	14	19	21	3
-2°	27	15	23	21	27	15	23	27	5
-1°	30	18	26	25	30	18	26	30	5
0°	33	28	29	27	33	27	30	33	3
1°	38	37	31	30	38	30	35	38	4
2°	42	39	33	35	42	33	38	42	4
3°	48	40	38	46	48	38	44	48	5
4°	57	45	44	58	57	44	52	58	7
5°	66	58	53	62	66	53	61	66	5
6°	70	59	68	65	69	59	66	70	5
7°	78	54	82	67	77	54	72	82	11
8°	87	54	90	70	87	54	77	90	15
9°	90	66	97	73	90	66	83	97	13
10°	88	73	92	77	87	73	83	92	8
11°	79	72	81	66	78	66	75	81	6
12°	67	71	79	54	66	54	68	79	9
13°	56	71	63	52	55	52	59	71	8
14°	46	64	45	48	46	45	49	64	8
15°	42	48	34	31	42	31	40	48	7
16°	34	61	37	18	34	18	37	61	16
17°	20	50	37	12	20	12	28	50	15
18°	14	20	28	9	14	9	17	28	7
19°	11	10	11	7	10	7	10	11	1
20°	9	7	8	7	8	7	8	9	1
21°	8	7	7	6	8	6	7	8	1
22°	8	6	6	6	7	6	7	8	1
23°	7	6	6	6	7	6	6	7	1
24°	7	5	5	5	7	5	6	7	1
25°	6	5	5	5	6	5	6	6	1
26°	6	5	5	5	6	5	5	6	1
27°	6	5	5	5	6	5	5	6	1
28°	5	5	5	4	5	4	5	5	0
29°	5	5	5	4	5	4	5	5	0
30°	5	5	5	4	5	4	5	5	0
31°	5	5	5	4	5	4	5	5	0
32°	4	4	5	5	5	4	5	5	0
33°	4	4	5	5	5	4	5	5	0
34°	5	5	5	5	5	5	5	5	0
35°	5	5	5	6	6	5	5	6	0
36°	6	5	5	6	6	5	6	6	0
37°	6	5	5	5	6	5	6	6	0
38°	6	6	6	5	6	5	6	6	0
39°	8	6	6	6	8	6	7	8	1
40°	10	6	8	6	11	6	8	11	2
41°	13	6	11	6	13	6	10	13	4
42°	15	6	12	7	15	6	11	15	4
43°	15	6	11	10	16	6	11	16	4
44°	14	6	13	25	14	6	15	25	7
45°	12	8	16	16	13	8	13	16	3
46°	13	12	13	22	14	12	15	22	4

47°	23	27	15	15	24	15	21	27	5
48°	27	32	21	11	26	11	23	32	8
49°	14	18	15	12	14	12	14	18	2
50°	14	12	14	13	14	12	13	14	1
51°	14	11	13	13	15	11	13	15	2
52°	19	12	13	14	20	12	15	20	4
53°	24	13	16	13	24	13	18	24	5
54°	21	14	18	13	21	13	18	21	4
55°	20	14	24	17	20	14	19	24	4
56°	18	15	24	37	18	15	22	37	9
57°	18	21	21	21	19	18	20	21	1
58°	28	26	18	25	28	18	25	28	4
59°	22	25	20	22	23	20	22	25	2
60°	21	24	31	16	21	16	22	31	5
61°	18	18	22	16	18	16	19	22	2
62°	18	17	18	16	18	16	17	18	1
63°	18	17	18	16	18	16	17	18	1
64°	19	15	18	15	19	15	17	19	2
65°	17	15	16	14	17	14	16	17	1
66°	17	15	16	15	17	15	16	17	1
67°	17	16	16	15	17	15	16	17	0
68°	17	18	16	16	17	16	17	18	1
69°	17	18	16	16	17	16	17	18	1
70°	17	18	17	15	17	15	17	18	1
71°	16	18	17	15	16	15	16	18	1
72°	15	19	17	14	15	14	16	19	2
73°	14	18	18	13	14	13	15	18	2
74°	14	18	17	13	13	13	15	18	2
75°	13	17	16	12	13	12	14	17	2
76°	12	15	15	11	12	11	13	15	2
77°	12	14	14	11	12	11	13	14	1
78°	11	12	12	10	11	10	12	12	1
79°	10	11	11	10	10	10	10	11	1
80°	9	10	10	9	9	9	9	10	1
81°	7	10	9	8	7	7	8	10	1
82°	7	8	8	7	7	7	7	8	1
83°	6	8	7	6	6	6	6	8	1
84°	6	7	5	5	6	5	6	7	1
85°	5	5	5	5	5	5	5	5	0
86°	4	5	5	5	4	4	5	5	0
87°	4	5	4	4	4	4	4	5	0
88°	4	4	4	4	4	4	4	4	0
89°	4	4	4	4	4	4	4	4	0
90°	4	4	4	4	4	4	4	4	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***6.7***	***49.2***	***96.5***	***24.2***
4° to 20° beam	6.7	52.1	96.5	25.9
7° to 17° beam	12.2	61.0	96.5	21.5

Table D-3. Radiant intensity (mW/sr) distribution of sample 110158 IR

Vertical angles	180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
	Horizontal angles								
-5°	56	59	56	71	57	56	60	71	7
-4°	63	63	74	79	64	63	69	79	8
-3°	86	68	80	87	85	68	81	87	8
-2°	121	85	92	97	120	85	103	121	17
-1°	139	135	111	109	139	109	127	139	15
0°	150	178	119	122	149	119	143	178	24
1°	164	203	129	140	163	129	160	203	28
2°	199	196	141	186	199	141	184	199	25
3°	228	209	173	240	228	173	216	240	26
4°	262	265	215	294	260	215	259	294	28
5°	271	279	256	344	271	256	284	344	34
6°	298	302	323	356	296	296	315	356	25
7°	343	293	338	351	344	293	334	351	23
8°	337	335	347	351	339	335	342	351	7
9°	350	380	325	350	349	325	351	380	20
10°	353	398	352	317	354	317	355	398	29
11°	292	385	346	249	287	249	312	385	53
12°	265	348	284	190	258	190	269	348	57
13°	229	274	204	177	227	177	222	274	36
14°	197	251	194	177	185	177	201	251	29
15°	138	215	220	114	134	114	164	220	50
16°	75	194	172	65	74	65	116	194	62
17°	52	153	80	42	50	42	75	153	46
18°	41	41	43	30	40	30	39	43	5
19°	34	32	33	26	34	26	32	34	3
20°	30	29	27	24	29	24	28	30	2
21°	27	24	24	23	26	23	25	27	1
22°	24	23	23	24	23	23	23	24	0
23°	24	23	21	22	23	21	23	24	1
24°	23	22	19	21	23	19	22	23	2
25°	22	21	19	19	22	19	21	22	2
26°	22	20	18	18	21	18	20	22	2
27°	20	20	18	18	19	18	19	20	1
28°	19	20	18	17	19	17	19	20	1
29°	18	19	17	17	18	17	18	19	1
30°	18	19	17	17	18	17	18	19	1
31°	19	18	18	18	19	18	18	19	0
32°	19	18	19	18	19	18	19	19	0
33°	20	19	19	19	20	19	19	20	1
34°	21	21	19	19	21	19	20	21	1
35°	22	20	20	19	21	19	20	22	1
36°	23	21	19	19	22	19	21	23	2
37°	24	20	19	20	23	19	21	24	2
38°	26	20	20	23	26	20	23	26	3
39°	33	21	22	26	33	21	27	33	6
40°	24	22	29	27	24	22	25	29	3
41°	24	24	24	32	24	24	25	32	4
42°	35	32	26	56	35	26	37	56	11
43°	44	38	33	34	45	33	39	45	6
44°	52	49	41	43	53	41	48	53	5
45°	54	76	47	88	53	47	63	88	18
46°	122	42	49	44	122	42	76	122	42

47°	38	53	80	37	37	37	49	80	19
48°	36	79	48	35	35	35	47	79	19
49°	41	40	41	39	40	39	40	41	1
50°	52	41	36	47	52	36	45	52	7
51°	48	42	45	50	49	42	47	50	3
52°	48	49	43	48	49	43	47	49	3
53°	48	58	43	51	48	43	49	58	6
54°	48	65	50	60	49	48	54	65	7
55°	61	58	44	55	61	44	56	61	7
56°	68	59	54	55	69	54	61	69	7
57°	68	59	59	77	67	59	66	77	8
58°	57	64	73	53	56	53	60	73	8
59°	47	59	72	42	45	42	53	72	13
60°	44	60	52	42	43	42	48	60	8
61°	44	54	48	42	42	42	46	54	5
62°	42	51	47	46	40	40	45	51	4
63°	42	49	49	44	40	40	45	49	4
64°	42	47	49	44	40	40	44	49	4
65°	42	46	51	42	40	40	44	51	4
66°	43	48	53	43	40	40	45	53	5
67°	46	48	54	45	44	44	47	54	4
68°	45	51	55	45	42	42	48	55	5
69°	46	53	53	46	43	43	48	53	5
70°	48	57	53	45	44	44	49	57	5
71°	50	62	55	44	46	44	51	62	8
72°	50	65	56	49	47	47	53	65	7
73°	50	64	54	50	47	47	53	64	7
74°	49	64	53	51	46	46	53	64	7
75°	47	60	52	52	44	44	51	60	6
76°	43	54	49	45	41	41	46	54	5
77°	42	53	48	44	39	39	45	53	5
78°	40	52	47	40	38	38	43	52	6
79°	36	48	43	35	34	34	39	48	6
80°	35	42	38	31	34	31	36	42	4
81°	33	36	33	30	32	30	33	36	2
82°	31	32	31	26	29	26	30	32	2
83°	26	29	25	25	25	25	26	29	2
84°	25	25	21	22	24	21	23	25	2
85°	23	22	20	20	22	20	21	23	1
86°	20	20	19	18	19	18	19	20	1
87°	19	19	18	18	19	18	19	19	1
88°	18	18	18	17	18	17	18	18	0
89°	17	18	18	17	17	17	17	18	0
90°	18	18	17	17	18	17	18	18	1

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***24.4***	***209.6***	***398.1***	***111.0***
4° to 20° beam	24.4	217.6	398.1	120.9
7° to 17° beam	41.7	249.2	398.1	103.0

APPENDIX E—DETAILED TESTING RESULTS FOR SAMPLE 110159:
L-810 (L) FIXTURE WITH INFRARED EMITTER

Figures E-1 through E-4 and tables E-1 through E-3 provide detailed testing results for sample 110159: L-810 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

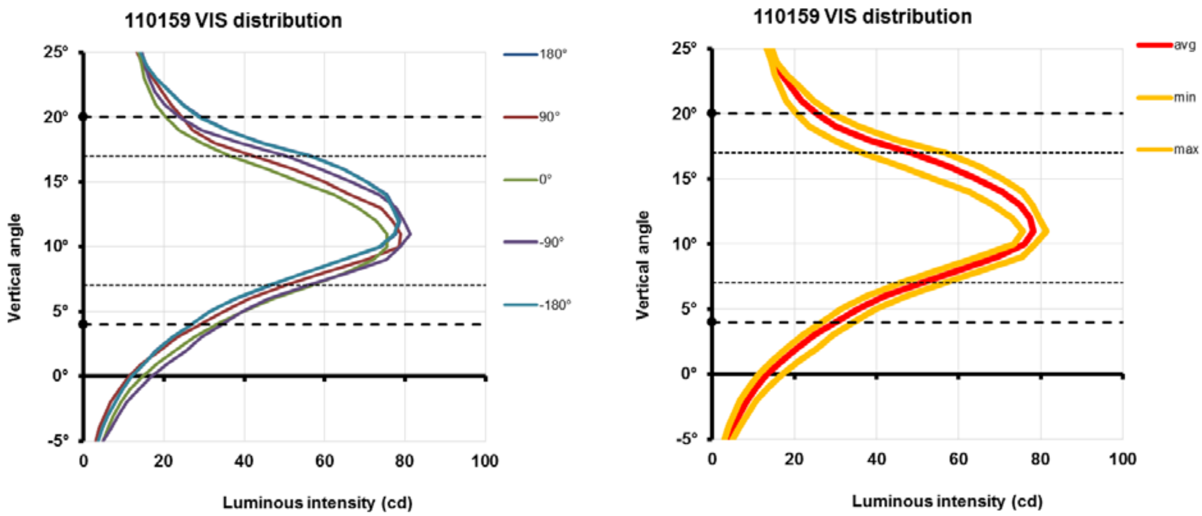


Figure E-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110159

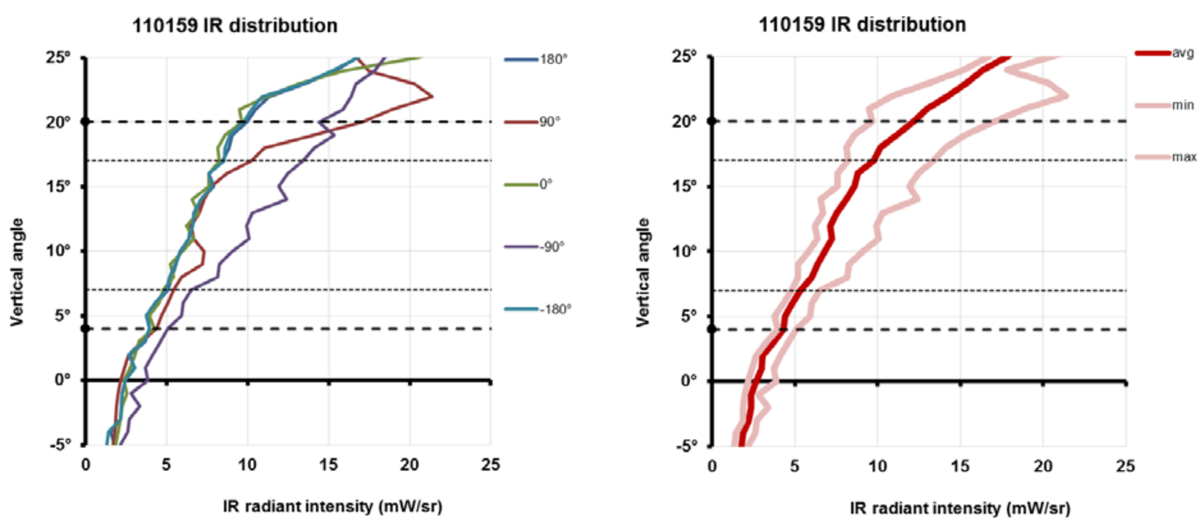


Figure E-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110159

Table E-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110159

Beam Region	Luminous Intensity (cd)				IR radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	11.3	47.8	81.2	22.0	2.2	6.7	17.0	3.1
4° to 20° Beam	20.6	54.6	81.2	18.6	3.8	7.6	17.0	2.8
7° to 17° Beam	36.4	66.1	81.2	11.5	4.8	7.4	13.4	2.0

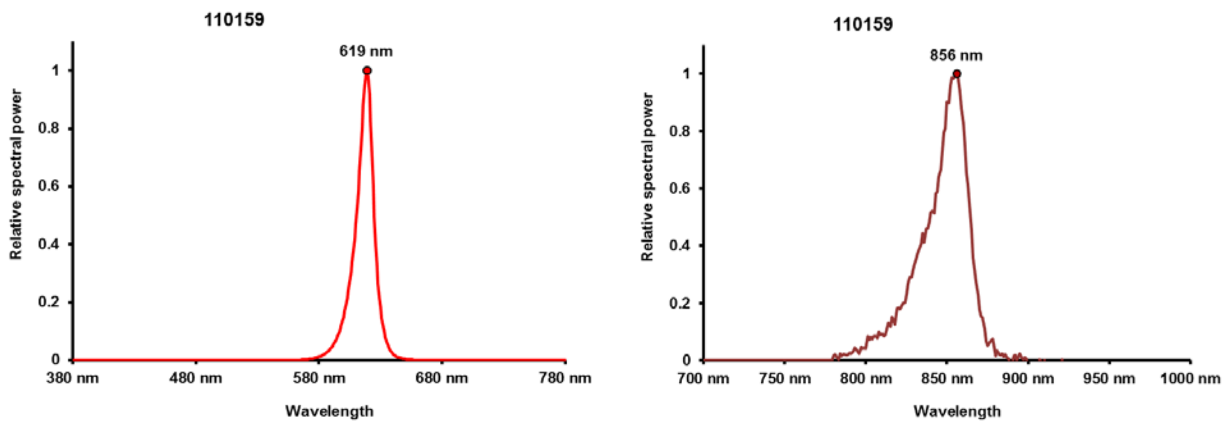


Figure E-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110159
(The peak wavelength in each region is also shown.)

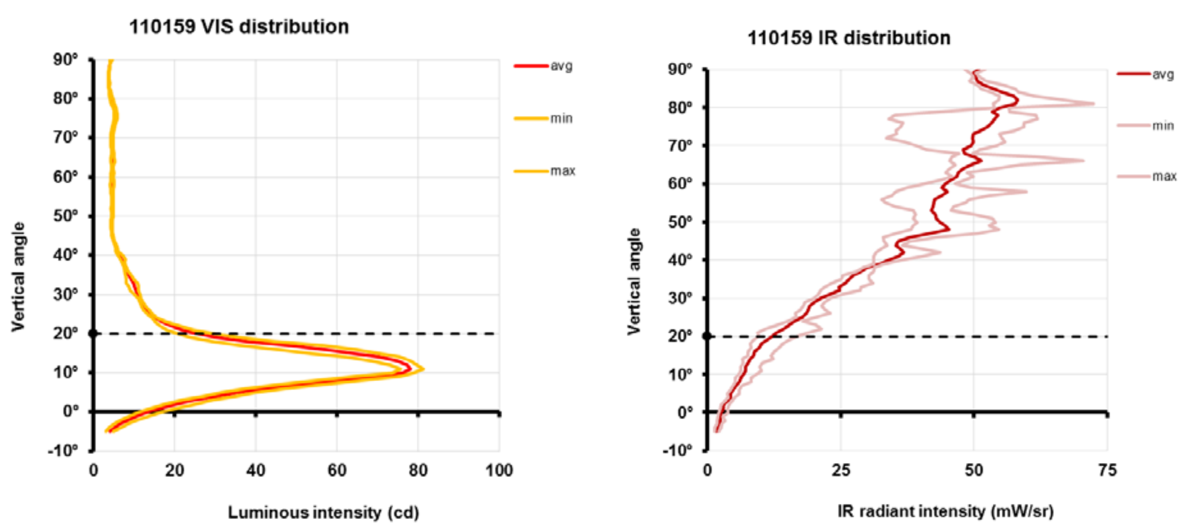


Figure E-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110159

Table E-2. Luminous intensity (cd) distribution of sample 110159VIS

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	4	3	5	5	4	3	4	5	1
-4°	5	4	6	7	5	4	5	7	1
-3°	6	5	8	9	6	5	7	9	1
-2°	8	7	9	11	8	7	8	11	2
-1°	10	9	12	14	10	9	11	14	2
0°	12	11	15	17	12	11	13	17	2
1°	15	14	18	21	15	14	17	21	3
2°	18	19	23	26	18	18	21	26	3
3°	22	23	28	29	22	22	25	29	3
4°	27	29	33	35	27	27	30	35	4
5°	31	35	40	40	32	31	35	40	4
6°	38	41	47	46	38	38	42	47	4
7°	46	50	57	56	46	46	51	57	5
8°	55	60	65	66	55	55	60	66	5
9°	65	70	72	75	65	65	69	75	5
10°	74	79	75	79	73	73	76	79	3
11°	78	79	76	81	77	76	78	81	2
12°	79	77	73	80	78	73	77	80	3
13°	77	74	68	78	77	68	75	78	4
14°	75	66	62	73	75	62	71	75	6
15°	71	60	54	67	70	54	64	71	7
16°	65	52	46	59	64	46	57	65	8
17°	57	42	36	50	56	36	48	57	9
18°	45	33	29	39	44	29	38	45	7
19°	36	27	24	29	35	24	30	36	5
20°	29	24	21	24	29	21	25	29	4
21°	25	22	18	20	25	18	22	25	3
22°	22	19	17	18	21	17	19	22	2
23°	18	17	15	16	18	15	17	18	1
24°	16	15	14	15	16	14	15	16	1
25°	14	13	14	14	14	13	14	14	0
26°	13	12	13	14	13	12	13	14	0
27°	13	12	12	13	13	12	12	13	0
28°	12	11	12	12	12	11	12	12	0
29°	12	12	11	11	12	11	11	12	0
30°	11	11	10	10	11	10	11	11	1
31°	11	11	9	10	11	9	10	11	1
32°	11	11	9	9	11	9	10	11	1
33°	11	10	8	9	11	8	10	11	1
34°	10	10	8	8	10	8	9	10	1
35°	9	9	8	8	9	8	9	9	1
36°	8	8	8	8	8	8	8	8	0
37°	8	8	8	8	8	8	8	8	0
38°	7	8	7	8	7	7	7	8	0
39°	7	7	7	8	7	7	7	8	0
40°	6	6	6	7	6	6	6	7	0
41°	6	6	6	6	6	6	6	6	0
42°	5	5	5	6	6	5	6	6	0
43°	5	5	5	5	5	5	5	5	0
44°	5	5	5	5	5	5	5	5	0
45°	4	5	5	5	5	4	5	5	0
46°	4	5	5	5	5	4	5	5	0

47°	4	5	5	5	4	4	5	5	0
48°	4	5	5	5	4	4	4	5	0
49°	4	5	4	5	5	4	5	5	0
50°	4	5	4	5	5	4	5	5	0
51°	4	5	4	5	5	4	5	5	0
52°	4	5	4	5	5	4	5	5	0
53°	5	5	5	5	5	5	5	5	0
54°	4	5	5	5	5	4	5	5	0
55°	5	4	5	5	5	4	5	5	0
56°	5	4	5	5	5	4	5	5	0
57°	5	4	5	5	5	4	5	5	0
58°	4	4	5	5	5	4	5	5	0
59°	5	4	5	5	5	4	5	5	0
60°	5	4	5	5	5	4	5	5	0
61°	5	4	5	5	5	4	5	5	0
62°	5	4	4	5	5	4	5	5	0
63°	5	5	4	5	5	4	5	5	0
64°	5	5	4	5	5	4	5	5	0
65°	5	4	4	5	5	4	5	5	0
66°	5	4	4	5	5	4	5	5	0
67°	5	4	4	5	5	4	5	5	0
68°	5	4	5	5	5	4	5	5	0
69°	5	4	5	5	5	4	5	5	0
70°	5	4	5	5	5	4	5	5	0
71°	5	4	5	5	5	4	5	5	0
72°	5	4	5	5	5	4	5	5	0
73°	5	5	5	5	5	5	5	5	0
74°	5	5	6	5	5	5	5	6	0
75°	5	5	6	5	5	5	5	6	0
76°	5	5	6	5	5	5	5	6	0
77°	5	5	6	5	5	5	5	6	0
78°	5	5	5	5	5	5	5	5	0
79°	4	5	5	5	4	4	5	5	0
80°	4	4	5	4	4	4	4	5	0
81°	4	4	5	4	4	4	4	5	0
82°	4	4	4	4	4	4	4	4	0
83°	4	4	4	4	4	4	4	4	0
84°	4	4	4	4	4	4	4	4	0
85°	4	4	4	4	4	4	4	4	0
86°	4	4	4	4	4	4	4	4	0
87°	4	4	4	4	4	4	4	4	0
88°	4	4	4	4	4	4	4	4	0
89°	4	4	4	4	4	4	4	4	0
90°	4	4	5	4	4	4	4	5	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***11.3***	***47.8***	***81.2***	***22.0***
4° to 20° beam	20.6	54.6	81.2	18.6
7° to 17° beam	36.4	66.1	81.2	11.5

Table E-3. Radiant intensity (mW/sr) distribution of sample 110159 IR

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	2	2	2	2	1	1	2	2	0
-4°	2	2	2	3	1	1	2	3	0
-3°	2	2	2	3	2	2	2	3	0
-2°	2	2	2	3	2	2	2	3	1
-1°	2	2	3	3	2	2	2	3	0
0°	2	2	2	4	2	2	3	4	1
1°	3	2	3	4	3	2	3	4	0
2°	3	3	3	4	3	3	3	4	1
3°	4	3	3	5	4	3	4	5	1
4°	4	4	4	5	4	4	4	5	0
5°	4	5	4	6	4	4	4	6	1
6°	4	5	5	6	4	4	5	6	1
7°	5	5	5	6	5	5	5	6	1
8°	5	6	5	8	5	5	6	8	1
9°	6	7	5	8	6	5	6	8	1
10°	6	7	6	9	6	6	7	9	1
11°	6	7	7	10	6	6	7	10	2
12°	6	7	6	10	7	6	7	10	2
13°	7	7	7	10	7	7	8	10	2
14°	7	7	7	12	7	7	8	12	2
15°	8	8	8	12	8	8	9	12	2
16°	8	9	8	12	8	8	9	12	2
17°	8	10	8	13	9	8	10	13	2
18°	9	11	8	14	9	8	10	14	2
19°	9	14	9	15	9	9	11	15	3
20°	10	17	10	14	10	10	12	17	3
21°	10	19	9	16	10	9	13	19	4
22°	11	21	11	16	11	11	14	21	5
23°	14	20	13	17	13	13	15	20	3
24°	15	17	16	18	15	15	16	18	1
25°	17	17	21	18	17	17	18	21	2
26°	17	17	23	20	17	17	19	23	3
27°	18	17	22	20	17	17	19	22	2
28°	18	18	21	20	18	18	19	21	2
29°	18	21	21	22	18	18	20	22	2
30°	20	23	21	22	20	20	21	23	1
31°	22	25	21	24	22	21	23	25	2
32°	24	29	21	25	24	21	25	29	3
33°	25	29	22	23	25	22	25	29	3
34°	25	31	23	24	25	23	26	31	3
35°	26	30	25	25	26	25	27	30	2
36°	27	30	27	25	27	25	27	30	2
37°	28	31	28	28	28	28	29	31	1
38°	30	30	31	29	29	29	30	31	1
39°	33	32	33	31	33	31	32	33	1
40°	36	34	31	33	36	31	34	36	2
41°	40	35	31	32	40	31	36	40	4
42°	44	34	32	32	43	32	37	44	6
43°	40	35	33	33	40	33	36	40	3
44°	37	36	34	34	36	34	35	37	1
45°	33	37	38	37	34	33	36	38	2
46°	34	40	43	41	33	33	38	43	5

47°	35	41	51	46	36	35	42	51	7
48°	39	44	55	51	38	38	45	55	7
49°	39	43	49	53	39	39	44	53	6
50°	39	44	41	54	40	39	44	54	6
51°	40	42	40	53	39	39	43	53	6
52°	41	44	39	50	40	39	43	50	4
53°	43	46	39	41	42	39	42	46	3
54°	46	46	38	35	46	35	42	46	5
55°	46	48	39	33	45	33	42	48	6
56°	45	49	41	33	46	33	43	49	6
57°	45	53	43	35	45	35	44	53	6
58°	44	60	42	35	44	35	45	60	9
59°	44	49	45	37	44	37	44	49	4
60°	46	44	46	41	46	41	45	46	2
61°	45	44	48	44	47	44	46	48	2
62°	46	46	50	46	46	46	47	50	2
63°	45	48	49	48	45	45	47	49	2
64°	45	54	47	48	46	45	48	54	4
65°	47	59	48	46	47	46	49	59	5
66°	45	70	49	46	46	45	51	70	11
67°	46	62	49	48	46	46	50	62	7
68°	48	50	47	49	48	47	48	50	1
69°	51	41	47	50	51	41	48	51	4
70°	54	39	47	53	54	39	49	54	6
71°	56	37	49	52	56	37	50	56	8
72°	55	34	52	53	55	34	50	55	9
73°	54	35	53	52	55	35	50	55	8
74°	57	35	55	51	58	35	51	58	9
75°	59	36	56	53	59	36	53	59	10
76°	59	37	56	55	59	37	53	59	9
77°	62	34	56	56	62	34	54	62	11
78°	62	35	59	55	61	35	54	62	11
79°	56	43	57	56	55	43	53	57	6
80°	54	57	55	54	54	54	55	57	1
81°	54	72	55	54	54	54	58	72	8
82°	57	67	55	55	57	55	58	67	5
83°	57	61	55	56	57	55	57	61	2
84°	55	53	54	58	55	53	55	58	2
85°	53	51	54	58	53	51	54	58	2
86°	51	51	52	55	51	51	52	55	2
87°	50	49	51	52	50	49	51	52	1
88°	50	50	51	51	50	50	50	51	1
89°	50	50	49	50	50	49	50	50	0
90°	52	52	51	48	52	48	51	52	2

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***2.2***	***6.7***	***17.0***	***3.1***
4° to 20° beam	3.8	7.6	17.0	2.8
7° to 17° beam	4.8	7.4	13.4	2.0

APPENDIX F—DETAILED TESTING RESULTS FOR SAMPLE 110164:
L-810 (L) FIXTURE WITH INFRARED EMITTER

Figures F-1 through F-4 and tables F-1 through F-3 provide detailed testing results for sample 110164: L-810 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

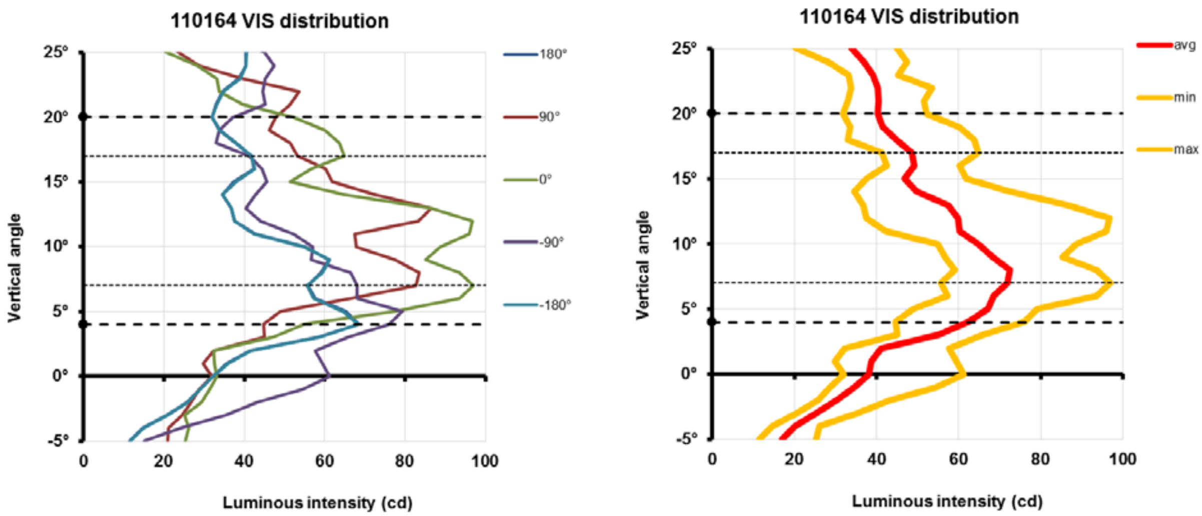


Figure F-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110164

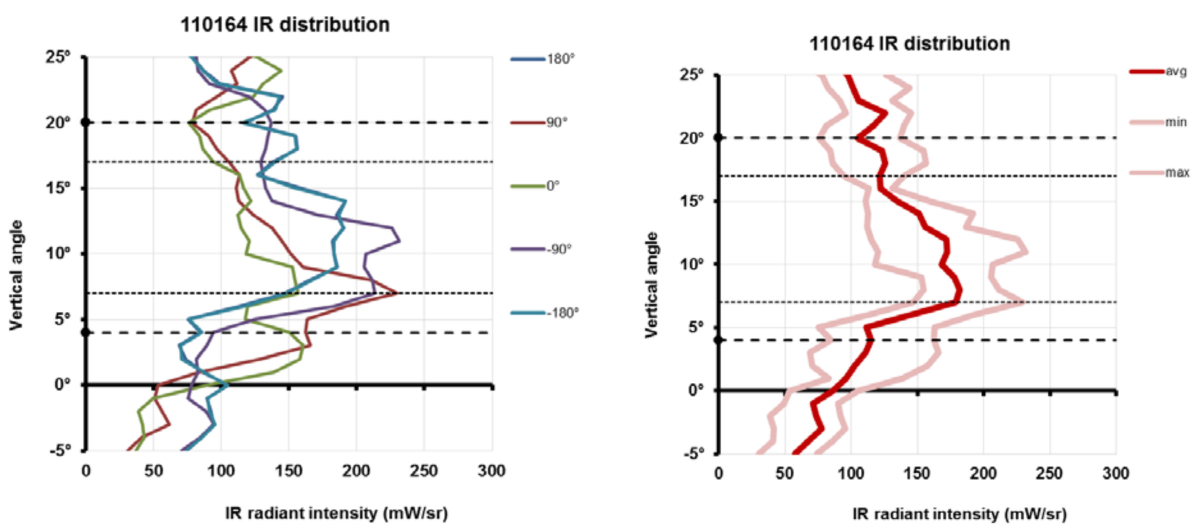


Figure F-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110164

Table F-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110164

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	29.8	54.6	96.9	17.9	53.4	136.0	231.5	42.4
4° to 20° Beam	31.9	57.3	96.9	18.0	75.2	144.8	231.5	39.5
7° to 17° Beam	34.5	59.0	96.9	18.6	94.4	157.8	231.5	36.2

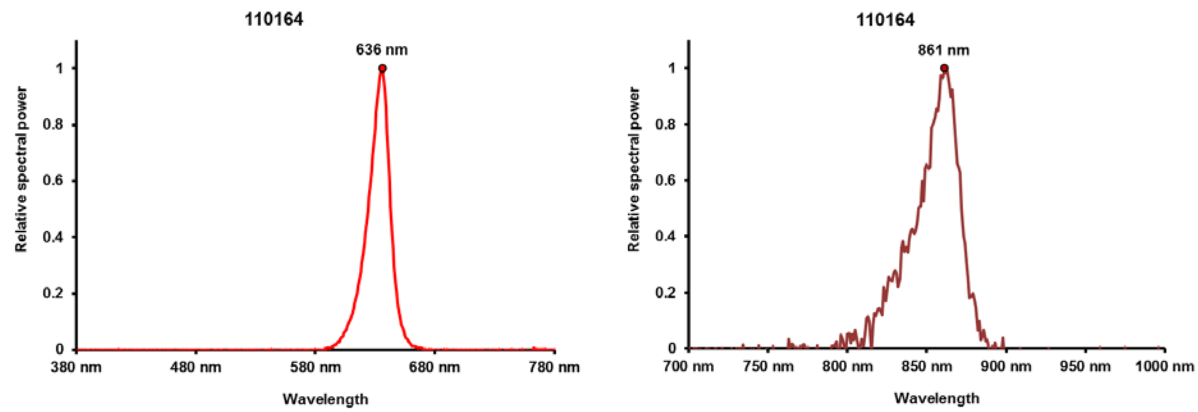


Figure F-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110164
(The peak wavelength in each region is also shown.)

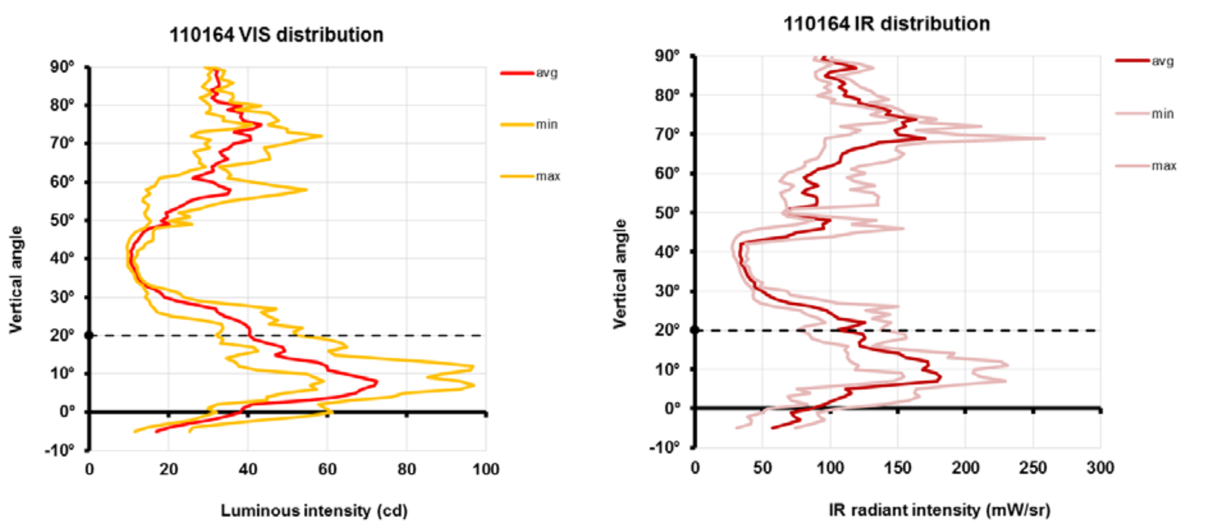


Figure F-4. Average, Minimum and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110164

Table F-2. Luminous intensity (cd) distribution of sample 110164 VIS

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	12	21	25	15	12	12	17	25	6
-4°	15	21	26	24	15	15	20	26	5
-3°	21	24	25	35	21	21	25	35	6
-2°	26	27	29	43	26	26	30	43	7
-1°	29	29	31	55	29	29	35	55	11
0°	32	32	33	61	32	32	38	61	13
1°	36	30	32	59	36	30	39	59	12
2°	41	32	32	58	42	32	41	58	10
3°	59	45	47	66	59	45	55	66	9
4°	68	45	55	76	68	45	62	76	13
5°	65	49	77	79	65	49	67	79	12
6°	58	67	94	68	57	57	69	94	15
7°	56	83	97	68	56	56	72	97	18
8°	59	84	94	67	59	59	72	94	15
9°	61	78	85	57	61	57	68	85	12
10°	55	68	89	57	55	55	65	89	14
11°	43	68	96	52	42	42	60	96	22
12°	38	83	97	44	38	38	60	97	28
13°	37	87	87	40	37	37	57	87	27
14°	34	72	65	43	35	34	50	72	18
15°	37	62	51	46	38	37	47	62	10
16°	42	60	57	44	43	42	49	60	9
17°	42	53	65	41	42	41	49	65	10
18°	38	51	64	33	38	33	45	64	13
19°	34	46	60	34	34	34	42	60	12
20°	32	48	52	37	32	32	40	52	9
21°	33	51	40	45	33	33	40	51	8
22°	35	54	34	45	35	34	40	54	9
23°	39	40	33	45	39	33	39	45	4
24°	40	29	28	47	40	28	37	47	8
25°	40	23	21	45	41	21	34	45	11
26°	43	21	17	37	43	17	32	43	13
27°	47	18	16	31	47	16	32	47	15
28°	38	18	15	27	38	15	27	38	11
29°	28	18	15	22	27	15	22	28	6
30°	24	16	14	17	24	14	19	24	5
31°	23	15	15	15	23	15	18	23	4
32°	19	14	14	15	19	14	16	19	3
33°	16	14	13	14	16	13	14	16	1
34°	14	13	13	12	14	12	13	14	1
35°	13	12	13	12	13	12	12	13	0
36°	12	12	12	11	12	11	12	12	1
37°	12	11	12	10	12	10	11	12	1
38°	11	11	12	10	11	10	11	12	1
39°	10	11	11	10	10	10	10	11	1
40°	10	11	11	10	10	10	10	11	1
41°	10	11	12	10	10	10	11	12	1
42°	10	11	12	10	10	10	10	12	1
43°	10	12	14	9	10	9	11	14	2
44°	10	13	14	10	10	10	11	14	2
45°	10	16	15	10	10	10	12	16	3
46°	11	16	16	11	11	11	13	16	3

47°	12	16	15	14	12	12	14	16	2
48°	14	17	15	17	14	14	15	17	1
49°	26	16	15	19	25	15	20	26	5
50°	20	17	15	19	20	15	18	20	2
51°	25	14	16	18	25	14	20	25	5
52°	22	14	15	22	23	14	19	23	4
53°	26	15	15	25	28	15	22	28	6
54°	30	16	15	26	31	15	24	31	8
55°	35	14	14	28	35	14	25	35	11
56°	35	14	15	42	35	14	28	42	13
57°	48	15	16	46	49	15	35	49	17
58°	55	14	16	39	53	14	35	55	20
59°	47	18	17	36	45	17	33	47	15
60°	41	21	17	37	40	17	31	41	11
61°	28	22	18	35	28	18	26	35	7
62°	31	24	23	36	30	23	28	36	5
63°	33	25	30	35	33	25	31	35	4
64°	31	29	33	29	32	29	31	33	2
65°	28	35	41	31	29	28	33	41	5
66°	30	39	46	28	32	28	35	46	7
67°	27	45	41	27	27	27	33	45	9
68°	28	45	35	26	30	26	33	45	7
69°	31	37	44	30	33	30	35	44	6
70°	29	39	49	35	29	29	36	49	8
71°	31	52	53	37	30	30	41	53	11
72°	26	56	58	36	26	26	41	58	16
73°	28	44	50	33	28	28	36	50	10
74°	37	47	50	37	37	37	41	50	6
75°	42	43	45	45	41	41	43	45	2
76°	34	39	39	48	34	34	39	48	6
77°	37	35	34	47	38	34	38	47	5
78°	45	30	31	42	45	30	39	45	7
79°	37	30	36	34	37	30	35	37	3
80°	40	36	31	41	43	31	38	43	5
81°	33	31	29	35	33	29	32	35	2
82°	29	36	31	30	28	28	31	36	3
83°	31	36	31	31	32	31	32	36	2
84°	31	30	32	31	30	30	31	32	1
85°	34	29	34	32	34	29	33	34	2
86°	34	29	36	31	33	29	33	36	3
87°	33	31	33	32	32	31	32	33	1
88°	33	31	34	30	31	30	32	34	2
89°	34	31	31	32	33	31	32	34	1
90°	30	31	30	30	29	29	30	31	1

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***29.8***	***54.6***	***96.9***	***17.9***
4° to 20° beam	31.9	57.3	96.9	18.0
7° to 17° beam	34.5	59.0	96.9	18.6

Table F-3. Radiant intensity (mW/sr) distribution of sample 110164 IR

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	74	31	37	71	74	31	57	74	22
-4°	85	41	43	84	86	41	68	86	23
-3°	94	62	42	95	95	42	78	95	25
-2°	92	56	39	89	91	39	73	92	25
-1°	89	51	49	75	90	49	71	90	20
0°	105	53	88	78	105	53	86	105	22
1°	87	84	139	83	87	83	96	139	24
2°	73	128	158	81	71	71	102	158	39
3°	69	166	161	89	70	69	111	166	49
4°	85	162	150	94	86	85	115	162	38
5°	75	163	118	125	76	75	111	163	37
6°	113	192	119	183	117	113	145	192	39
7°	147	229	157	213	149	147	179	229	39
8°	165	211	155	211	167	155	182	211	27
9°	186	160	153	205	185	153	178	205	21
10°	183	151	118	207	183	118	169	207	34
11°	182	145	121	231	183	121	173	231	42
12°	190	137	115	226	190	115	172	226	45
13°	185	123	112	171	187	112	156	187	35
14°	191	113	122	138	192	113	151	192	38
15°	159	111	117	133	154	111	135	159	22
16°	127	113	113	131	127	113	122	131	8
17°	138	106	94	129	140	94	121	140	20
18°	156	97	86	132	155	86	125	156	33
19°	155	90	84	134	154	84	124	155	34
20°	118	79	76	137	116	76	105	137	27
21°	138	81	91	132	140	81	117	140	28
22°	145	96	123	121	143	96	126	145	20
23°	99	111	131	91	97	91	106	131	16
24°	87	107	144	83	86	83	101	144	26
25°	78	121	126	82	78	78	97	126	24
26°	62	150	97	58	61	58	86	150	40
27°	52	106	90	48	52	48	70	106	26
28°	48	68	91	43	48	43	60	91	20
29°	46	70	65	43	46	43	54	70	13
30°	46	68	43	44	45	43	49	68	10
31°	45	47	41	43	45	41	44	47	2
32°	50	37	39	44	50	37	44	50	6
33°	44	36	38	41	45	36	41	45	4
34°	41	34	36	39	42	34	39	42	3
35°	40	33	35	38	40	33	37	40	3
36°	39	33	34	36	40	33	36	40	3
37°	36	31	33	36	36	31	34	36	2
38°	38	30	30	35	39	30	35	39	4
39°	37	30	29	33	38	29	33	38	4
40°	38	29	28	33	39	28	33	39	5
41°	39	28	29	34	39	28	34	39	5
42°	37	28	30	38	36	28	34	38	5
43°	59	29	31	69	59	29	49	69	18
44°	102	31	33	72	100	31	68	102	34
45°	120	35	35	66	120	35	75	120	43
46°	154	51	49	67	154	49	95	154	54

47°	116	85	76	80	116	76	94	116	20
48°	88	93	134	93	91	88	100	134	19
49°	68	96	79	72	68	68	77	96	12
50°	67	67	66	67	65	65	66	67	1
51°	68	72	69	71	69	68	70	72	1
52°	68	135	105	71	67	67	89	135	30
53°	76	95	135	67	78	67	90	135	27
54°	85	77	136	64	86	64	90	136	27
55°	64	71	131	66	63	63	79	131	29
56°	72	83	115	70	73	70	83	115	19
57°	73	97	133	78	74	73	91	133	25
58°	64	101	118	71	63	63	83	118	25
59°	65	113	93	67	65	65	80	113	21
60°	72	125	95	68	72	68	86	125	24
61°	85	115	92	77	84	77	91	115	15
62°	83	122	120	95	81	81	100	122	20
63°	82	124	108	140	81	81	107	140	26
64°	92	104	102	151	91	91	108	151	25
65°	95	101	102	155	93	93	109	155	26
66°	117	95	99	148	119	95	116	148	21
67°	148	96	105	150	143	96	128	150	26
68°	169	107	95	147	161	95	136	169	33
69°	258	116	96	126	254	96	170	258	79
70°	194	114	117	135	192	114	150	194	39
71°	163	122	142	149	163	122	148	163	17
72°	201	107	123	134	212	107	155	212	48
73°	163	141	152	143	166	141	153	166	11
74°	166	149	178	153	171	149	163	178	12
75°	132	154	156	130	136	130	141	156	13
76°	138	142	144	144	153	138	144	153	5
77°	127	145	135	125	141	125	134	145	9
78°	123	129	125	101	128	101	121	129	12
79°	103	143	118	134	108	103	121	143	17
80°	90	134	111	121	95	90	110	134	18
81°	100	130	106	118	104	100	112	130	12
82°	95	122	110	107	98	95	107	122	11
83°	112	100	104	118	117	100	110	118	8
84°	112	91	96	114	114	91	106	114	11
85°	92	100	97	105	89	89	96	105	6
86°	95	121	89	102	93	89	100	121	12
87°	124	123	120	95	132	95	119	132	14
88°	104	121	107	107	102	102	108	121	7
89°	88	92	100	98	90	88	94	100	5
90°	99	89	94	102	99	89	96	102	5

Summary

Luminous intensity (cd)	**Min**	**Avg**	**Max**	**Std**
0° to 20° beam	***53.4***	***136.0***	***231.5***	***42.4***
4° to 20° beam	75.2	144.8	231.5	39.5
7° to 17° beam	94.4	157.8	231.5	36.2

APPENDIX G—DETAILED TESTING RESULTS FOR SAMPLE 110165:
L-810 INCANDESCENT FIXTURE

Figures G-1 through G-4 and tables G-1 through G-3 provide detailed testing results for sample 110165: L-810 incandescent fixture. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

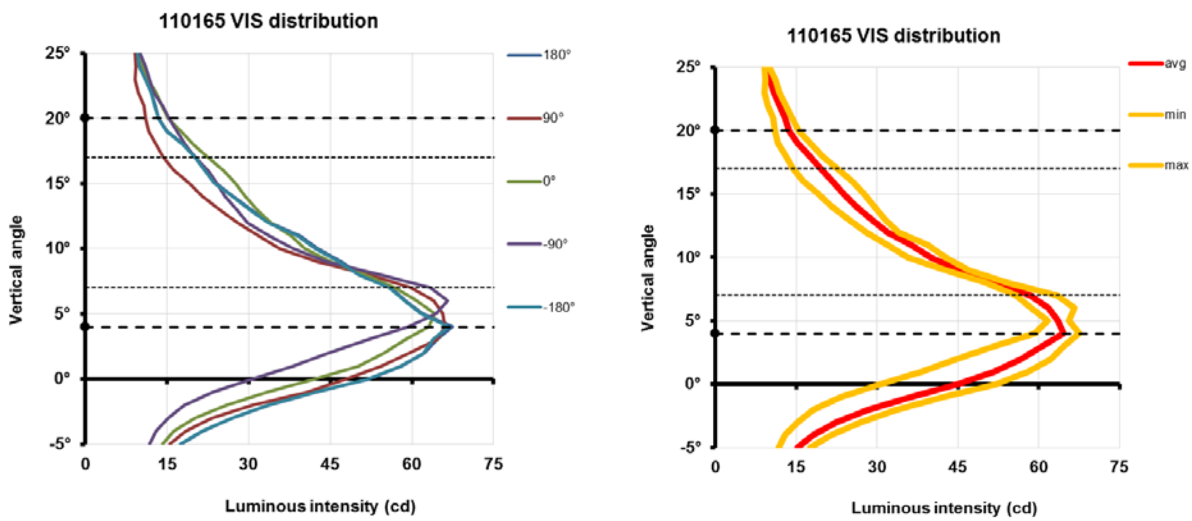


Figure G-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110165

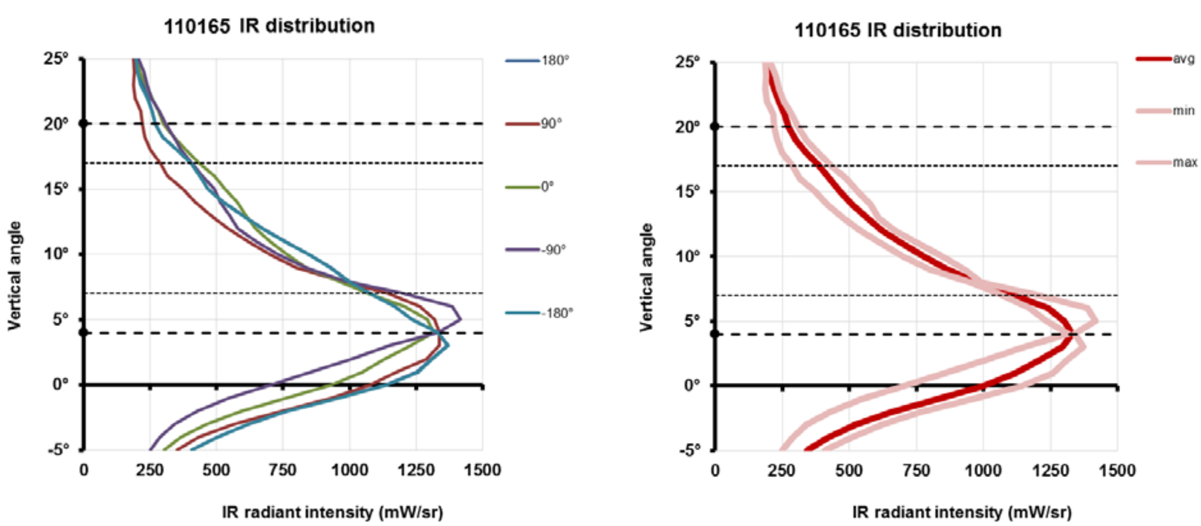


Figure G-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110165

Table G-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110165

Beam Region	Luminous intensity (cd)				IR radiant intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	10.8	39.1	66.4	17.4	220.0	800.3	1415.9	371.3
4° to 20° Beam	10.8	35.9	66.4	17.4	220.0	717.1	1415.9	356.0
7° to 17° Beam	14.1	34.3	62.4	12.3	287.6	673.3	1203.0	233.8

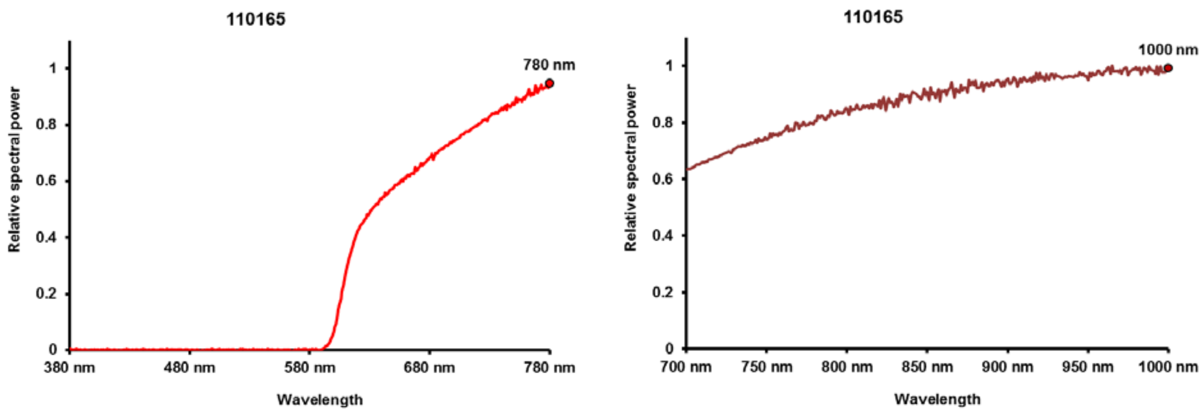


Figure G-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110165
(The peak wavelength in each region is also shown.)

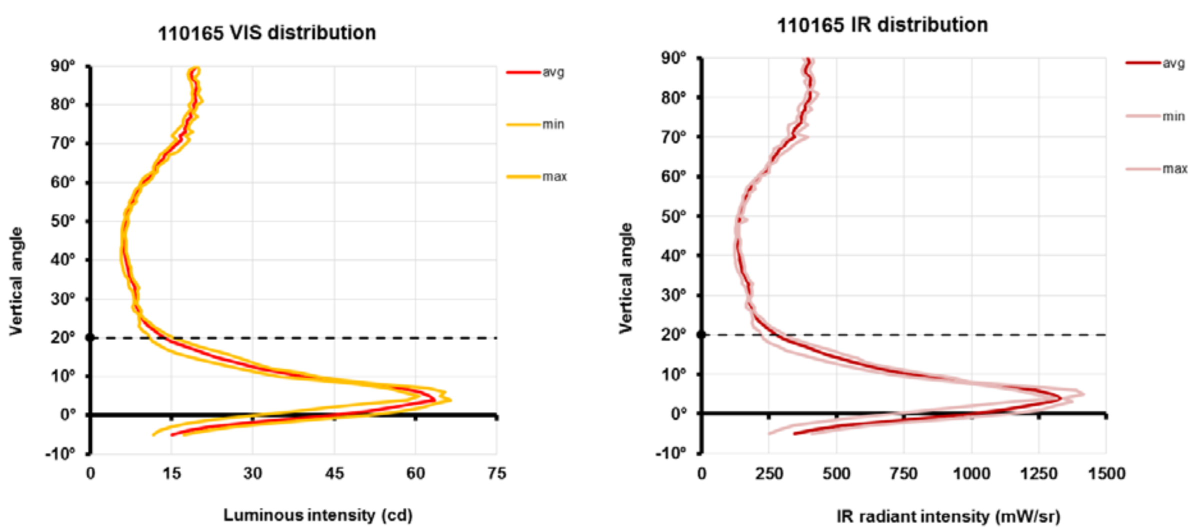


Figure G-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110165

Table G-2. Luminous intensity (cd) distribution of sample 110165 VIS

Vertical angles	Horizontal angles 180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	17	15	14	12	17	12	15	17	2
-4°	21	18	16	13	21	13	18	21	4
-3°	27	23	20	15	27	15	22	27	5
-2°	33	30	25	18	33	18	28	33	6
-1°	42	40	33	23	42	23	36	42	8
0°	51	47	41	30	51	30	44	51	9
1°	57	53	49	38	57	38	51	57	8
2°	61	58	54	44	61	44	56	61	7
3°	64	64	58	51	63	51	60	64	5
4°	66	65	62	58	66	58	64	66	3
5°	61	65	63	63	61	61	63	65	2
6°	58	63	60	65	58	58	61	65	3
7°	55	59	56	62	55	55	57	62	3
8°	50	51	50	53	49	49	51	53	2
9°	46	42	44	44	46	42	44	46	2
10°	42	35	40	38	42	35	39	42	3
11°	39	31	37	33	38	31	36	39	3
12°	33	28	34	29	33	28	31	34	3
13°	30	24	31	27	30	24	29	31	3
14°	27	21	29	25	27	21	26	29	3
15°	24	19	27	24	23	19	23	27	3
16°	22	16	25	22	22	16	21	25	3
17°	20	14	22	20	20	14	19	22	3
18°	18	13	20	18	18	13	17	20	3
19°	15	11	17	17	15	11	15	17	2
20°	13	11	15	15	13	11	13	15	2
21°	13	11	14	14	13	11	13	14	1
22°	12	10	13	12	12	10	12	13	1
23°	11	9	11	12	11	9	11	12	1
24°	10	9	10	11	10	9	10	11	1
25°	9	9	10	10	9	9	10	10	0
26°	9	9	9	9	9	9	9	9	0
27°	9	8	9	9	9	8	9	9	1
28°	9	8	9	9	9	8	9	9	0
29°	8	8	8	9	8	8	8	9	0
30°	9	8	8	8	9	8	8	9	0
31°	9	8	8	8	9	8	8	9	0
32°	9	8	8	8	9	8	8	9	0
33°	9	7	8	8	9	7	8	9	1
34°	8	7	8	8	8	7	8	8	1
35°	8	7	8	7	8	7	8	8	0
36°	8	6	7	7	8	6	7	8	0
37°	8	6	7	7	7	6	7	8	1
38°	7	6	7	7	7	6	7	7	1
39°	7	6	7	6	7	6	7	7	1
40°	7	6	7	6	7	6	7	7	1
41°	7	6	7	6	7	6	6	7	1
42°	7	6	7	6	7	6	6	7	0
43°	7	6	7	6	7	6	6	7	0
44°	7	6	6	6	7	6	6	7	0
45°	7	6	7	6	6	6	6	7	0
46°	6	6	6	6	6	6	6	6	0

47°	6	6	6	6	6	6	6	6	0
48°	6	6	7	6	6	6	6	7	0
49°	6	6	7	6	6	6	6	7	0
50°	6	7	7	6	6	6	6	7	0
51°	7	6	7	6	7	6	7	7	0
52°	7	6	7	7	7	6	7	7	0
53°	7	7	7	7	7	7	7	7	0
54°	7	7	8	7	7	7	7	8	0
55°	8	7	8	7	8	7	8	8	1
56°	8	8	8	8	8	8	8	8	0
57°	8	8	9	8	8	8	8	9	0
58°	8	9	9	8	8	8	9	9	1
59°	9	9	9	9	9	9	9	9	0
60°	10	9	11	10	10	9	10	11	1
61°	11	10	11	10	11	10	11	11	1
62°	12	11	12	10	12	10	11	12	1
63°	12	12	12	12	12	12	12	12	0
64°	12	12	12	12	12	12	12	12	0
65°	12	13	13	13	12	12	13	13	1
66°	13	14	14	14	13	13	13	14	1
67°	13	14	14	14	13	13	14	14	1
68°	14	16	14	14	14	14	14	16	1
69°	15	17	14	15	15	14	15	17	1
70°	16	18	15	16	16	15	16	18	1
71°	17	18	16	16	17	16	17	18	1
72°	17	15	16	16	18	15	16	18	1
73°	19	17	16	17	19	16	18	19	1
74°	18	18	16	17	18	16	17	18	1
75°	18	18	17	17	18	17	18	18	1
76°	19	17	17	17	19	17	18	19	1
77°	20	17	18	18	20	17	19	20	1
78°	19	18	18	18	19	18	18	19	0
79°	19	19	20	19	20	19	19	20	0
80°	19	20	19	18	19	18	19	20	1
81°	19	19	21	20	19	19	19	21	1
82°	19	20	20	19	19	19	19	20	1
83°	20	19	19	19	20	19	19	20	0
84°	20	19	19	19	20	19	19	20	1
85°	20	19	20	19	20	19	20	20	1
86°	20	19	19	19	20	19	19	20	1
87°	19	18	19	19	19	18	19	19	0
88°	18	18	20	19	18	18	19	20	1
89°	18	18	20	19	18	18	19	20	1
90°	20	20	20	20	20	20	20	20	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***10.8***	***39.1***	***66.4***	***17.4***
4° to 20° beam	10.8	35.9	66.4	17.4
7° to 17° beam	14.1	34.3	62.4	12.3

Table G-3. Radiant intensity (mW/sr) distribution of sample 110165 IR

Vertical angles	180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
	Horizontal angles								
-5°	407	351	302	250	406	250	343	407	68
-4°	505	432	367	289	506	289	420	506	93
-3°	622	567	465	341	621	341	523	622	120
-2°	765	748	595	428	767	428	660	767	149
-1°	955	934	761	547	960	547	831	960	179
0°	1135	1075	930	701	1140	701	996	1140	186
1°	1253	1176	1049	853	1259	853	1118	1259	171
2°	1307	1288	1130	1005	1309	1005	1208	1309	136
3°	1369	1339	1230	1153	1372	1153	1293	1372	97
4°	1332	1338	1315	1335	1333	1315	1330	1338	9
5°	1233	1321	1291	1416	1235	1233	1299	1416	75
6°	1171	1266	1207	1388	1171	1171	1241	1388	91
7°	1078	1146	1070	1203	1075	1070	1115	1203	58
8°	992	960	953	976	990	953	974	992	18
9°	929	800	836	835	927	800	865	929	59
10°	848	700	764	732	846	700	778	848	67
11°	759	620	702	649	757	620	697	759	62
12°	673	542	648	581	672	542	623	673	59
13°	600	478	608	550	598	478	567	608	55
14°	524	418	578	514	523	418	511	578	58
15°	466	372	530	490	466	372	465	530	58
16°	438	316	490	445	437	316	425	490	65
17°	402	288	433	405	401	288	386	433	57
18°	352	249	384	367	351	249	341	384	53
19°	298	230	338	339	297	230	300	339	44
20°	269	220	300	309	269	220	273	309	35
21°	257	215	281	285	256	215	259	285	28
22°	240	193	256	252	240	193	236	256	25
23°	222	186	234	239	214	186	219	239	21
24°	202	190	211	226	201	190	206	226	14
25°	197	186	203	205	197	186	197	205	7
26°	194	183	188	195	194	183	191	195	5
27°	196	166	184	188	196	166	186	196	12
28°	183	165	179	181	182	165	178	183	7
29°	177	170	177	179	177	170	176	179	3
30°	185	171	170	180	185	170	178	185	7
31°	185	175	166	172	185	166	177	185	8
32°	183	162	169	166	183	162	173	183	10
33°	189	150	170	166	188	150	173	189	16
34°	174	151	167	160	173	151	165	174	10
35°	167	143	161	153	168	143	159	168	10
36°	158	135	156	149	158	135	151	158	10
37°	160	128	148	144	160	128	148	160	13
38°	155	126	146	142	155	126	145	155	12
39°	151	125	143	135	151	125	141	151	11
40°	150	122	142	133	150	122	139	150	12
41°	145	121	141	131	144	121	136	145	10
42°	141	122	138	129	141	122	134	141	8
43°	144	124	137	131	145	124	136	145	9
44°	143	125	140	129	143	125	136	143	8
45°	136	127	138	128	136	127	133	138	5
46°	133	133	137	126	133	126	133	137	4

47°	132	132	138	126	133	126	132	138	4
48°	134	133	139	128	134	128	133	139	4
49°	135	137	167	130	135	130	141	167	15
50°	138	137	144	133	138	133	138	144	4
51°	153	137	144	138	153	137	145	153	8
52°	147	140	155	139	147	139	146	155	6
53°	151	150	157	147	152	147	152	157	4
54°	166	154	164	153	167	153	161	167	7
55°	172	157	178	154	169	154	166	178	10
56°	163	165	178	165	163	163	167	178	6
57°	166	200	194	178	167	166	181	200	16
58°	181	188	193	178	183	178	185	193	6
59°	194	195	212	192	195	192	198	212	8
60°	213	209	221	219	215	209	215	221	5
61°	249	219	232	222	247	219	234	249	14
62°	238	234	250	239	238	234	240	250	6
63°	254	242	252	245	248	242	248	254	5
64°	253	277	254	260	252	252	259	277	11
65°	255	282	274	277	255	255	268	282	13
66°	264	288	283	301	266	264	280	301	15
67°	269	325	296	285	269	269	289	325	23
68°	299	338	295	315	298	295	309	338	18
69°	309	359	299	311	311	299	318	359	24
70°	337	392	324	322	339	322	343	392	28
71°	347	322	342	340	347	322	339	347	10
72°	373	318	321	337	372	318	344	373	26
73°	386	358	323	342	392	323	360	392	29
74°	378	378	354	367	377	354	371	378	10
75°	383	364	352	355	384	352	368	384	15
76°	383	361	363	362	384	361	371	384	12
77°	408	369	357	378	405	357	383	408	22
78°	387	362	389	388	391	362	383	391	12
79°	398	386	408	376	396	376	393	408	12
80°	387	422	413	401	383	383	401	422	17
81°	386	396	432	409	389	386	402	432	19
82°	405	404	398	396	402	396	401	405	4
83°	414	393	406	389	415	389	403	415	12
84°	416	408	387	382	418	382	402	418	17
85°	406	394	414	402	407	394	405	414	7
86°	386	373	407	384	385	373	387	407	12
87°	379	371	400	390	377	371	384	400	11
88°	378	378	403	405	378	378	388	405	14
89°	386	393	414	410	389	386	398	414	13
90°	409	399	377	374	410	374	394	410	17

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***220.0***	***800.3***	***1415.9***	***371.3***
4° to 20° beam	220.0	717.1	1415.9	356.0
7° to 17° beam	287.6	673.3	1203.0	233.8

APPENDIX H—DETAILED TESTING RESULTS FOR SAMPLE 110166: L-864 (L) FIXTURE WITH INFRARED EMITTER

Figures H-1 through H-4 and tables H-1 through H-3 provide detailed testing results for sample 110166: L-864 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

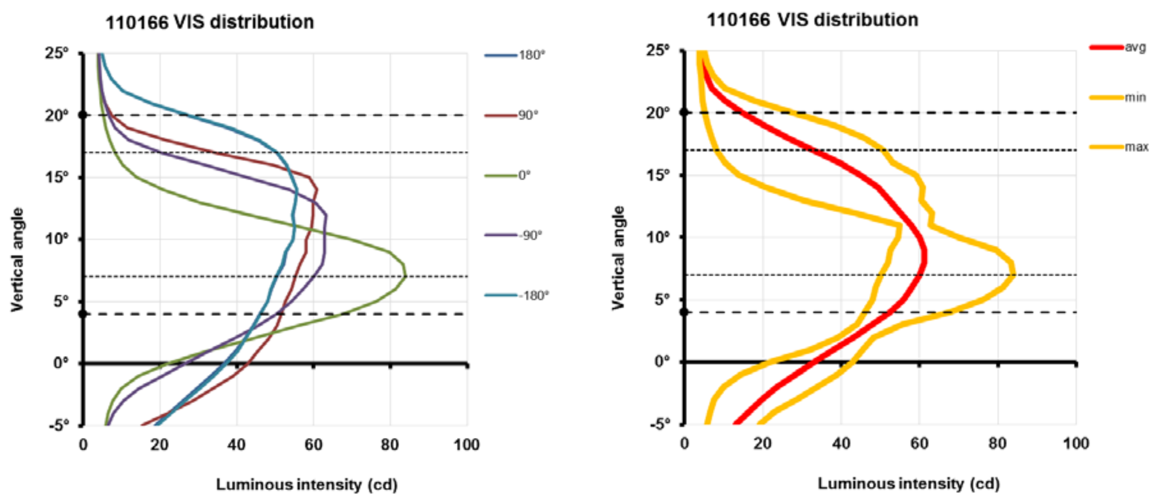


Figure H-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across all Horizontal Cuts (Right) for Sample 110166

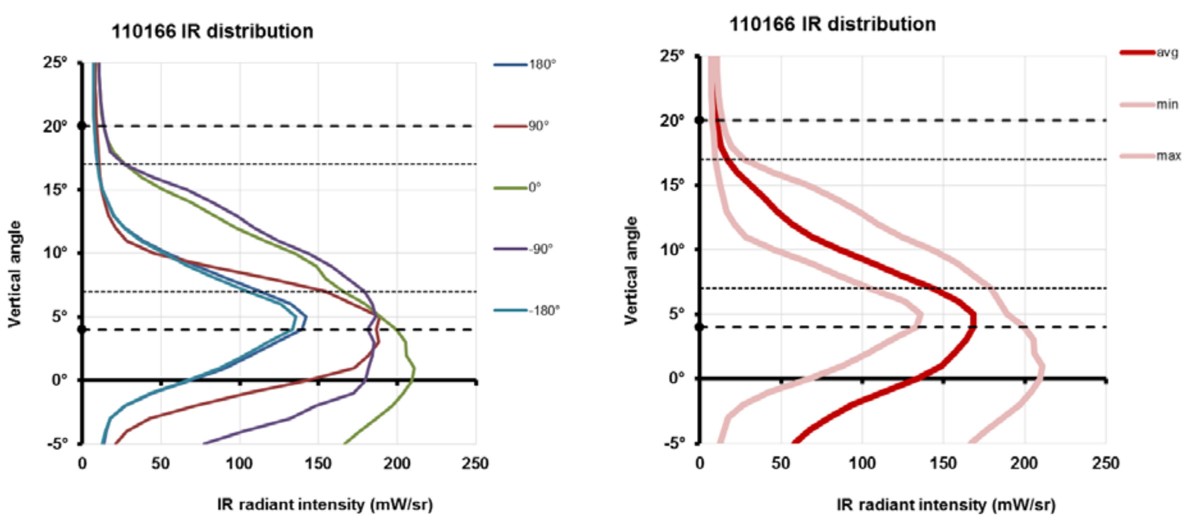


Figure H-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110166

Table H-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110166

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 20° Beam	5.2	45.9	83.9	17.8	7.7	89.3	210.9	68.2
4° to 20° Beam	5.2	47.2	83.9	19.2	7.7	74.9	199.2	63.9
7° to 17° Beam	8.2	52.2	83.9	15.4	9.7	67.6	179.0	52.3

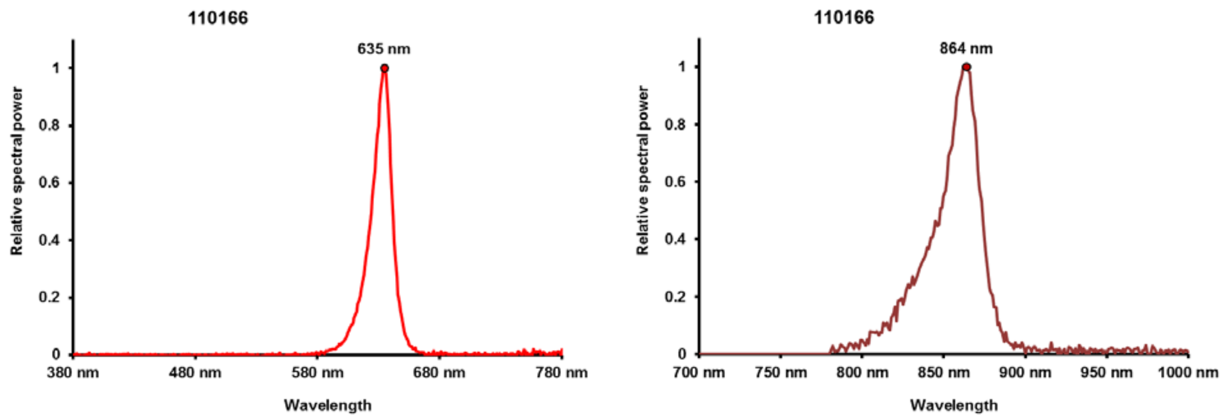


Figure H-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110166
(The peak wavelength in each region is also shown.)

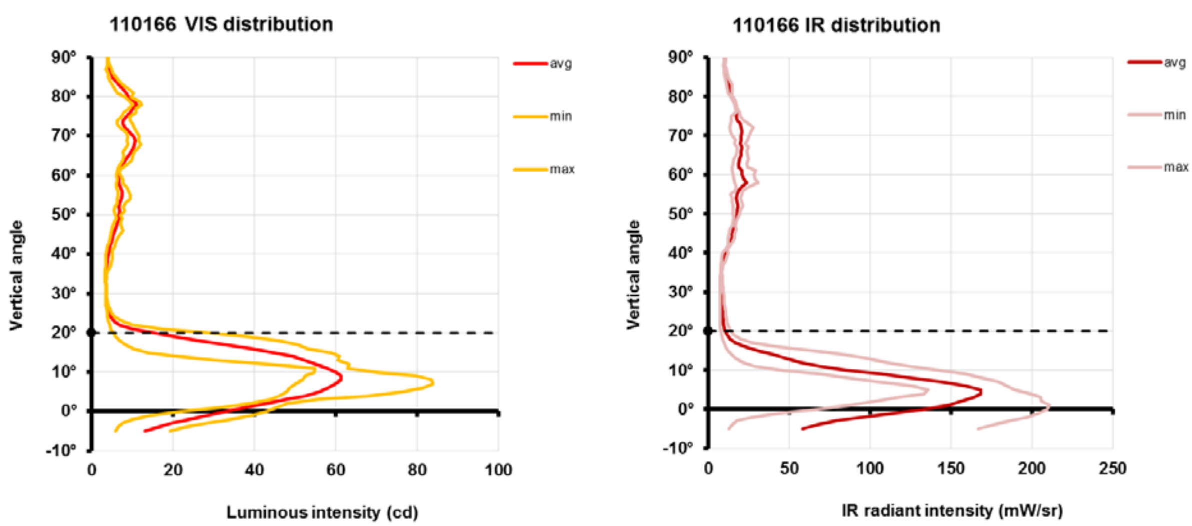


Figure H-4. Average, Minimum, and Maximum Luminous Intensity (Left) and Radiant Intensity (Right) as a Function of Vertical Angle From -5° to 90° for Sample 110166

Table H-2. Luminous intensity (cd) distribution of sample 110166 VIS

Vertical angles	180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
	Horizontal angles								
-5°	19	15	6	6	19	6	13	19	7
-4°	22	22	7	8	23	7	16	23	8
-3°	26	29	8	10	27	8	20	29	10
-2°	30	34	10	15	30	10	24	34	11
-1°	33	39	14	21	34	14	28	39	10
0°	37	43	22	26	37	22	33	43	9
1°	40	45	32	33	40	32	38	45	6
2°	42	48	44	39	42	39	43	48	3
3°	44	50	56	45	44	44	48	56	5
4°	46	52	68	50	46	46	52	68	9
5°	48	53	76	54	48	48	56	76	12
6°	49	54	81	57	49	49	58	81	14
7°	50	55	84	60	50	50	60	84	14
8°	52	56	83	62	52	52	61	83	13
9°	53	58	80	63	53	53	61	80	11
10°	55	58	70	63	55	55	60	70	7
11°	55	59	57	63	55	55	58	63	3
12°	55	60	43	63	54	43	55	63	8
13°	55	60	30	60	55	30	52	60	12
14°	56	61	21	54	56	21	49	61	16
15°	54	59	14	43	54	14	45	59	18
16°	53	49	10	32	53	10	39	53	19
17°	50	34	8	20	51	8	33	51	19
18°	45	22	7	12	46	7	26	46	18
19°	38	11	6	8	38	6	20	38	16
20°	27	7	5	7	28	5	15	28	12
21°	18	6	5	6	18	5	10	18	7
22°	10	5	4	5	10	4	7	10	3
23°	7	4	4	5	7	4	6	7	2
24°	6	4	4	4	6	4	5	6	1
25°	5	4	4	4	5	4	4	5	1
26°	4	4	4	4	4	4	4	4	0
27°	4	4	4	4	4	4	4	4	0
28°	4	4	4	4	4	4	4	4	0
29°	4	4	4	4	4	4	4	4	0
30°	4	4	3	4	3	3	4	4	0
31°	3	4	3	3	3	3	3	4	0
32°	3	4	3	4	3	3	3	4	0
33°	3	3	3	3	3	3	3	3	0
34°	3	3	4	3	3	3	3	4	0
35°	3	4	4	4	3	3	4	4	0
36°	3	4	4	4	3	3	4	4	0
37°	3	4	5	3	3	3	4	5	1
38°	3	4	5	4	3	3	4	5	1
39°	3	4	5	4	3	3	4	5	1
40°	4	4	5	4	4	4	4	5	1
41°	4	4	5	5	4	4	4	5	1
42°	4	5	6	5	4	4	5	6	1
43°	4	5	6	5	4	4	5	6	1
44°	4	5	6	5	4	4	5	6	1
45°	5	5	7	5	5	5	5	7	1
46°	5	5	8	6	5	5	6	8	1

47°	5	6	7	6	5	5	6	7	1
48°	6	7	7	7	5	5	6	7	1
49°	6	8	7	7	6	6	7	8	1
50°	7	6	7	7	7	6	7	7	0
51°	8	6	7	5	8	5	7	8	1
52°	7	6	8	6	7	6	7	8	1
53°	6	7	8	7	6	6	7	8	1
54°	6	7	9	7	6	6	7	9	1
55°	7	7	9	8	7	7	8	9	1
56°	7	7	9	8	7	7	7	9	1
57°	6	7	9	8	6	6	7	9	1
58°	6	6	8	8	6	6	7	8	1
59°	6	6	7	8	6	6	7	8	1
60°	6	6	7	7	6	6	6	7	0
61°	6	7	7	7	6	6	6	7	0
62°	7	8	8	7	7	7	7	8	1
63°	7	9	8	7	7	7	8	9	1
64°	8	10	8	8	8	8	8	10	1
65°	10	10	8	9	10	8	9	10	1
66°	10	10	8	9	11	8	10	11	1
67°	11	11	9	9	11	9	10	11	1
68°	11	12	9	10	11	9	11	12	1
69°	11	11	9	11	11	9	11	11	1
70°	10	10	9	12	10	9	10	12	1
71°	9	8	9	11	9	8	9	11	1
72°	8	7	8	11	8	7	8	11	1
73°	7	6	8	10	7	6	8	10	2
74°	7	6	9	10	7	6	8	10	1
75°	7	9	9	9	7	7	8	9	1
76°	8	10	10	11	8	8	9	11	1
77°	9	11	11	10	9	9	10	11	1
78°	12	10	10	10	12	10	11	12	1
79°	12	10	9	9	12	9	10	12	1
80°	10	9	8	9	10	8	9	10	1
81°	9	8	6	10	9	6	8	10	2
82°	8	7	6	9	8	6	8	9	1
83°	8	6	5	7	8	5	7	8	1
84°	7	5	5	7	7	5	6	7	1
85°	6	4	4	6	6	4	5	6	1
86°	5	4	4	5	5	4	5	5	1
87°	5	4	4	5	5	4	4	5	1
88°	4	4	4	4	4	4	4	4	0
89°	4	4	4	4	4	4	4	4	0
90°	4	4	4	4	4	4	4	4	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***5.2***	***45.9***	***83.9***	***17.8***
4° to 20° beam	5.2	47.2	83.9	19.2
7° to 17° beam	8.2	52.2	83.9	15.4

Table H-3. Radiant intensity (mW/sr) distribution of sample 110166IR

	Horizontal angles								
Vertical angles	180°	90°	0°	-90°	-180°	Min	Avg	Max	Std
-5°	13	21	167	77	13	13	58	167	66
-4°	15	28	176	102	15	15	67	176	71
-3°	18	43	187	132	18	18	79	187	76
-2°	27	71	197	148	27	27	94	197	76
-1°	44	105	204	172	43	43	114	204	73
0°	68	142	209	180	67	67	133	209	65
1°	91	172	211	182	88	88	149	211	56
2°	107	182	206	184	103	103	156	206	48
3°	124	188	205	185	118	118	164	205	40
4°	140	187	199	181	133	133	168	199	30
5°	142	189	189	186	136	136	168	189	27
6°	133	172	180	184	126	126	159	184	28
7°	113	155	166	179	105	105	143	179	33
8°	93	120	155	169	86	86	124	169	37
9°	73	81	149	158	68	68	106	158	44
10°	55	46	135	143	52	46	86	143	49
11°	39	28	116	125	37	28	69	125	47
12°	27	21	98	110	27	21	57	110	43
13°	20	17	84	98	20	17	48	98	40
14°	16	14	69	83	16	14	40	83	33
15°	13	12	51	66	13	12	31	66	26
16°	11	11	37	44	11	11	23	44	17
17°	10	11	27	27	10	10	17	27	9
18°	9	10	20	18	9	9	13	20	5
19°	8	10	16	16	8	8	12	16	4
20°	8	9	13	14	8	8	10	14	3
21°	7	9	12	13	7	7	10	13	3
22°	7	8	12	12	7	7	9	12	2
23°	7	8	11	11	7	7	9	11	2
24°	7	8	10	11	7	7	9	11	2
25°	7	8	10	10	7	7	9	10	2
26°	7	8	9	10	7	7	8	10	1
27°	7	8	9	10	7	7	8	10	1
28°	7	8	9	10	7	7	8	10	1
29°	7	8	9	10	7	7	8	10	1
30°	7	7	8	9	7	7	8	9	1
31°	7	8	8	9	7	7	8	9	1
32°	7	8	8	9	7	7	8	9	1
33°	7	8	8	9	7	7	8	9	1
34°	7	8	8	9	7	7	8	9	1
35°	8	8	8	8	8	8	8	8	0
36°	8	8	9	9	8	8	8	9	0
37°	8	9	9	9	8	8	9	9	1
38°	9	10	9	8	9	8	9	10	1
39°	9	11	10	8	9	8	10	11	1
40°	11	12	10	9	11	9	10	12	1
41°	11	12	11	11	12	11	11	12	0
42°	14	12	12	12	14	12	13	14	1
43°	15	13	12	14	15	12	14	15	1
44°	16	15	12	14	16	12	15	16	2
45°	16	16	13	13	16	13	15	16	2
46°	17	17	13	13	16	13	15	17	2

47°	17	17	15	15	16	15	16	17	1
48°	17	15	16	17	17	15	16	17	1
49°	18	16	16	17	18	16	17	18	1
50°	19	16	15	17	19	15	17	19	2
51°	20	17	15	16	20	15	18	20	2
52°	21	17	15	16	21	15	18	21	3
53°	21	17	16	15	20	15	18	21	3
54°	20	16	17	14	19	14	17	20	2
55°	20	16	17	14	20	14	17	20	3
56°	21	18	17	17	21	17	19	21	2
57°	24	20	17	18	25	17	21	25	3
58°	28	23	16	20	31	16	23	31	6
59°	26	20	16	18	29	16	22	29	6
60°	27	17	15	17	28	15	21	28	6
61°	28	16	14	16	29	14	21	29	7
62°	24	15	14	15	24	14	19	24	5
63°	23	16	15	16	24	15	19	24	4
64°	24	17	16	16	24	16	19	24	4
65°	23	18	17	17	24	17	20	24	4
66°	23	19	18	18	24	18	20	24	3
67°	24	20	18	18	25	18	21	25	3
68°	22	20	17	16	23	16	20	23	3
69°	23	21	17	17	24	17	20	24	3
70°	25	21	15	16	25	15	20	25	5
71°	26	20	14	18	26	14	21	26	6
72°	27	16	13	16	28	13	20	28	7
73°	25	20	14	15	24	14	19	25	5
74°	22	17	14	14	22	14	18	22	4
75°	20	17	16	14	20	14	17	20	2
76°	18	17	17	19	18	17	18	19	1
77°	17	18	17	18	17	17	17	18	1
78°	16	17	16	17	16	16	17	17	0
79°	16	16	15	16	16	15	16	16	1
80°	15	14	14	15	15	14	14	15	1
81°	14	14	12	13	14	12	14	14	1
82°	14	13	12	13	15	12	13	15	1
83°	15	13	11	13	15	11	13	15	1
84°	13	11	11	13	13	11	12	13	1
85°	12	10	11	12	12	10	12	12	1
86°	12	10	10	11	12	10	11	12	1
87°	10	11	10	11	10	10	10	11	0
88°	9	10	10	10	10	9	10	10	0
89°	10	10	10	10	11	10	10	11	0
90°	10	10	10	10	10	10	10	10	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 20° beam	***7.7***	***89.3***	***210.9***	***68.2***
4° to 20° beam	7.7	74.9	199.2	63.9
7° to 17° beam	9.7	67.6	179.0	52.3

APPENDIX I—DETAILED TESTING RESULTS FOR SAMPLE 110154:
L-864 (L) FIXTURE WITH INFRARED EMITTER

Figures I-1 through I-3 and tables I-1 through I-3 provide detailed testing results for sample 110154: L-810 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

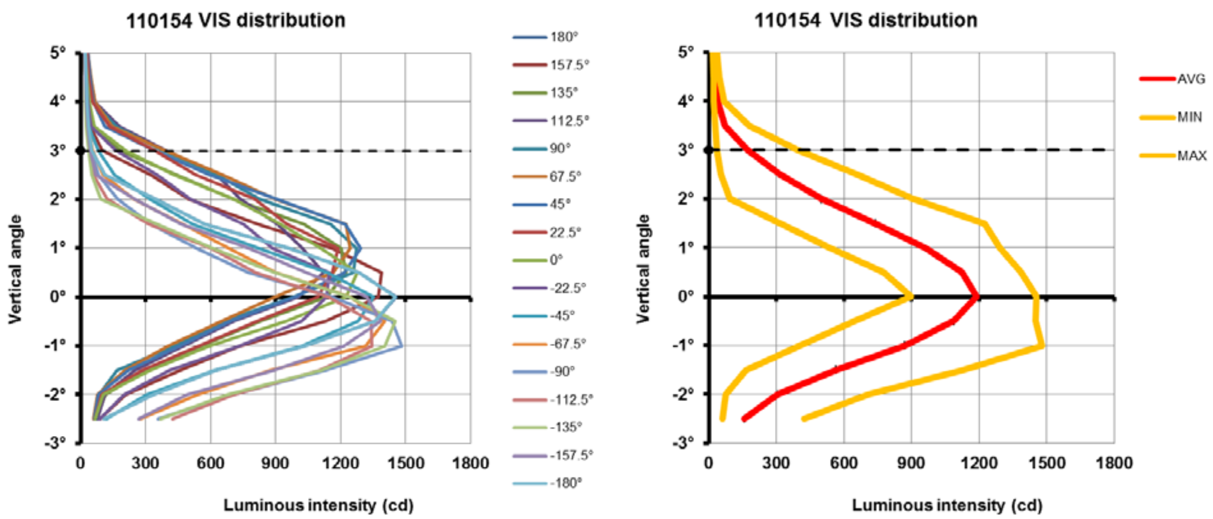


Figure I-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110154

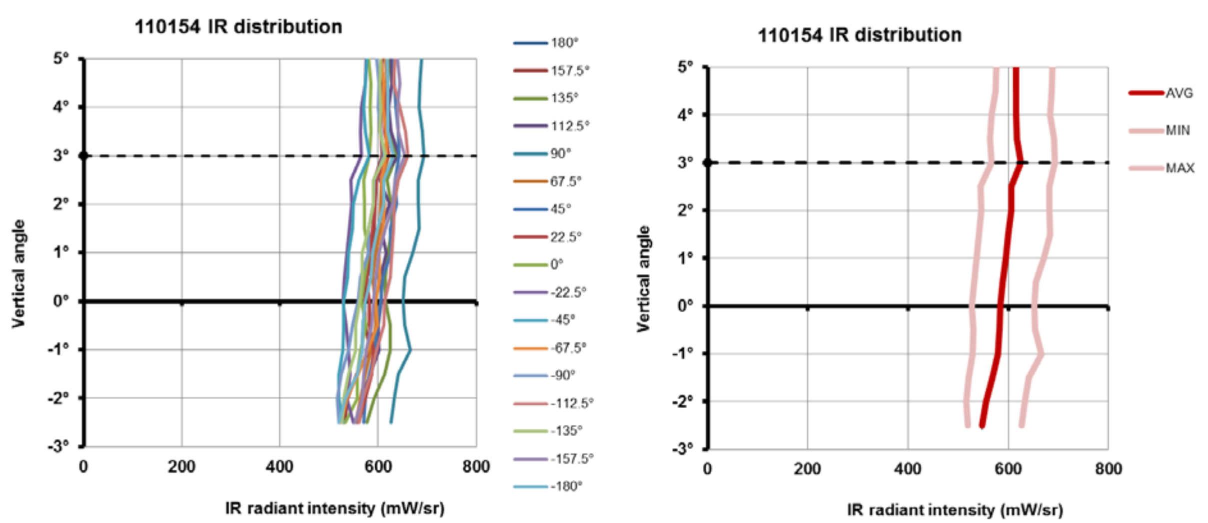
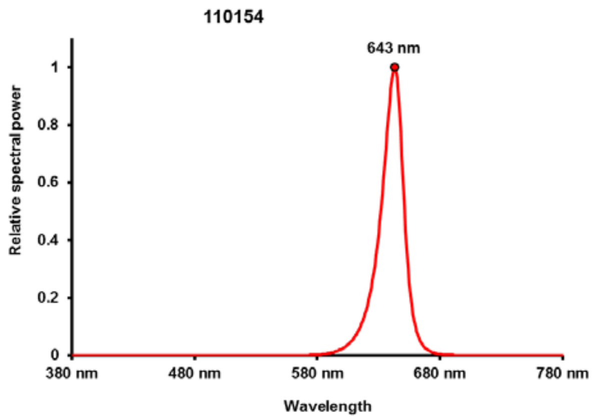


Figure I-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110154

Table I-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110154

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 3° Beam	36.7	714.1	1454.6	434.7	527.8	600.5	693.0	33.6
0° to 5° Beam	18.4	469.4	1454.6	475.1	527.8	606.1	693.0	32.2
-2.5° to 0° Beam	61.2	665.0	1480.4	470.8	516.2	586.5	665.4	32.9



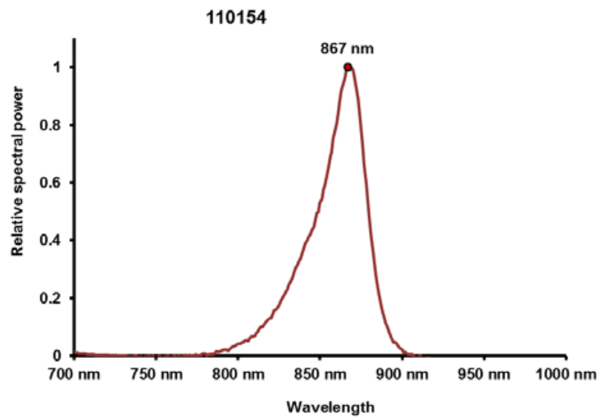


Figure I-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110154
(The peak wavelength in each region is also shown.)

Table I-2. Luminous Intensity Distribution of Sample 110154 VIS

Table I-2. Luminous intensity (cd) distribution of sample 110154 VIS

Vertical angles	Horizontal angles																				
	180°	**157.5°**	**135°**	**112.5°**	**90°**	**67.5°**	**45°**	**22.5°**	**0°**	**-22.5°**	**-45°**	**-67.5°**	**-90°**	**-112.5°**	**-135°**	**-157.5°**	**-180°**	**Min**	**Avg**	**Max**	**Std**
-2.5°	109	88	68	76	69	61	64	66	66	89	119	275	358	424	370	269	109	61	158	424	126
-2°	334	210	116	111	86	77	81	96	105	202	306	541	706	707	679	490	334	77	305	707	235
-1.5°	622	458	295	251	166	203	220	283	319	409	617	873	1128	1103	1111	890	622	166	563	1128	342
-1°	1030	734	556	473	433	404	458	542	593	731	1019	1314	1480	1343	1405	1214	1030	404	868	1480	381
-0.5°	1360	1133	829	706	662	651	694	816	950	1022	1283	1405	1437	1339	1451	1385	1360	651	1087	1451	309
0°	1455	1376	1137	1005	984	897	991	1096	1225	1137	1351	1243	1161	1144	1242	1323	1454	897	1189	1455	167
0.5°	1283	1388	1225	1122	1257	1165	1216	1161	1276	1146	1139	902	776	809	898	1042	1284	776	1123	1388	179
1°	964	1161	1204	1024	1272	1245	1294	1187	1108	885	823	683	538	602	612	777	964	538	961	1294	254
1.5°	572	818	1033	908	1154	1225	1223	953	922	754	517	474	323	318	352	467	572	318	740	1225	315
2°	348	499	703	738	827	898	905	805	707	506	321	245	170	123	94	249	348	94	499	905	283
2.5°	112	324	444	631	629	656	595	531	433	352	157	104	83	61	53	71	112	53	315	656	233
3°	52	99	183	394	380	391	342	343	208	163	80	57	46	40	37	43	52	37	171	394	142
3.5°	35	44	56	179	165	145	110	135	62	49	36	33	34	31	28	32	35	28	71	179	53
4°	29	30	35	68	60	66	61	55	39	32	27	25	29	27	23	27	29	23	39	68	16
4.5°	25	25	28	45	39	46	43	36	29	25	22	22	26	24	21	22	25	21	30	46	9
5°	21	21	25	32	29	34	35	29	24	21	20	20	22	21	18	19	21	18	24	35	6

Summary

Luminous intensity (cd)	**Min**	**Avg**	**Max**	**Std**
0° to 3° beam	***36.7***	***714.1***	***1454.6***	***434.7***
0° to 5° beam	18.4	469.4	1454.6	475.1
-2.5° to 0° beam	61.2	695.1	1480.4	470.8

Table I-3. Radiant Intensity Distribution of Sample 110154 IR

Table I-3. Radiant intensity (mW/sr) distribution of sample 110154   IR

Vertical angles	Horizontal angles																				
	180°	**157.5°**	**135°**	**112.5°**	**90°**	**67.5°**	**45°**	**22.5°**	**0°**	**-22.5°**	**-45°**	**-67.5°**	**-90°**	**-112.5°**	**-135°**	**-157.5°**	**-180°**	**Min**	**Avg**	**Max**	**Std**
-2.5°	520	532	578	557	626	555	570	561	534	550	529	525	520	561	527	552	520	520	548	626	27
-2°	533	539	591	565	633	564	574	574	558	537	520	537	516	569	530	567	533	516	555	633	30
-1.5°	558	556	613	583	641	575	583	587	558	543	520	559	525	586	540	570	558	520	568	641	30
-1°	567	583	625	601	665	585	593	591	564	540	528	580	540	598	554	576	567	528	580	665	33
-0.5°	569	574	625	600	654	595	598	583	576	535	530	598	548	612	555	587	569	530	583	654	32
0°	574	573	616	607	651	594	605	582	566	528	530	595	560	613	562	590	574	528	584	651	31
0.5°	586	578	615	606	654	589	609	576	573	531	539	604	564	625	568	595	586	531	588	654	30
1°	588	589	620	617	671	596	626	582	581	536	540	602	581	628	567	603	588	536	595	671	33
1.5°	600	591	628	607	683	603	625	588	572	541	548	610	581	631	581	615	599	541	600	683	33
2°	611	594	626	622	682	606	637	594	573	546	550	613	590	633	590	630	611	546	606	682	33
2.5°	612	592	619	604	682	606	634	598	570	545	561	607	593	641	591	634	611	545	606	682	32
3°	631	609	637	643	693	621	643	622	582	566	582	617	612	660	615	654	631	566	625	693	31
3.5°	619	604	624	627	691	615	640	613	585	564	575	617	605	656	604	641	619	564	618	691	30
4°	619	607	619	621	683	619	636	615	584	566	570	610	600	644	604	639	619	566	615	683	28
4.5°	620	606	620	627	686	618	633	611	585	574	574	611	602	632	604	645	619	574	616	686	27
5°	619	609	622	626	688	616	631	605	581	576	578	606	597	635	605	640	619	576	615	688	27

Summary

Radiant intensity (mW/sr)	**Min**	**Avg**	**Max**	**Std**
0° to 3° beam	***527.8***	***600.5***	***693.0***	***33.6***
0° to 5° beam	527.8	606.1	693.0	32.2
-2.5° to 0° beam	516.2	569.6	665.4	32.9

APPENDIX J—DETAILED TESTING RESULTS FOR SAMPLE 110162:
L-864 (L) FIXTURE WITH INFRARED EMITTER

Figures J-1 through J-3 and tables J-1 through J-3 provide detailed testing results for sample 110162: L-864 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

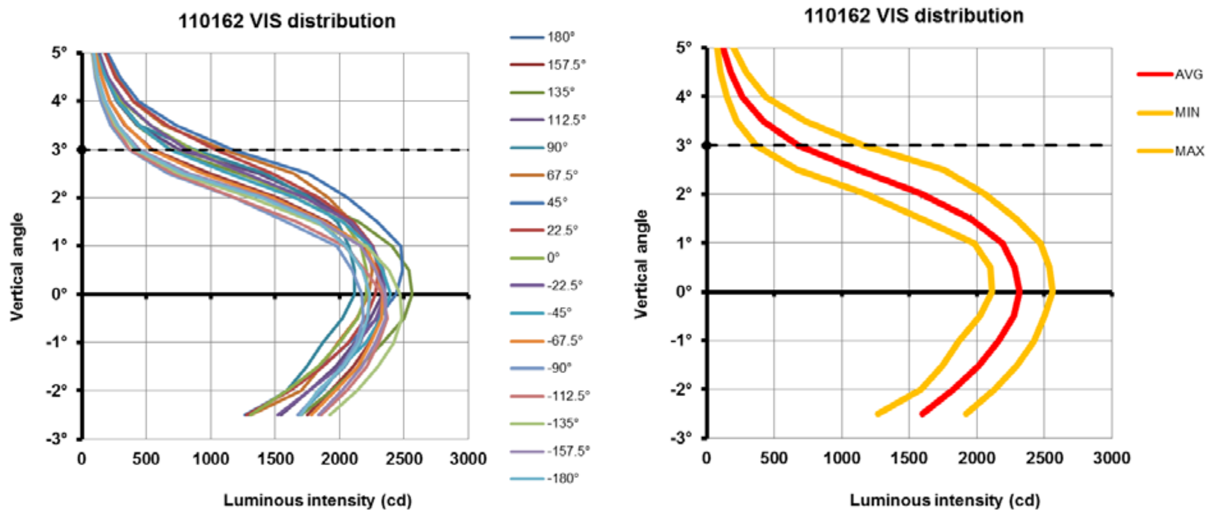


Figure J-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110162

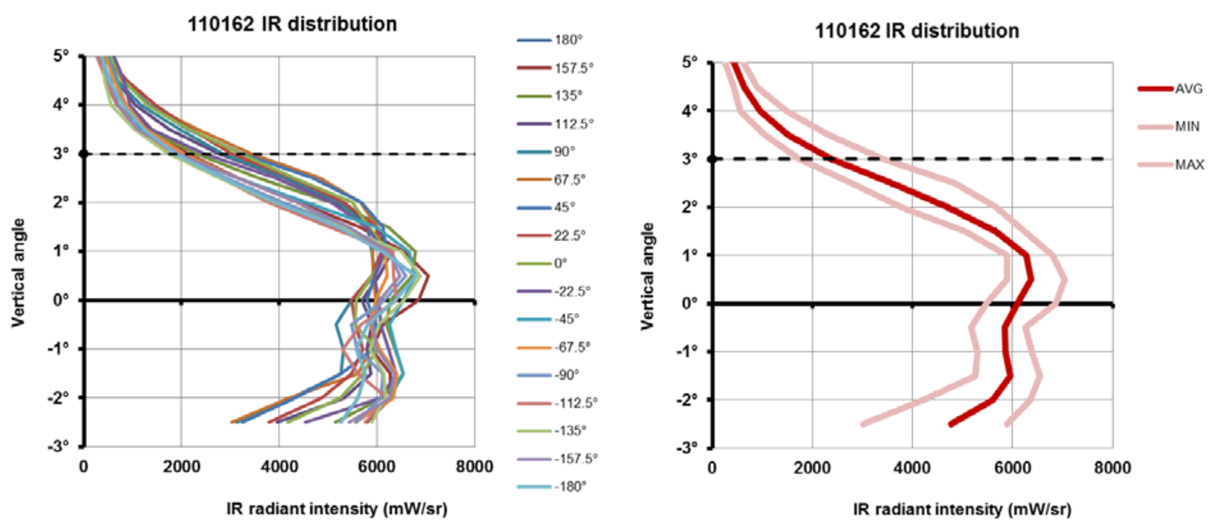
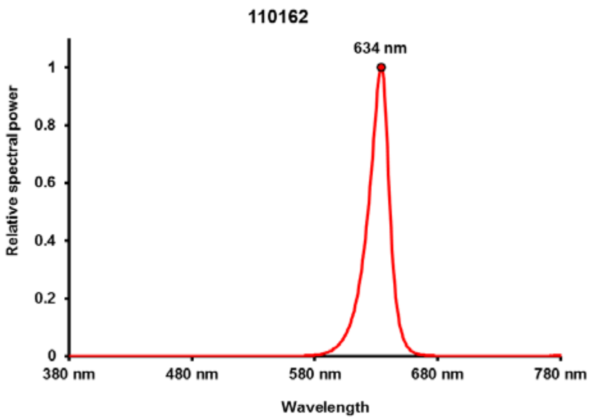


Figure J-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110162

Table J-1. Summary of Visible Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110162

Beam Region	Visible Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 3° Beam	363.1	1733.2	2563.7	626.5	1735.1	5006.5	7042.9	1510.8
0° to 5° Beam	78.7	1191.7	2563.7	879.2	259.2	3507.5	7042.9	2343.5
-2.5° to 0° Beam	1268.8	1833.8	2563.7	297.9	3022.5	5254.4	6858.6	727.5



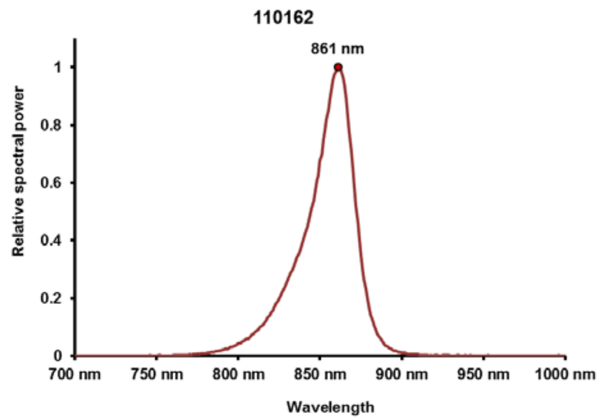


Figure J-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110162
(The peak wavelength in each region is also shown.)

Table J-2. Luminous Intensity Distribution of Sample 110162 VIS

Table J-2. Luminous intensity (cd) distribution of sample 110162 VIS

Vertical angles	Horizontal angles: 180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	1703	1748	1701	1543	1295	1308	1269	1278	1312	1523	1681	1780	1674	1855	1922	1839	1700	1269	1596	1922	224
-2°	1836	1932	1938	1760	1589	1701	1609	1616	1589	1760	1868	1966	1852	2057	2134	2019	1833	1589	1827	2134	169
-1.5°	2033	2106	2154	1967	1746	1859	1862	1868	1834	1999	2013	2139	2020	2209	2298	2174	2030	1746	2018	2298	151
-1°	2160	2232	2334	2119	1869	1988	2074	2067	1998	2143	2201	2242	2128	2303	2423	2280	2156	1869	2160	2423	139
-0.5°	2220	2308	2499	2242	2024	2134	2294	2203	2142	2282	2321	2329	2186	2373	2484	2361	2217	2024	2272	2499	122
0°	2236	2334	2564	2331	2116	2228	2436	2278	2212	2349	2399	2331	2174	2335	2468	2355	2232	2116	2316	2564	113
0.5°	2182	2298	2540	2320	2119	2252	2491	2304	2211	2342	2332	2283	2100	2197	2386	2279	2179	2100	2283	2540	118
1°	2053	2180	2408	2246	2072	2219	2475	2261	2166	2255	2231	2206	1981	2040	2211	2167	2051	1981	2190	2475	128
1.5°	1842	1910	2156	2074	1983	2096	2294	2108	2038	2090	2027	1884	1594	1675	1808	1871	1840	1594	1958	2294	179
2°	1394	1515	1744	1794	1761	1913	2061	1837	1656	1726	1653	1476	1181	1185	1310	1422	1392	1181	1589	2061	255
2.5°	786	992	1220	1374	1422	1647	1755	1477	1257	1270	1144	935	672	708	754	832	786	672	1119	1755	343
3°	428	544	687	759	872	1101	1164	1034	854	813	682	531	363	373	415	445	427	363	676	1164	264
3.5°	278	336	428	437	448	639	732	667	534	535	440	340	221	247	263	277	277	221	417	732	159
4°	179	219	275	274	289	395	438	402	310	326	276	218	148	173	176	178	179	148	262	438	90
4.5°	122	152	189	189	199	285	295	261	183	207	189	152	104	118	117	123	121	104	177	295	60
5°	91	104	114	126	134	192	197	177	128	128	115	103	79	84	82	86	90	79	119	197	38

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 3° beam	***363***	***1733***	***2564***	***627***
0° to 5° beam	79	1192	2564	879
-2.5° to 0° beam	1269	2032	2564	298

Table J-3. Radiant Intensity Distribution of Sample 110162 IR

Table J-3. Radiant intensity (mW/sr) distribution of sample 110162 IR

Vertical angles	Horizontal angles: 180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	5260	5788	5143	3956	3130	3022	3243	3793	4174	4528	5569	5560	5570	5758	5884	5432	5258	3022	4769	5884	1010
-2°	5612	6266	6102	5332	4251	4209	4327	4872	5245	6073	6264	6346	6075	6201	6169	6280	5611	4209	5602	6346	766
-1.5°	5767	6266	6538	5874	5263	5607	5259	5479	5709	6391	6538	6404	6120	5615	6139	6349	5765	5259	5946	6538	429
-1°	5577	5886	6379	5798	5316	5852	5915	5708	5994	6245	6383	6065	5596	5302	5865	6002	5571	5302	5850	6383	320
-0.5°	5804	6116	6193	5888	5166	5940	5968	5563	5543	6072	6257	5853	5478	5683	6036	5915	5801	5166	5840	6257	283
0°	6380	6859	6280	5697	5480	5977	5798	5472	5572	6047	6543	5967	6154	6409	6547	6051	6373	5472	6094	6859	403
0.5°	6801	7043	6718	6048	5954	5923	5958	5890	5889	5949	6789	6203	6587	6345	6882	6466	6795	5889	6367	7043	414
1°	6110	6554	6792	6304	5897	5905	6189	6095	6226	6164	6657	6179	6280	6314	6507	6243	6108	5897	6266	6792	243
1.5°	5236	5655	6245	6014	5815	6000	6118	5989	5835	5793	5995	5348	5399	5056	5302	5421	5232	5056	5674	6245	368
2°	3929	4398	5042	5164	5231	5653	5674	5314	5497	5058	4543	4350	4069	3766	3891	4361	3927	3766	4698	5674	665
2.5°	2850	3167	3575	4096	4152	4835	4692	4262	4309	3920	3146	3149	2911	2816	2779	3151	2851	2779	3568	4835	706
3°	1869	2138	2300	2762	2842	3423	3243	3033	3216	2460	1866	2046	1846	1848	1735	1935	1869	1735	2378	3423	585
3.5°	1243	1364	1298	1761	1973	2335	2134	2208	2174	1385	1171	1280	1087	1072	1049	1101	1244	1049	1522	2335	462
4°	802	841	678	1064	1176	1354	1333	1477	1311	936	866	872	687	702	566	704	803	566	951	1477	281
4.5°	534	520	453	678	698	796	838	886	822	832	679	628	555	455	427	516	533	427	638	886	153
5°	369	307	431	454	476	513	482	430	528	614	488	447	335	259	379	341	368	259	425	614	90

Summary

Radiant intensity (mW/sr)	Min	Avg	Max	Std
0° to 3° beam	***1735***	***5007***	***7043***	***1511***
0° to 5° beam	259	3507	7043	2343
-2.5° to 0° beam	3022	5684	6859	727

APPENDIX K—DETAILED TESTING RESULTS FOR SAMPLE 110167:
L-864 INCANDESCENT FIXTURE

Figures K-1 through K-3 and tables K-1 through K-3 provide detailed testing results for sample 110167: L-864 incandescent fixture. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

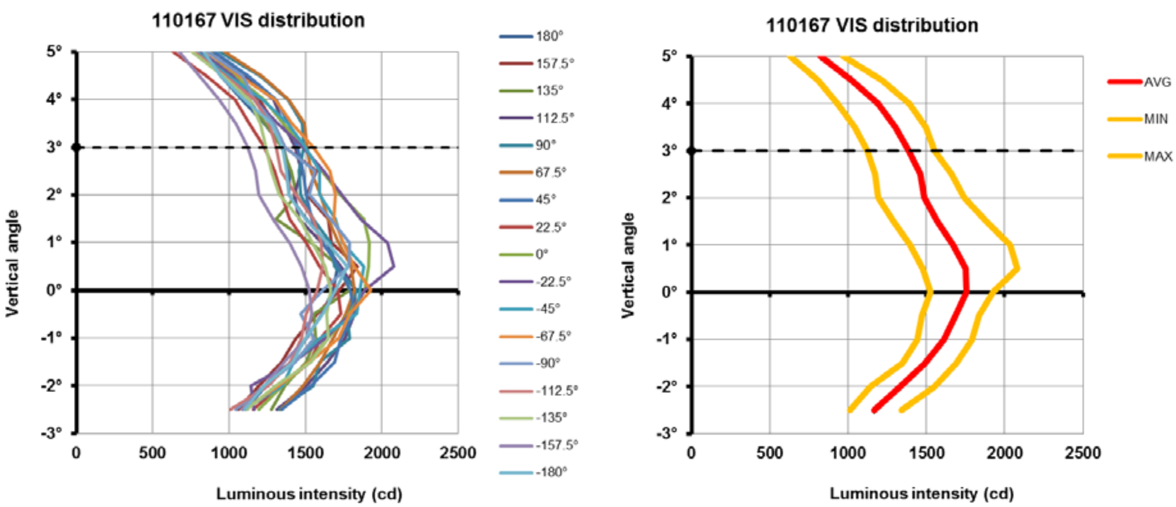


Figure K-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110167

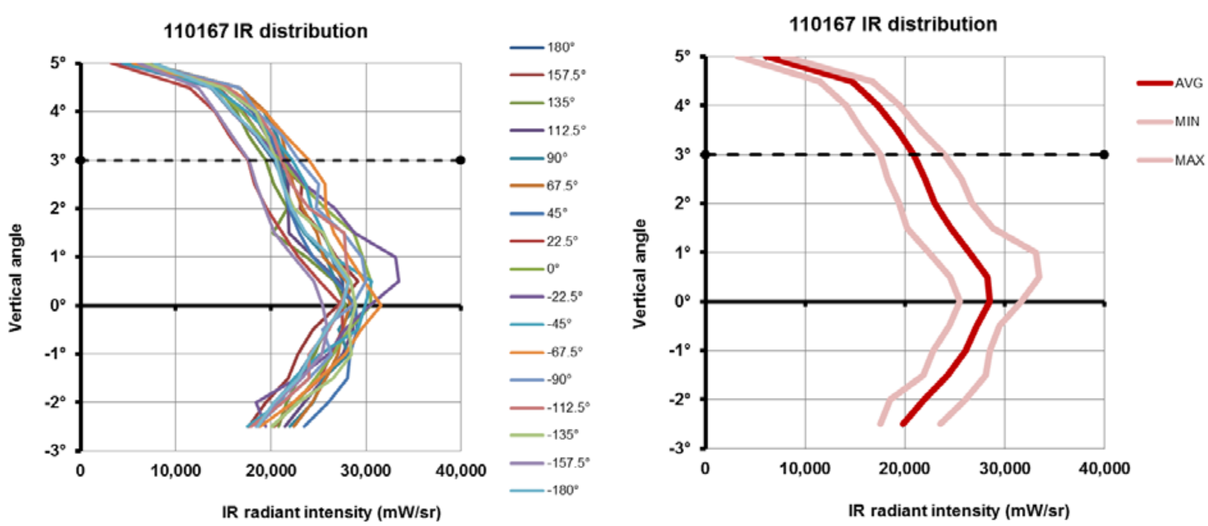


Figure K-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110167

Table K-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110167

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 3° Beam	1,122.7	1,583.0	2,077.7	192.8	1,7582.4	24,828.8	33,436.2	3,522.7
0° to 5° Beam	628.5	1,402.2	2,077.7	311.7	3217.0	21,009.6	33,436.2	6,604.8
-2.5° to 0° Beam	1,010.6	1,530.3	1,926.8	233.3	1,7549.5	24,428.5	31,635.8	3,447.9

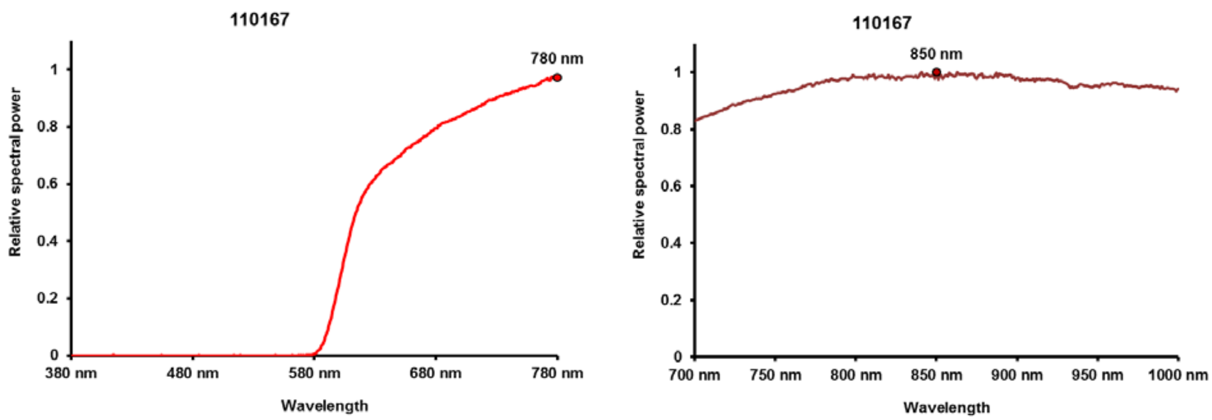


Figure K-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110167
(The peak wavelength in each region is also shown.)

Table K-2. Luminous Intensity Distribution of Sample 110167 VIS

Table K-2. Luminous intensity (cd) distribution of sample 110167 VIS

Vertical angles	Horizontal angles: 180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	1105	1063	1275	1314	1327	1341	1343	1158	1194	1162	1098	1102	1045	1011	1118	1087	1102	1011	1167	1343	111
-2°	1239	1192	1366	1505	1551	1486	1536	1335	1351	1144	1349	1326	1232	1255	1301	1229	1230	1144	1331	1551	124
-1.5°	1402	1345	1504	1645	1593	1599	1692	1533	1521	1423	1422	1527	1432	1403	1534	1360	1416	1345	1491	1692	102
-1°	1506	1440	1568	1761	1790	1678	1733	1600	1646	1631	1595	1715	1557	1475	1649	1505	1498	1440	1609	1790	105
-0.5°	1608	1576	1555	1822	1776	1763	1823	1731	1784	1795	1838	1789	1470	1507	1641	1541	1612	1470	1684	1838	125
0°	1680	1724	1788	1828	1839	1821	1796	1710	1890	1888	1859	1927	1611	1579	1664	1524	1698	1524	1754	1927	118
0.5°	1712	1839	1722	1730	1692	1802	1717	1595	1916	2078	1881	1821	1784	1615	1631	1476	1772	1476	1752	2078	139
1°	1644	1671	1535	1606	1663	1718	1616	1504	1916	2036	1741	1750	1788	1602	1548	1397	1643	1397	1669	2036	152
1.5°	1504	1652	1309	1460	1553	1652	1543	1398	1884	1860	1695	1687	1665	1554	1465	1290	1497	1290	1569	1884	167
2°	1392	1510	1441	1429	1468	1597	1503	1343	1725	1740	1593	1694	1524	1436	1331	1194	1392	1194	1489	1740	147
2.5°	1396	1571	1406	1475	1457	1536	1483	1297	1607	1619	1591	1659	1561	1339	1277	1172	1377	1172	1460	1659	138
3°	1354	1364	1345	1434	1488	1513	1449	1229	1488	1485	1500	1550	1366	1307	1240	1123	1349	1123	1387	1550	117
3.5°	1231	1295	1235	1353	1480	1495	1390	1130	1356	1317	1388	1414	1293	1260	1207	1044	1275	1044	1304	1495	117
4°	1086	1202	1130	1294	1385	1392	1309	1038	1232	1167	1220	1304	1162	1169	1132	934	1102	934	1192	1392	121
4.5°	946	1044	1008	1107	1205	1215	1127	851	1038	1023	997	1068	1091	978	962	808	945	808	1024	1215	109
5°	828	804	883	899	938	968	902	629	814	817	787	852	859	769	757	671	833	629	824	968	87

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 3° beam	***1123***	***1583***	***2078***	***193***
0° to 5° beam	629	1402	2078	312
-2.5° to 0° beam	1011	1506	1927	233

Table K-3. Radiant Intensity Distribution of Sample 110167 IR

Table K-3. Radiant intensity (mW/sr) distribution of sample 110167 IR

Vertical angles	Horizontal angles																				
	180°	**157.5°**	**135°**	**112.5°**	**90°**	**67.5°**	**45°**	**22.5°**	**0°**	**-22.5°**	**-45°**	**-67.5°**	**-90°**	**-112.5°**	**-135°**	**-157.5°**	**-180°**	**Min**	**Avg**	**Max**	**Std**
-2.5°	18668	17723	20809	21482	22027	22442	23514	20383	20264	19461	17550	18895	18477	17911	20030	18602	18611	17550	19815	23514	1767
-2°	20422	19462	21623	23519	24416	24341	26079	22459	22758	18493	20957	22357	21141	21240	22913	20548	20347	18493	21946	26079	1946
-1.5°	22677	21838	22928	25601	25508	25795	28078	25203	24721	22756	22388	25097	23999	24012	26556	23226	22894	21838	24310	28078	1701
-1°	24291	22860	24624	27549	28164	27042	28303	26257	26556	26052	25216	27833	26390	23992	28481	25378	24166	22860	26068	28481	1705
-0.5°	26015	24419	25678	28659	27174	27555	29091	27579	28253	27791	29174	29465	25445	26110	28262	25915	25858	24419	27202	29465	1516
0°	27525	27011	27923	28603	28995	28273	28944	27432	30465	30456	29886	31636	28602	27322	28874	25482	27573	25482	28529	31636	1502
0.5°	27588	29146	26680	27169	26821	28017	26854	25140	30520	33436	30553	29795	29983	28217	28407	24531	28113	24531	28292	33436	2168
1°	26366	26906	23721	24554	25762	25515	24406	22880	29672	33152	26502	28190	29553	27897	26686	22453	26405	22453	26507	33152	2687
1.5°	23609	25345	20259	21919	23470	24868	23020	21228	28711	28804	25574	26665	27639	27687	25506	20433	23670	20259	24612	28804	2743
2°	22254	23126	21742	21805	21877	23305	21883	19549	25702	26732	24286	25826	24781	23983	22445	19413	22200	19413	22995	26732	2045
2.5°	21457	23254	20307	21819	21403	22299	21351	18294	23253	23544	23673	25677	25019	22172	21206	18465	21267	18294	22027	25677	1975
3°	20314	20567	19467	20628	21472	21723	20808	17582	21038	21565	22284	23995	22915	21144	20593	17727	20437	17582	20839	23995	1600
3.5°	18417	18856	17730	19522	20685	21161	19944	15695	18993	18556	20264	21559	21270	20292	19586	15897	18628	15695	19238	21559	1693
4°	15949	17101	16400	18097	19262	19470	18239	14140	16971	15943	17523	19407	18568	18463	18471	14270	16018	14140	17311	19470	1664
4.5°	13741	14465	14465	15280	16694	16764	15519	11489	14183	13866	14121	15511	16764	15621	15018	12367	13783	11489	14685	16764	1459
5°	7707	6852	7594	6857	6937	6726	5563	3217	4325	4178	4449	5460	6478	6357	6634	6053	7780	3217	6069	7780	1345

Summary

Radiant intensity (mW/sr)	Min	Avg	Max	Std
0° to 3° beam	***17582***	***24829***	***33436***	***3523***
0° to 5° beam	3217	21010	33436	6605
-2.5° to 0° beam	17550	24645	31636	3448

APPENDIX L—DETAILED TESTING RESULTS FOR SAMPLE 110168:
L-864 (L) FIXTURE WITH INFRARED EMITTER

Figures L-1 through L-3 and tables L-1 through L-3 provide detailed testing results for sample 110168: L-864 (L) fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

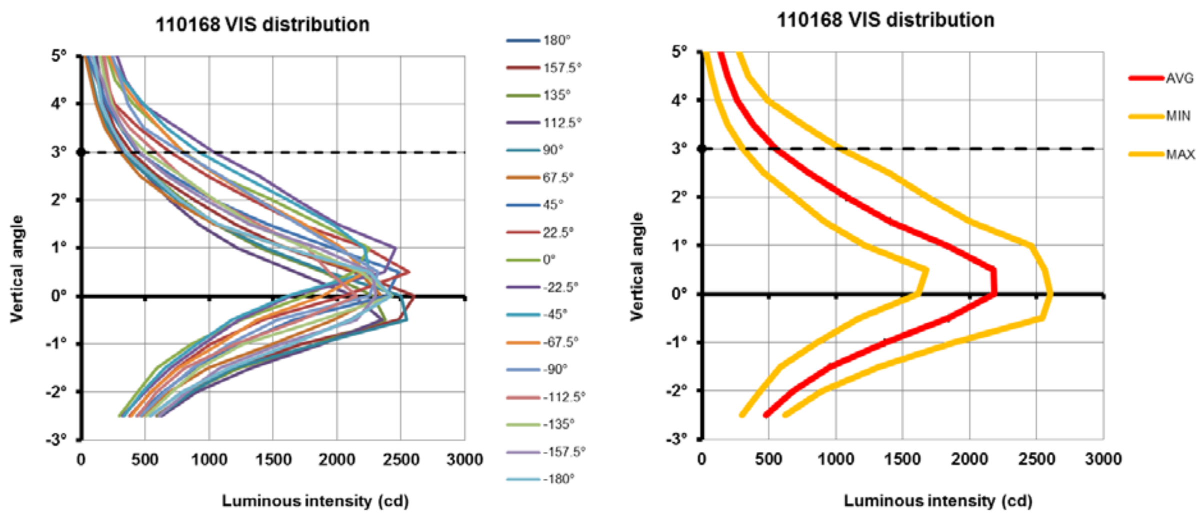


Figure L-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110168

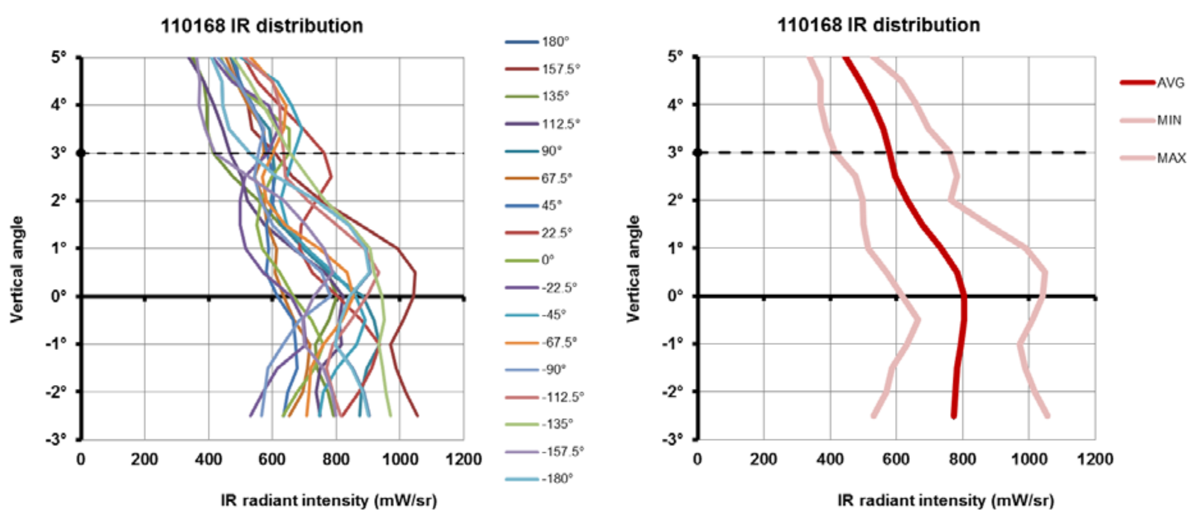


Figure L-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110168

Table L-1. Summary of Luminous Intensity (cd) and Radiant Intensity (mW/sr) Across Different Beam Regions for Sample 110168

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 3° Beam	302.8	1432.8	2604.4	678.2	414.2	687.0	1048.8	136.4
0° to 5° Beam	30.1	1000.7	2604.4	792.9	337.3	621.3	1048.8	149.5
-2.5° to 0° Beam	300.7	1279.9	2604.4	677.4	531.0	728.6	1055.7	115.6

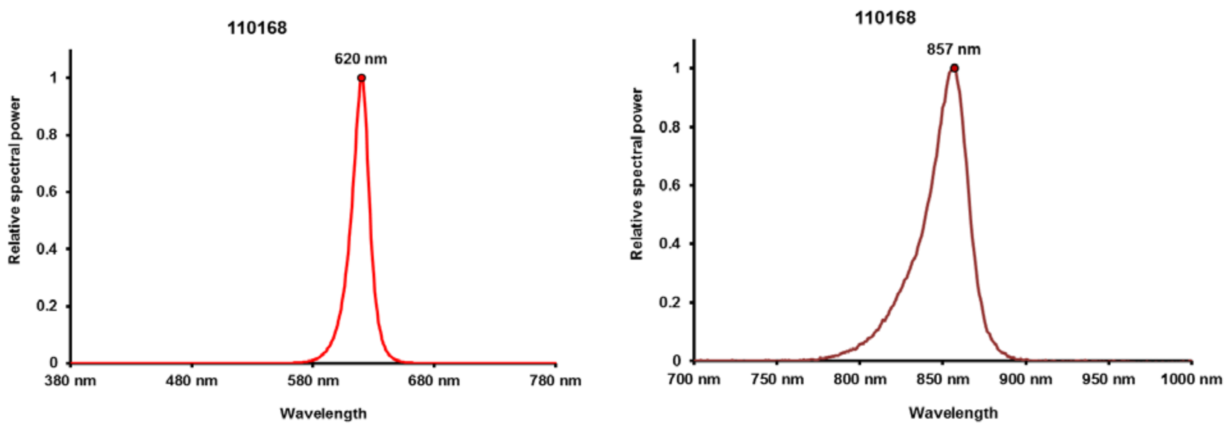


Figure L-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110168
(The peak wavelength in each region is also shown.)

Table L-2. Luminous Intensity Distribution of Sample 110168 VIS

Table L-2. Luminous intensity (cd) distribution of sample 110168 VIS

Vertical angles	Horizontal angles																				
	180°	**157.5°**	**135°**	**112.5°**	**90°**	**67.5°**	**45°**	**22.5°**	**0°**	**-22.5°**	**-45°**	**-67.5°**	**-90°**	**-112.5°**	**-135°**	**-157.5°**	**-180°**	**Min**	**Avg**	**Max**	**Std**
-2.5°	542	588	597	625	607	477	436	379	301	325	333	390	467	439	506	606	543	301	480	625	108
-2°	789	845	841	901	865	687	638	547	440	495	475	541	651	591	707	824	789	440	684	901	150
-1.5°	1156	1203	1230	1321	1188	988	886	746	589	697	653	760	871	809	919	1078	1156	589	956	1321	228
-1°	1640	1712	1833	1872	1836	1491	1222	1008	858	953	902	1071	1157	1196	1259	1550	1640	858	1365	1872	352
-0.5°	2107	2485	2375	2351	2542	1975	1661	1419	1255	1234	1178	1379	1534	1722	1873	2152	2107	1178	1844	2542	460
0°	2419	2604	2284	2127	2499	2347	2385	2054	1759	1639	1616	1885	2255	2153	2435	2300	2420	1616	2187	2604	302
0.5°	2255	2131	1895	1673	1926	2171	2482	2562	2128	2370	2253	2220	2321	1934	2185	2278	2255	1673	2179	2562	222
1°	1609	1602	1405	1221	1449	1621	1970	2237	2252	2458	2219	2041	2008	1771	1766	1855	1609	1221	1829	2458	343
1.5°	1065	1206	1056	916	1061	1044	1460	1717	1874	2005	1965	1746	1699	1383	1338	1317	1065	916	1407	2005	361
2°	768	884	793	689	751	709	1028	1334	1490	1684	1611	1386	1386	1033	1043	966	768	689	1078	1684	335
2.5°	559	594	563	512	518	462	712	986	1075	1392	1257	1069	1091	782	782	667	559	462	799	1392	290
3°	349	392	349	327	303	305	438	697	801	1034	919	793	780	581	502	453	349	303	551	1034	238
3.5°	244	263	230	231	209	189	311	450	617	756	667	614	489	380	316	329	244	189	385	756	181
4°	159	195	180	178	129	117	201	258	411	477	490	448	364	242	242	225	159	117	263	490	125
4.5°	128	123	150	150	88	71	130	193	265	348	332	303	309	211	184	166	129	71	193	348	87
5°	90	50	119	120	39	30	49	158	202	277	231	219	245	182	150	82	90	30	137	277	78

Summary

Luminous intensity (cd)	**Min**	**Avg**	**Max**	**Std**
0° to 3° beam	***303***	***1433***	***2604***	***678***
0° to 5° beam	30	1001	2604	793
-2.5° to 0° beam	301	1253	2604	677

Table L-3. Radiant Intensity Distribution of Sample 110168 IR

Table L-3. Radiant intensity (mW/sr) distribution of sample 110168 IR

Vertical angles	Horizontal angles: 180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	903	1056	792	750	873	653	636	820	634	531	747	707	566	815	970	800	902	531	774	1056	143
-2°	885	1017	774	737	880	696	648	871	677	571	761	714	576	790	957	788	884	571	778	1017	126
-1.5°	850	989	740	751	897	711	677	910	732	616	801	720	587	769	947	759	849	587	783	989	112
-1°	797	972	736	817	935	716	674	937	759	706	864	759	632	790	933	701	797	632	796	972	102
-0.5°	812	1010	777	810	920	668	665	879	723	697	891	819	684	847	950	695	813	665	803	1010	105
0°	843	1042	801	821	883	636	617	805	664	658	862	854	781	897	944	731	843	617	805	1042	115
0.5°	906	1049	776	764	778	608	581	724	624	571	791	834	755	933	919	788	903	571	782	1049	135
1°	894	992	710	666	698	613	589	686	568	516	707	748	670	888	907	761	891	516	736	992	136
1.5°	840	876	626	577	628	583	581	691	550	499	646	640	601	801	845	705	839	499	678	876	119
2°	739	753	555	521	597	573	604	737	563	499	625	581	563	709	764	635	737	499	632	764	88
2.5°	612	664	476	503	609	544	604	784	598	513	646	567	544	640	711	526	612	476	597	784	79
3°	528	607	414	466	602	572	583	761	653	587	667	600	557	635	655	420	528	414	579	761	90
3.5°	463	536	394	443	591	573	567	697	654	619	693	636	574	625	612	389	463	389	561	697	98
4°	443	524	395	418	531	523	540	624	566	588	660	642	534	622	571	371	444	371	529	660	88
4.5°	441	497	384	385	499	486	496	553	476	474	616	599	492	600	528	371	442	371	491	616	74
5°	410	469	351	337	472	453	482	508	437	412	502	530	428	512	477	364	410	337	444	530	58

Summary

Radiant intensity (mW/sr)	Min	Avg	Max	Std
0° to 3° beam	***414***	***687***	***1049***	***136***
0° to 5° beam	337	621	1049	149
-2.5° to 0° beam	531	790	1056	116

APPENDIX M—DETAILED TESTING RESULTS FOR SAMPLE 110169:
PROTOTYPE L-864(L) ADJUSTABLE INTENSITY FIXTURE WITH INFRARED EMITTER

Figures M-1 through M-3 and tables M-1 through M-3 provide detailed testing results for sample 110169: Prototype L-864 adjustable intensity fixture with infrared (IR) emitter. For reference, candelas (cd) are used as the unit of measure for luminous intensity, and milliwatts per steradian (mW/sr) are used as the unit of measure for radiant intensity.

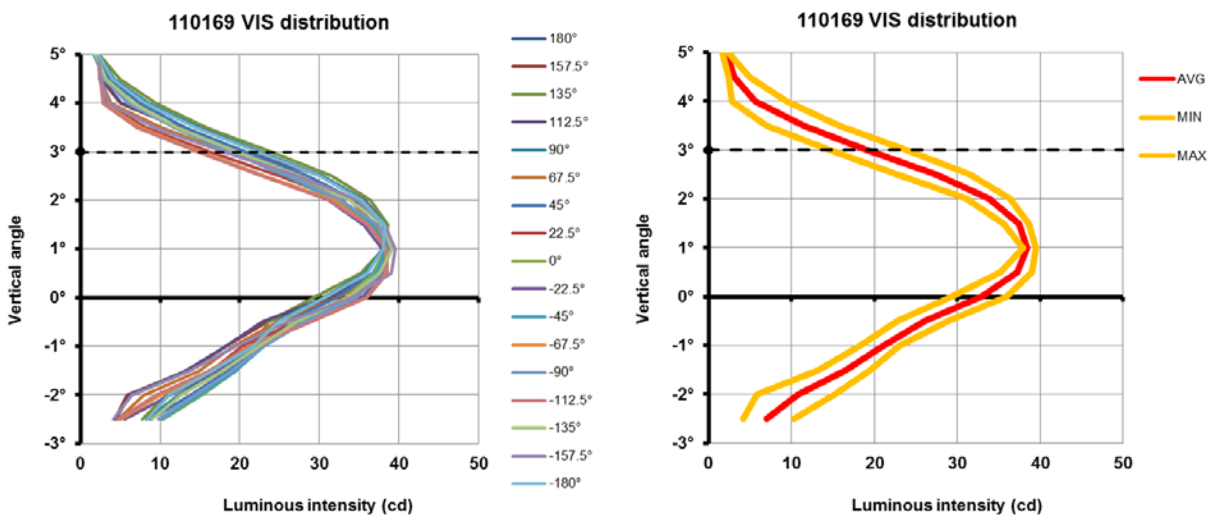


Figure M-1. Luminous Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110169

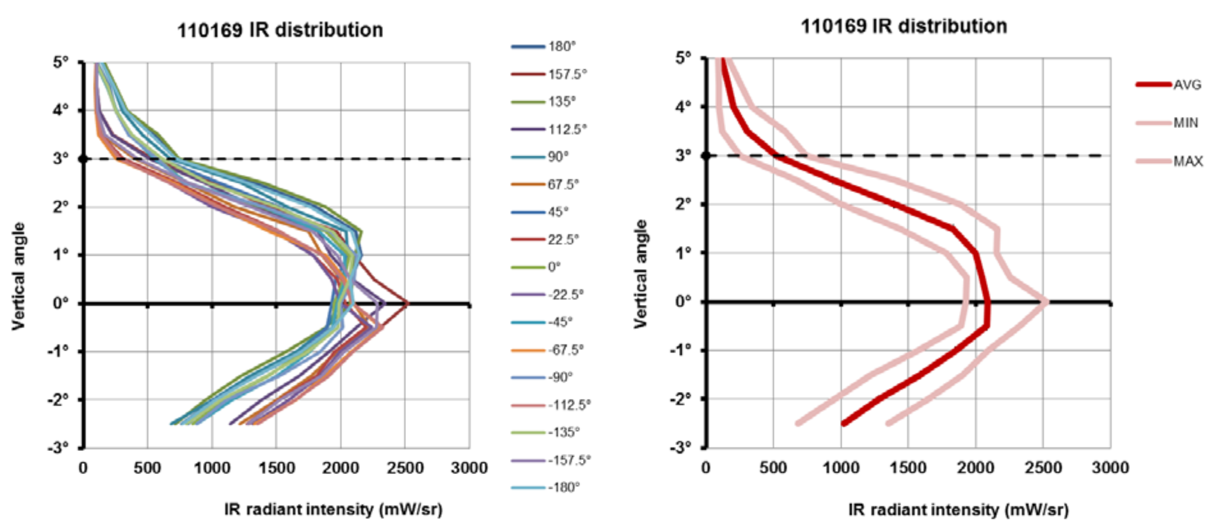
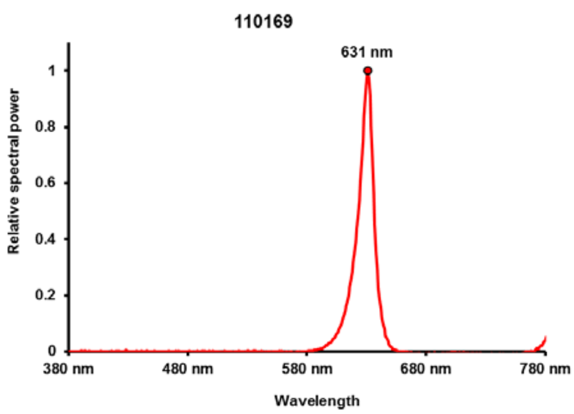


Figure M-2. Radiant Intensity as a Function of Vertical Angle Across Different Horizontal Cuts (Left) and Summary of Minimum, Average, and Maximum Intensity Values Across All Horizontal Cuts (Right) for Sample 110169

Table M-1. Summary of Luminous Intensity and Radiant Intensity Across Different Beam Regions for Sample 110169

Beam Region	Luminous Intensity (cd)				IR Radiant Intensity (mW/sr)			
	Min	Avg	Max	Std	Min	Avg	Max	Std
0° to 3° Beam	14.7	32.3	39.5	6.7	253.6	1,546.6	2,525.2	602.9
0° to 5° Beam	1.7	22.6	39.5	14.2	91.0	1,055.4	2,525.2	812.7
-2.5° to 0° Beam	4.2	25.7	36.0	9.1	680.4	1,553.9	2,525.2	453.8



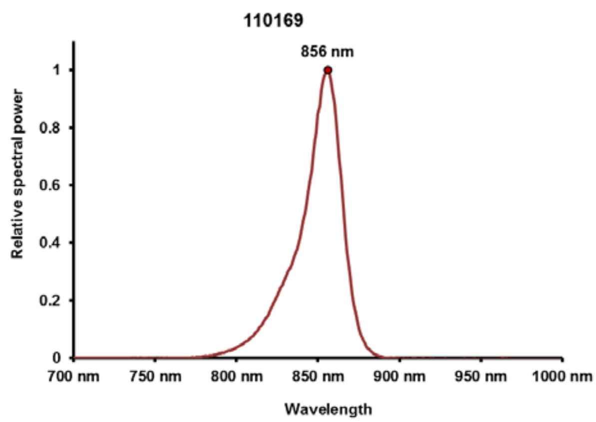


Figure M-3. Relative Spectral Power Distributions in the Visible (Left) and Infrared (Right) Regions for Sample 110169
(The peak wavelength in each region is also shown.)

Table M-2. Luminous Intensity Distribution of Sample 110169 VIS

Table M-2. Luminous intensity (cd) distribution of sample 110169 VIS

Vertical angles	Horizontal angles																				
	180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	8	4	8	4	8	5	9	5	10	6	10	5	10	5	9	4	8	4	7	10	2
-2°	11	6	11	6	12	8	14	10	15	11	15	10	14	9	13	6	11	6	11	15	3
-1.5°	17	13	16	13	17	15	18	16	20	17	19	16	19	16	18	14	17	13	17	20	2
-1°	22	18	21	18	22	19	23	20	23	21	23	21	23	21	22	19	22	18	21	23	2
-0.5°	25	23	24	23	25	25	26	27	27	29	28	29	28	29	27	26	25	23	26	29	2
0°	31	32	29	31	30	32	32	34	33	35	34	36	35	36	34	34	31	29	33	36	2
0.5°	36	38	35	37	36	38	37	38	37	38	37	38	38	39	38	39	36	35	37	39	1
1°	38	39	38	39	38	38	38	38	38	38	38	38	39	39	39	39	38	38	38	39	0
1.5°	38	38	39	38	38	37	38	36	37	36	37	36	37	36	38	38	38	36	37	39	1
2°	36	36	36	36	36	34	34	33	33	31	32	32	33	31	34	35	35	31	34	36	2
2.5°	30	30	32	30	30	27	28	25	27	23	26	23	26	23	28	27	30	23	27	32	3
3°	23	21	24	21	22	18	21	16	19	15	19	15	19	15	20	18	22	15	19	24	3
3.5°	15	12	16	12	15	10	13	8	12	7	12	8	12	7	12	9	14	7	11	16	3
4°	8	5	9	5	9	4	8	3	6	3	6	3	6	3	7	3	8	3	6	9	2
4.5°	4	3	5	3	4	3	4	2	3	3	3	2	3	2	3	2	4	2	3	5	1
5°	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0

Summary

Luminous intensity (cd)	Min	Avg	Max	Std
0° to 3° beam	***15***	***32***	***39***	***7***
0° to 5° beam	2	23	39	14
-2.5° to 0° beam	4	19	36	9

Table M-3. Radiant Intensity Distribution of Sample 110169 IR

Table M-3. Radiant intensity (mW/sr) distribution of sample 110169 IR

	Horizontal angles																				
Vertical angles	180°	157.5°	135°	112.5°	90°	67.5°	45°	22.5°	0°	-22.5°	-45°	-67.5°	-90°	-112.5°	-135°	-157.5°	-180°	Min	Avg	Max	Std
-2.5°	762	1285	714	1145	680	1217	814	1271	850	1318	883	1327	882	1355	800	1276	771	680	1021	1355	255
-2°	1015	1509	950	1382	1004	1501	1010	1521	1084	1596	1155	1649	1109	1642	1068	1528	1026	950	1279	1649	264
-1.5°	1324	1880	1221	1676	1288	1767	1343	1813	1432	1839	1505	1877	1518	1902	1420	1847	1342	1221	1588	1902	246
-1°	1682	2087	1567	1904	1653	1969	1693	1950	1709	1994	1755	2080	1835	2091	1745	2023	1686	1567	1848	2091	174
-0.5°	1935	2309	1889	2122	1891	2220	1894	2198	1944	2240	1936	2314	2015	2326	1978	2275	1942	1889	2084	2326	171
0°	2088	2525	2074	2346	1988	2105	1928	2038	1946	1999	1975	2085	2000	2091	1989	2287	2099	1928	2092	2525	157
0.5°	2075	2257	2093	2092	2009	2003	1960	1971	2022	1930	2036	2036	2102	2014	2065	2072	2072	1930	2048	2257	73
1°	2157	2103	2111	1926	2055	1853	2058	1790	2066	1785	2029	1885	2121	1865	2092	1976	2150	1785	2001	2157	126
1.5°	2113	1970	2162	1823	2039	1748	1884	1529	1887	1490	1829	1444	1919	1522	1939	1784	2087	1444	1833	2162	224
2°	1804	1447	1882	1329	1586	1173	1518	1096	1383	999	1402	1054	1410	1047	1504	1300	1761	999	1394	1882	268
2.5°	1329	1011	1394	943	1226	801	1055	733	795	667	805	703	774	672	966	822	1275	667	939	1394	239
3°	733	540	744	512	677	402	604	309	585	287	554	254	578	286	612	422	719	254	519	744	164
3.5°	551	230	584	225	456	140	355	137	368	139	364	117	352	135	380	170	525	117	308	584	159
4°	332	126	341	124	304	96	255	102	252	106	259	101	255	103	256	109	330	96	203	341	96
4.5°	242	103	252	106	235	95	204	101	187	105	188	102	190	102	195	103	241	95	162	252	61
5°	146	104	160	102	141	97	106	100	94	103	91	98	98	100	100	103	140	91	111	160	21

Summary

Radiant intensity (mW/sr)	Min	Avg	Max	Std
0° to 3° beam	***254***	***1547***	***2525***	***603***
0° to 5° beam	91	1055	2525	813
-2.5° to 0° beam	680	1652	2525	454

APPENDIX N—FLIGHT EVALUATION SUBJECT PILOT DATA SHEET

SUBJECT'S NAME ________________ DATE ________________

VISIBILITY (SM) ________________ START TIME ________________

RUN DATA

Run	Fixture #	Distance light became conspicuous (SM):
1		
2		
3		
4		
5		
6		
7		
8		