Energy Star Lighting Verification Program

(Program for the Evaluation and Analysis of Residential Lighting)

Semi-annual report

For the period of April 2003 to October 2003

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DISCLAIMER

ABSTRACT

The Program for the Evaluation and Analysis of Residential Lighting (PEARL) is a watchdog program. It was created in response to complaints received by utility program managers about the performance of certain Energy Star lighting products being promoted within their service territories and the lack of a self-policing mechanism within the lighting industry that would ensure the reliability of these products and their compliance with ENERGY STAR specifications. To remedy these problems, PEARL purchases and tests products that are available to the consumers in the marketplace. The Lighting Research Center (LRC) tests the selected products against the corresponding Energy Star specifications.

This report includes the experimental procedure and data results of Cycle Three and Cycle Four of PEARL program during the period of April 2003 to October 2003, along with the description of apparatus used, equipment calibration process, experimental methodology, and research findings from the testing. The parameter tested for Cycle three is lumen maintenance at 40% rated life, and parameters tested for Cycle Four are all parameters required in Energy Star specifications except lumen maintenance at 40% rated life.

TABLE OF CONTENTS

LIST OF GRAPHICAL MATERIALS

INTRODUCTION

In response to numerous complaints received by utility program managers about the performance of certain ENERGY STAR® lighting products promoted within their service territories, combined with the lack of industry-wide testing or self-policing mechanism, the Program for the Evaluation and Analysis of Residential Lighting (PEARL) was created. PEARL consists of utilities, energy efficiency advocates, and market transformation organizations. The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute in Troy, NY administers the program and performs the testing.

The ENERGY STAR labeling program for residential lighting products merely requires data submission and certification by the product manufacturers. Product samples tested are "self-picked" by the manufacturer. No follow-up testing on actual products purchased from retail is required by ENERGY STAR. In addition, no centralized data review or challenge process exists within the lighting industry relative to the performance of residential ENERGY STAR lighting products.

This report contains the experimental procedure and research findings for the testing of Energy Star products in Cycle Three and Cycle Four of PEARL program during the period of April 2003 to October 2003.

EXECUTIVE SUMMARY

PEARL is a watchdog program created to monitor the performance of certain Energy Star lighting products being promoted by utility companies. PEARL purchases and tests products that is available to the consumers in the marketplace.

During the period of to April 2003 to October 2003, LRC performed testing for two cycles of PEARL program --- Cycle Three and Cycle Four. For Cycle three, lumen maintenance at 40% rated life was tested for CFLs. For Cycle Four, all parameters required in Energy Star specifications were tested or evaluated, except lumen maintenance at 40% rated life. This report includes the experimental process and data results of the performed testing and description of apparatus used, equipment calibration process, experimental methodology, and research findings from the experiment.

For Cycle Three, all CFLs were seasoned to 40% rated life first. Some CFL samples failed before reaching 40% rated life and some were excluded from results analysis for various reasons: Two 3-way models were tested at middle wattage instead of highest wattage as stated in the Energy Star specifications, and one model was de-listed by Energy Star between the time it was selected and the time when testing was completed. For the remaining 80 samples at the end of their 40% rated lives, 45 CFL samples failed to meet the requirement of lumen maintenance at 40% rated life. Almost all covered lamp and reflector lamp samples failed this requirement.

For Cycle Four, the PEARL board selected 20 product models of compact fluorescent lamps (CFLs) and nine product models of fixtures to test. The 20 CFL models include different types of screw-based CFLs such as bare lamp, covered lamp, reflector lamp, and 3-way lamps, ranging from nine to 30 watts in rated power. These CFLs were made or marketed by 11 different manufacturers. The nine fixture models include eight indoor fixtures and one outdoor fixtures. The indoor fixtures include different types such as wall-mounted, ceiling mounted, and portable fixtures. Products were selected based on their availability in the consumer retail market. The CFL product samples were purchased from retail stores and shipped to the LRC for testing. The fixtures were purchased by LRC from local retailers. Sponsors were divided into three regions for procuring the products: Northeast/Midwest, Northwest, and California.

For CFLs in Cycle Four, the parameters tested include Efficacy, 1000-hour lumen maintenance, Rapid Cycle Stress Test, Power Factor (PF), Correlated Color Temperature (CCT), Color Rendering Index (CRI), and run-up time, etc. For fixtures, the parameters tested include System Efficacy, Lamp Start Time, PF, CCT, CRI, etc. Besides, a series of parameters were verified such as input voltage and frequency, lamp base, starting temperature, compatibility with controls, warranty, Energy Star label, Labeling (including incandescent equivalence), and average rated lamp life for CFLs, and fixture warranty, safety information, Energy Star label, lamp life, noise level, and ballast information for fixtures.

One of the 20 CFL models was removed from the results analysis due to the following reason: Samples received for this CFL model were actually two different models, even though the manufacturer claimed they were the same. For the remaining 19 models of CFL, 5% failed to meet Efficacy requirement, 37% failed to meet 1000-hour lumen maintenance requirement, and 28% failed Rapid Cycle Stress Test requirement. All eight indoor fixtures met System Efficacy requirement, and two failed to meet Lamp Start Time requirement. Socket Compatibility for the outdoor fixture is questionable.

Other than the parameters included in Energy Star specifications, LRC also made observations on other quality problems related to the selected products, and made recommendations on possible modifications to Energy Star specifications.

EXPERIMENTAL

Apparatus

Please refer to Appendix I of this document for description of apparatus used for testing in PEARL program.

Apparatus Calibration

LRC integrating sphere system was calibrated when necessary. Three calibrations were performed in the period of April 2003 to October 2003, in June, July, and September 2003.

Other equipment, including the Xitron 2503AH Power analyzer and Agilent 34970A Data Acquisition Unit, was calibrated annually.

Product Selection

The PEARL board selected 20 product models of compact fluorescent lamps (CFLs) and nine product models of fixtures to test. Products were selected based on their availability in the consumer retail market. Initially, PEARL sponsors went to retail stores to see what products were available. Then, the products from the compiled list were purchased and shipped to the LRC for testing.

Product Purchasing and Sampling

For details on product purchasing and sampling, please refer to PEARL Cycle Three Final Report and PEARL Cycle Four Final Report.

Product Testing

PEARL tested the CFL products against the ENERGY STAR specification dated August 9, 2001, and tested the fixture products against the ENERGY STAR specification Version 3.1 that was effective on April 1, 2002. All CFL and fixture testing was performed at the LRC. Product verification and compilation of results were also completed by the LRC.

For details on testing parameters and test methods please refer to PEARL Cycle Three Final Report and PEARL Cycle Four Final Report.

RESULTS AND DISCUSSION

The testing results of all CFLs and fixtures are presented in PEARL Cycle Three Final Report and PEARL Cycle Four Final Report, along with discussions of other quality problems that LRC found about the products during the testing and some recommendations on possible modifications to Energy Star specifications. For more details please refer to PEARL Cycle Three Final Report and PEARL Cycle Four Final Report.

CONCLUSION

In Cycle Three, 56% CFL models failed to meet the requirement of lumen maintenance at 40% rated life, and almost all covered lamps and reflector lamps failed this requirement.

In Cycle Four, 95% of the CFL models tested meet the Efficacy requirement, 72% met Rapid Cycle Stress Test requirement, and 63% met 1000-hour lumen maintenance requirement. All eight indoor fixtures met System Efficacy requirement and two failed to meet Lamp Start Time requirement.

In Cycle Four, covered lamps and reflector lamps have a lower rate of meeting the 1000-hour lumen maintenance requirement. This agrees with our finding from PEARL Cycle Three --- covered lamps and reflector lamps tend to be problematic, probably due to the raised ambient temperature for the fluorescent tube inside the housing of the cover or reflector. This conclusion also agrees with the research findings from LRC in the past --- extra heat affects fluorescent lamps' performance adversely.

As shown in previous cycles of PEARL program, products from different manufacturers continue to perform differently, and there is one model from a certain manufacturer that had all five samples failed before reaching 40% of rated life.

Other quality problems exist besides the Energy Star specified parameters, such as reflector glass cracking under heat and inconsistent claims and packaging for different samples of the same model.

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ANSI C78.4:1998 American National Standard for Fluorescent Lamps - Self-Supporting, Single-Based, Compact Types - Dimensional and Electrical Characteristics

ANSI C78.5:1997 American National Standard for Electrical Lamps - Specifications for Performance of Self-Ballasted Compact Fluorescent Lamps

ANSI C82.3:1995 American National Standard Specifications for Fluorescent Lamp Reference Ballasts

IES LM-20:1994 Photometric Testing of Reflector-Type Lamps

IES LM-40: 2001 Life Performance Testing of Fluorescent Lamps

IES LM-45:2000 Electrical and Photometric Measurements of General Service Incandescent Filament Lamps

IES LM-49:2001 Life Testing of General Lighting Incandescent Filament Lamps

IES LM-54:1999 IES Guide to Lamp Seasoning

IES LM-58:1994 Spectroradiometric Measurements

IES LM-65:2001 Life Testing of Single Ended Compact Fluorescent Lamps

IES LM-66:2000 Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps

IES LM-9:1999 Electrical and Photometric Measurements of Fluorescent Lamps

NIST HB 150-1:1994 National Voluntary Laboratory Accreditation Program (NVLAP) Handbook for Energy Efficient Lighting Products. Lawrence S. Galowin, Wiley Hall, and Walter J. Rossiter, Jr.

NBST PB93 196 038 Experimental Statistics Handbook 1991

UL 1993 Standard for Safety for Self-Ballasted Lamps and Lamp Adapters

LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternative Current
ANSI	American National Standard Institute
CCF	Current Crest Factor
CCT	Correlated Color Temperature
CFL	Compact Fluorescent Lamp
CRI	Color Rendering Index
DC	Direct Current
IES	Illuminating Engineering Society
ISS	Integrating Sphere System
Lm	Lumen
IES-LM	Illuminating Engineering Society Lighting Measurement Guidance
LRC	Lighting Research Center
NEMA	National Electrical Manufacturers Association
NLPIP	National Lighting Product Information Program
PEARL	Program for the Evaluation and Analysis of Residential Lighting
PF	Power Factor
RPI	Rensselaer Polytechnic Institute
UL	Underwriter Laboratories
W	Watt

APPENDIX 1: Apparatus

LRC Laboratory Description

The Lighting Research Center (LRC), part of Rensselaer Polytechnic Institute, is a university-based research and education institution dedicated to lighting. Its laboratory performs testing of energy efficient products for the Program for the Evaluation and Analysis of Residential Lighting (PEARL), the National Lighting Product Information Program (NLPIP), and some research for the LRC's partners.

Located at 21 Union Street in Troy, New York, the LRC laboratory employs a staff of 12 (please see the organizational chart). The lab consists of three sub areas, of a total size of 2060 square feet: the 20x8 foot Ballast Testing Room, the 34x30 foot Lamp Testing Room, and the 44x20 foot Photometry Lab.

Integrating Sphere System (ISS)

The main apparatus in Lamp Testing Room is an Integrating Sphere System (ISS). The ISS consists of following items/instruments:

- Integrating sphere; interior access type, 65-inch diameter (Mfg: Labsphere, Model: IAS650) Figure 1
- Double monochromator at 5 nm band pass (Mfg: Optronic Laboratories, Model: 750-M-D)
  - Entrance slit width – 1.25 mm
  - Exit slit width – 1.25 mm
  - Center slit width – 2.5 mm
- Enhanced silicone detector module (Mfg: Optronic Laboratories, Model: DH-300)
- Detector support module (Mfg: Optronic Laboratories, Model: DSM-1D)
- System controller for the monochromator/detector system (Mfg: Optronic Laboratories, Model: 750-C)
- OL750 application software (supplied by Optronic Laboratories)
- Personal computer with Windows NT 4.0 (Mfg: Dell, Model: OptiPlex GX1p)
- GPIB Interface (Mfg: National Instruments, Model: GPIB-PCI)

National Standards Used

The national standards used in the testing for LRC testing lab are from ANSI/NEMA, UL, and Illuminating Engineering Society (IES). Below is a list of them:

- ANSI C62.41:1991 IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
- ANSI C78.4:1998 American National Standard for Fluorescent Lamps - Self-Supporting, Single-Based, Compact Types - Dimensional and Electrical Characteristics
- ANSI C78.5:1997 American National Standard for Electrical Lamps - Specifications for Performance of Self-Ballasted Compact Fluorescent Lamps

- ANSI C82.3:1995 American National Standard Specifications for Fluorescent Lamp Reference Ballasts
- IES LM-20:1994 Photometric Testing of Reflector-Type Lamps
- IES LM-40: 2001 Life Performance Testing of Fluorescent Lamps
- IES LM-45:2000 Electrical and Photometric Measurements of General Service Incandescent Filament Lamps
- IES LM-49:2001 Life Testing of General Lighting Incandescent Filament Lamps
- IES LM-54:1999 IES Guide to Lamp Seasoning
- IES LM-58:1994 Spectroradiometric Measurements
- IES LM-65:2001 Life Testing of Single Ended Compact Fluorescent Lamps
- IES LM-66:2000 Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps
- IES LM-9:1999 Electrical and Photometric Measurements of Fluorescent Lamps
- NIST HB 150-1:1994 National Voluntary Laboratory Accreditation Program (NVLAP) Handbook for Energy Efficient Lighting Products. Lawrence S. Galowin, Wiley Hall, and Walter J. Rossiter, Jr.
- NBST PB93 196 038 Experimental Statistics Handbook 1991
- UL 1993 Standard for Safety for Self-Ballasted Lamps and Lamp Adapters

Spectral/flux Calibration of the ISS

The calibration procedure enables the integrating sphere system (ISS) to measure photometric output of test lamps. The process involves the determination of the relative spectral response of the ISS and normalization of the photometric output to a known flux standard(s). The relative spectral response is determined by comparing a spectral irradiance standard with the system response to the standard. This is done over the desired range of wavelengths. Once the relative spectral response is determined the flux standard(s) is used to normalize the system output to the known photometric output of the standard.

Standard lamps used for calibration

The following spectral/flux standards were used in the calibration process. All standards are traceable to NIST.

Relative spectral irradiance standard

FEL type incandescent lamp, traceable to NIST (Mfg: Hoffman Engineering, SN: 94406)

- Lamp current: 7.204 A (DC)
- Lamp voltage: 84.5 V (DC)
- Correlated color temperature: 2856 K
- CIE x: 0.448
- CIE y: 0.408
- Spectral range: 350 to 1100 nm

Flux standards, 200W Wi40/Globe incandescent, inside frosted, calibrated at NIST (Mfg: Osram)

Lamp_RPI_1
- Lamp current: 5.725 A
- Lamp voltage: 29.36 V
- Luminous flux: 2225 lumens
- Correlated color temperature: 2750 K

Lamp_RPI_2
- Lamp current: 5.728 A
- Lamp voltage: 29.45 V
- Luminous flux: 2288 lumens
- Correlated color temperature: 2750 K

Lamp_RPI_3
- Lamp current: 5.623 A
- Lamp voltage: 29.31 V
- Luminous flux: 2234 lumens
- Correlated color temperature: 2750 K

Spectral lamp (Mfg: Osram)

- Lamp type: HgCd/10

Working standard lamp to be calibrated

The following lamp was calibrated for luminous flux using the calibrated ISS.

Lamp RPI_WS, 200W incandescent, clear (Mfg: Osram)
- Type: Wi 40/G
- Rated voltage: 31.0 V
- Rated current: 6.0 A

Electrical equipment

- DC power supply (Mfg: Hewlett Packard, Model: 6675A)
- AC power supply (for the HgCd/10 spectral lamp; Mfg: Gates, Model: 12S-9)
- Data acquisition/switch unit (Mfg: Agilent Technologies, Model: 34970A)
- 20-channel multiplexer (Mfg: Agilent Technologies, Model: 34901A)
- Bench type multimeter (Mfg: Hewlett Packard, Model: 34401A)
- Shunt resistance (Mfg: Isotek, Model: RUG-R050, 50 mΩ)
- Computer controlled data acquisition system (using GPIB)

Sphere Calibration Procedure

The whole calibration process involves three steps:

- Wavelength calibration
- Relative spectral response calibration
- Flux calibration

Wavelength calibration

The monochromator system is pre-calibrated for wavelength. The experimental procedure was to determine possible changes in the pre-calibration due to shipping/handling etc.

The spectral (HgCd/10) lamp was mounted at the center of the sphere. It was turned on and stabilized for about 20 minutes before the test. A spectral scan from 360 to 650 nm at 0.2 nm intervals was taken using the monochromator system. Known spectral peaks for Hg and Cd were compared against the measured peaks. See Figure 2.

Relative Spectral Response Calibration

The relative spectral response of the ISS was determined using the spectral irradiance standard lamp 94406. The spectral data for the lamp were imported to the software program (software supplied by Optronic Laboratories).

The DC power supply was used to power up the lamp. The current limit was set at 7.204 A, and the power supply was operated at the constant current (CC) mode. The DC voltage across the shunt was monitored using the Data acquisition/switch unit to maintain the lamp current. The lamp voltage was measured using the multimeter. Lamp was stabilized for about 15 minutes before the scan. The room temperature was recorded at regular intervals.

A spectral scan from 350 to 800 nm was taken using the double monochromator system. The relative spectral response of the system is the ratio of the standard spectral data of the lamp to that of scanned data (the software program does the math automatically) for the wavelength range from 350 to 1100 nm. Figure 4 illustrates the system spectral response calibration curve.

Even though there was a slight discrepancy (figure 3) in the measured spectral power distribution of the spectral standard (94406) around 600 nm region, it produced close results of the reported CCT and chromaticity coordinates. Therefore the error introduced by placing the lamp inside the sphere is assumed negligible.

Flux calibration

The flux calibration was done using two flux standards RPI_2 and RPI_3 (calibrated at NIST). The lamp (RPI_2) was mounted at the center of the sphere. The DC power supply was used to power up the lamp. Current was set at 5.728

A, and the power supply was run at the CC mode. Lamp was stabilized for about 15 minutes before the test. The lamp current was monitored using the Data acquisition/switch unit to maintain the lamp current. The lamp voltage was measured using the multimeter. The room temperature was recorded at regular intervals.

A spectral scan from 350 to 1100 nm was taken using the double monochromator system. The same procedure was repeated for the lamp RPI_3. Photometric calculations were performed using the software program. The photometric output for each lamp was used to obtain the normalization factor to find the absolute luminous flux.

The flux standard RPI_1 was tested using the calibrated ISS to check the calibration. The lamp was operated using the same DC power supply similar to the manner described above for RPI_2 and RPI_3 at the specified current of 5.725 A.

Calibration of the working standard

The working standard was calibrated using the calibrated ISS. The lamp (working standard) was mounted at the center of the sphere. The DC power supply was used to power up the lamp. Current was set at 5.728 A, and the power supply was run at the CC mode. Lamp was stabilized for about 15 minutes before the test. Stabilization was determined by monitoring the lamp current. When the lamp current changes less than 0.01% within 3 minutes, the lamp is considered as stable in its current and its light output. The lamp current was monitored using the Data acquisition/switch unit to maintain the lamp current. The lamp voltage (29.468 V, at the lamp leads about 6 inches away from the actual lamp terminals) was measured using the multimeter. The room temperature was recorded at regular intervals.

A spectral scan from 350 to 800 nm was taken using the double monochromator system. Photometric calculations were performed using the software program.

The auxiliary lamp (12 V, Quartz halogen) was used to determine the self-absorption factor for flux standards. The DC power supply was used to power up the lamp. Current was set at 2.869 A, and the power supply was run at the CC mode. Lamp was stabilized about 10 minutes before the test. Two spectral scans from 380 to 800 nm were taken with and without the unlit flux standard RPI_1 inside the sphere. The software program was used to determine the numerical sum of each scan, and the ratio was used as the self-absorption factor.

Other Equipment

- Lamp Racks
- Fixture Racks
- Double Monochromator and Controller

- Instrument Rack:
  - Power meter
  - Data acquisition unit
  - Multimeter
  - Picoammeter
  - AC Power Supply
  - DC Power Supply
- Examination Tables
- Computers

References for Appendix I

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APPENDIX 2: Figures

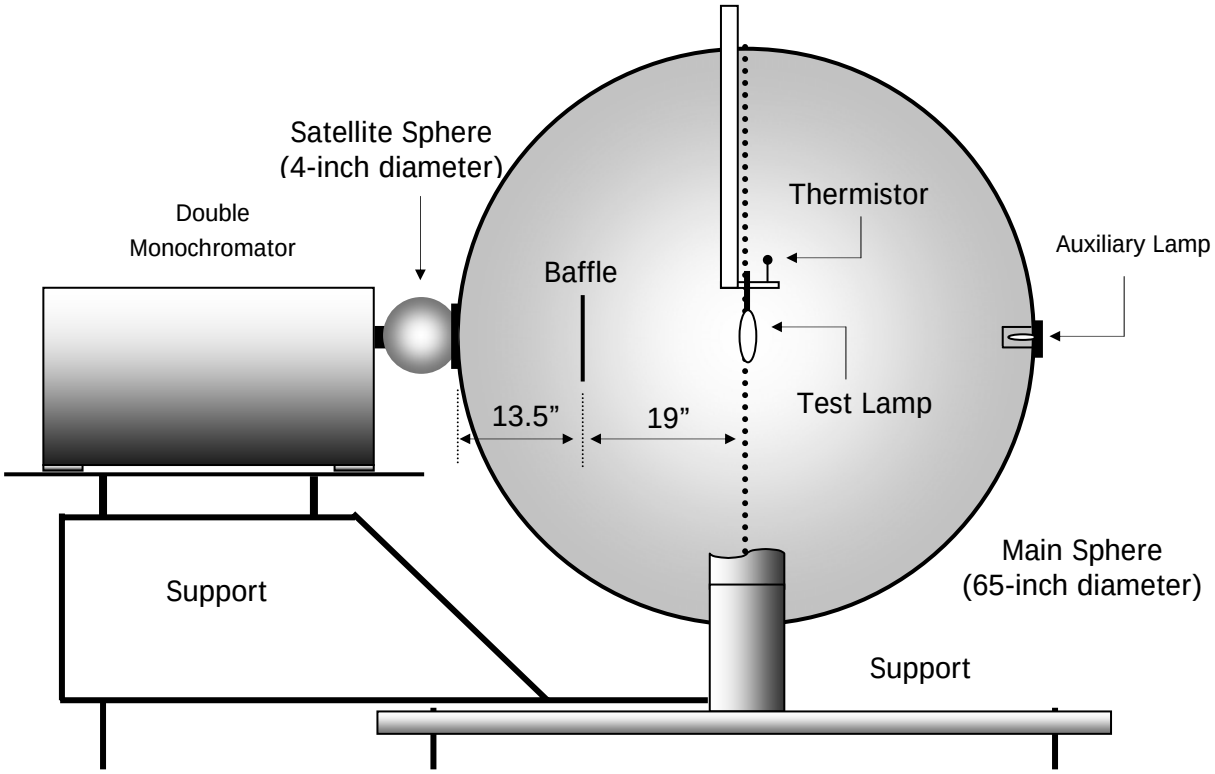

Figure 1. The integrating sphere system (ISS)

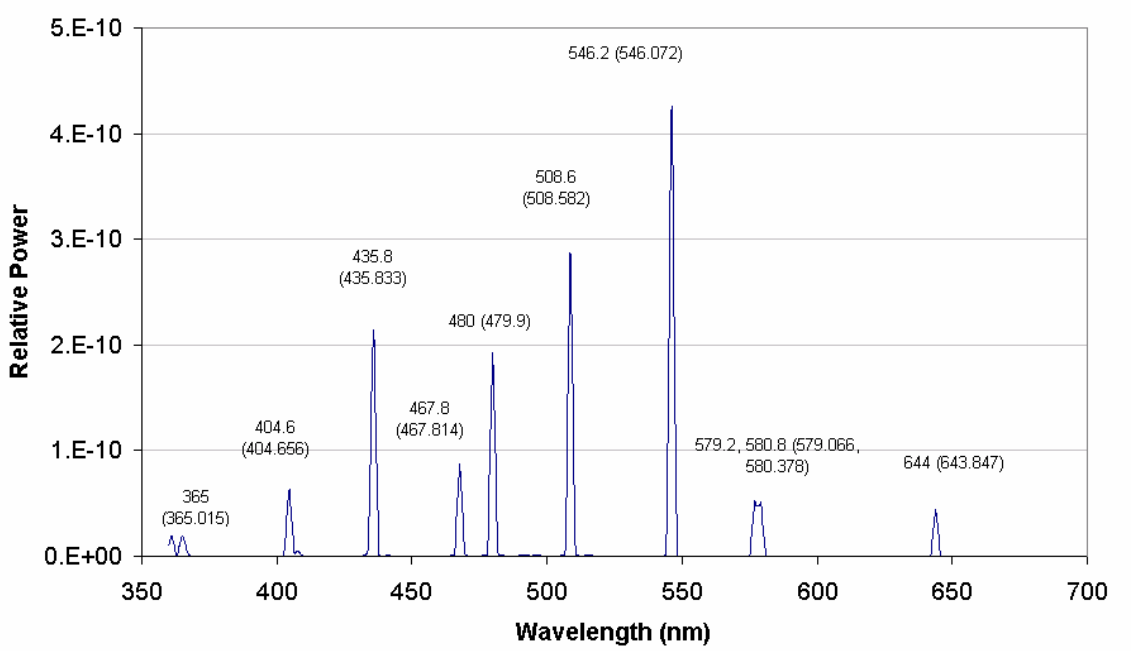

Figure 2. Measured line spectrum of the HgCd/10 spectral lamp. Values in parenthesis are the reference values for corresponding peaks.

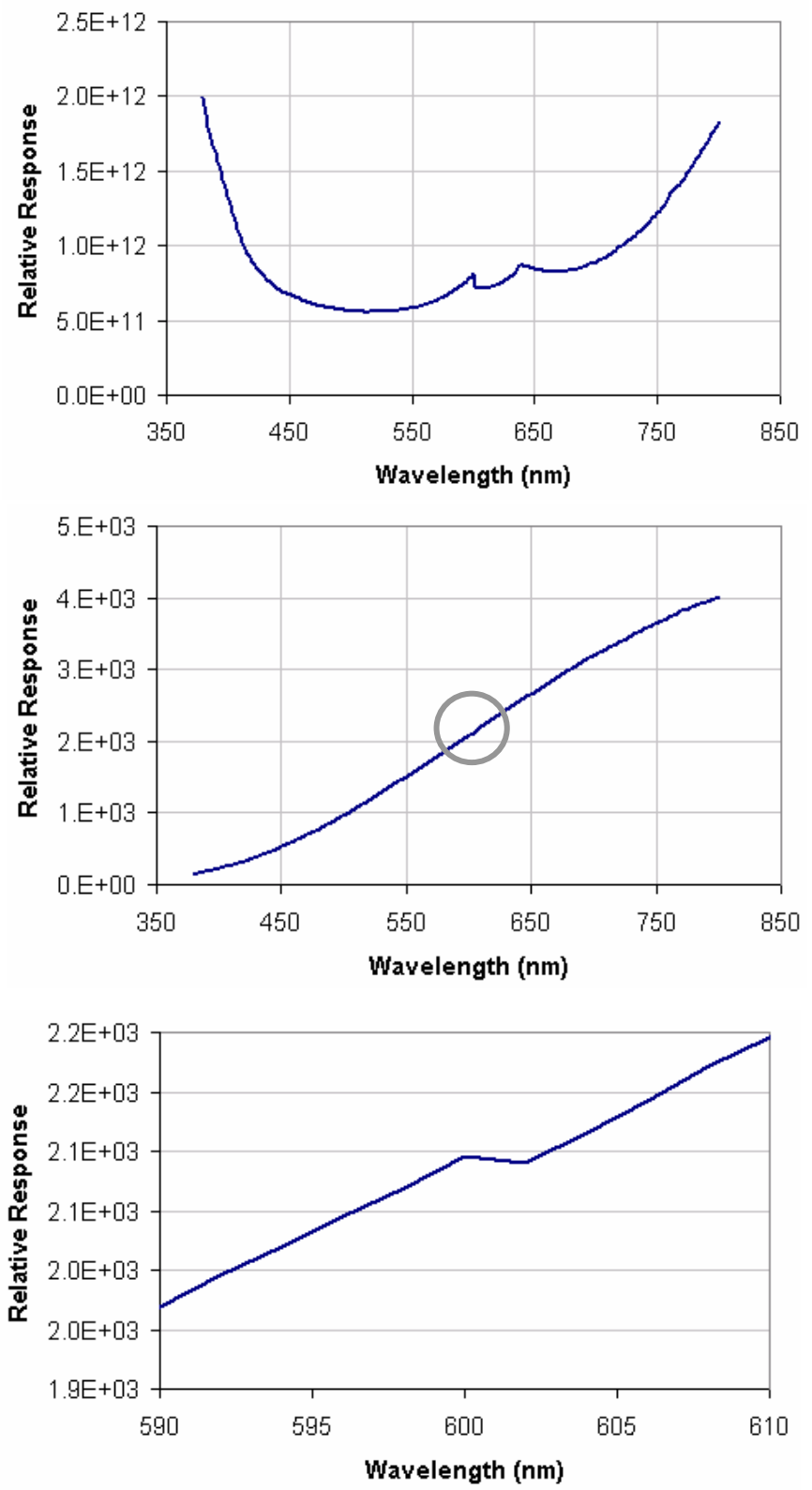

Figure 3. (a) Relative spectral response curve obtained by manual operation, (b) measured spectrum of the spectral standard (94406) inside the sphere using the calibration curve obtained by manual operation, and (c) enlarged portion showing the abnormal portion around 600 nm indicated by the circle in (b).

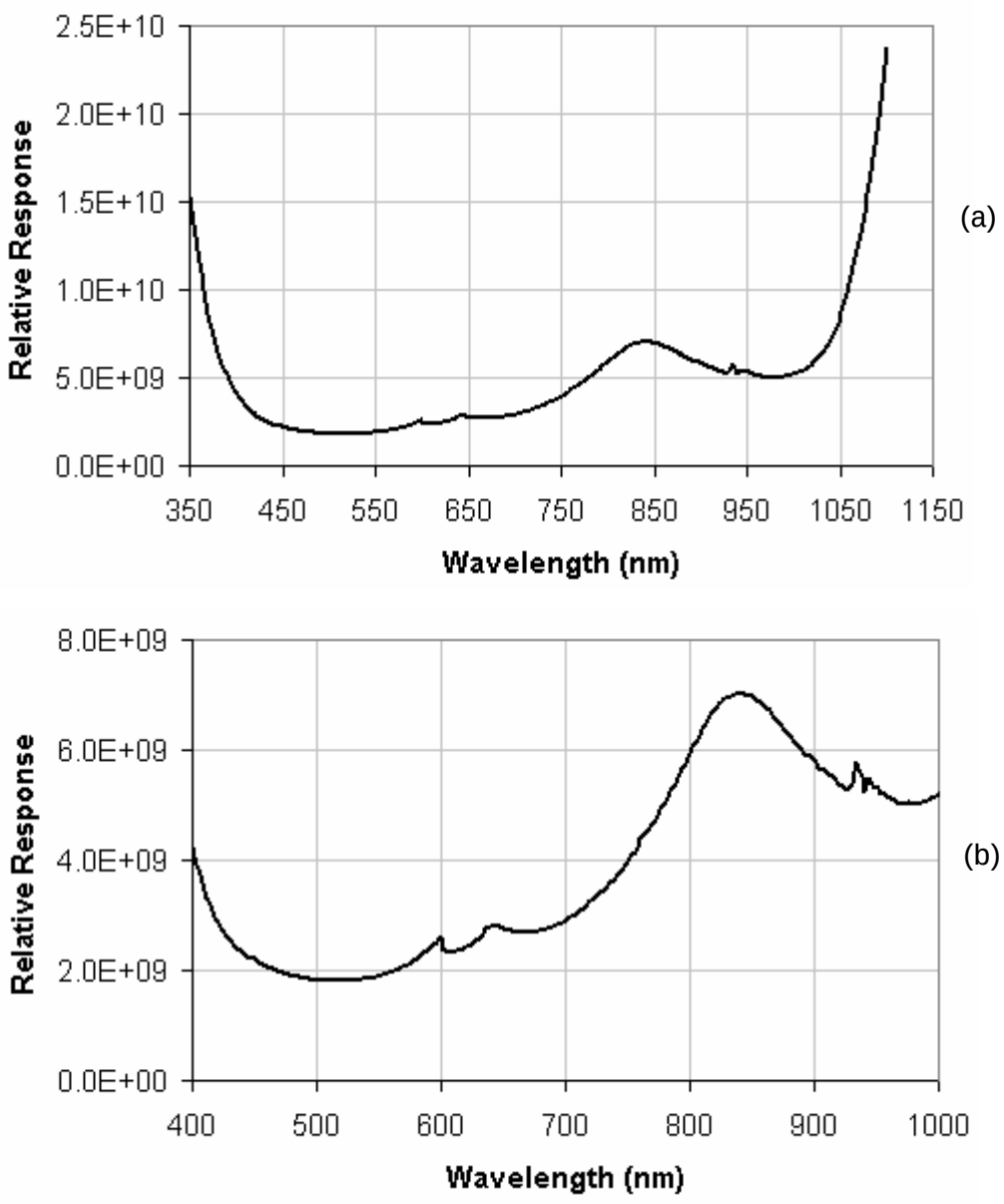

Figure 4. Relative spectral response of the ISS with the spectral standard located inside the sphere. (a) From 350 to 1100 nm measured at 2 nm intervals and (b) same data from 400 to 1000 nm at 2 nm intervals.