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Spectroradiometry and Conventional Photometry

An Interlaboratory Comparison

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2	8805	4.26	80	4.27	82	4.50	128
	8806	4.28	84	4.29	86	4.51	130
	8909	4.38	104	4.39	106	4.58	144
4	8809	4.30	88	4.31	90	4.52	132
	8810	4.32	92	4.33	94	4.53	134
	8911	4.40	108	4.41	110	4.59	146
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Spectroradiometry and Conventional Photometry
An Interlaboratory Comparison

D.A. McSparron, K. Mohan*, R.C. Raybold,
R.D. Saunders, and E.F. Zalewski

This report summarizes the results of a fluorescent lamp intercomparison carried out under the aegis of the National Bureau of Standards Photometry Section. The purpose of the intercomparison was to evaluate the interlaboratory precision obtainable in photometric and spectroradiometric measurements. The tests were also designed to disclose suspected systematic errors in measurement techniques.

The intercomparison consisted of five parts: (1) A homochromatic, photometric measurement of cool white fluorescent lamps and a heterochromatic, photometric measurement of a daylight fluorescent lamp and an incandescent lamp utilizing cool white fluorescent lamps as standards, all within an integrating sphere. (2) Spectroradiometric measurement of the above mentioned lamps in an integrating sphere. (3) Spectroradiometric measurement of a 25 cm section of the fluorescent lamps in a baffled enclosure. (4) An experiment designed to reveal systematic errors in heterochromatic photometry. (5) Measurement of the x and y chromaticity coordinates with a Barnes colorimeter.

Key words: Photometry, heterochromatic photometry, spectroradiometry, luminous flux, correlated color temperature, chromaticity coordinate, Barnes colorimeter, cool white fluorescent lamp, daylight fluorescent lamp, integrating sphere, color correction, intercomparison.

1. INTRODUCTION

1.1. Background information

From time to time the Lamp Testing Engineers Conference (LTEC) and the National Bureau of Standards (NBS) have conducted intercomparisons to compare the bases for luminous flux and color parameters used by lamp manufacturers and other members of the lamp industry.

In 1967 the National Bureau of Standards spectroradiometrically calibrated a set of eleven 40 watt, cool white fluorescent lamps by comparing their luminous flux output to those of a set of 200 watt, luminous flux standard incandescent lamps calibrated at 2854K.** Five of these fluorescent standards were retained at NBS and six were sent to the Electrical Testing Laboratories (ETL) where they were used in a statistically designed procedure to assign total luminous flux values to a group of eighty lamps of the same manufacturer and type. These lamps were sent in groups of six to some of the participating laboratories as new luminous flux standards. This intercomparison was conducted to see whether the use of these new standards would unify the base for total luminous flux throughout the lamp industry, and to compare it to the NBS base.

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**Color temperatures quoted in this intercomparison are based on the 1949 Color Temperature Scale. This scale is based on the 1948 International Practical Temperature Scale (IPTS). For a discussion of the 1970 Color Temperature Scale (1968 IPTS), see the NBS Technical News Bulletin, September, 1970.

This intercomparison was conducted among some of the member laboratories of the Lamp Testing Engineers Conference and other interested laboratories. The participating laboratories were (in alphabetical order):

Duro-Test Corporation, North Bergen, New Jersey.

Electrical Testing Laboratories, Inc., New York, New York.

El-Tronics Inc., Warren, Pennsylvania.

General Electric Company, Cleveland, Ohio.

International Telephone and Telegraph Corporation, Lynn, Massachusetts.

National Research Council, Ottawa, Canada.

Sylvania Electric Products Inc., Danvers, Massachusetts.

University of California, Richmond, California.

Westinghouse Electric Corporation, Bloomfield, New Jersey.

Each laboratory was randomly assigned a code number for use in all references to that laboratory.

1.2. Description of intercomparison

The intercomparison consisted of five parts:

1) A photometric intercomparison of 40 watt fluorescent lamps by conventional substitution photometry in an integrating sphere

2) A spectroradiometric study of 40 watt fluorescent lamps in an integrating sphere;

3) A spectroradiometric study of a 25 cm (10 inch) section of 40 watt fluorescent lamps;

4) A statistically designed check on systematic errors in conventional sphere photometry; and

5) A Barnes Colorimeter determination of the x any y chromaticity coordinates of 40 watt fluorescent lamps.

The National Bureau of Standards supplied the participating laboratories with the following:

1) Two type F40T12 cool white lamps,

2) One type F40T12 daylight lamp,

3) One 200 watt incandescent lamp calibrated for total flux at 2854K, and

4) One fixed inductance choke-ballast on which the fluorescent lamps (items 1 and 2) were to be operated.

The fluorescent lamps had been seasoned by the manufacturers for 500 burning hours and the operating conditions were specified (see appendix A).

Since several different types of standard and test lamps will be referred to in this report, it will be convenient to identify them here.

NBS Incandescent Standards: The 200 watt incandescent flux standards that are used at NBS in spectroradiometric work.

NBS CW Standards: The eleven type F40T12 cool white (CW) fluorescent lamps spectroradiometrically calibrated for luminous flux by using the NBS Incandescent Standards. These are the lamps referred to in section 1.1.

ETL CW Standards: The eighty lamps of type F40T12 CW, also referred to in section 1.1, that were assigned luminous flux values on the basis of the NBS CW Standards by ETL.

Intercomparison CW Lamps: The two cool white fluorescent lamps supplied directly by NBS to the participating laboratories for this intercomparison.

Intercomparison Daylight Lamps: The daylight fluorescent lamps supplied by NBS.

Intercomparison Incandescent Lamps: The 200 watt incandescent lamps supplied by NBS.

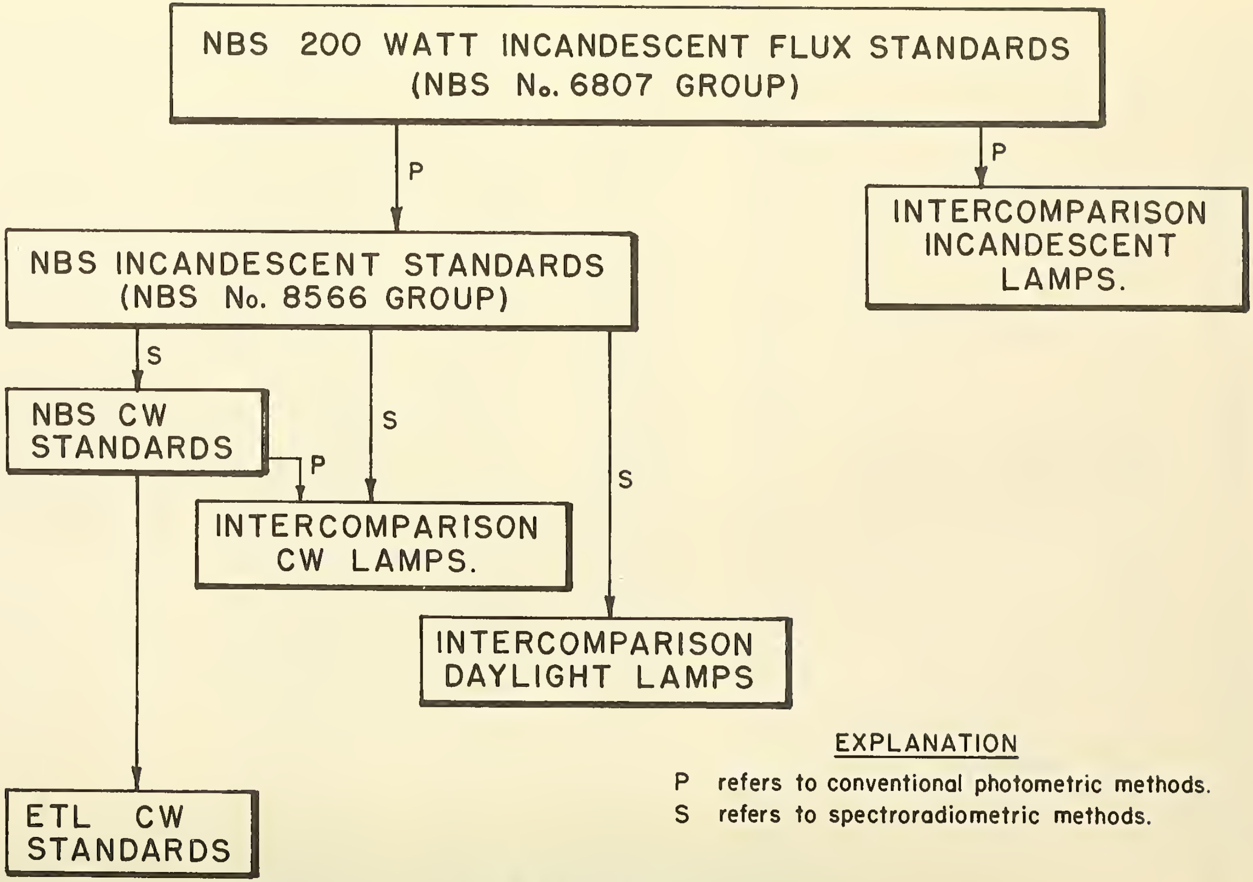
Choke-Ballast: The fixed inductance choke-ballast that was supplied by NBS for use with the Intercomparison CW Lamps and the Intercomparison Daylight Lamp.

The genealogy of these lamps is given in figure 1.1. The calibration on most of the lamps that were a part of this intercomparison can be traced back to the NBS 6807 group of incandescent luminous flux standards. This does not apply to the two laboratories in which ETL CW Standards were not used as a base, Laboratories 6 and 9.

Together with the incandescent and fluorescent intercomparison lamps and the choke-ballast, each participating laboratory was supplied with the experimental design and data sheets for each part of the intercomparison. A copy of the instructions and data sheets sent to each laboratory is attached as appendix A. Each participating laboratory also filled out a questionnaire on the type of equipment and procedures that were used. Appendix B is a copy of the questionnaire.

The intercomparison lamps were first measured at NBS by using both spectroradiometry and conventional substitution photometry. They were then measured at the participating laboratories where the fluorescent lamps were set up in the same lamp and choke-ballast combinations. The data and the lamps were returned to NBS, where the lamps were measured again. Measurements were made according to a statistical design.

The measurements taken at NBS before the lamps were sent out will be hereafter referred to as the "Initial" measurements; those taken at the laboratories will be referred to as "Laboratory" measurements; and those taken at NBS after the lamps were returned will be called "Repeat" measurements. Only Initial and Laboratory spectroradiometric measurements were taken on a 25 cm section of the fluorescent lamps. The data from the participating laboratories were to be returned untreated to NBS so that they could be reduced in a similar manner for all the laboratories. Unfortunately, due to the many different forms in which the data were received, the analysis of the data was different for each laboratory.



EXPLANATION

P refers to conventional photometric methods.
S refers to spectroradiometric methods.

LAMP GENEALOGY

FIGURE 1.1

2. NBS PROCEDURES FOR ASSIGNMENT OF LAMP PARAMETERS

2.1. Conventional photometric measurements

The fluorescent lamps, that is, the cool white and daylight lamps, were measured photometrically at NBS in a 2 meter (80 inch) sphere by using the NBS Incandescent Standards and the NBS CW Standards. A circuit diagram is given in figure 2.1. A high impedance, true RMS differential voltmeter was used for measuring lamp voltage. The "restoration of light" method (ref. 1) was, therefore, not required for lamp voltage measurements. Readings were taken both with and without an external color correcting filter. The ETL CW Standard lamps were operated on a Sylvania reference ballast and the fluorescent intercomparison lamps were operated on the choke-ballast. The same lamp and ballast combination was maintained throughout the period of the intercomparison.

During the Initial and Repeat measurements at NBS, NBS Incandescent Standards were used for the spectroradiometric transfers and the NBS CW Standards were used for the conventional photometric transfers.

2.2. Spectrcradiometric measurements

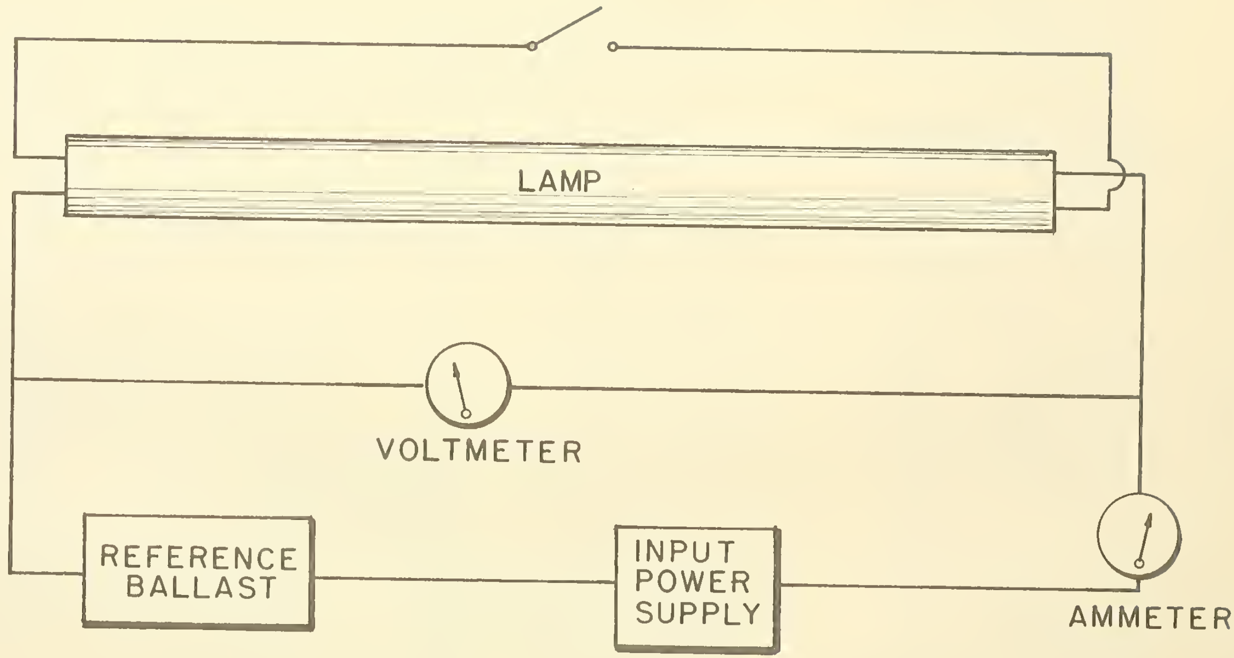
A block diagram of the spectroradiometer is given in figure 2.2. The spectroradiometer consisted of a 20 cm diameter sphere connected to the entrance slit of the monochromator. The inside of this sphere was coated with about 0.5 mm of barium sulphate powder which contained no binder, since binders tend to absorb radiation in the blue region of the spectrum. A 7.5 cm diameter aperture served to admit light from the measurement source into the sphere, perpendicular to the optical axis of the monochromator. The measurement source in this case was a lamp inside a 2 meter integrating sphere. The light was diffused inside the smaller collecting sphere and thus depolarized. The use of a collecting sphere minimized problems of alignment. Filters were inserted between the collecting sphere and the monochromator to eliminate second order spectra. However, this procedure was not followed in the 25 cm section measurements.

The monochromator used was a double grating instrument. Baffling along the optical path inside the monochromator served to reduce scattered radiation. The scattered radiation was further reduced by controlling the entrance slit height so that the radiation coming through the slit barely filled the first mirror in the monochromator. The entrance and exit slits were about equal and were approximately 5 nm in spectral bandpass.

The wavelength scale of the monochromator was calibrated against a set of standard emission lines to within an estimated uncertainty of ± 0.1 nm. The photomultiplier tube used in the spectroradiometer had an S-20 cathode and was selected for high sensitivity in the 600-800 nm region of the spectrum. The current from this photomultiplier tube was measured by a picoammeter that employed a cathode-follower type of amplifier for currents greater than 10^{-8} A, and an operational amplifier for currents less than 10^{-8} A. Since the picoammeter did not modulate the incoming signal to amplify it, problems arising from phase-difference effects between the source (if operated on power other than direct current) and the modulating signal of the amplifier were eliminated. The output of the picoammeter was connected to a stable resistor and the voltage drop across this resistor was measured by a digital voltmeter.

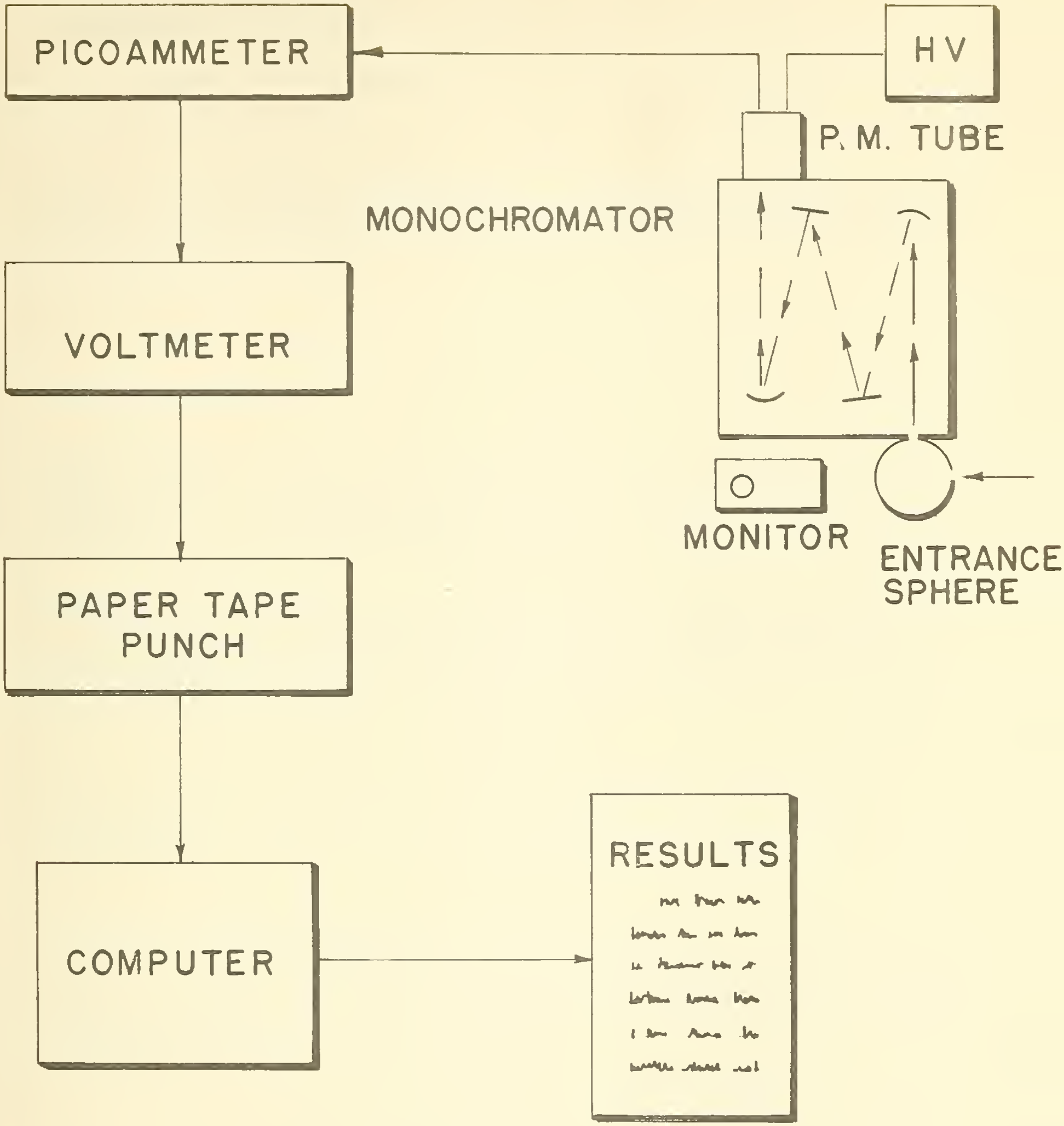
In order to monitor the drift in the electronics and photomultiplier tube sensitivity, a 200 watt quartz halogen lamp set at constant voltage was referenced by the spectroradiometer simply by rotating the collecting sphere. During the course of a run, readings were taken of the monitor lamp at 560 nm before, after, and during a run. If the difference was more than about 0.2% the run was aborted. The gain on the picoammeter was adjusted for each run so that the voltmeter reading for the monitor lamp was 0.8 of full scale. All the spectroradiometric data were reduced by using the following assumptions:

1) The conditions were the same for both the test and standard sources (that is, no change in monochromator, sphere, detector, background, gain, instrument bandwidth, etc.).



CIRCUIT USED FOR OPERATING FLUORESCENT LAMPS

FIGURE 2.1



SPECTRORADIOMETRIC
MEASUREMENTS AT NBS

FIGURE 2.2

2) The relative spectral distribution of the incandescent standard is the same as the relative spectral distribution of a Planckian radiator at 2854K.

3) Differences in beam geometry and polarization are eliminated by the entrance sphere.

4) The system response is linear at any given wavelength.

The last assumption leads to the conclusion that at a particular dial setting, Λ_i, the instrument reading, $R(\Lambda_i)$, is proportional to the spectral radiant flux admitted by the entrance aperture. That is,

$$R(\Lambda_i) = K \int_{(\lambda_i - b/2)}^{(\lambda_i + b/2)} \phi_\lambda \, D(\lambda) \, \tau(\Lambda_i, \lambda) \, d\lambda \qquad (2.1)$$

where $D(\lambda)$ is the relative system response as a function of wavelength (detector response and sphere or background absorption), $\tau(\Lambda_i, \lambda)$ is the instrument transmittance as a function of λ at the Λ_i dial setting, ϕ_λ is the spectral radiant flux per wavelength interval of the source and K is the instrument proportionality constant. The limits of integration are set by the instrument bandpass, b: outside these limits the instrument transmittance is effectively zero.

For an incandescent lamp (the standard source) or the continuum of a fluorescent lamp (the test source), ϕ_λ is a slowly varying function of λ. (The problem of the measurement of the mercury lines in a fluorescent lamp output will be treated separately.) It is also usually true that $D(\lambda)$ is a slowly varying function of λ. Within reasonable limits of accuracy these two functions may be assumed constant over the bandpass of the instrument. Therefore, eq. 2.1 becomes,

$$R(\Lambda_i) = K \, \phi_\lambda(\lambda_i) \, D(\lambda_i) \int_{(\lambda_i - b/2)}^{(\lambda_i + b/2)} \tau(\Lambda_i, \lambda) \, d\lambda \qquad (2.2)$$

Let $R^t(\Lambda_i)$, $R^s(\Lambda_i)$, and $\phi_\lambda^t(\lambda_i)$, $\phi_\lambda^s(\lambda_i)$ be the instrument readings and fluxes for the test and standard sources respectively. Within the approximations used to derive eq. 2.2, therefore, the spectral radiant flux ratio is equal to the ratio of the instrument readings.

$$\frac{R^t(\Lambda_i)}{R^s(\Lambda_i)} = \frac{\phi_\lambda^t(\lambda_i)}{\phi_\lambda^s(\lambda_i)} \qquad (2.3)$$

If $\phi_\lambda^s(\lambda_i)$ is known for each dial setting Λ_i, then the spectral radiant flux of the source can be evaluated. Although ϕ_λ^s is not known directly, it can be obtained from the total luminous flux, Φ^s which is known by comparison to the NBS luminous flux standards, and from the assumption that the standard source has the same relative spectral distribution, $B(\lambda)$, as a Planckian radiator at 2854K. That is,

$$\phi_\lambda^s = K_1 \, B(\lambda) \qquad (2.4)$$

The total luminous flux, Φ, is defined in general as,

$$\Phi = K_m \int_{380}^{760} \phi_\lambda V(\lambda) \, d\lambda \qquad (2.5)$$

where K_m is the maximum value of the spectral luminous efficacy (680 lumens per watt) and $V(\lambda)$ is the CIE luminous efficiency function. The limits of integration are given in nanometers and are set by the definition of $V(\lambda)$. For the standard source the total luminous flux is, therefore,

$$\Phi^s = K_1 K_m \int_{380}^{760} V(\lambda) \, B(\lambda) \, d\lambda \qquad (2.6)$$

This yields a value for K_1, so that eq. 2.4 becomes,

$$\phi_\lambda^s(\lambda_i) = \frac{B(\lambda_i) \, \Phi^s}{K_m \int V(\lambda) \, B(\lambda) \, d\lambda} \qquad (2.7)$$

Here $B(\lambda_i)$ is the value of $B(\lambda)$ (in relative power per wavelength interval) at the dial setting Λ_i. Using this result in eq. 2.3 the radiant flux per unit wavelength for the test source is:

$$\phi_\lambda^t(\lambda_i) = \frac{R^t(\Lambda_i)}{R^s(\Lambda_i)} \frac{B(\lambda_i) \, \Phi^s}{K_m \int V(\lambda) \, B(\lambda) \, d\lambda} \qquad (2.8)$$

In order to compute the total luminous flux of the test source from eq. 2.5, the integration over λ (the wavelength) may be approximated by a summation over Λ_i, (the wavelength dial setting). The total luminous flux of the test source is, therefore,

$$\Phi^t = K_m \sum_{380}^{760} \phi_\lambda^t(\lambda_i) \, V(\lambda_i) \, \Delta\Lambda \qquad (2.9a)$$

Combined with eq. 2.8, it becomes:

$$\Phi^t = \sum_{380}^{760} \frac{R^t(\Lambda_i)}{R^s(\Lambda_i)} \frac{V(\lambda_i) \, B(\lambda_i) \, \Phi^s}{\int V(\lambda) \, B(\lambda) \, d\lambda} \Delta\Lambda \qquad (2.9b)$$

The limits of summation in nanometers are again set by the definition of $V(\lambda_i)$, the value of $V(\lambda)$ at Λ_i. The summation interval, $\Delta\Lambda$, which is the analog of $d\lambda$, remains to be chosen. This interval does not have to be the same as the instrument bandpass; in fact, for this intercomparison it was chosen to be about twice as big: the summation interval was 10 nm, and the bandpass was approximately 5 nm. The same assumption, however, applies to both: the wavelength dependent instrument response and spectral radiant flux are assumed constant over the interval of summation and the bandpass. Choosing the summation interval fixes the dimensions of the ϕ_λ values to be used. In this case the dimensions of $\phi^s_\lambda(\lambda_i)$ and $\phi^t_\lambda(\lambda_i)$ are watts per 10 nm.

Note once again that the approximations which led up to eq. 2.9b were for a source without narrow lines. In order to treat the mercury lines present in the output of a fluorescent lamp, eq. 2.1 must be re-examined. For a dial setting at one of the mercury lines, Λ_m, the equation becomes:

$$R^t(\Lambda_m) = K \int_{(\lambda_m-b/2)}^{(\lambda_m+b/2)} \phi^t_\lambda \ D(\lambda) \ \tau(\Lambda_m,\lambda) \ d\lambda \qquad (2.10)$$

Since the mercury lines are much narrower than the instrument bandpass, the integrand is zero everywhere except at one wavelength, λ_m. Equation 2.10 can be rewritten as,

$$R^t(\Lambda_m) = K \ \phi^t(\lambda_m) \ D(\lambda_m) \ \tau(\Lambda_m, \lambda_m) \qquad (2.11)$$

Note that $\phi^t(\lambda_m)$ has been written without a subscript since it no longer is flux per wavelength interval--it is flux per mercury line. Dividing this by eq. 2.2 (written for a standard incandescent source) will obviously not yield the same cancellation that led to eq. 2.3. An additional experiment is necessary to evaluate the spectral radiant flux of a mercury line.

The experiment was performed as follows: By using the spectroradiometer, an analog plot of instrument reading versus dial setting was made of the output of a lamp having no continuum, only mercury line emission. The area under each plot of a mercury line was measured graphically. This area measurement is the value of the integral of the instrument reading as a function of the dial setting over the limits of the wavelength interval through which the mercury line is transmitted. That is,

$$\int_{(\Lambda_m-b/2)}^{(\Lambda_m+b/2)} R^t(\Lambda) \ d\Lambda = \int_{(\Lambda_m-b/2)}^{(\Lambda_m+b/2)} K \ \phi^t(\lambda_m) \ D(\lambda_m) \ \tau(\Lambda,\lambda_m) \ d\Lambda \qquad (2.12)$$

In the integral on the right side of eq. 2.12 only the transmittance function, $\tau(\Lambda,\lambda_m)$, is a function of Λ. The transmittance function is a function of two variables: the wavelength of the radiation and the instrument dial setting. Furthermore, it is a slowly varying function of the dial setting. If the transmittance function is assumed to remain unchanged within small variations of the dial setting, then for a line source of variable wavelength the following equation is true:

$$\int_{(\Lambda_i-b/2)}^{(\Lambda_i+b/2)} \tau(\Lambda,\lambda_i) \ d\Lambda = \int_{(\lambda_i-b/2)}^{(\lambda_i+b/2)} \tau(\Lambda_i,\lambda) \ d\lambda \qquad (2.13)$$

That is, the integral of the transmittance function obtained by holding the line source wavelength fixed and varying the dial position is equal to the integral obtained by fixing the dial setting and varying the wavelength of the line source. With this assumption eq. 2.12 becomes

$$\int_{(\Lambda_m - b/2)}^{(\Lambda_m + b/2)} R^t(\Lambda)\, d\Lambda = K\, \phi^t(\lambda_m)\, D(\lambda_m) \int_{(\lambda_m - b/2)}^{(\lambda_m + b/2)} \tau(\Lambda_m, \lambda)\, d\lambda \qquad (2.14)$$

Since the left side of this equation represents an area, it can be approximated by the product of two numbers. Choosing a specific instrument reading, for instance, $R^t(\Lambda_m)$, the reading at the mercury line wavelength, determines the value of the multiplicative constant to be used to obtain an area measurement from a single instrument reading. This factor, b_{eff} , termed the effective bandpass, will be unique for each mercury line and can now be used in the approximation of the integral on the left side of eq. 2.14 for any source containing mercury lines. This is, of course, only true if the characteristics of the instrument remain constant between the two experiments.

In order to compare eq. 2.14 to eq. 2.2 written for the standard incandescent source, the units of $\phi^t(\lambda_m)$ must be adjusted to the summation interval chosen for $\phi^s_\lambda(\lambda_m)$. Dividing both sides of eq. 2.14 by $\Delta\Lambda$ will change the flux per mercury line to flux per wavelength interval, or $\phi^t_\lambda(\lambda_m)$. Division of the adjusted version of eq. 2.14 by eq. 2.2 leads to:

$$\frac{R^t(\Lambda_m)\, b_{eff}}{R^s(\Lambda_m)\, \Delta\Lambda} = \frac{\phi^t_\lambda(\lambda_m)}{\phi^s_\lambda(\lambda_m)} \qquad (2.15)$$

Every term in this equation, except for the spectral radiant flux of the mercury line, has a known value. The $\phi^t_\lambda(\lambda_m)$ values in eq. 2.15 can now be included in the summation of eq. 2.9a as additional $\phi^t_\lambda(\lambda_i)$ values.

For the NBS spectroradiometer, the effective bandpass, b_{eff}, was measured for each mercury line and found to be: 5.84 nm at 405.0 nm (doublet); 5.53 nm at 435.8 nm; 5.48 nm at 546.1 nm; and 5.93 nm at 578.0 nm (doublet). The mercury line spectral radiant flux values listed in the tables in section 4 were adjusted to a 10 nm interval.

In the measurement of the mercury line flux above the continuum of a fluorescent lamp, the instrument reading produced by the continuum at that point was interpolated by fitting a quadratic polynomial to three instrument readings in the vicinity of the line. The instrument reading produced by the mercury line was calculated by subtracting the interpolated continuum value from the experimental instrument reading at the mercury line wavelength setting.

As indicated above, two of the four mercury lines in a fluorescent lamp output are actually double lines. The treatment of these doublets is a simple extension of the previous discussion. When eq. 2.12 is rewritten for two mercury lines at λ_j and λ_k it becomes:

$$\int_{(A-C)}^{(A+C)} R^t(\Lambda)\, d\Lambda = K \int_{(A-C)}^{(A+C)} [\phi^t(\lambda_j)\, D(\lambda_j)\, \tau(\Lambda,\lambda_j) + \phi^t(\lambda_k)\, D(\lambda_k)\, \tau(\Lambda,\lambda_k)]\, d\Lambda \qquad (2.16)$$

The limits of integration are defined by:

$$A = (\Lambda_j+\Lambda_k)/2$$

and

$$C = (b+\Lambda_j-\Lambda_k)/2$$

Since the mercury line separation is less than the instrument bandpass, the assumptions that have been made about the behavior of the functions can be applied in eq. 2.16. Namely,

$$D(\lambda_j) = D(\lambda_k)$$

and

$$\tau(\Lambda,\lambda_j) = \tau(\Lambda,\lambda_k)$$

Equation 2.16 reduces to

$$\int_{(A-C)}^{(A+C)} R^t(\Lambda)\, d\Lambda = K\, D(\lambda_j)\, [\phi^t(\lambda_j) + \phi^t(\lambda_k)] \int_{(a-c)}^{(a+c)} \tau(\Lambda_j,\lambda)\, d\lambda \qquad (2.17)$$

where a and c are defined with respect to λ in the same manner as A and C were defined with respect to Λ . By choosing a specific instrument reading (not necessarily at the wavelength of either mercury line)an effective bandpass is determined and an equation similar to eq. 2.15 can be derived where the unknown flux will be the sum of the spectral radiant fluxes of the two mercury lines.

In order to check the validity of measuring the mercury doublets as a single line, the spectroradiometric measurements were repeated with a smaller instrument bandpass (narrower slits). This resolved the doublets and allowed them to be treated as single lines. The results of these two measurements were identical within the uncertainty of the measurement.

2.3. Analysis of the NBS measurements

The photocell data were reduced by using the five NBS Cool White Standards which were retained at NBS. For the spectroradiometric measurements, NBS Incandescent Standards were used. First the data were analyzed to determine if the luminous flux of the lamps remained constant throughout the intercomparison. The results are listed in table 2.1.

Table 2.1

Initial minus Repeat luminous flux measurements at NBS

Measurement Method	Daylight Change (lumens)	Daylight Significant* Yes	Daylight Significant* No	Cool White Change (lumens)	Cool White Significant* Yes	Cool White Significant* No
Photocell (P)	13.5	X		33.2	X	
Photocell + Filter (PF)	8.4		X	31.9	X	
Spectroradio-meter (SR)	2.8		X	12.9	X	

*Significance at the 95% confidence level (t-test).

Table 2.2

Differences between NBS measurement methods of luminous flux

Methods Compared	Daylight Difference (lumens)	Daylight Significant* Yes	Daylight Significant* No	Cool White Difference (lumens)	Cool White Significant* Yes	Cool White Significant* No
P-PF**	-43.3	X		7.0	X	
SR-PF	- 4.4		X	3.5		X
SR-P	38.9	X		-3.5		X

*Significance at the 95% confidence level (t-test).
**See table 2.1 for a definition of these symbols.

Table 2.3

Precision (standard deviation) of an NBS measurement of luminous flux

	Photocell Without Filter (lumens)	Photocell With Filter (lumens)	Spectro-radiometer (lumens)
Initial	19.1	21.7	26.5
Repeat	14.1	13.6	12.6
F-Test	1.83	2.5	4.4
Significant* (s^2Before/s^2After)	Yes**	Yes	Yes

*Significant at the 95% confidence level (F-test).
**Both numerator and denominator had more than 40 degress of freedom.

Next the data were analyzed to determine if any difference exists among the methods used. These results are given in table 2.2. In table 2.3, the results of a statistical analysis are given which determine the precision of each method for Initial and Repeat measurements. The final values assigned to the lamps were an average of the spectroradiometric and photocell-filter Initial and Repeat values equally weighted.

Note that in table 2.1 there appears a significant drift in cool white lamps in all the three measurement methods. This could be due to some change in the characteristic of the lamp in the time between the Initial and the Repeat measurements. The daylight lamps, however, appear to change only when measured by a photocell without an additional color correcting filter. This may be due to a change in the spectral characteristics of either the sphere or photocell in the interim between measurements.

Table 2.2 compares the different methods used. Since the standards used for conventional photometry were cool white lamps, it is understandable that for daylight lamps the photocell values are significantly different from the photocell with filter values. The close agreement between the spectroradiometric and photocell with filter values lends further credence to the claim that a sphere can be spectrally corrected by using a color correcting filter. A small but significant difference was detected between the photocell and the photocell with filter values for cool white lamps. This could be due to the fact that the original standards used were of one manufacturer and the test lamps were of another manufacturer. Though they are all cool white lamps, there may be some spectral difference between them. It may also be noted that the original standards were mixed gas lamps and the test lamps are argon filled. Although the ambient temperature was maintained at 25 ± 1°C, mixed gas lamps are believed to be more sensitive to changes in ambient temperature than argon filled lamps. This might be a contributing factor.

The standard deviations given in table 2.3 are calculated estimates of the standard deviation of a single measurement. The difference in the precision between the Initial and Repeat measurements may be due to the level of experience of the different operators for the two cases.

In addition to the spectroradiometer measurements made on the entire lamp operated inside an integrating sphere, measurements were also made on a 25 cm section of the lamp operated inside a half-cylindrical enclosure. The enclosure was double shielded against drafts by wire nets. The base of this enclosure was baffled to enable the collecting sphere of the spectroradiometer to sample a 25 cm section of the lamp. Figure 2.3 is a diagram of this enclosure.

The spectroradiometric data were analyzed to yield values for of color temperature*, the x and y chromaticity coordinates, and, for the sphere measurements, total luminous flux.

Statistical tests were conducted to check whether there were significant differences between Initial and Repeat values for color temperature and chromaticity coordinates. Table 2.4 gives the Initial minus Repeat values for the measurements of color temperature and the x and y chromaticity coordinates for both cool white and daylight lamps. As in table 2.1, where the Initial and Repeat total luminous flux differed more for cool white lamps than for the daylight lamps, the cool white lamps seems to have changed significantly in the three color parameters. The daylight lamps have changed significantly in two: the x chromaticity coordinate and color temperature. A change in the characteristics of the lamp and ballast combination resulting in a spectral change in lamp output could account for both the color change and the change in total luminous flux.

The NBS values for color parameters were assigned from the average of both the Initial and Repeat spectroradiometric sphere measurements. The 25 cm section values were not used for this purpose. Because only the Initial measurements were performed, the 25 cm section values were not included in the average.

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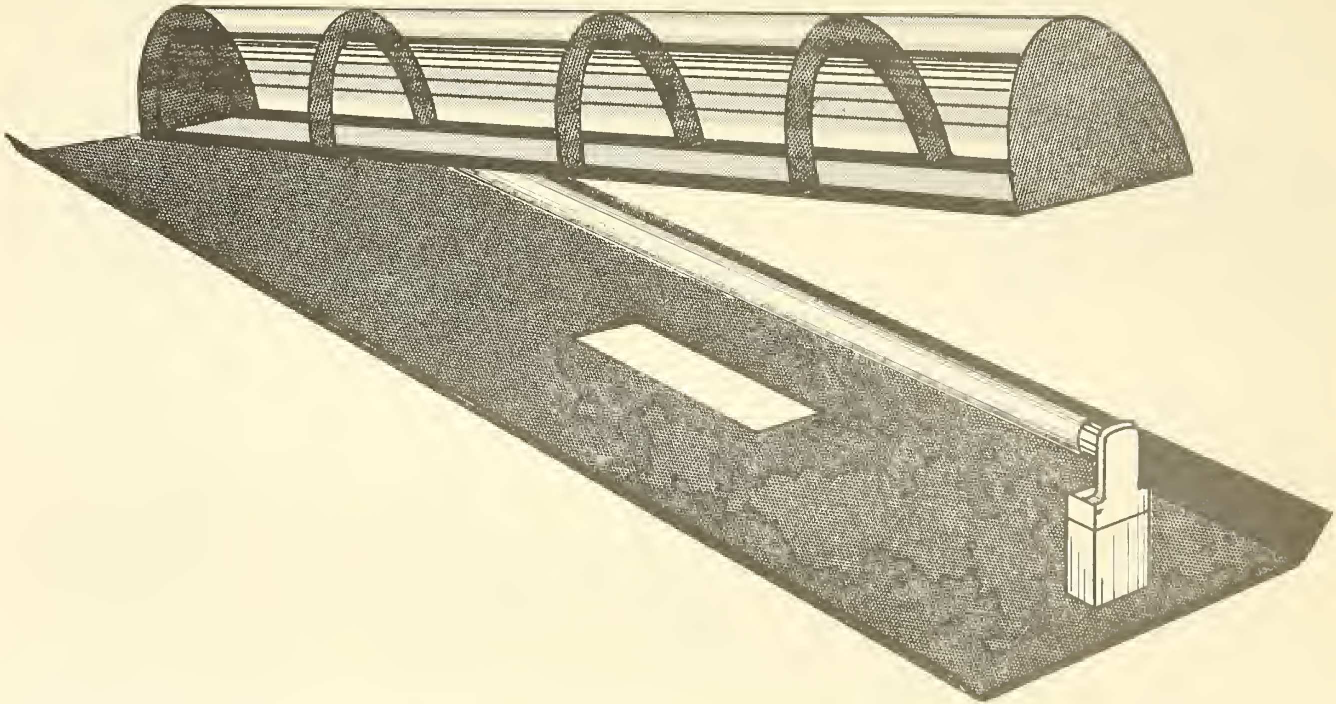
*The common use of the term "color temperature" in reference to a fluorescent lamp is, in a strict sense, incorrect. The prescribed terminology is "correlated color temperature". However, in deference to familiarity and simplicity "color temperature" will be used throughout.



ENCLOSURE FOR MEASUREMENTS ON A 25 cm SECTION OF A FLUORESCENT LAMP.

FIGURE 2.3

Table 2.4

Initial minus Repeat values of color parameter sphere measurements at NBS

	Cool White			Daylight		
Parameter	Difference	Significant* Yes	Significant* No	Difference	Significant* Yes	Significant* No
Color Temp.	29.9K	x		35.4K	x	
x	-0.0009	x		-0.0006	x	
y	0.0009	x		-0.0003		x

*Significance at the 95% confidence level (t-test).

Table 2.5

Initial sphere measurements minus Initial 25 cm section measurements of color parameters at NBS

	Cool White			Daylight		
Parameter	Difference	Significant* Yes	Significant* No	Difference	Significant* Yes	Significant* No
Color Temp.	16.0K	x		-5.4K		x
x	-0.0003	x		0.00002		x
y	0.0013	x		0.0009		x

*Significance at the 95% confidence level (t-test). Note that the number of cool white lamps tested was twice that of the daylight lamps.

Their use would, of course, have weighted the final averages in favor of the Initial measurements.

Table 2.5 gives the Initial readings inside an integrating sphere minus the 25 cm section readings. The purpose of this comparison is to determine whether color temperature and chromaticity coordinate determined by a total flux measurement are comparable with their determination from a 25 cm section measurement. (At many laboratories measurement of chromaticity coordinates is typically performed with a Barnes Colorimeter which utilizes a 25 cm section of the lamp.) Table 2.5 indicates that the color parameters obtained by the two methods did not differ significantly for daylight lamps, but that the opposite was true for cool white lamps.

3. PARTICIPATING LABORATORY MEASUREMENT PROCEDURES

3.1. Comparison of the photometric and spectroradiometric equipment used

Though the general photometric setup was similar in most laboratories, there still were some significant differences in both the equipment and the measurement procedures. The differences were more marked in the spectroradiometric equipment and methods among the various laboratories. In this section the photometric equipment used by participating laboratories will be described. A brief description will then be given of each of the spectroradiometers.

Tables 3.1 to 3.3 summarize the equipment used at the various laboratories for the measurements in part 1 of the intercomparison. Laboratories 2 and 4 have reported using external color correcting filters to correct for the wavelength dependence of sphere reflectivity and window absorption. The effects of using these filters will be more clearly brought out in the discussion of the results.

Laboratory 1 normally applies a mathematical correction to their data. The method is based on a separate determination of the wavelength dependence of sphere reflectivity, window absorption, the emission of the source, and the detector response. They did not apply this correction to any of the data submitted for this intercomparison, however, since the correction was relatively small.

All except Laboratory 1 used Weston photocells as detectors; five used the model 856V (hermetically sealed) and two used model 594V. All Weston cells were equipped with Viscor filters. It should be noted that hermetically sealed photocells are not sensitive to humidity variations and are less sensitive to temperature variation (ref. 2).

Photocell output was read at most laboratories by a potentiometer device. Laboratory 5 used an operational amplifier and digital voltmeter combination. Only Laboratory 6 applied any linearity corrections to their photocell data.

All except Laboratory 6 warmed up the lamps for at least 15 minutes. All the laboratories measured the ambient temperature periodically, though the locations at which this was measured varied from laboratory to laboratory. Only Laboratories 2 and 3 indicate having temperature control. The location at which ambient temperature should be measured and the extent to which it should be controlled still constitute problems. Different types of lamps behave differently with a change in ambient temperature and it is not clear what is meant by the ambient temperature inside an integrating sphere. Most spheres, particularly larger ones, will have a temperature gradient even when the temperature at the sensor is controlled. The light output of a fluorescent lamp is a function of the wall temperature at the coldest point on the bulb. No completely satisfactory measurement has been made of this parameter.

Detailed descriptions of spectroradiometric equipment and techniques can be found in the papers of Thorington, et al., (ref. 3), and Sanders and Gaw (ref. 4). The spectroradiometric equipment that was used for this intercomparison by each of the laboratories participating in the spectroradiometric intercomparison will now be described briefly.

LABORATORY 1: This laboratory used two different monochromators in making measurements for this intercomparison. Measurements for part 2 of the intercomparison were made by using a custom built Czerny-Turner type monochromator. In measurements for part 3 of the intercomparison, the lines in the spectrum were measured by using the custom made monochromator and the continuum was measured with a Leiss double prism monochromator with flint glass prisms. Wavelength calibration was performed before every run with the 435.8 nm and 546.1 nm mercury lines. Both monochromators employed a photomultiplier with an S-20 response (EMI-9558Q) as the detector. The detector ouptut for the custom made grating monochromator was amplified and displayed on an L & N type G, series 6000 recorder and amplifier. For the Leiss monochromator the detector output was amplified by a Keithley 610 electrometer and read on a Vidar 610 digital voltmeter and recorded on punched paper tape.

Table 3.1

Sphere equipment used in the participating laboratories for photometric measurements.

Laboratory	Diameter	Coating	Date Coated (See Note)	External Color Correcting Filter	Window
1	1.5 meter	G.E. Paint*	July 1968	None****	1.5 mm ground glass
2	3 meter	Burch**	July 1968	Wratten 78C	None***
3	3 meter	Burch	Nov. 1967	None	3 mm pot opal
4	1.5 meter	Burch	Oct. 1968	Corning 5900	3 mm flashed opal
5	2 meter	Burch	Aug. 1968	None	Opal
6	2.1 meter	MgO	1967	None	Depolished opal
7	1.8 meter	Burch	Aug. 1968	None	3 mm ground glass
8	3 meter	Burch	Aug. 1967	None	None***

*General Electric Sphere Paint
**Burch Sphere Paint
***Cells mounted inside sphere facing sphere wall
****A different method is normally used for color correction (See text)

Note: Measurements at all the laboratories were made in October and November 1968.

Table 3.2

Photocells used in the participating laboratories for photometric measurements

Laboratory	Type	Linearity Correction	Dectector Read Out
1	GE-PV-1	None	Standard Current Balance
2	Weston 856V	None	Operational Amplifier & Digital Voltmeter
3	Weston 856V	None	Rubicon Bridge
4	Weston 856V	None	Rubicon Bridge
5	Weston 594V	None	Operational Amplifier & Digital Voltmeter
6	Weston 594V	Yes	K-2 Potentiometer
7	Weston 856V	None	Rubicon Bridge
8	Weston 856V	None	Rubicon Bridge

Table 3.3

Lamp operation and temperature control during photometric measurements at the participating laboratories

Laboratory	Lamp Operation		Temperature		
	Power Regulation	Ballast for Standards	Sensor Type	Sensor Location	Control
1	0.1%	Sylvania Reference	Hg-thermometer	10 cm from wall on lamp axis	- -
2	1%	Sylvania Reference	Hg-thermometer & thermocouple	30 cm below lamp 45 cm above lamp	$\pm$ 0.5°C
3	0.1%	Sylvania Reference	Hg-thermometer & thermocouple	45 cm below at one end	$\pm$ 0.2°C
4	0.15%	Sylvania Reference	Hg-thermometer	5 cm from sphere wall in central plane	- -
5	0.25%	Sylvania Reference	Hg-thermometer	15 cm above lamp at end	- -
6	1%	Sylvania Reference	Hg-thermometer	45 cm below lamp from center	- -
7	0.1%	Sylvania Reference	Hg-thermometer	20 cm above lamp at one end	- -
8	- -	Sylvania Reference	- -	- -	- -

LABORATORY 2: The basic dispersing unit used by this laboratory is an Ebert type monochromator (Perkin Elmer model E-1) with a 10 cm diameter diffusing sphere at the entrance slit. NBS standard filters were used to calibrate the wavelength. The last calibration took place about a year before this intercomparison. A photomultiplier tube with an S-20 response (EMI-9558Q) was used as the detector. The signal from the detector was amplified and integrated over 2 nm intervals and recorded on punched paper tape.

LABORATORY 4: In this laboratory a Hilger Watts model D-300 quartz double monochromator with a variable speed wavelength drive was used as the basic dispersing unit. The manufacturer's wavelength calibration was checked by using Hg, Cd, He, Ne, and Rb line sources. A 9.3 cm diameter sphere was used before the entrance slit of the monochromator to collect and diffuse the light. A photomultiplier with a quartz window and an S-20 response (RCA-7265) was used as the detector. The incoming light was chopped at 90 Hz and the signal from the detector after a-c preamplification and amplification was recorded on an x-y chart recorder.

LABORATORY 5: This laboratory used a Bausch and Lomb model 33-86-45 Ebert type grating monochromator. A 25 cm integrating box, coated with 3M "Velvet White", was placed before the entrance slit of the monochromator. The wavelength scale was calibrated to within 1 nm by using mercury lines. A photomultiplier tube with an S-20 response (EMI-9558QB) was used as the detector. The output signal from the photomultiplier was amplified by using a Keithley model 610 DC electrometer and displayed on an Esterline - Augus E1101S chart recorder.

LABORATORY 7: This laboratory used a single prism monochromator (Beckman model DK-1) which was wavelength calibrated at the time of measurement by using the 546.1 nm mercury line. A photomultiplier tube with an S-10 response (RCA 6217) was used as the detector. The signal from the detector was amplified by a Keithley model 610A DC electrometer and displayed on a chart recorder.

LABORATORY 9: In this laboratory a quartz prism Hilger Watts model D-300 monochromator was used with an S-20 response photomultiplier tube (EMI-9558QB). The wavelength scale was calibrated to ± 0.2 nm by using 60 lines of the Ru, Hg, Cs, Kr, Ar, and Ne spectra. The current output from the photomultiplier was amplified by a Dymec type 2411A amplifier, the output of which was measured by a digital voltmeter (Dymec, type 2401B). The voltmeter then sent a BCD output to a card punch.

3.2. Comparison of the measurement procedures used

PART 1: Photometric intercomparison of 40 watt fluorescent lamps by conventional methods.

In order to standardize the experimental methods in the various participating laboratories, each laboratory was supplied with an experimental design and the necessary data sheets (appendix A). Part 1 of the interlaboratory check involved three days of measurements at each laboratory. Over the course of a day six ETL CW standards (or other lamps held as standards by the laboratory) were measured against the two cool white and one daylight fluorescent, and the 200 watt incandescent intercomparison lamps. Each intercomparison lamp was measured twice in the course of a day. Over a period of three days, therefore, the fluoresent intercomparison lamps and the incandescent intercomparison lamp had each been measured six times. The data were analyzed in blocks of one day's run. A calibration factor was obtained by taking the ratio of the instrument reading and the assigned luminous flux of the six ETL CW Standards (or substitutes). An average of these calibration factors was used to compute the luminous flux of the other test lamps that were measured that day. The data from all the participating laboratories were analyzed in the same manner. Only Laboratory 6 submitted linearity corrections for their photocell. These corrections, which were on the order of 2.5%, were used in the analysis of their data.

In order to check for any drifts that might be present during the course of a day's run all the data were corrected for linear drift in the sphere factors. Only in the case of Laboratory 3 did drift corrections improve precision--and then only for the daylight lamp. This one result was judged to be insignificant and it was, therefore, concluded that no appreciable linear drift existed at any of the participating laboratories. Linear drift corrections were not applied to any of the reported data.

PART 2: Spectroradiometric study of 40 watt fluorescent lamps inside an integrating sphere

This test was intended to give the maximum amount of information for the minimum amount of work. The procedure was to be as follows.

1) The data were to be taken at 10 nm intervals from 380 nm to 760 nm. These data were to be reported unreduced.

2) Data were to be taken at 405.0 nm, 435.8 nm, 546.1 nm, and 578.0 nm. These data were to be reported with the appropriate effective bandpass.

3) The lamps were to be run in the order specified on the data sheets supplied with the lamps.

Because of variations in laboratory, equipment, and technique, this test procedure was not uniformly followed. Therefore, the data from each participating laboratory had to be modified in order to conform to the designed test.

LABORATORY 1: The data received were completely reduced. Data for all the wavelengths of interest were not taken, however, because of equipment limitations. A missing point at 490 nm was interpolated by using a quadratic polynominal fit to the points around this wavelength. The points missing from each end of the spectrum were set equal to zero. Since the fluorescent and the incandescent standard lamps were compared against the same set of reference lamps, the reduced data were treated as though they were unreduced. The mercury lines had already been adjusted for a 10 nm interval and were, therefore, treated in the same manner as the continuum.

LABORATORY 2: These data were the most difficult to reduce. The reported data were already reduced and the photometric flux (Y) had been normalized to 1000 lumens. The Y values were subsequently obtained from this laboratory for each set of measurements. By using Y, the magnitude of the data was adjusted and the data were reduced again at NBS.

LABORATORY 4: These data were reported unreduced. The mercury line doublets which were supposed to be reported as a single measurement were reported as two separate lines. These separate measurements were combined to single values and then all the data were reduced at NBS. Corrections were also applied for apparent discrete changes in the gain factor within one standard lamp - test lamp run.

LABORATORY 5: Unreduced data were reported by this laboratory. The datum reported for a mercury line, however, was the area under an analog plot of the line minus that of the continuum. Since the data of interest were the instrument readings adjusted to a 10 nm interval, the reported data for the mercury lines were divided by 10 times the instrument reading for the continuum and then multiplied by the radiant flux of the continuum. The data were then reduced at NBS.

LABORATORY 7: These data were reported in three parts. The first part was the dark current of the photomultiplier, the second part was the relative reflectance of a reflecting plaque used only for the incandescent standards, and the third part included the first two parts plus the spectral radiant flux of the source. Therefore, the data from all three parts were combined to solve for the unreduced data and then reduced at NBS.

LABORATORY 9: This laboratory reported irradiance values relative to a quartz--halogen lamp. Since the same reference had been used for all measurements, these data were reduced at NBS in the same manner as untreated data.

PART 3: Spectroradiometric study of color on a 25 cm section of 40 watt fluorescent lamps

The 25 cm section data were treated the same way as the spectroradiometric data of Part 2. However, values were computed only for the color temperature and the x and y chromaticity coordinates.

PART 4: Check on systematic errors in conventional sphere photometry.

This part of the intercomparison was designed to provide information about the performance of the photometric equipment. This was obtained by using an additive design experiment (See sample data sheets for this part in appendix A). One block of data was to consist of five sphere measurements performed according to the following procedure:

1. C
2. C + (I)
3. C + I
4. (C) + I
5. I

Where C refers to a cool white fluorescent lamp and I to an incandescent 200 watt lamp, both of which had been calibrated for total luminous flux by NBS. The parentheses refer to the presence of an unlighted lamp in the sphere. For example, the second step represents a measurement taken with a lighted cool white fluorescent lamp and an unlighted incandescent lamp in the integrating sphere.

PART 5: Barnes Colorimeter determination of the x and y chromaticity coordinates of 40 watt fluorescent lamps.

Barnes Colorimeter measurements were not made at NBS, nor was an experimental design established for this test. The purpose of these measurements was to compare this method to the spectroradiometric method of determining the x and y chromaticity coordinates.

4. RESULTS OF THE INTERCOMPARISON

4.1. Results and comparison of the luminous flux measurements

In this section, the data obtained from the participating laboratories for each part of the intercomparison are compared against the assignments made at NBS. First a comparison is made of the parameters that were obtained from the conventional photometric measurements and those obtained spectroradiometrically. The differences in spectral distribution of the intercomparison lamps as measured at NBS and at the participating laboratories are then discussed.

Total luminous flux of the test lamps was obtained both from the photocell readings and from the spectral distribution measurements. Table 4.1 gives a summary of the conventional photometric luminous flux measurements at each laboratory averaged for each day. Tables 4.2 through 4.9 give the detailed results obtained from each laboratory and the differences between the laboratory and NBS values. Table 4.10 gives the final average total luminous flux measurements obtained at each laboratory and the calculated estimate of standard deviation.

Figure 4.1 is a combined plot of the percent difference between the daily laboratory average and the NBS assignment of total luminous flux. The plots of all differences for each laboratory are given in figures 4.2 through 4.9.

Total luminous flux was also determined from spectroradiometric measurements. The spectroradiometric flux determinations are given in table 4.11. Plots of the differences of these values from the NBS assignments are given in figure 4.10, and on an expanded scale in figure 4.11.

Table 4.1

Photometric measurement of total luminous flux--summary of the daily averages for all participating laboratories

Lab	Lamp	Lamp Type	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference	Lab	Lamp	Lamp Type	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
1	8797	CW1	2826.6	2797.8	-28.9	-1.0	5	8801	CW1	2750.5	2791.0	40.5	1.5
				2801.8	-24.8	-0.9					2788.0	37.5	1.4
				2811.9	-14.6	-0.5					2787.5	37.0	1.3
	8798	CW2	2838.1	2861.1	23.0	0.8		8802	CW2	2805.7	2839.5	33.8	1.2
				2849.5	11.4	0.4					2844.5	38.8	1.4
				2857.6	19.5	0.7					2846.5	40.8	1.5
	8906	D	2473.7	2488.2	14.5	0.6		8908	D	2450.9	2409.5	-41.4	-1.7
				2491.8	18.1	0.7					2414.0	-36.9	-1.5
				2489.5	15.9	0.6					2410.0	-40.9	-1.7
2	8805	CW1	2794.8	2793.5	- 1.3	0.0	6	8813	CW1	2804.9	2298.5	-506.4	-18.1
				2795.0	0.2	0.0					2256.6	-548.3	-19.5
				2802.0	7.2	0.3					2252.2	-552.7	-19.7
	8806	CW2	2863.1	2864.0	0.9	0.0		8814	CW2	2847.5	2265.5	-582.0	-20.4
				2872.5	9.4	0.3					2249.7	-597.8	-21.0
				2847.0	-16.1	-0.6					2257.1	-590.4	-20.7
	8909	D	2479.7	2449.5	-30.2	-1.2		8913	D	2460.9	2062.9	-398.0	-16.2
				2448.0	-31.7	-1.3					2041.2	-419.7	-17.1
				2459.5	-20.2	-0.8					2054.1	-406.8	-16.5
3	8807	CW1	2917.1	2912.3	- 4.9	-0.2	7	8795	CW1	2902.5	2914.5	11.9	0.4
				2923.9	6.9	0.2					2888.1	-14.4	-0.5
				2929.8	12.7	0.4					2887.6	-14.9	-0.5
	8808	CW2	2897.8	2887.5	-10.2	-0.4		8796	CW2	2505.2	2522.2	17.0	0.7
				2907.6	9.8	0.3					2513.8	8.6	0.3
				2912.5	14.7	0.5					2512.7	7.5	0.3
	8910	D	2465.9	2392.9	-73.1	-3.0		8905	D	2472.5	2441.5	-31.0	-1.3
				2390.7	-75.2	-3.1					2409.2	-63.3	-2.6
				2392.0	-73.9	-3.0					2397.6	-74.9	-3.0
4	8809	CW1	2783.2	2754.0	-29.2	-1.0	8	8803	CW1	2836.1	2849.9	13.8	0.5
				2773.3	- 9.9	-0.4					2816.6	-19.5	-0.7
				2779.2	- 4.0	-0.1					2853.2	17.1	0.6
	8810	CW2	2841.9	2804.9	-37.0	-1.3		8804	CW2	2858.3	2875.6	17.3	0.6
				2834.1	- 7.8	-0.3					2861.6	3.3	0.1
				2824.9	-17.0	-0.6					2864.3	6.0	0.2
	8911	D	2481.5	2462.1	-19.5	-0.8		8908A	D	2476.2	2442.2	-34.0	-1.4
				2471.8	- 9.7	-0.4					2433.6	-42.6	-1.7
				2470.7	-10.8	-0.4					2439.9	-36.3	-1.5

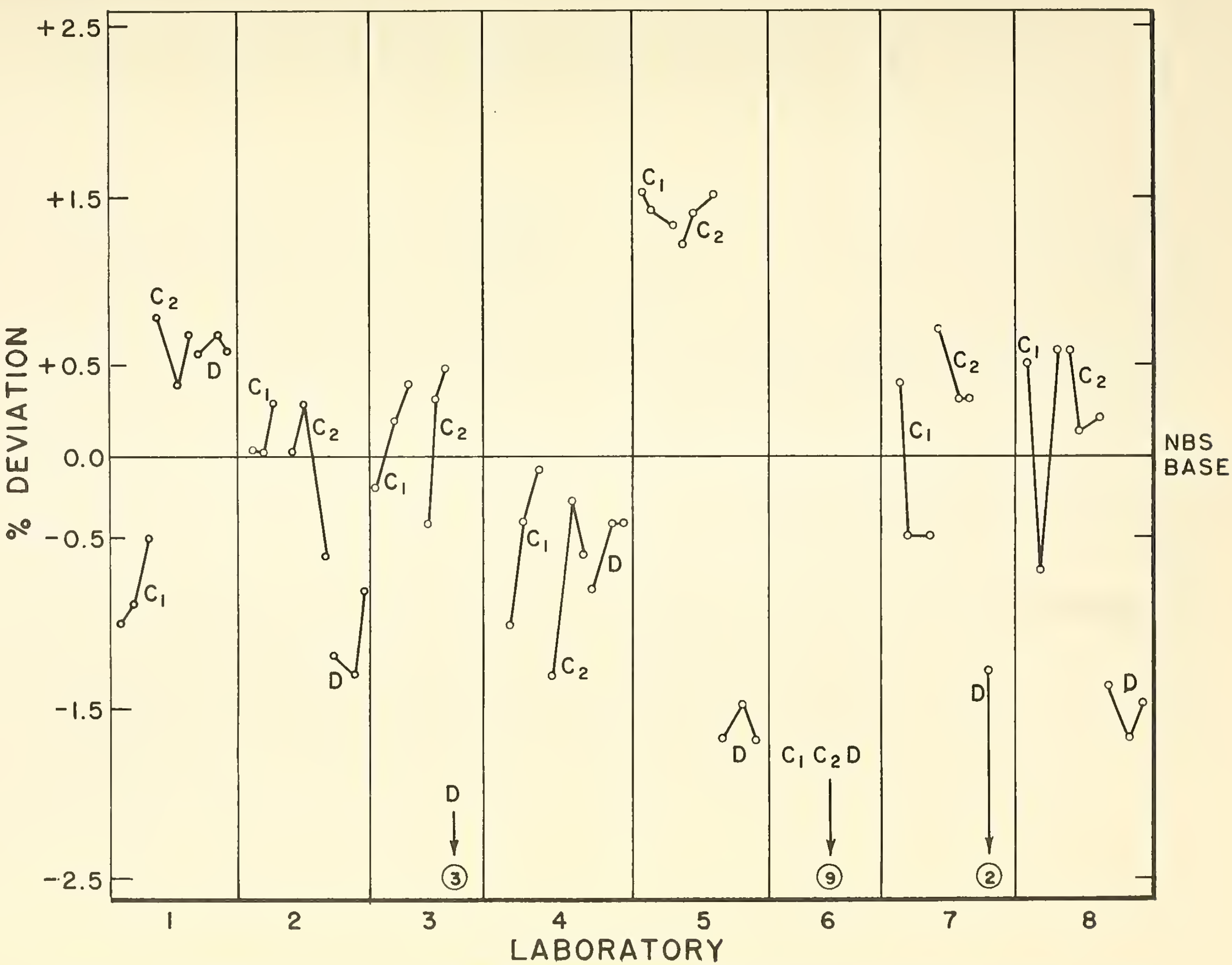


Fig. 4.1 NBS assignments compared to the daily average photometric measurements of total luminous flux by each of the participating laboratories.

Table 4.2

Photometric measurement of total luminous flux--Laboratory 1.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8797	2826.3	2781.3	-45.3	-1.6
		2814.2	-12.4	-0.4
		2796.3	-30.3	-1.1
		2807.3	-19.3	-0.7
		2824.0	- 2.6	-0.1
		2799.9	-26.7	-0.9
8798	2838.1	2890.1	52.0	1.8
		2832.2	- 5.9	-0.2
		2868.6	30.5	1.1
		2830.4	- 7.7	-0.3
		2848.0	9.9	0.3
		2867.1	29.0	1.0
8906	2473.7	2491.7	18.0	0.7
		2484.7	11.0	0.4
		2486.8	13.1	0.5
		2496.8	23.1	0.9
		2505.1	31.4	1.3
		2474.0	0.3	0.0

Table 4.3

Photometric measurement of total luminous flux--Laboratory 2.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8805	2794.8	2795	0	0.0
		2792	- 3	-0.1
		2792	- 3	-0.1
		2798	3	0.1
		2800	5	0.2
		2804	9	0.3
8806	2863.1	2887	24	0.8
		2841	- 22	-0.8
		2905	42	1.5
		2840	- 23	-0.8
		2844	- 19	-0.7
		2850	- 13	-0.5
8909	2479.7	2449	- 31	-1.2
		2450	- 30	-1.2
		2442	- 38	-1.5
		2454	- 26	-1.0
		2462	- 18	-0.7
		2457	- 23	-0.9

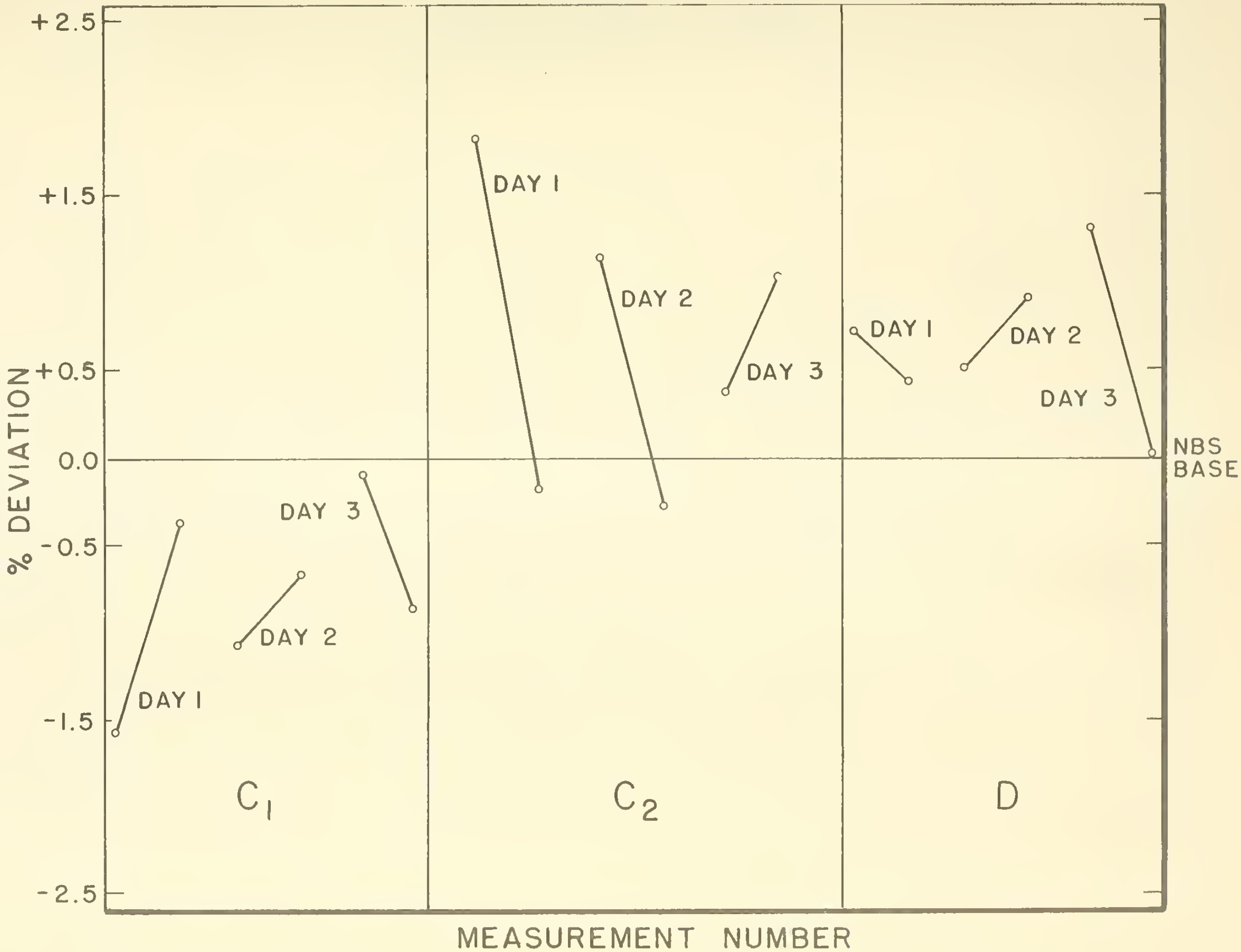


Fig. 4.2 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 1.

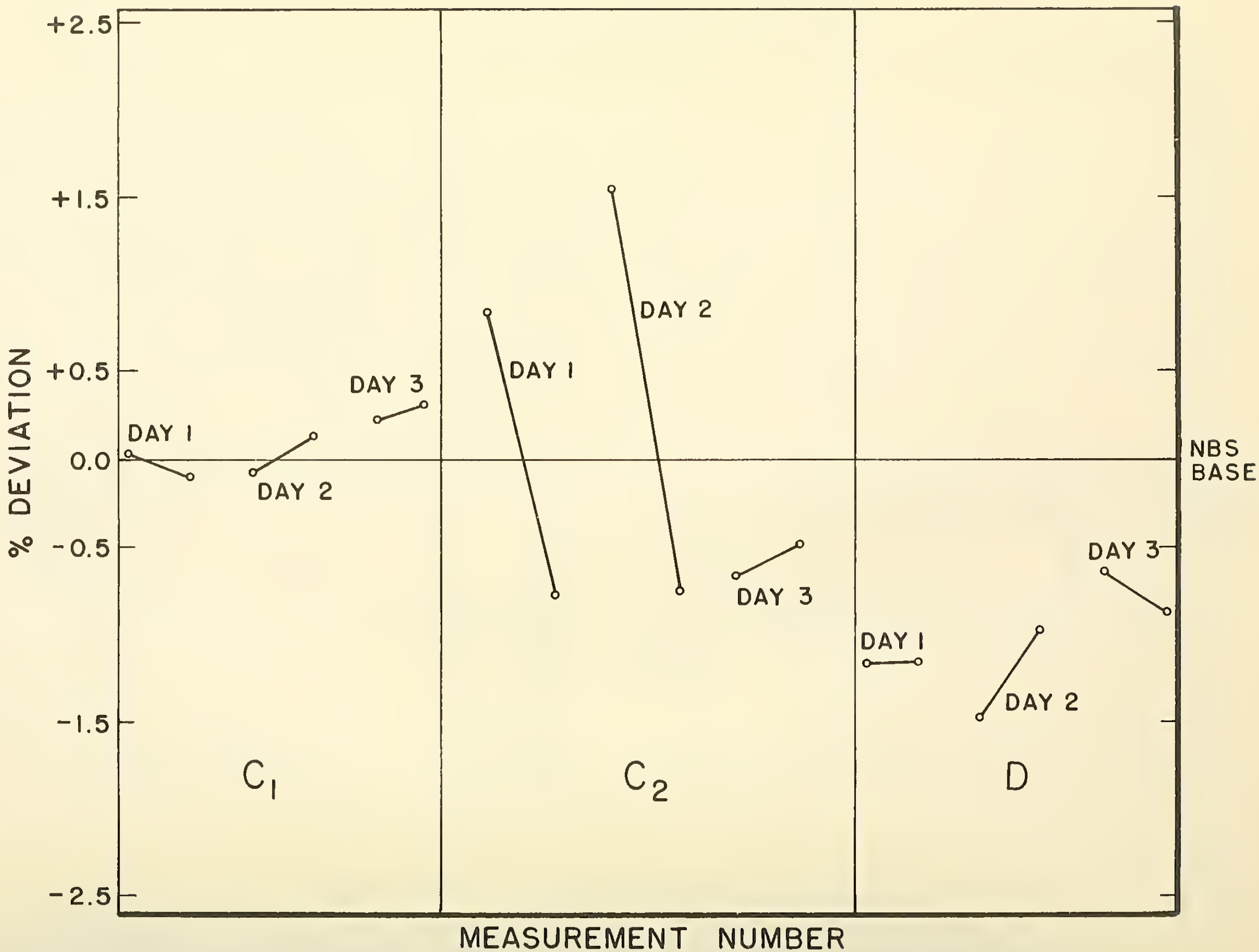


Fig. 4. 3 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 2.

Table 4.4

Photometric measurement of total luminous flux--Laboratory 3.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8807	2917.1	2919.8	2.7	0.1
		2904.7	-12.4	-0.4
		2927.0	9.9	0.3
		2920.9	3.8	0.1
		2936.9	19.8	0.7
		2922.7	5.6	0.2
8808	2897.8	2889.6	-8.2	-0.3
		2885.5	-12.3	-0.4
		2892.6	-5.2	-0.2
		2922.7	24.9	0.9
		2922.7	24.9	0.9
		2902.3	4.5	0.2
8910	2465.9	2400.4	-65.5	-2.7
		2385.3	-80.6	-3.3
		2385.6	-80.3	-3.3
		2395.7	-70.2	-2.8
		2388.9	-77.0	-3.1
		2395.1	-70.8	-2.9

Table 4.5

Photometric measurement of total luminous flux--Laboratory 4.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8809	2783.2	2751.2	-32.0	-1.1
		2756.8	-26.4	-0.9
		2775.7	-7.5	-0.3
		2771.0	-12.2	-0.4
		2781.1	-2.1	-0.1
		2777.4	-5.8	-0.2
8810	2841.9	2831.3	-10.6	-0.4
		2778.5	-63.4	-2.2
		2833.7	-8.2	-0.3
		2834.6	-7.3	-0.3
		2823.1	-18.8	-0.7
		2826.8	-15.1	-0.5
8911	2481.5	2461.1	-20.4	-0.8
		2463.0	-18.5	-0.7
		2476.5	-5.0	-0.2
		2467.2	-14.3	-0.6
		2472.6	-8.9	-0.4
		2468.9	-12.6	-0.5

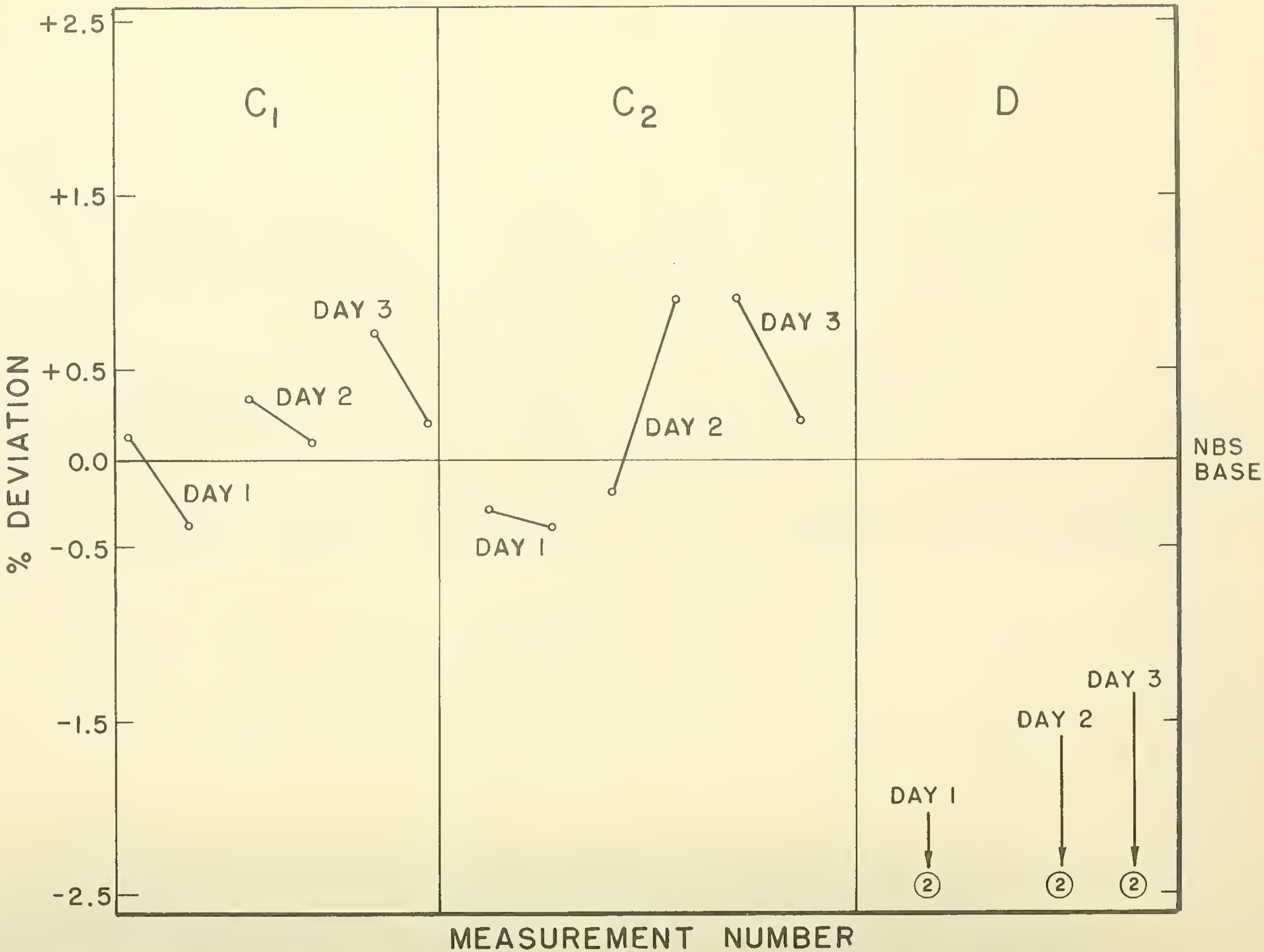


Fig. 4. 4 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 3.

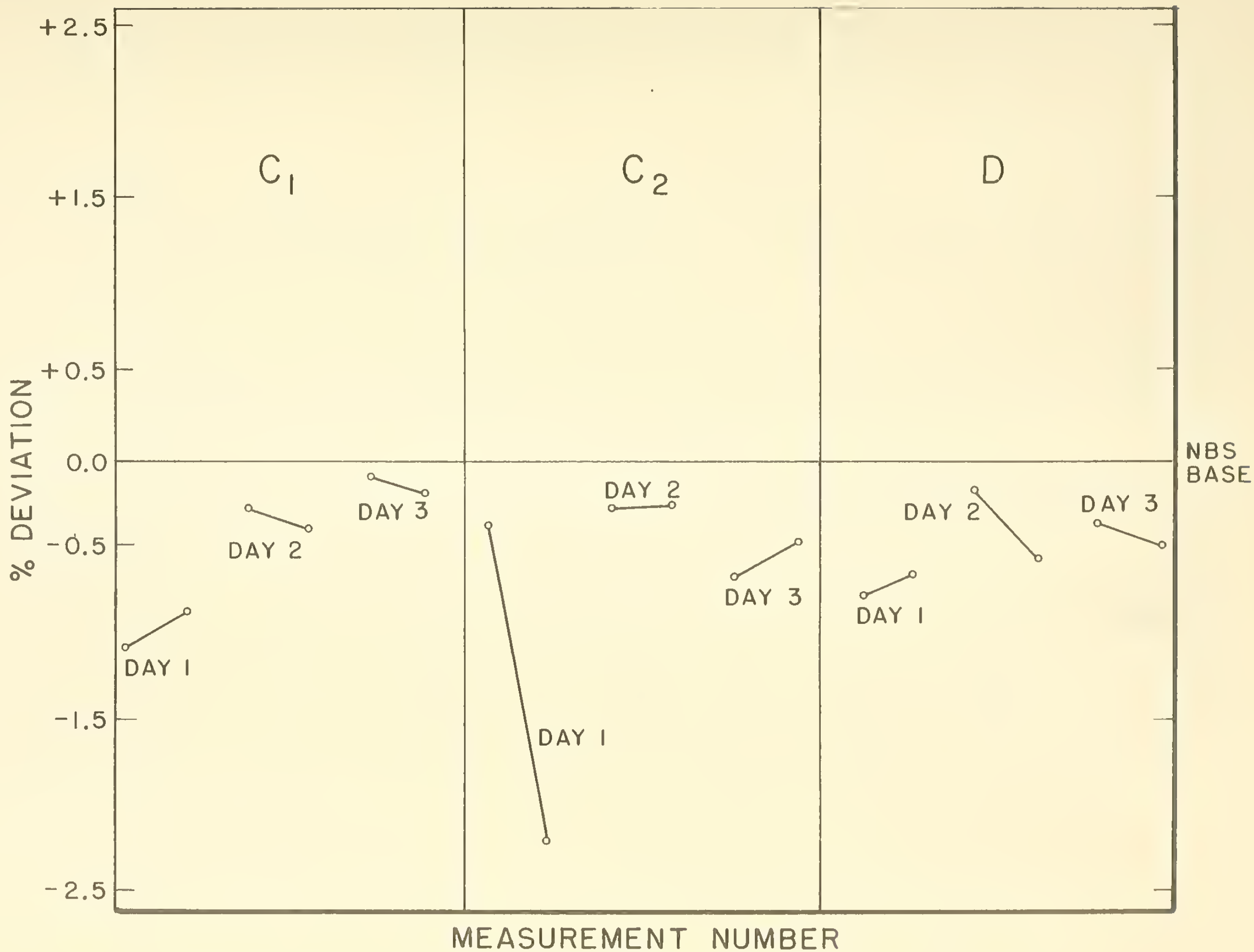


Fig. 4. 5 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 4.

Table 4.6

Photometric measurement of total luminous flux--Laboratory 5.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8801	2750.5	2794	43	1.6
		2788	37	1.4
		2788	37	1.4
		2788	37	1.4
		2787	36	1.3
		2788	37	1.4
8802	2805.7	2835	29	1.0
		2844	38	1.4
		2846	40	1.4
		2843	37	1.3
		2852	46	1.7
		2841	35	1.3
8908	2450.9	2411	-40	-1.6
		2408	-43	-1.8
		2418	-33	-1.3
		2410	-41	-1.7
		2411	-40	-1.6
		2409	-42	-1.7

Table 4.7

Photometric measurement of total luminous flux--Laboratory 6.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8813	2804.9	2293.5	-511.4	-18.2
		2303.5	-501.4	-17.9
		2263.6	-541.3	-19.3
		2249.7	-555.2	-19.8
		2253.2	-551.7	-19.7
		2251.2	-553.7	-19.7
8814	2847.5	2277.5	-570.0	-20.0
		2253.6	-593.9	-20.9
		2263.6	-583.9	-20.5
		2235.8	-611.7	-21.5
		2261.1	-586.4	-20.6
		2253.2	-594.3	-20.9
8913	2460.9	2069.9	-391.0	-15.9
		2056.0	-404.9	-16.5
		2043.2	-417.7	-17.0
		2039.2	-421.7	-17.1
		2058.1	-402.8	-16.4
		2050.2	-410.7	-16.7

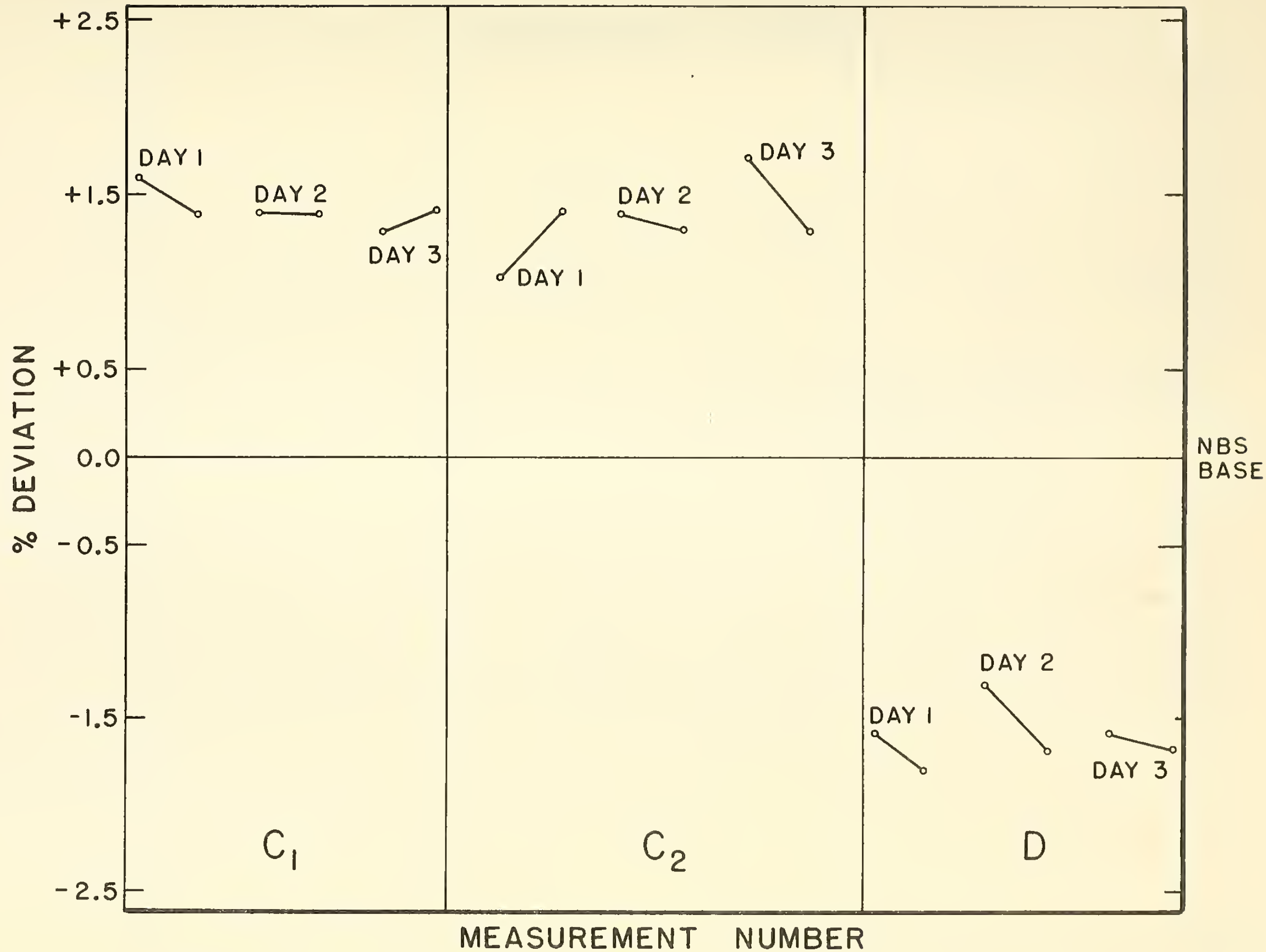


Fig. 4.6 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 5.

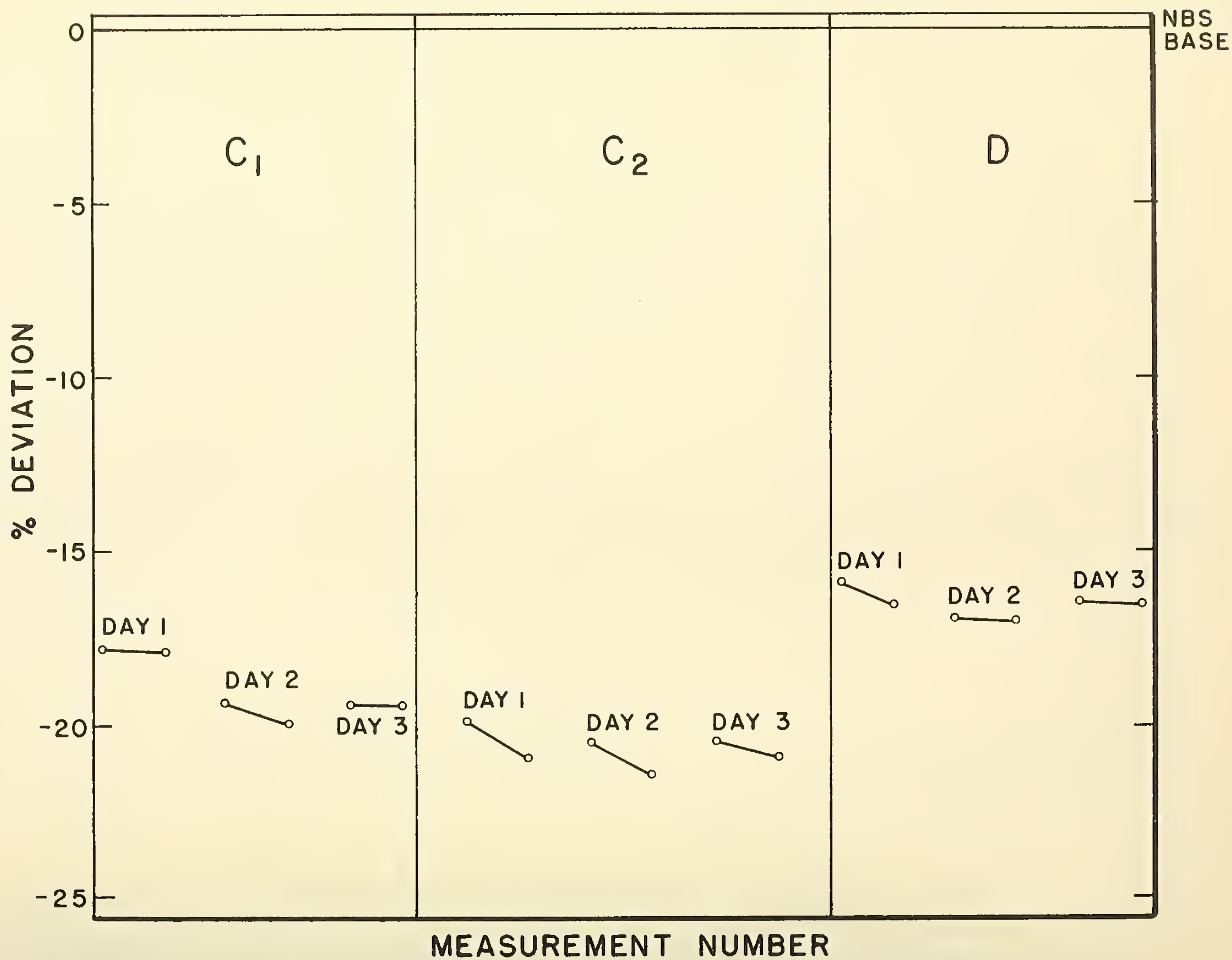


Fig. 4.7 NBS assignments compared to the photometric measurements of total luminous flux at laboratory 6.

Table 4.8

Photometric measurement of total luminous flux--Laboratory 7.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8795	2902.5	2918.5	16.0	0.6
		2910.4	7.9	0.3
		2895.1	- 7.4	-0.3
		2881.1	-21.4	-0.7
		2887.1	-15.4	-0.5
		2888.1	-14.4	-0.5
8796	2505.2	2492.7	-12.5	-0.5
		2551.8	46.6	1.9
		2506.4	1.2	0.0
		2521.3	16.1	0.6
		2512.7	7.5	0.3
		2512.7	7.5	0.3
8905	2472.5	2459.6	-49.0	-2.0
		2459.6	-12.9	-0.5
		2412.7	-59.8	-2.4
		2405.7	-66.8	-2.7
		2402.6	-69.9	-2.8
		2392.6	-79.9	-3.2

Table 4.9

Photometric measurement of total luminous flux--Laboratory 8.

Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
8803	2836.1	2836.9	0.8	0.0
		2862.9	26.8	0.9
		2812.7	-23.4	-0.8
		2820.6	-15.5	-0.5
		2856.2	20.1	0.7
		2850.3	14.2	0.5
8804	2858.3	2878.3	20.0	0.7
		2872.9	14.6	0.5
		2866.9	8.6	0.3
		2856.2	- 2.1	-0.1
		2850.3	- 8.0	-0.3
		2878.3	20.0	0.7
8908A	2476.2	2440.2	-36.0	-1.5
		2444.2	-32.0	-1.3
		2434.6	-41.6	-1.7
		2432.6	-43.6	-1.8
		2434.9	-41.3	-1.7
		2444.9	-31.3	-1.3

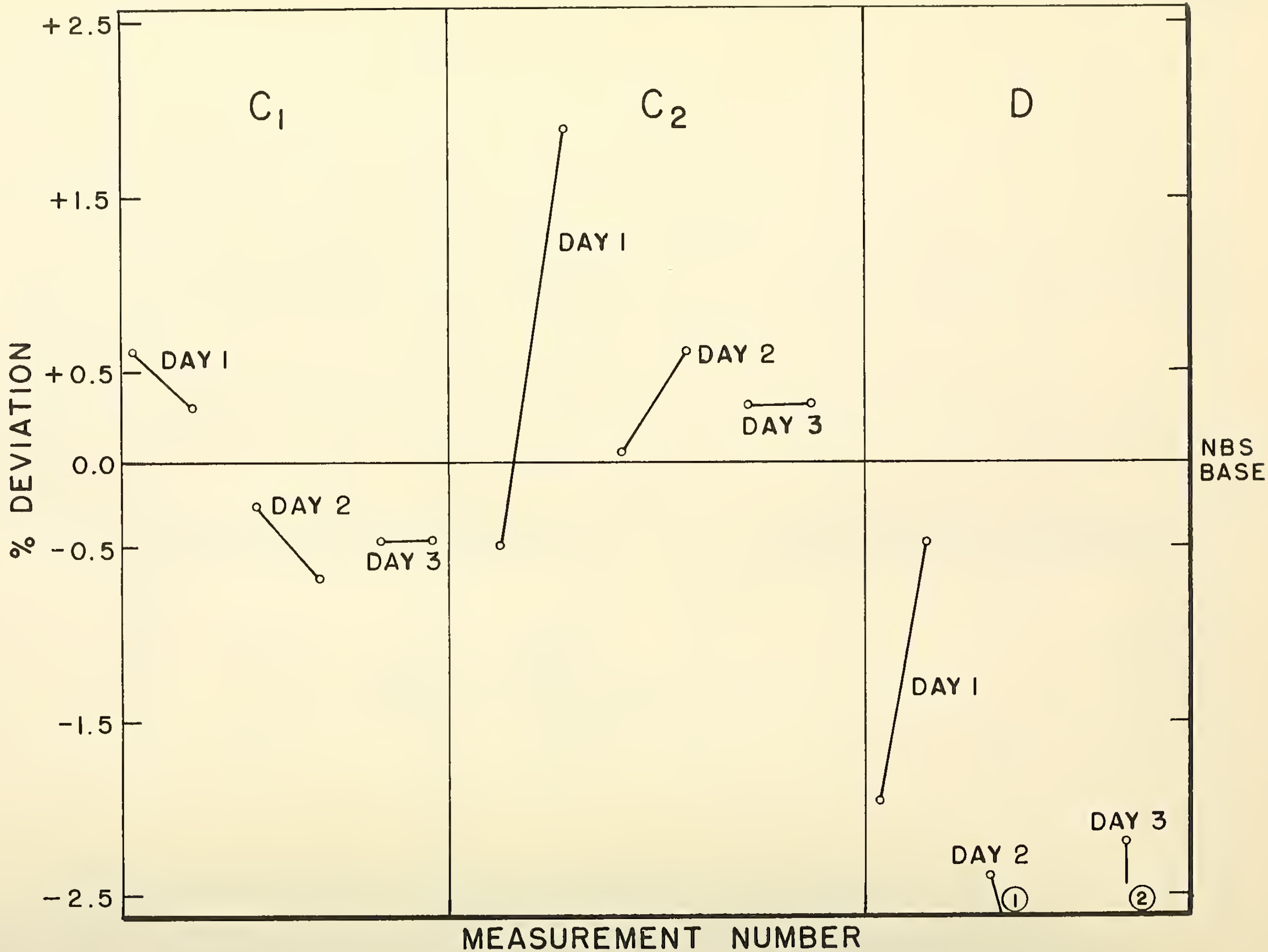


Fig. 4.8 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 7.

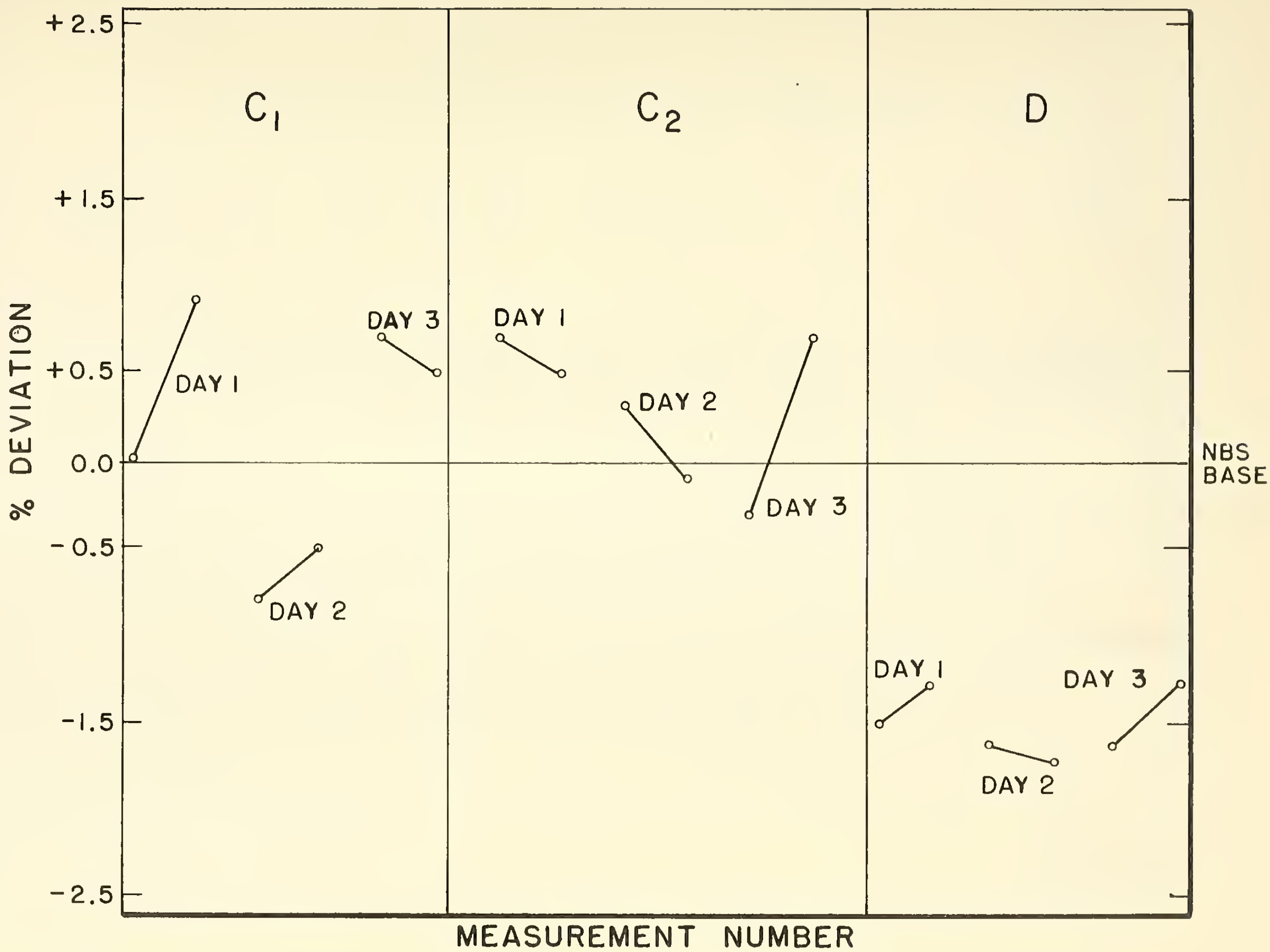


Fig. 4.9 NBS assignments compared to the photometric measurements of total luminous flux at Laboratory 8.

Table 4.10

Photometric measurement of total luminous flux--comprehensive average and standard deviation for each participating laboratory.

Laboratory	Lamp	Average (lumens)	Standard Deviation (lumens)
1	CW1 - 8797	2804	14.9
	CW2 - 8798	2856	23.4
	D - 8906	2490	10.7
2	CW1 - 8805	2797	4.8
	CW2 - 8806	2861	27.8
	D - 8909	2452	6.9
3	CW1 - 8807	2922	10.5
	CW2 - 8808	2903	16.6
	D - 8910	2392	6.2
4	CW1 - 8809	2769	12.1
	CW2 - 8810	2821	21.4
	D - 8911	2468	5.8
5	CW1 - 8801	2789	2.6
	CW2 - 8802	2844	5.6
	D - 8908	2411	3.5
6	CW1 - 8813	2269	23.5
	CW2 - 8814	2258	13.8
	D - 8913	2053	11.1
7	CW1 - 8795	2897	14.7
	CW2 - 8796	2516	19.8
	D - 8905	2416	23.7
8	CW1 - 8803	2840	20.1
	CW2 - 8804	2867	11.7
	D - 8908	2439	5.3

Table 4.11

Spectroradiometeric, integrating sphere measurement of total luminous flux

Laboratory	Lamp	NBS (lumens)	Lab (lumens)	Difference	Per Cent Difference
1	8797	2827	2770	- 57	- 2.0
			2808	- 19	- 0.7
			2825	- 2	- 0.1
	8798	2838	2851	13	0.5
			2830	- 8	- 0.3
			2823	- 15	- 0.5
	8906	2474	2407	- 67	- 2.7
			2424	- 50	- 2.0
			2427	- 47	- 1.9
2	8805	2795	2611	-184	- 6.6
			2587	-208	- 7.4
			2604	-191	- 6.8
	8806	2863	2685	-178	- 6.2
			2671	-192	- 6.7
			2629	-234	- 8.2
	8909	2480	2341	-139	- 5.6
			2337	-143	- 5.8
			2305	-175	- 7.0
4	8809	2783	3183	400	14.4
			3189	406	14.6
			3183	400	14.4
	8810	2842	3311	469	16.5
			3321	479	16.9
			3315	473	16.6
	8911	2481	2914	432	17.4
			2922	440	17.8
			2913	431	17.4
5	8801	2750	2737	- 13	- 0.5
			2748	- 3	- 0.1
			2752	1	0.1
	8802	2806	2782	- 24	- 0.8
			2775	- 31	- 1.1
			2800	- 6	- 0.2
	8908	2451	2393	- 58	- 2.4
			2394	- 57	- 2.3
			2548	97	4.0

Fig. 4.10 NBS assignments compared to the spectroradiometric, integrating sphere measurements of total luminous flux at each participating laboratory.

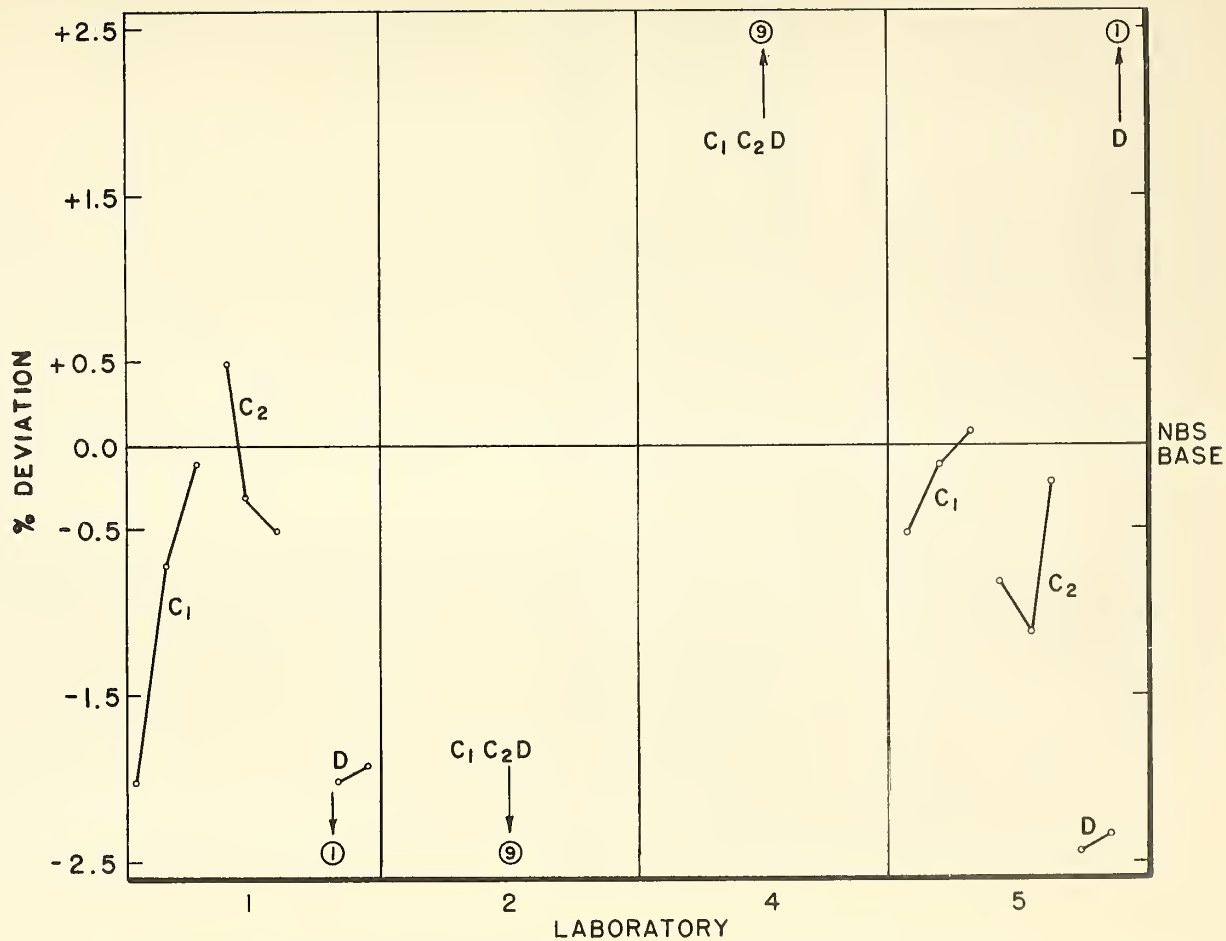


Fig. 4.11 NBS assignments compared to the spectroradiometric, integrating sphere measurements of total luminous flux at each participating laboratory--expanded scale.

4.2. Results and comparison of the measurements of color temperature and the x and y chromaticity coordinates

Color temperature and the x and y chromaticity coordinates were evaluated from the data obtained in parts 2 and 3 of the intercomparison; that is, from the spectroradiometric measurements of the lamp in an integrating sphere and of a 25 cm section of the lamp. The x and y chromaticity coordinates were also measured with a Barnes Colorimeter in part 5 of the intercomparison. Tables 4.12 through 4.21 contain the results of these three tests.

Table 4.12 gives the laboratory sphere determinations of color temperature and compares these with the NBS assignments. Figure 4.12 is a plot of this data.

The x and y chromaticity coordinates measured in the participating laboratories and assigned at NBS, as well as the differences between the two, are given in tables 4.13, 4.14, and figures 4.13, and 4.14.

Tables 4.15 and 4.16 present summaries of the precision of the spectroradiometric sphere measurements of total luminous flux, color temperature, and the x and y chromaticity coordinates.

Table 4.17 gives the laboratory evaluation of color temperature and the NBS assignment based on measurements of a 25 cm section of the lamps (part 3). Figure 4.15 gives a plot of the percent deviation of the laboratory values from the NBS values. Tables 4.18 and 4.19 and figures 4.16 and 4.17 present the same information for the x and y chromaticity coordinates. Tables 4.20 and 4.21 are summaries of the precision of 25 cm section measurements of color temperature and x and y chromaticity coordinates in the different laboratories. Table 4.22 gives a summary of the luminous flux measurements obtained by both the spectroradiometric and conventional photometric techniques.

Finally, tables 4.23, 4.24 and 4.25 give a summary of the average values obtained at NBS and at the participating laboratories for the color parameters measured in the intercomparison and the methods used to obtain them. These tables also contain the results of the Barnes Colorimeter measurements.

Table 4.12

Spectroradiometric, integrating sphere measurement of color temperature

Laboratory	Lamp	NBS (kelvins)	Lab (kelvins)	Difference
1	8797	4059	4076	17
			4066	7
			4109	50
	8798	4086	4127	41
			4133	47
			4061	- 25
	8906	6443	6584	141
			6518	75
			6527	84
2	8805	4110	4075	- 35
			3986	-124
			4095	- 15
	8806	4125	4100	- 25
			4097	- 28
			4093	- 32
	8909	6436	6351	- 85
			6319	-117
			6278	-158
4	8809	4101	4175	74
			4185	84
			4184	83
	8810	4085	4101	16
			4104	19
			4095	10
	8911	6450	6413	- 37
			6456	6
			6446	- 4
5	8801	4092	4144	52
			4129	37
			4134	42
	8802	4100	4111	11
			4144	44
			4142	42
	8908	6402	6291	-111
			6272	-130
			6457	55

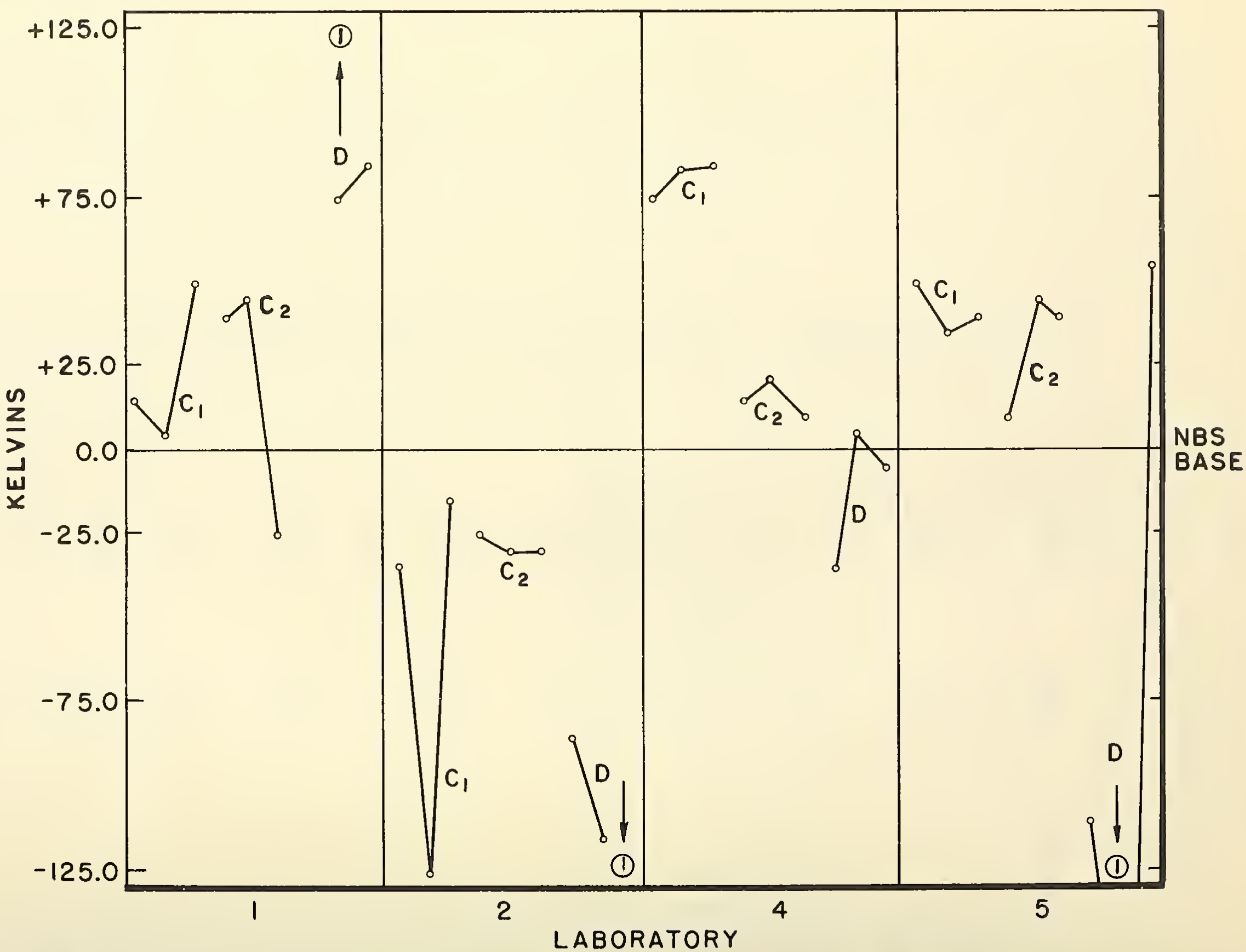


Fig. 4.12 NBS assignments compared to the spectroradiometric, integrating sphere measurements of color temperature at each participating laboratory.

Table 4.13

Spectroradiometric, integrating sphere measurement of the x chromaticity coordinate

Laboratory	Lamp	NBS x	Lab x	Difference
1	8797	0.3800	0.3786	-0.0014
			0.3794	-0.0006
			0.3777	-0.0023
	8798	0.3794	0.3769	-0.0025
			0.3770	-0.0024
			0.3796	0.0002
	8906	0.3131	0.3106	-0.0025
			0.3118	-0.0013
			0.3119	-0.0012
2	8805	0.3783	0.3806	0.0023
			0.3835	0.0052
			0.3797	0.0014
	8806	0.3774	0.3787	0.0013
			0.3790	0.0016
			0.3796	0.0022
	8909	0.3133	0.3147	0.0014
			0.3152	0.0019
			0.3158	0.0025
4	8809	0.3786	0.3768	-0.0018
			0.3760	-0.0026
			0.3762	-0.0024
	8810	0.3794	0.3795	0.0001
			0.3792	-0.0002
			0.3797	0.0003
	8911	0.3131	0.3132	0.0001
			0.3128	-0.0003
			0.3130	-0.0001
5	8801	0.3790	0.3783	-0.0007
			0.3795	0.0005
			0.3794	0.0004
	8802	0.3787	0.3800	0.0013
			0.3788	0.0001
			0.3790	0.0003
	8908	0.3137	0.3153	0.0016
			0.3159	0.0022
			0.3124	-0.0013

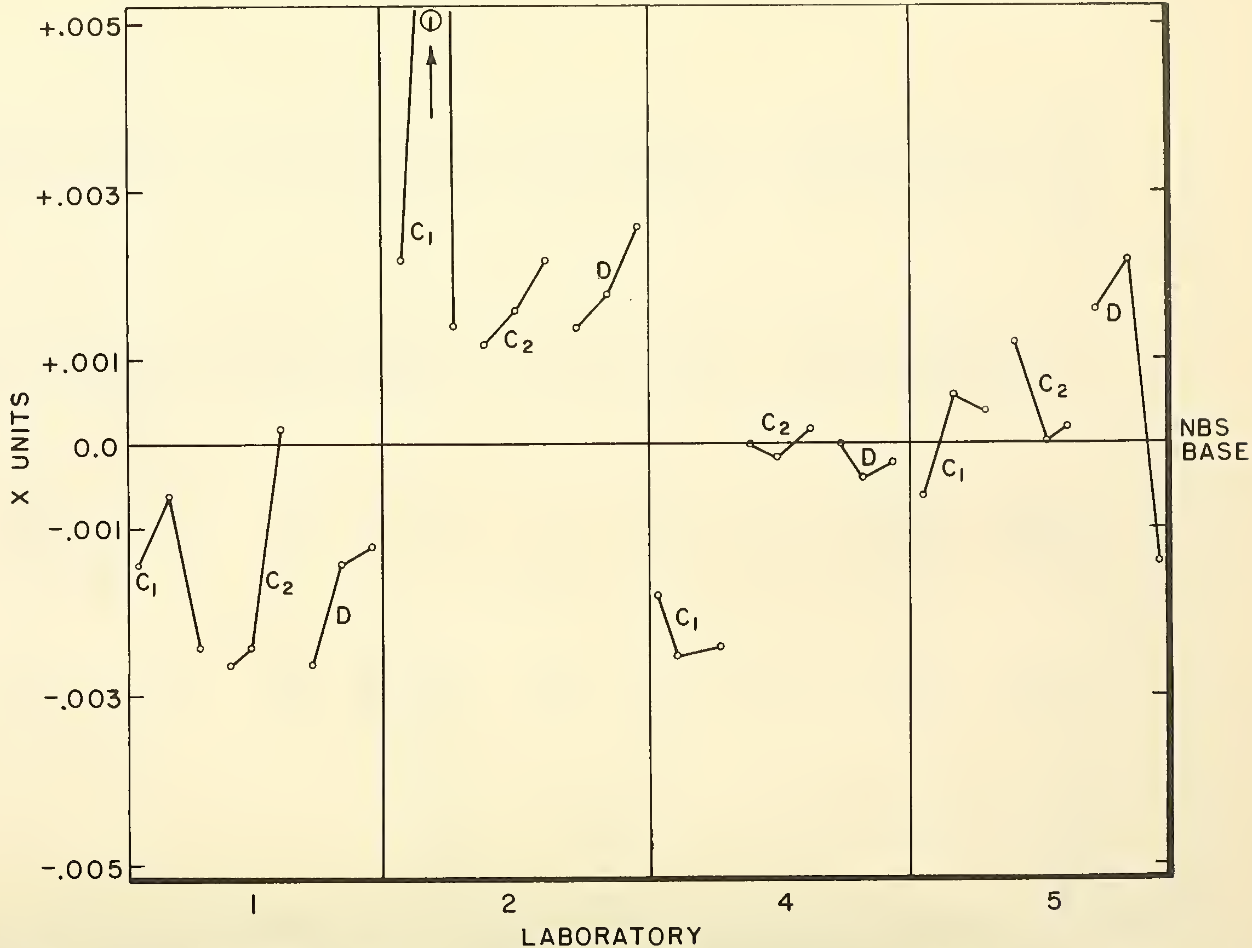


Fig. 4.13 NBS assignments compared to the spectroradiometric, integrating sphere measurements of the x chromaticity coordinate at each participating laboratory.

Table 4.14

Spectroradiometric, integrating sphere measurement of the y chromaticity coordinate

Laboratory	Lamp	NBS y	Lab y	Difference
1	8797	0.3837	0.3805	-0.0032
			0.3820	-0.0017
			0.3816	-0.0021
	8798	0.3850	0.3811	-0.0039
			0.3824	-0.0026
			0.3822	-0.0028
	8906	0.3358	0.3329	-0.0029
			0.3341	-0.0017
			0.3326	-0.0032
2	8805	0.3844	0.3881	0.0037
			0.3865	0.0021
			0.3880	0.0036
	8806	0.3830	0.3845	0.0015
			0.3852	0.0022
			0.3869	0.0039
	8909	0.3356	0.3370	0.0014
			0.3380	0.0024
			0.3395	0.0039
4	8809	0.3842	0.3870	0.0028
			0.3856	0.0014
			0.3865	0.0023
	8810	0.3851	0.3879	0.0028
			0.3870	0.0019
			0.3878	0.0027
	8911	0.3351	0.3381	0.0030
			0.3370	0.0019
			0.3373	0.0022
5	8801	0.3844	0.3899	0.0055
			0.3919	0.0075
			0.3922	0.0078
	8802	0.3844	0.3909	0.0065
			0.3922	0.0078
			0.3917	0.0073
	8908	0.3357	0.3424	0.0067
			0.3433	0.0076
			0.3410	0.0053

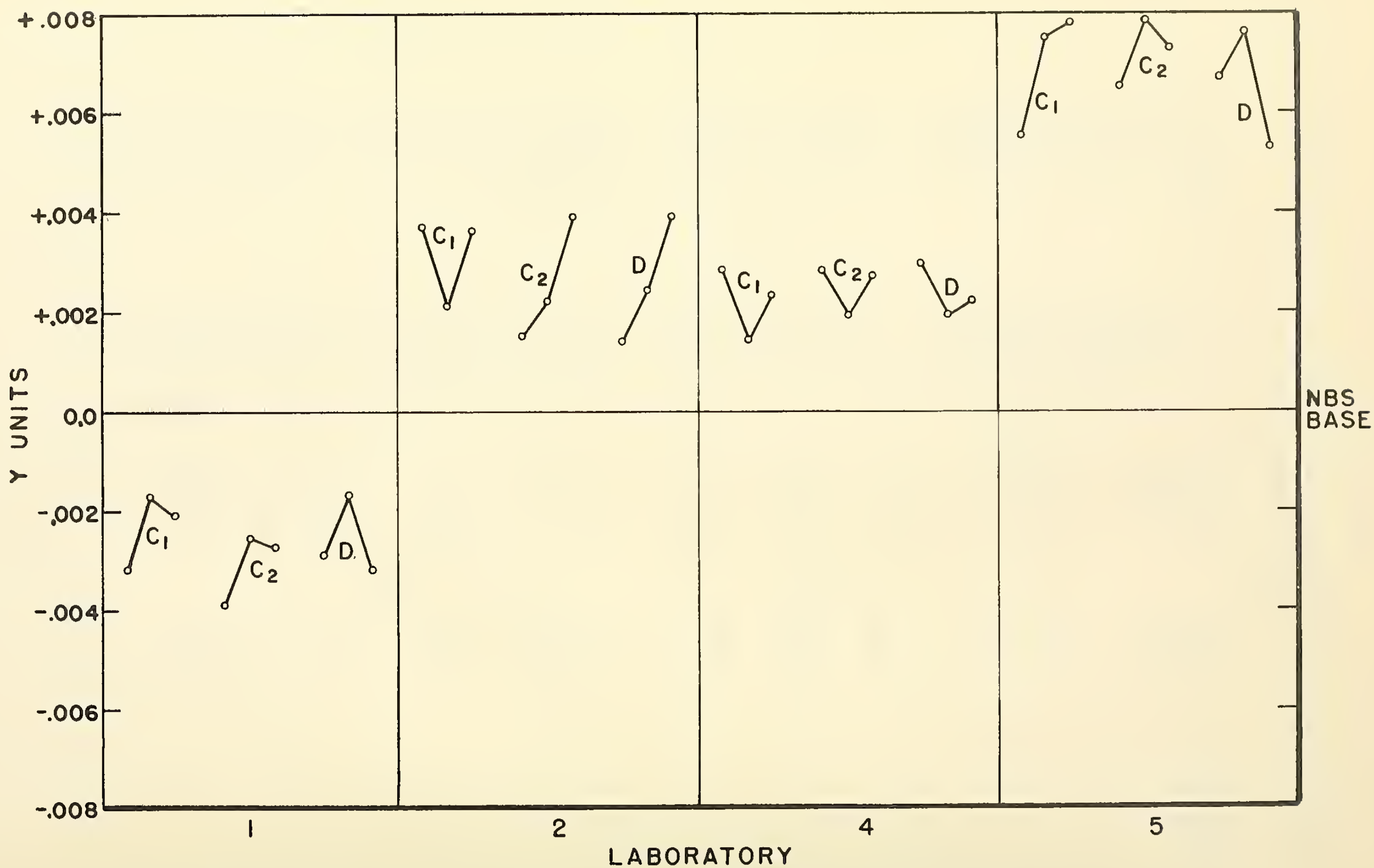


Fig. 4.14 NBS assignments compared to the spectroradiometric, integrating sphere measurements of the y chromaticity coordinate at each participating laboratory.

Table 4.15

Spectroradiometric, integrating sphere measurement of luminous flux and color temperature--comprehensive average and standard deviation for each participating laboratory

Laboratory	Lamp	Luminous Flux	Standard Deviation	Color Temperature	Standard Deviation
1	8797	2801	28	4084	23
	8798	2835	15	4107	40
	8906	2419	11	6543	36
2	8805	2601	12	4052	58
	8806	2662	29	4097	4
	8909	2328	20	6316	37
4	8809	3185	3	4181	6
	8810	3316	5	4100	5
	8911	2916	5	6438	23
5	8801	2746	8	4136	8
	8802	2786	13	4132	19
	8908	2445	89	6340	102

Table 4.16

Spectroradiometeric, integrating sphere measurement of the x and y chromaticity coordinates - comprehensive average and standard deviation for each participating laboratory

Laboratory	Lamp	x	Standard Deviation	y	Standard Deviation
1	8797	0.3786	0.0009	0.3814	0.0008
	8798	0.3778	0.0015	0.3819	0.0007
	8906	0.3114	0.0007	0.3332	0.0008
2	8805	0.3813	0.0020	0.3875	0.0009
	8806	0.3791	0.0005	0.3855	0.0012
	8909	0.3152	0.0006	0.3382	0.0013
4	8809	0.3763	0.0004	0.3864	0.0007
	8810	0.3795	0.0003	0.3876	0.0005
	8911	0.3130	0.0002	0.3375	0.0006
5	8801	0.3791	0.0007	0.3913	0.0013
	8802	0.3793	0.0006	0.3916	0.0007
	8908	0.3145	0.0019	0.3422	0.0012

Table 4.17

Spectroradiometric, 25 cm lamp section measurement of color temperature

Laboratory	Lamp	NBS (kelvins)	Lab (kelvins)	Difference
1	8797	4080	3987	- 93
			3990	- 90
			4033	- 47
	8798	4070	3990	- 80
			3982	- 88
			4002	- 68
	8906	6507	6193	- 314
			6476	- 31
			6492	- 15
2	8805	4093	4099	6
			4098	5
			4093	0
	8806	4107	4122	15
			4114	7
			4116	9
	8909	6457	6419	- 38
			6372	- 85
			6450	- 8
4	8809	4111	4129	18
			4090	- 21
			4070	- 41
	8810	4073	4083	9
			4101	27
			4128	54
	8911	6467	6280	- 187
			6271	- 196
			6374	- 93
5	8801	4091	4139	48
			4145	54
			4141	50
	8802	4118	4186	68
			4141	23
			4138	20
	8908	6412	6383	- 29
			6377	- 35
			6305	- 107
7	8795	4111	3773	- 338
			3758	- 353
			3711	- 400
	8796	3996	3658	- 338
			3693	- 303
			3606	- 390
	8905	6465	5269	-1196
			5381	-1084
			5151	-1314
9	8799	4089	4075	- 14
			4080	- 9
			4089	0
	8800	4071	4083	12
			4075	4
			4089	18
	8907	6435	6433	- 2
			6446	11
			6442	7

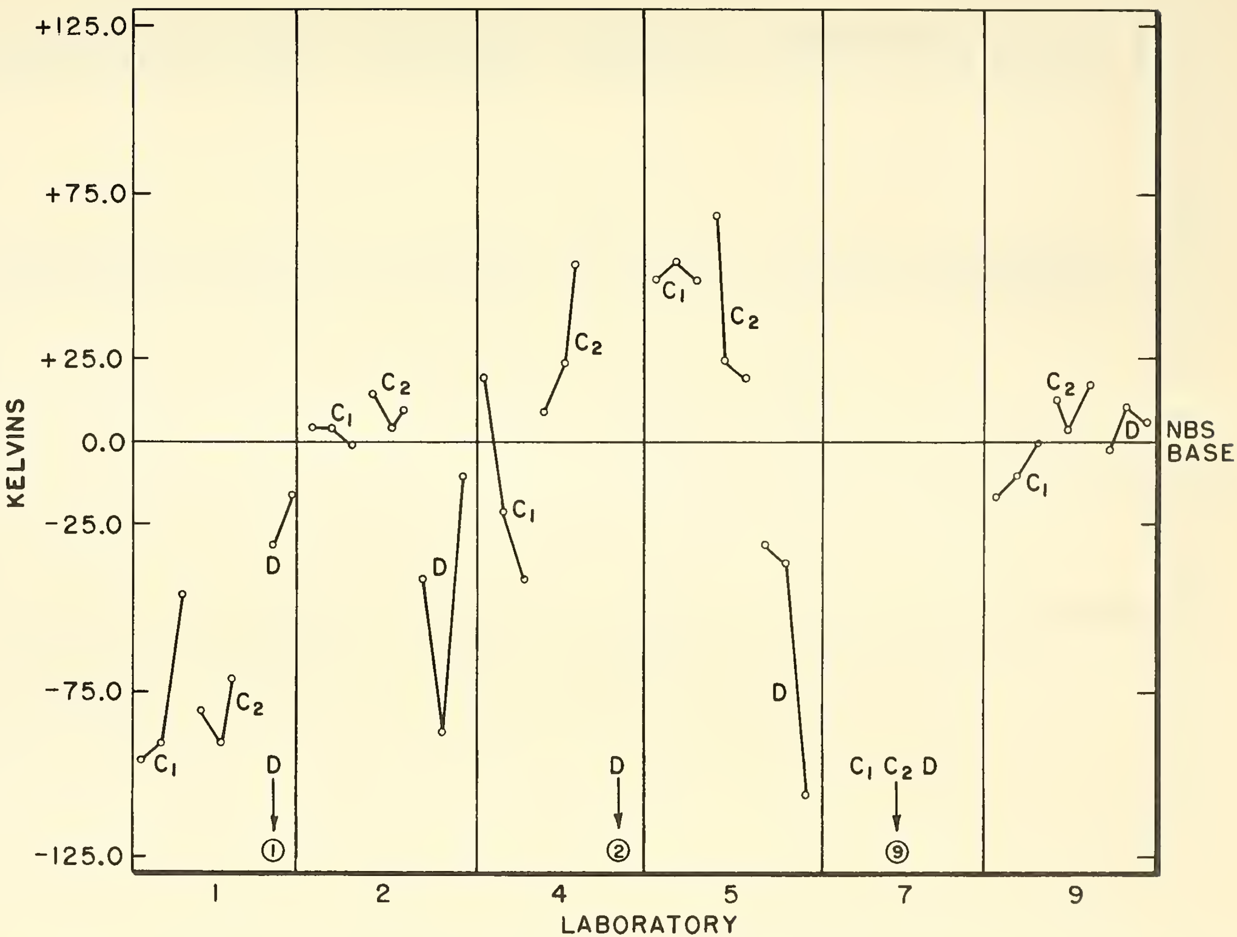


Fig. 4.15 NBS assignments compared to the spectroradiometric, 25 cm lamp section measurements of color temperature at each participating laboratory.

Table 4.18

Spectroradiometric, 25 cm lamp section measurement of the x chromaticity coordinate

Laboratory	Lamp	NBS x	Lab x	Difference
1	8797	0.3788	0.3837	0.0049
			0.3837	0.0049
			0.3823	0.0035
	8798	0.3801	0.3843	0.0042
			0.3843	0.0042
			0.3835	0.0034
	8906	0.3120	0.3171	0.0051
			0.3122	0.0002
			0.3124	0.0004
2	8805	0.3786	0.3788	0.0002
			0.3787	0.0001
			0.3792	0.0006
	8806	0.3778	0.3775	-0.0003
			0.3780	0.0002
			0.3779	0.0001
	8909	0.3132	0.3135	0.0003
			0.3144	0.0012
			0.3131	-0.0001
4	8809	0.3780	0.3780	0.0000
			0.3803	0.0023
			0.3810	0.0030
	8810	0.3800	0.3803	0.0003
			0.3793	-0.0007
			0.3791	-0.0009
	8911	0.3129	0.3157	0.0028
			0.3160	0.0031
			0.3142	0.0013
5	8801	0.3789	0.3786	-0.0003
			0.3784	-0.0005
			0.3785	-0.0004
	8802	0.3778	0.3766	-0.0012
			0.3783	0.0005
			0.3788	0.0010
	8908	0.3137	0.3138	0.0001
			0.3138	0.0001
			0.3150	0.0013
7	8795	0.3776	0.3994	0.0218
			0.4002	0.0226
			0.4031	0.0255
	8796	0.3832	0.4059	0.0227
			0.4049	0.0217
			0.4103	0.0271
	8905	0.3129	0.3392	0.0263
			0.3364	0.0235
			0.3426	0.0297
9	8799	0.3787	0.3793	0.0006
			0.3791	0.0004
			0.3785	-0.0002
	8800	0.3792	0.3793	0.0001
			0.3794	0.0002
			0.3789	-0.0003
	8907	0.3134	0.3134	0.0000
			0.3132	-0.0002
			0.3133	-0.0001

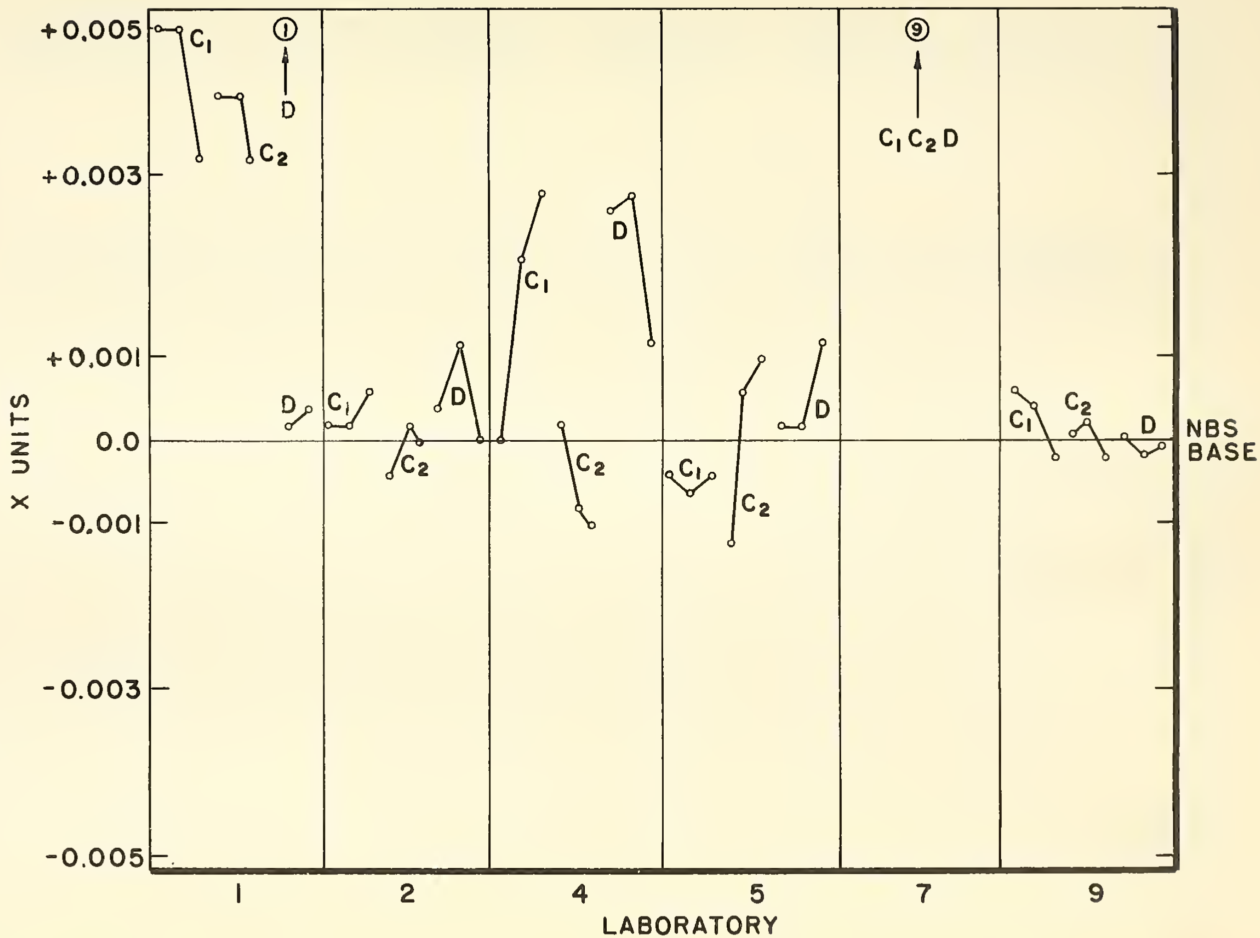


Fig. 4.16 NBS assignments compared to the spectroradiometric, 25 cm lamp section measurements of the x chromaticity coordinate at each participating laboratory.

Table 4.19

Spectroradiometric, 25 cm lamp section measurement of the y chromaticity coordinate

Laboratory	Lamp	NBS y	Lab y	Difference
1	8797	0.3819	0.3874	0.0055
			0.3877	0.0058
			0.3876	0.0057
	8798	0.3852	0.3897	0.0045
			0.3887	0.0035
			0.3887	0.0035
	8906	0.3347	0.3405	0.0058
			0.3350	0.0003
			0.3352	0.0005
2	8805	0.3823	0.3850	0.0027
			0.3844	0.0021
			0.3855	0.0032
	8806	0.3821	0.3825	0.0004
			0.3835	0.0014
			0.3833	0.0012
	8909	0.3342	0.3353	0.0011
			0.3366	0.0024
			0.3353	0.0011
4	8809	0.3830	0.3860	0.0030
			0.3891	0.0061
			0.3887	0.0057
	8810	0.3856	0.3881	0.0025
			0.3870	0.0014
			0.3902	0.0046
	8911	0.3342	0.3400	0.0058
			0.3394	0.0052
			0.3380	0.0038
5	8801	0.3837	0.3898	0.0061
			0.3900	0.0063
			0.3903	0.0066
	8802	0.3823	0.3885	0.0062
			0.3888	0.0065
			0.3904	0.0081
	8908	0.3350	0.3405	0.0055
			0.3409	0.0059
			0.3421	0.0071
7	8795	0.3817	0.4092	0.0275
			0.4096	0.0279
			0.4133	0.0316
	8796	0.3865	0.4126	0.0261
			0.4154	0.0289
			0.4185	0.0320
	8905	0.3336	0.3692	0.0356
			0.3692	0.0356
			0.3759	0.0423
9	8799	0.3828	0.3827	-0.0001
			0.3832	0.0004
			0.3820	-0.0008
	8800	0.3826	0.3842	0.0016
			0.3835	0.0009
			0.3834	0.0008
	8907	0.3349	0.3358	0.0009
			0.3351	0.0002
			0.3352	0.0003

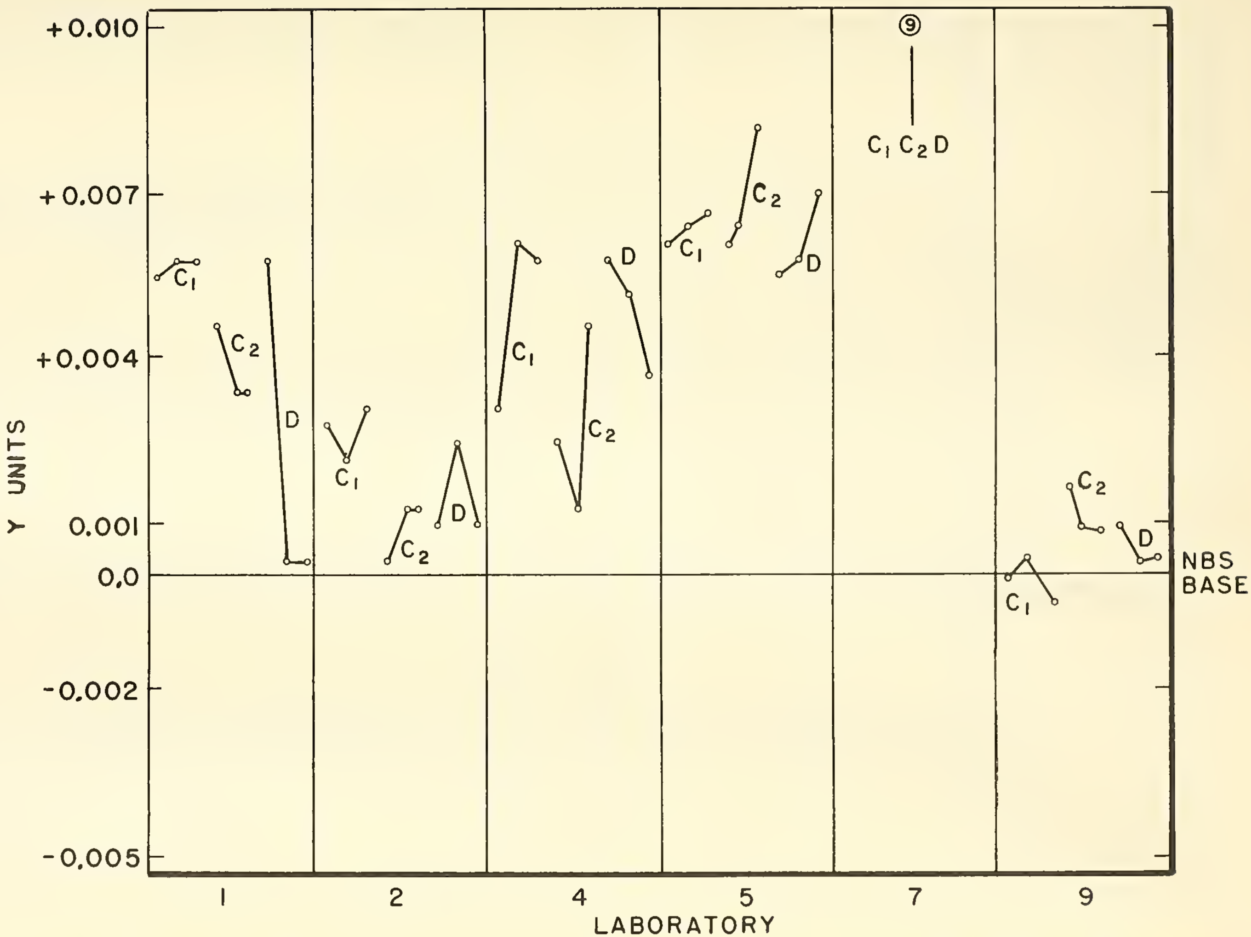


Fig. 4.17 NBS assignments compared to the spectroradiometric, 25 cm lamp section measurements of the y chromaticity coordinate at each participating laboratory.

Table 4.20

Spectroradiometric, 25 cm lamp section measurement of color temperature -- comprehensive average and standard deviation for each participating laboratory

Laboratory	Lamp	Average (kelvins)	Standard Deviation
1	8797	4003	26
	8798	3991	10
	8906	6387	168
2	8805	4097	3
	8806	4117	4
	8909	6414	39
4	8809	4096	30
	8810	4104	23
	8911	6308	57
5	8801	4142	3
	8802	4155	27
	8908	6355	43
7	8795	3747	32
	8796	3652	44
	8905	5267	115
9	8799	4081	7
	8800	4082	7
	8907	6440	7

Table 4.21

Spectroradiometric, 25 cm lamp section measurement of the x and y chromaticity coordinates -- comprehensive average and standard deviation for each participating laboratory

Laboratory	Lamp	Average x	Standard Deviation	Average y	Standard Deviation
1	8797	0.3832	0.0008	0.3876	0.0002
	8798	0.3840	0.0005	0.3890	0.0006
	8906	0.3139	0.0028	0.3369	0.0031
2	8805	0.3789	0.0003	0.3850	0.0006
	8806	0.3778	0.0003	0.3831	0.0005
	8909	0.3137	0.0007	0.3357	0.0008
4	8809	0.3798	0.0016	0.3879	0.0017
	8810	0.3796	0.0006	0.3884	0.0016
	8911	0.3153	0.0010	0.3391	0.0010
5	8801	0.3785	0.0001	0.3900	0.0003
	8802	0.3779	0.0012	0.3892	0.0010
	8908	0.3142	0.0007	0.3412	0.0008
7	8795	0.4009	0.0019	0.4107	0.0023
	8796	0.4070	0.0029	0.4155	0.0030
	8905	0.3394	0.0031	0.3714	0.0039
9	8799	0.3790	0.0004	0.3826	0.0006
	8800	0.3792	0.0003	0.3837	0.0004
	8907	0.3133	0.0001	0.3354	0.0004

Table 4.22

Comparison of the photometric and spectroradiometric measurements of total luminous flux.

Laboratory	Lamp	Lamp type	NBS (lumens) Photometric	NBS (lumens) Spectro-radiometric	Lab (lumens) Photometric	Lab (lumens) Spectro-radiometric
1	8797	CW1	2820	2833	2804	2801
	8798	CW2	2833	2842	2856	2835
	8906	D	2464	2482	2490	2419
2	8805	CW1	2792	2798	2797	2601
	8806	CW2	2863	2864	2861	2662
	8909	D	2485	2474	2452	2328
3	8807	CW1	2911	2924	2922	--
	8808	CW2	2895	2902	2903	--
	8910	D	2472	2460	2392	--
4	8809	CW1	2777	2789	2769	3185
	8810	CW2	2840	2844	2821	3316
	8911	D	2485	2478	2468	2916
5	8801	CW1	2751	2750	2789	2746
	8802	CW2	2808	2804	2844	2786
	8908	D	2452	2450	2411	2445
6	8813	CW1	2797	2812	2269	--
	8814	CW2	2847	2848	2258	--
	8913	D	2469	2454	2053	--
7	8795	CW1	2946	2936	2897	--
	8796	CW2	2514	2499	2516	--
	8905	D	2478	2467	2416	--
8	8803	CW1	2834	2838	2840	--
	8804	CW2	2857	2860	2867	--
	8908A	D	2480	2473	2439	--

Table 4.23

Comparison of the integrating sphere and the 25 cm lamp section spectroradiometric measurements of color temperature.

			NBS (kelvins)		Lab (kelvins)	
Laboratory	Lamp	Lamp type	Sphere	25 cm section	Sphere	25 cm section
1	8797	CW1	4059	4080	4084	4003
	8798	CW2	4086	4070	4107	3991
	8906	D	6443	6507	6543	6387
2	8805	CW1	4110	4093	4052	4097
	8806	CW2	4125	4107	4097	4117
	8909	D	6436	6457	6316	6414
4	8809	CW1	4101	4111	4181	4096
	8810	CW2	4085	4073	4100	4104
	8911	D	6450	6461	6438	6308
5	8801	CW1	4092	4091	4136	4142
	8802	CW2	4100	4118	4132	4155
	8908	D	6402	6412	6340	6355
7	8795	CW1	4130	4111	--	3747
	8796	CW2	3996	3996	--	3652
	8905	D	6431	6465	--	5267
9	8799	CW1	4073	4089	--	4081
	8800	CW2	4067	4071	--	4082
	8907	D	6427	6435	--	6440

Table 4.24

Comparison of the integrating sphere and the 25 cm lamp section spectroradiometric measurements, and the Barnes colorimetric measurement of the x chromaticity coordinate.

			NBS x		Lab x		
Laboratory	Lamp	Lamp type	Sphere	25 cm section	Sphere	25 cm section	Barnes
1	8797	CW1	0.3800	0.3788	0.3786	0.3832	0.3845
	8798	CW2	0.3794	0.3801	0.3778	0.3840	0.3845
	8906	D	0.3131	0.3120	0.3114	0.3139	0.3178
2	8805	CW1	0.3783	0.3786	0.3813	0.3789	0.3832
	8806	CW2	0.3774	0.3778	0.3791	0.3778	0.3825
	8909	D	0.3133	0.3132	0.3152	0.3137	0.3148
3	8807	CW1	0.3776	0.3778	-	-	0.3784
	8808	CW2	0.3766	0.3768	-	-	0.3776
	8910	D	0.3133	0.3134	-	-	0.3151
4	8809	CW1	0.3786	0.3780	0.3763	0.3798	0.3824
	8810	CW2	0.3794	0.3800	0.3795	0.3796	0.3842
	8911	D	0.3131	0.3130	0.3130	0.3153	0.3169
5	8801	CW1	0.3790	0.3789	0.3791	0.3785	0.3730
	8802	CW2	0.3787	0.3776	0.3793	0.3779	0.3730
	8908	D	0.3137	0.3137	0.3145	0.3142	0.3150
7	8795	CW1	0.3773	0.3776	-	0.4009	0.3820
	8796	CW2	0.3833	0.3832	-	0.4070	0.3875
	8905	D	0.3134	0.3129	-	0.3394	0.3161
8	8803	CW1	0.3798	0.3800	-	-	0.3854
	8804	CW2	0.3798	0.3798	-	-	0.3851
	8908A	D	0.3134	0.3136	-	-	0.3137
9	8799	CW1	0.3794	0.3787	-	0.3790	-
	8800	CW2	0.3794	0.3792	-	0.3792	-
	8907	D	0.3134	0.3134	-	0.3133	-

Table 4.25

Comparison of the integrating sphere and the 25 cm lamp section spectroradiometric measurements, and the Barnes colorimetric measurement of the y chromaticity coordinate.

			NBS y		Lab y		
Laboratory	Lamp	Lamp type	Sphere	25 cm section	Sphere	25 cm section	Barnes
1	8797	CW1	0.3837	0.3819	0.3814	0.3876	0.3895
	8798	CW2	0.3850	0.3852	0.3819	0.3890	0.3905
	8906	D	0.3358	0.3347	0.3332	0.3369	0.3410
2	8805	CW1	0.3844	0.3832	0.3875	0.3850	0.3895
	8806	CW2	0.3830	0.3821	0.3855	0.3831	0.3878
	8909	D	0.3356	0.3342	0.3382	0.3357	0.3401
3	8807	CW1	0.3827	0.3818	-	-	0.3857
	8808	CW2	0.3811	0.3792	-	-	0.3843
	8910	D	0.3351	0.3344	-	-	0.3401
4	8809	CW1	0.3842	0.3830	0.3864	0.3879	0.3885
	8810	CW2	0.3851	0.3856	0.3876	0.3884	0.3897
	8811	D	0.3351	0.3340	0.3375	0.3391	0.3402
5	8801	CW1	0.3844	0.3837	0.3913	0.3900	0.3850
	8802	CW2	0.3844	0.3823	0.3916	0.3892	0.3850
	8908	D	0.3357	0.3350	0.3422	0.3412	0.3370
7	8795	CW1	0.3831	0.3817	-	0.4107	0.3863
	8796	CW2	0.3870	0.3865	-	0.4155	0.3907
	8905	D	0.3350	0.3336	-	0.3714	0.3395
8	8803	CW1	0.3842	0.3837	-	-	0.3913
	8804	CW2	0.3843	0.3834	-	-	0.3916
	8908A	D	0.3352	0.3345	-	-	0.3416
9	8799	CW1	0.3830	0.3828	-	0.3826	-
	8800	CW2	0.3836	0.3826	-	0.3837	-
	8907	D	0.3357	0.3349	-	0.3354	-

4.3. Results and comparison of the spectral distribution measurements

The spectral distribution data from each laboratory are given in tables 4.26 through 4.67 and plotted in figures 4.18 through 4.59. These data include both the spectroradiometric measurement of the total lamp output in an integrating sphere and that of a 25 cm section of the lamp. Summarization and compilation of these results are included in the tables and figures listed in the previous section.

In examining the detailed data compiled in this section, one should note that the intercomparison was statistically designed to use the data acquired at NBS as a base. Therefore, data from the spectroradiometric equipment at the participating laboratories will be evaluated against the NBS base. Consistent differences from the NBS base in all the data would indicate, of course, that the problem may be at NBS itself.

From an examination of all of the spectral distribution curves it appears that most of the curves do not match in the regions of the mercury lines. The largest deviations are in the region near 580 nm. Since the curvature of the continuum is greatest at this mercury line, the efficiency of the fit of a quadratic polynominal may be in question. Perhaps a better interpolation procedure at NBS would have eliminated this problem. No other consistent deviations were observed between NBS and the other laboratories. The individual laboratory deviations will now be examined.

If the data from each laboratory (see also the tables and figures in section 4.2) are different from NBS or from the overall laboratory average, this could be indicative of problems in experimental technique. Effects of system non-linearity, improper sphere size, inadequate or improperly arranged baffling, scattered light within the monochromator, inadequate (or the absence of) filtering of second-order spectra and, of course, the individualism of each operator will contribute to differences in the measurement of the color parameters and total luminous flux.

LABORATORY 1: Agreement between this laboratory's spectroradiometric measurement of total luminous flux and that of NBS was close. The small difference may be attributable to system non-linearity either at this laboratory or at NBS. This point cannot be checked, of course, without additional experiments.

LABORATORY 2: The spectroradiometric values of total luminous flux obtained in this laboratory's sphere were low compared to the other participating laboratories. Small sphere size and the arrangement of lamps and baffling within the sphere are suspected as the principal reasons for these low values. However, the difficulties encountered in the data analysis may have introduced discrepancies and would, of course, obscure the identification of problems in experimental technique.

LABORATORY 4: This laboratory's sphere measurements of total luminous flux were extremely high and may have been caused by inadequate baffling of the lamps. Difficulties were encountered in the analysis of the data from this laboratory and may have obfuscated the identification of problems in experimental technique. The relative spectral flux distribution curves for this laboratory appear to be higher than those of NBS in the 440 to 520 nm region. This laboratory used synchronous amplification and, therefore, chopped the light output at 90 Hz. Because the various phosphors used in the lamp do not have the same decay time, the light output from each phosphor was probably sampled to a different extent. The spectral flux in the region around 590 nm is also considerably different from that of NBS. Since this laboratory used a prism monochromator and did not indicate frequent wavelength calibration checks, the cam in the wavelength drive of the instrument may have been off calibration in this region.

LABORATORY 5: This laboratory's sphere measurements of total luminous flux were close to those of NBS. However, a spurious line appears at 700 nm and the spectral flux distribution curves exhibit a decrease from the NBS curves toward the red region of the spectrum. The line may be due to an emission from the coating used on their integrating box but this does not explain the relative decrease in this region. If this is not an effect produced by the 3M "Velvet

White" coating, then it is suspected either that the sensitivity of their photomultiplier has decreased in this spectral region or that the gain and/or the sensitivity of their electronics consistently drifted during the course of a single run.

LABORATORY 7: Data from Laboratory 7 agreed very poorly with those of all of the other participating laboratories. Their spectroradiometric equipment appeared to have most of the problems that afflict spectroradiometry.

LABORATORY 9: This laboratory submitted only relative spectral irradiance measurements, and these agreed closely with those made at NBS.

NATIONAL BUREAU OF STANDARDS: Careful analysis of the NBS Initial and Repeat spectroradiometric measurements indicates that a small wavelength shift occurred in the interim between measurements. The shift was definitely less than the instrument bandpass and much too small to be detected in a data comparison with the other laboratories.

TABLE 4.26

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8797

	NBS INITIAL			LABORATORY 1			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	3.8	4.2	3.9	.0	.0	.0	3.6	3.6	3.7
390.0	5.8	6.2	6.0	6.6	6.1	7.3	5.7	5.6	5.8
400.0	8.5	8.6	8.6	8.9	9.2	8.8	8.2	8.1	8.3
410.0	10.8	10.8	10.8	11.1	10.5	10.8	10.6	10.4	10.6
420.0	13.1	13.2	13.2	13.5	13.0	13.5	13.0	12.9	13.0
430.0	15.9	16.1	16.0	16.1	16.7	16.9	15.8	15.9	15.8
440.0	18.4	18.6	18.5	19.3	18.8	19.4	18.4	18.4	18.3
450.0	20.7	20.6	20.7	21.5	20.8	21.0	20.7	20.8	20.6
460.0	22.4	22.3	22.5	22.7	22.7	21.7	22.5	22.5	22.4
470.0	23.5	23.4	23.5	23.9	23.6	23.9	23.5	23.6	23.6
480.0	23.8	23.8	23.9	24.0	24.0	23.8	23.9	24.0	23.9
490.0	23.8	23.8	23.9	23.7	23.8	23.4	23.9	23.9	23.9
500.0	22.8	22.8	22.9	22.9	22.9	22.7	23.0	23.1	23.0
510.0	22.4	22.4	22.5	22.8	22.5	22.5	22.5	22.6	22.5
520.0	23.4	23.4	23.2	23.6	23.7	23.5	23.5	23.4	23.4
530.0	27.5	27.4	27.6	27.7	27.9	28.3	27.4	27.2	27.2
540.0	35.5	35.4	35.6	34.8	35.1	35.7	35.1	34.9	35.0
550.0	45.6	45.4	45.7	44.9	45.2	45.6	45.3	45.0	45.1
560.0	58.3	58.0	58.5	58.0	58.3	58.1	58.1	57.9	57.9
570.0	66.4	66.1	66.7	65.4	65.2	64.9	66.4	66.3	66.2
580.0	69.0	68.7	69.4	67.8	67.5	67.0	69.3	69.2	69.1
590.0	65.0	64.6	65.1	65.3	65.1	64.4	65.5	65.5	65.5
600.0	57.1	56.8	57.4	57.8	58.1	57.1	57.7	57.6	57.6
610.0	47.2	47.0	47.4	48.8	48.4	47.7	48.0	47.9	48.1
620.0	37.0	36.8	37.1	39.1	38.4	37.7	37.7	37.9	37.9
630.0	28.4	28.4	28.5	29.0	29.7	28.9	28.9	28.9	29.0
640.0	21.2	21.2	21.2	21.6	22.0	22.0	21.7	22.0	21.7
650.0	15.5	15.7	15.6	16.1	16.6	16.8	16.0	16.0	16.0
660.0	11.4	11.5	11.4	12.0	12.8	12.7	11.6	11.6	11.6
670.0	8.4	8.6	8.4	9.4	10.1	10.0	8.5	8.5	8.7
680.0	6.2	6.4	6.0	7.2	7.5	7.8	6.2	6.4	6.4
690.0	5.0	5.0	4.7	5.2	5.4	5.9	5.0	5.0	5.0
700.0	3.6	3.7	3.3	4.1	4.5	4.5	3.6	3.6	3.6
710.0	3.0	3.2	2.7	3.1	3.3	4.3	2.9	3.0	3.0
720.0	2.3	2.7	2.0	3.2	3.1	3.0	2.3	2.3	2.3
730.0	3.2	3.5	3.2	.0	.0	.0	1.9	1.8	2.0
740.0	2.1	2.4	1.6	.0	.0	.0	2.0	2.1	2.1
750.0	2.5	2.8	1.9	.0	.0	.0	2.2	2.0	2.3
760.0	2.4	2.7	1.6	.0	.0	.0	1.5	1.5	1.6

MERCURY LINES

405.0	23.1	23.0	23.4	23.2	23.5	22.2	23.3	23.8	23.2
436.0	57.7	56.9	57.5	59.4	58.2	59.4	56.8	57.7	57.3
546.0	26.8	26.6	27.0	27.8	27.5	27.8	27.0	27.1	26.9
578.0	9.3	9.2	9.3	8.6	8.3	8.9	9.1	9.0	9.0

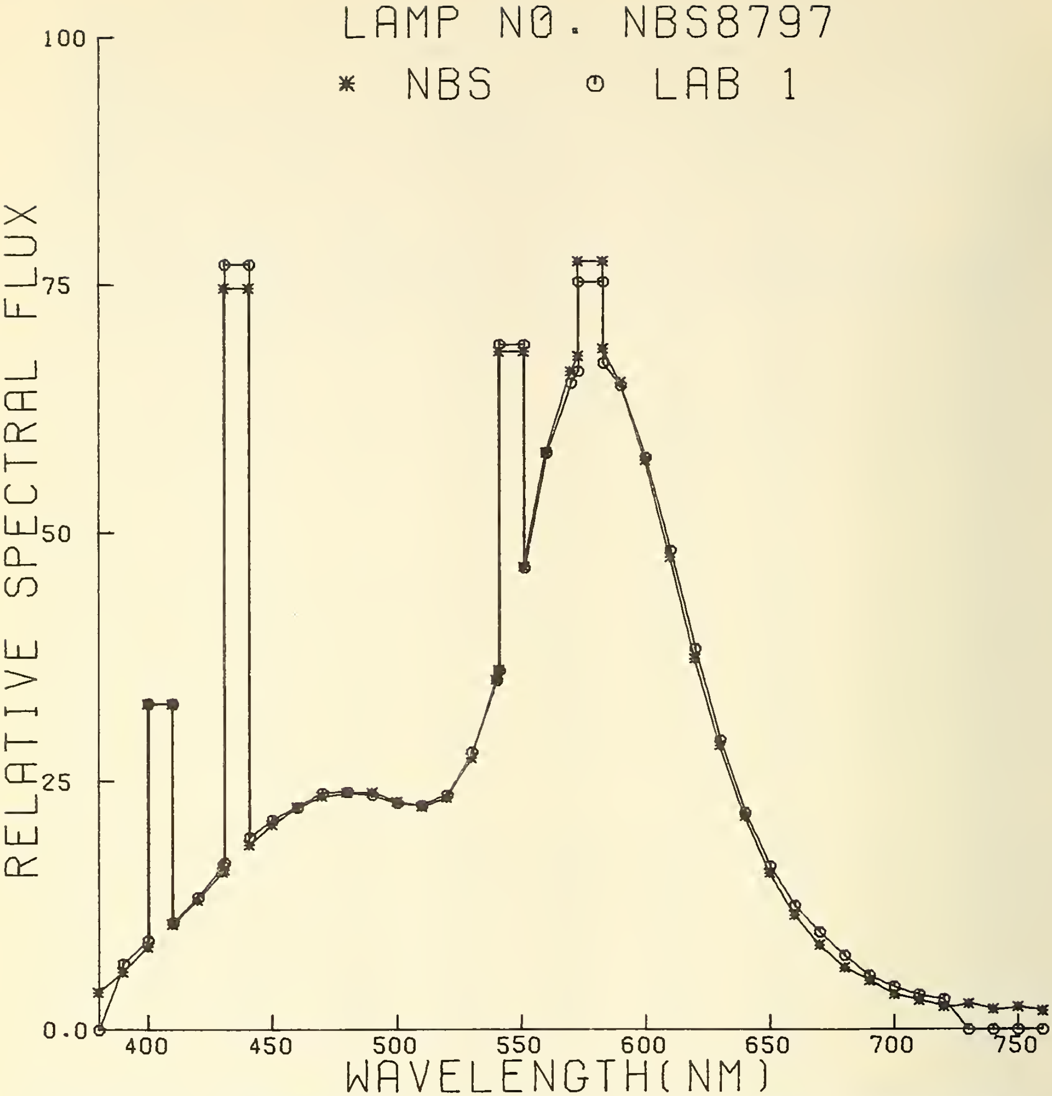


FIGURE 4.18 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.27

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8797

	NBS INITIAL			LABORATORY 1			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0320	.0354	.0328	.0000	.0000	.0000	.0295	.0297	.0302
390.0	.0482	.0521	.0497	.0537	.0505	.0604	.0468	.0467	.0477
400.0	.0708	.0723	.0714	.0722	.0758	.0733	.0672	.0670	.0679
410.0	.0899	.0908	.0903	.0900	.0861	.0900	.0863	.0863	.0872
420.0	.1097	.1107	.1099	.1096	.1066	.1123	.1066	.1076	.1073
430.0	.1329	.1356	.1331	.1309	.1374	.1403	.1293	.1319	.1298
440.0	.1535	.1559	.1539	.1567	.1546	.1607	.1501	.1531	.1508
450.0	.1726	.1734	.1727	.1746	.1710	.1741	.1691	.1726	.1699
460.0	.1868	.1875	.1871	.1848	.1867	.1805	.1839	.1868	.1842
470.0	.1959	.1970	.1955	.1939	.1942	.1985	.1926	.1961	.1939
480.0	.1988	.1996	.1993	.1947	.1977	.1972	.1958	.1995	.1970
490.0	.1983	.1996	.1987	.1921	.1959	.1940	.1955	.1984	.1963
500.0	.1903	.1918	.1908	.1861	.1887	.1887	.1881	.1919	.1891
510.0	.1873	.1882	.1874	.1850	.1853	.1872	.1845	.1878	.1852
520.0	.1955	.1964	.1936	.1920	.1950	.1950	.1919	.1947	.1922
530.0	.2297	.2304	.2298	.2251	.2297	.2348	.2240	.2263	.2241
540.0	.2964	.2971	.2962	.2827	.2887	.2960	.2875	.2899	.2881
550.0	.3807	.3818	.3807	.3647	.3721	.3786	.3703	.3740	.3712
560.0	.4863	.4876	.4870	.4711	.4799	.4826	.4752	.4815	.4765
570.0	.5538	.5555	.5556	.5310	.5370	.5390	.5434	.5513	.5445
580.0	.5761	.5774	.5783	.5507	.5559	.5563	.5669	.5755	.5688
590.0	.5423	.5424	.5426	.5302	.5364	.5346	.5361	.5453	.5387
600.0	.4765	.4773	.4781	.4697	.4786	.4739	.4718	.4791	.4736
610.0	.3944	.3946	.3950	.3960	.3981	.3960	.3929	.3986	.3961
620.0	.3090	.3095	.3093	.3178	.3164	.3129	.3088	.3151	.3120
630.0	.2367	.2383	.2377	.2355	.2443	.2399	.2361	.2408	.2387
640.0	.1770	.1785	.1766	.1754	.1812	.1827	.1779	.1834	.1784
650.0	.1297	.1318	.1296	.1309	.1370	.1393	.1310	.1327	.1320
660.0	.0950	.0967	.0949	.0972	.1058	.1055	.0951	.0965	.0953
670.0	.0704	.0725	.0703	.0763	.0829	.0832	.0697	.0708	.0712
680.0	.0521	.0536	.0500	.0581	.0620	.0646	.0511	.0529	.0524
690.0	.0415	.0422	.0392	.0424	.0445	.0493	.0409	.0417	.0411
700.0	.0302	.0311	.0277	.0330	.0370	.0373	.0295	.0301	.0293
710.0	.0254	.0266	.0226	.0254	.0275	.0359	.0240	.0246	.0248
720.0	.0195	.0225	.0163	.0256	.0253	.0251	.0187	.0191	.0192
730.0	.0264	.0298	.0264	.0000	.0000	.0000	.0158	.0147	.0163
740.0	.0177	.0197	.0133	.0000	.0000	.0000	.0167	.0172	.0173
750.0	.0212	.0235	.0160	.0000	.0000	.0000	.0179	.0164	.0186
760.0	.0197	.0228	.0132	.0000	.0000	.0000	.0123	.0127	.0128

MERCURY LINES

405.0	.1929	.1930	.1948	.1888	.1937	.1843	.1903	.1984	.1911
436.0	.4819	.4781	.4788	.4821	.4788	.4932	.4650	.4796	.4713
546.0	.2240	.2235	.2251	.2258	.2267	.2311	.2210	.2254	.2214
578.0	.0779	.0775	.0772	.0696	.0685	.0740	.0745	.0751	.0739

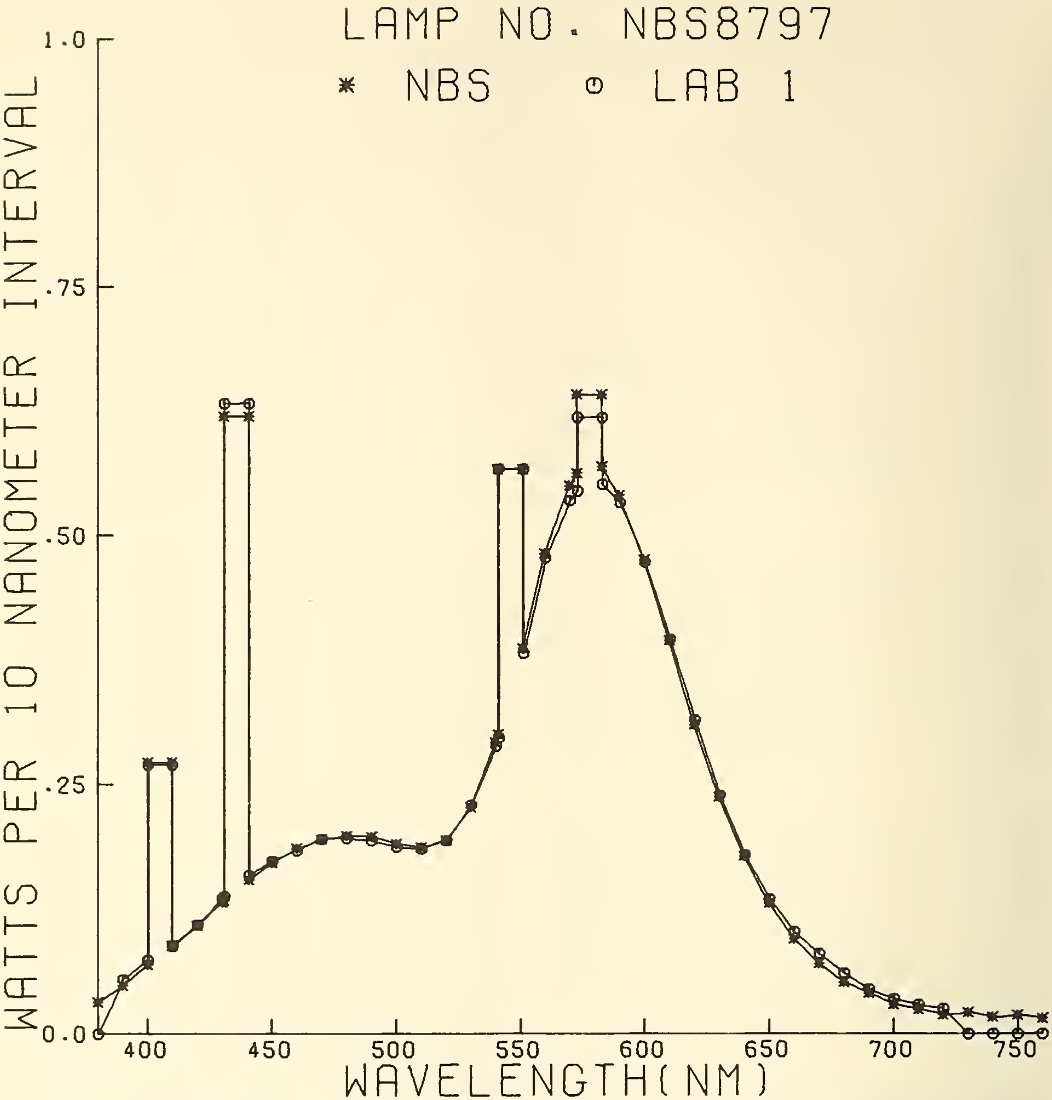


FIGURE 4.19 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.28

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8798

	NBS INITIAL			LABORATORY 1			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	3.7	3.7	3.9	.0	.0	.0	3.6	3.5	3.9
390.0	5.9	5.9	6.0	6.2	6.9	6.1	5.7	5.8	5.8
400.0	8.5	8.5	8.6	7.9	9.8	8.8	8.2	8.3	8.3
410.0	10.7	10.7	10.8	10.8	11.2	10.3	10.6	10.6	10.6
420.0	13.0	13.0	13.2	13.5	13.4	13.0	13.1	13.1	13.0
430.0	15.9	15.9	16.0	16.1	16.3	16.7	15.9	15.9	15.7
440.0	18.3	18.3	18.5	19.3	19.0	19.0	18.4	18.4	18.2
450.0	20.6	20.6	20.7	21.6	21.2	21.0	20.7	20.7	20.5
460.0	22.3	22.3	22.4	23.2	22.9	22.5	22.5	22.5	22.4
470.0	23.4	23.4	23.6	24.2	23.5	23.7	23.6	23.6	23.4
480.0	23.8	23.8	23.9	24.1	24.1	24.1	24.0	24.0	23.9
490.0	23.8	23.1	23.8	23.7	23.9	23.8	24.0	23.9	23.8
500.0	22.8	22.9	22.9	22.9	23.0	22.9	23.1	23.0	22.9
510.0	22.5	22.5	22.5	22.7	22.6	23.2	22.6	22.6	22.5
520.0	23.6	23.6	23.6	23.9	23.5	23.6	23.7	23.6	23.5
530.0	27.8	27.8	27.7	28.5	28.6	28.0	27.7	27.4	27.4
540.0	35.9	35.8	35.9	35.9	36.1	35.2	35.7	35.2	35.1
550.0	46.1	46.0	46.1	46.2	46.1	45.3	45.9	45.4	45.2
560.0	58.6	58.7	58.7	59.3	58.5	58.2	58.7	58.3	58.0
570.0	66.6	66.8	66.8	66.0	65.0	65.5	66.9	66.4	66.1
580.0	69.2	69.3	69.4	68.0	66.9	67.9	69.6	69.1	68.9
590.0	64.8	65.0	64.9	65.2	64.1	65.7	65.7	65.2	64.8
600.0	56.9	57.1	57.1	57.5	56.8	58.6	57.7	57.3	57.1
610.0	47.3	47.1	47.1	48.3	47.5	48.6	47.9	47.6	47.6
620.0	36.9	37.0	36.9	37.9	37.7	38.7	37.6	37.5	37.5
630.0	28.3	28.3	28.4	29.2	29.0	29.3	28.8	28.7	28.8
640.0	21.2	21.3	21.2	21.2	21.8	21.9	18.1	21.9	21.9
650.0	15.6	15.6	15.6	16.0	16.2	16.8	15.9	16.1	16.1
660.0	11.4	11.4	11.3	11.8	12.7	12.1	11.6	11.7	11.8
670.0	8.6	8.5	8.4	8.9	9.0	9.0	8.6	8.5	8.8
680.0	6.3	6.3	6.1	6.7	6.5	7.1	6.3	6.3	6.6
690.0	5.0	5.0	4.8	5.1	5.6	5.5	5.0	5.0	5.3
700.0	3.6	3.6	3.5	3.7	4.5	4.4	3.6	3.7	4.0
710.0	3.1	3.1	2.9	3.0	3.1	3.5	2.9	3.1	3.2
720.0	2.6	2.4	2.1	2.4	2.7	3.0	2.3	2.3	2.6
730.0	3.2	3.2	2.9	.0	.0	.0	1.9	1.9	2.3
740.0	2.1	2.1	1.9	.0	.0	.0	2.0	2.1	2.5
750.0	2.5	2.6	2.2	.0	.0	.0	2.2	1.8	2.7
760.0	2.4	2.4	1.6	.0	.0	.0	1.5	1.5	2.2
				MERCURY LINES					
405.0	22.7	23.0	23.2	21.8	25.0	23.0	23.2	23.4	22.8
436.0	56.2	56.3	56.6	61.0	58.6	58.0	56.7	57.2	56.6
546.0	27.0	27.0	27.0	27.7	28.1	27.2	27.3	27.1	26.8
578.0	9.2	9.2	9.1	9.0	8.9	8.7	9.1	9.1	9.0

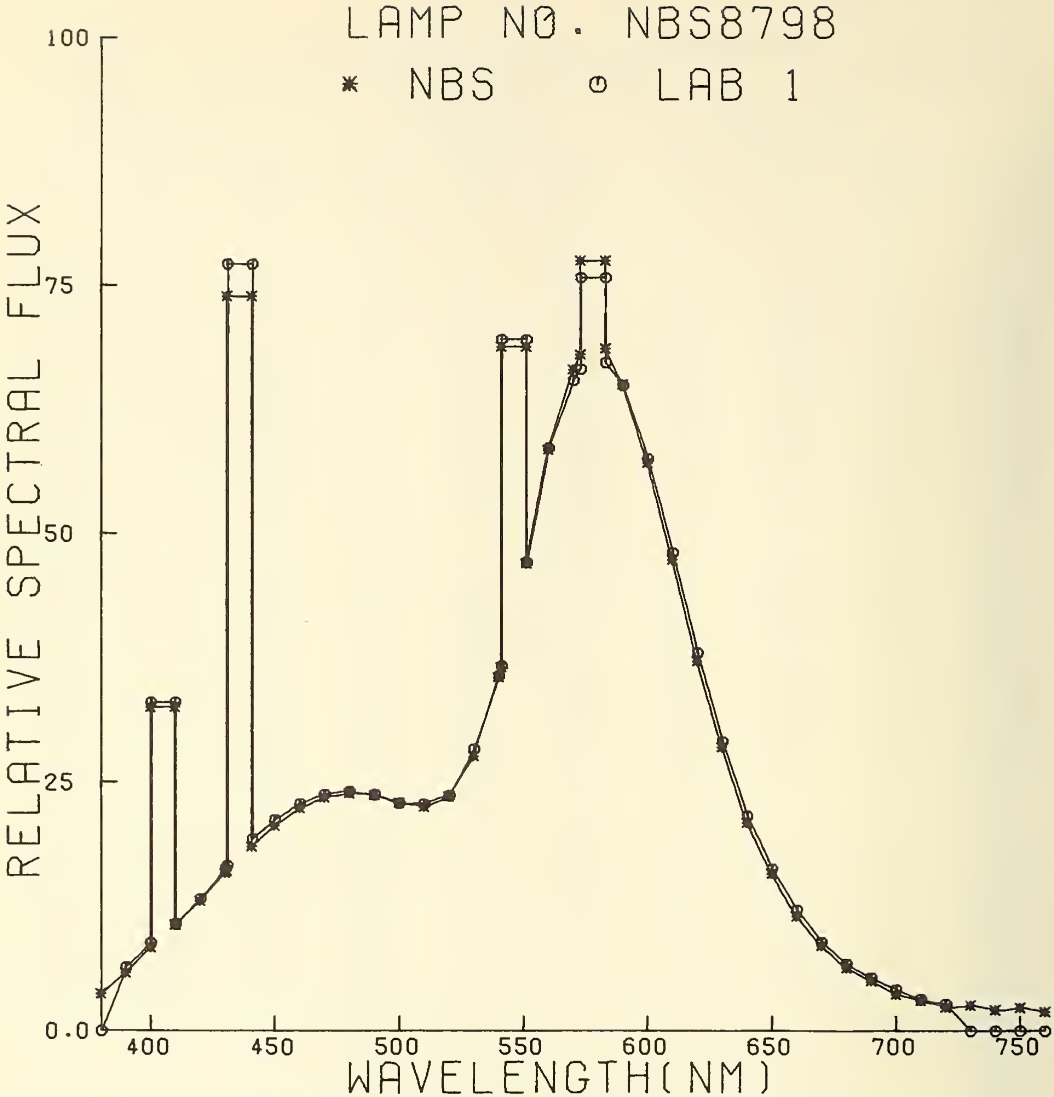


FIGURE 4.20 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.29

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8798

	NBS INITIAL			LABORATORY 1			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0313	.0305	.0328	.0000	.0000	.0000	.0295	.0293	.0326
390.0	.0490	.0494	.0497	.0511	.0572	.0503	.0468	.0479	.0486
400.0	.0708	.0708	.0714	.0655	.0813	.0729	.0672	.0688	.0692
410.0	.0898	.0886	.0903	.0891	.0929	.0852	.0865	.0877	.0885
420.0	.1091	.1083	.1099	.1117	.1108	.1068	.1070	.1084	.1085
430.0	.1329	.1321	.1331	.1334	.1350	.1376	.1301	.1318	.1309
440.0	.1531	.1524	.1538	.1596	.1577	.1569	.1509	.1525	.1518
450.0	.1719	.1709	.1723	.1791	.1759	.1728	.1697	.1720	.1708
460.0	.1867	.1854	.1864	.1919	.1899	.1853	.1845	.1866	.1865
470.0	.1960	.1945	.1963	.2004	.1952	.1957	.1938	.1957	.1950
480.0	.1992	.1976	.1990	.1996	.1996	.1988	.1969	.1990	.1989
490.0	.1988	.1922	.1984	.1960	.1981	.1964	.1963	.1981	.1982
500.0	.1910	.1901	.1908	.1897	.1905	.1884	.1892	.1912	.1909
510.0	.1877	.1868	.1874	.1878	.1871	.1912	.1855	.1876	.1874
520.0	.1972	.1960	.1968	.1977	.1950	.1944	.1942	.1955	.1957
530.0	.2322	.2311	.2309	.2359	.2369	.2309	.2275	.2274	.2284
540.0	.3000	.2976	.2993	.2974	.2992	.2906	.2923	.2922	.2928
550.0	.3851	.3818	.3843	.3825	.3819	.3736	.3760	.3767	.3768
560.0	.4902	.4882	.4892	.4911	.4849	.4799	.4812	.4837	.4833
570.0	.5569	.5550	.5566	.5471	.5390	.5397	.5480	.5511	.5514
580.0	.5780	.5761	.5778	.5634	.5547	.5602	.5702	.5730	.5742
590.0	.5415	.5399	.5404	.5400	.5319	.5414	.5381	.5406	.5407
600.0	.4759	.4744	.4758	.4769	.4708	.4832	.4729	.4750	.4763
610.0	.3956	.3915	.3924	.3998	.3939	.4006	.3923	.3948	.3973
620.0	.3081	.3074	.3072	.3138	.3129	.3192	.3082	.3112	.3126
630.0	.2365	.2349	.2361	.2420	.2407	.2416	.2361	.2378	.2400
640.0	.1774	.1770	.1766	.1759	.1804	.1809	.1481	.1819	.1828
650.0	.1306	.1299	.1295	.1325	.1341	.1384	.1302	.1336	.1345
660.0	.0956	.0948	.0938	.0977	.1055	.0997	.0952	.0971	.0980
670.0	.0718	.0703	.0703	.0737	.0744	.0740	.0705	.0708	.0730
680.0	.0524	.0522	.0510	.0551	.0535	.0584	.0520	.0522	.0550
690.0	.0418	.0415	.0404	.0422	.0468	.0456	.0409	.0412	.0438
700.0	.0304	.0303	.0290	.0309	.0372	.0363	.0295	.0307	.0333
710.0	.0256	.0255	.0240	.0251	.0254	.0288	.0240	.0253	.0270
720.0	.0213	.0196	.0179	.0202	.0226	.0248	.0187	.0188	.0218
730.0	.0265	.0265	.0246	.0000	.0000	.0000	.0158	.0160	.0193
740.0	.0178	.0178	.0156	.0000	.0000	.0000	.0167	.0170	.0208
750.0	.0213	.0213	.0186	.0000	.0000	.0000	.0179	.0152	.0227
760.0	.0198	.0198	.0132	.0000	.0000	.0000	.0123	.0126	.0179
					MERCURY LINES				
405.0	.1897	.1908	.1931	.1806	.2072	.1897	.1903	.1943	.1903
436.0	.4696	.4681	.4713	.5054	.4856	.4785	.4651	.4743	.4722
546.0	.2255	.2242	.2252	.2298	.2330	.2240	.2236	.2245	.2233
578.0	.0769	.0761	.0761	.0746	.0737	.0721	.0748	.0752	.0751

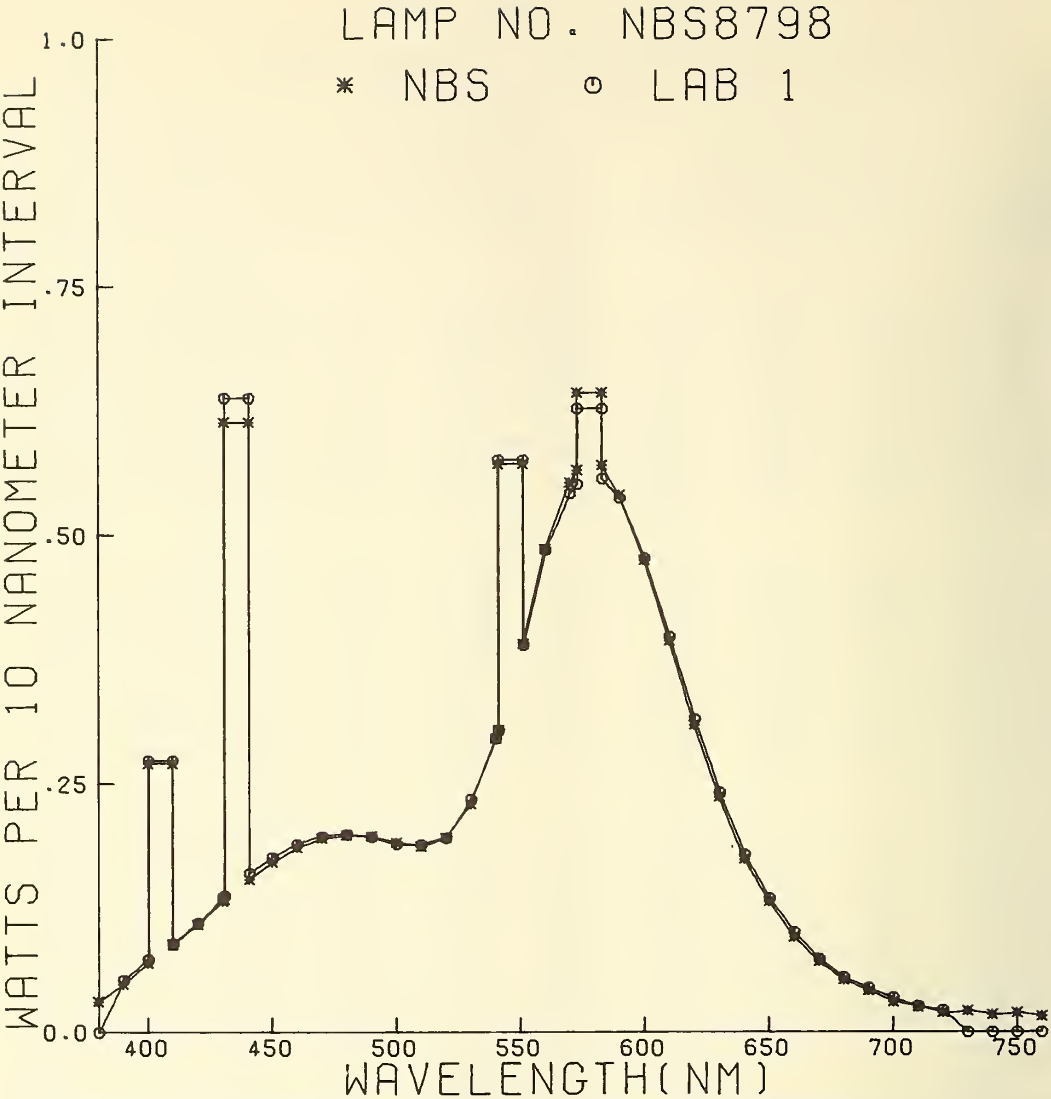


FIGURE 4.21 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.30

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8801

	NBS INITIAL			LABORATORY 5			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	4.0	3.8	4.1	3.7	3.3	3.4	3.8	3.7	3.8
390.0	5.9	6.0	5.9	5.9	5.4	5.5	5.7	5.7	5.9
400.0	8.4	8.4	8.5	9.1	8.9	9.0	8.3	8.3	8.2
410.0	10.7	10.7	10.8	10.8	10.6	10.5	10.7	10.7	10.6
420.0	13.1	13.1	13.2	13.9	13.8	13.8	13.1	13.1	12.9
430.0	16.0	16.1	16.0	16.3	16.2	16.3	15.9	15.8	15.9
440.0	18.6	18.6	18.6	18.8	18.8	18.7	18.4	18.4	18.5
450.0	20.8	20.8	20.9	21.7	21.6	21.6	20.7	19.4	20.9
460.0	22.5	22.6	22.6	23.2	23.0	23.2	22.6	22.6	22.6
470.0	23.6	23.7	23.7	24.3	24.4	24.3	23.6	23.7	23.8
480.0	24.0	24.0	24.0	24.5	24.6	24.6	24.1	24.2	24.0
490.0	23.9	24.0	24.0	24.4	24.4	24.4	24.0	24.1	23.9
500.0	23.0	23.0	23.0	24.1	24.0	24.0	23.1	23.2	23.1
510.0	22.6	22.6	22.7	23.6	23.7	24.2	22.7	22.7	22.6
520.0	23.7	23.7	23.8	24.8	24.9	24.8	23.6	23.9	23.6
530.0	27.8	27.8	28.0	29.4	29.7	29.8	27.6	27.7	27.6
540.0	35.9	36.0	36.0	38.3	38.7	38.6	35.5	35.1	35.4
550.0	46.0	46.1	46.2	49.5	50.4	49.9	45.6	45.7	45.4
560.0	58.6	58.7	58.8	61.8	62.0	61.8	58.3	58.4	58.0
570.0	66.5	66.6	66.8	68.1	66.9	67.4	66.4	66.6	66.3
580.0	68.9	69.1	69.3	68.5	67.6	68.4	69.2	69.4	69.0
590.0	64.6	64.6	65.0	67.2	67.2	67.3	65.4	65.5	65.1
600.0	56.9	56.9	57.1	59.0	59.6	59.5	57.4	57.5	57.3
610.0	47.1	46.9	47.1	47.7	48.5	48.5	47.7	47.9	47.7
620.0	36.9	36.7	36.8	37.6	37.6	37.4	37.5	37.8	37.9
630.0	28.4	28.2	28.4	28.1	28.2	28.0	28.6	28.9	28.9
640.0	21.2	21.1	21.2	20.2	20.7	20.3	21.5	21.6	21.6
650.0	15.5	15.5	15.5	13.5	13.8	13.6	15.9	15.8	15.8
660.0	11.2	11.3	11.2	9.8	9.8	9.8	11.4	11.5	11.6
670.0	8.4	8.3	8.4	5.6	5.7	5.7	8.6	8.6	8.5
680.0	6.2	6.1	5.9	3.1	3.2	3.2	6.2	6.2	6.3
690.0	4.8	4.8	4.6	2.5	2.1	1.8	4.9	4.9	4.9
700.0	3.4	3.5	3.4	2.0	2.0	2.4	3.6	3.6	3.6
710.0	3.1	2.9	2.8	.0	.4	.4	3.0	3.1	3.1
720.0	2.4	2.4	2.0	.0	.0	.0	2.4	2.3	2.2
730.0	3.3	3.2	2.8	.0	.0	.0	2.0	1.8	1.8
740.0	2.2	2.2	1.6	.0	.0	.0	2.1	2.1	2.2
750.0	2.6	2.6	2.0	.0	.0	.0	2.5	2.2	2.3
760.0	2.4	2.0	1.6	.0	.0	.0	1.9	1.5	1.6
MERCURY LINES									
405.0	22.7	22.9	22.9	19.7	18.8	19.6	22.8	22.9	23.2
436.0	56.7	56.9	56.9	55.0	53.0	52.3	56.4	56.7	57.1
546.0	26.4	26.5	26.7	28.0	28.4	28.8	26.5	26.3	26.5
578.0	9.1	9.1	9.1	16.2	18.2	17.1	8.9	8.9	8.9

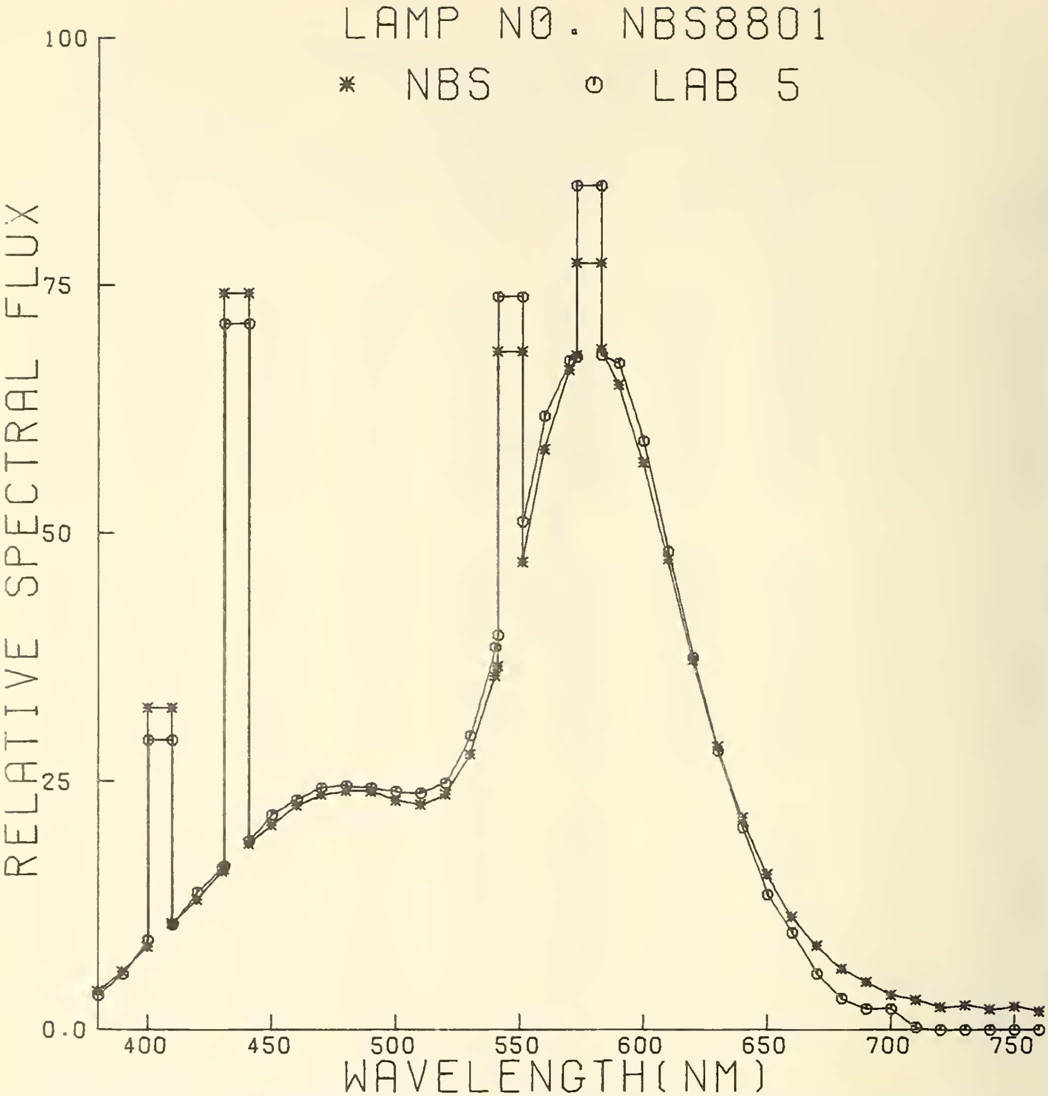


FIGURE 4.22 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.31

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8801

	NBS INITIAL			LABORATORY 5			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0320	.0308	.0328	.0282	.0250	.0260	.0298	.0292	.0307
390.0	.0482	.0488	.0474	.0452	.0412	.0421	.0456	.0453	.0473
400.0	.0683	.0679	.0690	.0696	.0678	.0690	.0659	.0664	.0665
410.0	.0867	.0859	.0876	.0825	.0805	.0802	.0845	.0852	.0854
420.0	.1065	.1056	.1068	.1061	.1055	.1054	.1039	.1041	.1043
430.0	.1301	.1302	.1295	.1248	.1233	.1248	.1264	.1259	.1286
440.0	.1504	.1503	.1501	.1437	.1431	.1431	.1462	.1465	.1491
450.0	.1688	.1678	.1689	.1660	.1652	.1653	.1646	.1544	.1682
460.0	.1823	.1821	.1827	.1774	.1752	.1772	.1791	.1802	.1823
470.0	.1915	.1912	.1920	.1861	.1860	.1853	.1876	.1889	.1916
480.0	.1945	.1937	.1944	.1874	.1876	.1878	.1912	.1925	.1939
490.0	.1935	.1935	.1939	.1866	.1865	.1868	.1902	.1920	.1932
500.0	.1861	.1856	.1860	.1843	.1831	.1834	.1831	.1848	.1863
510.0	.1831	.1824	.1832	.1806	.1809	.1850	.1799	.1810	.1826
520.0	.1919	.1908	.1922	.1900	.1901	.1899	.1877	.1902	.1901
530.0	.2252	.2246	.2261	.2246	.2269	.2274	.2189	.2205	.2223
540.0	.2909	.2901	.2914	.2926	.2950	.2948	.2816	.2794	.2857
550.0	.3730	.3721	.3736	.3786	.3843	.3812	.3623	.3641	.3664
560.0	.4748	.4733	.4756	.4721	.4730	.4724	.4625	.4656	.4677
570.0	.5388	.5375	.5398	.5204	.5107	.5153	.5274	.5311	.5347
580.0	.5586	.5571	.5603	.5233	.5159	.5229	.5494	.5531	.5570
590.0	.5238	.5215	.5252	.5134	.5131	.5147	.5192	.5220	.5252
600.0	.4611	.4587	.4616	.4510	.4549	.4544	.4560	.4584	.4624
610.0	.3814	.3787	.3809	.3646	.3701	.3710	.3785	.3817	.3849
620.0	.2990	.2962	.2979	.2872	.2870	.2862	.2979	.3015	.3061
630.0	.2304	.2275	.2299	.2145	.2151	.2143	.2273	.2306	.2329
640.0	.1717	.1699	.1713	.1548	.1577	.1549	.1706	.1721	.1744
650.0	.1257	.1248	.1255	.1034	.1050	.1037	.1260	.1260	.1273
660.0	.0907	.0914	.0905	.0749	.0750	.0751	.0908	.0920	.0933
670.0	.0682	.0673	.0682	.0430	.0432	.0433	.0679	.0682	.0685
680.0	.0499	.0493	.0478	.0240	.0241	.0241	.0493	.0494	.0505
690.0	.0392	.0387	.0369	.0189	.0162	.0135	.0391	.0392	.0391
700.0	.0277	.0285	.0277	.0152	.0152	.0182	.0285	.0285	.0293
710.0	.0254	.0238	.0226	.0000	.0031	.0031	.0240	.0251	.0247
720.0	.0196	.0193	.0163	.0000	.0000	.0000	.0187	.0187	.0180
730.0	.0264	.0261	.0227	.0000	.0000	.0000	.0158	.0144	.0148
740.0	.0177	.0175	.0133	.0000	.0000	.0000	.0167	.0167	.0174
750.0	.0212	.0209	.0160	.0000	.0000	.0000	.0199	.0179	.0187
760.0	.0197	.0162	.0132	.0000	.0000	.0000	.0147	.0123	.0128
MERCURY LINES									
405.0	.1840	.1844	.1855	.1509	.1436	.1498	.1806	.1825	.1871
436.0	.4598	.4587	.4603	.4205	.4045	.4000	.4473	.4521	.4606
546.0	.2143	.2137	.2159	.2141	.2171	.2202	.2101	.2099	.2134
578.0	.0740	.0738	.0737	.1241	.1390	.1303	.0709	.0707	.0717

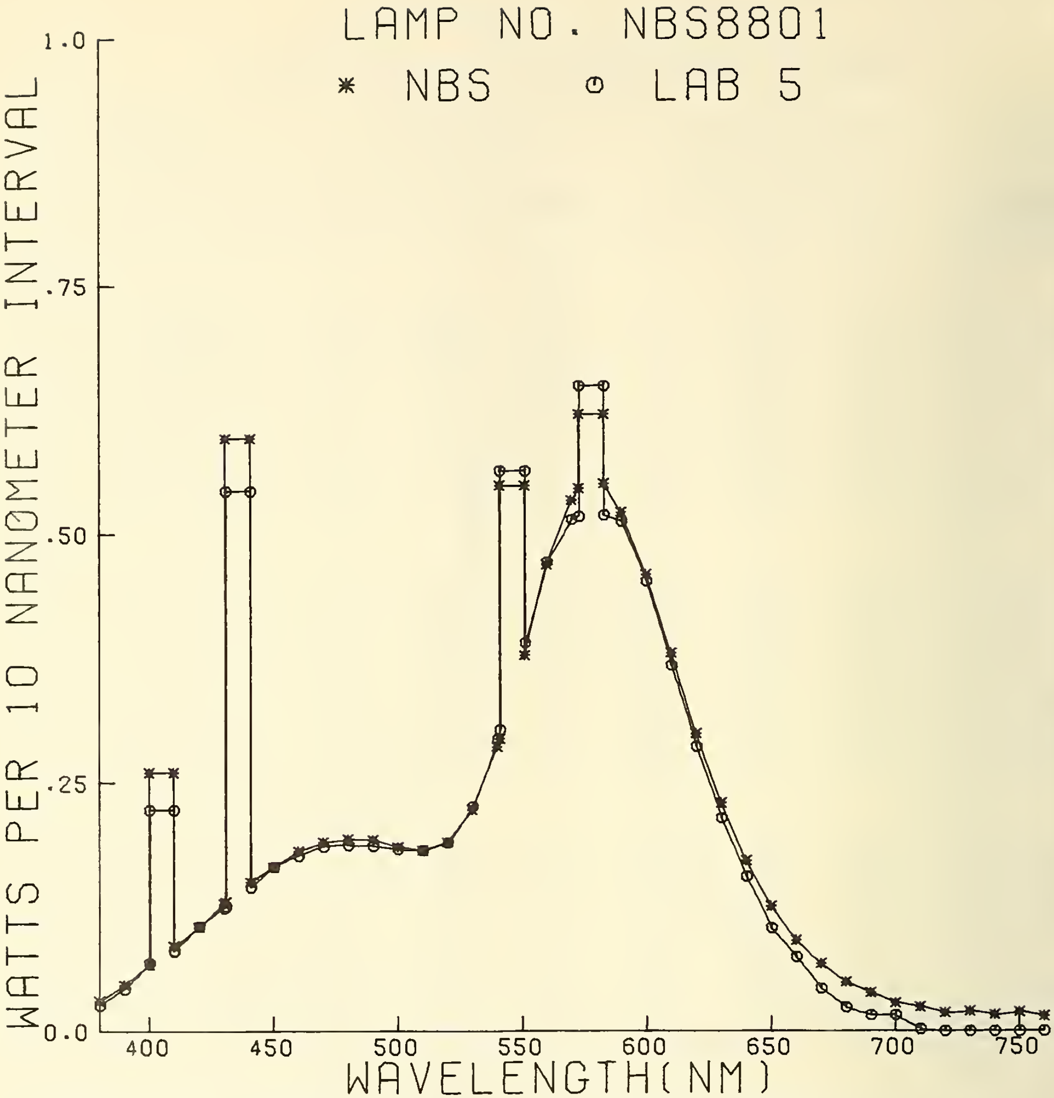


FIGURE 4.23 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.32

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8802

	NBS INITIAL			LABORATORY 5			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	4.0	3.9	4.0	3.6	3.4	3.5	3.5	3.6	3.9
390.0	5.9	6.1	6.0	5.7	5.7	5.8	5.7	5.7	6.0
400.0	8.4	8.7	8.7	9.0	9.0	9.0	8.3	8.3	8.5
410.0	10.7	10.9	11.0	10.9	10.8	6.0	10.6	10.7	10.8
420.0	13.1	13.2	13.4	13.7	13.7	13.8	13.1	13.1	13.1
430.0	16.2	16.1	16.2	16.6	16.4	16.5	16.0	15.9	16.1
440.0	18.7	18.6	18.7	18.8	18.7	19.0	18.5	18.5	18.6
450.0	21.0	20.9	21.0	21.6	21.5	21.9	20.9	19.5	21.0
460.0	22.6	22.6	22.8	23.0	23.3	23.5	22.6	22.8	22.7
470.0	23.7	23.7	23.8	24.1	24.2	24.2	23.8	23.8	23.8
480.0	24.0	24.0	24.2	24.7	24.7	24.8	24.2	24.2	24.1
490.0	23.9	23.3	24.0	24.5	24.3	24.7	23.5	24.1	24.1
500.0	23.0	23.0	23.1	23.8	23.8	23.9	23.2	23.3	23.1
510.0	22.6	22.6	22.6	23.3	24.1	24.4	22.8	22.8	22.6
520.0	23.7	23.7	23.7	24.8	25.1	25.0	23.7	23.9	23.6
530.0	27.8	27.9	27.9	29.5	29.7	29.7	27.7	27.7	27.6
540.0	36.0	35.9	36.0	38.3	38.9	39.0	35.6	35.0	35.4
550.0	46.1	46.0	46.2	49.5	50.1	50.2	45.8	45.6	45.5
560.0	58.5	58.6	58.7	61.7	62.1	62.3	58.4	58.5	58.0
570.0	66.4	66.5	66.7	67.4	67.4	67.4	66.6	66.7	66.2
580.0	68.8	68.9	69.2	68.1	67.9	68.2	69.3	69.3	68.8
590.0	64.5	64.6	64.8	67.2	67.4	67.6	65.3	65.4	64.9
600.0	57.1	56.7	56.7	59.3	59.0	59.3	57.5	57.6	57.1
610.0	46.8	47.0	47.0	48.3	48.0	48.0	47.6	47.8	47.6
620.0	36.6	36.8	36.8	37.7	37.4	37.8	37.4	37.7	37.8
630.0	28.2	28.1	28.3	28.4	27.9	28.7	28.6	28.7	28.5
640.0	21.1	21.1	21.1	21.0	20.4	20.8	21.5	21.5	21.4
650.0	15.4	15.5	15.3	14.6	13.8	14.5	15.7	15.8	16.2
660.0	11.3	11.3	11.3	9.9	9.7	9.9	11.5	11.5	11.7
670.0	8.4	8.5	8.3	5.8	5.6	5.9	8.4	8.5	8.5
680.0	6.2	6.2	6.1	3.1	3.1	3.1	6.2	6.2	6.2
690.0	4.9	4.9	4.8	2.8	2.1	2.8	4.9	4.9	4.9
700.0	3.7	3.5	3.4	3.1	1.6	2.7	3.5	3.6	3.6
710.0	3.1	3.1	2.8	.8	.4	.8	3.0	2.9	2.9
720.0	2.4	2.4	2.0	.4	.0	.0	2.2	2.1	2.2
730.0	3.2	3.2	2.8	.0	.0	.0	1.8	1.9	1.8
740.0	2.2	2.1	1.6	.0	.0	.0	2.1	2.1	2.1
750.0	2.6	2.6	1.9	.0	.0	.0	2.5	2.4	2.5
760.0	2.4	2.4	1.6	.0	.0	.0	1.5	1.5	1.6

MERCURY LINES

405.0	22.8	22.9	23.2	19.8	20.1	15.2	23.0	23.1	23.2
436.0	56.1	56.3	56.8	52.2	52.8	53.7	56.2	56.8	56.7
546.0	26.6	26.6	26.6	26.9	28.8	28.7	26.6	26.3	26.4
578.0	9.2	9.2	9.2	16.2	17.1	17.4	9.0	9.0	9.0

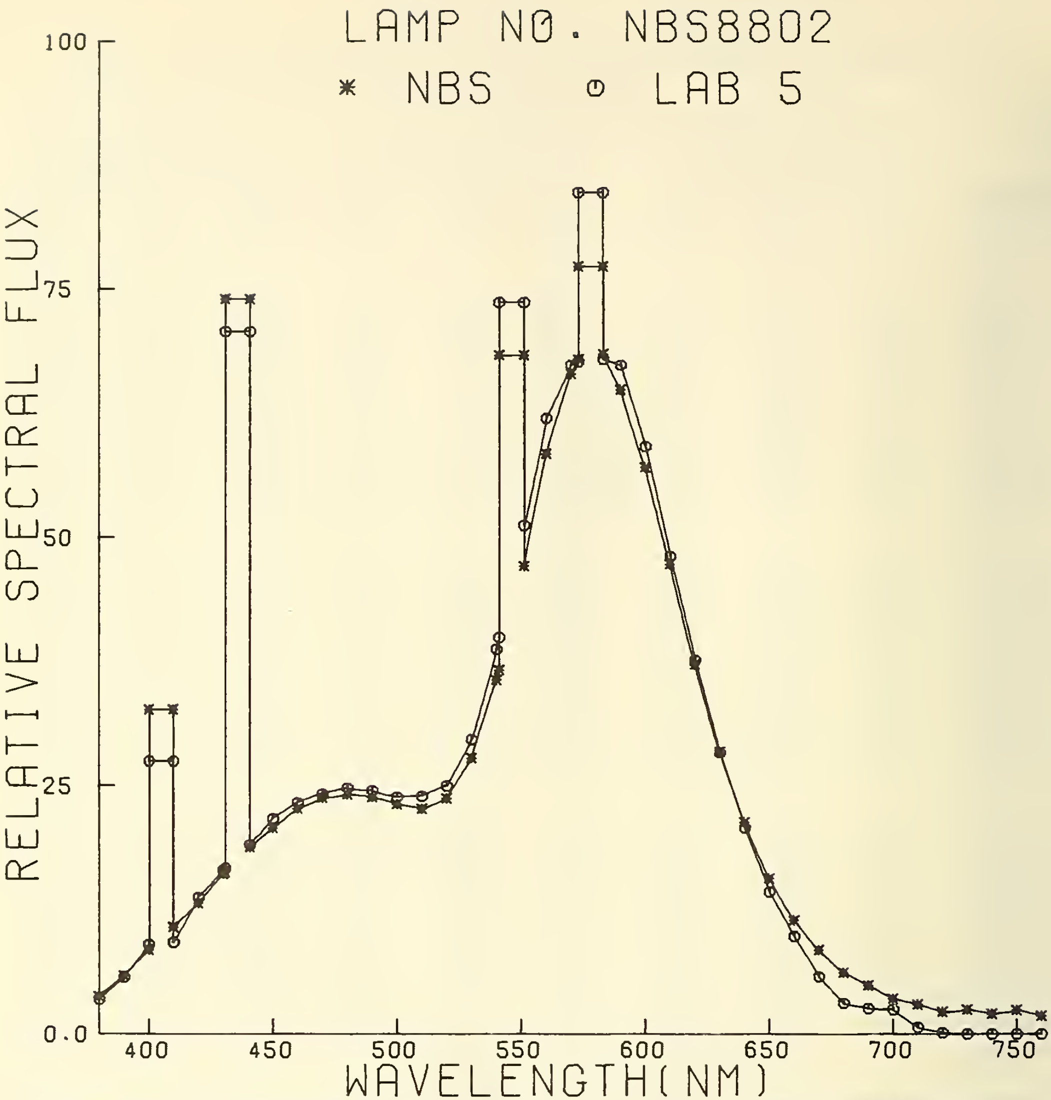


FIGURE 4.24 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.33

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8802

	NBS INITIAL			LABORATORY 5			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0328	.0320	.0328	.0282	.0260	.0269	.0285	.0292	.0320
390.0	.0490	.0505	.0497	.0442	.0441	.0450	.0456	.0462	.0492
400.0	.0696	.0720	.0714	.0705	.0696	.0699	.0666	.0678	.0697
410.0	.0886	.0900	.0903	.0846	.0833	.0468	.0858	.0872	.0891
420.0	.1085	.1098	.1099	.1068	.1055	.1069	.1057	.1067	.1081
430.0	.1334	.1339	.1331	.1291	.1262	.1276	.1287	.1293	.1322
440.0	.1541	.1545	.1539	.1465	.1445	.1473	.1492	.1506	.1531
450.0	.1731	.1731	.1726	.1680	.1659	.1696	.1685	.1588	.1728
460.0	.1867	.1872	.1871	.1793	.1797	.1822	.1824	.1857	.1867
470.0	.1956	.1963	.1956	.1879	.1866	.1878	.1917	.1939	.1962
480.0	.1984	.1994	.1986	.1921	.1903	.1919	.1949	.1972	.1986
490.0	.1977	.1936	.1973	.1908	.1872	.1911	.1890	.1966	.1981
500.0	.1899	.1908	.1901	.1857	.1839	.1856	.1869	.1896	.1903
510.0	.1867	.1875	.1859	.1812	.1860	.1894	.1834	.1856	.1861
520.0	.1953	.1964	.1950	.1931	.1935	.1937	.1913	.1951	.1942
530.0	.2295	.2315	.2290	.2299	.2292	.2305	.2233	.2256	.2268
540.0	.2968	.2979	.2961	.2983	.3000	.3023	.2868	.2853	.2916
550.0	.3805	.3815	.3796	.3856	.3861	.3894	.3688	.3721	.3742
560.0	.4831	.4863	.4826	.4803	.4787	.4829	.4709	.4769	.4779
570.0	.5479	.5512	.5481	.5252	.5198	.5224	.5366	.5434	.5448
580.0	.5684	.5715	.5689	.5305	.5234	.5283	.5583	.5653	.5668
590.0	.5327	.5360	.5328	.5233	.5200	.5238	.5265	.5329	.5345
600.0	.4711	.4702	.4663	.4617	.4549	.4593	.4631	.4698	.4701
610.0	.3865	.3895	.3860	.3760	.3701	.3724	.3836	.3896	.3917
620.0	.3024	.3053	.3022	.2940	.2884	.2931	.3016	.3070	.3110
630.0	.2325	.2333	.2330	.2214	.2151	.2228	.2306	.2339	.2349
640.0	.1739	.1752	.1731	.1636	.1577	.1613	.1735	.1750	.1759
650.0	.1275	.1289	.1255	.1134	.1067	.1120	.1268	.1285	.1332
660.0	.0934	.0937	.0927	.0768	.0750	.0770	.0926	.0938	.0959
670.0	.0697	.0703	.0682	.0452	.0432	.0454	.0679	.0690	.0703
680.0	.0513	.0511	.0500	.0240	.0241	.0241	.0502	.0503	.0514
690.0	.0406	.0404	.0392	.0216	.0162	.0216	.0391	.0401	.0401
700.0	.0304	.0290	.0278	.0243	.0122	.0212	.0285	.0295	.0292
710.0	.0256	.0255	.0226	.0061	.0031	.0061	.0240	.0240	.0236
720.0	.0197	.0196	.0163	.0033	.0000	.0000	.0174	.0174	.0180
730.0	.0265	.0265	.0227	.0000	.0000	.0000	.0144	.0158	.0149
740.0	.0178	.0178	.0133	.0000	.0000	.0000	.0168	.0167	.0173
750.0	.0213	.0213	.0160	.0000	.0000	.0000	.0199	.0199	.0207
760.0	.0198	.0198	.0132	.0000	.0000	.0000	.0122	.0123	.0128
MERCURY LINES									
405.0	.1885	.1901	.1906	.1544	.1552	.1176	.1854	.1882	.1912
436.0	.4633	.4667	.4665	.4064	.4071	.4164	.4527	.4627	.4672
546.0	.2195	.2203	.2190	.2097	.2223	.2228	.2140	.2143	.2170
578.0	.0759	.0766	.0752	.1260	.1318	.1349	.0727	.0732	.0737

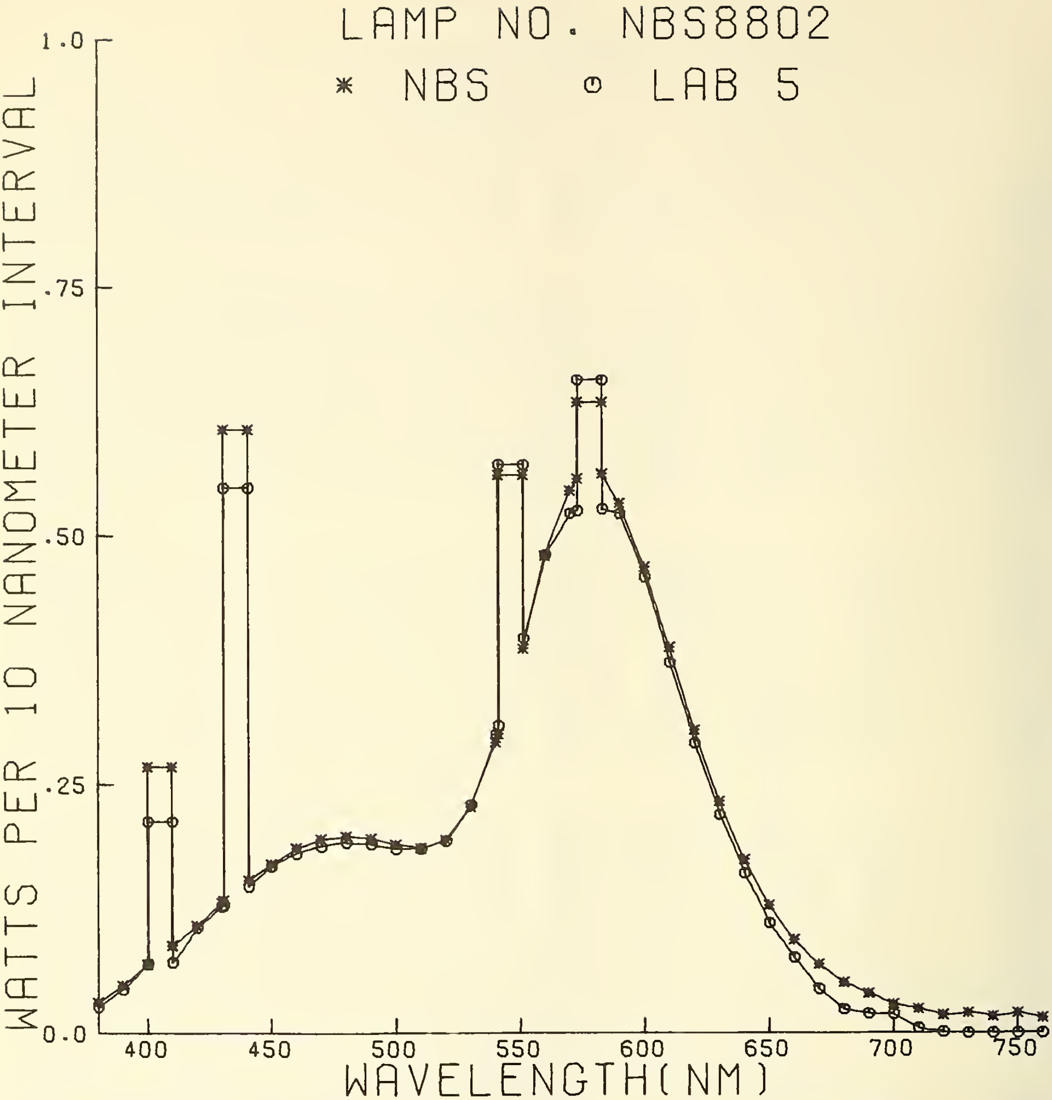


FIGURE 4.25 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.34

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8805

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	3.9	3.8	3.8	.0	.0	.0	3.8	3.8	3.7
390.0	5.9	6.0	5.9	6.3	4.7	4.1	5.9	5.7	5.8
400.0	8.7	8.4	8.5	8.3	7.6	7.4	8.5	8.3	8.3
410.0	11.0	10.6	10.7	10.8	10.3	10.4	10.8	10.7	10.7
420.0	13.3	14.0	13.2	13.1	12.9	13.1	13.3	13.1	13.1
430.0	16.0	16.0	16.1	16.0	15.8	16.2	16.1	16.1	16.0
440.0	18.5	18.6	18.6	18.6	18.4	18.9	18.7	18.5	18.5
450.0	20.9	20.8	20.9	20.6	20.5	20.8	21.0	20.9	20.9
460.0	22.7	22.7	22.2	22.4	22.3	22.6	22.7	22.6	22.6
470.0	23.8	23.9	23.7	23.5	23.4	23.7	23.9	23.8	23.8
480.0	24.2	24.2	24.1	24.0	23.8	24.1	24.3	24.2	24.2
490.0	24.0	24.0	23.9	23.9	23.8	24.0	24.1	24.1	24.0
500.0	23.1	23.1	23.1	23.2	23.0	23.3	23.2	23.2	23.2
510.0	22.7	22.7	22.7	22.9	22.7	23.0	22.8	22.8	22.7
520.0	23.7	23.8	23.7	24.2	24.0	24.3	23.7	23.7	23.8
530.0	27.9	27.9	27.9	28.4	28.1	28.6	27.7	27.7	27.7
540.0	36.0	36.0	36.0	36.9	36.6	37.1	35.6	35.6	35.5
550.0	46.1	46.2	46.2	47.2	46.7	47.4	45.7	45.7	45.6
560.0	58.7	58.9	58.9	59.2	58.6	59.4	58.4	58.4	58.3
570.0	66.5	66.8	66.7	67.0	66.4	67.4	66.5	66.4	66.4
580.0	68.9	69.1	69.1	69.3	68.7	69.6	69.1	69.1	69.1
590.0	64.5	64.7	64.8	65.5	64.9	65.6	65.1	65.1	65.1
600.0	56.7	56.9	56.8	57.6	57.2	57.5	57.2	57.2	57.3
610.0	46.8	47.0	46.9	47.8	47.6	47.5	47.4	47.5	47.5
620.0	36.6	36.7	36.8	37.8	37.4	37.6	37.3	37.3	37.2
630.0	28.0	28.3	28.3	28.9	28.7	28.8	28.5	28.4	28.4
640.0	21.0	21.1	20.9	21.7	21.5	21.6	21.4	21.4	21.5
650.0	15.4	15.6	15.5	16.1	15.9	16.0	15.6	15.7	15.6
660.0	11.1	11.2	11.4	11.8	11.8	11.7	11.4	11.4	11.4
670.0	8.4	8.2	8.2	8.7	8.6	8.6	8.3	8.5	8.5
680.0	6.1	6.0	6.0	6.4	6.3	6.3	6.1	6.3	6.2
690.0	4.8	4.7	4.8	4.9	4.8	4.8	4.8	4.9	5.0
700.0	3.4	3.3	3.4	3.7	3.6	3.6	3.5	3.5	3.6
710.0	3.1	2.7	2.7	2.8	2.8	2.8	2.8	2.9	3.1
720.0	2.4	2.4	2.4	2.1	2.0	2.0	2.2	2.4	2.4
730.0	3.2	3.2	3.2	1.7	1.6	1.7	1.8	1.9	1.9
740.0	2.2	2.1	2.1	1.6	1.4	1.5	1.9	2.3	2.3
750.0	2.6	1.9	2.6	1.4	1.3	1.3	2.2	2.2	2.4
760.0	2.4	1.6	1.6	.0	.0	.0	1.5	1.8	1.8
MERCURY LINES									
405.0	22.7	22.7	23.1	24.2	23.8	24.3	23.0	22.9	22.9
436.0	56.5	56.4	56.4	53.4	54.3	53.9	56.4	56.5	56.8
546.0	26.5	26.6	26.9	26.3	25.9	27.0	26.7	26.5	26.5
578.0	9.0	9.1	9.1	9.9	10.0	10.2	8.8	8.9	8.8

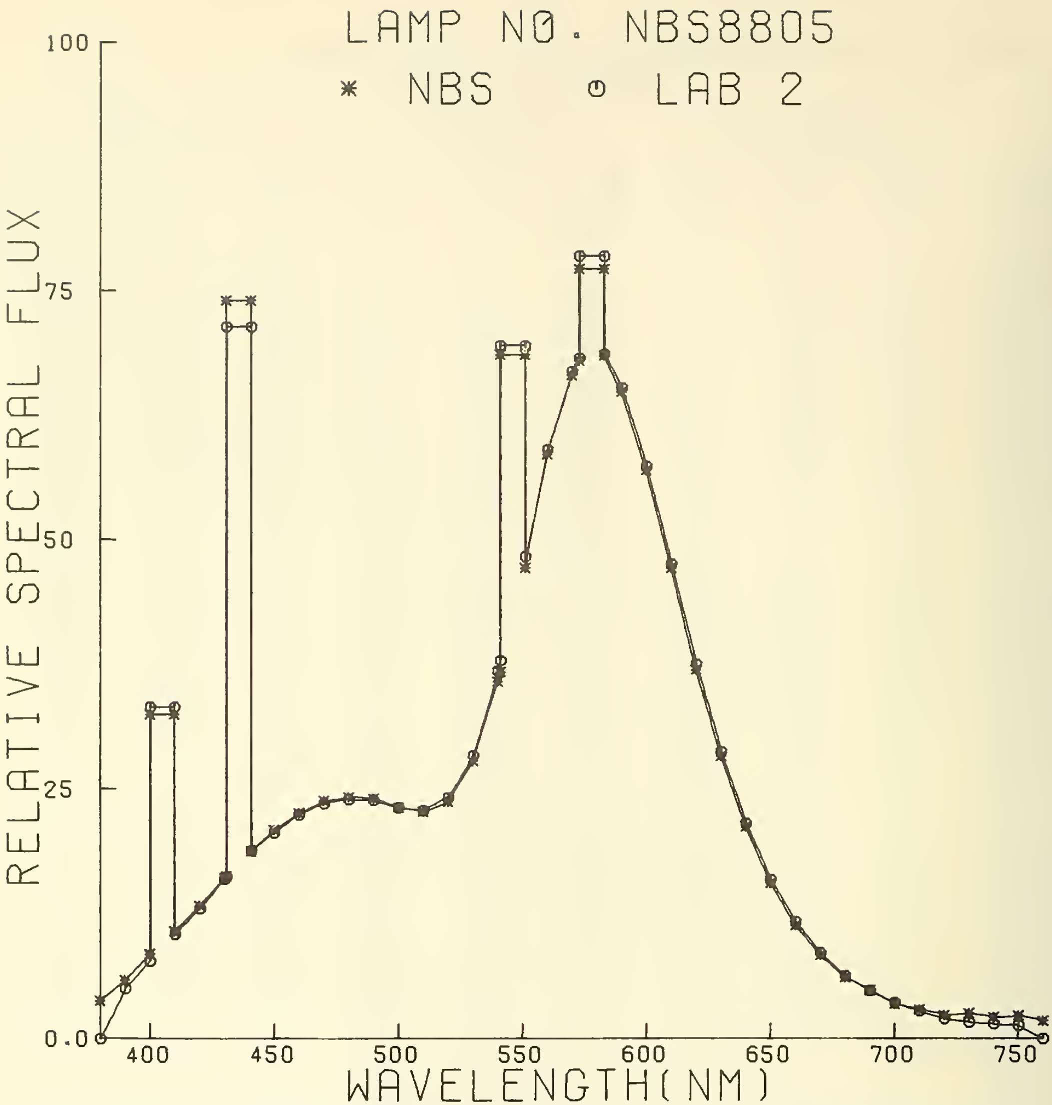


FIGURE 4.26 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.35

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8805

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0320	.0315	.0316	.0000	.0000	.0000	.0311	.0308	.0304
390.0	.0482	.0490	.0489	.0473	.0354	.0308	.0478	.0467	.0476
400.0	.0708	.0691	.0701	.0623	.0565	.0553	.0690	.0673	.0679
410.0	.0895	.0870	.0884	.0813	.0771	.0781	.0882	.0867	.0876
420.0	.1086	.1149	.1088	.0989	.0959	.0982	.1081	.1067	.1072
430.0	.1310	.1317	.1330	.1203	.1181	.1212	.1310	.1305	.1306
440.0	.1515	.1526	.1538	.1398	.1373	.1412	.1520	.1507	.1513
450.0	.1711	.1710	.1721	.1552	.1527	.1558	.1710	.1697	.1707
460.0	.1853	.1861	.1828	.1684	.1659	.1691	.1851	.1839	.1847
470.0	.1944	.1958	.1957	.1770	.1741	.1773	.1945	.1935	.1944
480.0	.1973	.1984	.1987	.1804	.1771	.1804	.1982	.1971	.1980
490.0	.1963	.1968	.1974	.1801	.1771	.1798	.1961	.1960	.1964
500.0	.1888	.1899	.1906	.1745	.1713	.1740	.1892	.1886	.1894
510.0	.1852	.1862	.1872	.1724	.1694	.1722	.1858	.1853	.1855
520.0	.1940	.1950	.1957	.1823	.1787	.1815	.1935	.1927	.1941
530.0	.2282	.2288	.2301	.2142	.2097	.2136	.2260	.2252	.2264
540.0	.2940	.2955	.2969	.2782	.2724	.2774	.2904	.2891	.2904
550.0	.3766	.3794	.3811	.3554	.3482	.3544	.3727	.3712	.3728
560.0	.4792	.4835	.4855	.4456	.4365	.4445	.4755	.4743	.4761
570.0	.5435	.5481	.5503	.5047	.4952	.5042	.5417	.5399	.5425
580.0	.5629	.5671	.5699	.5217	.5121	.5208	.5633	.5614	.5645
590.0	.5270	.5311	.5343	.4937	.4836	.4907	.5307	.5290	.5321
600.0	.4635	.4673	.4687	.4342	.4265	.4302	.4664	.4652	.4683
610.0	.3827	.3857	.3871	.3598	.3526	.3556	.3861	.3864	.3879
620.0	.2990	.3011	.3036	.2844	.2788	.2812	.3037	.3030	.3040
630.0	.2289	.2322	.2330	.2177	.2138	.2152	.2319	.2311	.2320
640.0	.1717	.1735	.1723	.1633	.1602	.1613	.1740	.1740	.1754
650.0	.1256	.1282	.1274	.1211	.1184	.1194	.1273	.1275	.1279
660.0	.0907	.0920	.0937	.0889	.0883	.0875	.0927	.0924	.0929
670.0	.0682	.0676	.0680	.0658	.0639	.0644	.0678	.0688	.0691
680.0	.0499	.0494	.0498	.0483	.0467	.0475	.0500	.0511	.0505
690.0	.0392	.0388	.0392	.0369	.0358	.0361	.0395	.0399	.0410
700.0	.0277	.0275	.0277	.0275	.0265	.0270	.0289	.0285	.0296
710.0	.0254	.0224	.0226	.0213	.0207	.0207	.0231	.0240	.0251
720.0	.0196	.0194	.0196	.0159	.0151	.0151	.0175	.0198	.0199
730.0	.0264	.0262	.0265	.0128	.0118	.0126	.0145	.0157	.0158
740.0	.0176	.0176	.0177	.0123	.0107	.0112	.0152	.0183	.0184
750.0	.0212	.0158	.0212	.0105	.0099	.0101	.0181	.0178	.0199
760.0	.0196	.0135	.0132	.0000	.0000	.0000	.0124	.0147	.0148

MERCURY LINES

WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
405.0	.1854	.1866	.1908	.1826	.1775	.1817	.1876	.1862	.1871
436.0	.4612	.4628	.4655	.4024	.4049	.4027	.4597	.4588	.4639
546.0	.2164	.2182	.2219	.1981	.1931	.2021	.2176	.2157	.2165
578.0	.0737	.0746	.0754	.0749	.0742	.0763	.0720	.0722	.0722

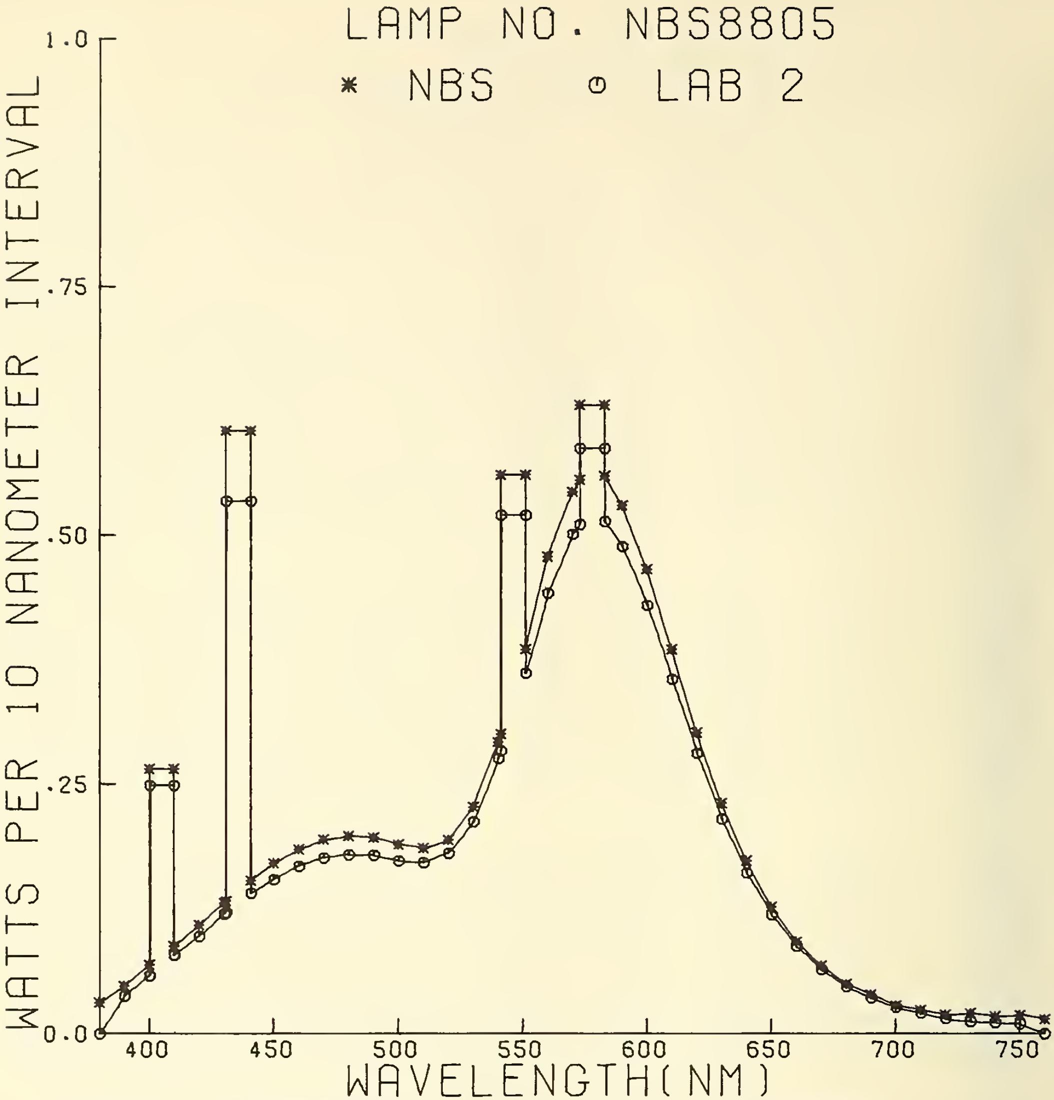


FIGURE 4.27 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.36

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8806

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	4.0	4.1	3.9	.0	.0	.0	3.9	3.8	3.9
390.0	6.0	6.1	6.1	5.7	5.2	4.6	5.9	5.9	6.0
400.0	8.8	8.8	8.7	8.0	8.0	7.8	8.5	8.5	8.5
410.0	11.1	11.2	11.0	10.7	10.8	10.8	10.9	10.9	10.9
420.0	13.4	14.3	13.5	13.3	13.3	13.3	13.4	13.3	13.3
430.0	16.3	16.4	16.4	16.3	16.3	16.3	16.3	16.3	16.2
440.0	18.8	18.9	18.9	19.0	18.9	18.9	18.9	18.8	18.8
450.0	21.2	21.6	21.2	21.0	21.1	21.0	21.2	21.1	21.2
460.0	22.9	22.6	22.9	22.8	22.8	22.8	23.0	22.9	22.9
470.0	24.0	24.0	24.1	23.8	23.9	23.8	24.2	24.1	24.1
480.0	24.3	24.3	24.4	24.2	24.3	24.2	24.6	24.5	24.5
490.0	24.3	24.2	24.3	24.2	24.3	24.2	24.4	24.4	24.3
500.0	23.3	23.3	23.4	23.4	23.4	23.4	23.5	23.5	23.4
510.0	22.8	22.8	22.9	23.0	23.1	23.1	23.0	23.0	22.9
520.0	23.8	23.8	23.9	24.2	24.2	24.2	23.8	23.8	23.8
530.0	27.8	27.8	27.8	28.2	27.7	28.4	27.6	27.6	27.6
540.0	35.7	35.7	35.7	36.4	36.6	36.7	35.3	35.2	35.3
550.0	45.7	45.7	45.8	46.5	46.9	46.8	45.2	45.2	45.2
560.0	58.1	58.2	58.3	58.3	58.5	58.8	57.7	57.7	57.7
570.0	65.9	66.1	66.2	66.2	66.4	66.8	65.8	65.8	65.9
580.0	68.4	68.6	68.7	68.6	68.8	69.1	68.6	68.5	68.7
590.0	64.2	64.4	64.5	65.1	65.1	65.4	64.7	64.7	64.9
600.0	56.5	56.6	56.8	57.4	57.4	57.5	57.0	57.0	57.0
610.0	46.8	46.8	46.9	47.6	47.5	47.6	47.2	47.3	47.4
620.0	36.6	36.7	36.8	37.7	37.7	37.7	37.2	37.4	37.3
630.0	28.1	28.1	28.3	28.9	28.9	29.0	28.5	28.4	28.5
640.0	21.4	20.9	21.0	21.7	21.7	21.7	21.4	21.4	21.4
650.0	15.4	15.3	15.5	16.1	16.1	16.1	15.7	15.8	15.8
660.0	11.3	11.2	11.2	11.8	11.9	11.9	11.5	11.5	11.5
670.0	8.5	8.3	8.3	8.7	8.8	8.7	8.5	8.7	8.5
680.0	6.2	6.0	6.0	6.4	6.4	6.4	6.2	6.3	6.3
690.0	4.9	4.8	4.8	4.9	4.9	4.9	4.9	5.0	5.0
700.0	3.6	3.4	3.4	3.7	3.7	3.7	3.6	3.6	3.5
710.0	3.0	2.8	2.8	2.9	2.9	2.8	2.9	2.9	2.9
720.0	2.5	2.3	2.3	2.1	2.1	2.1	2.2	2.4	2.4
730.0	3.4	3.1	3.1	1.7	1.7	1.7	1.9	1.9	1.9
740.0	2.1	1.8	1.8	1.6	1.6	1.6	1.8	2.0	2.0
750.0	2.2	1.9	1.9	1.5	1.5	1.4	1.9	2.1	1.9
760.0	2.3	1.9	1.6	.0	.0	.0	1.5	1.7	1.5
MERCURY LINES									
405.0	22.6	23.1	23.0	24.3	24.5	23.8	23.3	23.0	23.2
436.0	56.3	56.4	56.4	55.9	54.8	53.6	56.7	56.6	56.6
546.0	26.4	26.6	26.7	26.1	26.2	27.1	26.8	26.6	26.7
578.0	9.0	9.0	9.0	9.9	9.8	10.2	8.9	8.8	8.9

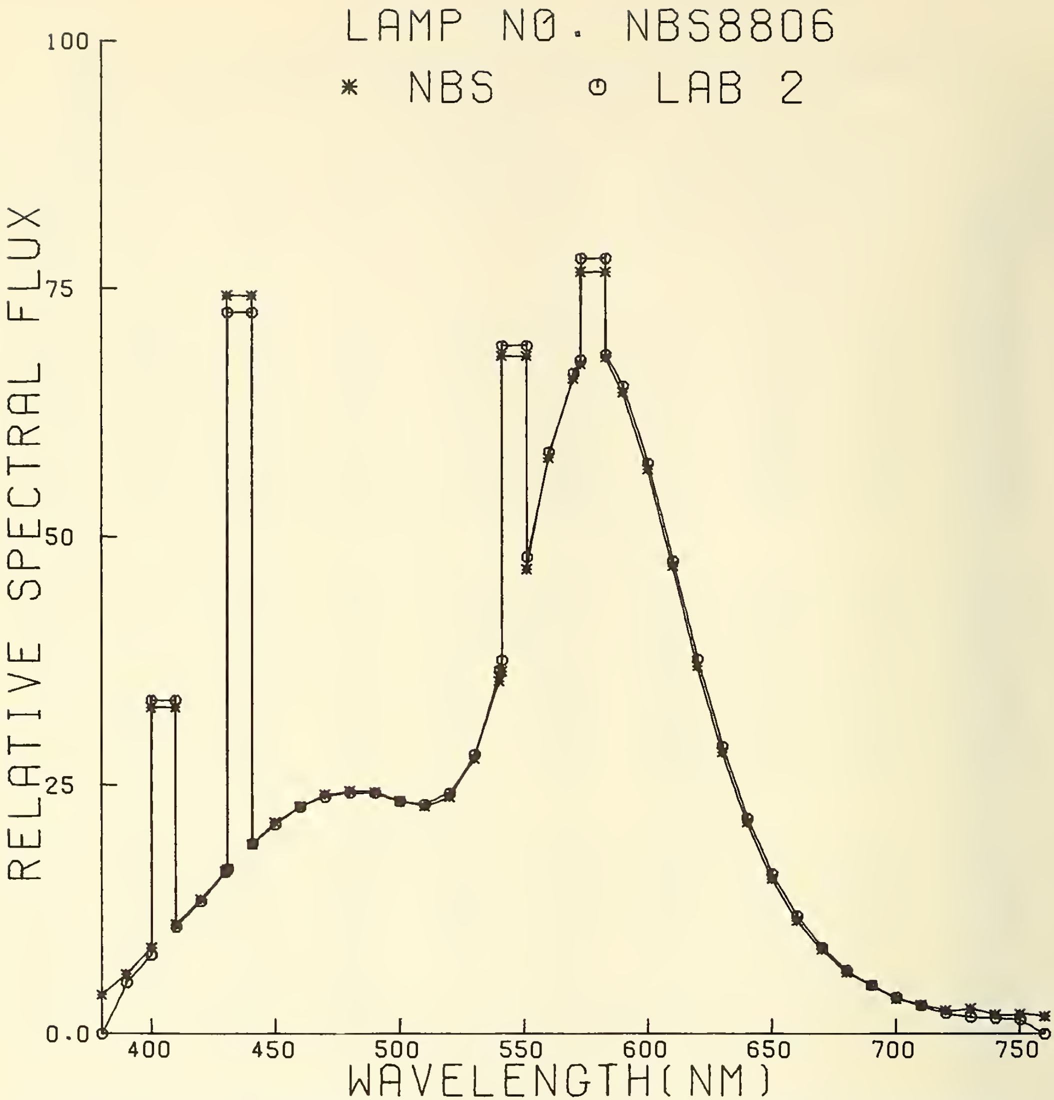


FIGURE 4.28 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.37

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8806

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0340	.0343	.0330	.0000	.0000	.0000	.0325	.0322	.0331
390.0	.0508	.0512	.0511	.0447	.0400	.0350	.0498	.0496	.0505
400.0	.0742	.0745	.0735	.0624	.0623	.0596	.0712	.0710	.0717
410.0	.0931	.0941	.0930	.0838	.0839	.0820	.0912	.0912	.0921
420.0	.1130	.1203	.1134	.1037	.1035	.1013	.1122	.1120	.1124
430.0	.1374	.1380	.1380	.1276	.1267	.1234	.1365	.1366	.1366
440.0	.1583	.1591	.1591	.1484	.1468	.1436	.1584	.1577	.1581
450.0	.1784	.1823	.1785	.1637	.1633	.1595	.1781	.1775	.1783
460.0	.1927	.1905	.1931	.1777	.1766	.1729	.1929	.1927	.1931
470.0	.2020	.2023	.2029	.1861	.1853	.1809	.2029	.2022	.2031
480.0	.2046	.2052	.2052	.1893	.1884	.1840	.2062	.2061	.2064
490.0	.2042	.2043	.2044	.1886	.1881	.1836	.2048	.2051	.2048
500.0	.1960	.1962	.1970	.1826	.1817	.1775	.1970	.1973	.1975
510.0	.1919	.1926	.1928	.1797	.1790	.1751	.1927	.1929	.1932
520.0	.2004	.2009	.2011	.1888	.1879	.1840	.1993	.1998	.2005
530.0	.2339	.2347	.2346	.2202	.2147	.2154	.2315	.2318	.2327
540.0	.3002	.3007	.3012	.2844	.2839	.2785	.2959	.2962	.2977
550.0	.3841	.3852	.3857	.3630	.3638	.3555	.3790	.3797	.3813
560.0	.4885	.4907	.4910	.4555	.4536	.4461	.4836	.4849	.4864
570.0	.5545	.5573	.5576	.5171	.5150	.5070	.5517	.5529	.5552
580.0	.5753	.5783	.5789	.5356	.5333	.5248	.5746	.5760	.5788
590.0	.5397	.5428	.5438	.5082	.5050	.4960	.5427	.5440	.5471
600.0	.4752	.4770	.4783	.4479	.4449	.4363	.4780	.4794	.4804
610.0	.3935	.3941	.3952	.3716	.3687	.3612	.3959	.3977	.3993
620.0	.3075	.3096	.3097	.2941	.2922	.2861	.3118	.3145	.3144
630.0	.2366	.2370	.2383	.2255	.2243	.2197	.2386	.2390	.2400
640.0	.1796	.1765	.1774	.1695	.1683	.1650	.1792	.1799	.1805
650.0	.1299	.1288	.1306	.1260	.1250	.1222	.1315	.1325	.1329
660.0	.0950	.0944	.0941	.0925	.0919	.0900	.0962	.0968	.0973
670.0	.0714	.0699	.0702	.0682	.0679	.0662	.0713	.0731	.0717
680.0	.0521	.0507	.0509	.0502	.0496	.0488	.0517	.0528	.0531
690.0	.0415	.0401	.0403	.0386	.0382	.0373	.0413	.0418	.0420
700.0	.0302	.0288	.0289	.0292	.0288	.0278	.0299	.0304	.0296
710.0	.0254	.0239	.0240	.0227	.0228	.0215	.0242	.0240	.0240
720.0	.0212	.0195	.0195	.0166	.0166	.0158	.0188	.0198	.0199
730.0	.0283	.0263	.0264	.0135	.0135	.0127	.0159	.0157	.0158
740.0	.0177	.0154	.0155	.0126	.0126	.0121	.0152	.0167	.0167
750.0	.0185	.0158	.0159	.0118	.0118	.0107	.0161	.0178	.0160
760.0	.0196	.0164	.0132	.0000	.0000	.0000	.0124	.0147	.0123

MERCURY LINES

405.0	.1903	.1943	.1939	.1897	.1899	.1810	.1957	.1936	.1952
436.0	.4733	.4752	.4749	.4366	.4253	.4065	.4749	.4760	.4769
546.0	.2223	.2241	.2246	.2035	.2033	.2057	.2244	.2238	.2255
578.0	.0755	.0762	.0760	.0773	.0761	.0772	.0746	.0740	.0747

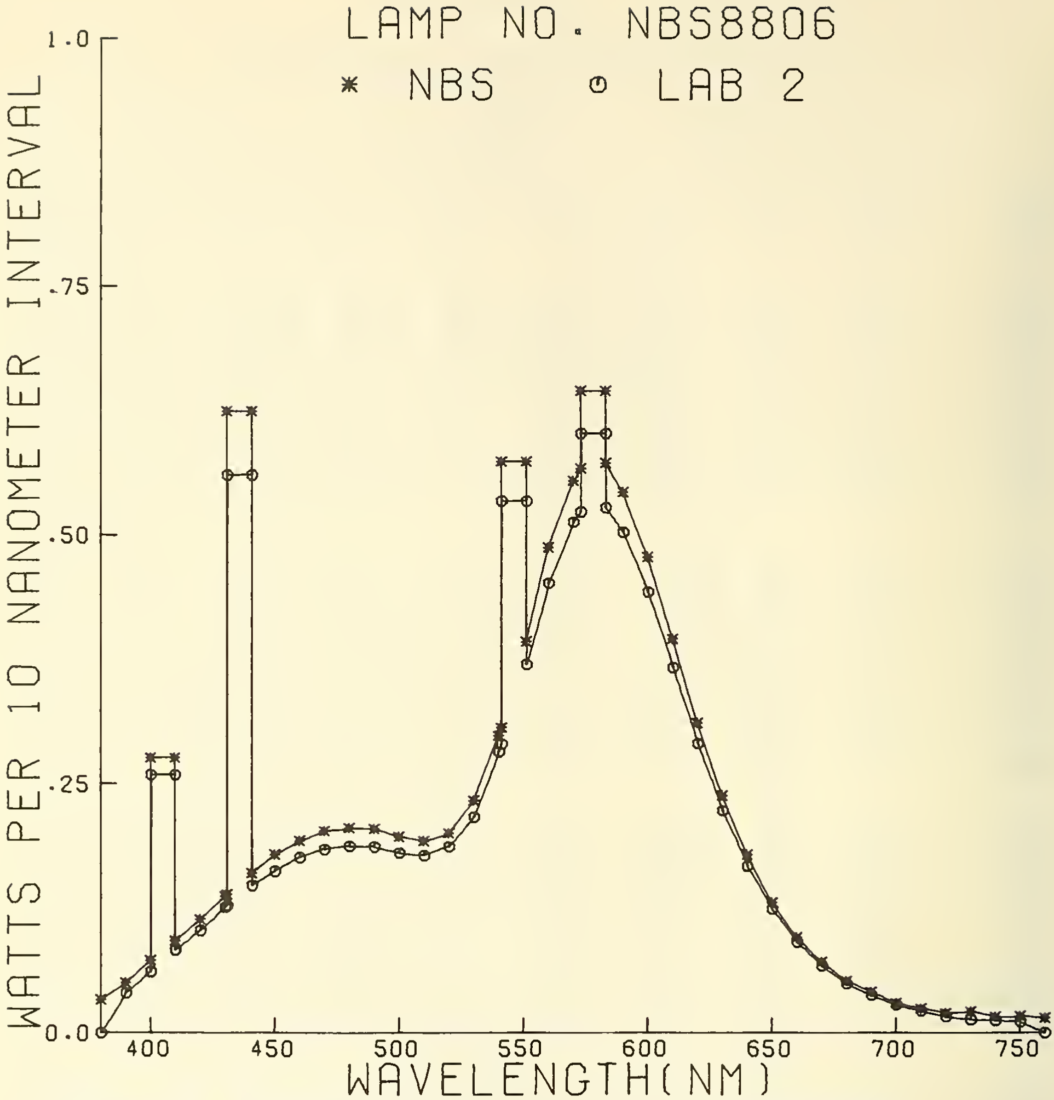


FIGURE 4.29 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.38

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8809

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	4.0	3.9	3.9	4.3	4.3	4.3	3.6	3.9	3.9
390.0	5.9	5.9	6.0	6.5	6.5	6.5	5.8	5.9	6.0
400.0	8.5	8.6	8.4	8.9	8.9	8.9	8.3	8.3	8.4
410.0	10.7	10.7	10.6	11.5	11.5	11.5	10.7	10.6	10.8
420.0	13.1	14.0	13.2	14.4	14.4	14.4	13.2	13.1	13.3
430.0	16.1	15.9	16.2	17.1	17.1	17.1	16.0	16.0	16.1
440.0	18.5	18.4	18.7	19.7	19.7	19.7	18.5	18.5	18.6
450.0	20.8	20.8	20.8	22.3	22.5	22.2	20.9	20.8	20.8
460.0	22.6	22.6	22.1	24.1	24.1	24.1	22.6	22.6	22.5
470.0	23.7	23.7	23.7	25.0	25.1	25.0	23.7	23.7	23.7
480.0	23.9	24.0	24.0	25.2	25.2	25.4	24.1	24.0	24.1
490.0	24.0	23.9	23.9	24.7	24.8	25.0	24.1	24.0	24.0
500.0	23.1	23.1	23.1	23.8	23.7	23.9	23.2	23.1	23.0
510.0	22.6	22.6	22.6	23.3	23.1	23.3	22.7	22.7	22.6
520.0	23.7	23.7	23.8	24.4	24.4	24.4	23.7	23.7	23.6
530.0	27.8	27.9	27.9	28.6	28.4	28.5	27.7	27.7	27.5
540.0	35.9	35.8	36.0	36.8	36.6	36.8	35.6	35.5	35.4
550.0	46.1	46.0	46.2	48.1	48.0	48.2	45.7	45.5	45.5
560.0	58.7	58.7	58.9	59.3	59.1	59.3	58.3	58.2	58.0
570.0	66.5	66.6	66.8	67.0	66.7	66.7	66.4	66.4	66.1
580.0	69.0	69.0	69.2	70.8	71.4	70.7	69.1	69.1	68.7
590.0	64.7	64.7	64.9	65.2	65.0	65.0	65.1	65.1	64.7
600.0	57.1	57.0	57.0	56.9	56.7	56.7	57.3	57.3	57.0
610.0	46.9	47.1	47.1	46.7	46.5	46.6	47.4	47.5	47.3
620.0	36.7	36.9	36.9	36.8	36.7	36.7	37.3	37.4	37.2
630.0	28.2	28.3	28.3	28.2	28.1	28.2	28.5	28.6	28.5
640.0	21.0	21.0	21.0	21.1	20.9	21.0	21.4	21.5	21.3
650.0	15.5	15.5	15.4	15.6	15.5	15.6	15.8	15.9	15.8
660.0	11.2	11.3	11.3	11.5	11.4	11.5	11.5	11.6	11.6
670.0	8.4	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.6
680.0	6.2	6.1	6.1	6.1	6.0	6.0	6.2	6.3	6.3
690.0	4.8	4.9	4.8	4.9	4.8	4.7	4.8	4.9	5.0
700.0	3.4	3.5	3.4	3.5	3.5	3.7	3.5	3.6	3.8
710.0	2.8	2.9	2.8	2.9	2.9	3.1	3.0	3.1	3.1
720.0	2.4	2.2	2.0	2.0	1.9	1.9	2.3	2.4	2.4
730.0	3.3	3.0	3.3	1.8	1.6	1.6	1.9	2.1	2.3
740.0	2.2	1.9	2.2	1.8	1.6	1.6	2.1	2.3	2.2
750.0	2.6	2.2	2.6	1.6	1.4	1.4	2.5	2.4	2.9
760.0	2.4	2.1	1.6	1.0	1.3	1.3	1.8	1.8	2.1
				MERCURY LINES					
405.0	22.8	22.7	22.9	11.6	11.9	11.8	22.8	22.6	22.9
436.0	56.4	56.4	56.5	50.8	52.5	51.5	57.0	56.8	57.5
546.0	26.6	26.6	26.5	28.6	28.5	28.5	26.2	26.2	26.1
578.0	9.3	9.7	9.1	7.4	7.4	7.5	8.9	9.0	8.9

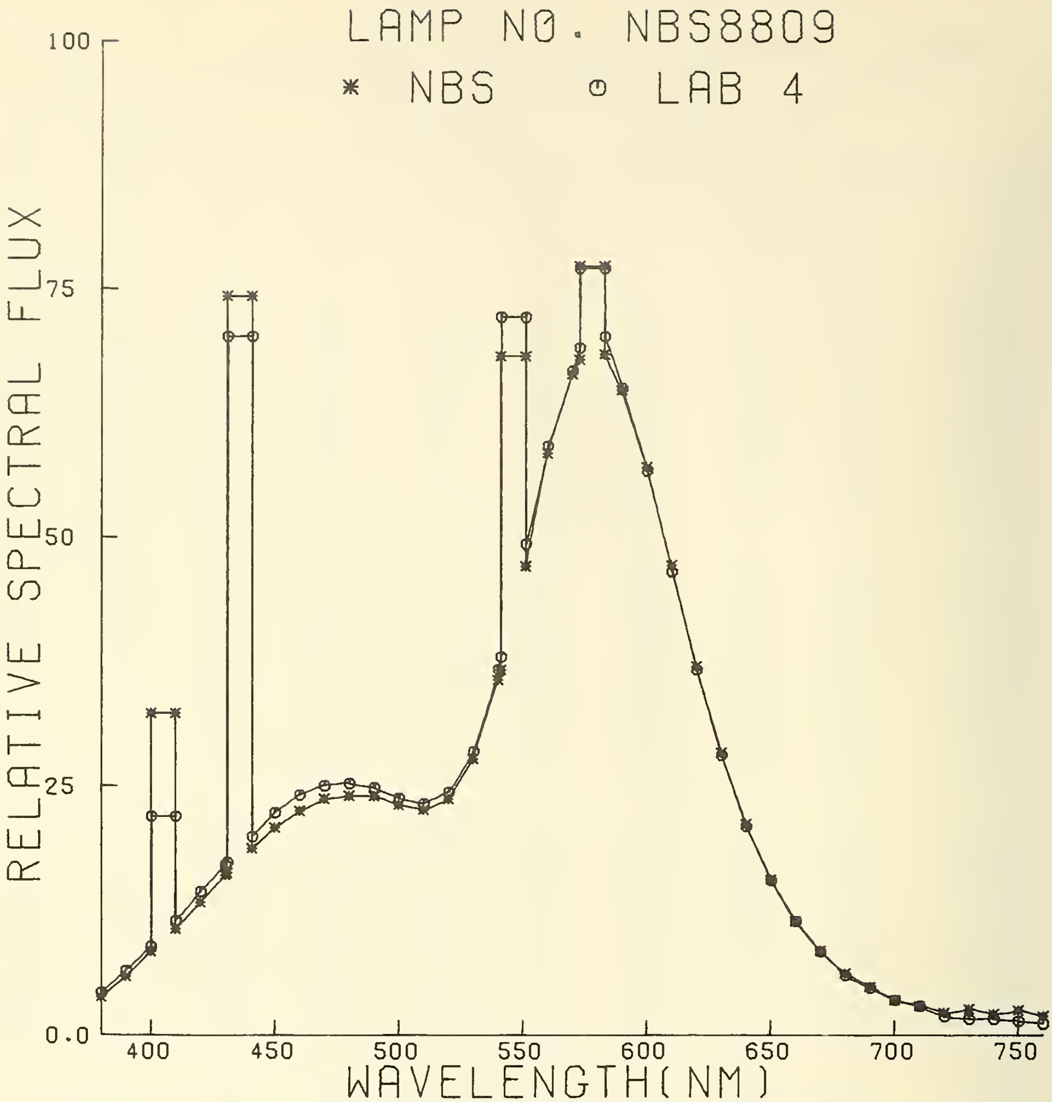


FIGURE 4.30 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.39

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8809

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0327	.0314	.0316	.0396	.0398	.0399	.0298	.0317	.0324
390.0	.0482	.0479	.0489	.0597	.0600	.0599	.0472	.0485	.0490
400.0	.0692	.0699	.0685	.0812	.0821	.0815	.0681	.0680	.0695
410.0	.0872	.0876	.0863	.1052	.1057	.1055	.0874	.0869	.0888
420.0	.1066	.1144	.1067	.1318	.1326	.1321	.1081	.1071	.1093
430.0	.1307	.1295	.1312	.1563	.1569	.1568	.1305	.1306	.1324
440.0	.1506	.1503	.1516	.1804	.1813	.1811	.1513	.1508	.1528
450.0	.1688	.1699	.1691	.2043	.2068	.2034	.1708	.1700	.1715
460.0	.1834	.1843	.1792	.2205	.2220	.2210	.1845	.1842	.1855
470.0	.1925	.1933	.1921	.2291	.2304	.2290	.1938	.1935	.1955
480.0	.1947	.1960	.1945	.2307	.2318	.2329	.1970	.1963	.1985
490.0	.1949	.1951	.1940	.2265	.2278	.2290	.1967	.1957	.1974
500.0	.1875	.1882	.1872	.2181	.2180	.2189	.1894	.1886	.1896
510.0	.1841	.1845	.1837	.2136	.2127	.2136	.1857	.1850	.1866
520.0	.1929	.1936	.1928	.2232	.2240	.2237	.1937	.1931	.1946
530.0	.2263	.2274	.2264	.2617	.2609	.2615	.2259	.2259	.2267
540.0	.2918	.2924	.2922	.3372	.3369	.3374	.2904	.2898	.2916
550.0	.3747	.3753	.3750	.4405	.4412	.4420	.3731	.3719	.3744
560.0	.4769	.4792	.4776	.5431	.5438	.5435	.4760	.4751	.4780
570.0	.5408	.5439	.5419	.6139	.6134	.6122	.5424	.5418	.5443
580.0	.5608	.5634	.5615	.6487	.6567	.6482	.5640	.5638	.5659
590.0	.5260	.5284	.5267	.5971	.5974	.5960	.5315	.5311	.5326
600.0	.4644	.4650	.4628	.5212	.5210	.5201	.4679	.4676	.4694
610.0	.3811	.3844	.3819	.4281	.4279	.4279	.3874	.3881	.3897
620.0	.2983	.3011	.2993	.3373	.3373	.3365	.3048	.3050	.3062
630.0	.2295	.2307	.2298	.2587	.2585	.2589	.2329	.2338	.2348
640.0	.1706	.1718	.1705	.1930	.1926	.1924	.1751	.1756	.1758
650.0	.1263	.1262	.1254	.1427	.1429	.1428	.1292	.1302	.1304
660.0	.0909	.0920	.0915	.1051	.1045	.1052	.0939	.0944	.0954
670.0	.0683	.0687	.0680	.0769	.0770	.0778	.0697	.0697	.0707
680.0	.0501	.0494	.0498	.0559	.0551	.0551	.0509	.0511	.0521
690.0	.0393	.0400	.0392	.0446	.0437	.0427	.0396	.0400	.0410
700.0	.0278	.0287	.0277	.0324	.0324	.0335	.0288	.0295	.0315
710.0	.0227	.0238	.0226	.0266	.0267	.0280	.0242	.0251	.0251
720.0	.0196	.0178	.0163	.0186	.0171	.0171	.0188	.0199	.0199
730.0	.0265	.0242	.0265	.0163	.0146	.0146	.0159	.0172	.0186
740.0	.0178	.0154	.0177	.0169	.0149	.0149	.0169	.0184	.0184
750.0	.0213	.0184	.0212	.0150	.0125	.0125	.0200	.0199	.0239
760.0	.0198	.0169	.0132	.0089	.0119	.0118	.0148	.0147	.0172
MERCURY LINES									
405.0	.1851	.1850	.1855	.1061	.1092	.1083	.1860	.1844	.1883
436.0	.4586	.4606	.4588	.4650	.4829	.4725	.4659	.4636	.4737
546.0	.2159	.2173	.2153	.2616	.2625	.2615	.2143	.2140	.2148
578.0	.0754	.0792	.0738	.0680	.0682	.0687	.0725	.0731	.0734

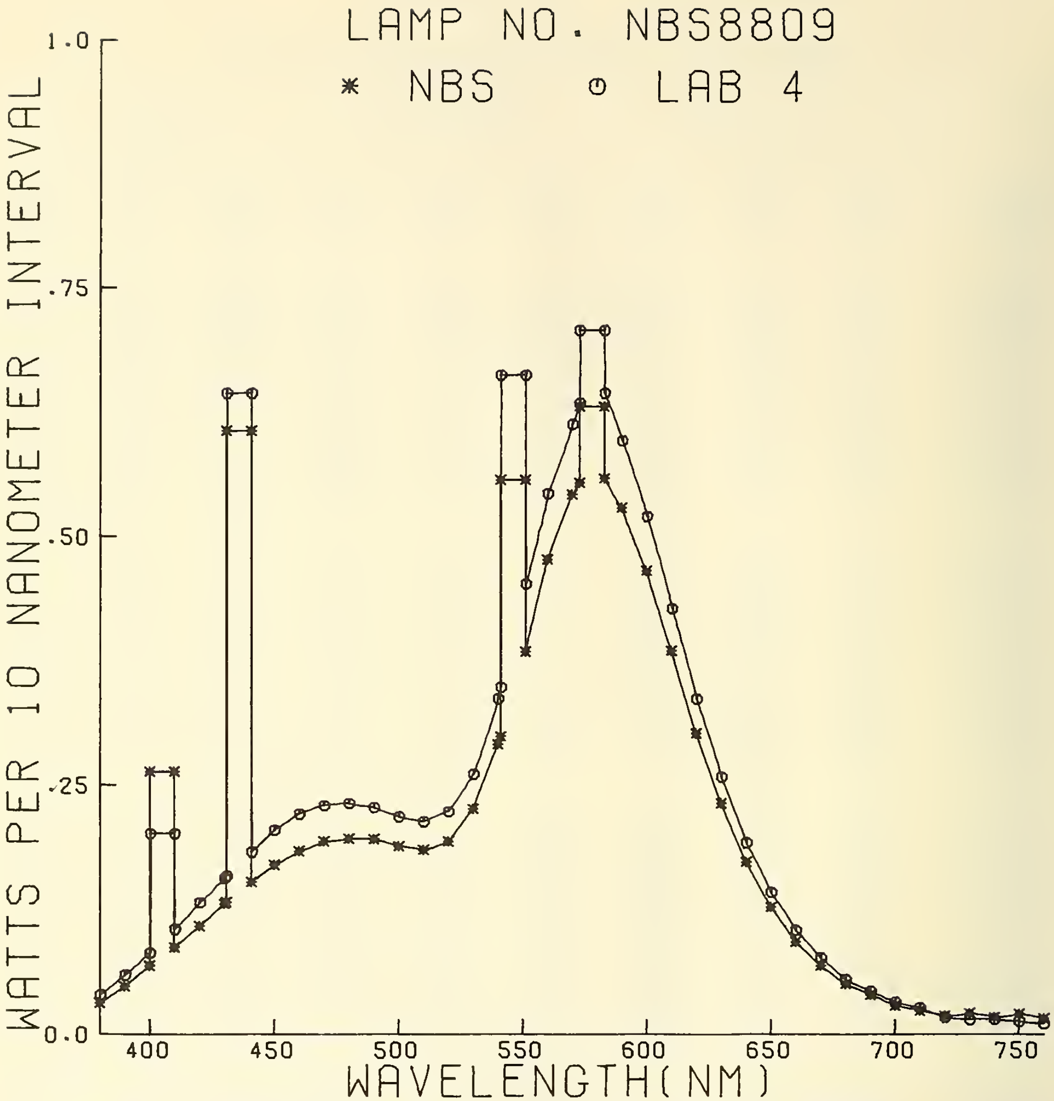


FIGURE 4.31 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.40

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8810

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	3.7	3.8	3.8	4.3	4.3	4.3	3.8	3.6	3.7
390.0	5.8	5.9	5.9	6.5	6.5	6.5	5.7	5.8	5.7
400.0	8.4	8.5	8.4	8.6	8.7	8.6	8.3	8.2	8.2
410.0	10.7	10.7	10.7	11.1	7.9	7.9	10.7	10.6	10.6
420.0	13.1	13.8	13.1	13.8	13.8	13.8	13.2	13.0	13.1
430.0	16.0	15.9	15.9	16.6	16.5	16.5	15.8	15.8	15.9
440.0	18.4	17.7	18.4	19.2	19.2	19.1	18.3	18.3	18.4
450.0	20.5	19.2	20.6	22.1	22.3	22.3	20.7	20.6	20.6
460.0	22.3	22.3	22.4	23.7	23.8	23.8	22.4	22.3	22.4
470.0	23.5	23.4	23.5	24.7	24.5	24.4	23.6	23.5	23.6
480.0	23.8	23.8	23.8	24.7	24.8	25.0	24.0	23.9	24.0
490.0	23.7	23.7	23.7	24.4	24.2	24.3	23.9	23.8	23.8
500.0	22.9	22.9	22.9	23.5	23.4	23.4	23.0	22.9	22.9
510.0	22.5	22.5	22.5	23.0	22.9	22.9	22.6	22.6	22.5
520.0	23.6	23.7	23.6	23.9	23.9	23.9	23.6	23.5	23.6
530.0	27.8	27.8	27.8	28.1	28.1	28.2	27.6	27.6	27.5
540.0	35.9	35.9	35.9	36.1	36.0	36.2	35.4	35.4	35.5
550.0	46.0	46.1	46.2	47.3	47.3	47.4	45.6	45.6	45.6
560.0	58.6	58.9	58.9	58.5	58.4	58.6	58.3	58.2	58.3
570.0	66.6	66.9	66.8	66.2	66.2	66.5	66.4	66.5	66.4
580.0	68.9	69.5	69.4	76.6	78.2	78.3	69.1	69.2	69.1
590.0	64.6	65.1	65.0	65.3	65.3	65.5	65.2	65.3	65.2
600.0	56.8	57.2	57.1	57.2	57.2	57.3	57.4	57.4	57.3
610.0	47.1	47.3	47.2	47.2	47.1	47.3	47.5	47.6	47.6
620.0	36.9	37.1	36.9	37.2	37.2	37.3	37.4	37.5	37.4
630.0	28.7	28.5	28.4	28.5	28.4	28.5	28.6	28.7	28.6
640.0	21.3	21.3	21.2	21.3	21.3	21.4	21.6	21.6	21.4
650.0	15.6	15.7	15.6	15.9	15.9	15.9	15.9	16.0	15.8
660.0	11.4	11.4	11.3	11.8	11.7	11.7	11.5	11.6	11.4
670.0	8.5	8.6	8.4	8.7	8.6	8.5	8.6	8.6	8.5
680.0	6.4	6.1	6.1	6.4	6.4	6.4	6.4	6.4	6.2
690.0	5.0	4.8	4.8	5.0	5.0	4.9	5.0	5.0	4.9
700.0	3.7	3.5	3.5	3.9	3.9	3.8	3.7	3.6	3.7
710.0	3.2	3.0	2.9	3.1	3.1	3.0	3.1	2.9	3.0
720.0	2.5	2.3	2.1	2.3	2.3	2.3	2.4	2.2	2.2
730.0	3.3	3.2	3.2	1.9	1.7	1.7	2.1	1.9	1.9
740.0	2.3	1.9	1.9	2.0	1.8	1.8	2.0	2.2	2.0
750.0	2.5	2.2	2.2	1.8	1.8	1.8	2.4	2.1	2.2
760.0	2.3	2.0	2.0	1.2	1.3	1.3	1.8	1.8	1.8
MERCURY LINES									
405.0	22.6	23.2	23.0	11.1	11.7	11.7	23.2	23.2	23.4
436.0	56.4	56.4	56.6	50.4	52.3	51.3	56.6	57.3	57.7
546.0	26.8	27.0	27.0	28.9	29.0	28.9	26.9	27.1	27.0
578.0	9.2	9.2	9.2	6.0	5.8	5.7	8.9	9.1	9.1

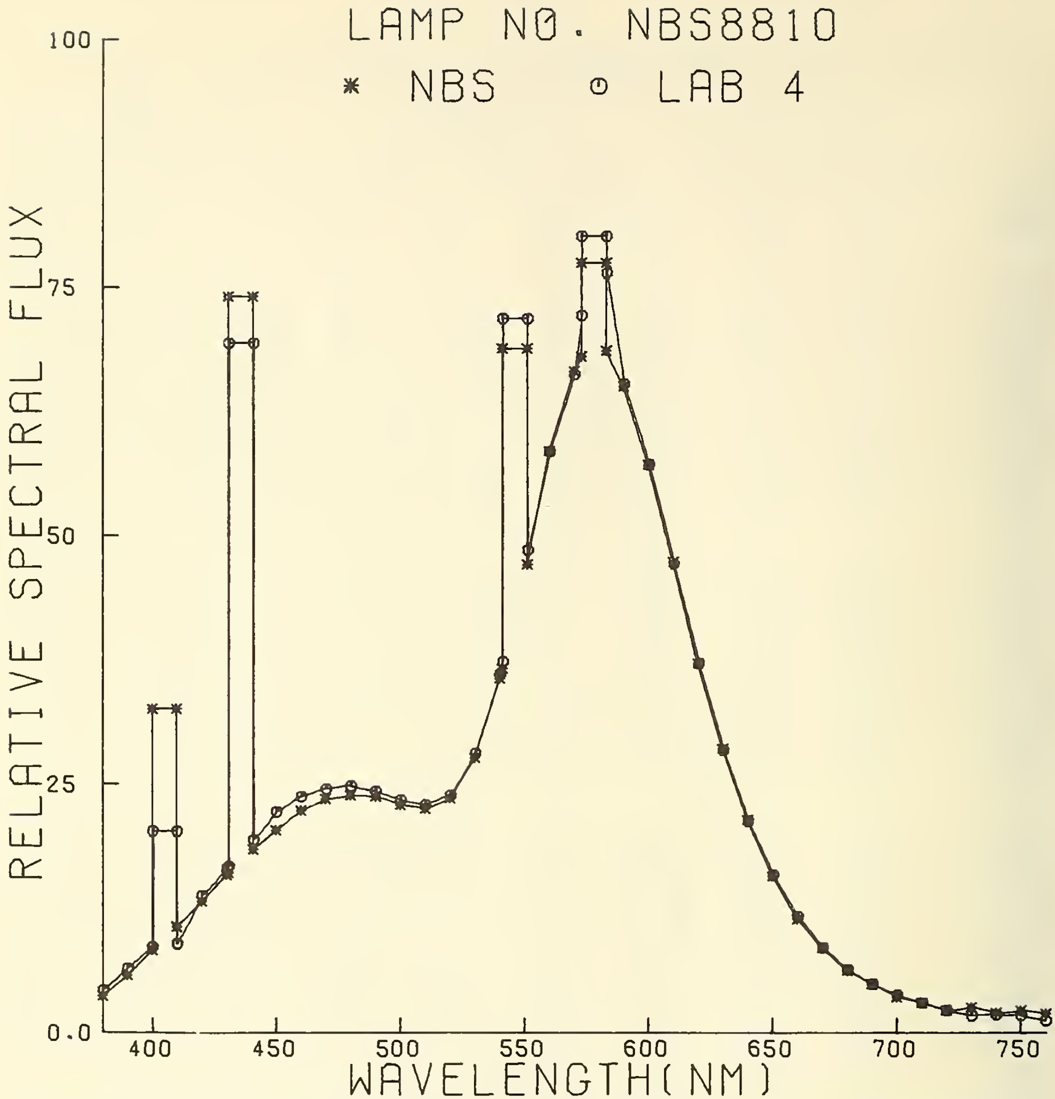


FIGURE 4.32 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.41

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8810

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0308	.0312	.0315	.0408	.0408	.0408	.0311	.0304	.0311
390.0	.0481	.0490	.0489	.0616	.0619	.0617	.0472	.0485	.0471
400.0	.0690	.0705	.0702	.0821	.0825	.0819	.0687	.0690	.0684
410.0	.0878	.0891	.0892	.1052	.0756	.0752	.0882	.0885	.0884
420.0	.1080	.1144	.1088	.1313	.1314	.1312	.1089	.1089	.1093
430.0	.1317	.1318	.1327	.1576	.1576	.1569	.1311	.1325	.1328
440.0	.1514	.1468	.1531	.1826	.1830	.1817	.1519	.1530	.1533
450.0	.1691	.1591	.1718	.2102	.2127	.2113	.1715	.1725	.1718
460.0	.1837	.1850	.1862	.2253	.2270	.2258	.1854	.1870	.1864
470.0	.1933	.1945	.1954	.2347	.2332	.2318	.1950	.1968	.1967
480.0	.1960	.1976	.1983	.2355	.2365	.2376	.1984	.1999	.2000
490.0	.1955	.1969	.1976	.2317	.2309	.2301	.1978	.1995	.1983
500.0	.1884	.1898	.1908	.2236	.2226	.2216	.1905	.1919	.1913
510.0	.1856	.1867	.1873	.2185	.2177	.2169	.1870	.1888	.1879
520.0	.1947	.1963	.1965	.2277	.2277	.2267	.1951	.1970	.1963
530.0	.2289	.2306	.2316	.2673	.2678	.2677	.2285	.2307	.2293
540.0	.2954	.2976	.2993	.3436	.3434	.3432	.2933	.2966	.2958
550.0	.3791	.3826	.3845	.4502	.4509	.4499	.3772	.3813	.3805
560.0	.4828	.4881	.4902	.5570	.5566	.5562	.4823	.4874	.4864
570.0	.5482	.5550	.5567	.6302	.6307	.6307	.5501	.5563	.5539
580.0	.5675	.5760	.5776	.7292	.7453	.7428	.5724	.5793	.5763
590.0	.5317	.5402	.5417	.6215	.6217	.6215	.5396	.5462	.5435
600.0	.4675	.4747	.4753	.5440	.5449	.5440	.4748	.4802	.4777
610.0	.3880	.3923	.3933	.4490	.4488	.4487	.3936	.3984	.3965
620.0	.3039	.3076	.3076	.3537	.3544	.3541	.3093	.3135	.3117
630.0	.2364	.2362	.2368	.2712	.2709	.2708	.2366	.2398	.2388
640.0	.1752	.1765	.1765	.2031	.2033	.2026	.1785	.1808	.1788
650.0	.1282	.1298	.1296	.1515	.1517	.1510	.1315	.1335	.1320
660.0	.0940	.0944	.0941	.1118	.1119	.1111	.0955	.0970	.0954
670.0	.0700	.0710	.0702	.0826	.0819	.0810	.0713	.0723	.0707
680.0	.0525	.0507	.0509	.0613	.0614	.0605	.0534	.0537	.0521
690.0	.0413	.0402	.0403	.0477	.0478	.0468	.0413	.0419	.0410
700.0	.0305	.0288	.0289	.0370	.0371	.0359	.0308	.0305	.0305
710.0	.0260	.0253	.0240	.0293	.0293	.0280	.0253	.0240	.0251
720.0	.0205	.0195	.0179	.0217	.0218	.0218	.0200	.0186	.0187
730.0	.0273	.0263	.0264	.0182	.0165	.0165	.0173	.0157	.0158
740.0	.0193	.0154	.0155	.0191	.0170	.0170	.0169	.0184	.0167
750.0	.0203	.0185	.0186	.0175	.0175	.0175	.0200	.0179	.0179
760.0	.0190	.0164	.0165	.0119	.0119	.0119	.0148	.0147	.0148
MERCURY LINES									
405.0	.1862	.1926	.1915	.1053	.1115	.1108	.1920	.1940	.1951
436.0	.4643	.4680	.4717	.4793	.4979	.4867	.4682	.4794	.4807
546.0	.2208	.2241	.2249	.2752	.2762	.2746	.2231	.2265	.2248
578.0	.0755	.0759	.0766	.0567	.0549	.0542	.0739	.0764	.0762

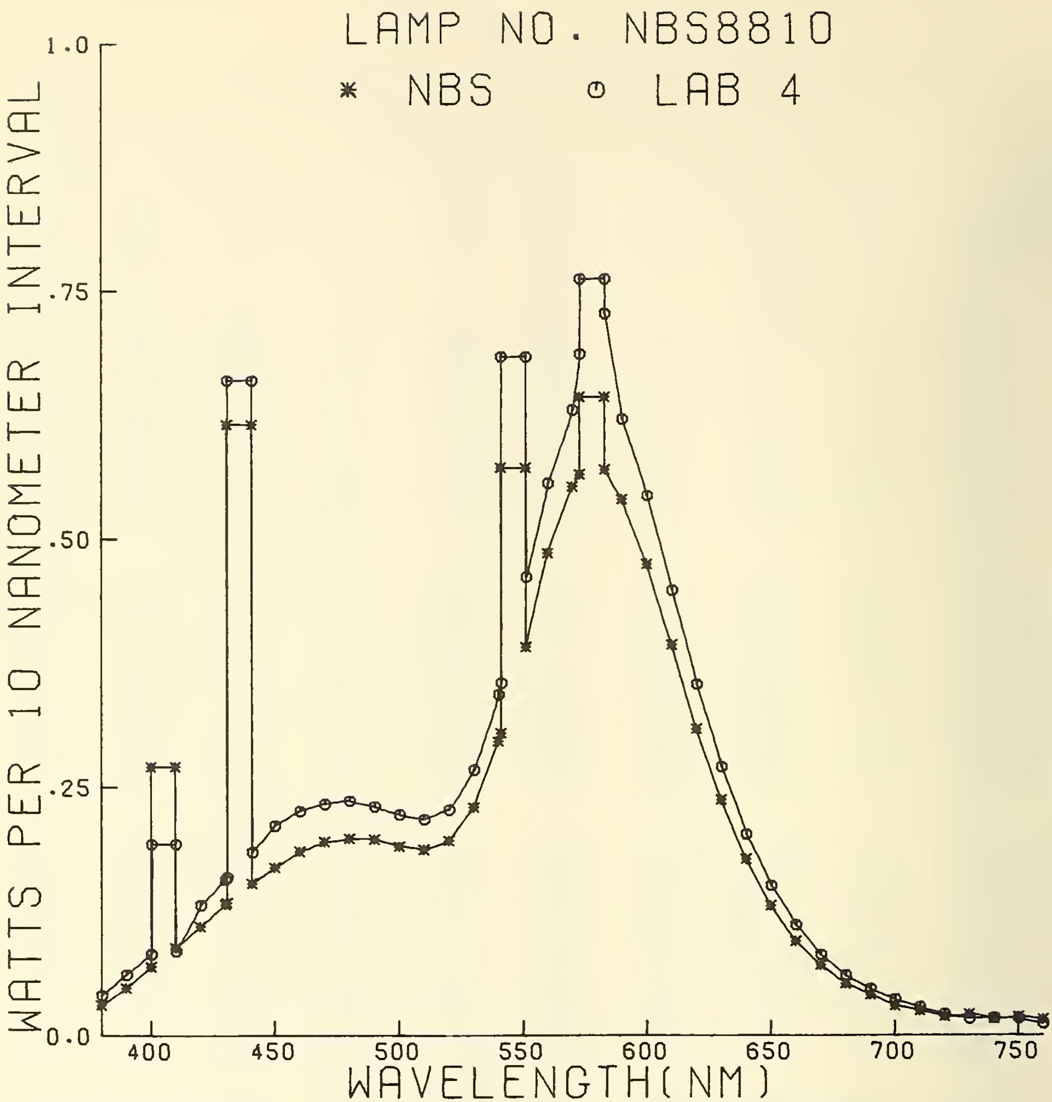


FIGURE 4.33 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.42

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8906

	NBS INITIAL			LABORATORY 1			NBS REPEAT			
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9	RUN 10
380.0	5.1	5.0	5.1	5.3	.0	.0	.0	4.8	5.0	5.0
390.0	8.8	8.8	8.8	8.8	7.7	9.3	10.0	8.5	8.3	8.4
400.0	14.2	13.5	14.0	13.7	14.8	13.8	13.4	13.2	13.4	13.5
410.0	18.5	17.9	18.4	17.9	18.7	18.4	17.9	17.8	17.9	17.9
420.0	23.1	22.6	22.8	22.6	23.5	23.4	23.1	22.5	22.5	22.5
430.0	28.3	28.2	28.2	28.1	29.3	28.9	28.9	27.9	27.8	27.7
440.0	32.7	32.6	32.5	32.4	33.1	33.4	33.5	32.4	32.2	32.2
450.0	36.3	36.2	36.2	36.1	36.5	36.8	36.9	36.2	36.1	36.0
460.0	38.6	38.5	38.6	37.7	39.6	39.1	39.0	38.6	38.5	38.4
470.0	39.7	39.7	39.7	39.6	40.4	40.1	40.0	39.7	39.7	39.5
480.0	39.3	39.4	39.3	39.2	39.0	39.3	38.3	39.5	39.4	39.4
490.0	38.0	38.0	38.0	37.9	37.5	37.9	36.9	38.2	38.1	38.0
500.0	35.6	35.7	35.7	35.7	35.9	35.9	35.7	35.9	35.8	35.7
510.0	33.3	33.3	33.3	33.4	33.5	33.4	33.3	33.6	33.6	33.4
520.0	31.6	31.6	31.6	31.7	31.7	32.0	31.5	31.9	31.8	31.6
530.0	31.8	31.8	31.9	31.9	32.7	32.8	32.5	31.9	31.9	31.7
540.0	34.7	34.5	34.5	34.6	35.2	35.2	35.1	34.6	34.4	34.3
550.0	38.8	38.6	38.6	38.7	39.2	39.2	39.1	38.7	38.6	40.5
560.0	44.5	44.5	44.4	44.6	44.8	44.8	44.7	44.5	44.4	51.0
570.0	47.9	47.8	47.9	48.0	47.2	47.1	47.1	48.0	48.0	47.6
580.0	48.2	48.2	48.2	48.3	47.1	47.0	47.0	48.4	48.4	45.4
590.0	44.7	44.8	44.6	44.7	44.4	44.5	44.5	45.0	45.0	44.7
600.0	38.8	39.1	39.0	39.1	39.1	39.6	39.5	39.5	39.4	39.1
610.0	32.3	32.6	32.2	32.3	32.4	32.8	33.4	32.8	32.7	32.5
620.0	25.2	25.5	25.4	27.0	25.6	26.2	26.0	25.9	25.9	25.7
630.0	19.6	20.0	19.8	19.8	19.9	20.1	20.2	20.1	20.1	19.8
640.0	14.6	15.0	14.9	15.0	15.4	15.4	15.4	15.2	15.3	15.1
650.0	10.7	11.1	11.1	11.1	11.4	11.4	11.6	11.4	11.4	11.2
660.0	7.7	8.2	8.2	8.3	8.5	8.6	9.0	8.4	8.5	8.3
670.0	5.8	6.4	6.2	6.1	6.1	7.0	7.3	6.4	6.4	6.2
680.0	4.1	4.7	4.6	4.7	4.8	5.1	5.1	4.6	4.8	4.6
690.0	3.4	3.9	3.8	3.6	4.3	4.2	4.2	3.8	3.9	3.8
700.0	2.5	3.0	2.8	2.9	3.3	3.2	3.2	2.8	2.9	2.8
710.0	1.9	2.4	2.3	2.4	2.5	2.5	3.0	2.3	2.5	2.3
720.0	1.5	1.9	1.9	1.9	2.4	2.4	2.4	1.9	2.1	1.8
730.0	2.1	2.7	2.7	2.7	.0	.0	.0	1.5	1.7	1.4
740.0	1.0	1.6	1.6	1.6	.0	.0	.0	1.6	1.6	1.4
750.0	.6	1.9	1.9	1.9	.0	.0	.0	1.4	1.9	1.7
760.0	.4	1.6	1.9	1.6	.0	.0	.0	1.2	1.5	1.2

MERCURY LINES

405.0	22.8	21.1	21.1	21.2	23.9	22.7	21.1	21.3	21.1	21.2
436.0	55.2	52.0	52.1	51.7	54.5	52.5	55.5	51.9	51.6	51.8
546.0	26.9	25.8	25.8	25.7	26.9	26.4	26.9	25.8	25.6	25.1
578.0	9.2	8.4	8.5	8.5	7.4	7.7	7.8	8.3	8.2	8.5

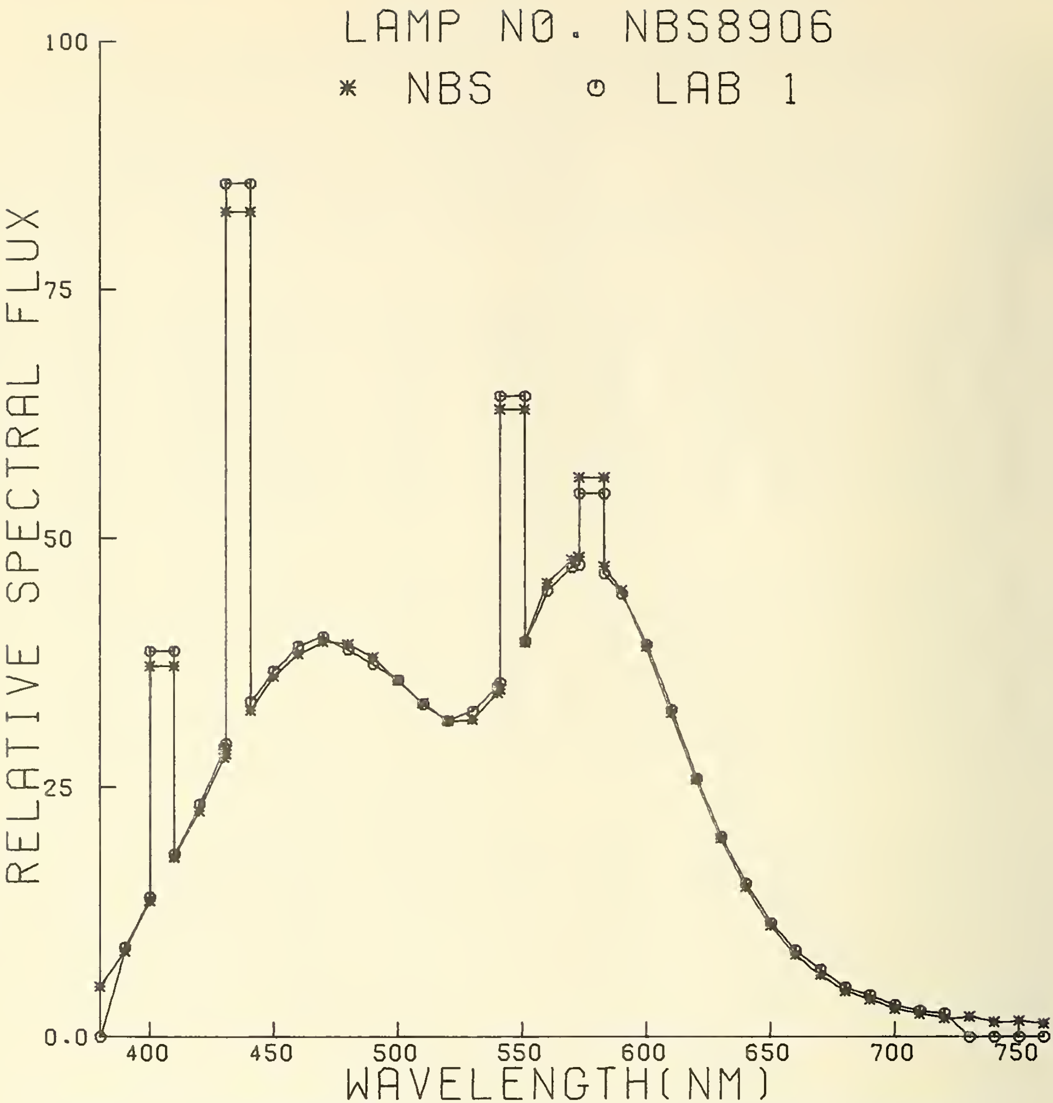


FIGURE 4.34 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.43

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8906

	NBS INITIAL			LABORATORY 1			NBS REPEAT			
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9	RUN 10
380.0	.0461	.0417	.0431	.0443	.0000	.0000	.0000	.0403	.0421	.0424
390.0	.0796	.0735	.0744	.0735	.0636	.0769	.0836	.0712	.0699	.0718
400.0	.1277	.1134	.1182	.1146	.1225	.1146	.1117	.1112	.1124	.1144
410.0	.1668	.1505	.1552	.1502	.1547	.1524	.1493	.1493	.1507	.1526
420.0	.2075	.1900	.1927	.1893	.1944	.1941	.1921	.1895	.1896	.1915
430.0	.2550	.2365	.2379	.2350	.2416	.2395	.2401	.2343	.2339	.2355
440.0	.2939	.2733	.2743	.2716	.2733	.2770	.2786	.2721	.2710	.2735
450.0	.3267	.3039	.3056	.3019	.3016	.3054	.3068	.3039	.3041	.3062
460.0	.3474	.3231	.3259	.3159	.3267	.3247	.3248	.3246	.3242	.3265
470.0	.3572	.3330	.3353	.3319	.3335	.3323	.3325	.3340	.3342	.3359
480.0	.3538	.3306	.3319	.3284	.3217	.3259	.3187	.3321	.3321	.3351
490.0	.3421	.3186	.3211	.3175	.3094	.3144	.3069	.3215	.3210	.3229
500.0	.3207	.2995	.3016	.2988	.2968	.2978	.2971	.3019	.3017	.3039
510.0	.2994	.2795	.2812	.2793	.2764	.2767	.2770	.2822	.2826	.2838
520.0	.2840	.2652	.2668	.2652	.2617	.2655	.2619	.2678	.2675	.2690
530.0	.2865	.2672	.2691	.2673	.2698	.2720	.2706	.2685	.2684	.2699
540.0	.3118	.2896	.2916	.2894	.2905	.2919	.2918	.2905	.2898	.2915
550.0	.3490	.3241	.3262	.3241	.3237	.3250	.3255	.3250	.3246	.3445
560.0	.4004	.3732	.3749	.3734	.3696	.3716	.3718	.3738	.3736	.4337
570.0	.4306	.4015	.4040	.4020	.3901	.3910	.3916	.4037	.4037	.4047
580.0	.4333	.4045	.4066	.4040	.3891	.3903	.3910	.4072	.4074	.3862
590.0	.4022	.3764	.3762	.3738	.3667	.3694	.3701	.3785	.3788	.3800
600.0	.3492	.3282	.3291	.3273	.3227	.3284	.3289	.3316	.3317	.3329
610.0	.2903	.2735	.2720	.2707	.2672	.2724	.2778	.2756	.2755	.2761
620.0	.2263	.2142	.2142	.2261	.2116	.2176	.2163	.2177	.2184	.2189
630.0	.1759	.1679	.1667	.1659	.1647	.1665	.1677	.1686	.1692	.1683
640.0	.1310	.1263	.1260	.1254	.1268	.1276	.1283	.1278	.1292	.1284
650.0	.0965	.0933	.0940	.0931	.0938	.0949	.0966	.0955	.0963	.0956
660.0	.0697	.0692	.0692	.0698	.0701	.0715	.0753	.0705	.0715	.0704
670.0	.0518	.0534	.0526	.0510	.0500	.0583	.0606	.0534	.0542	.0531
680.0	.0372	.0391	.0386	.0390	.0400	.0420	.0421	.0390	.0407	.0395
690.0	.0303	.0323	.0319	.0300	.0352	.0352	.0351	.0319	.0327	.0322
700.0	.0229	.0252	.0236	.0239	.0272	.0262	.0264	.0236	.0246	.0239
710.0	.0171	.0198	.0196	.0198	.0207	.0207	.0250	.0197	.0208	.0198
720.0	.0132	.0163	.0161	.0163	.0198	.0198	.0200	.0162	.0174	.0150
730.0	.0191	.0227	.0224	.0227	.0000	.0000	.0000	.0129	.0144	.0116
740.0	.0090	.0132	.0132	.0133	.0000	.0000	.0000	.0134	.0134	.0118
750.0	.0054	.0159	.0157	.0159	.0000	.0000	.0000	.0120	.0159	.0141
760.0	.0033	.0131	.0163	.0132	.0000	.0000	.0000	.0098	.0123	.0099

MERCURY LINES

405.0	.2054	.1770	.1780	.1778	.1977	.1882	.1753	.1791	.1780	.1807
436.0	.4963	.4366	.4402	.4331	.4497	.4352	.4618	.4363	.4342	.4410
546.0	.2417	.2163	.2181	.2154	.2223	.2193	.2241	.2172	.2159	.2138
578.0	.0830	.0703	.0714	.0708	.0610	.0642	.0649	.0700	.0692	.0721

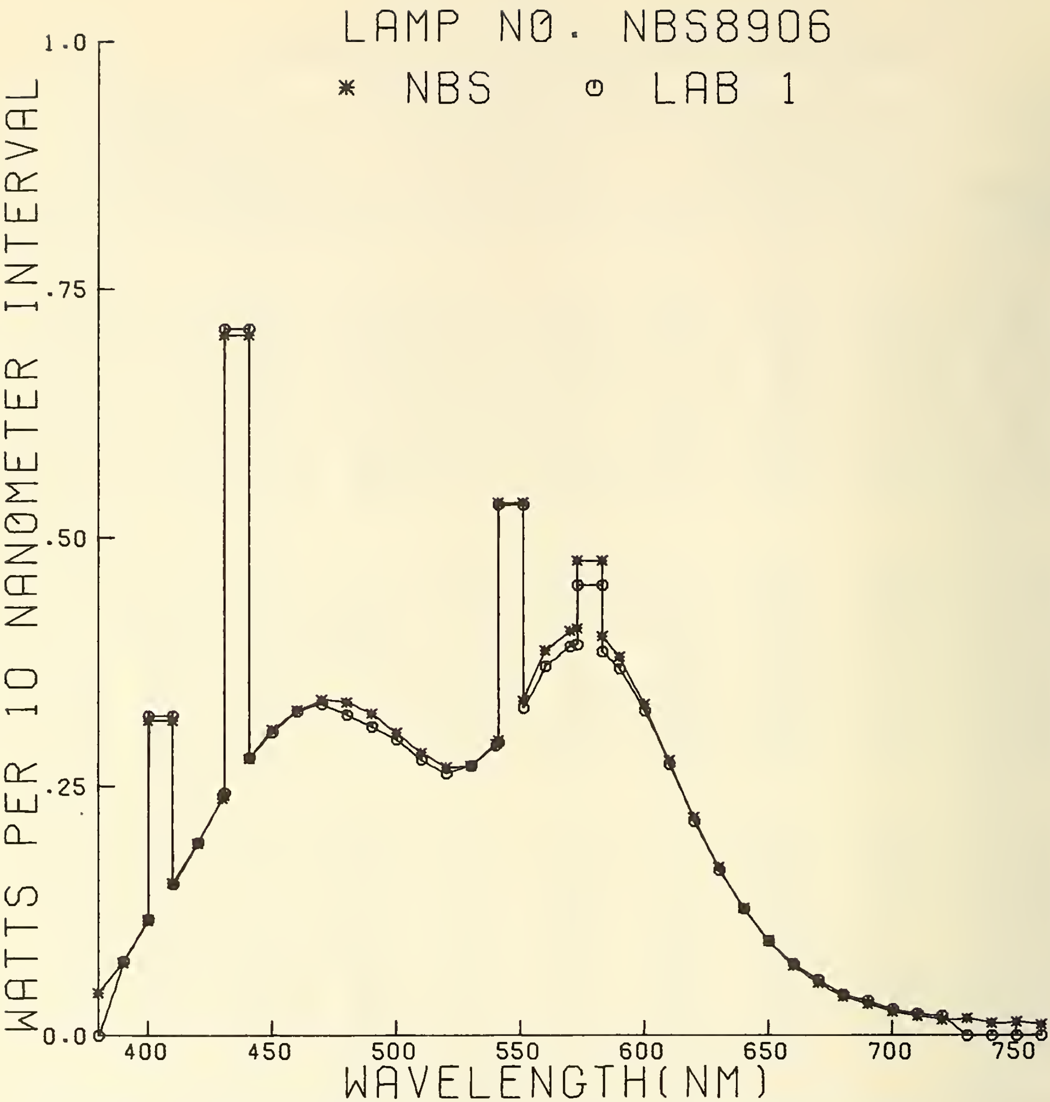


FIGURE 4.35 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.44

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8908

	NBS INITIAL			LABORATORY 5			NBS REPEAT	
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8
380.0	5.0	5.2	4.9	4.6	4.9	5.2	4.9	5.1
390.0	8.7	8.7	8.8	8.4	9.1	8.7	8.3	8.7
400.0	13.8	13.8	14.8	14.6	15.1	13.8	13.4	13.4
410.0	18.2	17.9	18.5	18.2	18.6	18.1	17.9	17.9
420.0	22.5	24.0	23.7	23.6	23.9	22.6	22.7	22.6
430.0	27.8	27.6	28.5	27.9	28.3	27.9	27.7	27.8
440.0	32.1	32.0	32.3	32.0	32.3	32.2	32.1	32.2
450.0	36.0	35.8	36.8	36.7	37.0	35.9	36.0	35.8
460.0	38.3	38.2	38.8	38.4	39.1	38.2	38.3	38.2
470.0	39.3	39.5	39.9	40.1	39.9	39.3	39.4	39.4
480.0	39.0	39.1	39.7	39.7	39.7	39.0	39.3	39.2
490.0	37.7	37.8	38.3	38.4	38.3	37.8	38.0	37.8
500.0	35.4	35.5	36.6	36.8	36.3	35.5	35.7	35.5
510.0	33.1	33.1	34.0	34.1	34.7	33.3	33.5	33.3
520.0	31.4	31.5	33.0	33.2	32.7	31.5	31.7	31.6
530.0	31.7	31.8	33.4	33.5	33.4	31.8	31.8	31.7
540.0	34.4	34.5	37.4	37.0	37.3	34.5	34.4	34.3
550.0	38.6	38.7	42.3	42.2	42.2	38.7	38.6	38.4
560.0	44.5	44.5	47.5	47.1	47.0	44.6	44.5	44.3
570.0	47.9	48.0	50.0	50.1	49.2	48.1	48.1	47.8
580.0	48.2	48.4	49.1	49.3	48.6	48.4	48.5	48.3
590.0	44.6	44.9	47.2	47.6	46.4	44.8	45.2	44.9
600.0	39.0	39.4	41.7	41.6	40.4	39.2	39.6	39.4
610.0	32.6	32.6	33.4	33.3	32.3	32.6	32.8	32.8
620.0	26.0	25.7	25.7	26.1	24.9	25.8	26.0	25.9
630.0	19.9	19.9	19.6	19.7	19.0	19.9	20.0	20.0
640.0	15.2	15.1	14.5	14.6	13.6	15.1	15.2	15.3
650.0	11.2	11.0	9.0	9.0	8.4	11.2	11.3	11.4
660.0	8.4	8.1	6.2	6.4	5.5	8.2	8.4	8.5
670.0	6.4	6.3	3.0	3.1	2.9	6.2	6.4	6.4
680.0	4.7	4.6	1.2	1.2	1.2	4.6	4.7	4.8
690.0	3.9	3.5	.7	.7	.6	3.7	3.7	3.9
700.0	2.9	2.7	1.2	1.2	.7	2.8	2.9	2.9
710.0	2.5	2.3	.4	.0	.0	2.4	2.4	2.5
720.0	1.9	1.9	.0	.0	.0	1.7	1.8	2.1
730.0	2.9	2.7	.0	.0	.0	2.7	1.6	1.7
740.0	1.8	1.6	.0	.0	.0	1.6	1.6	1.8
750.0	1.9	1.3	.0	.0	.0	1.6	1.7	1.9
760.0	2.0	1.6	.0	.0	.0	1.6	1.2	1.7

MERCURY LINES

405.0	21.3	21.5	17.7	17.8	19.6	21.6	21.5	21.5
436.0	52.6	53.0	51.0	51.1	54.3	52.8	52.7	53.1
546.0	26.2	26.2	26.0	27.0	28.2	26.0	25.9	25.7
578.0	8.7	8.7	13.4	13.8	14.4	8.6	8.4	8.5

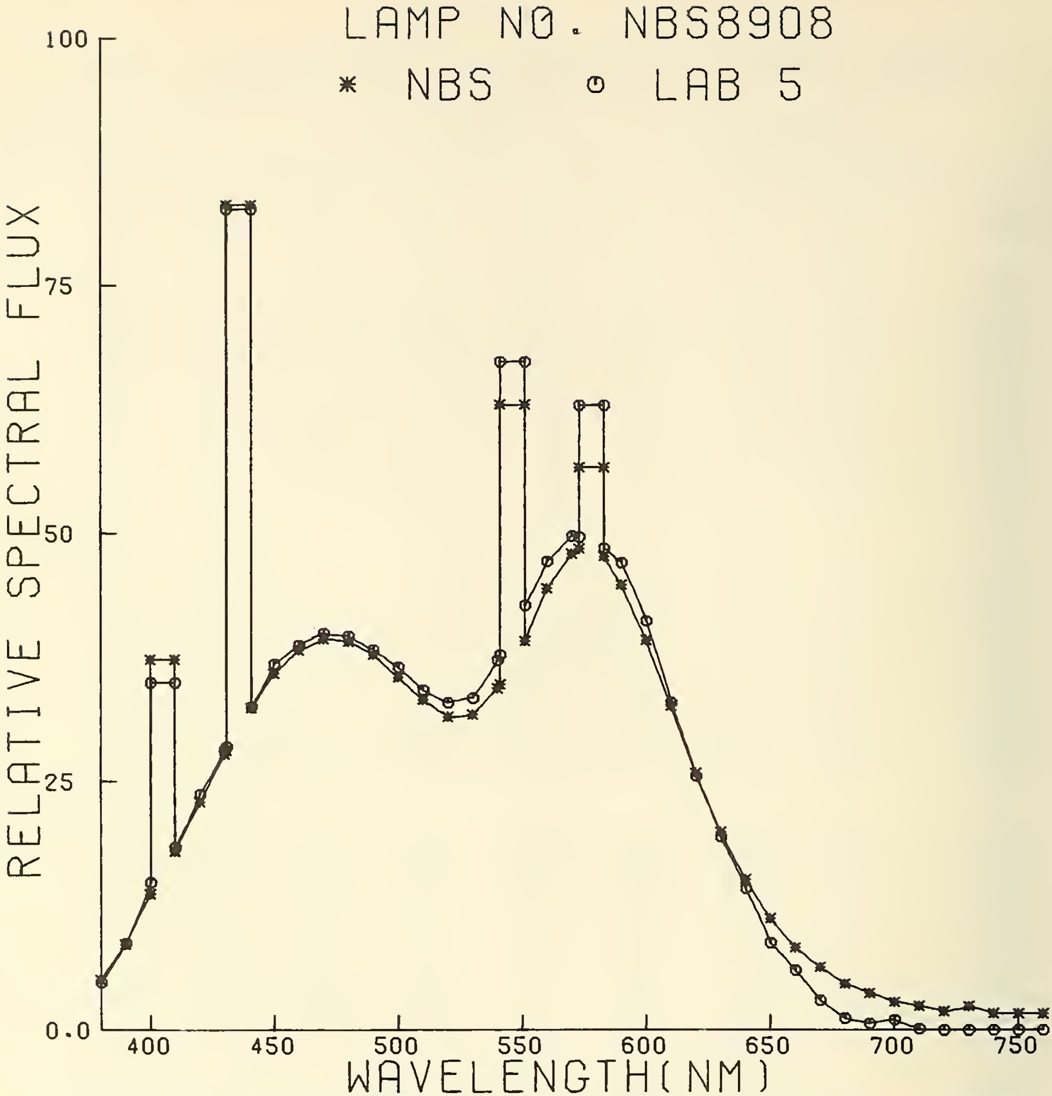


FIGURE 4.36 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.45

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8908

	NBS INITIAL			LABORATORY 5			NBS REPEAT	
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8
380.0	.0423	.0441	.0384	.0357	.0405	.0441	.0406	.0433
390.0	.0730	.0736	.0688	.0657	.0757	.0734	.0694	.0732
400.0	.1161	.1158	.1152	.1137	.1259	.1157	.1117	.1133
410.0	.1529	.1509	.1443	.1419	.1549	.1525	.1498	.1513
420.0	.1895	.2019	.1846	.1835	.1992	.1898	.1895	.1909
430.0	.2338	.2325	.2222	.2168	.2362	.2344	.2316	.2350
440.0	.2701	.2694	.2520	.2488	.2695	.2705	.2684	.2715
450.0	.3027	.3013	.2875	.2855	.3081	.3020	.3010	.3027
460.0	.3219	.3218	.3028	.2990	.3259	.3210	.3203	.3222
470.0	.3305	.3322	.3111	.3123	.3325	.3306	.3295	.3327
480.0	.3280	.3288	.3097	.3091	.3309	.3281	.3281	.3308
490.0	.3175	.3180	.2988	.2988	.3194	.3175	.3177	.3191
500.0	.2978	.2984	.2858	.2861	.3028	.2985	.2985	.2999
510.0	.2784	.2787	.2656	.2655	.2896	.2795	.2796	.2808
520.0	.2641	.2649	.2573	.2583	.2723	.2643	.2652	.2666
530.0	.2670	.2673	.2609	.2610	.2786	.2673	.2659	.2674
540.0	.2896	.2904	.2919	.2877	.3112	.2903	.2875	.2895
550.0	.3247	.3255	.3303	.3280	.3520	.3255	.3223	.3244
560.0	.3741	.3747	.3703	.3666	.3917	.3751	.3717	.3740
570.0	.4031	.4043	.3900	.3897	.4105	.4042	.4018	.4039
580.0	.4060	.4073	.3828	.3838	.4048	.4070	.4055	.4077
590.0	.3756	.3781	.3682	.3704	.3868	.3768	.3773	.3795
600.0	.3285	.3313	.3254	.3240	.3368	.3296	.3305	.3324
610.0	.2740	.2740	.2604	.2594	.2696	.2736	.2740	.2771
620.0	.2192	.2159	.2003	.2030	.2077	.2168	.2171	.2188
630.0	.1673	.1674	.1529	.1534	.1581	.1674	.1670	.1693
640.0	.1281	.1268	.1130	.1133	.1132	.1268	.1270	.1293
650.0	.0940	.0922	.0701	.0701	.0703	.0943	.0948	.0964
660.0	.0707	.0685	.0480	.0500	.0463	.0685	.0706	.0716
670.0	.0537	.0529	.0237	.0238	.0238	.0521	.0531	.0543
680.0	.0394	.0387	.0096	.0096	.0096	.0390	.0394	.0408
690.0	.0325	.0297	.0054	.0054	.0054	.0311	.0312	.0328
700.0	.0241	.0225	.0091	.0091	.0061	.0239	.0238	.0246
710.0	.0213	.0196	.0031	.0000	.0000	.0198	.0198	.0208
720.0	.0164	.0162	.0000	.0000	.0000	.0147	.0151	.0174
730.0	.0247	.0224	.0000	.0000	.0000	.0227	.0130	.0143
740.0	.0156	.0132	.0000	.0000	.0000	.0133	.0135	.0151
750.0	.0160	.0105	.0000	.0000	.0000	.0133	.0140	.0159
760.0	.0165	.0135	.0000	.0000	.0000	.0132	.0099	.0148
MERCURY LINES								
405.0	.1791	.1809	.1383	.1381	.1633	.1814	.1799	.1819
436.0	.4423	.4459	.3982	.3976	.4525	.4434	.4401	.4481
546.0	.2205	.2202	.2025	.2103	.2351	.2187	.2168	.2172
578.0	.0732	.0733	.1045	.1071	.1203	.0719	.0705	.0716

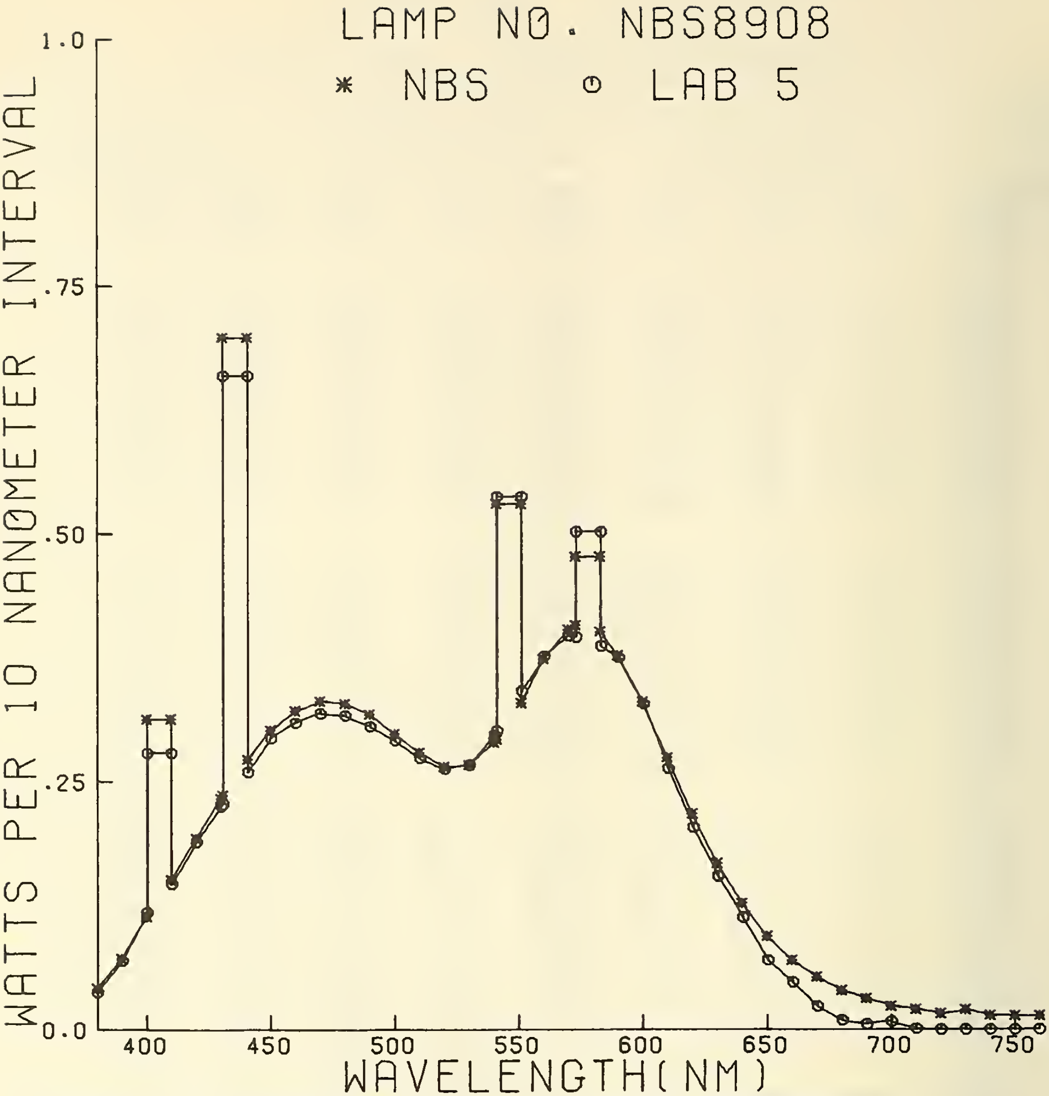


FIGURE 4.37 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.46

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8909

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	5.1	5.2	5.2	.0	.0	.0	5.1	5.1	5.0
390.0	8.8	8.8	7.6	9.7	8.0	6.2	8.6	8.7	8.5
400.0	13.9	13.8	13.8	13.8	13.4	12.4	13.4	13.6	13.9
410.0	18.3	18.0	18.3	18.6	18.4	18.0	17.9	18.2	18.2
420.0	22.6	24.2	22.7	22.9	22.8	22.7	22.5	22.5	22.6
430.0	27.9	27.9	27.9	27.9	27.9	27.9	27.8	27.9	27.5
440.0	32.2	32.3	32.2	32.4	32.3	32.4	32.1	32.2	30.7
450.0	36.1	36.0	36.0	35.7	35.8	35.8	35.9	36.0	32.8
460.0	38.3	38.4	38.6	38.0	38.1	38.2	38.4	38.5	38.4
470.0	39.4	39.6	39.5	39.1	39.2	39.3	39.5	39.7	39.8
480.0	39.1	39.2	39.1	38.9	39.0	39.1	39.4	39.3	39.5
490.0	37.8	37.8	37.9	37.8	37.9	38.1	38.1	38.0	38.2
500.0	35.5	35.5	35.5	35.6	35.6	35.8	35.8	35.8	35.9
510.0	33.2	33.1	33.2	33.4	33.5	33.6	33.4	33.5	33.5
520.0	32.2	31.5	31.5	32.0	32.1	32.3	31.7	31.7	31.8
530.0	31.7	32.7	31.9	32.3	32.4	32.6	31.8	31.7	31.9
540.0	34.4	34.4	34.7	35.3	35.5	35.8	34.4	34.3	34.4
550.0	38.5	38.2	38.7	39.5	39.8	40.1	38.5	38.4	38.5
560.0	44.3	44.4	44.7	44.9	45.1	45.6	44.3	44.1	44.5
570.0	47.7	47.8	48.0	48.3	48.6	49.0	47.9	47.7	48.0
580.0	48.0	48.0	48.2	48.5	48.8	49.2	48.3	48.2	48.5
590.0	44.5	44.5	44.7	45.3	45.5	45.9	44.9	44.8	45.1
600.0	38.8	39.0	39.3	39.7	39.9	40.2	39.4	39.2	39.5
610.0	32.3	32.1	32.4	33.0	33.1	33.4	32.7	32.7	32.8
620.0	25.4	25.3	25.6	26.2	26.4	26.6	25.8	26.1	26.0
630.0	19.7	19.8	19.7	20.3	20.5	20.6	19.9	19.9	20.5
640.0	15.1	14.9	15.4	15.5	15.5	15.7	15.2	15.3	15.3
650.0	11.1	11.1	11.2	11.6	11.7	11.7	11.4	11.4	11.5
660.0	8.4	8.3	7.9	8.7	8.7	8.8	8.3	8.4	8.5
670.0	6.3	6.2	6.2	6.5	6.5	6.5	6.3	6.4	6.4
680.0	4.7	4.5	4.6	4.9	4.8	4.8	4.8	4.8	4.9
690.0	3.8	3.5	3.8	3.8	3.8	3.8	3.8	3.8	4.0
700.0	3.0	2.6	2.7	2.8	2.8	2.8	2.9	2.8	3.0
710.0	2.5	2.3	2.4	2.2	2.2	2.1	2.5	2.4	2.5
720.0	1.9	1.9	2.0	1.6	1.6	1.6	1.9	1.8	2.0
730.0	2.9	2.6	2.8	1.3	1.2	1.2	1.7	1.6	1.7
740.0	1.8	1.5	1.6	1.1	1.1	1.1	1.8	1.6	1.8
750.0	1.9	1.9	2.0	.9	1.0	.8	1.9	1.7	1.9
760.0	1.9	1.6	1.6	.0	.0	.0	1.5	1.2	1.5
MERCURY LINES									
405.0	21.3	21.4	21.3	23.4	23.3	22.5	21.6	21.8	21.2
436.0	53.1	53.1	52.9	52.4	51.8	50.9	52.9	53.2	53.6
546.0	26.0	26.2	26.0	25.2	25.5	26.3	25.9	25.7	26.0
578.0	8.6	8.7	8.7	8.9	9.0	9.0	8.4	8.4	8.4

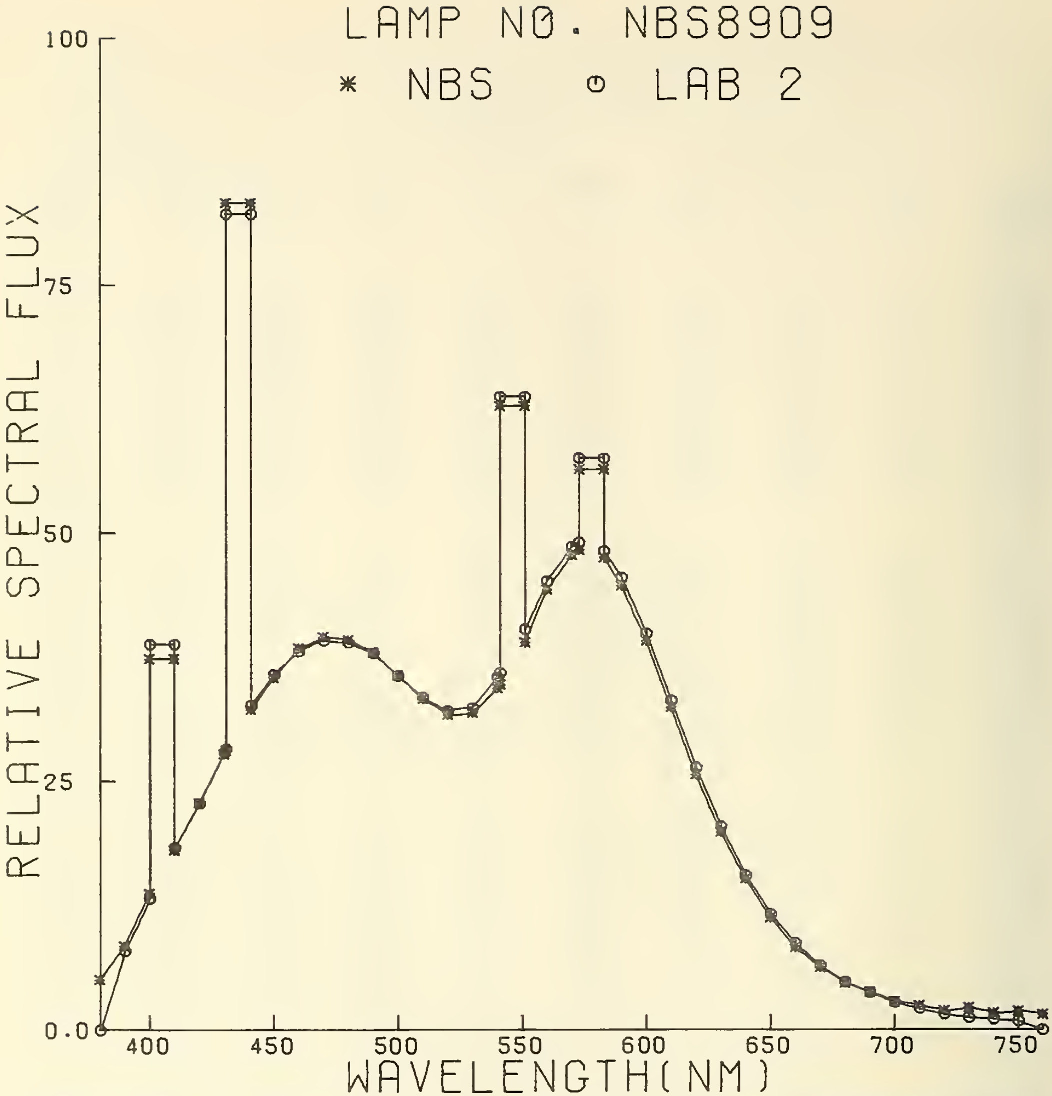


FIGURE 4.38 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.47

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8909

	NBS INITIAL			LABORATORY 2			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0438	.0441	.0438	.0000	.0000	.0000	.0430	.0436	.0425
390.0	.0753	.0747	.0643	.0771	.0632	.0482	.0726	.0738	.0719
400.0	.1190	.1178	.1177	.1101	.1056	.0959	.1133	.1163	.1172
410.0	.1564	.1539	.1556	.1479	.1453	.1388	.1511	.1549	.1535
420.0	.1937	.2062	.1929	.1821	.1804	.1752	.1896	.1918	.1909
430.0	.2388	.2379	.2373	.2221	.2207	.2154	.2345	.2376	.2318
440.0	.2758	.2753	.2737	.2576	.2553	.2507	.2710	.2747	.2588
450.0	.3089	.3069	.3065	.2843	.2826	.2771	.3034	.3075	.2769
460.0	.3276	.3272	.3282	.3028	.3015	.2956	.3238	.3285	.3245
470.0	.3371	.3376	.3360	.3111	.3096	.3040	.3334	.3389	.3358
480.0	.3340	.3343	.3328	.3097	.3080	.3023	.3326	.3355	.3331
490.0	.3234	.3224	.3225	.3005	.2993	.2942	.3221	.3245	.3226
500.0	.3033	.3028	.3026	.2833	.2816	.2767	.3019	.3055	.3028
510.0	.2843	.2821	.2828	.2660	.2645	.2602	.2822	.2856	.2832
520.0	.2753	.2685	.2685	.2549	.2537	.2494	.2677	.2705	.2681
530.0	.2711	.2791	.2712	.2569	.2560	.2524	.2686	.2705	.2690
540.0	.2944	.2935	.2952	.2806	.2806	.2766	.2903	.2929	.2902
550.0	.3297	.3256	.3294	.3141	.3143	.3099	.3248	.3273	.3247
560.0	.3790	.3782	.3803	.3571	.3566	.3522	.3738	.3760	.3753
570.0	.4078	.4072	.4088	.3844	.3840	.3787	.4041	.4071	.4053
580.0	.4107	.4093	.4105	.3863	.3858	.3803	.4079	.4110	.4092
590.0	.3805	.3792	.3805	.3606	.3596	.3546	.3791	.3820	.3806
600.0	.3315	.3325	.3342	.3161	.3154	.3107	.3330	.3342	.3337
610.0	.2759	.2740	.2759	.2625	.2618	.2579	.2758	.2793	.2770
620.0	.2170	.2159	.2177	.2089	.2086	.2056	.2182	.2224	.2193
630.0	.1681	.1690	.1681	.1618	.1617	.1590	.1679	.1697	.1728
640.0	.1290	.1268	.1314	.1231	.1227	.1211	.1283	.1304	.1296
650.0	.0950	.0943	.0953	.0926	.0922	.0908	.0962	.0973	.0972
660.0	.0717	.0707	.0676	.0693	.0690	.0677	.0705	.0718	.0716
670.0	.0537	.0529	.0524	.0520	.0515	.0506	.0534	.0545	.0543
680.0	.0405	.0387	.0392	.0389	.0383	.0375	.0407	.0408	.0415
690.0	.0325	.0297	.0326	.0302	.0298	.0291	.0318	.0327	.0334
700.0	.0254	.0225	.0232	.0225	.0220	.0215	.0246	.0243	.0251
710.0	.0213	.0196	.0204	.0176	.0174	.0163	.0207	.0203	.0212
720.0	.0164	.0162	.0169	.0130	.0125	.0121	.0161	.0154	.0166
730.0	.0247	.0224	.0236	.0102	.0095	.0094	.0143	.0134	.0148
740.0	.0156	.0132	.0139	.0090	.0087	.0084	.0150	.0139	.0155
750.0	.0160	.0158	.0169	.0073	.0078	.0064	.0159	.0145	.0164
760.0	.0165	.0135	.0137	.0000	.0000	.0000	.0123	.0103	.0127
				MERCURY LINES					
405.0	.1818	.1827	.1817	.1862	.1840	.1738	.1822	.1856	.1793
436.0	.4541	.4524	.4506	.4174	.4093	.3938	.4467	.4539	.4524
546.0	.2219	.2235	.2216	.2006	.2017	.2031	.2185	.2194	.2194
578.0	.0736	.0744	.0740	.0710	.0710	.0694	.0712	.0716	.0707

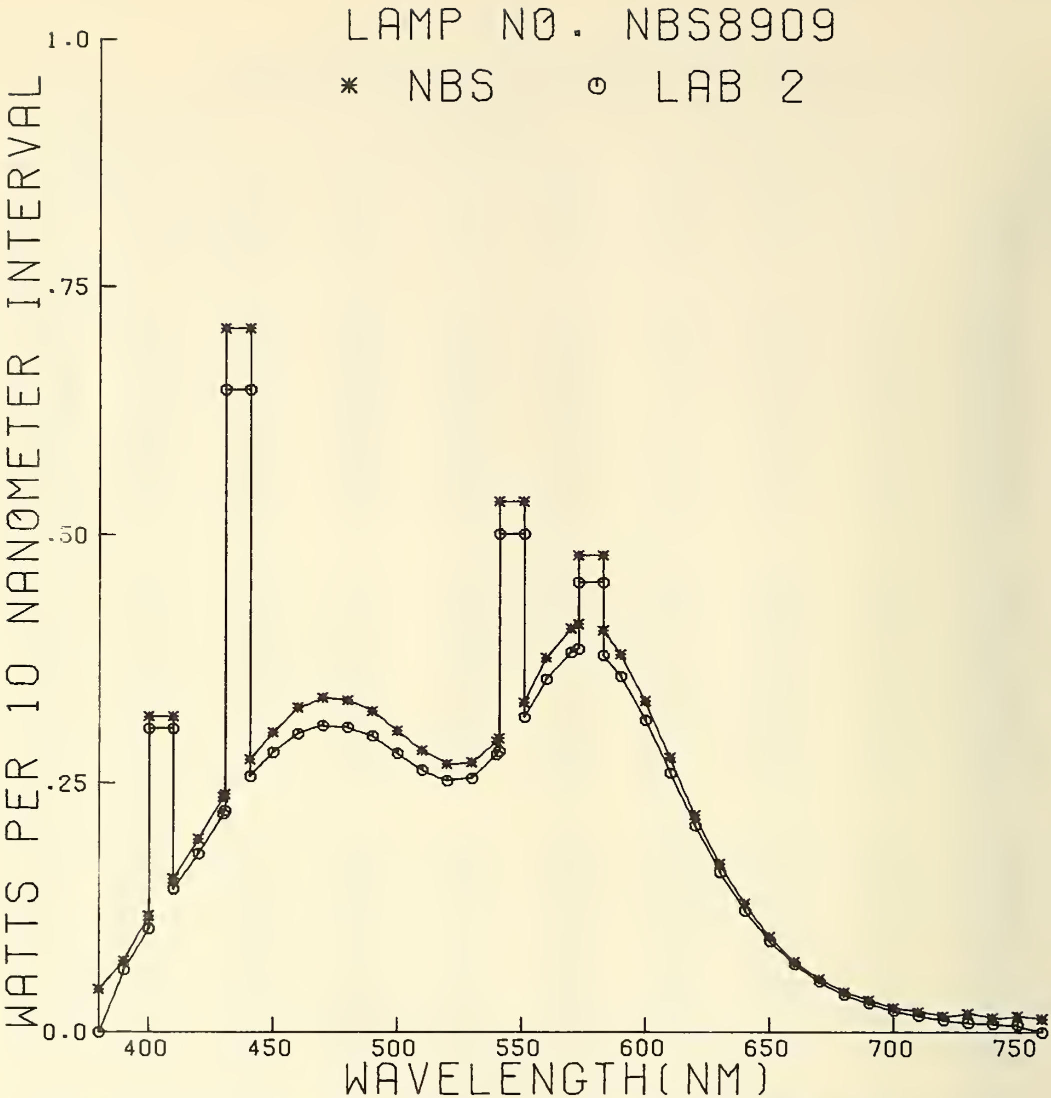


FIGURE 4.39 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.48

RELATIVE SPECTRAL FLUX DISTRIBUTION IN SPHERE-NORMALIZED TO AREA
LAMP NUMBER NBS8911

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	5.2	5.1	5.2	5.6	5.6	5.6	4.9	5.0	5.0
390.0	8.7	8.6	8.7	9.0	9.0	9.0	8.4	8.3	8.5
400.0	14.0	13.9	14.0	13.1	13.2	13.2	13.4	13.4	13.6
410.0	18.3	18.3	18.4	18.0	18.0	18.1	18.0	18.0	18.0
420.0	22.7	23.9	22.8	23.4	23.3	23.4	22.6	22.5	22.7
430.0	28.0	27.8	28.1	29.2	29.1	29.4	27.8	27.6	28.0
440.0	32.2	32.0	32.4	33.9	34.0	34.1	32.3	32.1	32.3
450.0	36.0	36.5	36.2	38.3	38.4	38.3	33.6	35.9	36.1
460.0	38.4	38.2	38.6	40.4	40.5	40.5	38.7	38.4	38.6
470.0	39.4	39.4	39.6	41.2	41.2	41.6	39.8	39.5	39.7
480.0	39.1	39.1	39.2	40.5	40.4	40.6	39.6	39.4	39.4
490.0	37.8	37.9	38.0	38.7	38.7	38.8	38.3	38.1	38.1
500.0	35.5	35.6	35.7	36.2	36.0	36.0	36.0	35.7	35.9
510.0	33.1	33.2	33.2	33.7	33.5	33.5	33.6	33.4	33.5
520.0	31.4	31.5	31.6	31.9	31.8	31.9	32.2	31.7	31.7
530.0	31.7	31.7	31.8	32.0	31.8	31.8	32.0	31.7	31.8
540.0	34.3	34.4	34.5	34.6	34.4	34.4	34.1	34.3	34.3
550.0	38.4	38.5	38.7	39.2	39.1	39.2	38.7	38.4	38.4
560.0	44.3	44.3	44.5	44.2	44.0	44.2	44.5	44.1	44.2
570.0	47.6	47.7	47.9	47.3	47.1	47.3	48.1	47.7	47.7
580.0	47.9	48.1	48.2	57.4	58.4	57.8	48.5	48.1	48.2
590.0	44.4	44.6	44.6	44.4	44.2	44.3	45.2	45.5	45.0
600.0	38.8	39.1	39.1	38.6	38.4	38.6	39.5	39.2	39.1
610.0	32.2	32.7	32.3	31.9	31.7	31.8	32.9	32.6	32.6
620.0	25.5	25.4	25.4	25.2	25.1	25.2	26.1	26.0	25.9
630.0	19.7	19.8	19.8	19.5	19.4	19.5	20.0	20.1	19.8
640.0	15.0	14.9	14.8	14.8	14.7	14.8	15.2	15.4	15.2
650.0	11.2	11.1	10.9	11.1	11.0	11.1	11.4	11.4	11.3
660.0	8.2	8.1	8.0	8.3	8.2	8.2	8.3	8.5	8.3
670.0	6.3	6.2	6.2	6.3	6.2	6.1	6.4	6.5	6.3
680.0	4.6	4.6	4.6	4.8	4.8	4.7	4.6	4.9	4.7
690.0	3.9	3.8	3.7	3.8	3.7	3.6	3.8	4.0	3.8
700.0	2.9	2.8	2.8	2.9	2.9	2.8	2.8	3.0	2.8
710.0	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.6	2.5
720.0	2.1	1.9	1.7	1.7	1.7	1.7	1.8	1.9	1.8
730.0	2.8	2.7	2.7	1.5	1.5	1.3	1.4	1.7	1.5
740.0	1.8	1.6	1.6	1.5	1.5	1.3	1.4	1.8	1.6
750.0	1.8	1.9	1.6	1.5	1.5	1.3	1.4	1.9	1.7
760.0	1.9	1.5	1.5	1.2	1.2	1.2	1.2	1.5	1.2
				MERCURY LINES					
405.0	21.6	21.5	21.6	10.1	10.3	10.3	21.8	21.4	21.8
436.0	53.7	52.7	53.1	45.0	46.5	45.6	53.1	52.8	53.2
546.0	26.2	26.0	26.0	28.8	28.8	28.8	25.8	25.6	25.8
578.0	8.8	8.7	8.6	6.9	6.8	6.9	8.5	8.3	8.3

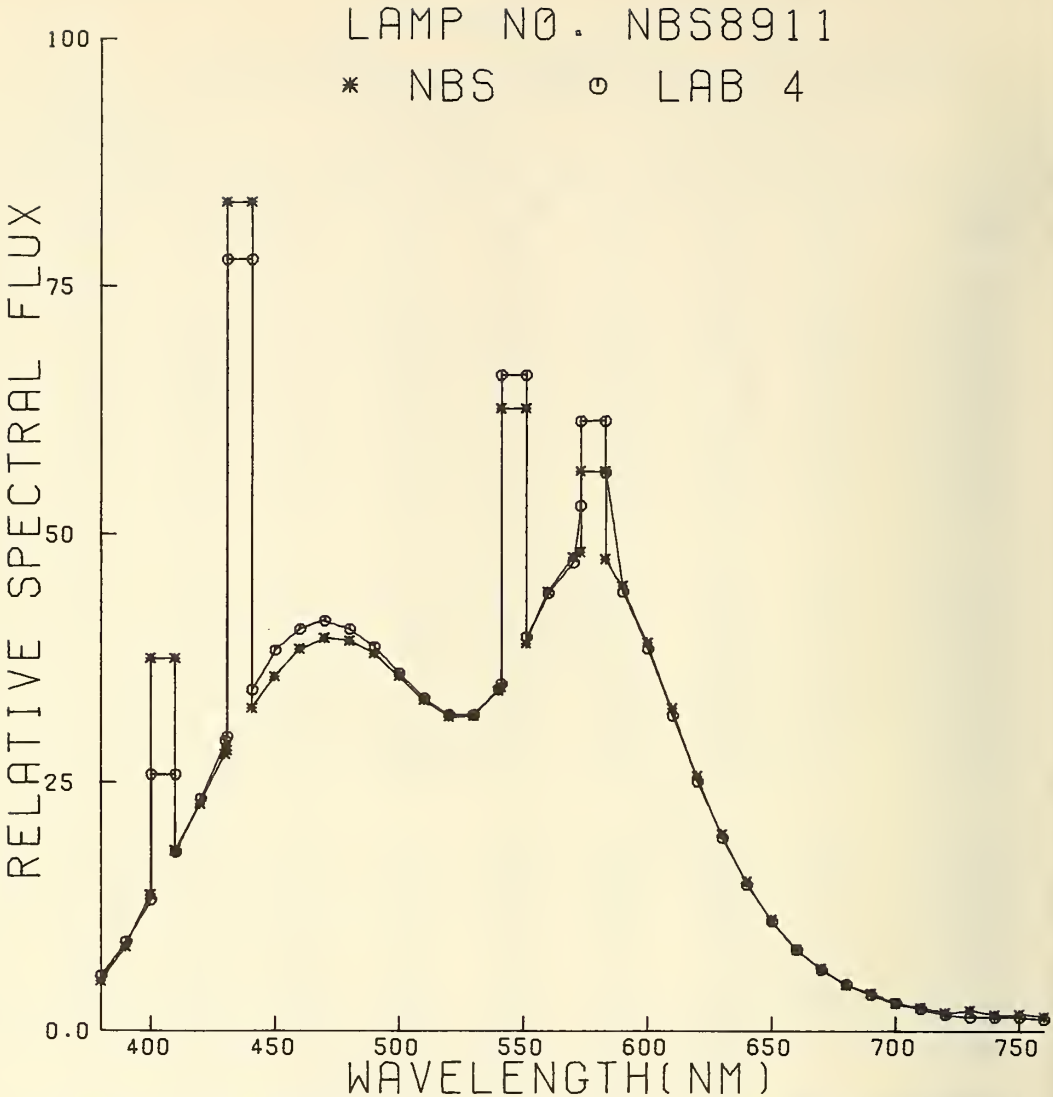


FIGURE 4.40 AVERAGE RELATIVE SPECTRAL FLUX (SPHERE MEASUREMENTS) NORMALIZED TO AREA

TABLE 4.49

SPECTRAL FLUX DISTRIBUTION (WATTS) IN SPHERE
LAMP NUMBER NBS8911

	NBS INITIAL			LABORATORY 4			NBS REPEAT		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
380.0	.0450	.0438	.0441	.0550	.0552	.0552	.0413	.0425	.0427
390.0	.0757	.0736	.0746	.0884	.0889	.0885	.0708	.0702	.0720
400.0	.1217	.1186	.1190	.1285	.1299	.1293	.1128	.1141	.1151
410.0	.1590	.1558	.1566	.1761	.1773	.1771	.1514	.1532	.1529
420.0	.1972	.2034	.1944	.2290	.2296	.2291	.1900	.1911	.1929
430.0	.2432	.2363	.2393	.2866	.2871	.2884	.2342	.2349	.2375
440.0	.2796	.2728	.2760	.3323	.3345	.3342	.2718	.2725	.2742
450.0	.3121	.3111	.3084	.3761	.3786	.3761	.2830	.3047	.3066
460.0	.3329	.3256	.3287	.3964	.3993	.3974	.3259	.3266	.3273
470.0	.3420	.3356	.3374	.4040	.4062	.4076	.3352	.3360	.3367
480.0	.3390	.3330	.3343	.3972	.3978	.3978	.3332	.3351	.3347
490.0	.3280	.3223	.3236	.3798	.3809	.3803	.3223	.3236	.3235
500.0	.3077	.3032	.3040	.3552	.3547	.3530	.3027	.3036	.3045
510.0	.2869	.2830	.2830	.3301	.3297	.3284	.2829	.2840	.2843
520.0	.2726	.2684	.2689	.3127	.3134	.3131	.2709	.2696	.2690
530.0	.2748	.2702	.2710	.3138	.3131	.3118	.2690	.2697	.2698
540.0	.2978	.2926	.2942	.3389	.3387	.3373	.2868	.2913	.2913
550.0	.3335	.3278	.3296	.3846	.3851	.3849	.3254	.3259	.3259
560.0	.3839	.3776	.3795	.4335	.4339	.4337	.3748	.3749	.3751
570.0	.4127	.4066	.4084	.4643	.4642	.4638	.4045	.4052	.4052
580.0	.4152	.4095	.4108	.5629	.5754	.5673	.4083	.4087	.4090
590.0	.3848	.3799	.3800	.4355	.4350	.4344	.3799	.3864	.3815
600.0	.3365	.3332	.3331	.3785	.3786	.3785	.3323	.3331	.3321
610.0	.2792	.2784	.2755	.3126	.3119	.3120	.2765	.2769	.2767
620.0	.2213	.2166	.2161	.2474	.2472	.2471	.2195	.2213	.2198
630.0	.1710	.1688	.1690	.1909	.1911	.1911	.1685	.1711	.1684
640.0	.1299	.1271	.1259	.1448	.1449	.1449	.1278	.1308	.1291
650.0	.0975	.0947	.0932	.1090	.1085	.1085	.0963	.0971	.0957
660.0	.0713	.0687	.0685	.0818	.0811	.0804	.0699	.0722	.0707
670.0	.0544	.0531	.0532	.0616	.0609	.0600	.0536	.0552	.0536
680.0	.0402	.0389	.0390	.0469	.0470	.0461	.0391	.0417	.0401
690.0	.0335	.0322	.0311	.0376	.0367	.0356	.0319	.0339	.0321
700.0	.0252	.0238	.0239	.0289	.0290	.0278	.0236	.0258	.0238
710.0	.0212	.0197	.0198	.0227	.0227	.0227	.0197	.0220	.0210
720.0	.0179	.0162	.0146	.0171	.0171	.0171	.0150	.0164	.0151
730.0	.0245	.0226	.0227	.0146	.0146	.0128	.0115	.0145	.0131
740.0	.0155	.0133	.0133	.0149	.0149	.0128	.0117	.0153	.0136
750.0	.0159	.0159	.0133	.0150	.0150	.0125	.0120	.0163	.0142
760.0	.0164	.0131	.0132	.0119	.0119	.0119	.0099	.0126	.0101
				MERCURY LINES					
405.0	.1877	.1834	.1843	.0986	.1015	.1006	.1833	.1815	.1851
436.0	.4657	.4491	.4524	.4414	.4584	.4475	.4467	.4483	.4511
546.0	.2276	.2216	.2217	.2823	.2833	.2824	.2167	.2179	.2193
578.0	.0766	.0743	.0733	.0675	.0667	.0673	.0713	.0709	.0706

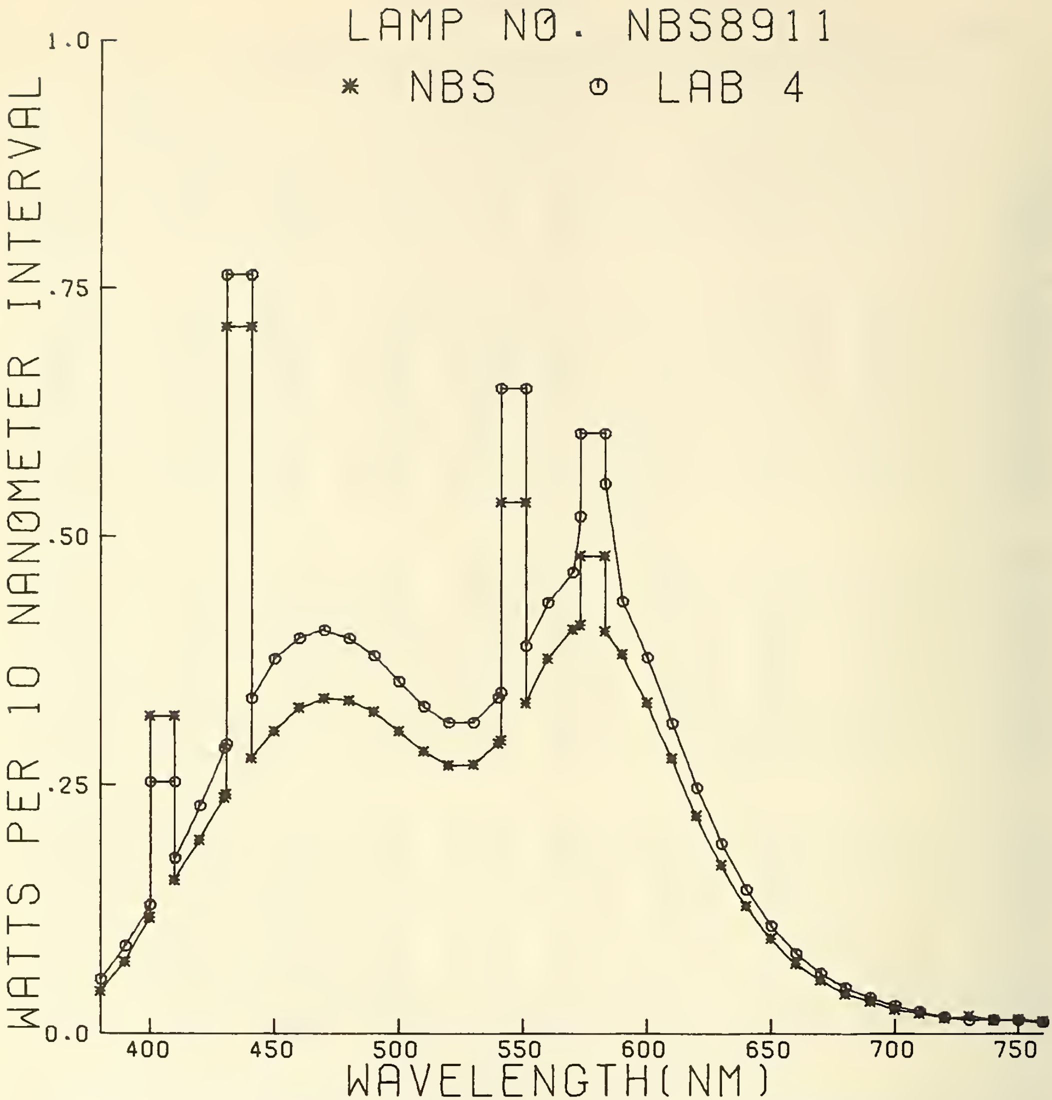


FIGURE 4.41 AVERAGE SPECTRAL FLUX (SPHERE MEASUREMENTS)

TABLE 4.50

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8795

	NBS			LABORATORY 7		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.9	3.7	4.0	2.9	12.9	1.9
390.0	6.0	5.8	5.9	3.4	3.9	2.9
400.0	8.2	8.0	8.1	4.7	5.0	4.2
410.0	10.7	10.5	10.5	6.4	6.6	5.9
420.0	13.3	13.0	13.2	8.9	9.0	8.4
430.0	16.3	15.8	16.0	11.3	11.4	10.5
440.0	18.9	18.5	18.5	14.0	14.1	13.6
450.0	21.0	20.9	21.0	16.6	15.4	15.4
460.0	22.8	22.7	22.7	18.3	17.6	17.9
470.0	24.0	23.9	23.8	20.3	19.2	19.7
480.0	24.3	24.4	24.2	20.2	20.8	20.9
490.0	24.3	24.1	24.2	20.6	20.4	21.5
500.0	23.3	23.3	23.2	20.9	20.6	21.0
510.0	22.8	22.6	22.6	20.7	20.1	20.8
520.0	23.7	23.6	23.7	21.3	20.9	21.8
530.0	27.6	27.3	27.5	24.4	24.0	24.6
540.0	35.3	35.0	35.2	31.4	31.1	32.0
550.0	45.3	44.9	45.1	40.7	40.4	41.3
560.0	57.9	57.6	57.6	52.5	52.5	53.8
570.0	65.9	65.7	65.7	59.6	60.2	61.5
580.0	68.6	68.5	68.4	62.1	63.0	64.0
590.0	64.3	64.3	64.3	58.6	60.9	61.2
600.0	56.4	57.2	56.6	52.9	53.3	54.6
610.0	46.8	47.6	47.0	44.0	45.7	45.0
620.0	36.7	37.5	36.7	35.1	36.3	36.5
630.0	28.6	29.4	28.5	28.8	29.3	30.1
640.0	21.1	21.5	21.2	21.5	22.7	22.1
650.0	15.4	15.6	15.6	16.9	18.2	17.8
660.0	11.3	11.4	11.4	13.5	14.0	14.0
670.0	8.5	8.8	8.5	12.0	12.0	11.6
680.0	6.2	6.4	6.3	10.8	8.1	10.1
690.0	4.8	4.8	5.1	10.9	10.3	9.9
700.0	3.5	3.7	3.8	11.2	10.6	9.8
710.0	2.9	3.2	3.3	12.5	11.9	11.2
720.0	2.5	2.6	2.9	14.5	13.3	13.2
730.0	4.8	5.1	5.6	17.3	16.7	15.9
740.0	2.0	2.1	2.5	20.4	20.1	19.7
750.0	2.1	2.0	2.5	25.1	23.2	22.4
760.0	2.1	2.0	2.9	28.4	26.5	24.5
			MERCURY LINES			
405.0	22.5	21.5	21.9	5.9	6.9	6.2
436.0	58.5	58.6	58.0	28.7	29.7	28.6
546.0	25.9	25.9	25.6	25.0	24.6	26.3
578.0	8.8	8.8	8.9	24.7	25.0	25.8

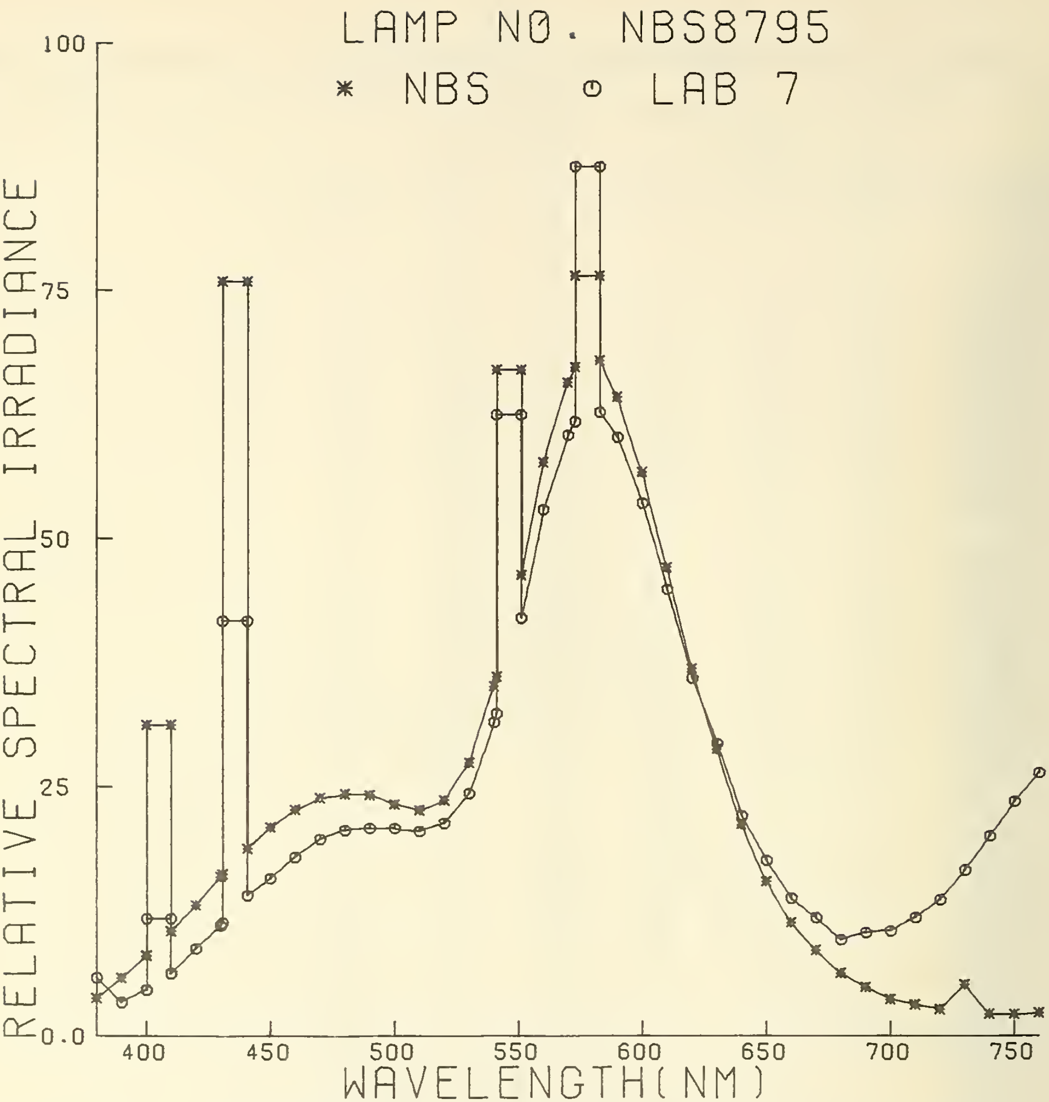


FIGURE 4.42 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.51

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8796

	NBS			LABORATORY 7		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.5	3.4	3.6	2.2	12.6	1.7
390.0	5.5	5.3	5.4	2.8	3.8	2.6
400.0	7.6	7.4	7.5	4.1	5.0	3.9
410.0	10.0	9.7	9.9	5.9	6.7	5.5
420.0	12.5	12.3	12.4	8.3	8.7	7.7
430.0	15.4	15.1	15.0	10.6	10.6	9.5
440.0	17.9	17.6	17.5	13.1	13.1	12.3
450.0	20.0	19.8	19.8	15.4	14.4	14.0
460.0	21.8	21.6	21.5	17.3	16.7	16.4
470.0	23.0	22.8	22.8	19.2	18.0	17.8
480.0	23.5	23.4	23.2	19.9	19.5	19.6
490.0	23.4	23.3	23.3	20.9	19.5	20.2
500.0	22.7	22.5	22.4	20.5	19.9	20.0
510.0	22.3	22.1	22.0	20.4	19.9	19.7
520.0	23.3	23.1	23.2	21.0	21.0	20.7
530.0	27.5	27.1	27.2	24.3	24.5	23.9
540.0	35.5	35.2	35.3	30.5	32.0	32.0
550.0	45.9	45.5	45.5	40.0	41.7	41.5
560.0	58.9	58.4	58.5	52.8	54.1	53.9
570.0	67.2	67.0	66.9	61.2	61.9	61.7
580.0	70.1	70.2	69.8	64.8	64.5	65.6
590.0	66.1	66.5	65.8	61.8	62.0	65.6
600.0	58.4	58.6	58.1	53.7	54.5	54.4
610.0	48.6	48.4	48.3	45.3	47.0	46.3
620.0	37.8	38.4	37.8	37.5	37.9	37.6
630.0	29.4	29.7	29.7	30.7	29.8	29.8
640.0	21.7	22.2	21.9	24.0	24.5	23.0
650.0	16.0	16.5	16.2	18.3	18.4	17.8
660.0	11.7	12.0	11.8	14.9	14.4	14.8
670.0	8.6	8.9	9.1	12.1	11.9	12.2
680.0	6.3	6.3	6.5	10.5	10.4	10.2
690.0	5.0	5.1	5.3	10.4	10.1	10.0
700.0	3.7	4.1	4.1	10.5	10.0	9.4
710.0	3.1	3.2	3.5	11.6	11.1	10.9
720.0	2.4	2.7	3.0	13.2	12.4	25.1
730.0	4.6	4.9	5.3	15.4	15.5	14.9
740.0	1.8	2.4	2.8	18.3	19.0	18.2
750.0	1.7	2.4	2.8	22.6	21.8	20.8
760.0	2.1	2.3	2.8	25.7	25.2	23.2
MERCURY LINES						
405.0	21.7	20.8	21.1	5.8	6.5	5.9
436.0	56.2	56.7	56.4	29.0	28.8	27.6
546.0	26.1	25.9	25.8	27.1	25.3	26.8
578.0	9.2	9.0	9.0	26.4	24.9	25.4

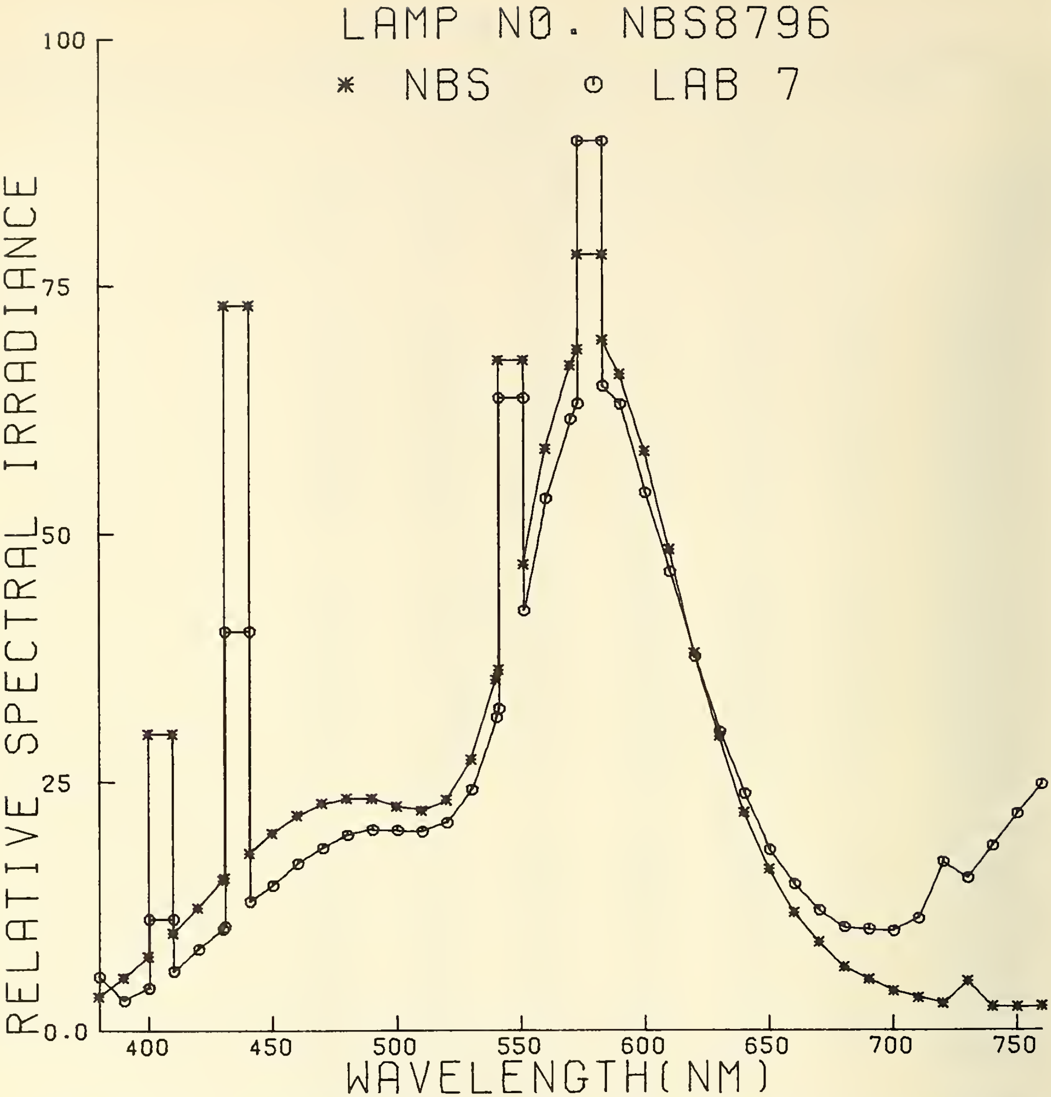


FIGURE 4.43 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.52

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8797

	NBS			LABORATORY 1		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.5	3.5	3.8	.0	.0	.0
390.0	5.7	5.6	5.8	5.4	5.5	5.9
400.0	8.0	7.9	7.9	7.5	7.5	7.7
410.0	10.5	10.3	10.3	10.0	10.1	10.1
420.0	13.0	12.8	12.9	12.7	12.8	12.7
430.0	15.8	15.5	15.7	15.6	15.6	15.5
440.0	18.3	18.1	18.1	18.2	18.3	18.2
450.0	20.5	20.3	20.5	20.5	20.6	20.4
460.0	22.3	22.1	22.3	22.4	22.5	22.3
470.0	23.5	23.3	23.3	23.6	23.8	23.5
480.0	23.9	23.8	23.7	24.0	24.2	23.9
490.0	23.9	23.6	23.7	23.7	23.9	23.8
500.0	23.0	22.8	22.8	22.6	22.8	23.2
510.0	22.5	22.3	22.3	22.3	22.4	22.8
520.0	23.3	23.3	23.3	23.4	23.5	23.9
530.0	27.4	27.1	27.3	27.9	27.9	28.3
540.0	35.4	35.1	35.2	35.4	35.4	35.7
550.0	45.6	45.1	45.3	46.0	46.1	46.2
560.0	58.4	57.7	58.1	59.7	59.9	59.7
570.0	66.6	65.7	66.3	67.8	68.2	67.6
580.0	69.5	68.6	69.0	70.5	70.9	70.1
590.0	65.3	65.0	65.0	67.7	68.0	67.2
600.0	57.3	57.2	57.0	59.5	59.5	58.8
610.0	47.5	47.3	47.3	49.1	49.2	48.6
620.0	37.1	37.6	37.1	39.7	39.6	39.2
630.0	28.6	29.7	29.0	29.9	29.9	29.5
640.0	21.2	21.4	21.5	21.8	21.8	21.7
650.0	15.4	15.8	15.5	16.2	16.1	16.2
660.0	11.4	11.7	11.5	11.9	11.8	12.1
670.0	8.5	8.6	8.7	8.7	8.5	8.9
680.0	6.1	6.1	6.3	6.5	6.3	6.8
690.0	4.7	4.9	4.9	5.0	4.8	5.3
700.0	3.5	3.8	4.0	3.8	3.6	4.1
710.0	2.8	3.1	3.4	2.9	2.8	3.2
720.0	2.4	2.4	2.8	2.3	2.0	2.6
730.0	4.6	4.9	5.2	.0	.0	.0
740.0	1.6	2.1	2.2	.0	.0	.0
750.0	1.9	2.1	2.6	.0	.0	.0
760.0	1.5	2.0	2.0	.0	.0	.0
MERCURY LINES						
405.0	22.5	22.5	21.0	24.1	21.1	21.1
436.0	60.5	61.6	61.0	54.4	54.4	55.7
546.0	25.7	26.1	25.8	28.1	28.4	28.4
578.0	9.3	9.7	9.0	9.5	10.3	9.1

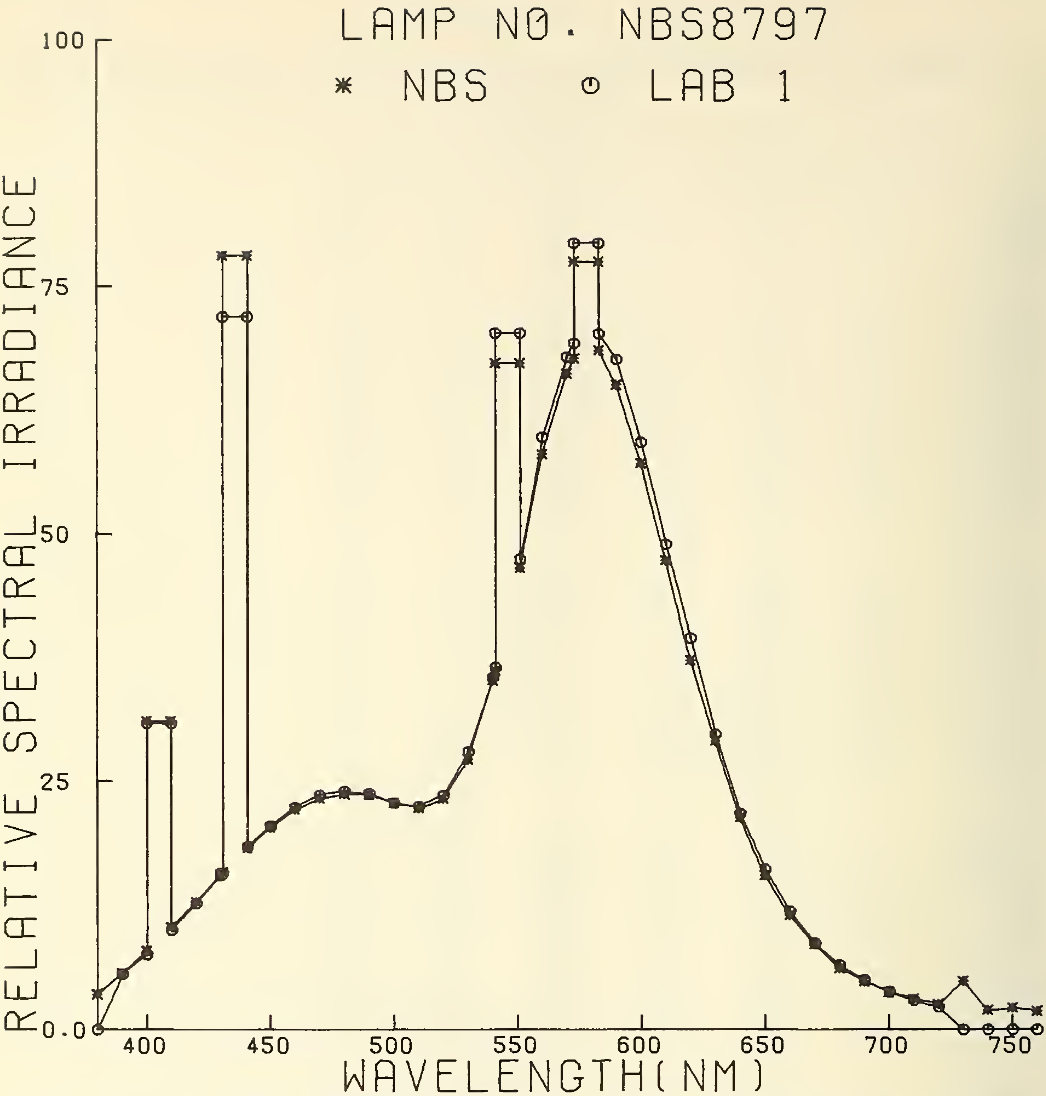


FIGURE 4.44 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.53

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8798

	NBS			LABORATORY 1		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.5	3.5	3.7	.0	.0	.0
390.0	5.7	5.5	5.8	5.8	5.7	5.8
400.0	7.9	7.6	7.8	7.8	7.7	7.6
410.0	10.4	10.0	10.2	10.1	10.1	9.9
420.0	13.0	12.6	12.9	12.7	12.7	12.5
430.0	16.0	15.4	15.7	15.5	15.5	15.3
440.0	18.5	18.1	16.8	18.1	18.2	18.1
450.0	20.6	20.4	18.6	20.4	20.4	20.4
460.0	22.4	22.2	22.4	22.2	22.2	22.2
470.0	23.7	23.3	23.4	23.4	23.6	23.4
480.0	23.9	23.8	23.8	23.8	23.8	23.9
490.0	23.9	23.7	23.9	23.7	23.6	23.8
500.0	22.9	22.8	22.9	23.1	23.1	23.1
510.0	22.6	22.5	22.5	22.7	22.6	22.7
520.0	23.6	23.4	23.6	23.9	23.7	23.9
530.0	27.8	27.4	27.7	28.3	28.2	28.3
540.0	35.8	35.4	35.9	35.9	35.7	35.8
550.0	46.1	45.5	46.1	46.4	46.2	46.3
560.0	58.9	58.0	58.9	60.1	59.7	59.9
570.0	66.9	66.5	67.1	68.0	67.7	68.0
580.0	69.5	69.5	69.7	70.5	70.4	70.6
590.0	64.9	65.5	65.3	67.6	67.6	67.7
600.0	57.0	57.3	57.2	59.1	59.4	59.2
610.0	47.1	47.3	47.4	49.0	49.1	48.9
620.0	36.7	38.2	37.3	39.5	39.8	39.5
630.0	28.4	30.2	29.0	29.9	29.9	29.8
640.0	21.0	21.7	21.4	21.9	22.0	21.9
650.0	15.5	15.9	16.0	16.5	16.5	16.4
660.0	11.3	11.9	11.5	12.2	12.2	12.1
670.0	8.4	8.7	8.8	8.9	8.9	8.9
680.0	6.4	6.3	6.5	6.8	6.8	6.7
690.0	4.7	5.0	4.9	5.3	5.3	5.2
700.0	3.5	3.8	2.2	4.1	4.1	4.0
710.0	2.8	3.2	3.5	3.3	3.3	3.2
720.0	2.4	.3	2.8	2.6	2.6	2.5
730.0	4.6	4.8	5.6	.0	.0	.0
740.0	1.6	2.2	2.6	.0	.0	.0
750.0	1.9	2.2	2.8	.0	.0	.0
760.0	1.5	2.6	3.1	.0	.0	.0

MERCURY LINES

405.0	22.7	21.9	22.1	20.4	20.8	21.5
436.0	58.5	58.9	58.1	52.5	53.4	54.3
546.0	26.2	25.9	25.6	27.6	27.7	27.9
578.0	9.2	8.9	8.9	10.2	10.1	8.9

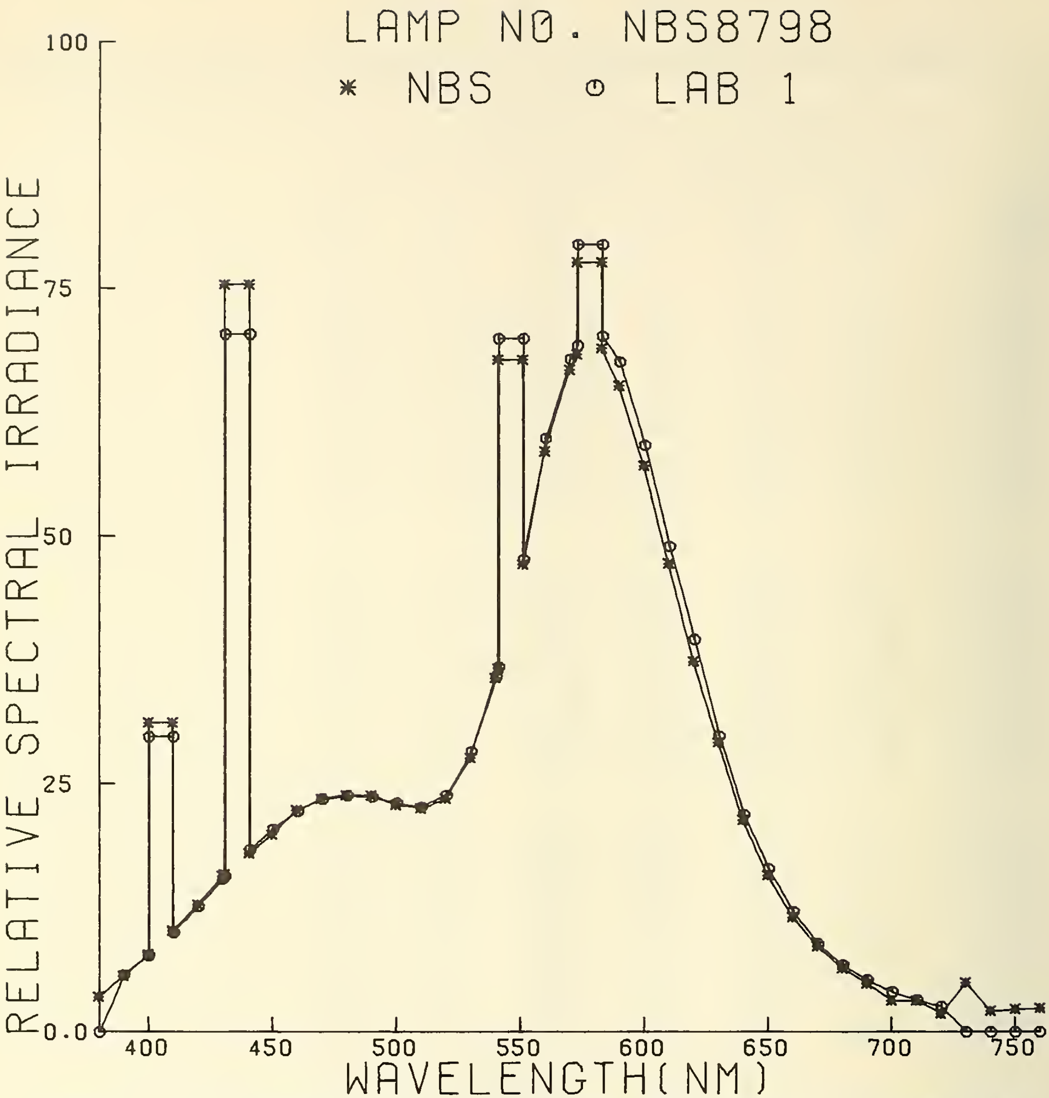


FIGURE 4.45 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.54

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8799

	NBS			LABORATORY 9				
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8
380.0	3.6	3.7	3.8	3.7	3.7	3.7	3.7	3.6
390.0	5.8	5.9	5.9	6.5	6.6	5.8	5.8	5.6
400.0	7.9	8.1	7.9	7.8	7.8	7.9	7.9	7.8
410.0	10.5	10.6	10.4	10.5	10.4	10.5	10.4	10.3
420.0	13.1	13.1	13.1	13.0	13.0	13.1	13.0	13.1
430.0	16.2	15.8	16.1	15.8	15.8	15.8	15.9	15.9
440.0	18.8	18.5	18.6	18.5	18.5	18.6	18.6	18.5
450.0	21.0	21.0	20.9	20.9	20.8	20.8	20.9	20.9
460.0	22.7	22.9	22.7	22.8	22.5	22.7	22.8	22.7
470.0	23.9	24.0	23.7	23.9	23.8	23.7	23.7	23.9
480.0	24.2	24.6	24.0	24.4	24.1	24.2	24.2	24.2
490.0	24.2	24.3	24.1	24.2	24.1	24.1	24.2	24.3
500.0	23.1	23.5	23.0	23.1	23.1	23.2	23.2	23.2
510.0	22.7	22.9	22.6	22.6	22.4	22.6	22.5	22.7
520.0	23.5	23.8	23.1	23.5	23.4	23.6	23.7	23.7
530.0	27.5	27.7	27.5	27.5	27.5	27.5	27.5	27.5
540.0	35.3	35.1	35.5	35.5	35.0	35.5	35.6	35.4
550.0	45.5	45.2	45.6	46.8	46.4	46.9	46.7	47.1
560.0	58.3	58.6	58.3	58.1	58.0	58.4	58.6	58.4
570.0	66.5	67.2	66.4	65.7	65.5	65.7	65.8	65.9
580.0	69.2	70.3	69.0	67.1	66.8	67.0	67.1	67.4
590.0	65.0	66.2	65.0	65.6	65.0	65.5	65.6	65.6
600.0	57.2	58.3	57.0	58.0	58.1	57.8	57.7	57.9
610.0	47.9	48.2	47.1	48.2	47.8	46.9	47.4	48.0
620.0	37.1	37.8	37.3	37.7	37.8	37.9	37.7	38.1
630.0	28.9	30.0	28.6	28.6	28.8	28.9	28.8	28.4
640.0	21.3	22.4	21.1	21.3	21.4	21.4	21.5	20.9
650.0	15.9	16.1	15.7	15.7	15.9	15.8	15.2	15.9
660.0	11.5	11.9	11.5	11.6	11.6	11.6	11.5	11.7
670.0	8.6	8.9	8.6	8.6	8.5	8.5	8.5	8.6
680.0	6.0	6.5	6.3	6.3	6.2	6.2	6.3	6.4
690.0	4.6	5.1	5.1	4.9	5.0	4.9	4.8	5.0
700.0	3.5	4.0	3.8	3.8	3.8	3.7	3.7	3.7
710.0	2.8	3.2	3.3	3.0	3.0	3.0	3.0	3.0
720.0	2.4	2.5	2.7	2.4	2.3	2.3	2.3	2.4
730.0	4.5	4.7	5.0	1.9	1.9	1.9	1.9	2.0
740.0	1.6	2.2	2.1	1.6	1.6	1.6	1.7	1.6
750.0	1.9	2.2	2.5	1.5	1.5	1.4	1.4	1.4
760.0	1.5	2.1	3.0	1.3	1.3	1.3	1.2	1.4
MERCURY LINES								
405.0	22.4	22.2	21.6	19.4	20.0	20.0	20.8	19.9
436.0	57.9	58.2	56.7	58.8	59.0	60.4	59.6	58.3
546.0	25.2	26.1	25.0	25.1	27.5	24.9	25.0	25.7
578.0	9.0	9.0	8.8	12.5	12.9	12.9	12.4	12.1

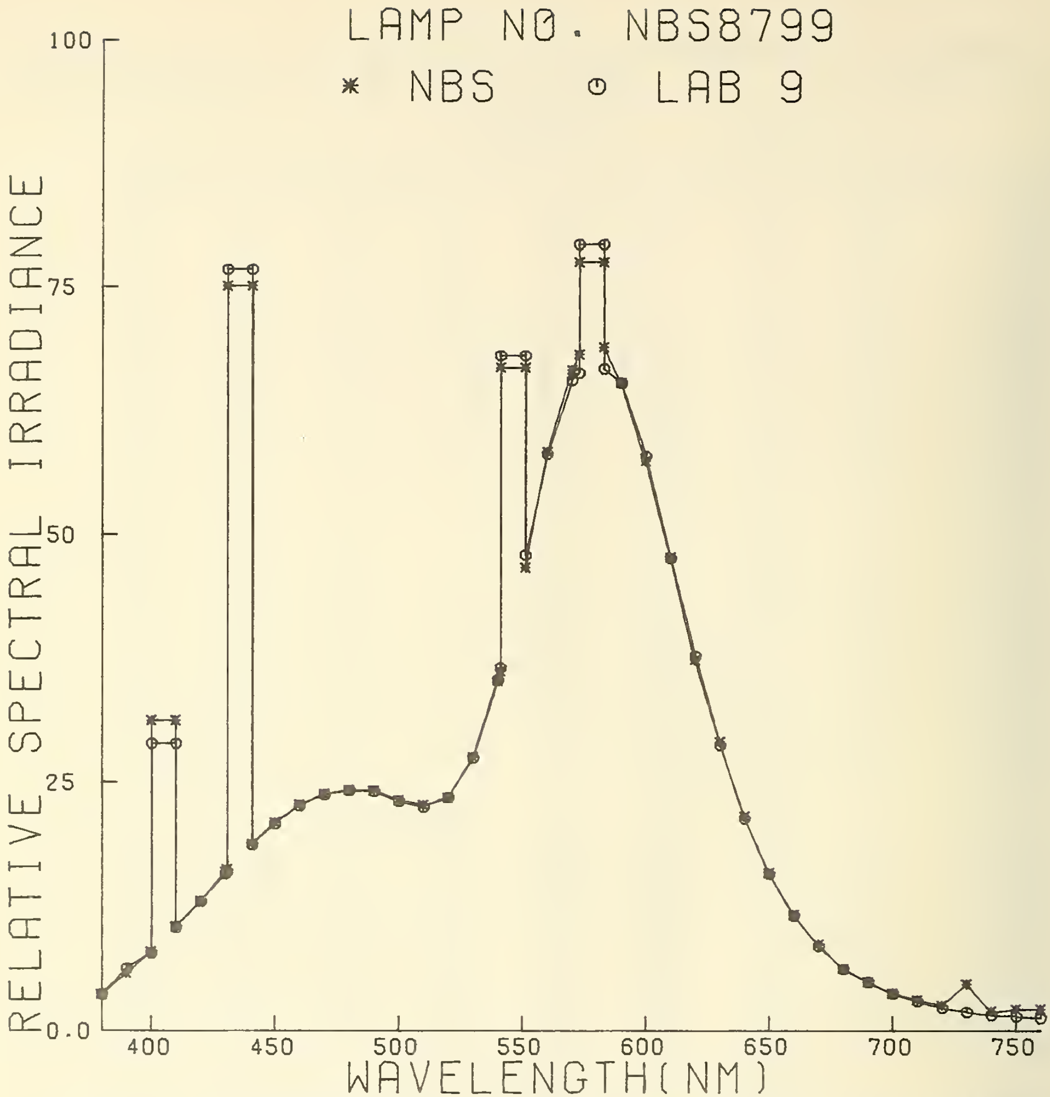


FIGURE 4.46 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.55

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8800

	NBS			LABORATORY 9		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.5	3.6	3.8	3.6	3.5	3.6
390.0	5.7	5.7	5.7	6.5	5.6	5.6
400.0	7.9	7.6	7.7	7.7	7.7	7.6
410.0	10.4	10.0	10.1	10.2	10.2	10.3
420.0	13.0	12.7	12.9	12.8	12.7	12.9
430.0	16.0	15.8	15.8	15.7	15.7	15.6
440.0	18.6	18.5	18.3	18.4	18.4	18.3
450.0	20.8	20.7	20.6	20.8	20.7	20.6
460.0	22.5	22.5	22.5	22.6	22.7	22.7
470.0	23.8	23.7	23.6	23.9	23.8	23.8
480.0	24.2	24.1	24.0	24.2	24.2	24.2
490.0	24.2	24.0	24.0	24.2	24.2	24.2
500.0	23.3	23.1	23.0	23.2	23.3	23.2
510.0	22.8	22.6	22.6	22.7	22.7	22.7
520.0	23.6	23.6	23.5	23.7	23.7	23.6
530.0	27.4	27.3	27.5	27.6	27.7	27.5
540.0	35.3	34.9	35.4	35.6	35.6	35.6
550.0	45.5	44.8	45.4	46.9	47.0	46.7
560.0	58.2	57.5	58.0	58.6	58.4	58.3
570.0	66.5	66.3	66.2	65.7	66.0	65.7
580.0	69.4	69.6	68.9	67.1	67.3	66.8
590.0	65.2	65.6	64.8	65.6	65.9	65.5
600.0	57.5	58.0	56.9	57.8	58.1	57.8
610.0	47.5	48.1	47.1	47.1	47.8	48.0
620.0	37.0	38.3	36.9	37.5	37.3	37.5
630.0	28.7	30.3	28.5	28.7	28.9	28.9
640.0	21.4	21.6	21.4	21.6	21.4	21.0
650.0	15.7	16.0	15.7	15.7	16.0	15.9
660.0	11.4	11.4	11.5	11.8	11.6	11.7
670.0	8.5	8.6	8.7	8.6	8.5	8.5
680.0	6.1	6.1	6.3	6.4	6.3	6.3
690.0	4.7	4.8	5.1	5.0	5.0	5.0
700.0	3.5	3.5	3.8	3.8	3.7	3.8
710.0	2.8	2.9	3.3	3.1	3.0	2.9
720.0	2.4	2.2	2.7	2.4	2.4	2.4
730.0	4.6	4.4	5.3	1.9	2.0	2.0
740.0	1.6	2.2	2.8	1.6	1.6	1.6
750.0	1.9	1.7	2.9	1.4	1.5	1.4
760.0	1.5	2.1	3.0	1.3	1.4	1.3
MERCURY LINES						
405.0	22.2	20.7	21.7	20.7	20.1	20.1
436.0	58.8	58.6	58.1	57.7	58.9	59.6
546.0	25.6	25.7	25.3	25.6	25.0	27.0
578.0	8.7	8.8	9.0	12.7	12.7	12.3

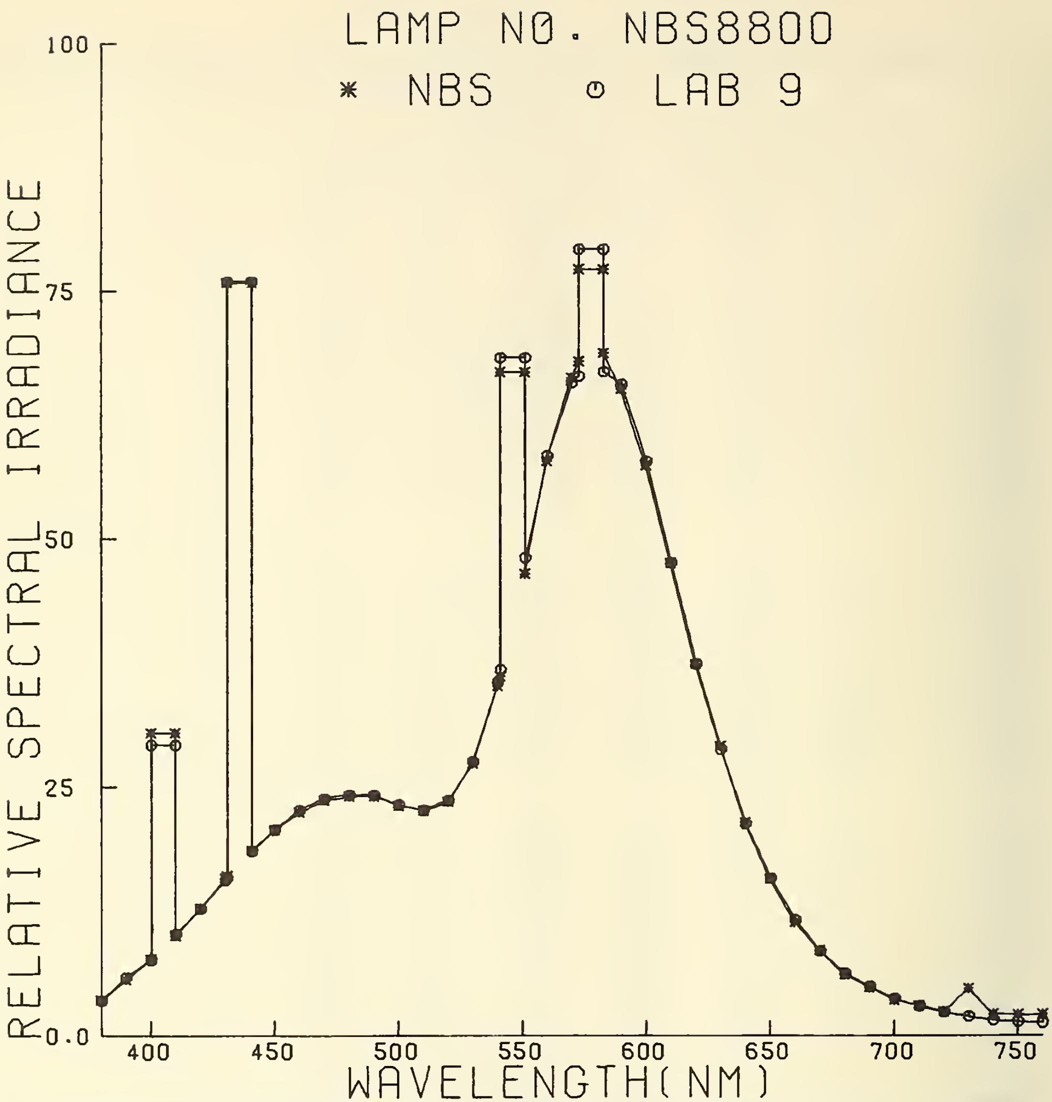


FIGURE 4.47 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.56

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8801

	NBS			LABORATORY 5		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.6	3.6	3.6	.0	1.1	.0
390.0	5.8	5.5	5.7	.0	1.2	1.2
400.0	8.0	7.9	7.9	15.9	17.8	16.9
410.0	10.4	10.4	10.4	15.9	13.3	12.7
420.0	13.0	12.8	13.1	13.6	13.7	13.5
430.0	16.0	15.4	15.9	15.7	15.9	15.5
440.0	18.6	18.0	18.4	18.4	18.3	18.1
450.0	20.8	20.5	20.8	21.2	21.5	22.0
460.0	22.6	22.4	22.5	22.7	23.3	23.3
470.0	23.8	23.4	23.6	24.3	24.0	24.1
480.0	24.2	24.0	23.9	24.7	24.7	24.9
490.0	24.1	23.8	24.0	24.6	24.7	24.8
500.0	23.2	23.0	23.0	24.1	24.6	24.1
510.0	22.7	22.5	22.6	23.9	24.2	24.3
520.0	23.6	23.5	23.7	24.6	24.9	24.9
530.0	27.8	27.2	27.8	29.4	29.2	29.6
540.0	35.9	35.5	36.0	37.8	38.2	38.1
550.0	46.1	45.6	46.1	49.4	49.4	48.9
560.0	58.8	57.9	58.6	61.2	61.0	60.6
570.0	66.8	66.4	66.8	66.9	65.9	66.4
580.0	69.4	69.4	69.3	68.0	66.8	68.3
590.0	64.9	65.2	64.7	66.8	66.8	67.1
600.0	57.3	58.6	56.7	58.0	59.0	58.5
610.0	47.1	48.0	47.0	47.5	47.0	48.0
620.0	36.7	37.8	36.8	37.8	37.6	37.4
630.0	28.5	29.5	28.4	28.0	28.9	28.3
640.0	21.1	21.9	21.1	21.5	21.0	20.7
650.0	15.4	15.7	15.6	14.4	14.2	14.0
660.0	11.3	11.4	11.3	9.4	9.6	9.5
670.0	8.4	8.6	8.5	6.2	5.6	5.6
680.0	6.0	6.1	6.0	4.8	4.4	4.5
690.0	4.7	4.8	5.2	4.8	2.5	1.9
700.0	3.5	3.5	3.9	2.0	1.4	1.4
710.0	2.8	2.9	3.3	1.4	.7	1.4
720.0	2.2	2.2	2.7	.7	.8	1.6
730.0	4.6	4.4	5.1	9.5	7.8	7.8
740.0	1.9	2.2	2.1	2.6	2.8	2.8
750.0	1.9	1.7	2.5	1.6	1.7	1.7
760.0	1.9	2.0	2.0	.0	.0	.0
MERCURY LINES						
405.0	22.4	21.5	21.5	5.5	5.0	5.6
436.0	58.2	58.7	57.4	54.6	54.7	55.0
546.0	25.8	25.7	25.7	26.8	27.7	28.7
578.0	8.4	8.7	8.9	13.8	16.8	16.3

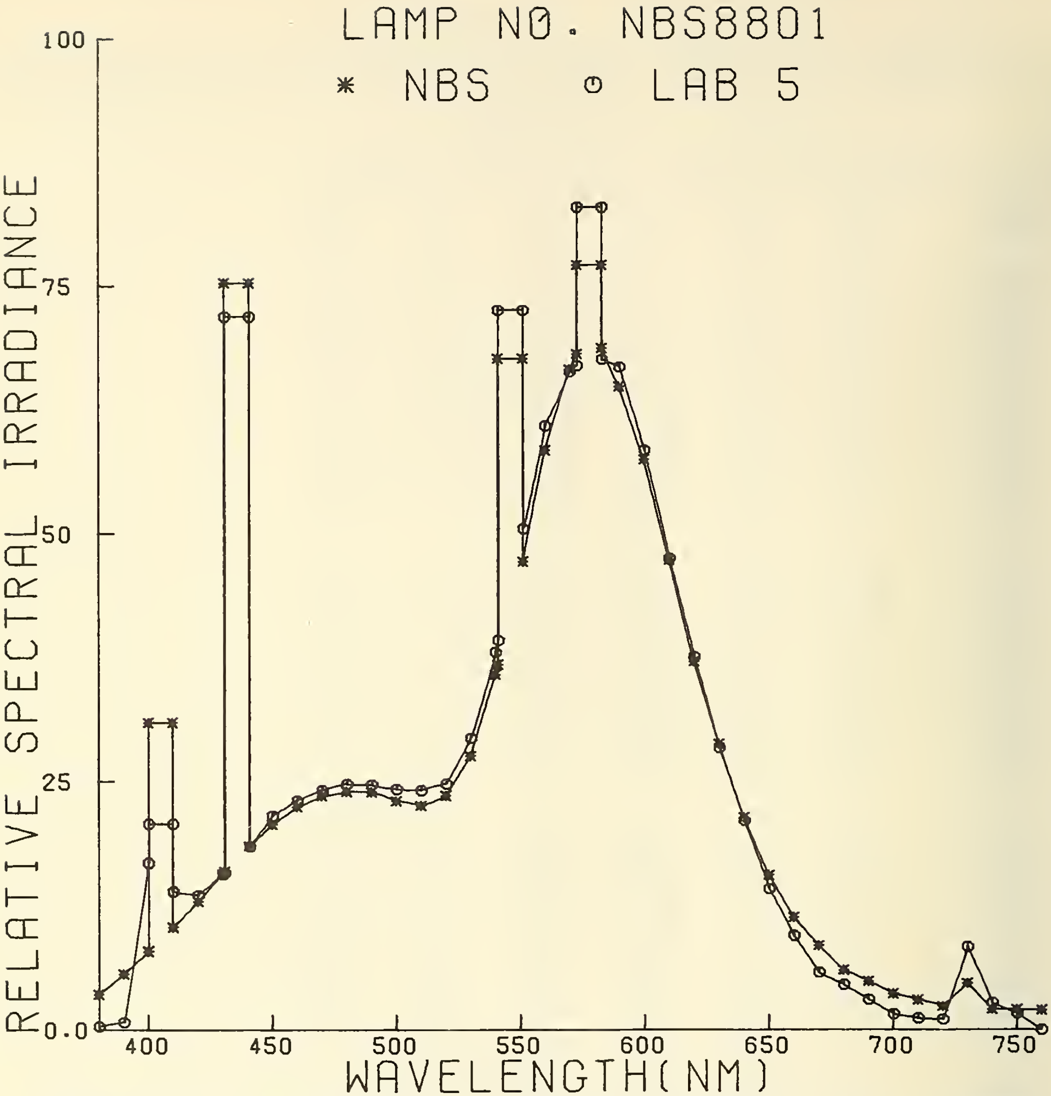


FIGURE 4.48 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.57

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8802

	NBS			LABORATORY 5		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.8	3.6	3.8	.0	1.0	.0
390.0	5.9	5.7	5.9	1.1	1.1	1.1
400.0	7.9	7.9	7.8	17.6	21.8	16.3
410.0	10.4	10.3	10.3	16.4	13.6	12.6
420.0	13.0	12.8	13.0	13.9	13.8	13.4
430.0	16.1	15.6	16.0	15.3	16.0	15.5
440.0	18.6	18.3	18.5	18.3	18.1	18.4
450.0	20.7	20.7	20.8	21.5	21.7	21.6
460.0	22.4	22.4	22.6	23.0	23.0	23.2
470.0	23.6	23.6	23.6	24.4	23.9	24.4
480.0	23.9	24.1	23.9	24.9	24.6	24.9
490.0	23.9	23.9	24.0	24.7	24.5	24.8
500.0	22.9	23.1	22.9	24.4	24.2	24.4
510.0	22.4	22.7	22.5	24.3	24.2	24.1
520.0	23.5	23.5	23.6	24.7	24.4	24.9
530.0	27.6	27.5	27.7	29.7	29.3	29.5
540.0	35.5	35.1	35.8	38.4	37.6	38.1
550.0	45.6	45.1	45.9	49.8	49.0	49.1
560.0	58.2	58.1	58.4	61.4	60.2	61.5
570.0	66.0	66.4	66.6	66.1	66.4	66.7
580.0	68.4	69.4	69.2	66.9	67.6	67.7
590.0	64.0	65.8	64.6	66.7	66.2	67.0
600.0	56.0	57.3	56.5	58.7	59.1	59.2
610.0	46.3	47.4	46.7	47.0	46.8	47.4
620.0	36.2	37.6	36.6	36.7	37.6	38.1
630.0	28.3	28.9	28.1	28.0	27.9	27.8
640.0	20.8	21.2	21.2	20.6	21.3	21.4
650.0	15.1	15.3	15.7	14.2	14.2	14.7
660.0	11.0	11.5	11.1	9.0	9.3	9.1
670.0	8.3	8.5	8.4	5.3	5.2	5.4
680.0	6.0	6.0	6.3	3.8	4.1	4.3
690.0	4.7	5.0	5.1	1.8	4.1	3.1
700.0	3.4	3.7	3.8	1.4	2.7	1.4
710.0	2.8	3.1	3.3	.7	1.4	1.4
720.0	2.3	2.5	2.7	.7	.7	1.5
730.0	4.7	4.7	5.0	6.4	8.3	8.6
740.0	1.7	2.2	2.1	2.7	2.6	2.7
750.0	1.7	2.1	2.5	1.7	1.6	1.7
760.0	2.0	2.0	3.0	.0	.0	.0

MERCURY LINES

405.0	24.2	22.0	22.2	5.5	5.3	4.8
436.0	63.3	59.0	57.5	58.3	54.7	54.6
546.0	26.7	25.9	25.6	26.9	26.6	27.7
578.0	10.1	8.6	8.9	17.2	14.2	16.0

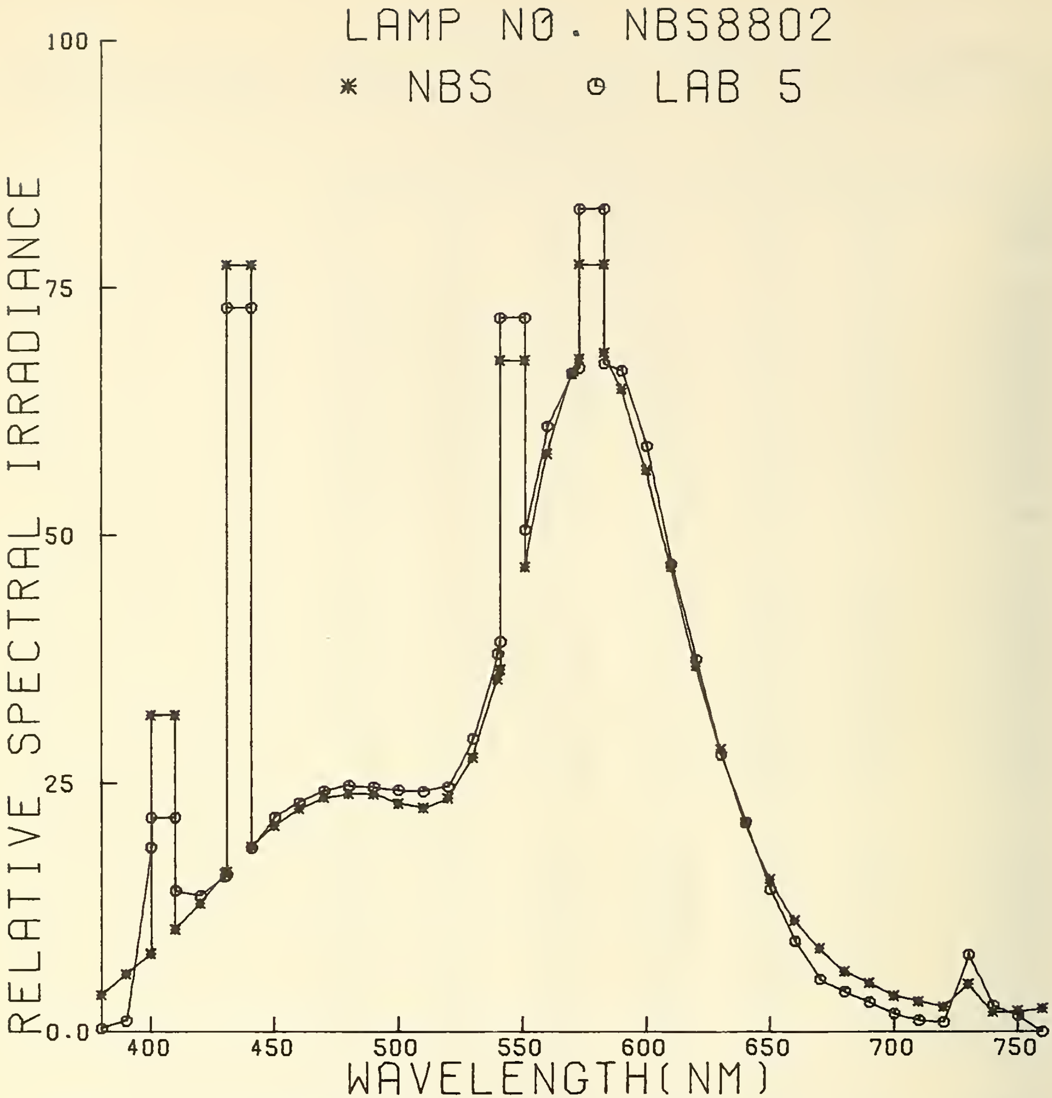


FIGURE 4.49 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.58

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8805

	NBS			LABORATORY 2		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.5	3.6	3.7	.0	.0	.0
390.0	5.6	5.7	5.7	5.4	4.8	5.3
400.0	7.8	7.7	7.7	7.6	7.3	7.6
410.0	10.3	10.1	10.2	10.2	10.0	10.2
420.0	12.9	12.8	13.0	13.0	12.9	12.9
430.0	15.8	15.8	16.0	16.1	16.1	16.1
440.0	18.4	18.4	18.6	18.8	18.8	18.9
450.0	20.7	20.6	20.9	20.9	20.9	21.0
460.0	22.5	22.5	22.6	22.8	22.8	22.8
470.0	23.6	23.6	23.7	23.9	24.0	23.9
480.0	24.1	24.1	24.0	24.4	24.4	24.4
490.0	24.1	24.0	24.2	24.3	24.4	24.3
500.0	23.2	23.1	23.0	23.5	23.5	23.5
510.0	22.7	22.6	22.7	23.1	23.1	23.1
520.0	23.5	23.6	23.8	24.2	24.2	24.3
530.0	27.6	27.3	27.9	28.4	28.5	28.4
540.0	35.7	35.3	35.9	36.9	37.0	37.0
550.0	45.8	45.5	46.1	47.3	47.5	47.4
560.0	58.3	58.4	58.8	59.4	59.8	59.6
570.0	66.5	66.4	66.8	67.7	68.0	67.7
580.0	69.2	69.1	69.2	69.7	70.2	69.8
590.0	64.9	64.8	64.9	66.0	66.3	66.0
600.0	58.0	57.0	56.9	57.9	58.3	58.2
610.0	47.5	48.3	46.7	47.8	48.1	48.0
620.0	37.1	37.2	36.7	37.7	37.9	37.8
630.0	29.6	29.2	28.3	28.7	28.9	28.9
640.0	21.4	21.1	21.3	21.4	21.5	21.5
650.0	15.7	15.7	15.2	15.8	15.7	15.8
660.0	11.2	11.2	11.2	11.5	11.4	11.5
670.0	8.5	8.6	8.3	8.3	8.2	8.3
680.0	6.1	6.1	6.2	6.0	5.8	6.0
690.0	4.6	5.0	4.9	4.6	4.3	4.5
700.0	3.4	3.7	2.2	3.3	3.0	3.3
710.0	2.9	3.2	3.4	2.6	2.1	2.5
720.0	2.3	2.5	2.8	2.0	1.5	1.8
730.0	4.5	4.7	5.2	1.6	1.0	1.4
740.0	1.6	2.2	2.2	1.3	.8	1.2
750.0	1.6	2.1	2.6	.9	.1	.6
760.0	1.5	2.6	2.6	.0	.0	.0
MERCURY LINES						
405.0	22.3	22.0	21.8	22.0	22.1	21.7
436.0	59.3	58.2	57.8	57.7	59.4	57.2
546.0	25.4	25.5	25.5	25.2	25.2	25.5
578.0	8.8	8.8	8.7	10.2	10.1	10.1

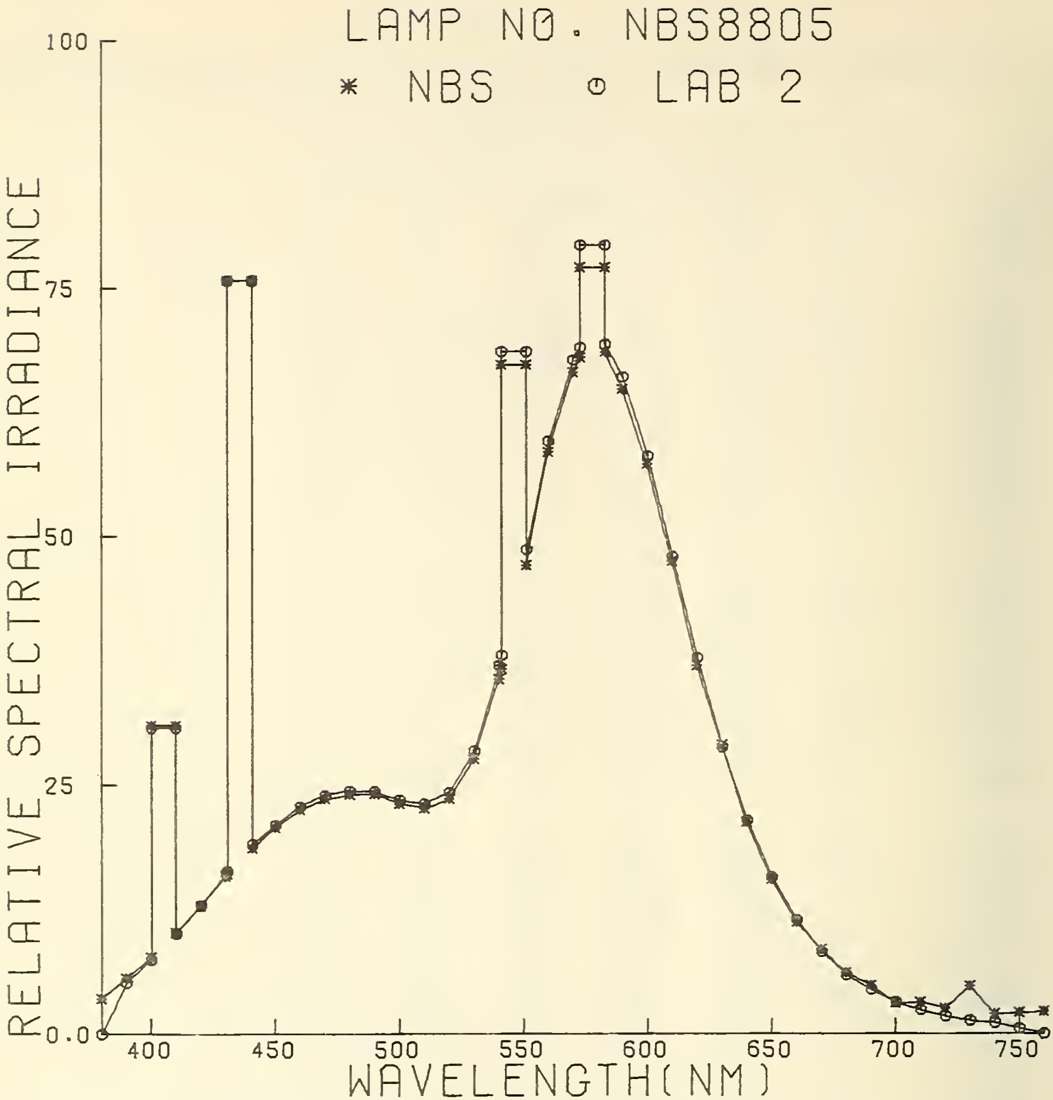


FIGURE 4.50 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.59

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8806

	NBS			LABORATORY 2		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.7	3.7	3.8	.0	.0	.0
390.0	5.9	5.9	5.9	5.8	5.7	5.6
400.0	8.3	11.1	7.9	8.0	7.9	7.8
410.0	10.9	13.2	10.4	10.4	10.5	10.4
420.0	13.4	13.2	13.2	13.2	13.3	13.2
430.0	16.1	11.7	16.2	16.3	16.4	16.3
440.0	18.7	14.5	18.8	19.1	19.1	19.2
450.0	21.0	20.9	21.1	21.2	21.3	21.3
460.0	22.8	22.8	22.8	23.0	23.1	23.1
470.0	23.9	23.9	23.8	24.2	24.3	24.3
480.0	24.5	24.4	24.2	24.6	24.7	24.7
490.0	24.4	24.2	24.3	24.5	24.6	24.5
500.0	23.5	23.3	23.3	23.6	23.6	23.7
510.0	22.9	22.8	22.6	23.2	23.2	23.2
520.0	23.7	23.7	23.7	24.2	24.2	24.2
530.0	27.5	27.4	27.7	28.2	28.2	28.2
540.0	35.1	35.1	35.5	36.4	36.5	36.6
550.0	45.1	45.0	45.4	46.6	46.7	46.8
560.0	57.6	57.6	57.9	58.5	58.7	58.8
570.0	65.9	65.9	65.7	66.9	66.8	67.0
580.0	68.8	68.7	68.3	68.9	69.1	69.3
590.0	64.6	64.4	64.2	65.3	65.5	65.7
600.0	57.8	56.6	56.5	57.4	57.6	57.7
610.0	47.6	47.4	46.4	47.6	47.7	47.6
620.0	37.2	37.2	36.6	37.6	37.7	37.6
630.0	29.4	29.0	28.3	28.7	28.8	28.8
640.0	21.4	21.6	21.0	21.5	21.5	21.5
650.0	15.6	15.8	15.5	15.8	15.9	15.8
660.0	11.4	11.2	11.4	11.5	11.6	11.5
670.0	8.6	8.7	8.7	8.4	8.5	8.4
680.0	6.0	6.2	6.2	6.1	6.2	6.0
690.0	4.7	4.9	4.9	4.7	4.7	4.6
700.0	3.5	2.1	3.9	3.4	3.4	3.3
710.0	2.8	3.1	3.3	2.6	2.7	2.6
720.0	2.2	2.7	3.0	2.1	2.1	1.9
730.0	4.4	5.3	5.4	1.7	1.5	1.5
740.0	1.6	2.1	2.5	1.4	1.7	1.2
750.0	1.6	2.1	2.5	1.2	.5	.8
760.0	1.5	2.5	3.0	.0	.0	.0

MERCURY LINES

405.0	21.7	19.5	21.9	22.0	22.2	22.1
436.0	58.7	64.2	57.8	58.9	57.1	57.7
546.0	25.9	25.6	25.3	25.2	25.5	25.4
578.0	8.7	8.7	8.8	10.1	9.9	9.9

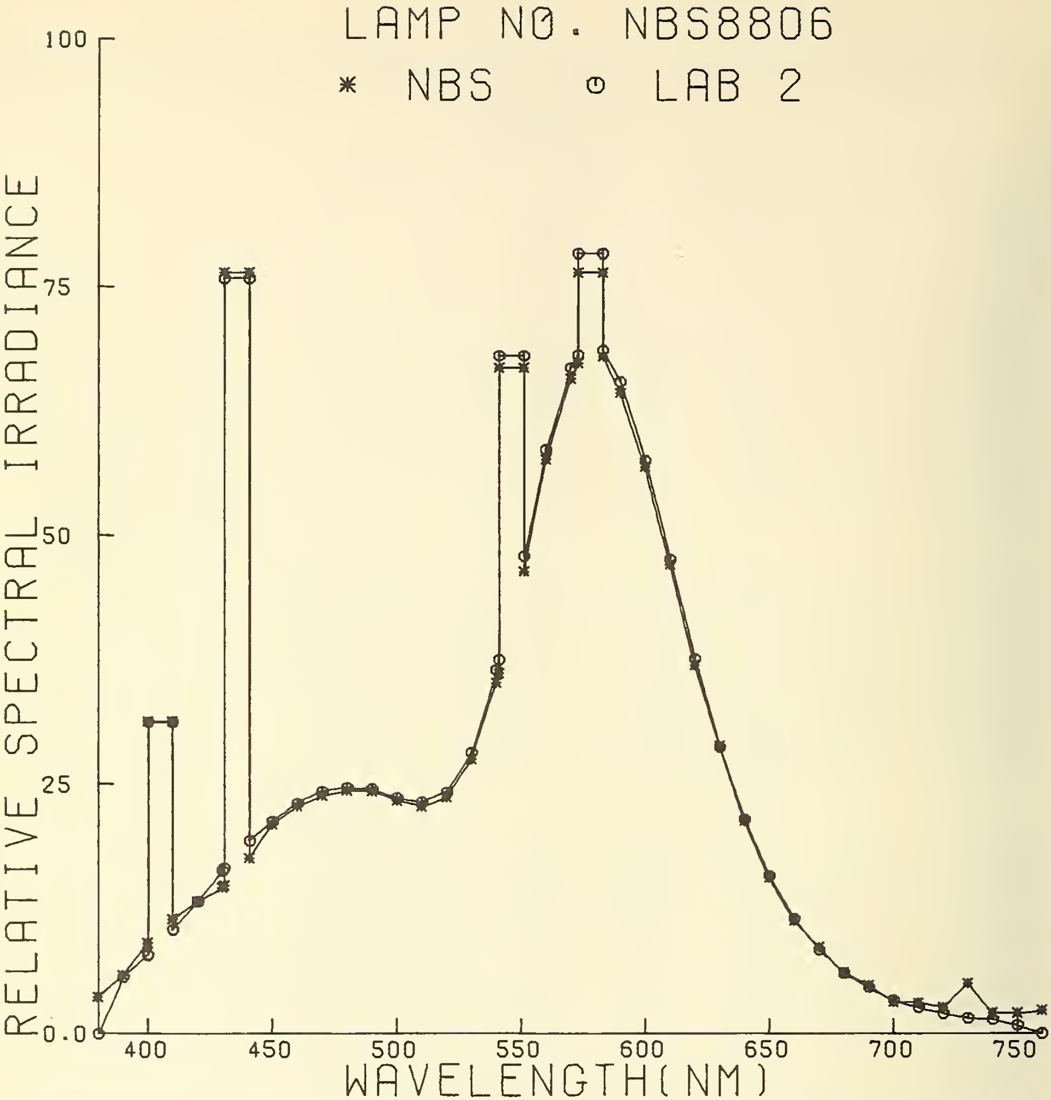


FIGURE 4.51 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.60

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8809

	NBS			LABORATORY 4		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.6	3.6	3.9	4.2	3.8	4.0
390.0	5.8	4.2	5.8	6.2	6.3	5.5
400.0	8.1	6.7	7.9	8.5	8.0	8.2
410.0	10.5	8.9	10.3	11.5	10.6	10.2
420.0	13.1	10.9	13.0	13.6	13.3	13.1
430.0	15.9	12.9	16.0	16.5	15.7	16.1
440.0	18.4	19.7	18.5	19.2	18.3	18.6
450.0	20.8	20.8	20.8	21.4	20.3	20.4
460.0	22.5	22.8	22.6	22.6	22.7	21.1
470.0	23.6	21.9	23.6	24.3	22.8	23.8
480.0	24.1	22.3	24.1	25.0	25.5	24.0
490.0	24.0	22.4	24.1	24.2	23.9	23.3
500.0	23.2	22.4	23.1	24.2	23.7	23.4
510.0	22.7	21.9	22.6	23.2	23.0	22.9
520.0	23.6	22.1	23.7	24.5	23.7	24.0
530.0	27.7	24.4	27.9	29.1	28.7	28.4
540.0	35.4	30.2	35.9	37.4	36.9	36.7
550.0	45.5	41.0	45.9	45.5	47.9	47.9
560.0	58.3	57.7	58.5	57.0	58.5	59.1
570.0	66.3	61.1	66.4	64.6	66.5	66.9
580.0	69.1	65.0	68.8	76.5	76.1	74.8
590.0	65.2	69.5	64.4	63.1	64.8	65.5
600.0	57.4	61.9	56.6	55.7	56.9	57.4
610.0	47.5	53.5	46.6	45.7	46.8	47.2
620.0	36.9	43.6	36.6	37.2	36.9	37.4
630.0	29.2	34.6	28.2	28.5	28.3	28.6
640.0	21.2	26.6	21.2	21.6	21.6	21.5
650.0	15.6	20.5	15.4	16.3	15.9	15.9
660.0	11.0	14.2	11.4	12.0	11.7	11.8
670.0	8.3	10.0	8.6	8.8	8.6	8.7
680.0	6.2	7.3	6.1	6.5	6.4	6.4
690.0	4.8	5.6	5.1	5.1	5.1	5.2
700.0	3.6	4.3	2.2	3.8	3.7	3.7
710.0	2.9	3.6	3.4	3.1	2.9	3.0
720.0	2.0	3.1	2.8	2.4	2.2	2.3
730.0	4.7	3.5	4.9	1.9	1.9	2.0
740.0	1.6	3.1	2.5	1.6	1.5	1.7
750.0	1.9	2.4	2.6	1.4	1.4	1.5
760.0	1.5	2.4	3.1	1.2	1.0	1.3
MERCURY LINES						
405.0	22.5	14.8	22.1	20.8	20.8	19.5
436.0	59.1	54.7	58.3	52.2	52.9	54.1
546.0	25.9	21.6	25.6	24.8	25.7	25.5
578.0	8.9	6.6	8.9	7.2	6.9	7.2

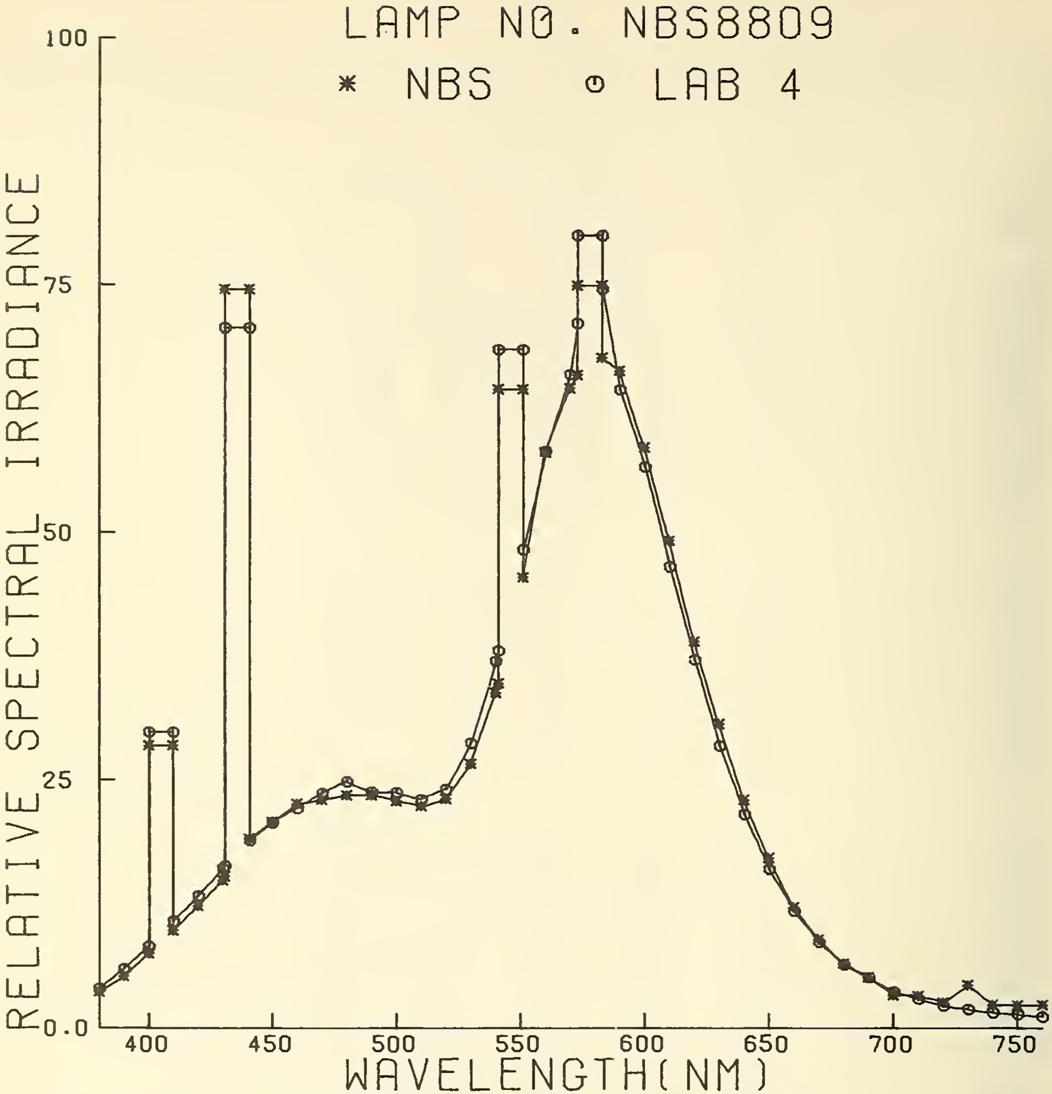


FIGURE 4.52 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.61

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8810

	NBS			LABORATORY 4		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	3.7	3.4	3.9	4.0	3.6	4.2
390.0	5.7	4.0	5.6	6.5	5.9	6.2
400.0	7.9	9.5	7.8	8.2	8.2	7.9
410.0	10.4	12.3	10.3	10.4	11.2	10.5
420.0	12.9	13.3	13.0	13.2	13.0	12.8
430.0	15.8	13.2	15.8	15.8	15.9	15.7
440.0	18.4	18.3	18.3	18.4	18.6	18.5
450.0	20.5	20.5	20.6	20.6	20.7	20.0
460.0	22.3	21.9	20.3	23.2	22.0	22.3
470.0	23.6	21.4	23.5	23.4	24.5	23.4
480.0	23.9	21.9	23.9	24.7	24.8	24.0
490.0	23.9	22.0	23.9	22.5	23.9	23.5
500.0	23.0	22.0	23.0	23.7	22.8	23.1
510.0	22.7	21.7	22.5	22.9	22.6	22.0
520.0	23.6	21.9	23.5	23.7	24.6	24.1
530.0	27.6	24.1	27.8	27.5	28.2	28.4
540.0	35.7	30.1	35.9	35.9	35.6	36.4
550.0	45.9	40.7	46.1	47.1	46.3	47.8
560.0	58.6	57.1	58.8	58.2	58.4	58.9
570.0	66.6	61.1	66.9	66.2	66.1	66.8
580.0	69.4	65.2	69.5	78.0	74.4	76.5
590.0	65.3	69.3	65.2	64.0	64.8	64.9
600.0	57.6	61.1	57.0	56.6	56.7	57.0
610.0	47.9	53.1	47.0	46.7	46.7	47.1
620.0	37.3	42.9	37.0	36.7	36.9	37.3
630.0	29.1	34.5	28.6	28.0	28.4	28.5
640.0	21.6	27.1	21.2	21.5	21.4	21.5
650.0	15.7	21.0	15.6	15.9	15.9	16.1
660.0	11.3	14.4	11.3	11.9	11.9	11.8
670.0	8.7	10.4	8.5	8.8	8.7	8.9
680.0	6.3	7.7	6.1	6.5	6.6	6.5
690.0	4.9	5.9	5.2	5.2	5.2	5.1
700.0	3.5	4.6	3.9	3.7	3.7	3.8
710.0	2.8	3.8	3.4	3.0	3.0	3.1
720.0	2.4	3.3	2.7	2.4	2.3	2.4
730.0	4.5	3.4	5.1	1.9	2.0	1.8
740.0	1.6	3.3	2.2	1.5	1.6	1.5
750.0	1.9	2.7	2.5	1.3	1.3	1.4
760.0	1.5	2.8	3.0	1.1	1.0	1.0
MERCURY LINES						
405.0	22.1	13.4	22.1	21.2	21.5	20.7
436.0	56.9	52.5	56.4	53.2	54.3	53.0
546.0	26.2	24.3	26.1	27.6	27.8	26.4
578.0	9.0	6.1	9.0	7.4	7.0	7.3

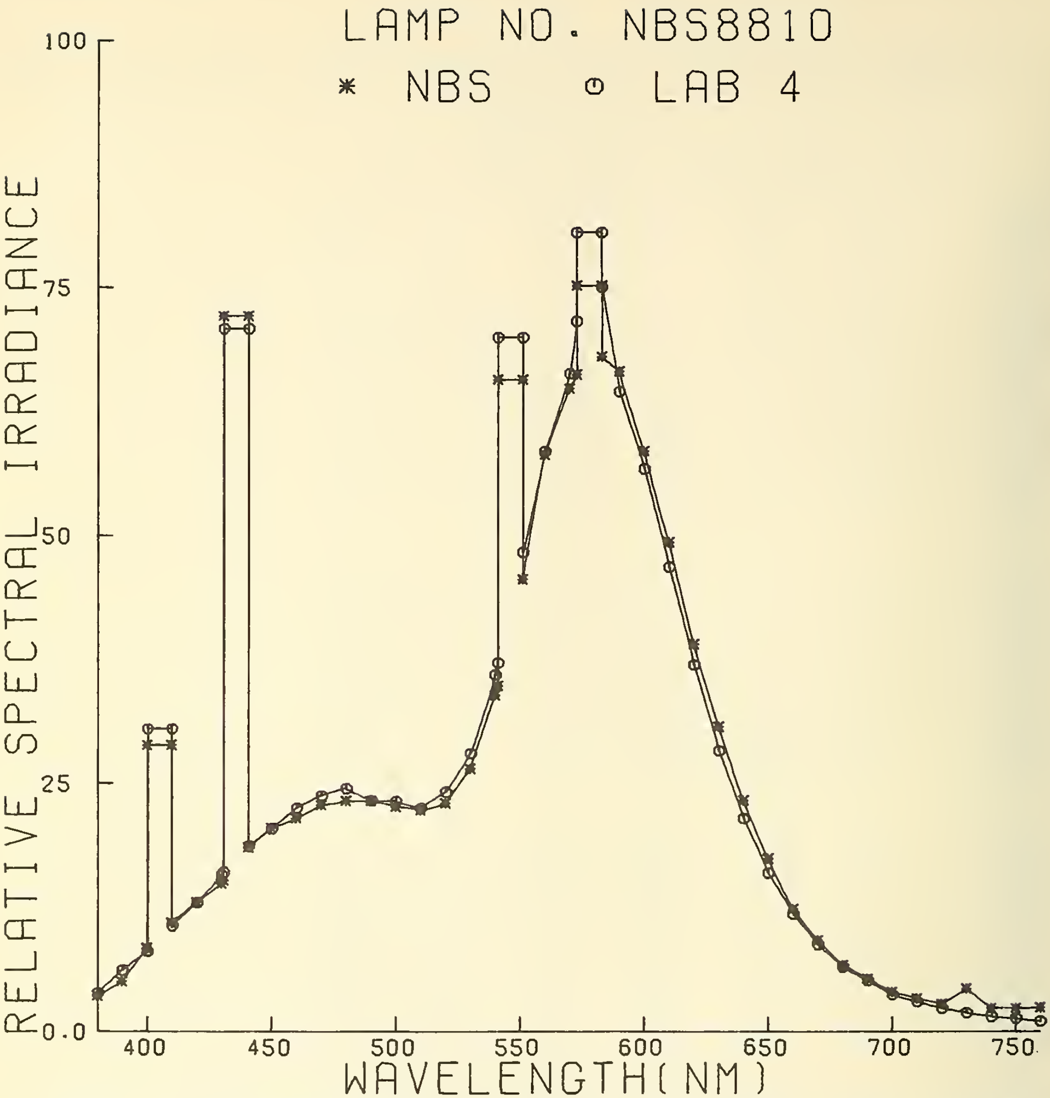


FIGURE 4.53 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.62

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8905

	NBS			LABORATORY 7		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	4.9	4.8	4.9	3.2	14.7	2.5
390.0	8.4	8.2	8.1	4.1	5.0	4.0
400.0	12.8	12.6	12.5	6.2	7.2	6.3
410.0	17.6	17.3	17.2	9.3	10.3	9.3
420.0	22.4	22.1	22.1	13.8	14.7	13.6
430.0	27.7	27.4	27.3	18.8	19.0	17.2
440.0	32.2	31.9	31.7	23.6	24.0	22.6
450.0	36.0	35.6	35.8	27.4	26.5	26.0
460.0	38.4	38.0	38.1	28.3	30.0	29.2
470.0	39.5	39.1	39.1	32.7	31.9	31.0
480.0	39.3	39.1	39.0	32.8	33.6	32.6
490.0	38.2	37.7	37.9	34.0	32.6	33.1
500.0	35.7	35.5	35.4	31.9	31.8	32.3
510.0	33.3	33.3	33.0	30.7	29.9	30.8
520.0	31.6	31.6	31.5	29.1	28.5	29.5
530.0	31.8	31.5	31.6	29.2	29.0	29.7
540.0	34.4	34.2	34.3	31.2	31.6	32.5
550.0	38.6	38.2	38.3	35.1	35.6	36.3
560.0	44.4	44.0	44.2	40.9	41.4	42.4
570.0	47.9	47.7	47.8	45.6	46.2	46.5
580.0	48.3	48.3	48.2	46.7	46.7	46.8
590.0	44.6	44.7	44.7	42.9	43.0	43.1
600.0	39.1	39.2	39.1	37.1	30.9	38.7
610.0	32.2	32.5	32.4	32.3	31.6	33.3
620.0	25.3	26.0	25.4	25.7	26.0	25.7
630.0	19.8	21.4	20.2	21.4	21.1	21.2
640.0	14.8	15.3	15.2	17.3	16.8	17.0
650.0	10.9	11.2	11.3	13.9	14.1	14.1
660.0	8.2	8.2	8.4	11.9	11.7	12.0
670.0	6.3	6.5	6.5	10.7	10.2	10.6
680.0	4.5	4.7	4.8	9.8	9.1	9.5
690.0	3.6	4.0	3.9	10.2	9.5	10.1
700.0	2.7	3.1	2.9	10.1	9.7	10.3
710.0	2.4	2.5	2.8	12.3	11.3	12.1
720.0	1.9	2.1	2.1	14.3	12.8	14.6
730.0	3.9	4.4	4.9	17.1	16.0	17.9
740.0	1.5	2.1	2.1	20.7	20.4	22.0
750.0	1.8	2.0	2.4	25.6	23.5	24.6
760.0	1.4	1.9	2.9	28.3	26.9	27.7
MERCURY LINES						
405.0	21.2	20.7	20.8	6.1	7.0	6.1
436.0	56.9	56.2	55.9	31.1	30.4	28.3
546.0	25.0	24.8	24.8	25.3	25.6	25.1
578.0	8.6	8.4	8.6	21.2	22.0	21.4

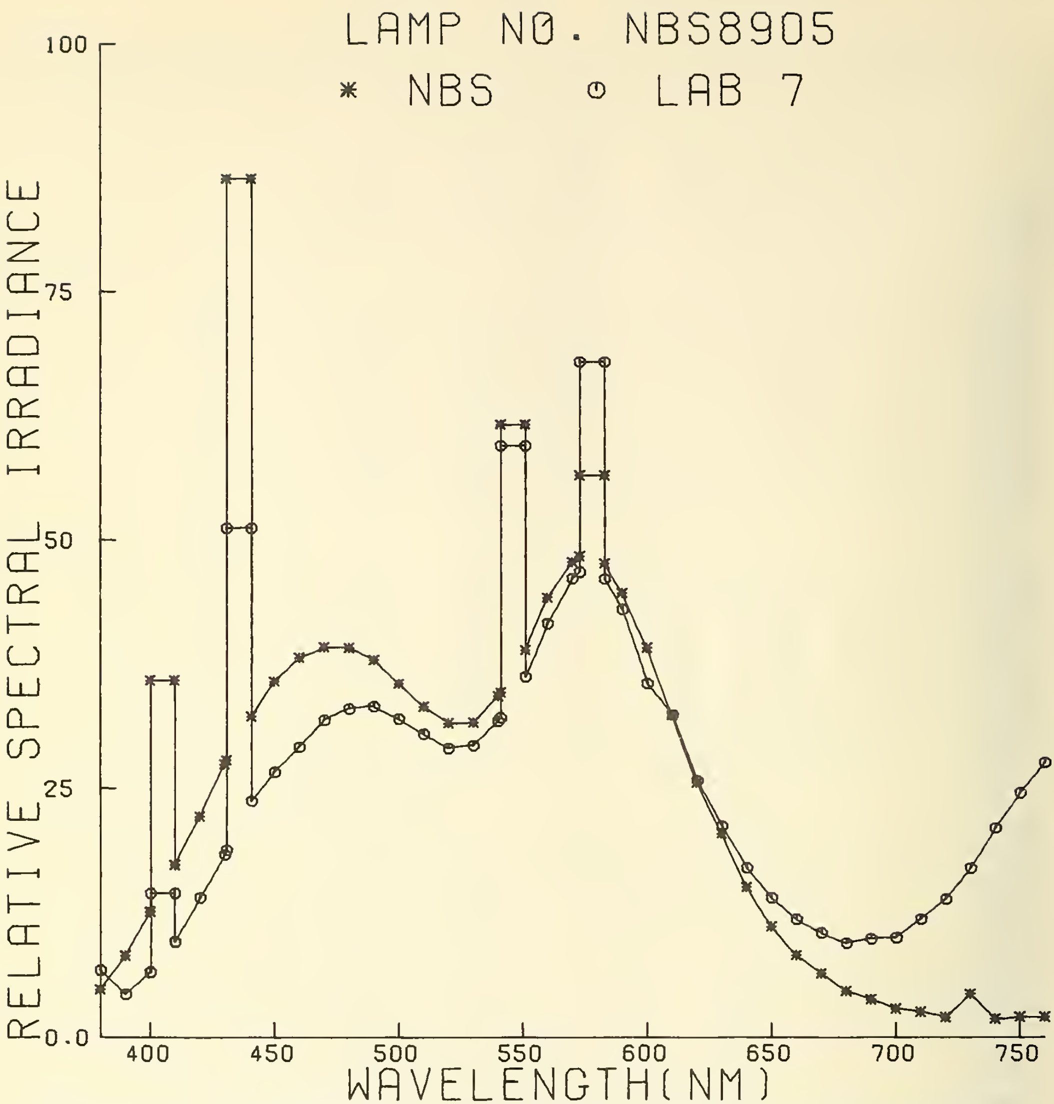


FIGURE 4.54 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.63

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8906

	NBS			LABORATORY 1		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	4.9	4.9	5.1	.0	.0	.0
390.0	8.5	8.2	8.4	8.2	8.9	8.7
400.0	13.1	12.9	12.9	12.0	12.8	12.9
410.0	17.8	17.5	17.6	16.9	18.0	18.0
420.0	22.6	22.2	22.6	22.0	23.2	23.2
430.0	27.8	27.1	27.7	27.3	28.6	28.6
440.0	32.4	31.7	32.2	32.1	33.5	33.5
450.0	36.3	35.8	36.4	35.9	37.2	37.1
460.0	38.6	38.4	38.8	38.6	39.7	39.6
470.0	39.9	39.5	39.7	39.7	40.7	40.5
480.0	39.5	39.5	39.6	39.7	40.2	40.1
490.0	38.3	38.1	38.5	38.6	38.8	38.8
500.0	36.0	35.8	36.0	36.5	36.6	36.5
510.0	33.5	33.4	33.7	34.1	34.0	34.0
520.0	31.8	31.6	31.7	32.4	32.3	32.2
530.0	31.9	31.8	31.9	32.7	32.5	32.4
540.0	34.5	34.4	34.6	35.0	34.7	34.7
550.0	38.7	38.4	38.7	39.4	39.0	39.0
560.0	44.4	44.3	44.7	45.8	45.4	45.4
570.0	47.9	47.8	48.3	49.4	48.6	48.7
580.0	48.3	48.4	48.6	49.7	48.6	48.9
590.0	44.7	45.1	44.8	46.8	45.6	45.8
600.0	38.9	39.3	38.6	40.7	39.5	39.4
610.0	32.3	33.2	32.4	33.7	32.6	32.6
620.0	25.4	25.9	25.7	27.3	26.1	26.1
630.0	19.9	20.7	20.1	20.8	19.9	19.9
640.0	14.8	15.3	15.2	15.5	14.7	14.6
650.0	11.2	11.4	11.3	11.9	11.2	11.1
660.0	8.3	8.2	8.4	9.0	8.4	8.2
670.0	6.3	6.5	6.6	6.7	6.3	6.2
680.0	4.4	4.8	5.0	5.3	4.8	4.8
690.0	3.8	4.0	4.2	4.2	3.7	3.8
700.0	2.9	3.1	3.3	3.4	2.9	2.9
710.0	2.5	2.7	2.9	2.7	2.3	2.4
720.0	2.0	2.2	2.5	2.2	1.8	1.9
730.0	4.1	4.4	4.8	.0	.0	.0
740.0	1.6	1.8	2.5	.0	.0	.0
750.0	1.9	2.1	2.5	.0	.0	.0
760.0	1.5	2.1	3.1	.0	.0	.0

MERCURY LINES

405.0	20.5	19.7	20.2	19.2	20.4	20.6
436.0	53.5	53.1	53.1	49.6	51.7	51.7
546.0	24.7	24.8	24.5	26.4	26.2	26.2
578.0	8.3	8.1	8.0	8.6	8.6	8.6

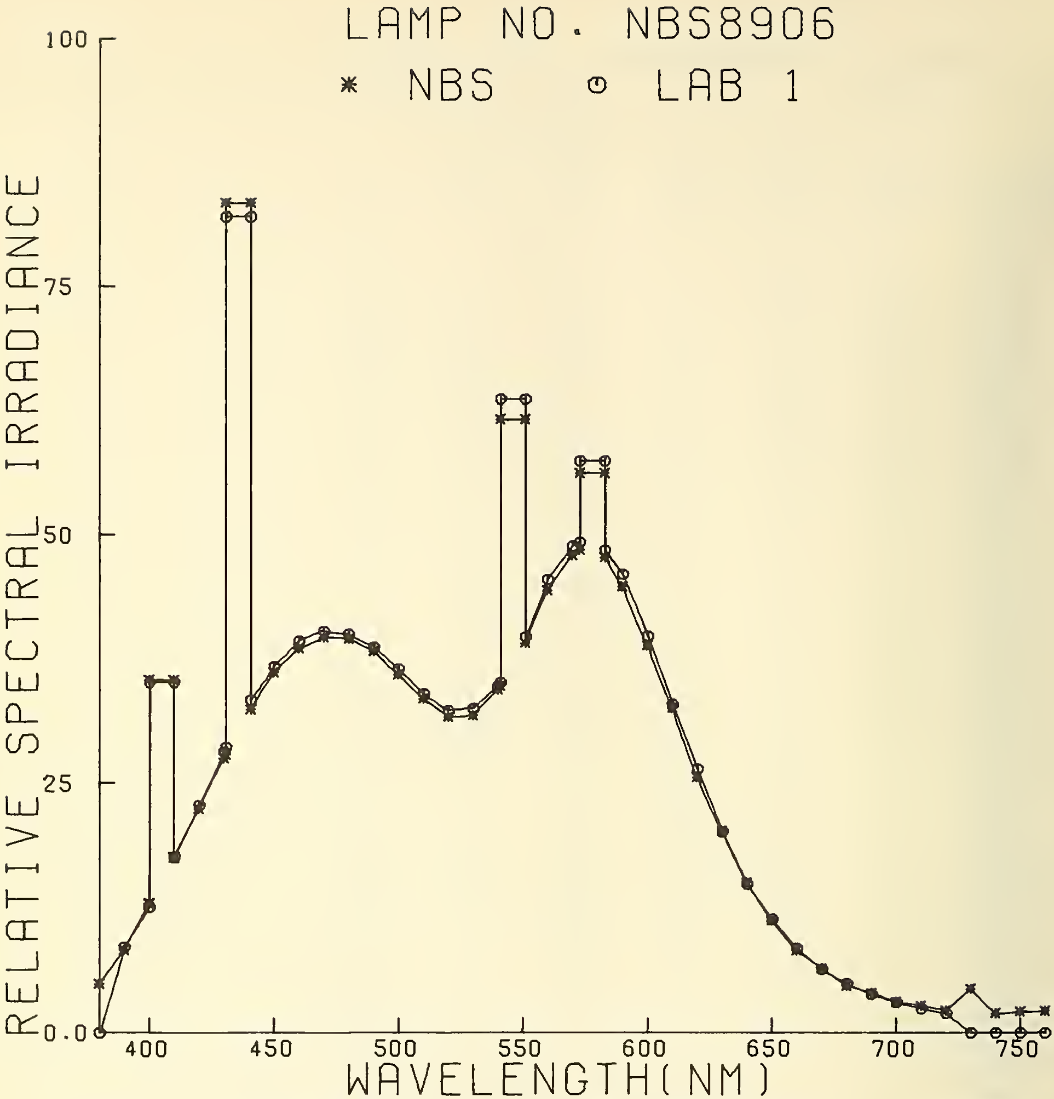


FIGURE 4.55 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.64

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8907

	NBS			LABORATORY 9		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	5.1	4.7	5.2	4.9	4.9	4.6
390.0	8.5	8.2	8.4	9.2	8.2	8.1
400.0	12.9	12.2	12.7	12.3	12.2	12.2
410.0	17.6	16.9	17.4	17.2	17.1	16.9
420.0	22.5	21.9	22.4	22.6	22.4	22.3
430.0	27.9	27.7	27.7	27.8	27.7	27.7
440.0	32.4	32.4	32.1	32.4	32.6	32.5
450.0	36.1	35.9	36.0	36.2	36.4	36.3
460.0	38.6	38.4	38.5	39.0	38.8	38.7
470.0	39.7	39.5	39.4	40.1	39.9	39.9
480.0	39.4	39.4	39.1	39.7	39.8	39.8
490.0	38.2	38.0	38.0	38.5	38.5	38.5
500.0	35.9	35.7	35.6	36.0	36.2	36.1
510.0	33.4	33.3	33.3	33.6	33.5	33.6
520.0	31.8	31.7	31.6	31.7	31.9	31.8
530.0	31.9	31.8	31.8	32.0	32.3	32.2
540.0	34.6	34.3	34.6	34.7	34.9	34.8
550.0	38.7	38.4	38.8	39.5	39.9	39.7
560.0	44.6	44.4	44.7	44.9	45.0	44.8
570.0	48.1	47.9	48.1	47.8	48.0	47.8
580.0	48.4	48.3	48.3	47.3	47.4	47.3
590.0	44.6	44.9	44.7	45.1	45.1	45.2
600.0	39.1	39.2	39.0	39.5	39.6	39.7
610.0	32.5	32.7	32.3	32.5	32.8	32.7
620.0	25.5	26.0	25.6	25.9	26.2	26.0
630.0	20.1	21.7	19.9	20.1	20.0	20.3
640.0	15.1	14.9	15.0	15.2	14.9	14.7
650.0	11.2	11.3	11.4	11.3	11.3	11.4
660.0	8.4	8.3	8.5	8.5	8.5	8.6
670.0	6.3	6.6	6.3	6.4	6.3	6.4
680.0	4.7	4.7	4.6	4.8	4.8	4.8
690.0	3.9	4.0	4.1	3.9	3.8	3.9
700.0	3.0	2.9	3.3	3.0	3.0	2.9
710.0	2.3	2.5	2.7	2.4	2.4	2.4
720.0	1.9	2.1	2.0	1.9	2.0	2.0
730.0	4.1	4.2	4.8	1.6	1.6	1.6
740.0	1.8	1.7	2.0	1.4	1.3	1.3
750.0	1.8	2.0	2.4	1.2	1.2	1.3
760.0	1.8	1.9	1.9	1.0	1.1	1.1

MERCURY LINES

405.0	20.8	20.2	20.2	19.0	17.5	18.9
436.0	52.3	54.0	52.8	52.5	54.3	54.0
546.0	24.2	24.7	24.6	25.2	24.3	24.8
578.0	8.4	8.2	8.3	10.4	10.4	10.4

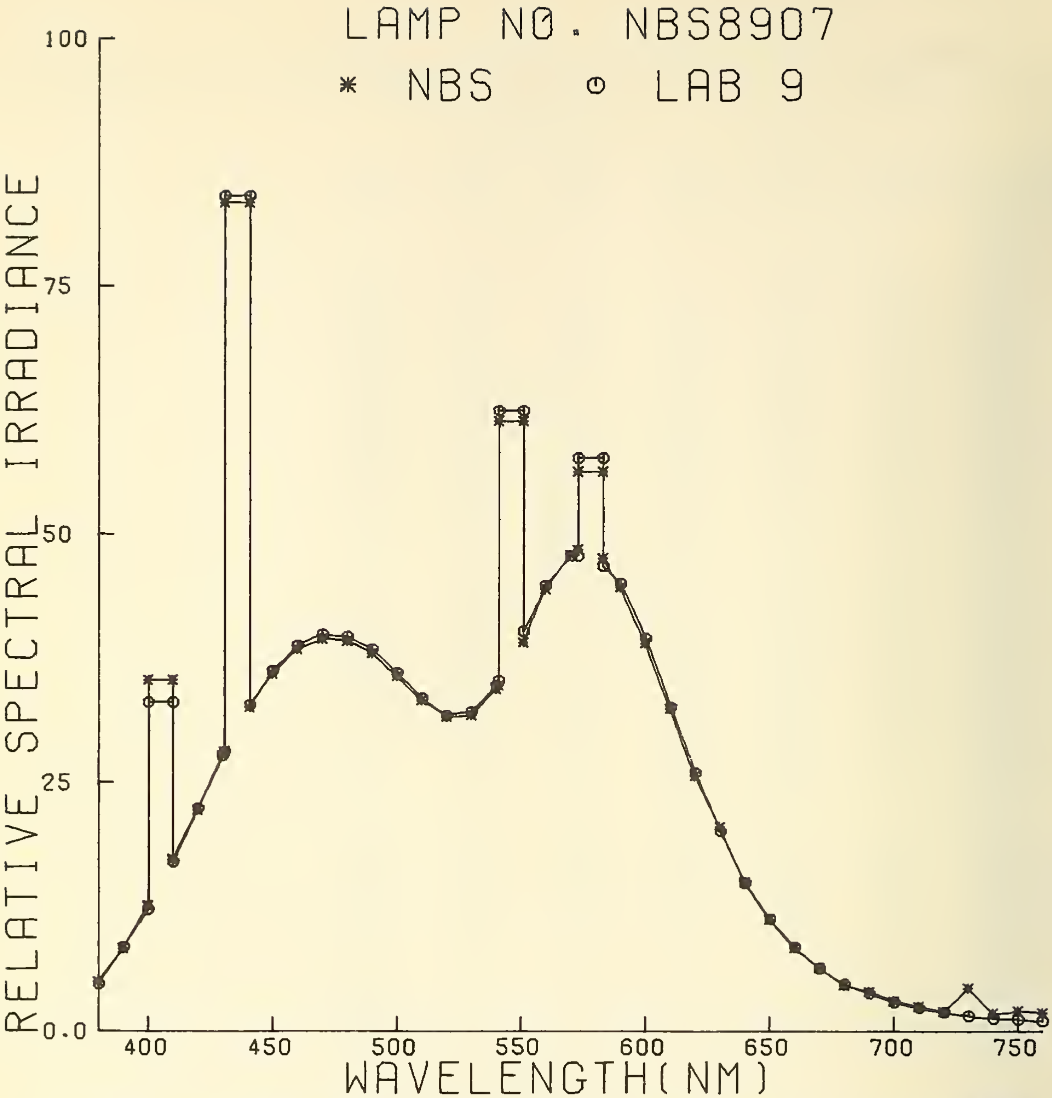


FIGURE 4.56 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.65

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8908

	NBS			LABORATORY 5		
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
380.0	4.9	4.8	5.0	.0	1.0	.0
390.0	8.4	8.2	8.2	1.1	1.2	2.3
400.0	12.6	12.4	12.5	28.9	30.0	24.5
410.0	17.2	17.0	17.2	26.0	22.4	20.7
420.0	21.9	21.9	22.2	23.2	23.4	23.1
430.0	27.3	27.2	27.5	26.7	26.9	26.6
440.0	31.9	31.8	31.8	30.7	30.9	31.0
450.0	35.9	35.4	35.7	35.4	36.6	36.7
460.0	38.2	38.1	38.2	37.3	38.5	38.8
470.0	39.4	39.3	39.1	38.7	39.4	39.7
480.0	39.3	39.1	38.9	38.6	39.7	40.0
490.0	38.1	38.0	37.9	37.4	38.4	38.7
500.0	35.8	35.7	35.4	35.8	36.6	36.9
510.0	33.5	33.2	33.0	33.3	34.7	34.4
520.0	31.6	31.6	31.4	32.1	32.3	32.9
530.0	31.9	31.7	31.6	32.3	32.8	33.5
540.0	34.5	34.4	34.4	36.0	36.8	37.1
550.0	38.6	38.6	38.6	40.8	41.6	42.0
560.0	44.5	44.5	44.6	45.8	46.8	47.1
570.0	48.3	48.3	48.2	48.0	48.9	49.0
580.0	48.8	49.0	48.5	47.4	48.3	48.2
590.0	44.9	45.6	44.9	45.9	46.0	46.1
600.0	39.7	40.0	39.2	40.0	40.9	41.0
610.0	33.1	32.5	32.4	32.0	33.1	33.2
620.0	25.7	26.0	25.5	24.5	25.5	26.8
630.0	19.9	20.1	19.9	18.5	18.9	19.5
640.0	15.1	15.1	15.0	14.0	14.1	14.8
650.0	11.2	11.3	11.5	9.2	8.0	9.5
660.0	8.4	8.4	8.5	6.4	4.8	5.7
670.0	6.4	6.6	6.5	4.3	2.5	4.5
680.0	4.6	4.8	4.8	1.6	1.1	1.7
690.0	3.6	3.9	3.9	1.2	.6	1.9
700.0	2.9	3.0	3.4	.7	.0	.7
710.0	2.3	2.6	2.8	.7	.0	.7
720.0	1.8	2.1	2.1	1.5	.0	.8
730.0	3.9	4.3	5.0	8.4	4.3	9.8
740.0	1.6	1.8	2.1	4.0	1.4	2.7
750.0	1.6	2.1	2.5	1.6	.0	1.7
760.0	1.5	2.0	3.0	.0	.0	.0
MERCURY LINES						
405.0	21.1	20.3	20.5	23.6	22.2	2.6
436.0	54.7	54.2	53.4	50.9	52.0	53.5
546.0	25.0	24.9	24.9	24.5	24.8	25.6
578.0	8.4	8.3	8.4	10.7	12.7	14.1

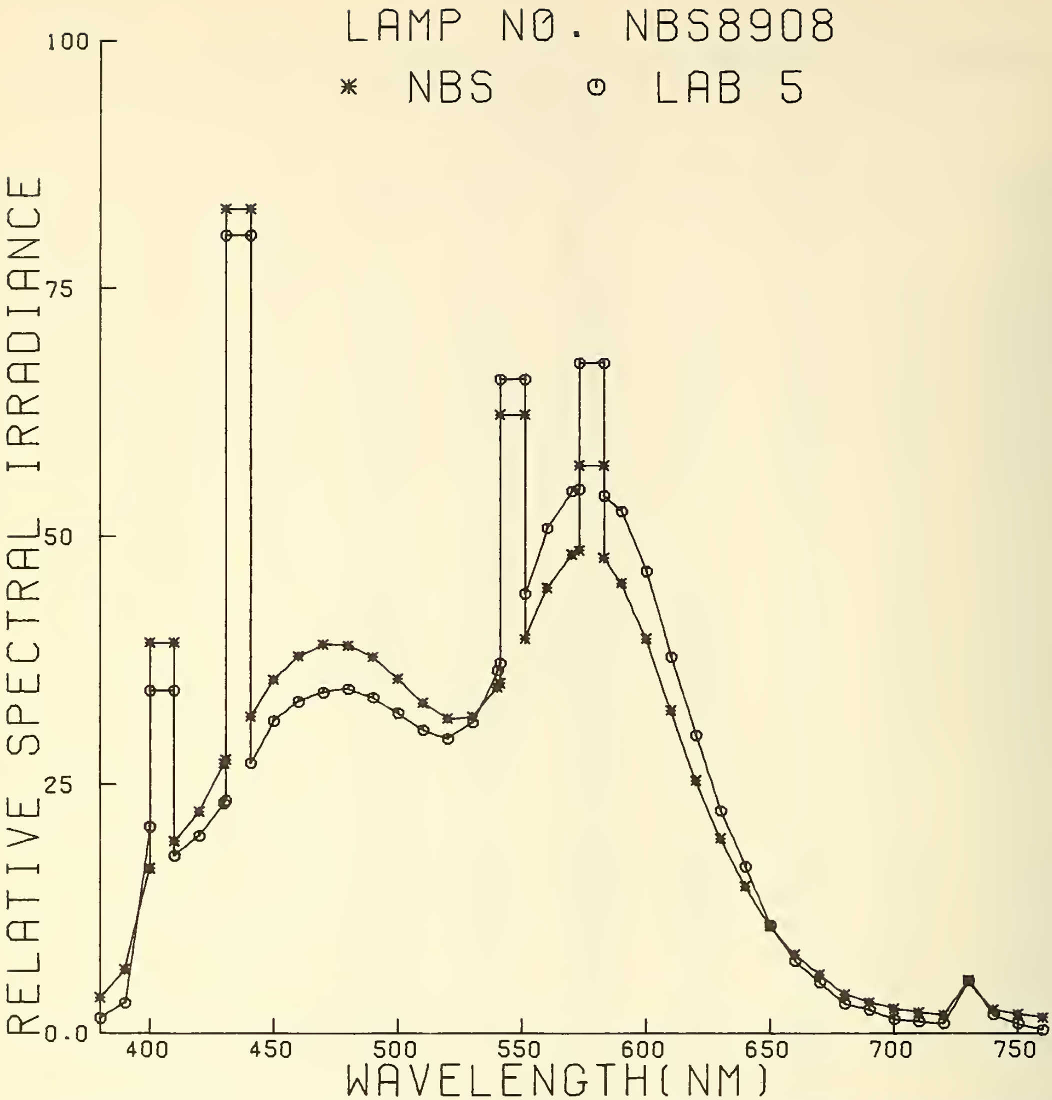


FIGURE 4.57 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

TABLE 4.66

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8909

	NBS			LABORATORY 2	
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
380.0	4.8	5.1	.0	.0	.0
390.0	8.3	8.3	8.2	8.3	7.7
400.0	12.9	12.8	12.6	12.5	12.3
410.0	17.7	17.5	17.4	17.2	17.3
420.0	22.4	22.5	22.4	22.1	22.5
430.0	27.5	27.7	27.9	27.5	27.9
440.0	32.0	32.1	32.6	32.2	32.8
450.0	35.8	36.0	36.1	35.9	36.5
460.0	38.4	38.4	38.6	38.5	39.0
470.0	39.5	39.4	39.8	39.8	40.2
480.0	39.3	39.1	39.6	39.5	40.0
490.0	38.2	38.0	38.4	38.4	38.7
500.0	35.8	35.6	36.1	36.1	36.3
510.0	33.5	33.1	33.7	33.7	34.0
520.0	31.8	31.5	32.1	32.1	32.4
530.0	31.8	31.8	32.3	32.4	32.6
540.0	34.3	34.5	35.3	35.3	35.6
550.0	38.4	38.5	39.5	39.7	39.9
560.0	44.2	44.2	45.0	45.2	45.4
570.0	47.8	47.8	48.6	48.7	48.8
580.0	48.4	48.2	48.6	48.9	49.0
590.0	44.9	44.7	45.4	45.6	45.7
600.0	39.4	39.1	39.8	40.0	40.0
610.0	33.0	32.2	32.9	33.1	33.1
620.0	25.8	25.5	26.2	26.3	26.2
630.0	20.8	20.0	20.2	20.3	20.2
640.0	15.1	15.0	15.3	15.4	15.2
650.0	11.3	11.3	11.4	11.5	11.3
660.0	8.2	8.4	8.5	8.6	8.3
670.0	6.3	6.4	6.3	6.3	6.1
680.0	4.6	4.9	4.6	4.7	4.4
690.0	3.7	4.2	3.6	3.7	3.4
700.0	2.8	3.3	2.7	2.8	2.5
710.0	2.2	2.8	2.2	2.3	1.8
720.0	1.7	.3	1.7	1.8	1.3
730.0	3.8	4.9	1.4	1.4	.9
740.0	1.5	2.1	1.1	1.6	.5
750.0	1.5	2.4	1.0	.5	.2
760.0	1.5	2.9	.0	.0	.0
MERCURY LINES					
405.0	20.9	20.3	21.1	21.0	20.7
436.0	55.0	54.3	55.3	54.5	55.4
546.0	24.8	24.5	25.1	25.1	24.9
578.0	8.2	8.2	9.4	9.3	9.0

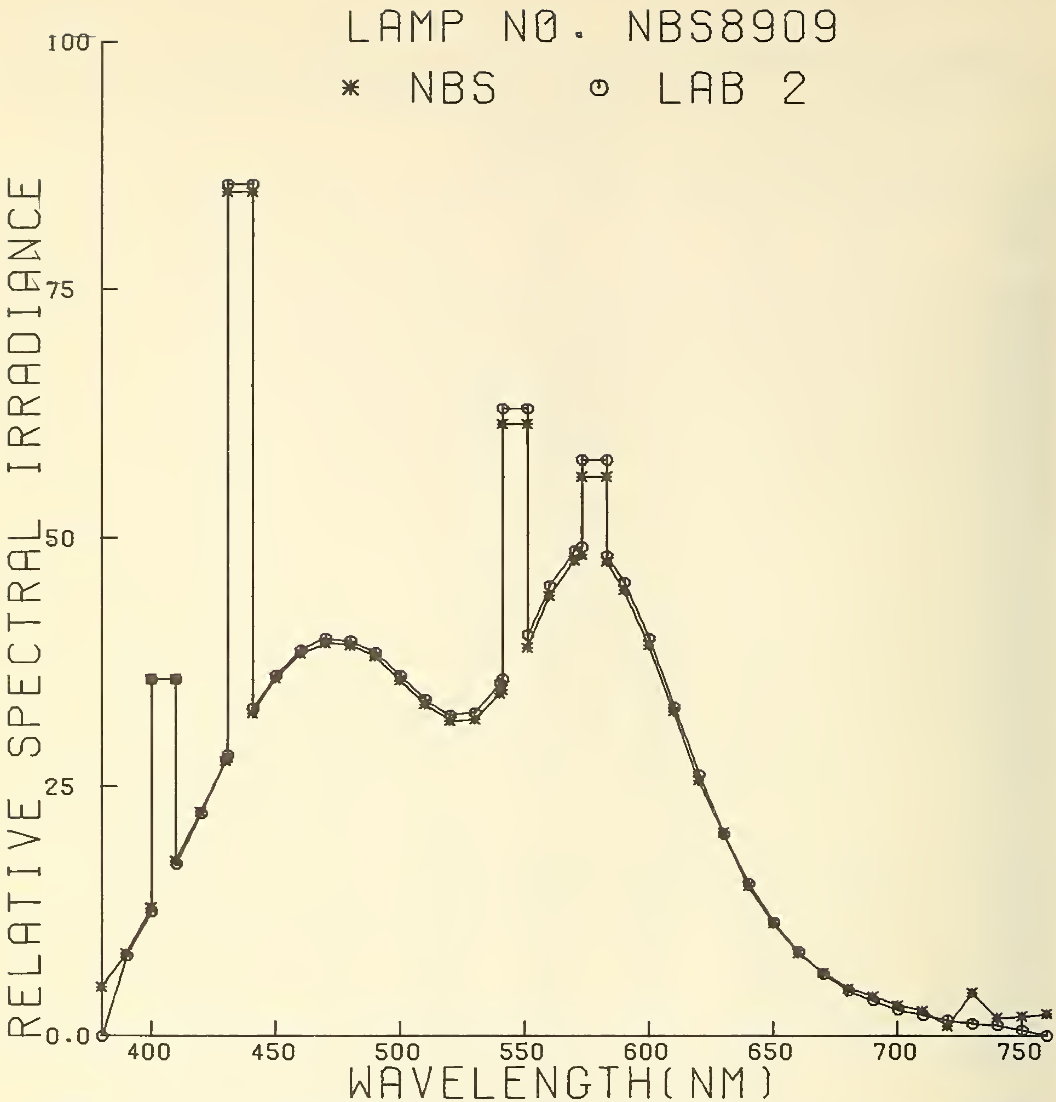


FIGURE 4.58 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION)
MEASUREMENTS NORMALIZED TO AREA

TABLE 4.67

RELATIVE SPECTRAL IRRADIANCE DISTRIBUTION(25CM SECTION)-NORMALIZED TO AREA
LAMP NUMBER NBS8911

	NBS			LABORATORY 4	
WAVELENGTH	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
380.0	5.0	5.0	5.3	5.1	4.9
390.0	8.3	8.3	8.4	8.6	8.9
400.0	12.5	9.4	14.0	12.1	13.0
410.0	17.1	16.0	17.3	16.9	17.7
420.0	22.0	21.8	22.3	22.3	22.2
430.0	27.6	27.1	27.7	27.4	27.8
440.0	32.2	31.4	31.0	31.9	32.3
450.0	36.1	35.1	34.9	35.0	37.0
460.0	38.5	37.5	37.4	38.1	38.4
470.0	39.6	38.5	39.2	39.4	41.1
480.0	39.4	38.3	38.8	39.3	38.6
490.0	38.2	37.1	37.5	37.2	37.4
500.0	35.9	34.7	35.6	35.8	35.9
510.0	33.5	32.5	33.0	33.7	33.6
520.0	31.8	30.8	31.8	32.3	32.0
530.0	31.9	31.1	31.5	32.1	32.0
540.0	34.4	31.9	35.2	34.8	34.7
550.0	38.5	34.4	40.0	39.5	39.9
560.0	44.2	43.4	45.1	44.6	45.0
570.0	47.9	46.7	48.6	48.2	48.4
580.0	48.5	47.0	53.6	53.0	50.7
590.0	44.8	43.5	44.7	45.4	45.1
600.0	39.5	38.1	39.0	39.8	39.3
610.0	32.4	31.6	32.2	32.8	32.5
620.0	25.7	25.1	26.0	25.9	25.8
630.0	20.5	19.6	20.1	20.1	20.0
640.0	15.0	14.6	15.3	15.4	15.1
650.0	11.1	11.1	11.4	11.6	11.5
660.0	8.3	8.1	8.5	8.6	8.5
670.0	6.4	6.5	6.4	6.6	6.4
680.0	4.6	4.8	4.9	4.9	4.9
690.0	3.7	4.2	4.0	4.1	4.1
700.0	2.8	3.3	2.9	2.9	3.0
710.0	2.4	2.7	2.4	2.4	2.4
720.0	1.9	2.3	1.9	1.9	1.9
730.0	4.0	4.9	1.5	1.6	1.5
740.0	1.5	2.4	1.4	1.3	1.3
750.0	1.8	2.4	1.1	1.0	1.2
760.0	1.5	2.9	.9	1.0	1.0

MERCURY LINES

405.0	21.3	20.8	20.4	20.3	19.8
436.0	54.6	52.9	52.6	51.6	49.5
546.0	24.8	9.7	26.7	26.2	26.2
578.0	8.2	8.3	7.3	7.6	7.5

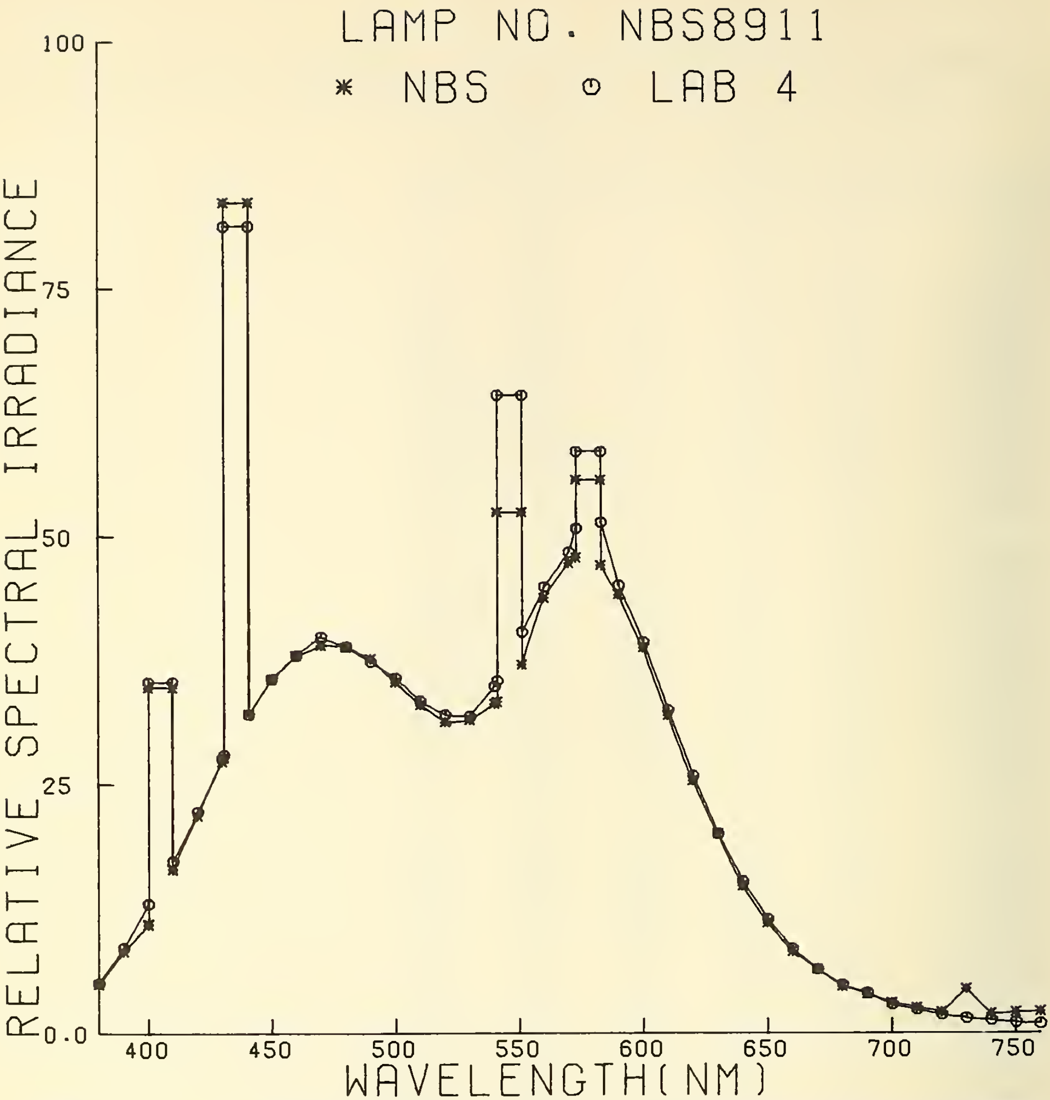


FIGURE 4.59 AVERAGE RELATIVE SPECTRAL IRRADIANCE (25 CM SECTION) MEASUREMENTS NORMALIZED TO AREA

4.4. Results of the check on systematic errors in conventional sphere photometry

In section 3.2 the experimental design for this part of the intercomparison was briefly discussed. Each experiment was to consist of five measurements performed in a prescribed manner. For example, the first step was to be the measurement of the total luminous flux of a cool white fluorescent lamp without other lamps in the sphere. The photocell reading in this case is proportional to the total luminous flux of the lamp, C, minus a fraction, A_c, of the light which is absorbed by the lamp. That is,

$$R_1 = K_1 C(1-A_c) \tag{4.1}$$

where K_1 is the proportionality factor for the spectral distribution of a cool white fluorescent lamp.

In the second step of the experiment the above measurement was repeated with an unlighted incandescent lamp present in the sphere. If the fraction of light absorbed by the incandescent lamp is A_I, the equation describing this step of the experiment is:

$$R_2 = K_1 C(1-A_c)(1-A_I) \tag{4.2}$$

Multiplication of the two factors enclosed by parenthesis yields four terms, one of which is the product of the two absorption fractions. Since the fraction of light absorbed by each bulb is much less than unity, their product may be neglected. Equation 4.2 becomes

$$R_2 = K_1 C(1-A_c-A_I) \tag{4.3}$$

If the change in the lamp absorption due to the different spectral distributions of the sources is assumed to be negligible, then the equation representing the photocell readout of a lighted incandescent and an unlighted fluorescent lamp is:

$$R_4 = K_2 I(1-A_c-A_I) \tag{4.4}$$

In this equation, I is the total luminous flux of the incandescent lamp and K_2 is the proportionality factor for an incandescent spectral distribution. In summary, the equations representing all five steps in this experiment are:

$$\begin{aligned}
R_1 &= K_1 C(1-A_c) \\
R_2 &= K_1 C(1-A_c-A_I) \\
R_3 &= K_1 C(1-A_c-A_I) + K_2 I(1-A_c-A_I)+W \\
R_4 &= K_2 I(1-A_c-A_I) \\
R_5 &= K_2 I(1-A_I)
\end{aligned}$$

In the third equation listed above, a term has been introduced to represent all the effects in the system that preclude closure. The two major effects included in W are the non-linearity of the system and the change of fluorescent lamp output caused by heat from the incandescent lamp nearby. These two effects cannot be separately determined from the data of this limited experiment. However, if such a separate determination is desired in future experiments, it is suggested that the experiment be expanded to include another lamp of the same spectral distribution as either of the two used in the present test. That is, a second fluorescent lamp in the sphere would test linearity without introducing a heating effect. Furthermore, if four lamps were tested (two of each type) in a series of single and double lamp measurements, then the assumption that lamp absorption is independent of spectral distribution would be unnecessary. In this case the fractional absorption of each source by the same bulb could be determined separately. For the present intercomparison it was decided to forgo completeness for the sake of simplicity.

Since the total luminous flux of both the fluorescent and incandescent lamps was assigned at NBS, the five equations listed above can be solved for the fractional absorption A_I and A_c, the sphere factors K_1 and K_2, and the closure term W. The absorption terms are:

$$A_I = \frac{R_4 (R_1 - R_2)}{R_2R_5 + R_1R_4 - R_2R_4} \qquad (4.5)$$

and

$$A_c = \frac{R_2 (R_5 - R_2)}{R_2R_5 + R_1R_4 - R_2R_4} \qquad (4.6)$$

The sphere factors are:

$$K_1 = R_1 /C(1-A_c) \qquad (4.7)$$

and $$K_2 = R_5 /I(1-A_I) \qquad (4.8)$$

And the closure term is:

$$W = R_3 - R_2 - R_4 \qquad (4.9)$$

By using the photocell readings supplied by the various laboratories, the values of each of these terms were calculated and are presented in tables 4.68 to 4.74. Table 4.75 is a summary of the results of these experiments. This table also lists the sphere size, paint, and color correction used by each laboratory. The "Percent Color Deviation" in the last line of the table is the difference between the two calculated sphere factors. That is,

$$\text{Percent Color Deviation} = 100(K_1 - K_2)/K_2 \qquad (4.10)$$

For perfectly color corrected spheres, this quantity would, of course, be zero.

It is readily seen from table 4.75 that the fraction of light absorbed by the fluorescent lamps can be closely correlated with the sphere diameter. These data and the data from the incandescent lamps are presented graphically in figure 4.60. The absolute value of the closure term can also be correlated to a small extent with the sphere diameter. This may mean that heating of the fluorescent lamp in smaller spheres is the slightly dominant effect. As discussed previously, an expanded experiment would be necessary actually to determine this.

The extent of color correction attempted by each laboratory and the calculated color deviation are related except in the case of Laboratories 1 and 5. Laboratory 1 is apparently correct in saying that any color corrections to their system are relatively small, however, an explanation for this apparent anomaly in the case of Laboratory 5 is not discernable from the available data. (See tables 3.1 to 3.3 and section 3.1)

The negative absorption observed by Laboratories 2 and 5 deserves some mention. In both cases it is quite close to the standard deviation of a single measurement and may not be meaningfully different from zero. It can be argued that inadequate baffling, leading to a direct reflection from the unlighted bulb to the detector, would appear as a negative absorption. There are, however, insufficient data to support this hypothesis.

TABLE 4.68

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 1 C = 2826.6 LUMENS   I = 2906.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
1	C	102.20	430			10.00	76.90	2800.0
2	C +(I)	102.20	430			10.02	77.10	2783.0
3	C + I	102.30	430	117.70	1.57	10.10	77.40	5664.0
4	(C)+ I			117.70	1.57	10.12	78.00	2856.0
5	I			117.70	1.57	10.13	78.40	2906.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
6	C	102.30	430			10.35	77.00	2807.0
7	C +(I)	102.40	430			10.36	77.20	2790.0
8	C + I	102.40	430	117.70	1.57	10.37	77.60	5666.0
9	(C)+ I			117.70	1.57	10.38	78.00	2853.0
10	I			117.70	1.57	10.39	78.40	2909.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
11	C	102.60	430			11.02	77.20	2811.0
12	C +(I)	102.60	430			11.03	77.20	2800.0
13	C + I	102.40	430	117.70	1.57	11.05	77.70	5667.0
14	(C)+ I			117.70	1.57	11.06	78.00	2848.0
15	I			117.70	1.57	11.07	78.60	2898.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.60	.59	.38	.53	.12	PERCENT
ABSORPTION C	1.71	1.91	1.72	1.78	.12	PERCENT
CLOSURE	.44	.41	.34	.40	.05	PERCENT
SPH FACTOR K1	1.0078	1.0124	1.0119	1.0107	.0025	
SPH FACTOR K2	1.0060	1.0070	1.0011	1.0047	.0032	

TABLE 4.69

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 2 C = 2794.8 LUMENS I = 2753.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
1	C	101.40	430			.00	77.40	2845.0
2	C +(I)	101.20	430			.00	77.20	2836.0
3	C + I	101.20	430	109.00	1.59	.00	77.30	5544.0
4	(C)+ I			109.00	1.59	.00	77.80	2725.0
5	I			109.00	1.59	.00	77.30	2708.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
6	C	100.80	430			.00	77.60	2828.0
7	C +(I)	101.00	430			.00	77.30	2819.0
8	C + I	100.60	430	109.00	1.59	.00	77.70	5544.0
9	(C)+ I			109.00	1.59	.00	77.80	2722.0
10	I			109.00	1.59	.00	78.20	2713.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
11	C	100.90	430			.00	77.40	2840.0
12	C +(I)	100.80	430			.00	77.40	2834.0
13	C + I	100.80	430	109.00	1.59	.00	78.00	5604.0
14	(C)+ I			109.00	1.59	.00	78.00	2731.0
15	I			109.00	1.59	.00	78.00	2734.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.32	.32	.21	.28	.06	PERCENT
ABSORPTION C	-.63	-.33	.11	-.28	.37	PERCENT
CLOSURE	-.31	.05	.70	.15	.51	PERCENT
SPH FACTOR K1	1.0116	1.0085	1.0173	1.0125	.0044	
SPH FACTOR K2	.9868	.9886	.9952	.9902	.0044	

TABLE 4.70

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 3 C = 2917.1 LUMENS I = 2701.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
1	C	102.80	430			13.10	76.90	2970.0
2	C +(I)	102.80	430			13.12	76.90	2970.0
3	C + I	102.80	430	108.60	1.60	13.15	77.90	5823.0
4	(C)+ I			108.60	1.60	13.17	78.00	2863.0
5	I			108.60	1.60	13.19	78.20	2865.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
6	C	101.80	430			13.35	76.50	2930.0
7	C +(I)	101.80	430			13.37	76.50	2920.0
8	C + I	101.80	430	108.60	1.60	13.40	77.50	5765.0
9	(C)+ I			108.60	1.60	13.42	77.50	2850.0
10	I			108.60	1.60	13.43	77.80	2855.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
11	C	101.80	430			14.25	76.40	2915.0
12	C +(I)	101.80	430			14.27	76.40	2916.0
13	C + I	101.80	430	108.60	1.60	14.29	76.90	5755.0
14	(C)+ I			108.60	1.60	14.33	77.20	2860.0
15	I			108.60	1.60	14.34	77.50	2865.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.00	.34	-.03	.10	.21	PERCENT
ABSORPTION C	.07	.17	.17	.14	.06	PERCENT
CLOSURE	-.17	-.09	-.36	-.21	.14	PERCENT
SPH FACTOR K1	1.0188	1.0062	1.0010	1.0087	.0092	
SPH FACTOR K2	1.0607	1.0606	1.0604	1.0606	.0002	

TABLE 4.71

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 4 C = 2783.2 LUMENS I = 2633.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
1	C	101.50	430			17.26	76.20	2937.0
2	C +(I)	101.50	430			17.32	76.20	2922.0
3	C + I	101.50	430	107.10	1.58	17.37	78.20	5622.0
4	(C)+ I			107.10	1.58	17.43	78.20	2732.0
5	I			107.10	1.58	17.48	82.00	2780.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
6	C	101.90	430			15.45	76.40	2973.0
7	C +(I)	101.90	430			15.47	76.40	2961.0
8	C + I	101.90	430	107.10	1.58	15.52	80.00	5711.0
9	(C)+ I			107.10	1.58	15.57	80.00	2768.0
10	I			107.10	1.58	16.00	80.00	2821.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
11	C	101.50	430			16.27	76.20	3001.0
12	C +(I)	101.50	430			16.28	76.20	2984.0
13	C + I	101.40	430	107.10	1.58	16.35	79.00	5747.0
14	(C)+ I			107.10	1.58	16.36	80.00	2774.0
15	I			107.10	1.58	16.37	80.00	2834.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.50	.40	.55	.48	.08	PERCENT
ABSORPTION C	1.72	1.87	2.11	1.90	.20	PERCENT
CLOSURE	-.57	-.31	-.19	-.36	.19	PERCENT
SPH FACTOR K1	1.0737	1.0886	1.1014	1.0879	.0139	
SPH FACTOR K2	1.0612	1.0757	1.0823	1.0731	.0108	

TABLE 4.72

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 5   C = 2750.5 LUMENS   I = 2680.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
1	C	101.00	430			4.44	24.70	3025.0
2	C +(I)	101.00	430			4.45	24.70	3029.0
3	C + I	101.00	430	107.90	1.58	4.47	25.20	5978.0
4	(C)+ I			107.90	1.58	4.48	25.50	2945.0
5	I			107.90	1.58	4.49	25.60	2974.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
6	C	100.50	430			4.21	24.80	3012.0
7	C +(I)	100.50	430			4.22	24.80	3014.0
8	C + I	101.00	430	107.90	1.58	4.25	24.80	6000.0
9	(C)+ I			107.90	1.58	4.26	25.00	2962.0
10	I			107.90	1.58	4.27	25.20	2990.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	CUR(SET)	INCANDESCENT LAMP VOLT(SET)	CUR	TIME	TEMP	PHOTOCELL READING
11	C	101.00	430			4.17	24.20	3028.0
12	C +(I)	101.00	430			4.18	24.20	3034.0
13	C + I	101.20	430	.00	.00	4.21	24.40	6004.0
14	(C)+ I			107.90	1.58	4.22	24.60	2955.0
15	I			107.90	1.58	4.23	24.80	2983.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	-.13	-.07	-.20	-.13	.07	PERCENT
ABSORPTION C	.98	.94	.94	.95	.02	PERCENT
CLOSURE	.07	.40	.25	.24	.17	PERCENT
SPH FACTOR K1	1.1106	1.1054	1.1113	1.1091	.0032	
SPH FACTOR K2	1.1083	1.1149	1.1109	1.1114	.0034	

TABLE 4.73

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 6 C = 2804.9 LUMENS I = 2646.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
1	C	234.00	430			9.05	14.80	1167.0
2	C +(I)	234.00	430			9.10	14.80	1158.0
3	C + I	234.00	430	107.50	1.59	9.15	16.00	2507.0
4	(C)+ I			107.50	1.59	9.20	16.30	1350.0
5	I			107.50	1.59	9.23	16.40	1358.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
6	C	235.00	430			11.10	15.80	1165.0
7	C +(I)	235.00	430			11.15	16.00	1162.0
8	C + I	235.00	430	107.50	1.59	11.20	17.00	2507.0
9	(C)+ I			107.50	1.59	11.22	17.50	1346.0
10	I			107.50	1.59	11.25	17.50	1354.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
11	C	234.00	430			12.05	17.30	1165.0
12	C +(I)	234.00	430			12.10	16.40	1158.0
13	C + I	234.00	430	107.50	1.59	12.15	17.60	2505.0
14	(C)+ I			107.50	1.59	12.17	18.00	1344.0
15	I			107.50	1.59	12.25	18.00	1352.0

	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.77	.26	.60	.54	.26	PERCENT
ABSORPTION C	.58	.59	.59	.59	.00	PERCENT
CLOSURE	-.04	-.04	.12	.01	.09	PERCENT
SPH FACTOR K1	.4185	.4178	.4178	.4180	.0004	
SPH FACTOR K2	.5172	.5130	.5140	.5148	.0022	

TABLE 4.74

SYSTEMATIC ERROR CHECK OF PHOTOMETRIC EQUIPMENT

LABORATORY 7 C = 2902.5 LUMENS I = 2769.0 LUMENS

RUN 1

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
1	C	102.30	430			10.16	24.90	2900.0
2	C +(I)	102.40	430			10.19	25.00	2886.0
3	C + I	103.10	430	109.10	.00	10.23	26.30	6000.0
4	(C)+ I			109.10	.00	10.25	27.40	3105.0
5	I			109.10	.00	10.27	27.60	3118.0

RUN 2

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
6	C	102.70	430			10.55	25.00	2910.0
7	C +(I)	102.70	430			10.57	25.10	2890.0
8	C + I	102.70	430	109.10	.00	11.01	26.50	5981.0
9	(C)+ I			109.10	.00	11.03	27.20	3124.0
10	I			109.10	.00	11.05	27.40	3143.0

RUN 3

OBS.	LAMP	FLUORESCENT LAMP VOLT	FLUORESCENT LAMP CUR(SET)	INCANDESCENT LAMP VOLT(SET)	INCANDESCENT LAMP CUR	TIME	TEMP	PHOTOCELL READING
11	C	103.00	430			11.32	25.00	2910.0
12	C +(I)	103.00	430			11.34	25.00	2891.0
13	C + I	103.00	430	109.10	.00	11.37	26.50	5974.0
14	(C)+ I			109.10	.00	11.39	27.20	3085.0
15	I			109.10	.00	11.42	27.40	3165.0

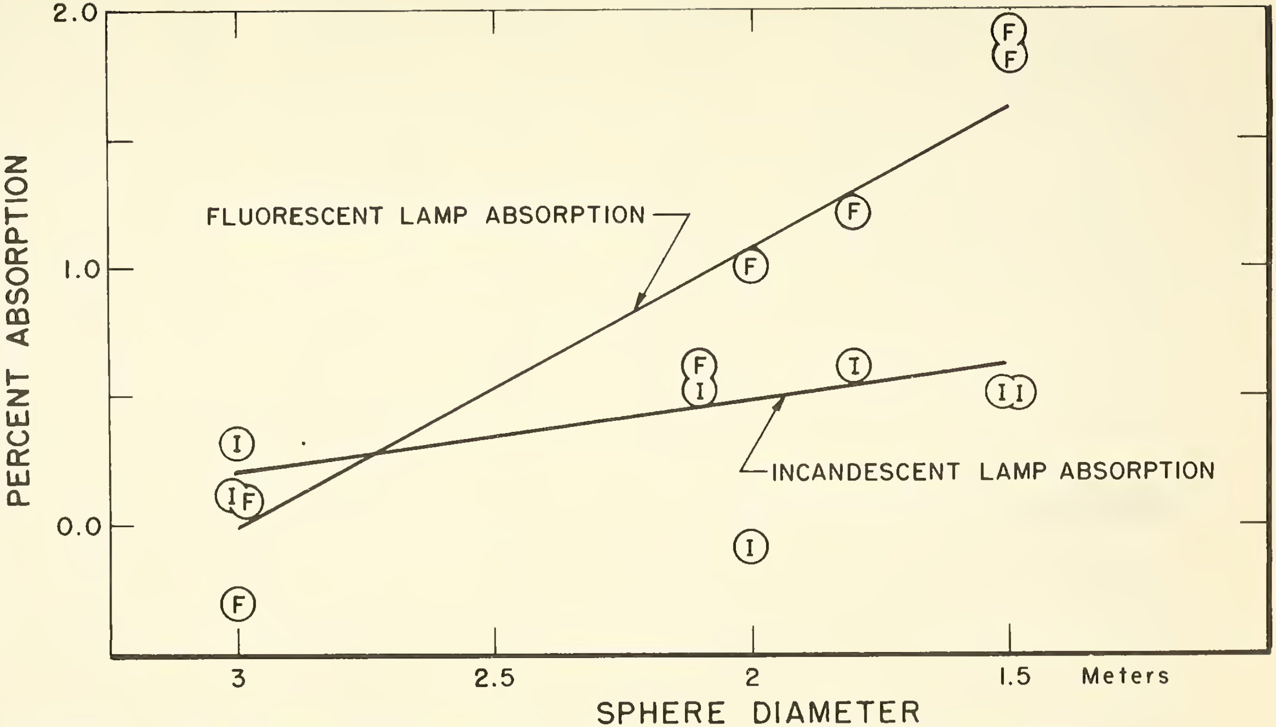
	RUN 1	RUN 2	RUN 3	MEAN	S.D.	
ABSORPTION I	.48	.68	.64	.60	.11	PERCENT
ABSORPTION C	.41	.60	2.51	1.18	1.16	PERCENT
CLOSURE	.15	-.55	-.03	-.14	.36	PERCENT
SPH FACTOR K1	1.0033	1.0086	1.0284	1.0135	.0132	
SPH FACTOR K2	1.1315	1.1429	1.1503	1.1416	.0095	

Table 4.75

Systematic error check of photometric equipment
summarization of results

Laboratory	1	2	3	4	5	6	7
Sphere Diameter	1.5 meter	3 meter	3 meter	1.5 meter	2 meter	2.1 meter	1.8 meter
Sphere Paint	G. E.*	Burch**	Burch	Burch	Burch	MgO	Burch
Color Correcting Filter	None***	Wratten 78C	None	Corning 5900	None	None	None
Percent Absorption (Incandescent)	0.5	0.3	0.1	0.5	-0.1	0.5	0.6
Percent Absorption (Fluorescent)	1.8	-0.3	0.1	1.9	1.0	0.6	1.2
Percent Closure	0.4	0.2	-0.2	-0.4	0.2	0.0	-0.1
Percent Color Deviation	0.6	2.3	-4.9	1.4	-0.2	-18.8	-11.2

*General Electric Sphere Paint
**Burch Sphere Paint
***See Section 3.1



EFFECT OF SPHERE DIAMETER ON THE SELF ABSORPTION OF FLUORESCENT AND INCANDESCENT LAMPS

FIGURE 4.60

(NOTE: The lines drawn here are estimates and not an attempt to fit the data)

5. DUSCUSSION AND CONCLUSIONS

5.1. The status of substitutional photometry

In the introduction it was stated that this intercomparison was conducted primarily to determine whether the use of a uniform set of cool white fluorescent lamps standardized at one laboratory would improve the agreement among the values of total luminous flux measured in laboratories throughout the lamp industry. The purpose of this intercomparison has not, however, been limited to just this. This was the first interlaboratory intercomparison to attempt an experimental design that would answer the more general question: What is the present capability of the lamp industry in the fields of photometry and spectroradiometry? The tests were also designed so that many specific questions could be answered about the performance of the equipment and the experimental techniques of the laboratories taking part in this intercomparison. Some of these specific conclusions have already been presented in section 4.

Considering the first question asked above: Did the use of the ETL CW Standards improve the agreement among the many laboratories that utilize conventional substitution photometry? If the results of the previous intercomparison* are used as an example of past performance, the answer is no. The range of agreement in the measurement of total luminous flux of cool white 40 watt fluorescent lamps by the laboratories participating in the 1964 Intercomparison** was 1.6%. That is, the individual measurements were all within ± 0.8% of the average. In the present intercomparison this range was 2.0%, if the results of Laboratory 6 are excluded. Laboratory 6 did not use the ETL CW Standards; and, although their measurements were precise, their results were far outside the range quoted above. This could be used as an argument for the use of one source for fluorescent lamp standards. The argument is further bolstered by the lack of agreement of the lamp industry's average measurement of total luminous flux with that of NBS** in the 1964 Intercomparison. In spite of the close agreement among the laboratories, their average was 2.6% above the NBS base. In the present intercomparison the agreement of the industry average with the NBS base is +0.2%, which is not significantly different from zero at the 95% confidence level.

One conclusion drawn from this part of the present intercomparison is that the use of a single source of fluorescent lamp standards would indeed form a uniform base among all the laboratories measuring luminous flux. However, the use of one source for standard lamps has not served to improve the range of agreement among these laboratories. This can only be accomplished by the improvement of photometric measuring techniques and equipment, and by developing sources that are more stable.

Each laboratory also measured, by conventional substitution photometry, a daylight fluorescent lamp against the ETL CW Standards in order to test agreement in heterochromatic photometry. The range of agreement among all, except Laboratory 6, was 3.6% and the difference of the industry average from the NBS base*** was -1.4%. In the 1964 Intercomparison the standards to be used in measuring daylight lamps were unspecified: a daylight lamp base was probably used. The range of agreement was 4.1% and the difference of the industry average from the NBS base was +0.1%. Thus it may be concluded that the present

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*The results of the 1964 Intercomparison were the subject of a National Bureau of Standards report to members of the Lamp Testing Engineers Conference (LTEC) and, as such, are not available for general circulation except by permission of LTEC.

**This includes the measurements made by the Electrical Testing Laboratories which were not included in the report since they were received at NBS after publication. The NBS measurements were also not included as part of the published form of the 1964 Intercomparison.

***A degree of confidence in the NBS measurements can be estimated by comparing the results of two different measurements on the same lamps. The results of the measurement of luminous flux of daylight and cool white fluorescent lamps by spectroradiometry and color corrected substitutional photometry, given in table 2.2, agree to within 0.2% for the daylight lamps and 0.1% for the cool white lamps.

status of heterochromatic photometry is at the same level as that of daylight lamp homochromatic photometry in 1964.

From the data gathered for this intercomparison it can be seen that the increased lack of agreement in the measurements of daylight fluorescent lamps is directly traceable to the extent of the color correction applied at each laboratory. Laboratory 4 applied a suitable color correction filter for both their sphere and sphere window. Laboratory 1 reported their color correction to be relatively small. (See sections 3.1 and 4.4.) The difference between the average of their measurements of the daylight fluorescent lamp and the NBS base was -0.1%, whereas the average of their measurements of the cool white fluorescent lamps differed from NBS by -0.4%. Laboratory 2 achieved partial color correction by using Wratten filters and eliminating the sphere window. Laboratory 8 did not apply color corrections to its sphere but did not use a sphere window; they had, in a sense, a partial color correction. Their average difference from NBS for daylight lamps was -1.3% and for cool white lamps, +0.1%. The remaining three laboratories, Laboratories 3, 5 and 7, used sphere windows and did not apply any color corrections. Their average difference from NBS for daylight lamps was -2.3% and for cool white lamps, ±0.5%.

The value of color correction in heterochromatic substitutional photometry has been clearly demonstrated by the results of this intercomparison.

5.2. The status of spectroradiometry and color parameter measurement.

Evaluation of the present status of spectroradiometry is based on the data supplied by four laboratories: Laboratories 1, 2, 4, and 5. Since their measurements were made with standards supplied by NBS and since they submitted data for all parts of the intercomparison, the relative merit of the two techniques for measuring total luminous flux (conventional substitution photometry and spectroradiometry) and the three techniques for measuring color parameters (spectroradiometry of the entire lamp in a sphere, spectroradiometry of a 25 cm section in a baffled enclosure, and the Barnes Colorimeter measurements) could be evaluated.

Conventional photometry and spectroradiometry were compared by measuring total luminous flux by using both techniques. Measurements of the total luminous flux of a 200 watt incandescent lamp against a set of 40 watt cool white standards by conventional substitution photometry are summarized in table 5.1. It would be well to note once again that only Laboratories 1 and 4 achieved suitable color correction of their equipment. Laboratory 2 attempted only a partial color correction, while Laboratory 5 did not color correct at all. The percent differences between the average of their measurements and the NBS assignments were: -1.4% and -1.3% for Laboratories 1 and 4 respectively; -2.7% for Laboratory 2; and +2.4% for Laboratory 5. These percent differences can be compared with the differences found from the average of their spectroradiometric measurements of luminous flux of two 40 watt cool white fluorescent lamps versus a 200 watt incandescent lamp (see Table 4.11). They are as follows: -0.5% for Laboratory 1; -7.0% for Laboratory 2; +15.6% for Laboratory 4; and -0.4% for Laboratory 5. The range of agreement among the reported spectroradiometric measurements averaged for each laboratory is 22.6% and their average difference from the NBS base is +1.9%. Using conventional photometry the same laboratories reported a range of agreement of 5.1% and an average difference from the NBS base of -0.8%.

It appears, therefore, that overall spectroradiometric capability has to be developed much further before the agreement between the spectroradiometric measurement of total luminous flux made at different laboratories will be comparable to the agreement presently attainable by substitutional photometry. The experimental difficulties that Laboratories 2 and 4 may have encountered have been described in Section 4.4. The causes of the present lack of agreement are probably to be found there. The results achieved at NBS, where a comparison (see table 2.2) of spectroradiometry and color corrected substitutional photometry showed differences of at most 0.2%, demonstrate that a significant improvement in spectroradiometric technique can be achieved. It should be noted that only since the introduction of automatic data acquisition systems has

Table 5.1

Luminous flux of a 200 watt incandescent lamp by conventional photometry using 40 watt cool white fluorescent lamps as standards

Laboratory	Lamp	NBS (lumens)	Lab (lumens)
1	8757	2906	2865.2
			2865.2
			2866.6
			2861.6
			2867.1
			2863.1
			Avg. 2864.7
2	8758	2753	2673.0
			2671.0
			2674.0
			2676.0
			2687.3
			2687.3
			Avg. 2678.1
4	8759	2633	2586.4
			2595.8
			2593.4
			2607.4
			2605.9
			2609.7
			Avg. 2599.7
5	8756	2680	2740.9
			2739.1
			2743.3
			2743.3
			2746.3
			2750.0
			Avg. 2743.8

spectroradiometry become a feasible routine measurement and that for most laboratories it is a very new technique. It is hoped that we may finally be in a position to fulfill the prediction made by Parry Moon (ref. 5) in the 1930's:

> "Evidently, we are getting rapidly to a place where our antiquated photometric notions must be discarded, and it seems advisable to analyze our concepts and see what can be done to replace them. In the present book, the entire development has been based not on the eighteenth century intuitive concept of 'light' but upon the firmly established concept of the spectroradiometric curve. It is true that the precision obtainable in radiometric measurements is still disappointingly low, so that actual photometry may be forced to stick to the old methods for a few years longer. But this does not appear to be an adequate reason why we should continue to force our minds into an eighteenth century mold as regards photometric concepts."

Turning now to the question of color measurement: What is the precision attainable in the measurement of the color parameters of a fluorescent lamp? This includes the agreement between different methods employed at the same laboratory and the agreement between different laboratories employing the same method. Table 5.2 is a comparison of the three techniques used to measure the x and y chromaticity coordinates. Since the color temperature of a lamp can be derived from the x and y chromaticity coordinates (ref. 6), this discussion will be limited to the measurement of these coordinates.

At NBS the x and y chromaticity coordinates were measured by using only the two spectroradiometric techniques. One technique samples the entire lamp in an integrating sphere and the other samples a 25 cm section of the lamp in a baffled enclosure. The first pair of columns in table 5.2 lists the differences observed between these two measurements on the same lamp (these are listed as differences in the fourth place). The second pair lists the same information for the x and y chromaticity coordinates measured at the four reporting laboratories. These two pairs of columns are an indication of the agreement between these two separate measurements made at the same laboratory. At NBS the internal range of agreement of the two methods of measurement was, therefore, -0.0021 to +0.0012, or 0.0033; and at the four reporting laboratories it was -0.0025 to +0.0071, or 0.0096.

The absolute value of the differences reported for Laboratory 1 are about twice those reported for the other laboratories. Four of these differences are much larger than the combined value of the standard deviations of each measurement. The reason for the internal disagreement in the case of Laboratory 1 is not clearly evident. Disagreement in the x and y chromaticity coordinates is not a diagnostic check on spectroradiometric performance: it merely indicates that a problem exists. It has already been pointed out that Laboratory 1 used two different monochromators for these measurements and that they reported their data in reduced form. They also failed to report data at several points in the spectrum, notably at the red and blue extremities. None of these factors can be cited as the primary cause of the internal disagreement. Their spectral distribution curves are in good agreement with those of NBS, as are their spectroradiometric values of total luminous flux. In the third pair of columns of table 5.2, it is evident that their sphere measurements of color parameters are also in good agreement with those of NBS. One may possibly conclude, therefore, that there is a systematic error in their measurements on a 25 cm section of a lamp that does not exist in their sphere measurements.

The last three pairs of columns of table 5.2 are an indication of the status of interlaboratory agreement in the measurement of color parameters. The third pair of columns compares the sphere measurements made on the same lamps at NBS and the four reporting laboratories. The range of agreement was from -0.0031 to +0.0072. The fourth pair is a comparison of the laboratory Barnes measurements and the NBS sphere measurement: range, -0.0060 to +0.0058. The last pair, which is a comparison of laboratory and NBS 25 cm section measurements, indicates a range of -0.0004 to +0.0069.

In the comparison of the sphere and 25 cm section measurements of Laboratory 5 in Table 5.2, there appears to be a large disagreement with the NBS measurements of the y chromaticity coordinate. From an examination of their spectral distribution curves it is clear that their match with the NBS points become poorer at

Table 5.2

Fourth place differences in the x and y chromaticity coordinates

Laboratory and Lamp Type		Difference Table* N(25)-N(SP)		L(25)-L(SP)		L(SP)-N(SP)		L(B)-N(SP)		L(25)-N(25)	
		x	y	x	y	x	y	x	y	x	y
1	CW	+12	-18	+46	+62	-14	-23	+45	+58	+44	+57
	CW	- 7	+ 2	+62	+71	-16	-31	+51	+55	+39	+38
	D	+11	-11	+25	+37	-17	-26	+47	+52	+19	+60
2	CW	- 3	-12	-24	-25	+30	+31	+49	+51	+ 3	+18
	CW	- 4	- 9	-13	-24	+17	-25	+51	+48	0	+10
	D	+ 1	-14	-15	-25	+19	+26	+15	+45	+ 5	+15
4	CW	+ 6	-12	+35	+15	-23	+22	+38	+43	+18	+49
	CW	- 6	+ 5	+ 1	+ 8	+ 1	+25	+48	+46	- 4	+28
	D	+ 1	-11	+23	+16	- 1	+24	+38	+51	+23	+51
5	CW	+ 1	- 7	- 6	-13	+ 1	+69	-60	+ 6	- 4	+63
	CW	+11	-21	-14	-24	+ 6	+72	-57	+ 6	+ 3	+69
	D	0	- 7	- 3	-10	+ 8	+65	+13	+13	+ 5	+62

*Symbol definitions:
N(25) - NBS spectroradiometric measurement on a 25 cm section of the lamp.
N(SP) - NBS spectroradiometric measurement in an integrating sphere.
L(25) - Laboratory spectroradiometric measurement on a 25 cm section of the lamp.
L(SP) - Laboratory spectroradiometric measurement in an integrating sphere.
L(B) - Laboratory measurement using a Barnes Colorimeter.

Note that all the differences in x and y have been mulitplied by 10,000.

the red end of the spectrum. As noted in section 4.4, this may be due to reduced photomultiplier sensitivity in this spectral region or to a systematic drift in the gain and/or sensitivity of their electronics.

The above discussion on agreement of color parameters is, of course, not at all rigorous. Since x and y are non-linear parameters, it is extremely difficult to obtain a statistical comparison of several measurements. However, from table 5.2 several conclusions are apparent:

1) In the most favorable case it is possible to obtain agreement to about ±0.002 between two different spectroradiometric measurements of the same chromaticity coordinate made at the same laboratory. The present capability within three of the laboratories under consideration is, however, only about ±0.003 in the best cases. (Note that the intralaboratory difference is as high as 0.007 for one of the laboratories.)

2) The level of agreement among measurements of chromaticity coordinates between three of the laboratories and NBS in performing the same spectroradiometric measurement on the same lamp is about ±0.003. (Note that the difference from NBS is as high as 0.007 for one of the laboratories.)

3) Agreement between a spectroradiometric measurement at one laboratory and a Barnes Colorimetric measurement at another is on the order of ±0.006.

4) The agreement between the four reporting laboratories and NBS in spectroradiometric measurement of chromaticity coordinates seems to be uncorrelated with the agreement in spectroradiometric measurement of total luminous flux.

It is expected that with improvements in spectroradiometric techniques throughout the lamp industry, agreement between laboratories in the measurement of color parameters will improve and spectroradiometry will become more important as a primary means of measuring these parameters.

5.3. Summary and conclusions

For the measurement of total luminous flux the most precise method presently in use is homochromatic substitutional photometry (range of agreement, 2%). The measurements are fast and relatively simple to perform; however, a standard of each type of lamp to be measured must be available in order to achieve maximum precision. Comparison of the luminous flux of two lamps with different spectral distributions, heterochromatic substitutional photometry, is considerably less precise unless the spectral response of the entire photometric system matches the CIE luminous efficiency function; that is, unless the system is fully color corrected. (Range of agreement: daylight versus coolwhite fluorescent, 3.6%; fluorescent versus incandescent, 5.1%.)

Although the range of agreement among the participating laboratories was found to be 22.6%, at NBS spectroradiometric and heterochromatic photometric measurements agreed within 0.2%. Therefore, with proper spectroradiometric techniques it should be possible to compare the total luminous flux of two lamps with very different spectral distributions to a precision close to that of homochromatic substitutional photometry. Furthermore, it would be unnecessary to correct for the spectral response of the system. Since it is difficult to produce and maintain reliably stable standard sources, the expense and effort necessary to set up and maintain a fully color corrected photometric system for all possible sources would be comparable to or might possibly exceed that of a single spectroradiometer. In addition to heterochromatic measurement of total luminous flux, the spectroradiometer data acquired in a single spectral flux distribution measurement permit the calculation of all the color parameters (chromaticity coordinates, color temperature, color rendering, flattery index, etc.), thereby replacing all other color measuring instruments.

We may look forward to a time when a well developed spectroradiometric laboratory would need only a few highly stable standards of flux and spectral distribution from which to derive accurate (though not necessarily stable or precise) secondary standards of each lamp in production. These secondary standards would then be used in homochromatic substitutional photometry for routine quality control testing and other intralaboratory needs.

5.4. Acknowledgement

The authors would like to express their sincere thanks to Dr. Frank Studer for his guidance in the development of NBS spectroradiometric photometry and his assistance in the early stages of this intercomparison.

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Appendix A

Procedures for interlaboratory intercomparison of fluorescent lamps

Part 1

The intercomparison of T12F40 cool-white and daylight lamps for luminous flux will be conducted by having each laboratory make a set of three runs. The runs are statistically designed and involve measurements on the cool-white, and one daylight fluorescent lamps and one incandescent lamp, all supplied by NBS. These lamps are designated as C_1, C_2, D and I respectively. The six T12F40 CW lumen standards supplied by ETL last Spring to the industry are to be used as reference standards for this intercomparison by the laboratories that have them; the other laboratories will use their customary reference standards. These are designated as S_1 through S_6 in the data sheets. A reference ballast is being supplied and should be used with the three fluorescent lamps being supplied by NBS. The ETL standards should be run on the Sylvania reference ballast, and should be operated according to the instructions sent out with them (see Appendix A of the minutes of the May 14, 1968 meeting of LTEC). The lamps being supplied by NBS should be run with the NBS supplied ballast in the same manner. The USASI circuitry (Ill. Eng. 62, 552-523, Sept. 1967) should be used and all fluorescent lamps should be operated by holding current at 430 mA. The incandescent lamp should be held at the specified voltage and should be in the sphere, but not lit during the fluorescent lamp runs. Similarly a fluorescent lamp should be in the sphere, but not lit, during the measurements on the incandescent lamp. Each run should be completed in the course of a day, and linearity corrections, if any, in the photometric equipment should be noted.

Part 2

The spectroradiometric intercomparison is designed to determine the uncertainty between measurements and between participating laboratories. The test will consist of three runs on each of the fluorescent lamps sent by NBS, and one run on each of the ETL standards. The incandescent lamp sent by the Bureau and one of the fluorescent lamps will be in the sphere at all times to eliminate the effect of absorption. The incandescent lamp will be measured at the beginning of each set of runs and after each fluorescent lamp is measured. The lamps should be operated in the same manner as they were for Part 1 (substitution method). Since one of the purposes of this test is to transfer lumen values from the incandescent lamp to the fluorescent lamp, it will be important to hold the temperature at the center of the sphere to $25^\circ C \pm .2^\circ C$ during the measurement of each fluorescent lamp. Uncorrected data points will be recorded at every 10 nm and at the mercury peaks. Any applicable correction curve will be recorded separately.

Part 3

This part of the intercomparison is the same as part 2 except that the flux of a fluorescent lamp from a 25-cm section of the fluorescent lamp rather than that from the entire lamp is measured. As in part 2 there will be three runs on each fluorescent lamp supplied and one run on each of the ETL standards, in each case by using the incandescent lamps supplied as a reference source. If the relative spectral distribution of the fluorescent lamps is to be made without reference to the incandescent lamp during the run, the 560 nm reading shall be recorded at the beginning and the end of each run. It is important that the reading does not change during the run. Although the temperature requirements are not strict, the fluorescent lamp should be free of drafts that will cause the output of the lamp to change during the run. Uncorrected data will be recorded at every 10 nm and at the mercury lines. Any appreciable correction curve will be recorded separately.

Part 4

In this part of the intercomparison the linearity of the system will be checked and the effects of absorption of the incandescent lamp and the fluorescent lamps will be measured. This part of the intercomparison will be used only in conjunction with part 1 (substitution method). The "I" notation stands for the incandescent lamp and the "C_1" notation for the first cool-white fluorescent lamp in the intercomparison group. The I or C_1 enclosed in parentheses means the lamp is in the sphere but is not lit. There should be approximately 15 minutes between the shutting off of I and the lighting of C_1. Since the incandescent lamp heats the sphere, time between readings C_1+(I) and C_1+I should be as short as possible; uncorrected data will be recorded together with the time it was taken. Any correction factor will also be recorded separately.

Part 5

The main purpose of this part of the intercomparison is to determine if any discrepancies exist between spectroradiometric and Barnes colorimeter determinations of chromaticity coordinates. The intercomparison lamps, C_1, C_2 and D, will be operated in accordance with the electrical procedures listed for part 1. Each participating laboratory will use the standards and test procedures it normally uses with the Barnes colorimeter. Each laboratory will report the CIE chromaticity coordinates for both the standards used and intercomparison fluorescent lamps. Any applicable correction factors will be recorded separately.

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Test 1 Run 1 Date

Lamp	Current (mA)	Voltage	Time	Temp.	photo cell reading		Correction Linearity	Other (if any)		
S_1	430									
C_1	430									
D	430									
S_2	430									
C_2	430									
I										
S_3	430									
S_4	430									
C_2	430									
C_1	430									
S_5	430									
D	430									
I										
S_6	430									

Test 1 Run 2 Date

Lamp	Current (mA)	Voltage	Time	Temp.	photo cell reading		Correction Linearity	Other (if any)		
S_6	430									
C_1	430									
D	430									
S_5	430									
C_2	430									
I										
S_4	430									
S_3	430									
C_2	430									
C_1	430									
S_2	430									
D	430									
I										
S_1	430									

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Test 1 Run 3 Date

Lamp	Current (mA)	Voltage	Time	Temp.	photo cell reading		Correction Linearity	Other (if any)		
S_3	430									
C_1	430									
C_2	430									
S_2	430									
D	430									
I										
S_1	430									
S_6	430									
I										
C_1	430									
S_5	430									
D	430									
C_2	430									
S_4	430									

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Test 2 Run 1 Date

901-102

Wave length	I	C_1	I	S_1	I	D	I	C_2	I	S_2	I
3800											
3900											
4000											
4100											
4200											
4300											
4400											
4500											
4600											
4700											
4800											
4900											
5000											
5100											
5200											
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6600											
6700											
6800											
6900											
7000											
7100											
7200											
7300											
7400											
7500											
7600											
4050											
4358											
5461											
5780											
	Temperature Before										
	After										
	Voltage Before										
	After										

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Test 2 Run 2 Date

901-102

Wave length	I	S_3	I	D	I	C_2	I	S_4	I	C_1	
3800											
3900											
4000											
4100											
4200											
4300											
4400											
4500											
4600											
4700											
4800											
4900											
5000											
5100											
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7000											
7100											
7200											
7300											
7400											
7500											
7600											
4050											
4358											
5461											
5780											
	Temperature Before										
	After										
	Voltage Before										
	After										

NBS 506—Analysis paper

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Test 2 Run 3 Date

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Wave length	I	D	I	S_6	I	C_1	I	S_5	I	C_2	I
3800											
3900											
4000											
4100											
4200											
4300											
4400											
4500											
4600											
4700											
4800											
4900											
5000											
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7000											
7100											
7200											
7300											
7400											
7500											
7600											
4050											
4358											
5461											
5780											
	Temperature Before										
	After										
	Voltage Before										
	After										

Test 4

Run	Lamp	Fluorescent Lamp Voltage	Current (set)		Incandescent Lamp Voltage (set)	Current		Time	Tempera-ture	Photo-cell reading		Correction Linearity	Other (if any)
1	C_1		430										
	$C_1+(I)$		430										
	C_1+I		430										
	$(C_1)+I$												
	I												
2	C_1		430										
	$C_1+(I)$		430										
	C_1+I		430										
	$(C_1)+I$												
	I												
3	C_1		430										
	$C_1+(I)$		430										
	C_1+I		430										
	$(C_1)+I$												
	I												

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Test 5 Measure and report below x,y,z values for C_1, C_2 and D on a Barnes colorimeter

901-10

Appendix B

Questionnaire on equipment and procedures used for the NBS intercomparison of October, 1968

Please fill in the following questionnaire for all portions of the intercomparison in which your laboratory participated.

General

A. Laboratory ___National Bureau of Standards*___

B. For further information contact ___R. D. Saunders___

Telephone ___(301) 921-2113___

C. Our laboratory participated in:

__X__ 40-W, cool-white, direct substitution intercomparison.

__X__ Spectroradiometric determination of the lumen outputs of 40-W fluorescent lamps.

__X__ Spectroradiometric determination of chromaticity coordinates on 10" sections of 40-W fluorescent lamps.

_____ Check of photometric equipment.

_____ Barnes colorimeter determinations of chromaticity coordinates on 40-W fluorescent lamps.

Test 1: Cool-White, Direct Substitution Intercomparison

A. Sphere

1. Size __2m__ diameter

2. Coating (please append spectral reflectance curve if available)

   Type $BaSO_4$ - see figure B-1 following this section.

   Last renewed April, 1966.

3. Color correcting (blue) filter (please append spectral transmittance curve if available)

   _____ not used

   __X__ used

   Type Corning 5900

   Thickness 1.55 mm

4. Sphere window (please append spectral transmittance curve if available)

   Material White plexiglass - see figure B-2 following this section.

   Thickness 0.5 cm

5. Geometry: please append a sketch of the sphere used showing lamp location, receiver location, baffle location and size, etc. - see figure B-3.

---

*Certain commercial instruments or materials are identified in this appendix in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

B. Photocell

1. Manufacturer Weston

2. Model 856 V

3. Color corrected X yes ____ no

(please append spectral response curve if available)

4. Measuring circuit (please append circuit diagram) - see figure B-4 following this section.

5. Linearity corrections

X Not applied

____ Applied

Method of determining linearity correction (specify) ____

C. Lamp Operation-Fluorescent (please append complete circuit diagram) - see figure 2.1 in text.

1. Power source

0.015 % distortion

____ AC line (regulated to ____%)

X Power supply (Manufacturer Elgar

Model 6000)

____ Other (specify) ____

2. Reference ballast for ETL C-W standards

Type variable reactance reference ballast

Manufacturer Sylvania

3. Power factor of reference ballast 7.5%

How determined (specify) by using a low power factor wattmeter, a true RMS voltmeter, and an ammeter.

4. Lamp voltage X measured ____ set

How measured by using a high impedance voltmeter (Fluke Model 931)

Voltmeter input impedance 10 meg ohms

5. Current ____ measured X set

How measured by using a Weston Model 904 AC ammeter

6. Stabilization time 20 minutes in sphere zero minutes prestabilization. The lamp (was/was not) turned off after prestabilization.

D. Lamp operation-incandescent (please append complete circuit diagram)

1. Power source

____ AC Power

_____ volts

_____ amperes

_____ Hertz

_____ % Distortion

_____ AC line (regulated to _____%)

_____ AC power supply (manufacturer ______________________________

model _____________________________________)

_____ Other (specify)____

____

__X__ DC power

_____ Batteries

__X__ DC power supply (manufacturer N.J.E. (2 units in series)

model SY 60-12)

2. Voltage

_____ measured

__X__ set

How determined by using a differential voltmeter (Keithley model 660)

3. Current

__X__ measured

_____ set

How determined by measuring the drop across a 1 ohm shunt with the above mentioned differential voltmeter

4. Warm-up time __5__ minutes

(If not in place in the sphere during warmup please give details_____________________________)

5. The incandescent lamp (was/was not) in the sphere when the fluorescent lamps were measured.

E. Ambient temperature

1. _____ not measured

2. __X__ measured

Method of measurement Digitec model 251 thermometer

Location of measurement 3 locations: 18 inches above center of lamp and 1 inch from each end

F. Other

1. Test was conducted by _____ technician __X__ professional

2. Treated as a routine test? _____ yes __X__ no

3. If no, please detail the special precautions used This was an experiment of special design. In addition, the equipment was checked out before these tests.

G. Comments

Test 2: Spectroradiometric Determination of the Lumen Output of 40-W Fluorescent Lamps

A. Sphere

1. __X__ The information supplied for Test 1, Section A is applicable. (If so, skip 2, 3, 4, 5, & 6)

2. Size _____ diameter

3. Coating (please append spectral reflectance curve if available)

   Type ______________

   Last renewed ______

4. Color correcting (blue) filter (please append spectral transmittance curve if available)

   _____ not used

   _____ used

   Type ________________

   Thickness __________

5. Sphere window (please append spectral transmittance curve if available)

   Material _________________

   Thickness ________________

6. Geometry: Please append a sketch of the sphere used showing lamp location, receiver location, baffle location and size, etc.

B. Lamp operation-Fluorescent (please append complete circuit diagram)

1. __X__ The information supplied for Test 1, Section C, is applicable. (If so, skip 2, 3, 4, 5, 6, & 7)

2. Power source

   _____ % Distortion

   _____ AC line (regulated to _____ %)

   _____ Power supply (Manufacturer ______________________________

   Model ______________________________________)

   _____ Other (specify) ____

   ____

3. Reference ballast for ETL C-W standards

   Type ________________________________

   Manufacturer ________________________

4. Power factor of reference ballast _____ %

   How determined (specify) ____

   ____

5. Lamp voltage _____ measured _____ set

   How measured ____

Voltmeter input impedance ____________ohms

6. Current _____measured _____set

How measured____

7. Stabilization time _____minutes in sphere _____minutes prestabilization. The lamp (was/was not) turned off after prestabilization.

C. Lamp operation-Incandescent (please append complete circuit diagram)

1. __X__The information supplied for Test 1, Section D, is applicable. (If so, skip 2, 3, 4, 5 & 6)

2. Power source

_____AC power

_____volts

_____amperes

_____Hertz

_____% Distortion

_____AC line (regulated to _____%)

_____AC power supply (manufacturer____________________

model___________________________)

_____Other (specify)____

____

_____DC power

_____Batteries

_____DC power supply (manufacturer____________________

model___________________________)

3. Voltage

_____measured

_____set

How determined____

4. Current

_____measured

_____set

How determined____

5. Warm-up time _____minutes

(If not in place in the sphere during warmup please give details ____________________

____)

6. The incandescent lamp (was/was not) in the sphere when the fluorescent lamps were measured.

D. Ambient temperature

1. __X__ The information supplied for Test 1, Section E is applicable (if so, skip to the next section)

2. _____ Not measured

3. _____ Measured

Method of measurement ____________________

Location of measurement ____________________

E. Spectroradiometer (Please append a block diagram of the instrument showing light path, major components, entrance and auxiliary optics, detector location, etc.) - see figure 2.2 of text.

1. Monochromator

   a. Bauschand Lomb Manufacturer 505 model

   ________ Prism __X__ grating

   Combination (specify) ____________________

   b. Effective spectral bandpass (Please append slit width correction curve if available)

   4050Å 5.84 nm

   4358Å 5.53 nm

   5461Å 5.48 nm

   5780Å 5.93 nm

   How determined (specify) from an analog plot of instrument reading versus dial setting and subsequent graphical area measurement.

2. Wavelength Calibration

   Last calibrated before each series of measurements

   Method (Specify spectral lines used) Hg and Cd emission lines

3. Detector (please append spectral response curve if available)

   EMI Manufacturer 9558QB Model

   PM Type (Photomultiplier, thermopile, etc.) S-20 response type

4. Readout electronics (please append block circuit diagram) - see figure 2.2 of text.

   Integrating time approximately 0.1 sec

   Light chopped? __X__ No _____ Yes (_____ Hertz)

   Other special features ____________________

5. System checks

   a. Linearity __X__ checked _____ not checked

   Method by using sector discs and neutral density filters

   b. Scattered light __X__ checked _____ not checked

   Method by using narrow band interference filters

   c. Other (specify) ____________________

6. Data reduction method normally used in your laboratory. - see section 2.2 of text

a. Calibration

Reference source used ____________________

Procedure ____________________

____

b. Line spectra (please describe method of evaluation) ____________________

____

c. Other reduction procedures (specify) ____________________

____

F. Other

1. Test was conducted by ________ technician

___X___ professional

2. Treated as a routine test? ____ Yes __X__ No

3. If No, please detail the special precautions used This was an experiment of special design. In addition, the equipment was checked out before these tests.

G. Comments

Test 3: Spectroradiometric Determination of Chromaticity Coordinates on 10" Section of 40-W Fluorescent Lamps

A. Geometry (Please append a sketch of the setup used) - see figure 2.3 in text.

__X__ The 10" section specified by NBS was used.

____ A 10" section other than specified by NBS was used (specify) ____________________

Method of isolating a 10" section for investigation (Please describe baffling, baffling material, baffling coating, etc.) ____________________

____

B. Lamp Operation-Fluorescent (Please append complete circuit diagram)

1. __X__ The information supplied for

(Test 1, Section C or Test 2, Section B) is applicable

(If so, state which and skip 2, 3, 4, 5, 6 & 7)

2. Power source

____ % Distortion

____ AC line (regulated to ____ %)

____ Power supply (Manufacturer ____________________

Model ____________________)

____ Other (specify) ____________________

____

3. Reference ballast for ETL C-W standards

Type____________________

Manufacturer_____________

4. Power factor of Reference ballast _____%

How determined____

5. Voltage _____measured _____set

How measured____

Voltmeter input impedance ___________ohms

6. Current _____measured _____set

How measured____

7. Stabilization time _____minutes in place _____minutes prestabilization. The lamp (was/was not) turned off after prestabilization.

C. Lamp operation-Incandescent (please append complete circuit diagram)

1. __X__The information supplied for (Test 1, Section D or Test 2, Section D) is applicable. (If so, state which and skip 2, 3, 4, & 5).

2. Power source

_____AC power

_____volts

_____amperes

_____hertz

_____% distortion

_____AC line (regulated to _____%)

_____AC power supply (manufacturer ____________________

model ____________________)

_____Other (specify)____

____

_____DC power

_____Batteries

_____DC power supply (manufacturer____________________

model____________________)

3. Lamp voltage

_____measured

_____set

How determined____

4. Current

_____measured

_____set

How determined____

5. Warm-up time _____minutes

(If not in place please give details____________________________________)

D. Ambient temperature

1. _____The information supplied for (Test 1, Section E or Test 2, Section D) is applicable (if so, state which and skip to the next Section)

2. __X__Not measured.

3. _____Measured.

Method of measurement____

Location of measurement____

E. Spectroradiometer

1. __X__The spectroradiometer described for Test 2, Section E, was used <u>without</u> modification.

2. _____The spectroradiometer described for Test 2, Section E, was modified as follows____________

____

3. _____Our laboratory did not participate in the spectroradiometric determination of the lumen output of 40-W fluorescent lamps. (Please fill in Test 2, Section E, above to describe the instrument used for the present test.)

F. Other

1. Test was conducted by _____technician __X__professional

2. Treated as a routine test? _____Yes __X__No

3. If no, please detail the special precautions used <u>This was an experiment of special design.</u>
<u>In addition, the equipment was checked out before these tests.</u>

G. Comments

<u>Test 4: Check of Photometric Equipment</u> (Test not performed at NBS)

A. Sphere

1. _____The information supplied for (Test 1, Section A or Test 2, Section A) is applicable. (If so, state which and skip 2, 3, 4, 5 & 6)

2. Size _____diameter

3. Coating (please append spectral reflectance curve if available)

Type ____________________

Last renewed_______________

4. Color correcting (blue) filter (please append spectral transmitting curve if available)

_____not used

_____used

Type______________________

Thickness_________________

5. Sphere window (please append spectral transmittance curve if available)

Material______________________

Thickness_____________________

6. Geometry: Please append a sketch of the sphere used showing lamp location, receiver location, baffle location and size, etc.

B. Photocell

1. _____The information supplied for Test 1, Section B, is applicable. (If so, skip 2, 3, 4, & 5)

2. Manufacturer____________________ Model__________________________

3. Color corrected _____Yes _____No

(please append spectral response curve if available)

4. Measuring circuit (please append circuit diagram)

5. Linearity corrections

_____Not applied

_____Applied

Method of determining linearity correction (specify)________________________________

____

C. Lamp Operation-Fluorescent (Please append complete circuit diagram)

1. _____The information supplied for (Test 1, Section C, Test 2, Section B or Test 3, Section B) is applicable. (If so, state which and skip 2, 3, 4, 5, 6 & 7)

2. Power source

_____% distortion

_____AC line (regulated to _____%)

_____Power supply (Manufacturer__________________

Model________________________)

_____Other (specify)____

____

3. Ballast for Fluorescent Lamp

Type______________________

Manufacturer__________________

4. Power factor of ballast _____%

How determined____

5. Lamp voltage _____measured _____set

How measured____

Voltmeter input impedance _________ohms.

6. Current _____measured _____set

How measured____

7. Stabilization time _____minutes in sphere _____minutes prestabilization. The lamp (was/was not) turned off after prestabilization.

D. Lamp Operation-Incandescent (please append complete circuit diagram)

1. _____The information supplied for (Test 1, Section D, Test 2, Section C or Test 3, Section C) is applicable. (If so, state which and skip 2, 3, 4 & 5)

2. Power source

_____AC power

_____volts

_____amperes

_____hertz

_____% distortion

_____AC line (regulated to _____%)

_____AC power supply (manufacturer____________________

model___________________________)

_____Other (specify)____

____

_____DC Power

_____Batteries

_____DC power supply (manufacturer ____________________

model_____________________________)

3. Voltage

_____measured

_____set

How determined____

4. Current

_____measured

_____set

How determined____

5. Warm-up time _____minutes

(If not in place in the sphere please give details__________________________________)

E. Ambient temperature

1. _____The information supplied for (Test 1, Section E, Test 2, Section D or Test 3, Section D) is applicable. (If so, state which and skip 2 & 3)

2. _____Not measured

3. _____Measured

Method of measurement______________________________

Location of measurement______________________________

F. Other

1. Test was conducted by technician_______ professional________

2. Treated as a routine test? Yes_____ No_____

3. If No, please detail the special precuations used______________________________

____

G. Comments

<u>Test 5: Barnes Colorimeter Determinations of Chromaticity Coordinates on 40-W Fluorescent Lamps</u> (Test not performed at NBS)

A. Lamp Geometry: Please give details of the geometric setup used including a sketch:______________

____

B. Lamp Operation: Please give details of the lamp operation including warmup time, voltage and current measurements, ballasts, power factor, etc.:______________________________

____

C. Standards: Please describe the standards used to calibrate the colorimeter as to lamp type, where and when calibrated, etc.:______________________________

____

D. Calibration Procedure: Please describe in detail the calibration procedure used, including the data reduction for a test lamp:______________________________

____

E. Photocells: Please describe the photocells in the colorimeter as to type, number, aperture , filters, hermetic sealing, etc.:______________________________

____

F. Readout Equipment: Please describe the equipment used to read the photocell outputs:______________

____

G. Other

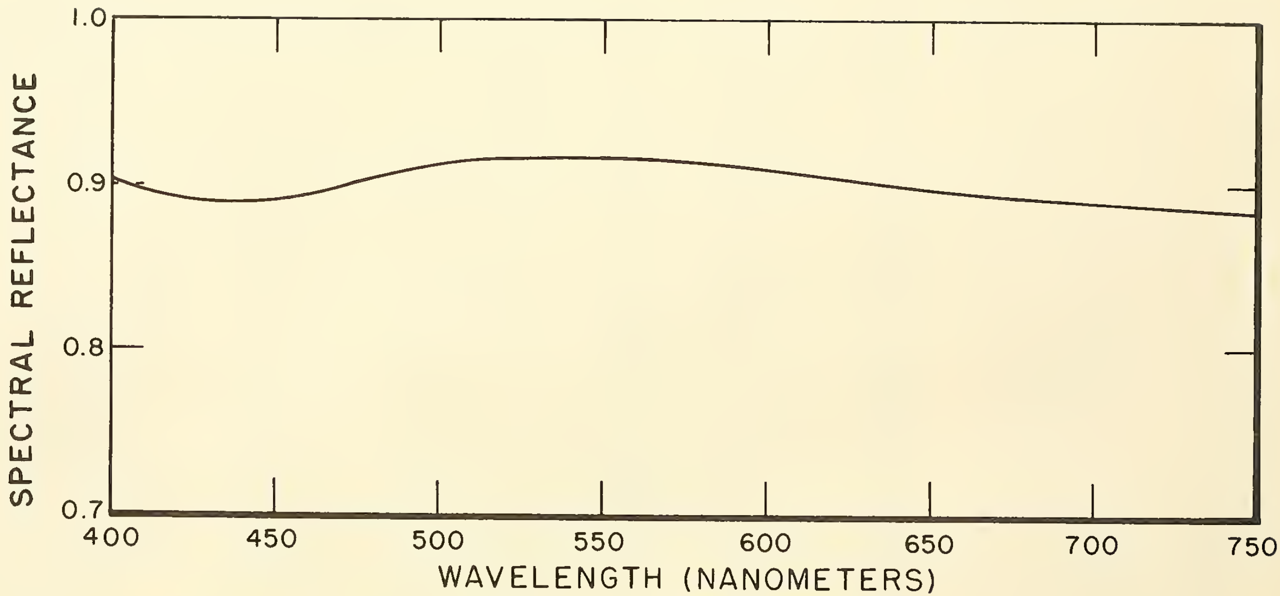
1. Test was conducted by _____technician _____professional

2. Treated as a routine test? _____Yes _____No

3. If no, please detail the special precautions used______________________________

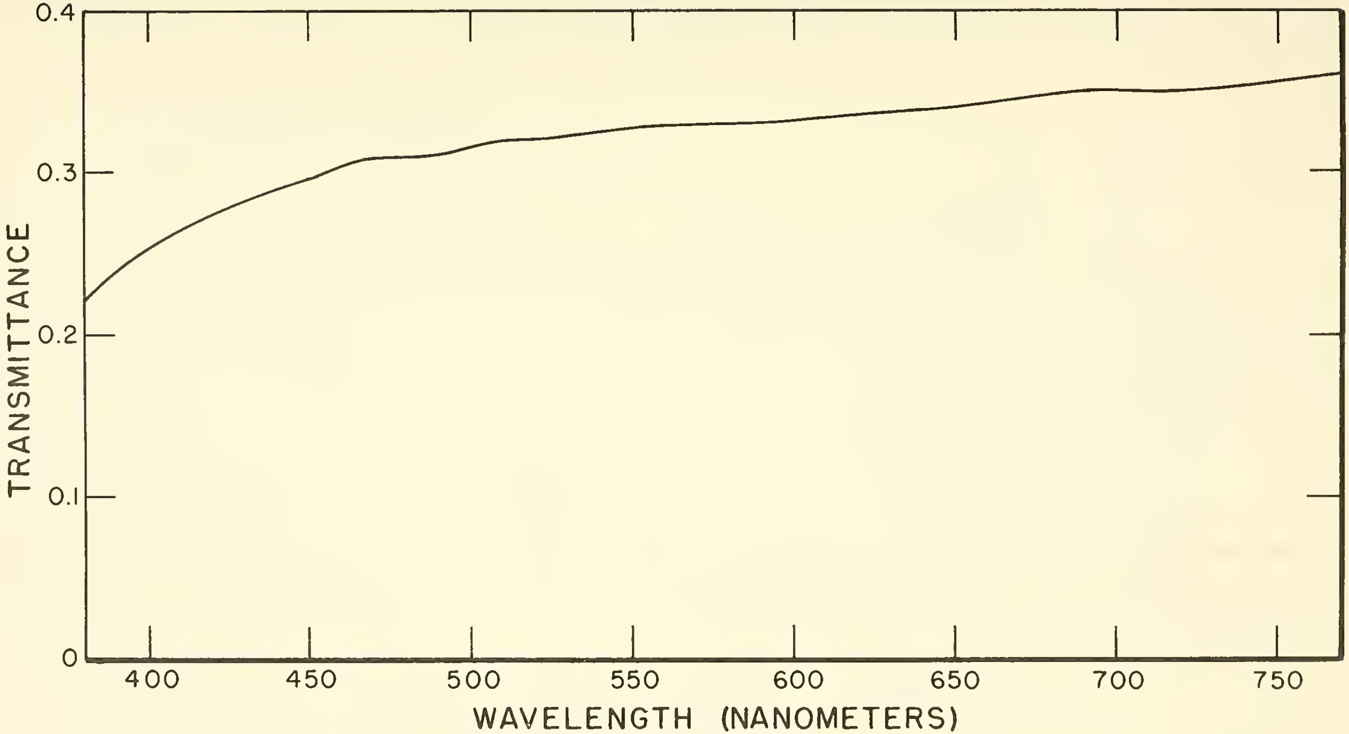
____

H. Comments



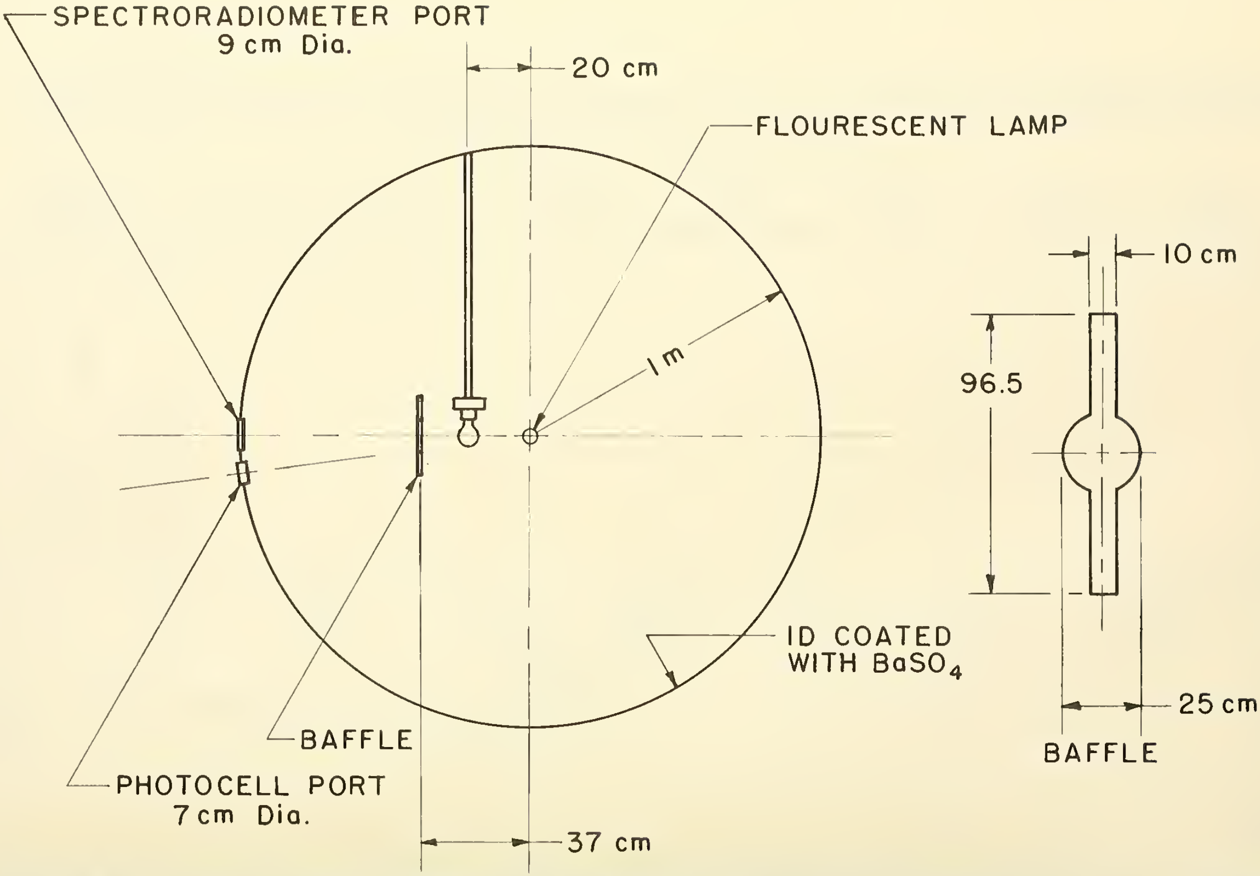
SPECTRAL REFLECTANCE, ρ, OF SPRAYED BARIUM SULFATE

FIGURE B-1



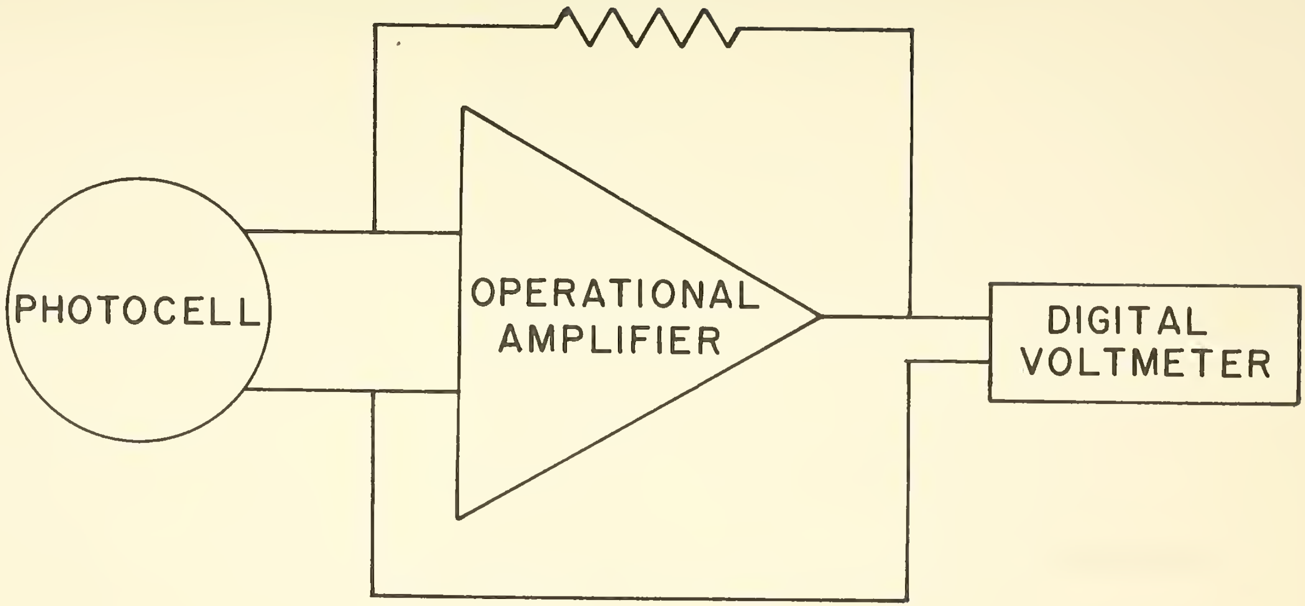
TRANSMITTANCE OF WHITE PLEXIGLASS INTEGRATING SPHERE WINDOW

FIGURE B-2



BAFFLE AND LAMP ARRANGEMENT IN THE NBS INTEGRATING SPHERE

FIGURE B-3



PHOTOCELL READ OUT

FIGURE B-4

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