Laboratory Accreditation for Testing Energy Efficient Lighting

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The Energy Policy Act of 1992 requires DoE specification of energy efficiency standards with test procedures for determining energy efficiency of certain fluorescent and incandescent lamps. DoE is to assist industry in development of a voluntary program to inform consumers of energy savings for certain luminaires.

NEMA requested establishment of the accreditation program for laboratory testing of lamps and luminaires from consensus standards prior to enactment of EPACT. NVLAP conducts regulatory and voluntary accreditation programs. Impacts cited by NEMA for NVLAP were: third-party objective accreditation programs for establishment of credible testing data, avoidance of duplicated efforts by different Federal government agencies, avoidance of confusion in the marketplace, improving product quality, and assistance to utilities/conservation planners. Following public comment by interested organizations, NVLAP developed the Energy Efficient Lighting Program for laboratories conducting standard test methods for electrical, photometric and color measurements. Industry recommendations at FTC hearings supported NVLAP accredited laboratory data for labeling.

NVLAP Procedures and General Requirements (Cigler, White 1994) incorporate international accreditation criteria that assures unbiased third-party evaluations of laboratory testing competence. Accreditation to specific test methods requires evaluation by technical experts of the quality assurance system during on-site assessments. Proficiency test rounds, with artifacts supplied to the laboratories, provides test data for comparative evaluations of performance capability; data are reported in Tech Briefs which are distributed to regulators, agencies, manufacturers, standards organizations and specialists. Representative results are presented in this report.

Introduction

The National Voluntary Laboratory Accreditation Program (NVLAP) established the Energy Efficient Lighting Program (EEL) for testing certain types of lamps and luminaires at the request of the National Electrical Manufacturers Association (NEMA) in anticipation of the passage of the Energy Policy Act of 1992 (EPACT, Public Law 102-486). Following public comment program development was announced in the Federal Register. The accreditation program supports the Department of Energy (DoE) in its regulatory role: industry supported NVLAP accredited laboratory test data for labeling and rating regulations at Federal Trade Commission (FTC) hearings. Industry specialists collaborated in setting technical requirements for the *Technical Handbook (NIST 150-01)* consistent with NVLAP accreditation criteria; standard test methods are in conformance with EPACT (see Application Form, List of Test Methods Table).

NVLAP accredits public and private laboratories worldwide and is available to commercial, manufacturer's in-house, university, state, and local government laboratories. Mutual Recognition Agreements (MRA's) extend accredited status acceptance internationally.

EEL Program Description

EPACT requires DoE specification of energy efficiency standards for certain fluorescent and incandescent lamps with standard test procedures prescribed for determining energy efficiency. DoE is to assist industry in the development of a voluntary program for luminaires to inform consumers of attainable energy savings. The EEL program handbook lists 28 test methods from standards of the Illumination Engineering Society of North America

(IESNA) and American National Standards Institute (ANSI), as required in the public law for lamps and luminaires for which laboratories may be accredited (see list). Tests of lamps and luminaires encompass methods for measurement of electrical, photometric, calorimetric, and life performance characteristics; for luminaires, the methods cover photometric measurements. Currently four laboratories are accredited.

Initial laboratory pre-accreditation on-site assessments for testing lamps were conducted by NVLAP technical experts, who were trained to apply NVLAP procedures, with extensive knowledge and experience in testing lamps. Proficiency testing conducted during pre-accreditation onsites were observed by the assessors. Under NVLAP direction a proficiency test contractor with extensive experience in lighting developed test plans, sample procurement/handling, and preparation of data sheets/formats. The on-site assessments included the evaluation of laboratory performance in the first proficiency test round; sample Round 1 data are presented herein *(TECH BRIEF* is available from NVLAP).

Laboratory Accreditation

NIST *Handbook 150* provides information on NVLAP accreditation requirements; it contains Part 285 of Title 15 of the U.S. Code of Federal Regulations (CFR) plus general procedures, criteria, and policies. The language of Sections 285.33 (a) through (n) is essentially identical to that of the world-wide *International Standards Organization Guide 25* for assuring laboratory accreditation and NVLAP accreditation actions are in conformance with *Guide 58.* NVLAP operates as an unbiased third party to accredit both calibration laboratories and testing laboratories. NVLAP provides mechanisms for national and international recognition of accreditation status of laboratories, facilitates removal of non-tariff barriers to trade, and accredits foreign laboratories.

Technical requirements for testing facilities for the EEL program are provided in *NLST Handbook 150.* Conditions include deficiency findings in on-site assessment and/or proficiency testing with resolution(s) or denial, suspension or revocation of accreditation. Other accreditation requirements include: independent decisional relationship from client or organizational management to avoid bias or influence on test report objectivity; technical and quality manager responsibilities; quality system and its maintenance; traceability of measurements and calibrations; personnel skills and training; documentation for determination of measurement uncertainty; participation in proficiency testing programs and/or interlaboratory comparisons; and periodic audits for quality of results. Laboratory test data cannot be authenticated and reputable without accreditation for competency through the totality of NVLAP requirements; "independent laboratory" objectivity claims are controversial because, generally in a search for rigor and confidence in data there is failure to meet any criteria for data reliability, no assurance of quality systems in place, nor provisions for independent validators.

NVLAP contractor technical experts are trained in the procedures for quality system evaluations for on-site assessments. They record observations on general and specific checklists related to NVLAP criteria and make technical competency appraisals for each test method selected by the laboratory applicant. On-sites are conducted biennially and monitoring visits occur at any time, and/or as appropriate. Technical assistance is provided, as warranted, during on-site assessments.

Proficiency Testing

Confusion exists about proficiency testing in the technical, commercial and regulatory communities insofar as understanding that *it is not product testing or certification.* Proficiency test samples may include conventional products or special artifacts intended to determine the laboratory capability to demonstrate competence in performing test methods for which they seek accreditation. *Proficiency testing is not product performance evaluation nor intended to provide evaluations other than a measure of the laboratory competence.* Those tests demonstrate knowledge and skill for implementation of the test procedures and measurement methods in accordance with the testing standard requirements.

Proficiency testing by laboratories is an integral part of the NVLAP accreditation process for determining competency and evaluates laboratory capability to generate reproducible test data and demonstrate agreement with other participants' results, based upon generally accepted statistical distribution analysis. Specimens or artifacts or samples may utilize randomly selected items, some of known properties or other materials/products that are uncharacterized, or standard reference materials with certificated characteristics. Data are analyzed and reported in Tech Briefs (blind coded) which are distributed to standards committees, researchers, regulators, and procurement officials, as an independent resource. When articles of commerce are utilized, the published information can be used by analysts, conservation planners and technically interested parties to compare with claimed product performance.

Unsatisfactory participation in a proficiency test is a technical deficiency that requires action for resolution; failure to resolve deficiencies will result in denial, revocation, or suspension of accreditation. Proficiency test data demonstrates that variability in test measurements exist and usually show statistical distributions from which problem outliers may be identified; unaccredited laboratories rarely have comparable rigorous authentication. Those data may be the only resource for formulating standards precision and bias statements.

Proficiency Test Round 1

Four laboratories participated in Round 1 pre-accreditation proficiency testing with three lamp types: 75 watt rough-service incandescent lamps, seven watt compact fluorescent lamps and 32 watt T-8 linear fluorescent lamps. Samples were hand carried to each laboratory; the measurements were observed by NVLAP Technical Experts.

Incandescent lamps were seasoned at voltage for 8 hours, both types of fluorescent lamps were seasoned for 500 hours beforehand. The same three lamps of each type were measured with the order of measurement changed during each run. Each group of lamps was measured three times; each set of measurements is referred to as a run. Lamps were turned off and removed from the measurement sphere between each run. The photometric system was calibrated between each run, if this was the laboratory's standard (written) operating procedure. Power and luminous flux, and also calculated values for efficacy, were used to prepare data results, tables and graphs. Sample copies of tables and graphs from the Tech Brief are shown.

Incandescent Lamp Measurements

Incandescent lamp (rough-service types) measurements were made using methods in *IES GUIDE LM45-1991.* All laboratories measured lamps, operated base up at 120 volts, using an integrating sphere and photometric detector. Measured values were lamp current (amperes) and total luminous flux (lumens). Lamp power (watts) and the efficacy were calculated (lumens per watt) from measured luminous flux and calculated power. Sample tables of calculated lamp power, luminous flux measurements, and calculated lamp efficacies are presented in the copies of data sample tables.

Compact Fluorescent Lamp Measurements

Compact fluorescent lamp electrical and photometric measurements, with the test lamp mounted base up at the center of an integrating sphere, were made following the methods in *IES GUIDE LM-66 1991.* Electrical measurements included lamp operating voltage, lamp current and lamp power. Total luminous flux measurements were obtained either directly with a photometric detector or calculated from spectroradiometric measurements to determine the total luminous flux. Lamp efficacy was calculated from the luminous flux and the measured lamp power. Color measurements were made following *IES GUIDE LM-58.* Sample data from the *Tech Brief* are shown for calorimetric values for chromaticity, correlated color temperature and color rendition, calculated from spectroradiometric measurements.

Test lamps were operated on a standard reference ballast as specified in *ANSI Standard C82.3 1983 (R1989) Fluorescent Lamp Reference Ballast, Specifications.* This ballast consists of a linear reactor and a resistor to set power factor. The operating line voltage, ballast impedance and ballast power factor are specified in *ANSI Standard C78.1-1978 (R1984).* Test conditions were line volts 118 volts, ballast impedance 60 hertz of 570 ohms and power factor of 0.075. Results for lamp power, luminous flux and calculated lamp efficacy and calculated calorimetric values are presented in copies of tables from the Tech Brief, Round 1.

Linear Fluorescent Lamp Measurements

Linear fluorescent lamp electrical and photometric measurements were made following the methods in *IES GUIDE LM-9-1991* with the test lamp mounted horizontally at the center of an integrating sphere. Electrical measurements included lamp operating voltage, lamp current and lamp power. Total luminous flux photometric measurements were obtained either directly with a photometric detector or calculated from spectroradiometric measurements. Lamp efficacy was calculated from the luminous flux value and measured lamp power. Calorimetric values reported for chromaticity, correlated color temperature and color rendition were calculated from spectroradiometric measurements following *IES GUIDE LM-58* are reproduced from Tech Brief Round 1.

The test lamps were operated on a standard reference ballast specified in *ANSI Standard C82.3 1983 (R1989) Fluorescent Lamp Reference Ballast, Specifications;* the ballast consists of a linear reactor and a resistor to set power factor. Operating line voltage, ballast impedance and ballast power factor are specified in *ANSI Standard C78.1-1978 (R1984) Guide for Dimensional and Electrical Characteristics of Fluorescent Lamps.* Test conditions were line volts 300 volts, ballast impedance 60 hertz of 910 ohms and a power factor of 0.075. The lamps were operated in the rapid start mode with separate power supplied to the cathodes.

Results for lamp power measurements, luminous flux results, calculated lamp efficacy and calculated colorimetric values are presented from tables of Tech Brief, Round 1.

Statistical Data Base from Proficiency Tests

The tests provide an initial block of data to establish a record for statistical analysis; the data base will expand as the number of rounds increase the number of tests available. NVLAP experience has shown that coefficient of variation has been nearly halved after several rounds indicating that upgraded performance as a goal of accreditation is achievable. From the four laboratories with 36 repeated measurements of each lamp type some initial observations may be made. Note that summary statistics calculated on the basis of a small population can differ considerably from values from a large population (ASTM *Standards on Precision and Bias for Various Applications).*

The distribution of efficacy determinations in Figure 1 for incandescent lamps shows trending toward a normal distribution. Efficacy results are calculated from individual measured values; the extremes differ by two percent for power and luminous flux extremes over nine percent. Another form of data examination is shown in Figure 2 shows compact fluorescent lamps that ordered rank distribution for those 36 tests. Laboratory data code permits review of data clusters from each facility and for three tests of each lamp. Increasing efficacy is seen for laboratories 1, 4, 2, and 3, in that order. The extreme values indicate differences of about twelve percent for compact fluorescent. Efficacy comparisons of the ranking in Figure 3 for compact fluorescent vs. linear fluorescent lamps indicates that cluster dispersion occurs without specific trendlines; laboratories 4 and 1 interchange order from compact tests while 2, 3 remain in same order. Laboratories 1, 4 tend toward lower and 2, 3 tend to higher test results for efficacies. The linear lamp extremes indicate differences of about eleven percent.

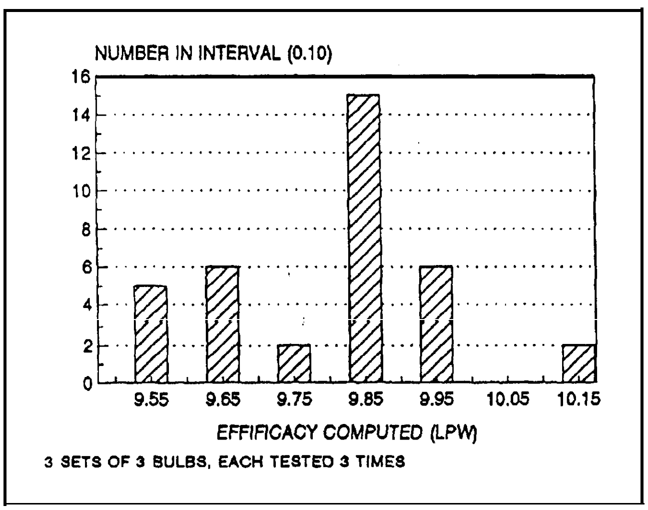

Figure 1. Efficacy Distributions for Incandescent Lamps

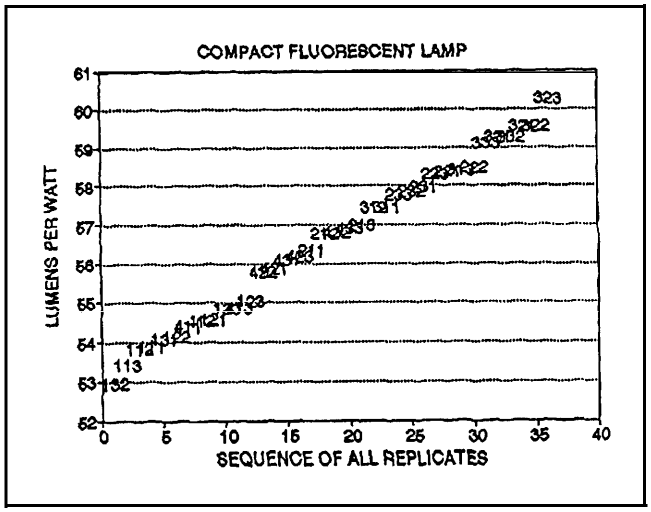

Figure 2. Sequenced Compact Fluorescent Lamp Efficacies

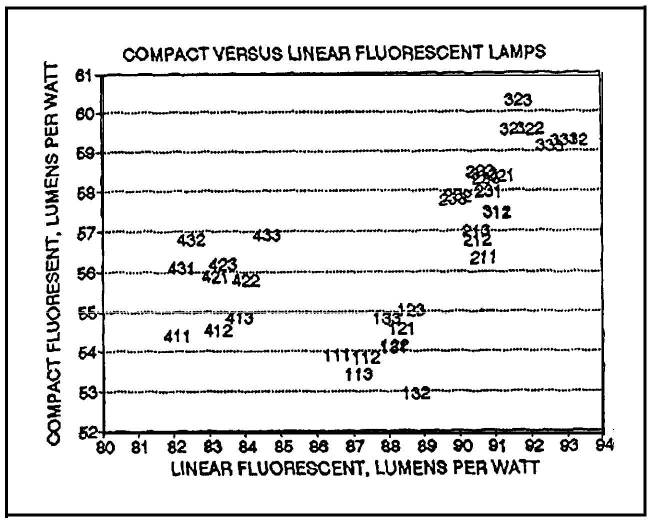

Figure 3. Compact and Linear Fluorescent Lamp Efficacies (Example: 411 = Laboratory 4, Lamp #1, Run #1)

Comments and Recommendations

This first round provides no data on time stability of the laboratory's measurements, variations from equipment/ calibration procedures, stability of the test lamps, or test design from standards. Future test rounds will examine such variables. Tested rough-service incandescent lamps have several supports touching the filament, not tightly clamped. Supports reduce probability of filament breakage, but tend to change the effective resistance of the filament and may be a source of observed variability of power for such lamps.

Differences from product performance claims in these tests were observed; conditions were set according to test methods from standards and instructions. However, proficiency tests are not designed for performance evaluation but data on products may be useful and informative as independent data to specifiers and researchers.

NVLAP accreditation programs assure competency of laboratories; conservation managers should specify in procurement contracts a requirement that performance based data come from accredited laboratory test reports to expand confidence that specifications are met.

References

ANSI Standard C82.3 1983 (R1989) Fluorescent Lamp Reference Ballast, Specifications.

ANSI Standard C78.1-1978 (R1984). Guide for Dimensional and Electrical Characteristics of Fluorescent Lamps.

ASTM Standards on Precision and Bias for Various Applications Fourth Edition 1992. ASTM Philadelphia, PA.

International Standards Organization for Standardization/International Electrotechnical Commission, *(Guide 25 1990) General Requirements for Competence of Laboratories* and *(Guide 58 1993) Laboratory Accreditation Systems-General Requirements for Operation and Recognition;* Geneva, Switzerland.

National Voluntary Laboratory Accreditation Program. *TECH BRIEF NVLAP Proficiency Testing Energy Efficient Lighting Products Program, Round 1 Revised.* National Institute of Standards and Technology, Gaithersburg, MD.

National Voluntary Laboratory Accreditation Program. 1994. *Procedures and General Requirements NIST Handbook 150.* National Institute of Standards and Technology, Gaithersburg, MD.

Galowin, L. S., W. A. Hall, W. J. Rossiter, Jr. *NIST Handbook 150-01, 1993. Energy Efficient Lighting Products.* National Institute of Standards and Technology, Gaithersburg, MD.

NVLAP LAB CODE: ____

APPLICATION FORM
for
ENERGY EFFICIENT LIGHTING PRODUCTS
TEST METHOD SELECTION LIST

Instructions: Check each test method for which you are requesting accreditation.

An asterisk beside the NVLAP Test Method Code indicates that proficiency testing is required. Notification will be given for the required proficiency testing by NVLAP and/or a NVLAP contractor.

	NVLAP Test Method Code	*Test Method Designation*	*Short Title of Standard*
	LAMPS		
	Electrical Measurements		
______	22/E01*	LM-9	Fluorescent Lamps-Electrical Measurements
______	22/E02*	LM-45	Incandescent Lamps-Electrical Measurements
______	22/E03[1]	LM-51	High Intensity Discharge (HID) Lamps - Electrical Measurements
______	22/E04*	LM-66	Single-Ended Compact Fluorescent Lamps - Electrical Measurements
______	22/E05	ANSI-C78.375	Fluorescent Lamps - Electrical Measurements
______	22/E06	ANSI-C78.386	Mercury Lamps - Measurement of Characteristics
______	22/E07	ANSI-C78.387	Metal-Halide Lamps - Measurement of Characteristics
______	22/E08	ANSI-C78.388	High Pressure Sodium Lamps - Measurement of Characteristics

Photometric Measurements

Note: Accreditation for Photometric Tests requires corresponding accreditation for Electrical Test Methods.

______	22/P01a*	LM-9	Fluorescent Lamps-Photometric-Total Flux Measurements

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[1] The Illuminating Engineering Society (IES) has temporarily withdrawn for revision LM-20, "IES Approved Method for Photometric Measuring and Reporting Tests on Reflector Type Lamps" (NVLAP Test Method Codes 22/P02a and b), and LM-51, "IES Approved Method for the Electrical and Photometric Measurements of High Intensity Discharge Lamps" (NVLAP Test Method Codes 22/E03, and 22/P04 a and b). NVLAP will offer initial accreditation for these when the Illuminating Engineering Society reissues the documents.

NVLAP LAB CODE: ______

______	22/P01b*	LM-9	Fluorescent Lamps-Photometric-Intensity Measurements
______	22/P02a	LM-20	Reflector Type Lamps-Photometric-Total Flux Measurements
______	22/P02b'	LM-20	Reflector Type Lamps Photometric-Intensity Measurements
______	22/P03a*	LM-45	Incandescent Lamps-Photometric-Total Flux Measurements
______	22/P03b*	LM-45	Incandescent Lamps Photometric-Intensity Measurements
______	22/P04a[1]	LM-51	High-Intensity Discharge Lamps-Photometric-Total Flux Measurements
______	22/P04b'	LM-51	High-Intensity Discharge Lamps-Photometric-Intensity Measurements
______	22/P05a*	LM-66	Single-Ended Compact Fluorescent Lamps-Photometric-Total Flux Measurements
______	22/P05b*	LM-66	Single-Ended Compact Fluorescent Lamps-Photometric-Intensity Measurements

Color Measurements

______	22/C01*	LM-58	Spectroradiometric Measurements

Life Tests

______	22/L01	LM-40	Fluorescent Lamps-Life Test Performance
______	22/L02	LM-47	High Intensity Discharge Lamps-Life Test Performance
______	22/L03	LM-49	Incandescent Filament Lamps-Life Test Performance
______	22/L04	LM-65	Single-Ended Compact Fluorescent Lamps-Life Test Performance

LUMINAIRES (LIGHTING FIXTURES)

______	22/F01	LM-10	Photometric Testing of Outdoor Fluorescent Luminaires
______	22/F02	LM-31	Photometric Testing of Roadway Luminaires
______	22/F03	LM-35	Photometric Testing of Floodlights Using Incandescent Filament or Discharge Lamps
______	22/F04	LM-41*	Photometric Testing of Indoor Fluorescent Luminaires
______	22/F05	LM-46*	Photometric Testing of Indoor Luminaires Using HID Lamps

______ **Total number of test methods selected for Energy Efficient Lighting Products (Enter total on Line 5b of the Program Fee Calculation Worksheet.)**

Table 1. Summary of Lamp Power for Three Types of Lamps

	Lamp Power (Watts)		
	Lamp Type		
	Incandescent	Compact Fluorescent	Linear Fluorescent
Grand Mean	71.82	7.14	30.68
Std. Dev.	0.07	0.10	0.35
CoV Percent	0.10	0.20	1.13
Range	0.15	0.33	0.80
% Range	0.21	4.68	2.60

Table 2. Summary of Lamp Luminous Flux for Three Types of Lamps

	Lamp Luminous Flux (Lumens)		
	Lamp Type		
	Incandescent	Compact Fluorescent	Linear Fluorescent
Grand Mean	703.93	403.62	2710.69
Std. Dev.	8.03	8.59	102.34
CoV Percent	1.14	2.13	3.78
Range	16.82	17.75	225.78
% Range	2.39	4.40	8.33

Table 3. Summary of Lamp Efficacy for Three Types of Lamps

	Lamp Efficacy (Lumens per Watt)		
	Lamp Type		
	Incandescent	Compact Fluorescent	Linear Fluorescent
Grand Mean	9.80	56.57	88.37
Std. Dev.	0.11	2.11	3.81
CoV Percent	1.11	3.73	4.31
Range	0.22	4.85	8.63
% Range	2.28	8.57	2.60

Power in Watts		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	71.90	71.75	72.20	71.75
1	2	71.90	71.68	71.70	71.68
1	3	71.90	71.69	72.10	71.75
2	1	72.30	72.58	72.00	72.01
2	2	72.20	71.95	72.30	72.53
2	3	72.20	71.97	72.00	72.05
3	1	71.60	71.47	71.50	71.30
3	2	71.60	71.37	71.40	71.39
3	3	71.60	71.50	71.40	71.41
Average		71.91	71.77	71.84	71.76
std dev		0.276	0.365	0.350	0.390

Grand Average:	71.82
std dev:	0.069

Electrical Power

Flux in Lumens		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	710.1	686.2	714.0	704.6
1	2	709.4	684.3	690.0	703.7
1	3	705.1	683.3	708.0	703.7
2	1	718.9	735.0	706.0	717.0
2	2	718.4	700.2	719.0	739.9
2	3	720.4	697.2	705.0	717.0
3	1	705.5	690.2	689.0	701.8
3	2	703.9	683.3	685.0	701.8
3	3	706.6	687.2	690.0	700.8
Average		710.92	694.10	700.67	710.03
std dev		6.55	16.51	12.37	12.84

Grand Average:	703.93
std dev:	8.03

Luminous Flux

Efficacy in LPW		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	9.88	9.56	9.89	9.82
1	2	9.87	9.55	9.62	9.82
1	3	9.81	9.53	9.82	9.81
2	1	9.94	10.13	9.81	9.96
2	2	9.95	9.73	9.94	10.20
2	3	9.98	9.69	9.79	9.95
3	1	9.85	9.66	9.64	9.84
3	2	9.83	9.57	9.59	9.83
3	3	9.87	9.61	9.66	9.81
Average		9.89	9.67	9.75	9.89
std dev		0.058	0.184	0.126	0.129

Grand Average:	9.80
std dev:	0.109

Efficacy

Incandescent Lamp Data

Flux in Lumens		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	393.0	402.0	408.0	389.4
1	2	392.0	404.0	408.0	388.6
1	3	396.0	405.0	409.0	388.9
2	1	399.0	413.0	417.0	397.6
2	2	399.0	412.0	417.0	397.9
2	3	403.0	412.0	416.0	398.8
3	1	397.0	409.0	415.0	398.8
3	2	395.0	410.0	415.0	400.0
3	3	402.0	409.0	414.0	399.3

Average	397.3	408.4	413.2	395.5
std dev	3.8	3.9	3.8	4.9

Grand Average:	403.6
std dev:	8.59

Luminous Flux

Efficacy in LPW		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	53.91	56.22	57.46	54.47
1	2	53.85	56.66	57.46	54.50
1	3	53.44	56.88	58.43	54.86
2	1	54.58	58.25	59.57	55.84
2	2	54.14	58.36	59.57	55.80
2	3	55.05	58.19	60.29	56.17
3	1	54.09	57.85	59.29	56.09
3	2	52.95	57.75	59.29	56.82
3	3	54.84	57.52	59.14	56.95

Average	54.09	57.52	58.95	55.72
std dev	0.67	0.76	0.97	0.93

Grand Average:	56.57
std dev:	2.11

Efficacy

Color Rendition and Chromaticity

Color Rendition		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	82.5	82.3	82.0	82.0
1	2	82.4	82.1	82.0	82.0
1	3	82.5	81.9	82.0	82.0
Average		82.47	82.10	82.00	82.00
std dev		0.06	0.20	0.00	0.00

x Chromaticity		1	2	3	4
1	1	0.4613	0.4638	0.4657	0.4624
1	2	0.4631	0.4625	0.4662	0.4622
1	3	0.4617	0.4625	0.4665	0.4624
Average		0.4620	0.4629	0.4661	0.4623
std dev		0.0009	0.0008	0.0004	0.0001

y Chromaticity		1	2	3	4
1	1	0.4093	0.4089	0.4141	0.4107
1	2	0.4112	0.4099	0.4143	0.4111
1	3	0.4092	0.4102	0.4142	0.4112
Average		0.4099	0.4097	0.4142	0.4110
std dev		0.0011	0.0007	0.0001	0.0003

Lab	No	2				Compact Fluorescent				
Lp. No.	Run	Volts	Current Amps	Power Watts	Flux Lumens	Efficacy LPW	Color x	Color y	Color Temp.	Color Rend.
1	1	47.89	0.1771	7.15	402	56.22	0.4638	0.4089	2632	82.3
1	2	47.89	0.1773	7.13	404	56.66	0.4625	0.4099	2657	82.1
1	3	47.83	0.1773	7.12	405	56.88	0.4625	0.4102	2660	81.9
Average		47.87	0.1772	7.13	404	56.59	0.4629	0.4097	2650	82.1
std dev		.03	0.0001	.02	2	0.34				
2	1	47.60	0.1778	7.09	413	58.25				
2	2	47.35	0.1781	7.06	412	58.36				
2	3	47.45	0.1780	7.08	412	58.19				
Average		47.47	0.1780	7.08	412	58.27				
std dev		.13	0.0002	.02	1	0.08				
3	1	47.39	0.1779	7.07	409	57.85				
3	2	47.62	0.1776	7.10	410	57.75				
3	3	47.67	0.1776	7.11	409	57.52				
Average		47.56	0.1777	7.09	409	57.71				
std dev		.15	0.0002	.02	1	0.17				

Compact Fluorescent Lamp Data

Power in Watts		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	31.37	30.44	30.40	30.96
1	2	31.14	30.42	30.40	30.73
1	3	31.13	30.47	30.50	30.71
2	1	31.05	30.37	30.40	30.82
2	2	31.06	30.43	30.30	30.81
2	3	31.14	30.34	30.40	30.87
3	1	31.16	30.50	30.20	30.84
3	2	30.98	30.78	30.10	30.59
3	3	31.15	30.76	30.30	30.57

Average	31.13	30.50	30.33	30.77
std dev	0.11	0.16	0.12	0.13

Grand Average:	30.68
std dev:	0.35

Electrical Power

Efficiency in LPW		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	86.55	90.67	91.05	82.07
1	2	87.35	90.47	91.02	83.21
1	3	87.12	90.45	90.69	83.82
2	1	88.34	91.18	91.55	83.16
2	2	88.15	90.57	91.98	84.00
2	3	88.60	90.74	91.68	83.38
3	1	88.13	90.82	92.95	82.23
3	2	88.70	89.93	93.22	82.48
3	3	87.93	89.82	92.54	84.63

Average	87.87	90.52	91.85	83.22
std dev	0.72	0.42	0.89	0.85

Grand Average:	88.37
std dev:	3.81

Efficacy

Color Rendition and Chromaticity

Color Rendition		Laboratory Number			
Lamp	Run	1	2	3	4
1	1	80.7	79.7	82.0	80.0
1	2	80.6	79.7	82.0	80.0
1	3	80.7	80.0	82.0	80.0
Average		80.67	79.80	82.00	80.00
std dev		0.06	0.17	0.00	0.00

x Chromaticity		1	2	3	4
1	1	0.4139	0.4153	0.4180	0.4158
1	2	0.4141	0.4155	0.4181	0.4157
1	3	0.4144	0.4161	0.4178	0.4148
Average		0.4141	0.4156	0.4180	0.4154
std dev		0.0003	0.0004	0.0002	0.0006

y Chromaticity		1	2	3	4
1	1	0.3904	0.3928	0.3953	0.3950
1	2	0.3913	0.3930	0.3953	0.3948
1	3	0.3914	0.3927	0.3948	0.3937
Average		0.3910	0.3928	0.3951	0.3945
std dev		0.0006	0.0002	0.0003	0.0007

Lab	No.	4				Linear Fluorescent					
Lp. No.	Run	Volts	Current Amps	Power Watts	Flux Lumens	Efficacy LPW		Color x	Color y	Color Temp.	Color Rend.
1	1	134.93	0.2665	30.96	2541	82.07		0.4158	0.3950	3314	80.0
1	2	135.48	0.2647	30.73	2557	83.21		0.4157	0.3948	3318	80.0
1	3	135.88	0.2643	30.71	2574	83.82		0.4148	0.3937	3325	80.0
Average		135.43	0.2652	30.80	2557	[illegible]		[illegible]	0.3945	[illegible]	80.0
std dev		.48	0.0012	.14	17	0.88					
2	1	136.22	0.2636	30.82	2563	83.16					
2	2	135.44	0.2648	30.81	2588	84.00					
2	3	135.63	0.2654	30.87	2574	83.38					
Average		135.76	0.2646	30.83	2575	[illegible]					
std dev		.41	0.0009	.03	13	0.43					
3	1	135.66	0.2647	30.84	2536	82.23					
3	2	135.61	0.2638	30.59	2523	82.48					
3	3	135.11	0.2646	30.57	2587	84.63					
Average		[illegible]	[illegible]	30.67	2549	[illegible]					
std dev		.30	0.0005	.15	34	1.32					

Linear Fluorescent Lamp Data