Energy Star Lighting Verification Program

(Program for the Evaluation and Analysis of Residential Lighting)

Semi-annual report

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The data in this report is a spot check of a particular model number from a particular manufacturer. The results cannot be regarded as a representation that all products with this model number will conform to the results.

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 of Cycle 7 of PEARL program during the period of October 2005 to March 2006, along with the description of apparatus used, equipment calibration process, experimental methodology, and research findings from the testing. LRC administered the purchasing of CFL samples to test in Cycle 7, performed 100-hour seasoning for most of the CFL samples received by March 2006, and performed sphere testing for some of the CFL samples at 100 hours of life (initial measurement).

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 Cycle 7 of PEARL program during the period of October 2005 to March 2006, including the administration of purchasing CFL samples to test, 100-hour seasoning for most of the CFL samples received by March 2006, and sphere testing for some of the CFL samples at 100 hours of life (initial measurement).

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 October 2005 to March 2006, LRC administered the purchasing of CFL samples to test in Cycle 7, performed 100-hour seasoning for most of the CFL samples received by March 2006, and performed the sphere testing for some of the CFL samples at 100 hours of life (initial measurement). This report includes the experimental process of the performed testing and description of apparatus used, equipment calibration process, experimental methodology, and research findings from the experiment.

LRC administered the nomination and selection of the list of CFL models to test in Cycle 7, starting from July 2005. PEARL sponsors initially nominated about 40 models of CFL as candidates to test in Cycle 7. PEARL sponsors went pre-shopping to check if all candidate models are available in their local retail stores. After that LRC administered a teleconference to collect the pre-shopping results from all sponsors and to finalize the list of CFL models to test. 34 models were eventually determined to be in the testing list, including 26 models of spare lamps, 5 models of covered lamps, and 3 models of reflector lamps.

LRC received the CFL samples of the 34 models from PEARL sponsors through the reporting period. The LRC also purchased some CFL samples that the sponsors weren't able to procure. The LRC noticed some problems related to the CFL samples received. The samples for one of the 34 models received had no ENERGY STAR label on the packaging or the product, and the model number printed on the packaging and the product was different from that listed on ENERGY STAR website. Due to these discrepancies of information related to this model, it was removed from the testing list. Therefore the total number of models to test in Cycle 7 dropped to 33. Another problem was that some CFL samples for a certain model number had totally different shape and different components from some samples for this same model number. Also, different rated light output and different rated lives were displayed on the packaging of samples for a certain model. That is to say, the manufacturers have provided to the consumers, for each of these two model numbers, products of different shape and different components in one case, and different rated light output and different rated lives on the product packaging in another case. Further more, some samples displayed different model numbers on the products of a same model, and some samples had ballasts and tubes physically separated upon arrival.

After receiving and inventory of the CFL samples, the LRC randomized the samples, separated ten samples as photometric testing samples and six samples as rapid cycle stress testing samples, and then installed the samples on life testing rack and rapid cycle stress testing rack respectively. Most of the CFL samples finished the 100-hour seasoning by the end of March 2006 except those arrived

at LRC in March 2006. In March 2006, LRC performed the sphere measurement for some CFL samples. By the end of March 2006, totally 26 models (79% of the 33 models) were received and seasoned for 100 hours, and totally 29 photometric testing samples (9% of the 330 photometric testing samples) completed sphere measurement at 100 hours of life (initial measurement).

An important upgrading in LRC's life testing rack control program was implemented during the time of November 2005 to February 2006. The new control program allows flexible selection of locations on rack for samples that belonged to a single group, and it keeps track of the number of aged hours for each group and turns the group off once it reaches a certain stage such as 100 hours, 1000 hours, or 40% of rated life.

EXPERIMENTAL

Apparatus

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

An important upgrading in LRC's life testing rack control program was implemented during the reporting period. The new control program allows flexible selection of locations on rack for samples that belong to a single group, and it keeps track of the number of aged hours for each group and turns the group off once it reaches a certain stage such as 100 hours, 1000 hours, or 40% of rated life. This improvement has reduced the overall testing time and increased the testing throughput of the sphere testing apparatus.

Apparatus Calibration

LRC integrating sphere system was calibrated when necessary. One calibration was performed during the reporting period, in February 2006. Agilent 34970A Data Acquisition Unit was calibrated annually.

During the reporting period, two pieces of instrument of the sphere testing apparatus were superseded by new instrument. The HP AC power supply was replaced by an AC power supply made by Pacific Power Source (model:112-AMX), and the Xitron 2503AH Power analyzer was replaced by digital power meter made by YOKOGAWA (model: WT210).

Product Selection

The PEARL board selected 34 product models of compact fluorescent lamps (CFLs) to test in Cycle 7. 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 and generated a list of the CFL models available in the consumer market. Then, the products from the compiled list were purchased and shipped to the LRC for testing.

Product Purchasing and Sampling

LRC received the CFL samples of the 34 models from PEARL sponsors through the reporting period. The LRC also purchased some CFL samples that the sponsors weren't able to procure. The LRC noticed some problems related to the CFL samples received. The samples for one of the 34 models received had no ENERGY STAR label on the packaging or the product, and the model number printed on the packaging and the product was different from that listed on ENERGY STAR website. Due to these discrepancies of information related to this model, it was removed from the testing list. Therefore the total number of models to test in Cycle 7 dropped to 33. Another problem was that some CFL samples for a certain model number had totally different shape and different components

from some samples for this same model number. Also, different rated light output and different rated lives were displayed on the packaging of samples for a certain model. Further more, some samples displayed different model numbers on the products of a same model, and some samples had ballasts and tubes physically separated upon arrival.

After receiving and inventory of the CFL samples, the LRC randomized the samples, separated ten samples as photometric testing samples and six samples as rapid cycle stress testing samples, and then installed the samples on life testing rack and rapid cycle stress testing rack respectively.

Product Testing

Most of the CFL samples finished the 100-hour seasoning by the end of March 2006 except those arrived at LRC in March 2006. In March 2006, LRC performed the sphere measurement for some CFL samples. By the end of March 2006, totally 26 models (79% of the 33 models) were received and seasoned for 100 hours, and totally 29 photometric testing samples (9% of the 330 photometric testing samples) completed sphere measurement at 100 hours of life (initial measurement).

LRC tested the CFL products against the ENERGY STAR CFL specifications dated October 30, 2003. All testing against ENERGY STAR specifications was performed at the LRC.

Details on testing parameters and test methods will be given in PEARL Cycle 7 Interim Report.

RESULTS AND DISCUSSION

LRC received totally about 590 CFL samples for PEARL Cycle 7 from December 2005 to March 2006. Most of the CFL samples finished the 100-hour seasoning by March 2006, except those arrived at LRC in the very end of the month. In March 2006, LRC also performed the sphere measurement for some CFL samples.

By the end of March 2006, totally 26 models (79% of the 33 models) were completely received and seasoned for 100 hours, and totally 29 photometric testing samples (9% of the 330 photometric testing samples) completed sphere measurement at 100 hours of life (initial measurement).

The testing results will be given in PEARL Cycle Seven Interim Report.

CONCLUSION

During the receiving process of PEARL Cycle 7, the LRC noticed some problems related to the CFL samples received. The samples for one of the 34 models received had no ENERGY STAR label on the packaging or the product, and the model number printed on the packaging and the product was different from that listed on ENERGY STAR website. Due to these discrepancies of information related to this model, it was removed from the testing list. Therefore the total number of models to test in Cycle 7 dropped from 34 to 33. Another problem was that some CFL samples for a certain model number had totally different shape and different components from some samples for this same model number. Also, different rated light output and different rated lives were displayed on the packaging of samples for a certain model. That is to say, the manufacturers have provided to the consumers, for each of these two model numbers, products of different shape and different components in one case, and different rated light output and different rated lives on the product packaging in another case. Further more, some samples displayed different model numbers on the products of a same model, and some samples had ballasts and tubes physically separated upon arrival.

PEARL Cycle 7 sphere measurement after 100 hours of seasoning (initial measurement) was not completed for all 33 models by the end of March 2006, and rapid cycle stress test was not started by then. Therefore, no conclusion about the measurement data was drawn for this reporting period. Conclusion on the testing results will be given in PEARL Cycle Seven Interim Report.

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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 (Mfg: Pacific Power Source, Model: 112-AMX)
- AC power supply (for the HgCd/10 spectral lamp; Mfg: Gates, Model: 12S-9)
- Data acquisition/switch unit (Mfg: Agilent Technologies, Model: 34970A)
- Digital power meter (Mfg: YOKOGAWA, Model: WT210)
- Bench type multimeter (Mfg: Hewlett Packard, Model: 34401A)
- Autoranging picoammeter (Mfg: KEITHLEY, Model: 485)
- 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. The stabilization was determined by monitoring the lamp current for a certain amount of time, and the lamp was considered as stabilized when the variation of lamp current was less than 1% within this period of time. 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

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APPENDIX 2: Figures

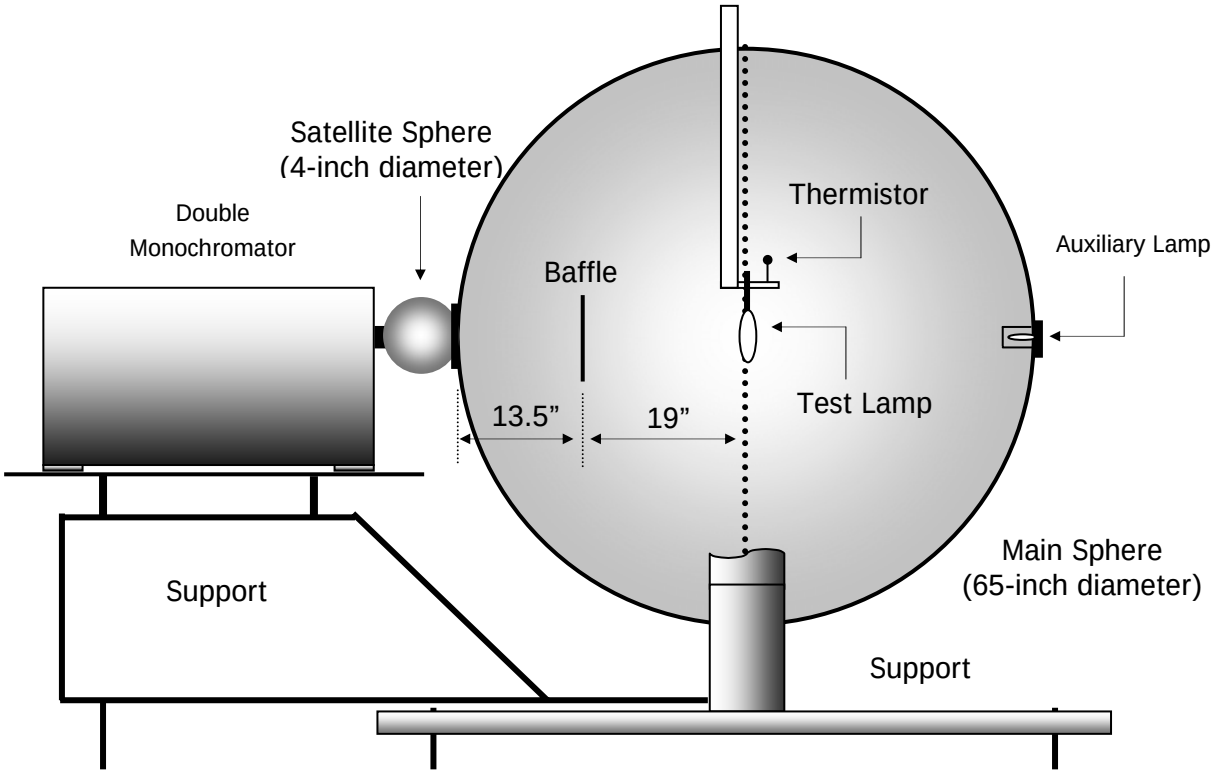

Figure 1. The integrating sphere system (ISS)

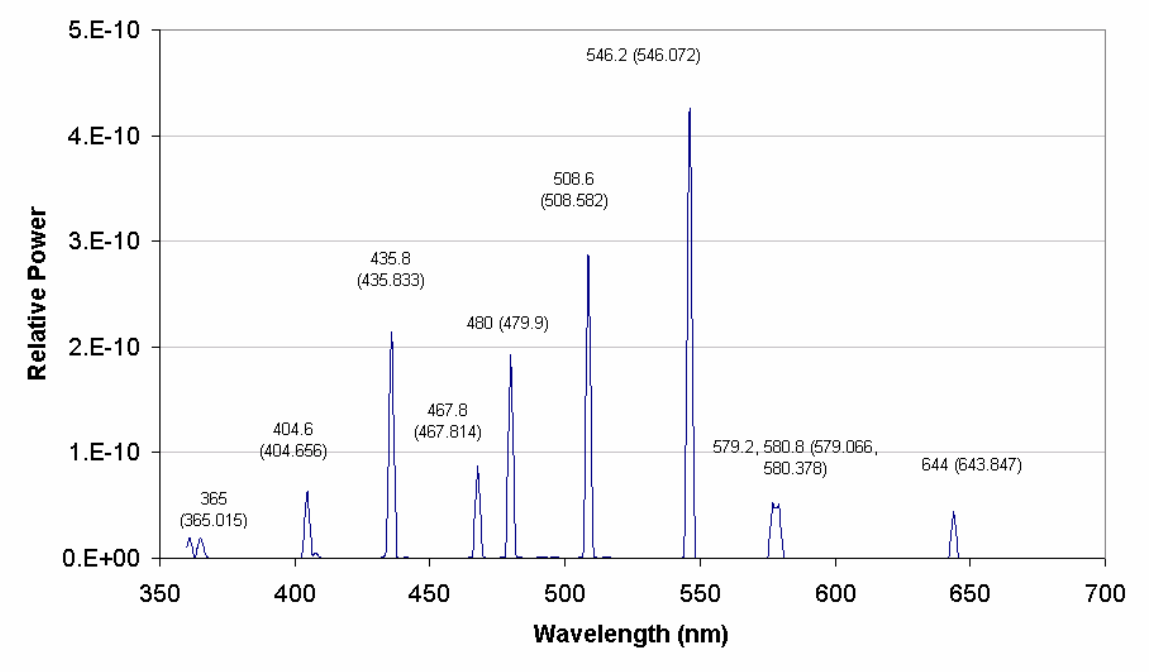

Figure 2. Measured line spectrum of the HgCd/10 spectral lamp. Values in parenthesis are the reference values for corresponding peaks.

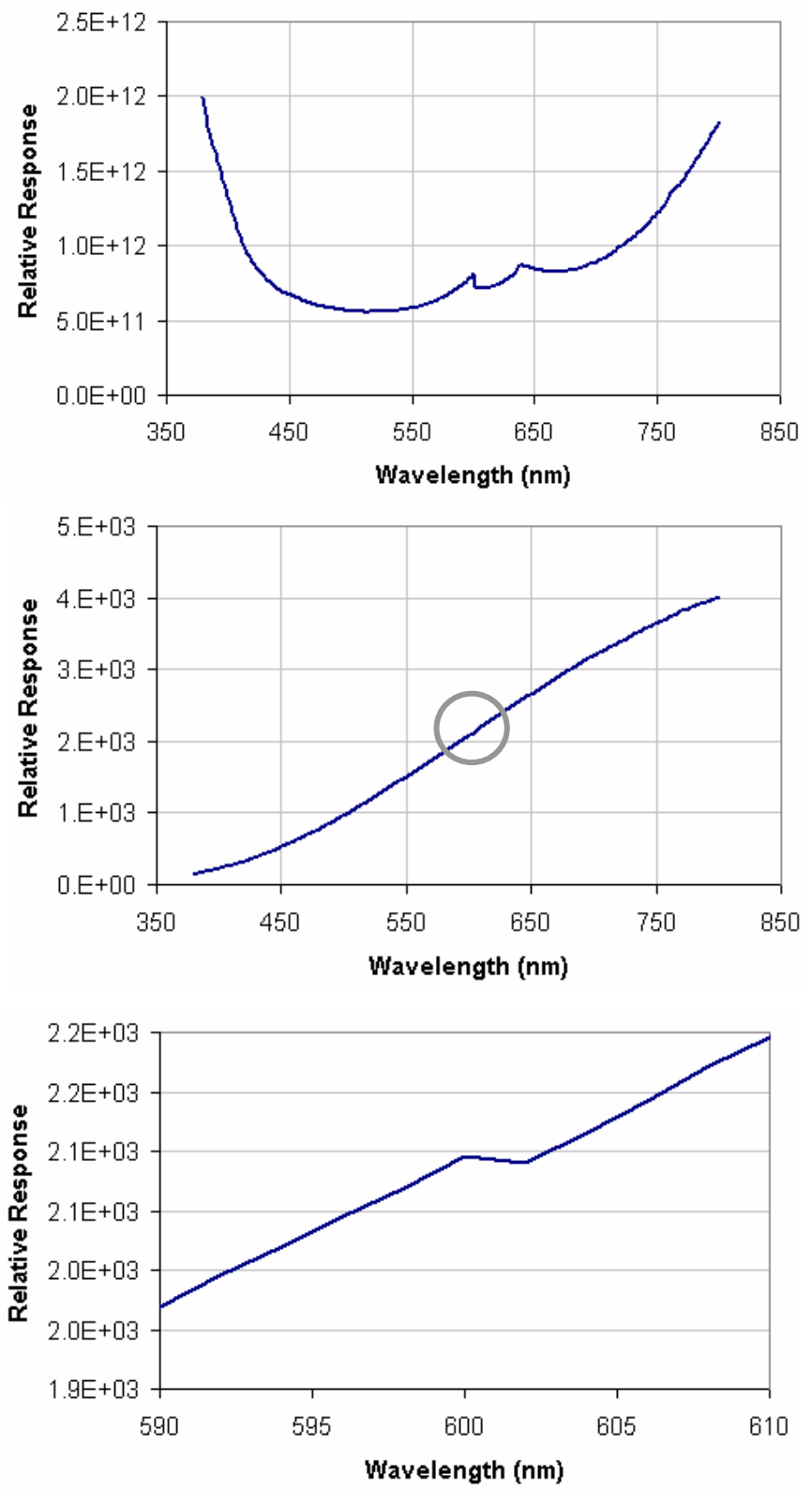

Figure 3. (a) Relative spectral response curve obtained by manual operation, (b) measured spectrum of the spectral standard (94406) inside the sphere using the calibration curve obtained by manual operation, and (c) enlarged portion showing the abnormal portion around 600 nm indicated by the circle in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

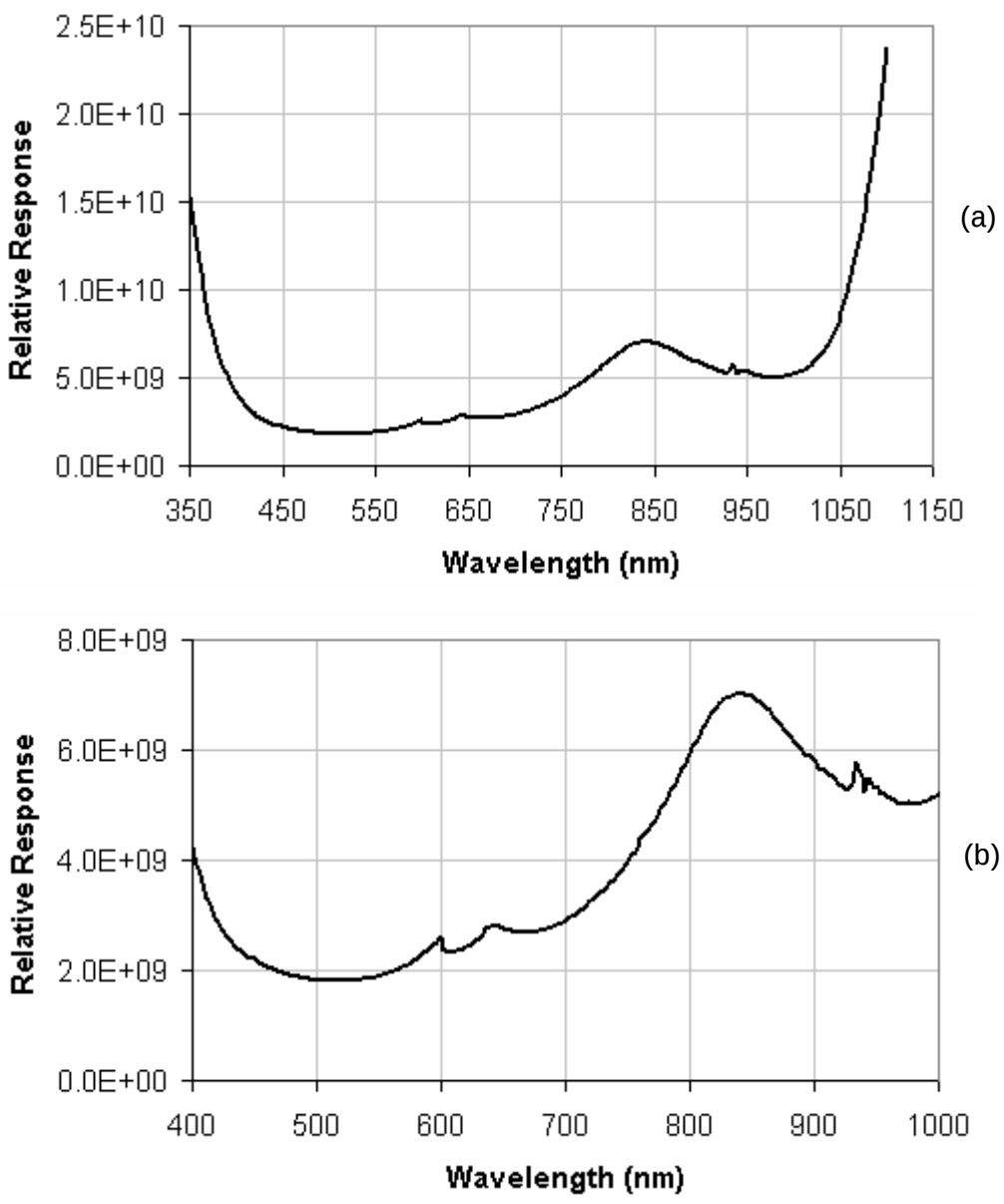

Figure 4. Relative spectral response of the ISS with the spectral standard located inside the sphere. (a) From 350 to 1100 nm measured at 2 nm intervals and (b) same data from 400 to 1000 nm at 2 nm intervals.