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TOMS FM-2 Calibration Report

Volume 1

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SEE ATTACHED.

PURPOSE

This report presents the results of the radiance and irradiance calibrations preformed on the TOMS FM-2 instrument at Perkin Elmer Applied Science Operation. The data was obtained during the validation tests performed over the April 28, 1991 to May 5, 1991 time period. This report and the irradiance response verification report, design note 30053-21000-46, complete the data reduction/reporting requirements specified in "Radiance and Irradiance Calibration Procedure", #83-0050.

SUMMARY

The radiance and irradiance sensitivities of the TOMS are tabulated in table 1. The results obtained with FEL standard F-281 are actual while those computed for lamps F-239 and F-207 are for reference purposes as those standards were out of calibration at the time of use. The irradiance results were computed for the serial number 5 carousel surfaces, the flight unit, and the serial number 4 carousel surfaces, the flight backup unit. The data and results are presented tabularly and graphically. The computed instrument sensitivities based on the radiance results are higher than those resulting from the irradiance data (see figure's 9 a,b,&c). No quantitative explanation for this difference has been determined. The radiance data was obtained with the instrument in the NADIR detent while the irradiance data was obtained with the scan mirror rotated 90 degrees from NADIR to view the diffuser. The sensitivity plots show the pronounce effects of the instruments measured spectral bandwidth used in the computations. The radiance data, figures 5 a,b & c, are quite smooth. Sources of error in the calibrations include the normalized radiance, source lamp irradiance , diffuser BRDF, and geometry factors. These are discussed in the errors of calibration section included in this report.

DATA REDUCTION

Data reduction for the TOMS FM-2 Radiance and Irradiance calibration was performed according to "Radiance and Irradiance Calibration Procedure" document 83-0050 section 10. The following material elaborates on some details of the particular numerical steps involved in the data reduction procedure.

I. Radiance Calibration.

a. BRDF of BaSO4 diffuser.

The BRDF of a BaSO4 diffuser was measured according to the diffuser calibration procedure # 82-0062 using the data sheets provided in 83-0050. The measurements had been done for all wavelengths of interest at two points on the diffuser surface (point #3 and point #6 as described in the test report). For additional confidence 4

more areas were sampled at the long (380 nm) and short (312.5 nm) wavelengths (see data sheets). Each measurement was repeated 3 times. In addition a full signal and dark current was measured before and after each wavelength measurement. The results were corrected for geometry factor and pulse pileup factors as described in DFM 30053-21000-44. These corrections were done at the time of final data reduction using new values listed in DFM 30053-21000-44 :

$$y_corr = y_msr*exp(t*y_corr)) \quad (1)$$

where y_msr is an observed value, t is a dead time, and y_corr is the corrected value. According to the eq. (1) a corrected value can be obtained by solving nonlinear equation. To resolve (1) it was restated as

$$\log(z) = t*y_msr*z \quad (2)$$

where z is a ratio between corrected and observed values : z=y_corr/y_msr. After correction is done BRDF can be computed as

$$BRDF = g*(mean(y_corrFilter)-dc)/(mean(y_corr100\%)-dc) \quad (3)$$

where g is a geometry factor. According to DFM 30053-21000-44 t=0.95e-9 and g=78.7424.

The final value for BRDF is taken as an average between the BRDF at the points number 3 and number 6. Fig. 1 gives BRDF(3), and BRDF(6) as a function of wavelength.

λ(Å)	3125	3175	3312	3398	3600	3800
BRDF3	0.2972	0.3038	0.3095	0.3127	0.3170	0.3195
BRDF6	0.2905	0.2944	0.2998	0.3080	0.3098	0.3133
$BRDF_{avr}$	0.2938	0.2991	0.3047	0.3103	0.3134	0.3164

b. The bandpass data (BW) were measured according to the test procedure #552960 and taken directly from the test data sheet. Fig. 2 gives measured bandwidth as a function of wavelength.

λ(Å)	3125	3175	3312	3398	3600	3800
BW(nm)	0.9400	1.0400	1.0000	1.0200	1.0300	1.0600

c. For each lamp used in the reflectance measurements (F-207, F-239, and F-281) lamp's spectral irradiance (H) was measured as described in report # 435/G-45254-86-900-502. To obtain irradiance at the desired wavelength a third order polynomial approximation to the FEL data was used. Fig. 3a shows irradiation curves obtained by such approximation. Fig. 3b gives relative approximation errors for the wavelengths of interest. The approximation errors were computed

only for the lamps F-239 and F-281 since lamp F-207 lacks some of the data. The following are the original FEL data measured for each lamp (micro watt/cm^2/nm)

λ(Å)\	F-207	F-239	F-281
2500	0.017	0.023	0.019
2600	0.030	0.039	0.033
2700	0.050	0.065	0.055
2800	0.079	0.100	0.086
2900	0.119	0.150	0.130
3000	0.174	0.216	0.188
3100	0.245	0.301	0.263
3200	0.335	0.410	0.360
3300	0.448	0.545	0.481
3400	0.586	0.708	0.628
3500	0.753	0.903	0.804
3700	NaN	1.400	1.250
4000	2.049	2.390	2.170

The 3d order polynomial approximation produced the following FEL data for the wavelengths of interest (micro watt/cm^2/nm).

λ(Å)\	F-207	F-239	F-281
3125	0.27	0.33	0.29
3175	0.31	0.38	0.34
3312	0.46	0.57	0.50
3398	0.58	0.71	0.63
3600	0.94	1.13	1.01
3800	1.42	1.68	1.52

d. Average normalized counts for each wavelength $I(\lambda)$ and for each lamp were obtained from the files RCL***. At each wavelength $I(\lambda)$ was measured at 4 independent sessions. Each session had 20 independent measurements. For each session the average and standard deviation were computed. For reflectance calibration an average among session averages was used. Fig.4 shows $I(\lambda)$ for all three lamps as a function of wavelength. To demonstrate that the measured data were consistent from session to session Fig. 5a-5c show measured radiance at different session for each lamp.

d. The resulted Spectral Radiance Sensitivity $Rs(\lambda)$ was computed as described in calibration procedure 83-0050

$$Rs(\lambda) = I(\lambda)/(BRDF(\lambda)\cdot\cos(F)\cdot H(\lambda)\cdot\Delta\lambda\cdot(A\cdot\Omega)) \qquad (4)$$

The following numerical values were used :

$A = 0.26^2\ cm^2$
$\Omega = (3x3\ dg^2)$
$F = 40\ dg$

Note: The value for the parameter F used, 40 dg, differs from that listed in the Radiance and Irradiance Calibration procedure. The angle of incidence for the radiance and the irradiance calibrations was 40 degrees. The angle listed in the procedure, 50 dg view angle, is the incorrect angle to use in the computation. This angle has subsequently been verified (see appendix VIII).

Fig. 9 gives Spectral Radiance Sensitivity Rs as a function of wavelength λ for all three lamps. The same data are listed in the Table 1.

II. Irradiance Sensitivity Calibration

a. To compute Spectral Irradiance sensitivity the BRDF value of diffuser surface at 0 dg pitch and 90 dg yaw need to be computed. This was done using cubic spline fit into reflectance data obtained in DFM 30053-21000-44 (S/N=5). Fig. 6a shows resulted fit for lambda=312.5 nm. Fig. 6b shows how Working Surface BRDF varies with λ. Reference and Stow surfaces have similar curves. The following table presents the resulted BRDF at yaw=90 dg for each surface of the carousel # 5

BRDF for Carousel # 5 at yaw = 90 dg

λ(Å)	3125	3175	3312	3398	3600	3800
Work	0.3065	0.3116	0.3187	0.3210	0.3259	0.3284
Ref	0.3110	0.3154	0.3220	0.3251	0.3283	0.3338
Stow	0.3139	0.3160	0.3234	0.3258	0.3296	0.3361

Subsequent to the launch of the instrument with the flight diffuser installed, serial number 5, some additional measurements were made on the carousel 4 diffuser to quantify the possible error using the spline fit procedure. The data and MathCAD analysis listings are included as appendix VII of this report.

b. Irradiance counts were taken from the files ICR***, ICW***, and ICS*** for the Reference, Working, and Stow surfaces correspondingly. Each value was obtained only once. Fig. 7a shows measured irradiance as a function of wavelength for all three surfaces of the Carousel # 4 when the lamp F-207 was used. Correspondingly, Fig. 7b gives measured irradiance with the lamp F-239, and Fig. 7c with the lamp F-281. To demonstrate how irradiance curves depend on lamp characteristic Fig. 7d gives spectral irradiance for the Working surface for all three lamps. Figs. 8a-8d show corresponding curves for the carousel # 5.

c. The Spectral Irradiance Sensitivity was computed according to the procedure 83-0050 as

$$Ri(\lambda) = I(\lambda)/(BRDF(\lambda)\cdot\cos(F)\cdot H(\lambda)\cdot\Delta\lambda\cdot(A\cdot\Omega)) \quad (5)$$

with the same parameter values as listed above. Here $I(\lambda)$ is computed according to (II b) and $BRDF(\lambda)$ is computed according to (II a). Fig. 10a-10c present the resulted curves for the carrousels #4 with each lamp. The Radiance Sensitivity curve is plotted on the same scale. Relative difference between Radiance and Irradiance sensitivity for carousel # 4 is plotted in the Fig. 11. This plot is done only for the lamp F-281 as the only lamp with current calibration date. Figs 12a-12c and Fig.13 show corresponding data for the carousel #5 which is installed at the FM-2.

All computations were done using MATLAB ver. 3.5h. Program and input data listings are attached.

RESULTS

The results of the data reduction are presented graphically in figures 1 through 13. Included for each graph are tabulations of the plotted material. The computed radiance and irradiance sensitivities are tabulated below for each lamp and surface. Data are in 1.0e+14 count/watt. Rs stands for Radiance Sensitivity, Iw - Irradiance Sensitivity for Working surface, Ir - for Reference surface, Is - for Stow surface. All surfaces are for the Carousel serial number 5.

The values listed in table 1 are in units of counts/watt. These may be converted to Watts/(cm^3.sr) per count by taking the reciprocal of the listed value and dividing by the A and Ω terms (values listed on page 5 of this report) making the appropriate conversion form degrees^2 to sr. This value must then be divided by the bandwidth (in cm) at the appropriate wavelength.

Measured Radiance for the BaSo4 Diffuser (counts)

Lamp F-207

λ(Å)	3125	3175	3312	3398	3600	3800
Sess#1	1998	2461	4059	5511	9736	14439
Sess#2	1996	2460	4057	5505	9728	14419
Sess#3	2011	2475	4080	5544	9792	14509
Sess#4	1994	2463	4067	5522	9770	14505
Aver	2000	2465	4066	5521	9757	14468

Lamp F-239

λ(Å)	3125	3175	3312	3398	3600	3800
Sess#1	2830	3469	5625	7573	13161	19194
Sess#2	2812	3448	5598	7529	13080	19072
Sess#3	2808	3439	5581	7508	13045	19030
Sess#4	2833	3487	5658	7615	13242	19318
Aver	2821	3461	5615	7556	13132	19154

Lamp F-281

λ(Å)	3125	3175	3312	3398	3600	3800
Sess#1	2456	3023	4930	6675	11673	17141
Sess#2	2452	3013	4917	6655	11639	17095
Sess#3	2449	3010	4918	6654	11630	17093
Sess#4	2445	3015	4924	6660	11669	17148
Aver	2450	3015	4922	6661	11653	17119

Radiance Sensitivity (*1.e+14 count/watt)

Lamp\λ(Å)	3125	3175	3312	3398	3600	3800
F-207	1.9126	1.7879	2.0229	2.1057	2.2600	2.1349
F-239	2.1888	2.0409	2.2884	2.3733	2.5390	2.3900
F-281	2.1744	2.0299	2.2768	2.3656	2.5241	2.3729

Measured Irradiance for Carousel #4

Irradiance in normalized counts with Lamp F-207

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1691	2089	3471	4728	8443	12639
Ref	1605	1986	3299	4495	8022	12002
Stow	1675	2075	3451	4706	8396	12587

Irradiance in normalized counts with Lamp F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2390	2945	4808	6504	11396	16754
Ref	2266	2793	4561	6184	10823	15885
Stow	2331	2875	4695	6353	11160	16422

Irradiance in normalized counts with Lamp F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2071	2556	4203	5709	10083	14929
Ref	1966	2425	3998	5419	9573	14161
Stow	2053	2535	4177	5677	10028	14880

Measured Irradiance for Carousel #5

Irradiance in normalized counts with Lamp F-207

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1845	2278	3795	5158	9216	13755
Ref	1822	2257	3756	5112	9134	13658
Stow	1857	2296	3820	5200	9307	13896

Irradiance in normalized counts with Lamp F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2640	3252	5309	7170	12576	18482
Ref	2612	3220	5264	7099	12462	18347
Stow	2660	3274	5359	7229	12712	18689

Irradiance in normalized counts with Lamp F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2262	2791	4592	6235	11010	16299
Ref	2233	2760	4545	6172	10912	16174
Stow	2279	2811	4632	6279	11119	16470

Irradiance Sensitivity for Carousel #4

*1.e+14 count/watt

Lamp F-207

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.5506	1.4549	1.6506	1.7433	1.8804	1.7968
Ref	1.4498	1.3660	1.5533	1.6361	1.7738	1.6788
Stow	1.4998	1.4245	1.6172	1.7100	1.8491	1.7485

Lamp F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.7776	1.6671	1.8725	1.9750	2.1185	2.0142
Ref	1.6610	1.5621	1.7588	1.8539	1.9976	1.8789
Stow	1.6929	1.6049	1.8021	1.9010	2.0515	1.9292

Lamp F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.7614	1.6519	1.8582	1.9600	2.1001	1.9938
Ref	1.6483	1.5484	1.7499	1.8369	1.9796	1.8606
Stow	1.7055	1.6153	1.8198	1.9207	2.0654	1.9418

Difference Between Radiance an Irradiance in %

Carousel # 4, Lamp F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	18.99	18.61	18.38	17.14	16.79	15.97
Ref	24.19	23.72	23.14	22.34	21.57	21.59
Stow	21.56	20.42	20.07	18.80	18.17	18.16

Irradiance Sensitivity for Carousel #5

*1.e+14 count/watt

Lamp F-207

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.6916	1.5862	1.8044	1.9017	2.0528	1.9555
Ref	1.6459	1.5526	1.7684	1.8609	2.0198	1.9103
Stow	1.6627	1.5768	1.7905	1.8892	2.0496	1.9304

Lamp F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.9638	1.8411	2.0679	2.1770	2.3380	2.2219
Ref	1.9143	1.8007	2.0299	2.1282	2.3001	2.1701
Stow	1.9323	1.8275	2.0574	2.1630	2.3368	2.1955

Lamp F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.9240	1.8036	2.0303	2.1407	2.2933	2.1767
Ref	1.8720	1.7620	1.9893	2.0919	2.2565	2.1251
Stow	1.8929	1.7915	2.0183	2.1243	2.2899	2.1492

Difference Between Radiance an Irradiance in %

Carousel # 5, Lamp F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	11.51	11.14	10.82	9.51	9.15	8.27
Ref	13.91	13.20	12.63	11.57	10.60	10.44
Stow	12.95	11.74	11.35	10.20	9.28	9.43

Errors of Calibration.

The error bars at each frequency for the computed values are estimated as the following.

We assume that all the measurements have independent unbiased errors. Therefore, according to the eq. (4) and (5) a square of relative error for the computed sensitivity is equal to a sum of the squares of relative errors for the members of the right hand side part of the equations (4) and (5).

I. Radiance Sensitivity.

The following is relative error computations for all members of the eq.(4).

a. Normalized radiance.

Radiance is computed as an average of the measurements at 4 sessions. Each session had 20 major frames 70 measurements each. Therefore, for each session an accuracy of radiance estimation is $\sigma/\sqrt{20 \cdot 70}$ which is about 0.05% . However, radiance measured at 4 sessions differ by about 1% which is much more than a value expected only due to the random measurement errors. This discrepancy reflects longer term variation that are due to lamp instability, temperature difference, bearing errors, etc. The longer term lamp variance is taken into account explicitly in the paragraph I-c. To be on a conservative side we attribute the full observed differences between measured radiance at four sessions to the causes other than the lamps. Therefore, radiance error was assume to be the largest between random measurement errors at one session and 1/2 of the max differences between 4 sessions.

b. BRDF for BaSO4.

BRDF for BaSO4 was measured at two points on the BaSO4 plate. As a measure of error we take one half of the difference between the measured BRDF at these points. The resulted value is 1.22%

c. Lamp FEL.

The relative errors of calibrations for the lamps F-239 and F-281 are provided in the corresponding Reports of Calibration (attached). Two types of errors : NIST Uncertainty and Transfer Uncertainty are provided for a range of wavelengths from 250 to 2500 nm. To determine relative errors for the wavelength of interest we used linear interpolation in the relevant regions. Namely, the relative errors for the wavelengths 312.5 nm, 317.5 nm, 331.2 nm, and 339.8 nm were approximated as

$$e(\lambda) = e_o(250) + (e_o(350) - e_o(250)) \cdot (\lambda - 250)/(350 - 250) \quad (6)$$

and for the wavelengths 360.0 nm and 380.0 nm

$$e(\lambda) = e_o(350) + (e_o(654.6)-e_o(350))\cdot(\lambda-350)/(654.6-350) \quad (7)$$

where $e_o()$ denotes error values provided in the report. Therefore, the total FEL relative error was computed as

$$(\delta_{FEL}(\lambda))^2 = e^2_{NIST}(\lambda) + e^2_{TRNSF}(\lambda) \quad (8)$$

To account for the errors in polynomial approximation (see Fig. 3b) an rms error among the frequencies of interest was used for all the wavelengths. According to Fig. 3b errors for F-239 and F-281 are very closed. Accordingly, the rms error value for the lamp F-281 (=0.51%) as the most recently calibrated was used for all the lamps.

The total uncertainty (in %) for the lamps are :

λ(Å)	3125	3175	3312	3398	3600	3800
err (%)	1.93	1.89	1.77	1.69	1.59	1.56

d. Bandwidth.

There are no available data to estimate accuracy of the bandwidth measurements. Therefore, $\Delta\lambda$ is regarded as absolute data.

e. Area and Solid Angle

These data are regarded as error free.

The total error consists only of the errors in normalized counts, BRDF measurements, and lamp's FEL determination error.

The following table presents uncertainty in Radiance Sensitivity estimation.

Error of Radiance Sensitivity Estimation (in %)

Lamp\λ(Å)	3125	3175	3312	3398	3600	3800
F-207	2.3260	2.2713	2.1690	2.1190	2.0333	2.0088
F-239	2.3342	2.3539	2.2560	2.2067	2.1413	2.1225
F-281	2.2992	2.2620	2.1550	2.0945	2.0146	1.9913

II. Irradiance Sensitivity.

Analogous to the Radiance Sensitivity Irradiance Sensitivity error bars are computed by taking into account only Irradiance measurement errors and Carousel # 5 reflectance (BRDF) uncertainty.

a. Irradiance for each surface was measured only at one session (20 frames 70 points each). Therefore, there are no data to estimate long term irradiance variation. It was assumed, that long term irradiance variation in % is the same as long term radiance variation estimated above in paragraph I.a. Again, the maximum between one session measurement error ($\sigma/\sqrt{20 \cdot 70}$) and a long term variation was used for error bar computations.

b. Relative error in Diffuser Carousel # 5 was reported to be better than 0.3% at all wavelengths (Conclusion of DFM 30053-21000-44). Accordingly, a value of 0.3% was used for total error estimate.

Fig. 15 gives relative errors in Radiance Sensitivity determination for all the lamps.

Fig. 16a-16c give relative errors for the Irradiance Sensitivity determination for all the surfaces of Carousel # 5 and all the lamps.

To compare errors in Radiance and Irradiance Sensitivity determination Fig. 17 plots them on the same scale for the lamp F-281.

The following table provides numerical values used for the listed above plots. Note, that estimation errors are the same for each surface. This is because lamp uncertainty dominates other error terms.

Error of Irradiance Sensitivity Estimation (in %)

Carousel # 5

LAMP F-207 (reference)

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2.0011	1.9373	1.8162	1.7562	1.6518	1.6215
Ref	2.0011	1.9373	1.8162	1.7562	1.6518	1.6215
Stow	2.0011	1.9373	1.8162	1.7562	1.6518	1.6215

LAMP F-239

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	2.0106	2.0334	1.9193	1.8610	1.7830	1.7604
Ref	2.0106	2.0334	1.9193	1.8610	1.7830	1.7604
Stow	2.0106	2.0334	1.9193	1.8610	1.7830	1.7604

LAMP F-281

Surf\λ(Å)	3125	3175	3312	3398	3600	3800
Work	1.9698	1.9264	1.7994	1.7266	1.6287	1.5998
Ref	1.9698	1.9264	1.7994	1.7266	1.6287	1.5998
Stow	1.9698	1.9264	1.7994	1.7266	1.6287	1.5998

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Fig. 7b Irradiance for all surfaces of carousel #4 with F-239 lamp.

Fig. 7c Irradiance for all surfaces of carousel #4 with F-281 lamp.

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Fig. 8b Irradiance for all surfaces of carousel #5 with F-239 lamp.

Fig. 8c Irradiance for all surfaces of carousel #5 with F-281 lamp.

Fig. 8d Irradiance for working surface of carousel #5 for all lamps.

Fig. 9 Radiance Sensitivity for all lamps.

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Fig. 10b Radiance and Irradiance Sensitivity for all surfaces of Carousel # 4 with lamp F-239

Fig. 10c Radiance and Irradiance Sensitivity for all surfaces of Carousel # 4 with lamp F-281

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VII. Spline Fit Analysis

VIII. $BaSO_4$ Diffuser Angle Verification

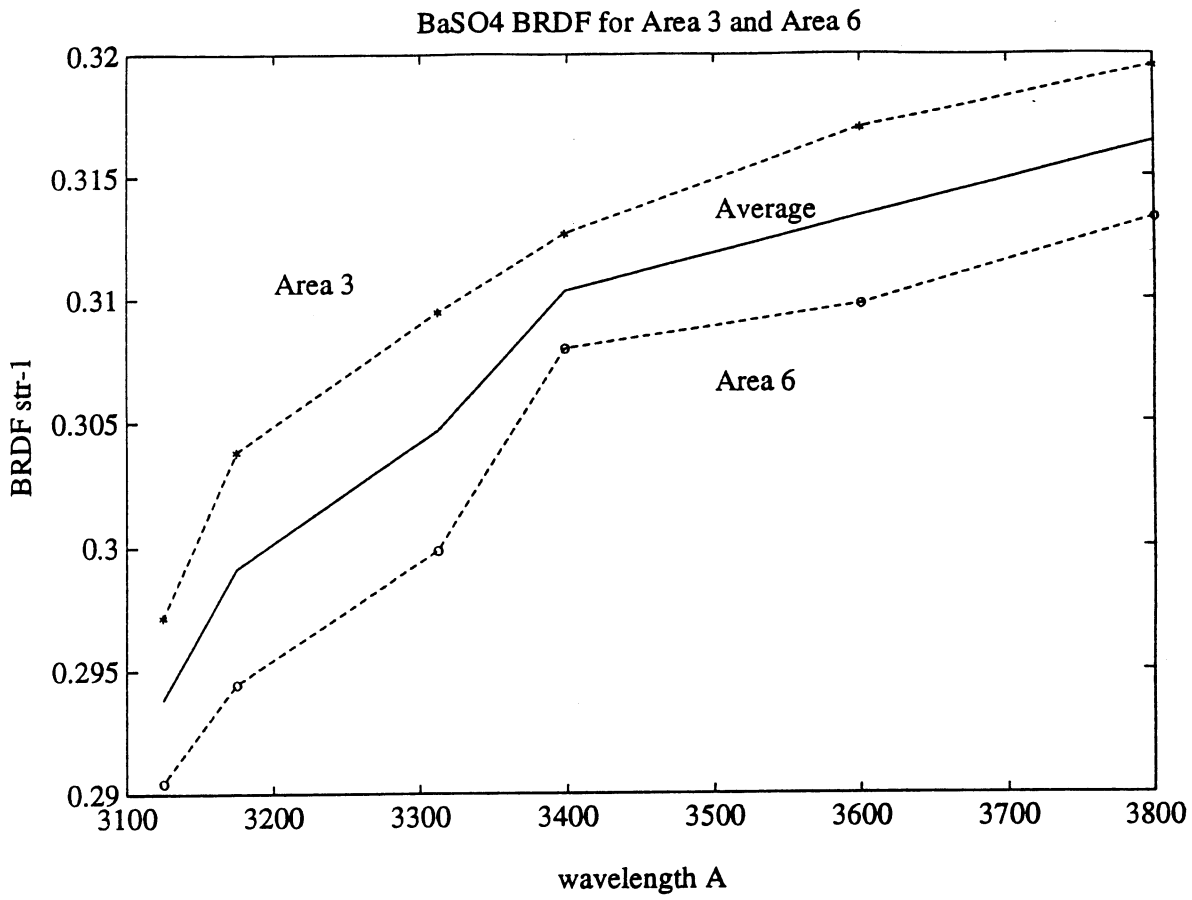

BaSO4 BRDF for Area 3 and Area 6
0.32
0.315
0.31
0.305
0.3
0.295
0.29
BRDF str-1
3100
3200
3300
3400
3500
3600
3700
3800
wavelength A
Area 3
Average
Area 6

Fig. 1

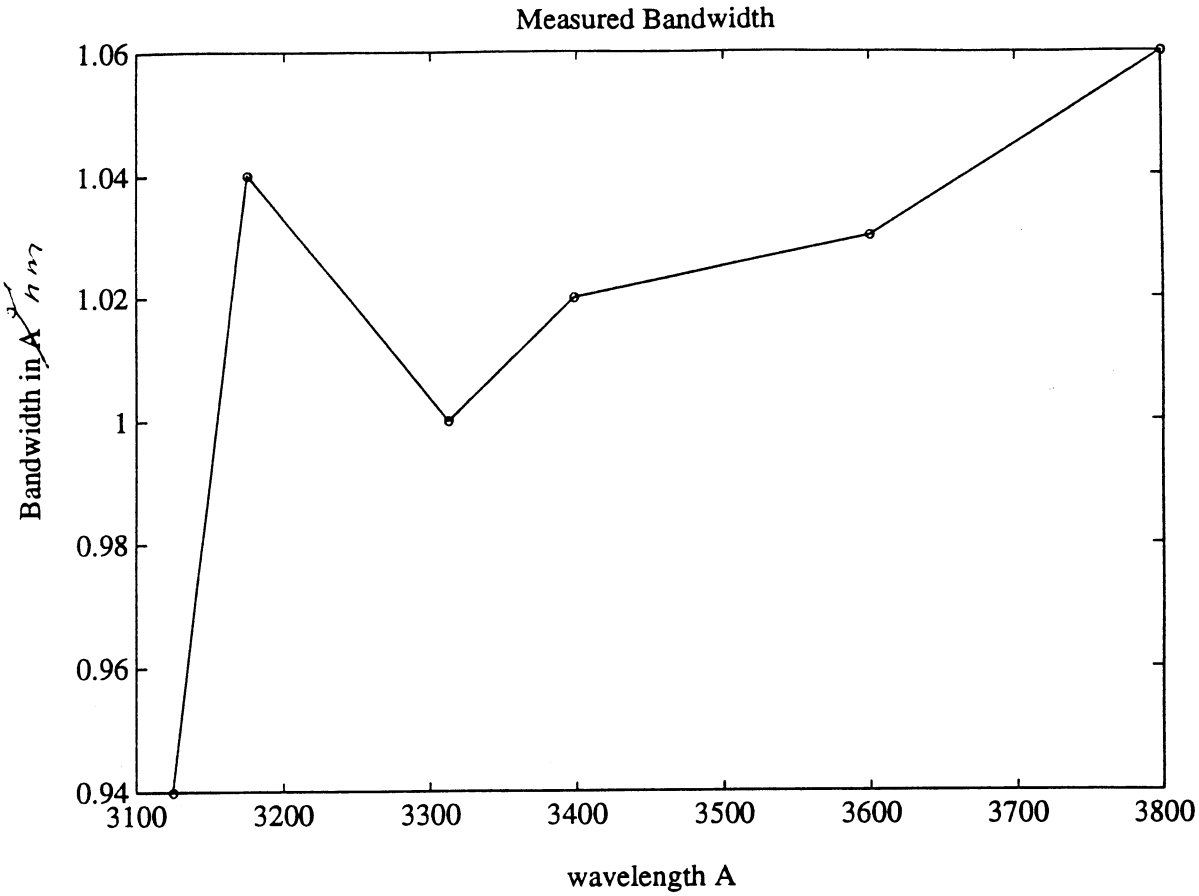

Measured Bandwidth
1.06
1.04
1.02
1
0.98
0.96
0.94
3100
3200
3300
3400
3500
3600
3700
3800
Bandwidth in A nm
wavelength A

Fig 2

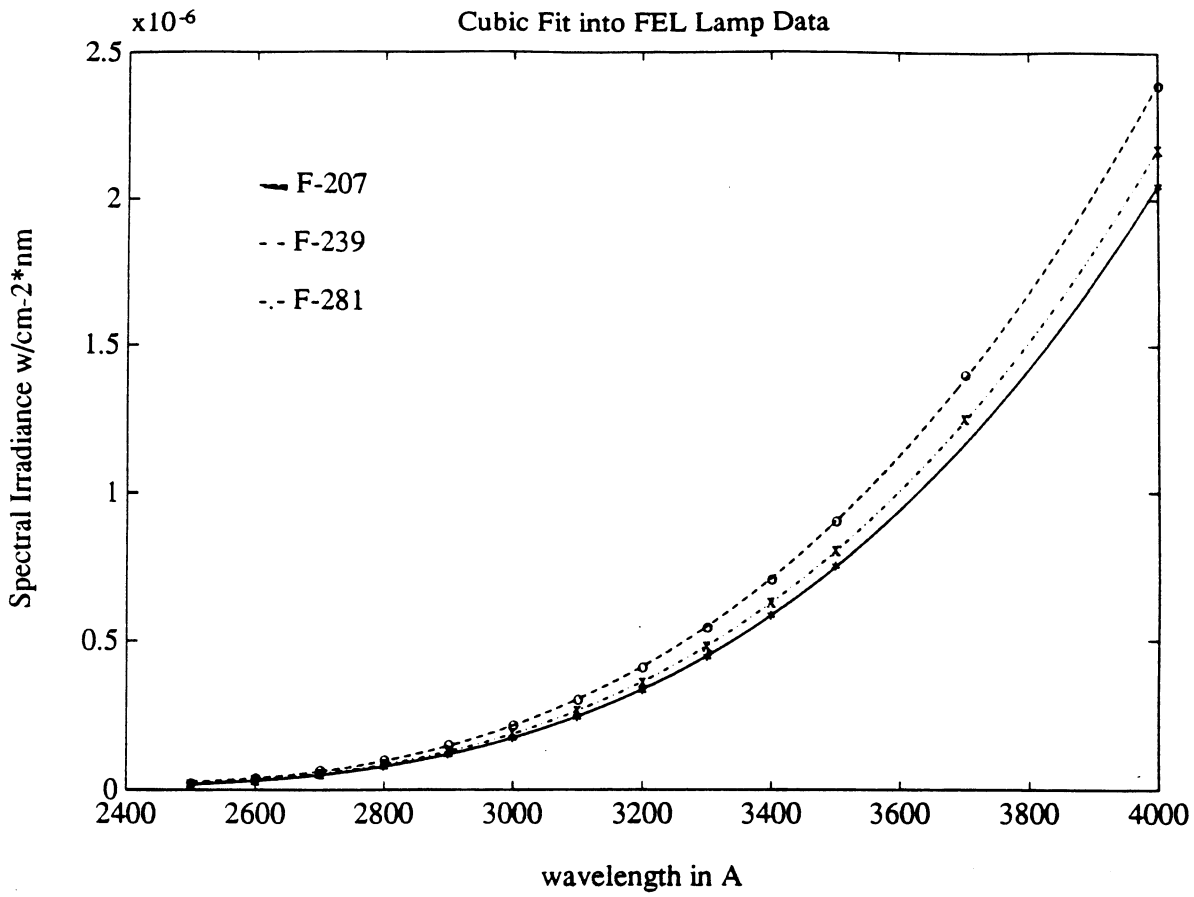

Cubic Fit into FEL Lamp Data
x10-6
2.5
2
1.5
1
0.5
0
2400
2600
2800
3000
3200
3400
3600
3800
4000
F-207
F-239
F-281
Spectral Irradiance w/cm-2*nm
wavelength in A

Fig 3a

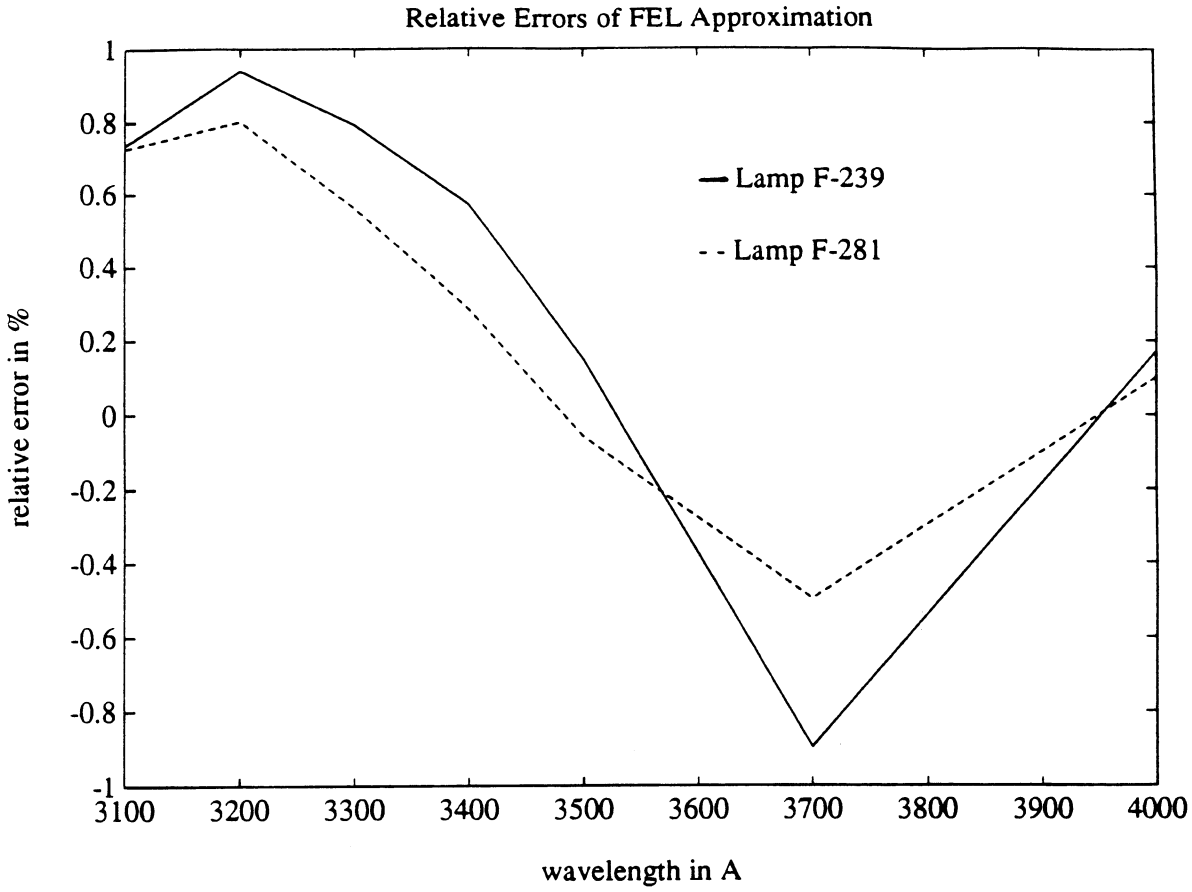

Relative Errors of FEL Approximation
relative error in %
wavelength in A
Lamp F-239
Lamp F-281
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000

Fig. 3b

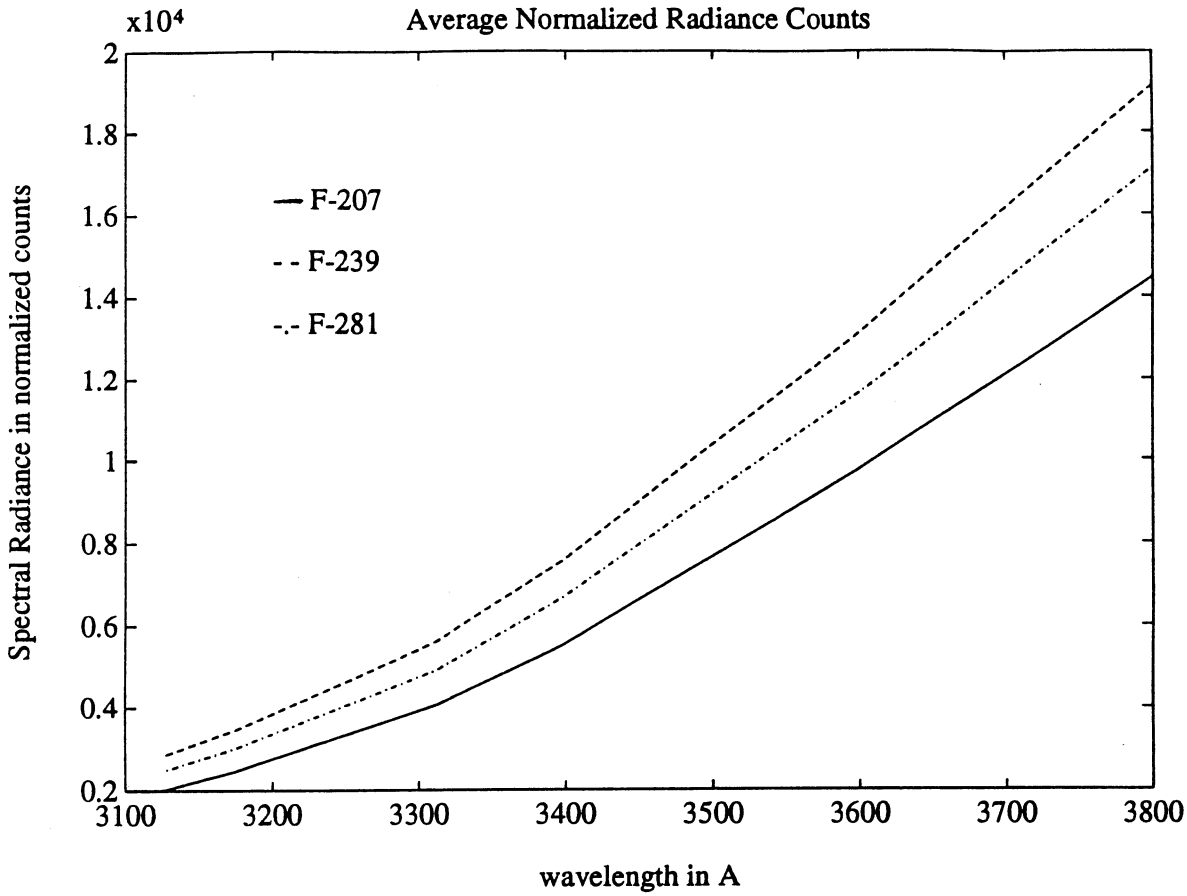

x10⁴
Average Normalized Radiance Counts
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Spectral Radiance in normalized counts
F-207
F-239
F-281
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 4

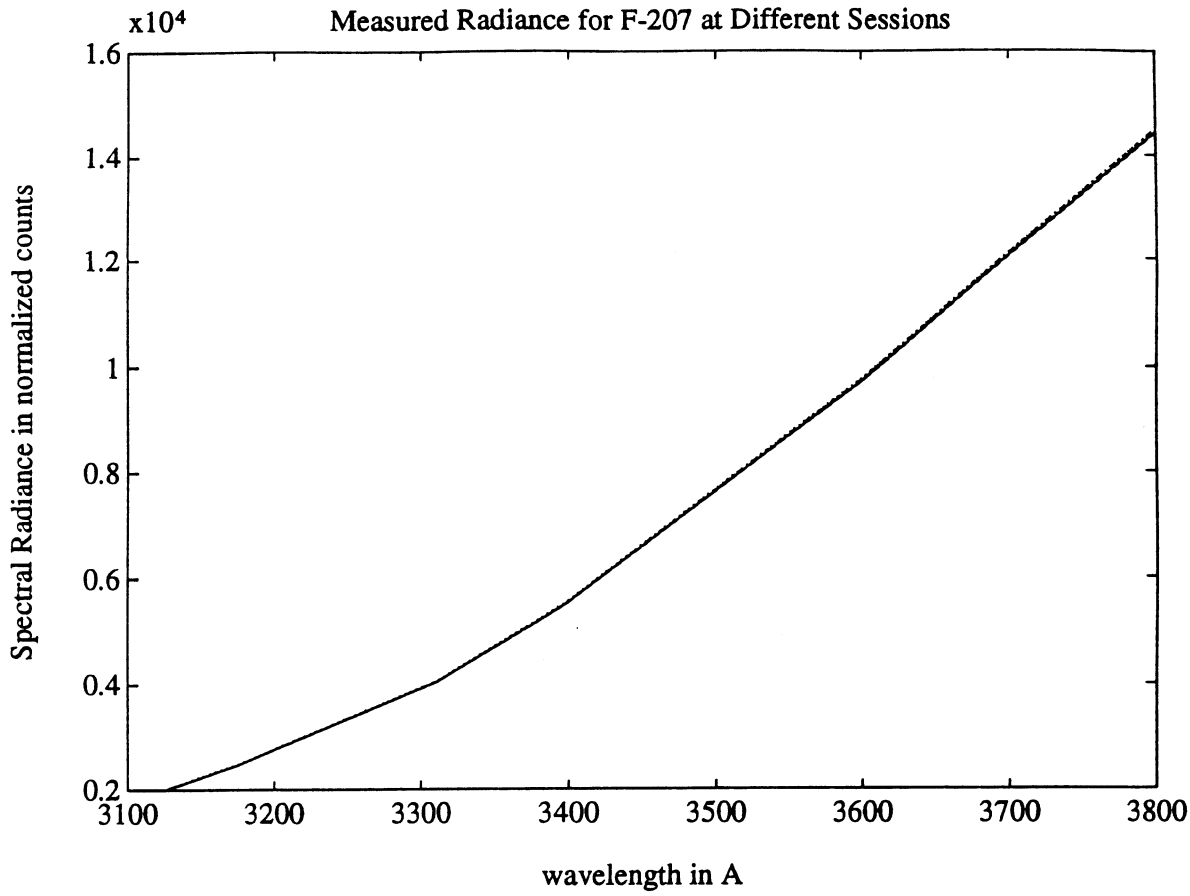

Measured Radiance for F-207 at Different Sessions
x10⁴
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Spectral Radiance in normalized counts
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig 5A

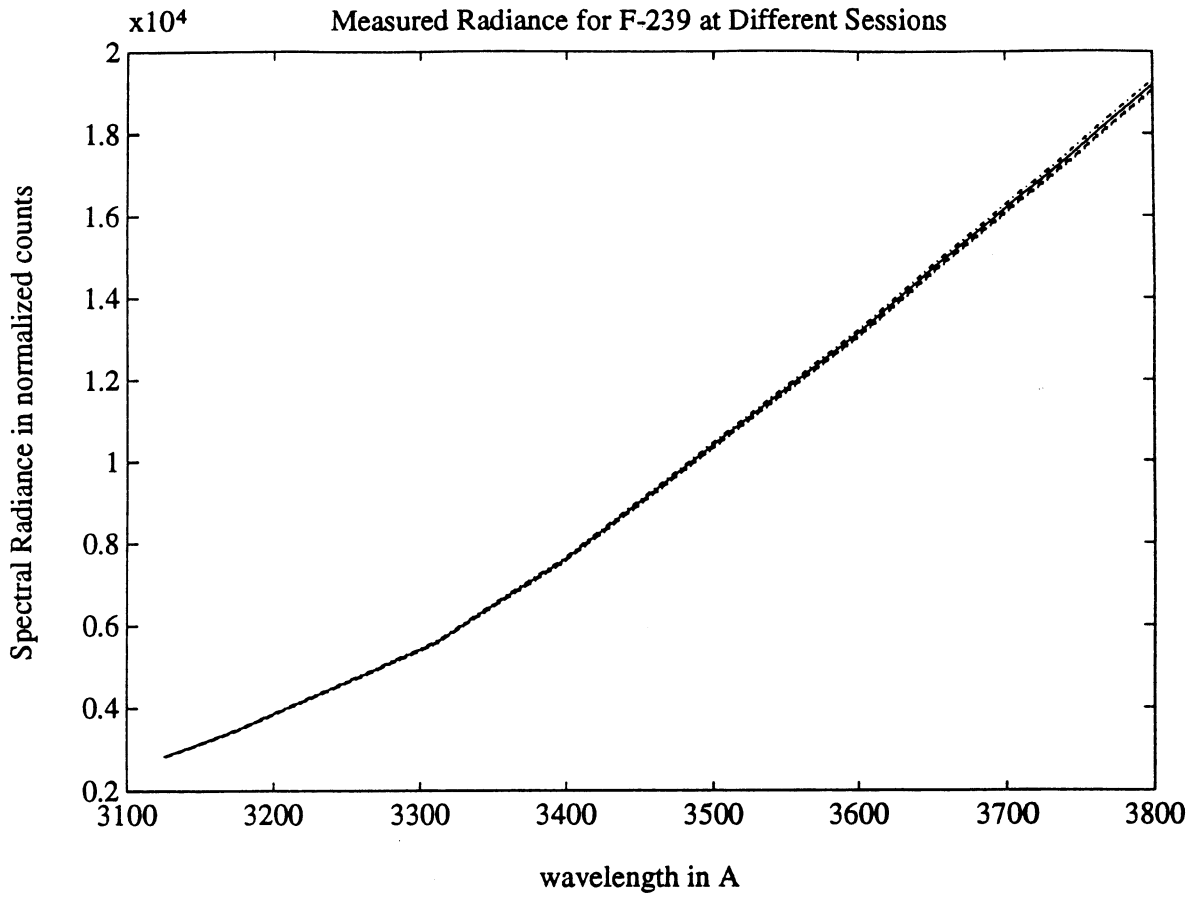

Measured Radiance for F-239 at Different Sessions
x10⁴
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Spectral Radiance in normalized counts
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 5b

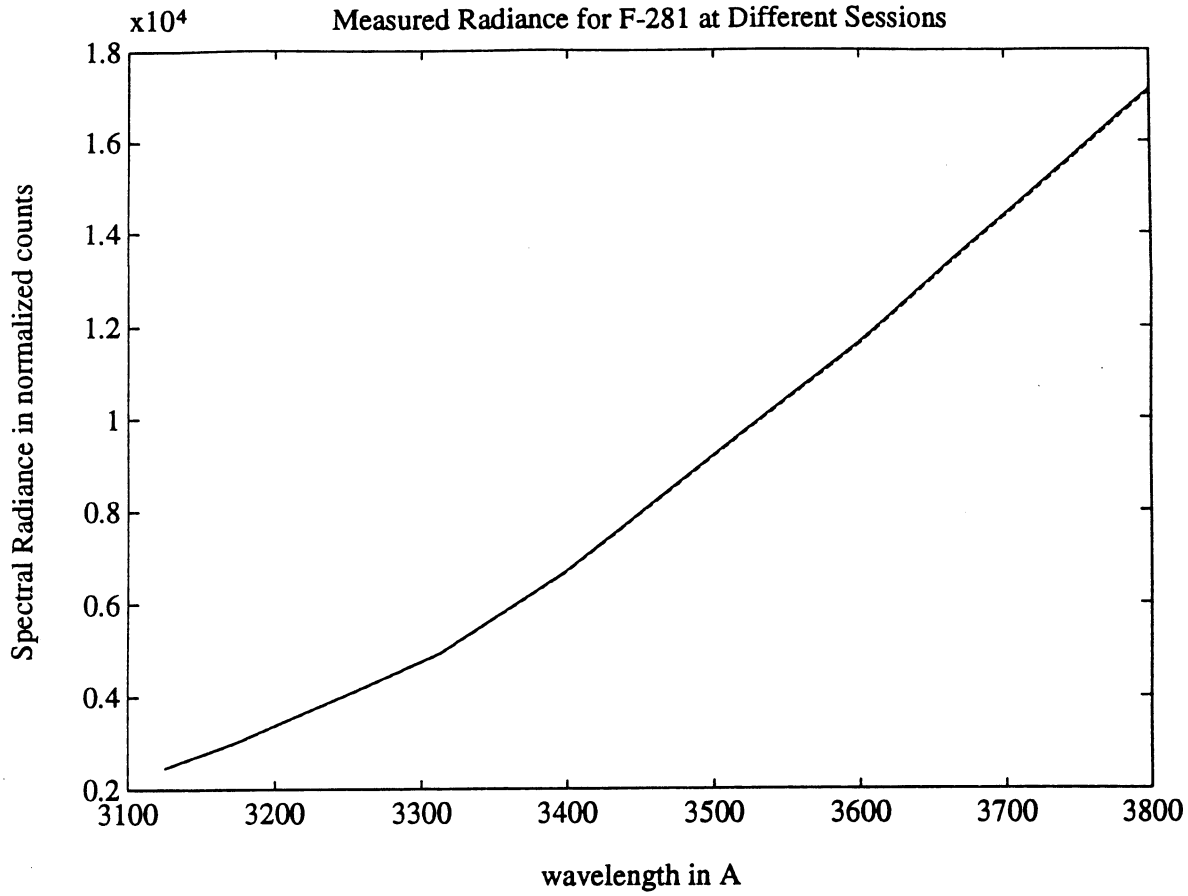

Measured Radiance for F-281 at Different Sessions
x10⁴
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Spectral Radiance in normalized counts
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig 5c

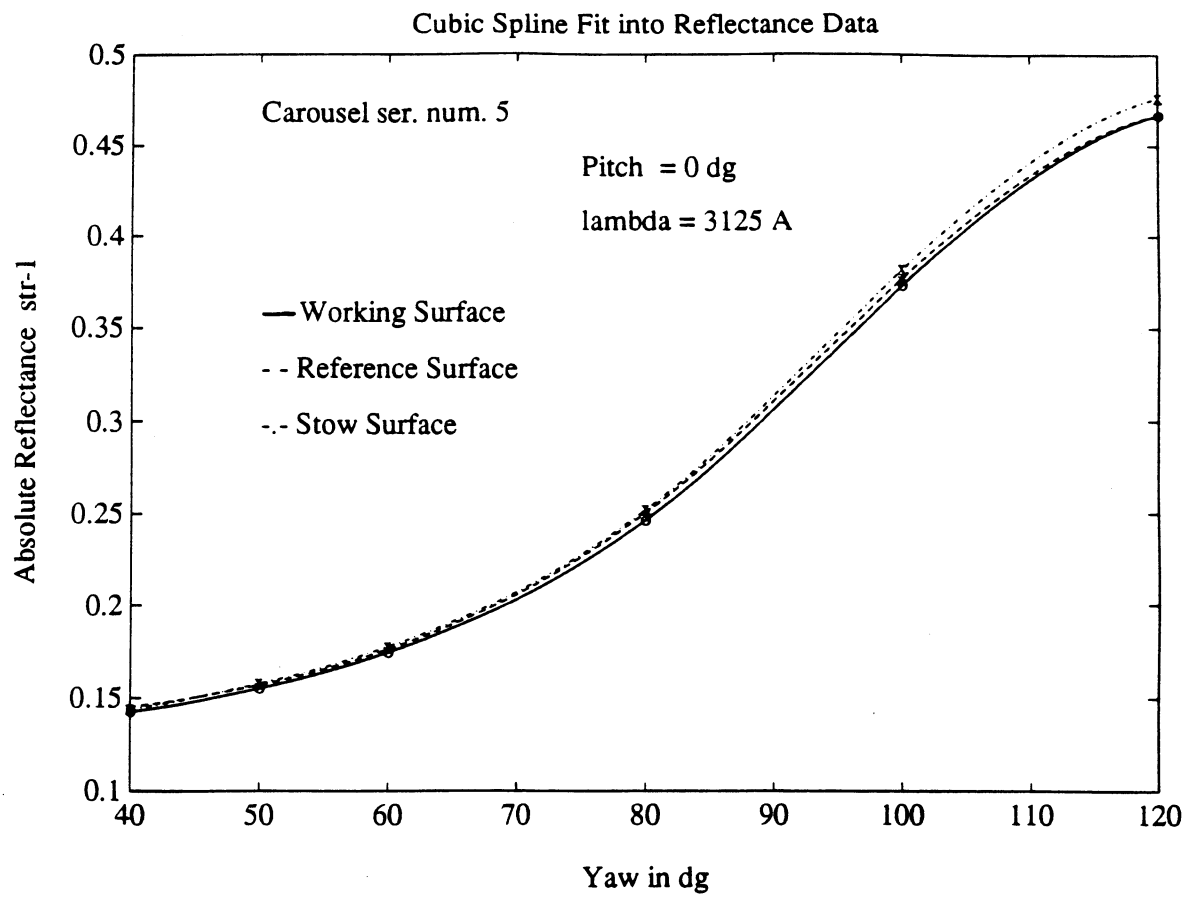

Cubic Spline Fit into Reflectance Data
Carousel ser. num. 5
Pitch = 0 dg
lambda = 3125 A
Working Surface
Reference Surface
Stow Surface
Absolute Reflectance str-1
Yaw in dg
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
40
50
60
70
80
90
100
110
120

Fig. 6a

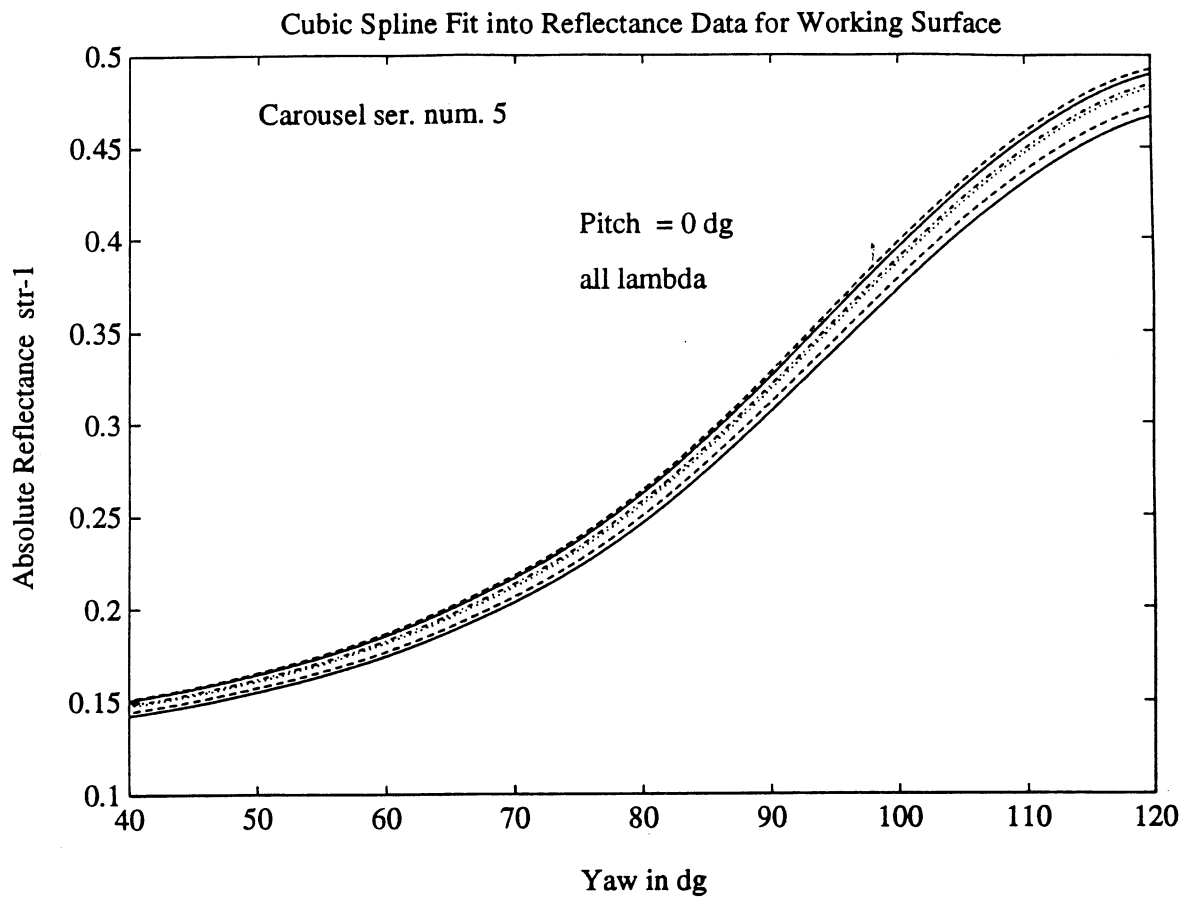

Cubic Spline Fit into Reflectance Data for Working Surface
Carousel ser. num. 5
Pitch = 0 dg
all lambda
Absolute Reflectance str-1
Yaw in dg
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
40
50
60
70
80
90
100
110
120

Fig 6b

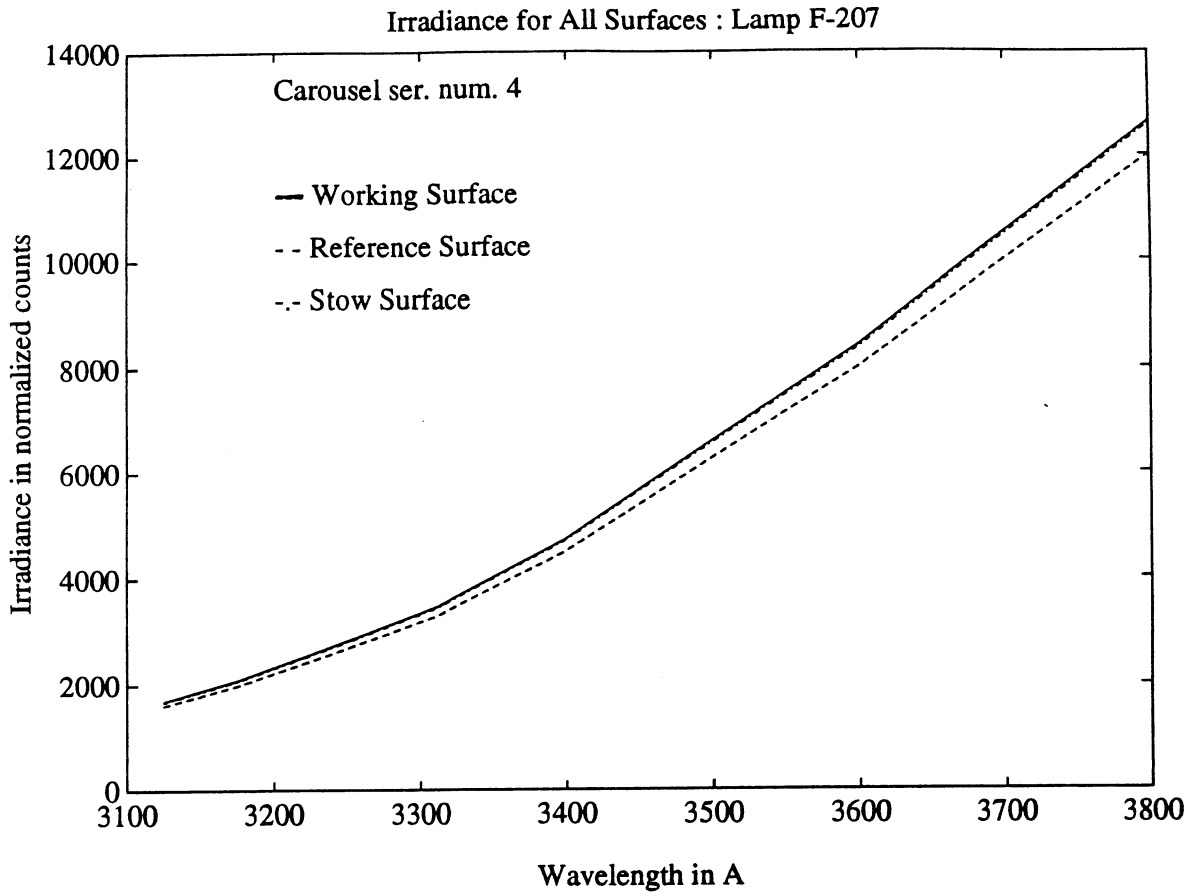

Irradiance for All Surfaces : Lamp F-207
Carousel ser. num. 4
Working Surface
Reference Surface
Stow Surface
Irradiance in normalized counts
14000
12000
10000
8000
6000
4000
2000
0
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig 7a

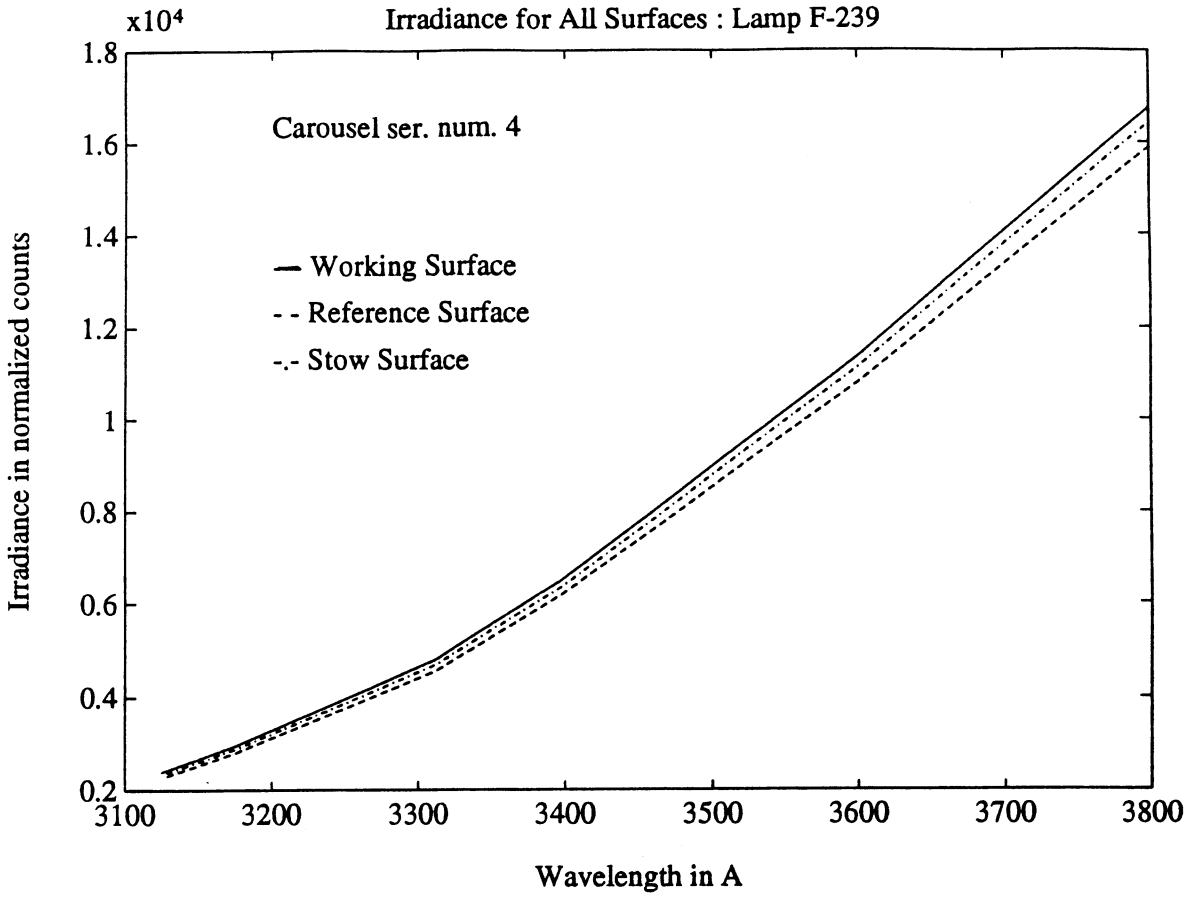

x10⁴
Irradiance for All Surfaces : Lamp F-239
Carousel ser. num. 4
— Working Surface
- - Reference Surface
-.- Stow Surface
Irradiance in normalized counts
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig. 7b

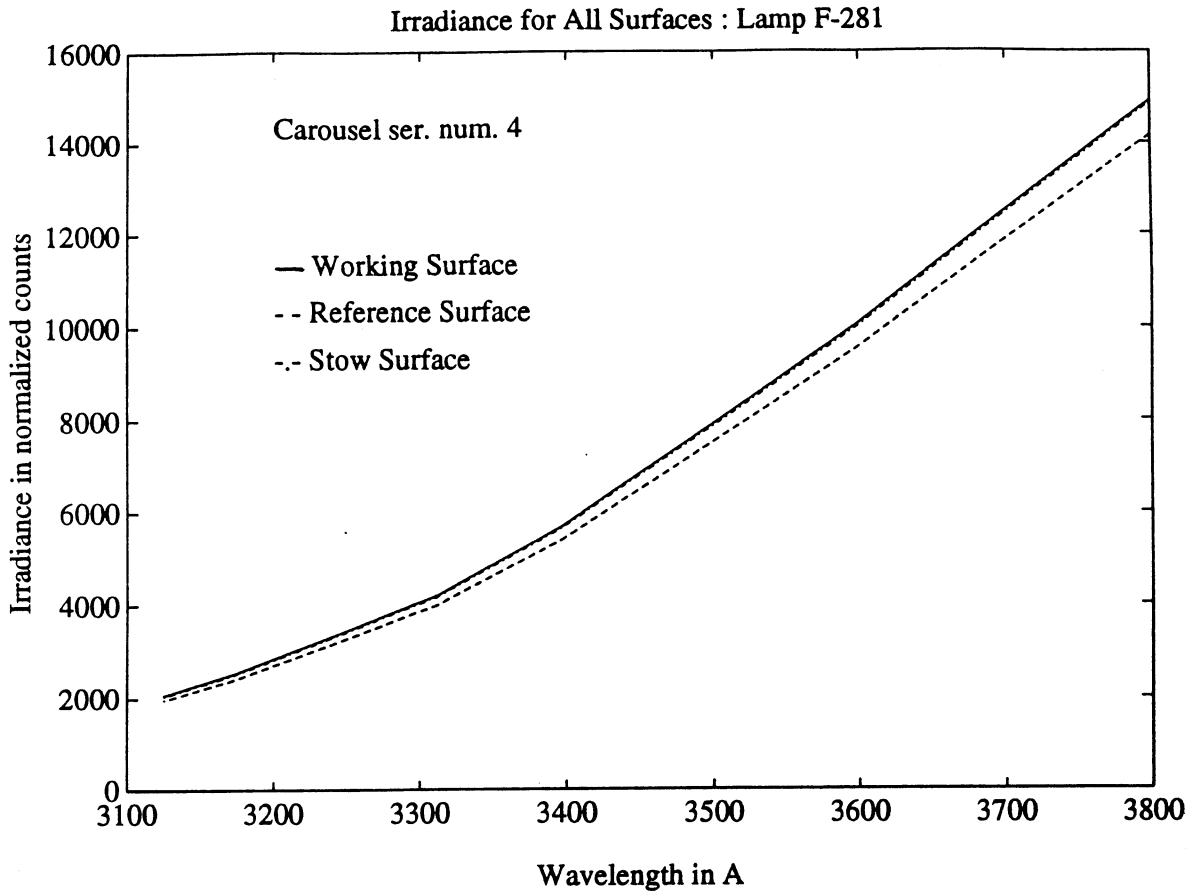

Irradiance for All Surfaces : Lamp F-281
Carousel ser. num. 4
— Working Surface
- - Reference Surface
-.- Stow Surface
Irradiance in normalized counts
16000
14000
12000
10000
8000
6000
4000
2000
0
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig. 7c

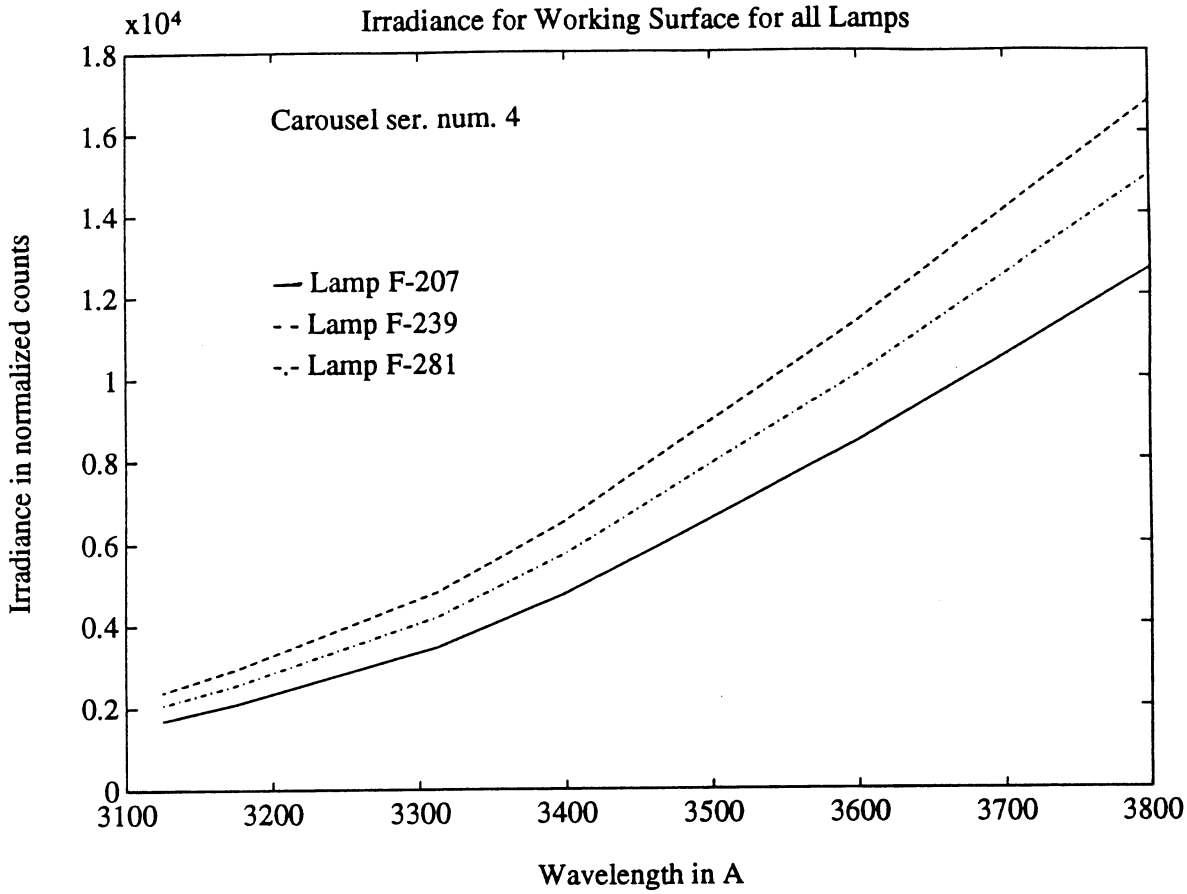

Irradiance for Working Surface for all Lamps
x10⁴
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Carousel ser. num. 4
— Lamp F-207
- - Lamp F-239
-.- Lamp F-281
Irradiance in normalized counts
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig 7d

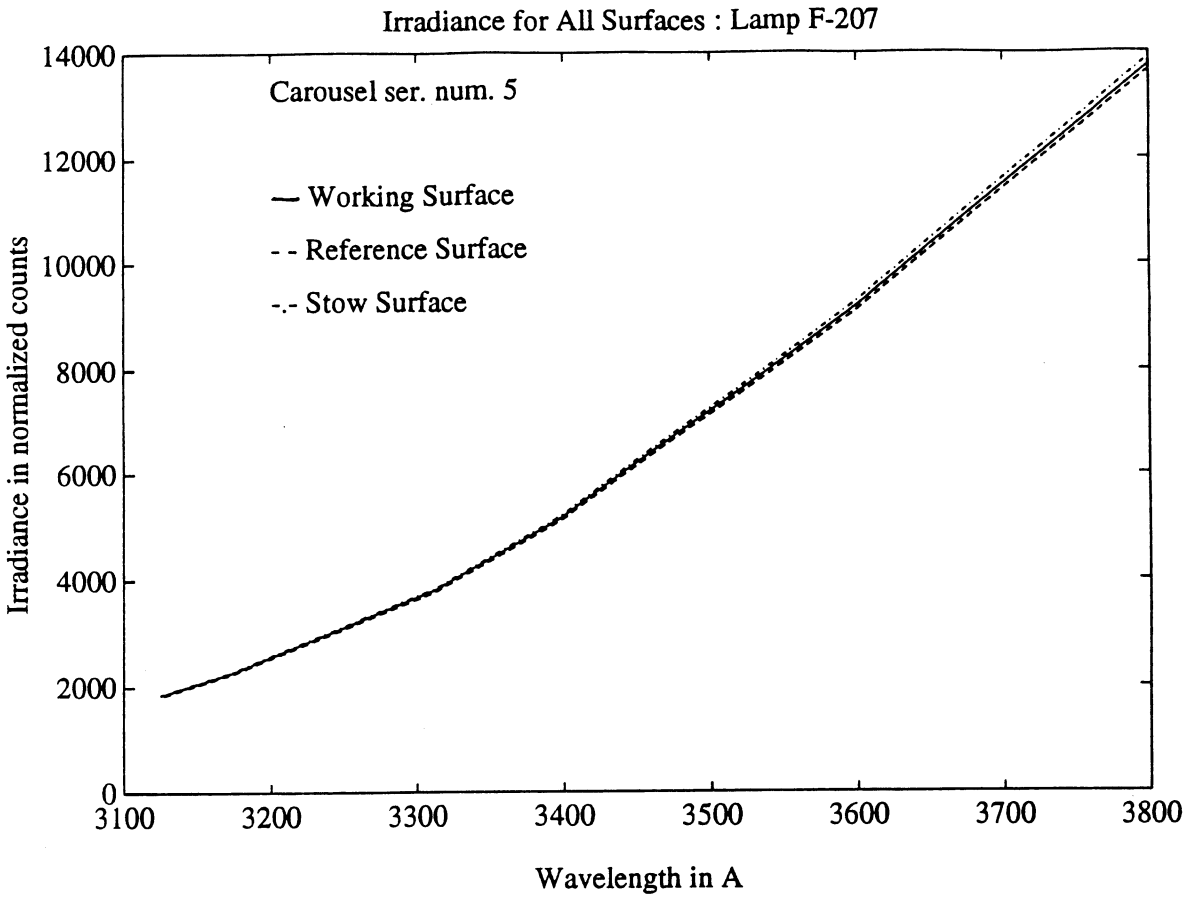

Irradiance for All Surfaces : Lamp F-207
Carousel ser. num. 5
— Working Surface
- - Reference Surface
-.- Stow Surface
Irradiance in normalized counts
14000
12000
10000
8000
6000
4000
2000
0
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig. 8a

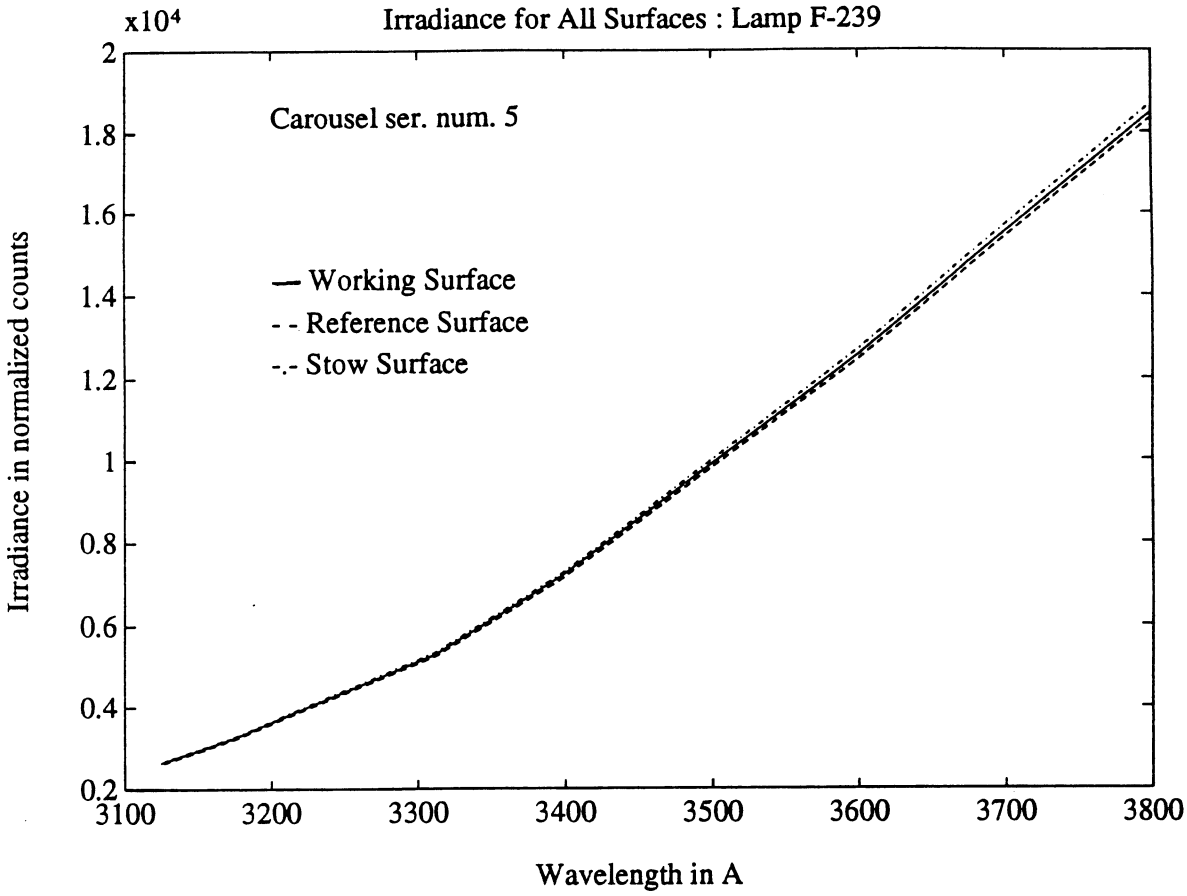

x10⁴
Irradiance for All Surfaces : Lamp F-239
Carousel ser. num. 5
— Working Surface
- - Reference Surface
-.- Stow Surface
Irradiance in normalized counts
Wavelength in A
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
3100
3200
3300
3400
3500
3600
3700
3800

Fig. 8b

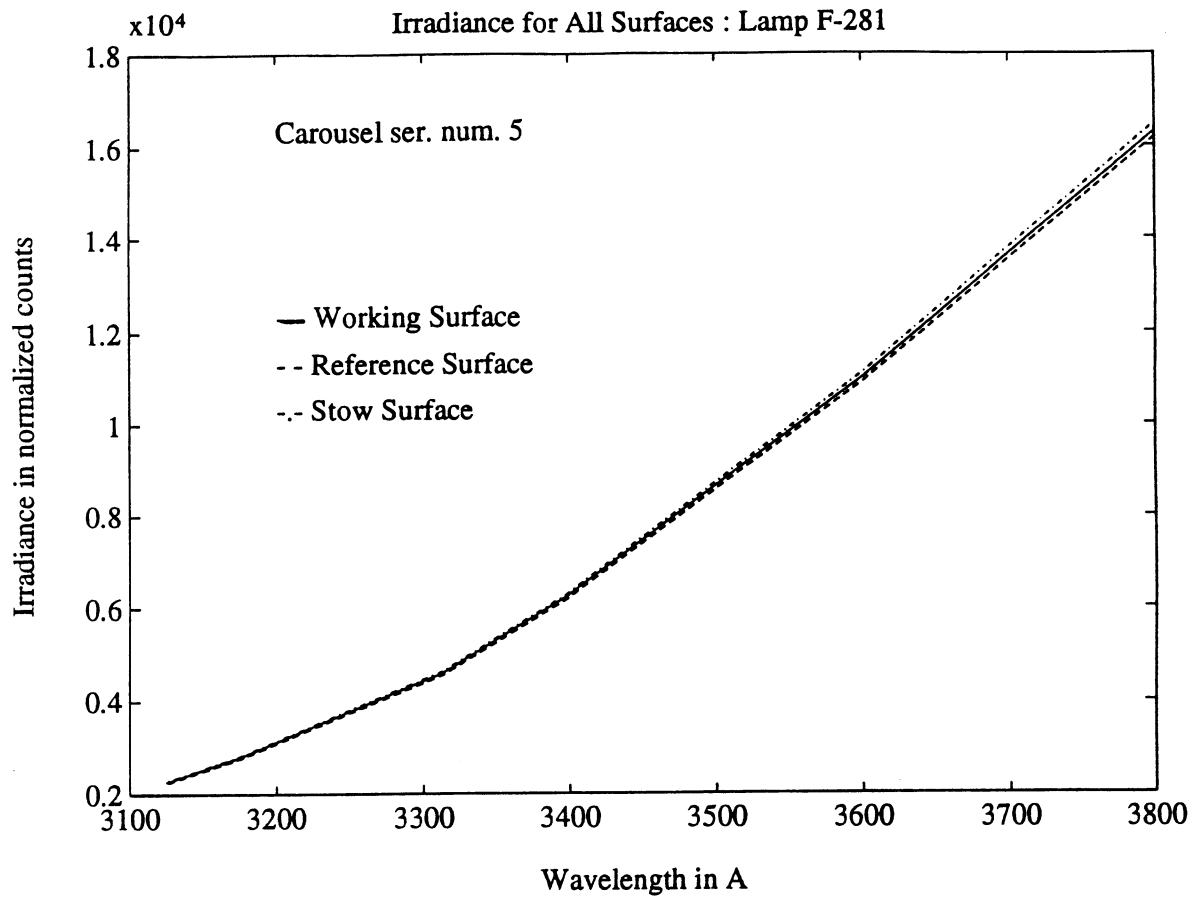

Irradiance for All Surfaces : Lamp F-281
x10⁴
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Carousel ser. num. 5
Working Surface
Reference Surface
Stow Surface
Irradiance in normalized counts
3100
3200
3300
3400
3500
3600
3700
3800
Wavelength in A

Fig. 8c

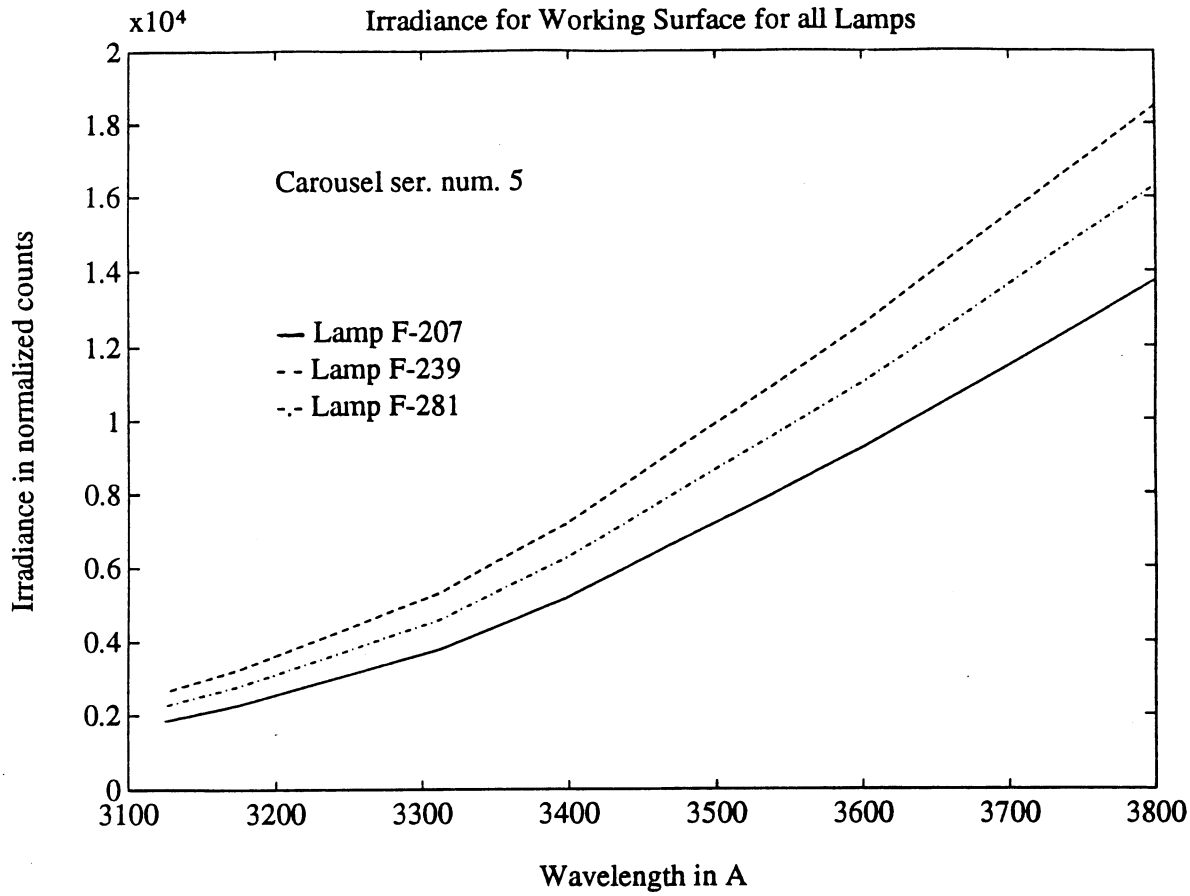

x10⁴
Irradiance for Working Surface for all Lamps
Carousel ser. num. 5
— Lamp F-207
- - Lamp F-239
-.- Lamp F-281
Irradiance in normalized counts
Wavelength in A
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
3100
3200
3300
3400
3500
3600
3700
3800

Fig. 8d

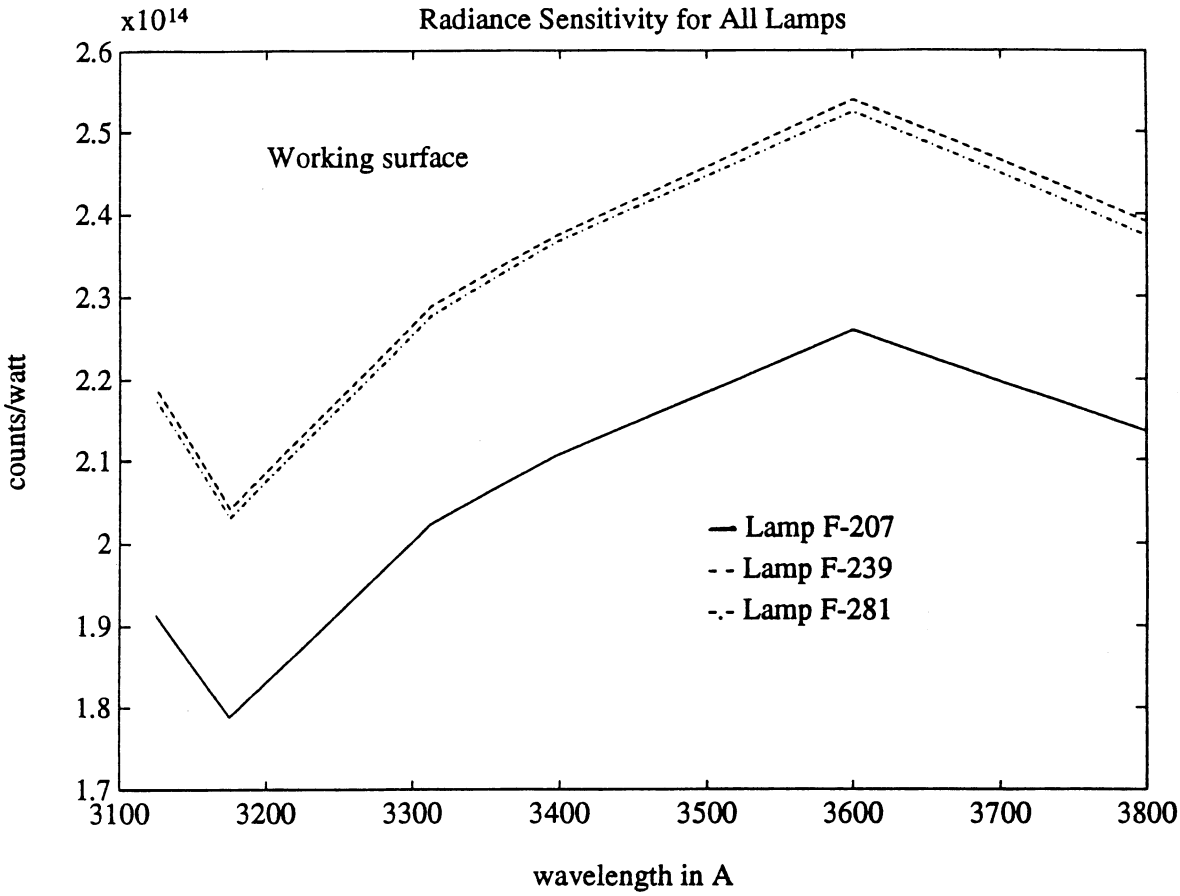

x10^14
Radiance Sensitivity for All Lamps
Working surface
counts/watt
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A
Lamp F-207
Lamp F-239
Lamp F-281

Fig. 9

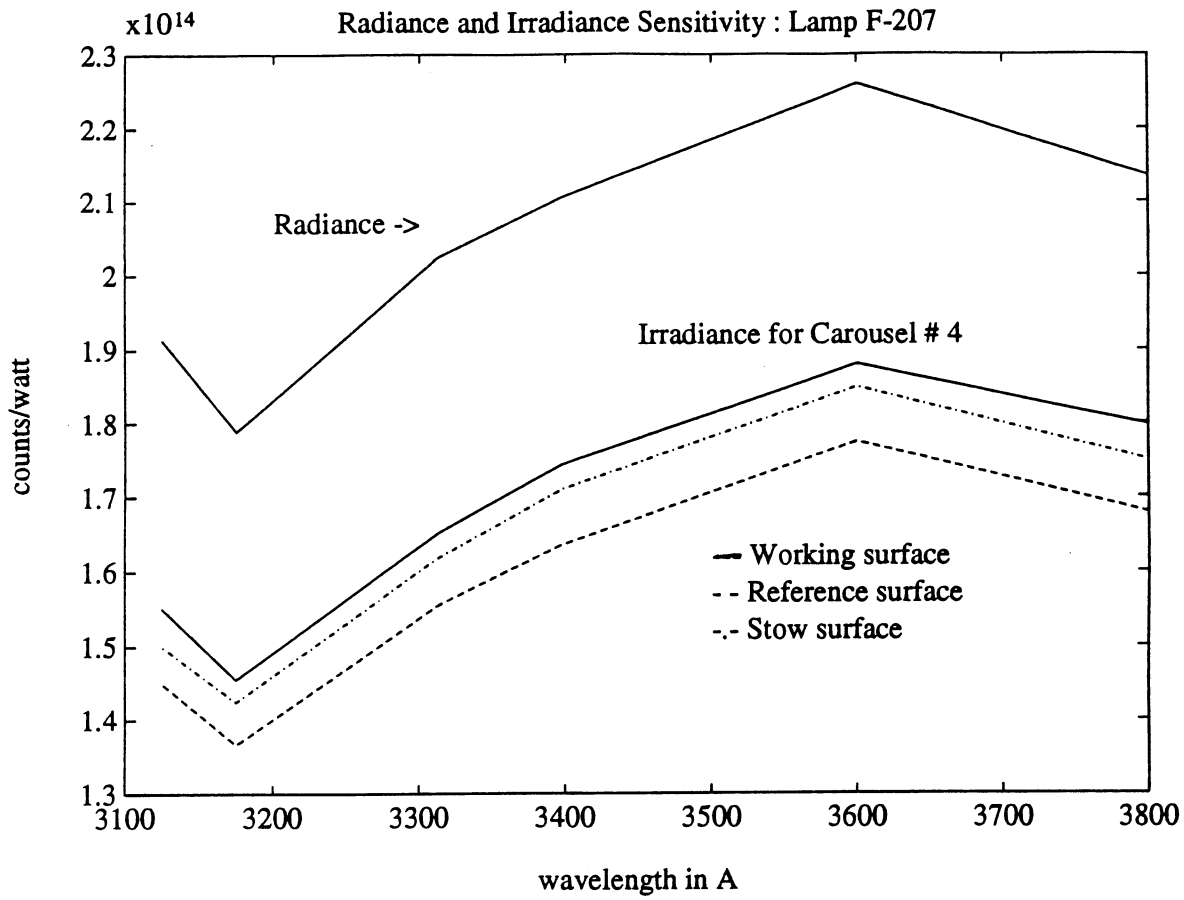

x10^14
Radiance and Irradiance Sensitivity : Lamp F-207
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
counts/watt
Radiance ->
Irradiance for Carousel # 4
Working surface
Reference surface
Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 10a

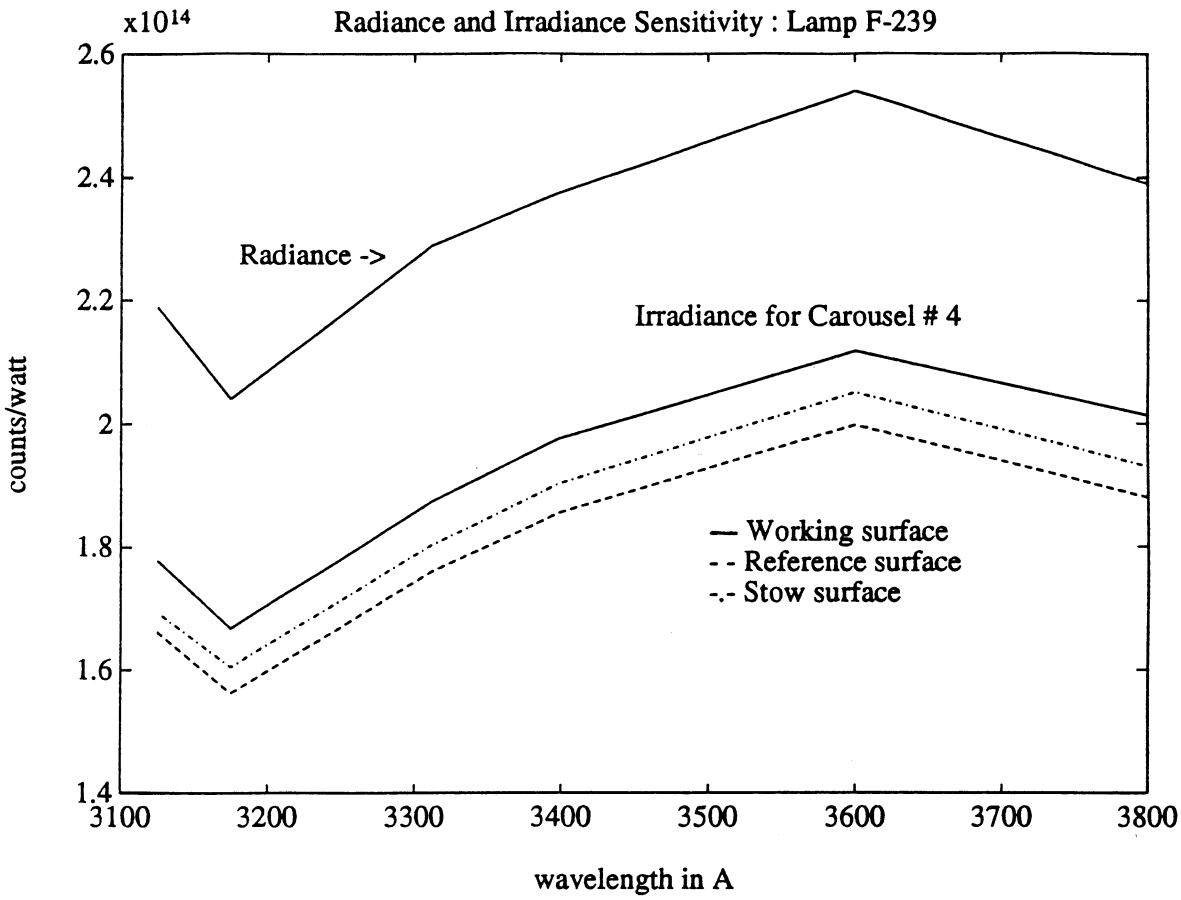

x10^14
Radiance and Irradiance Sensitivity : Lamp F-239
2.6
2.4
2.2
2
1.8
1.6
1.4
counts/watt
Radiance ->
Irradiance for Carousel # 4
— Working surface
- - Reference surface
-.- Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 10b

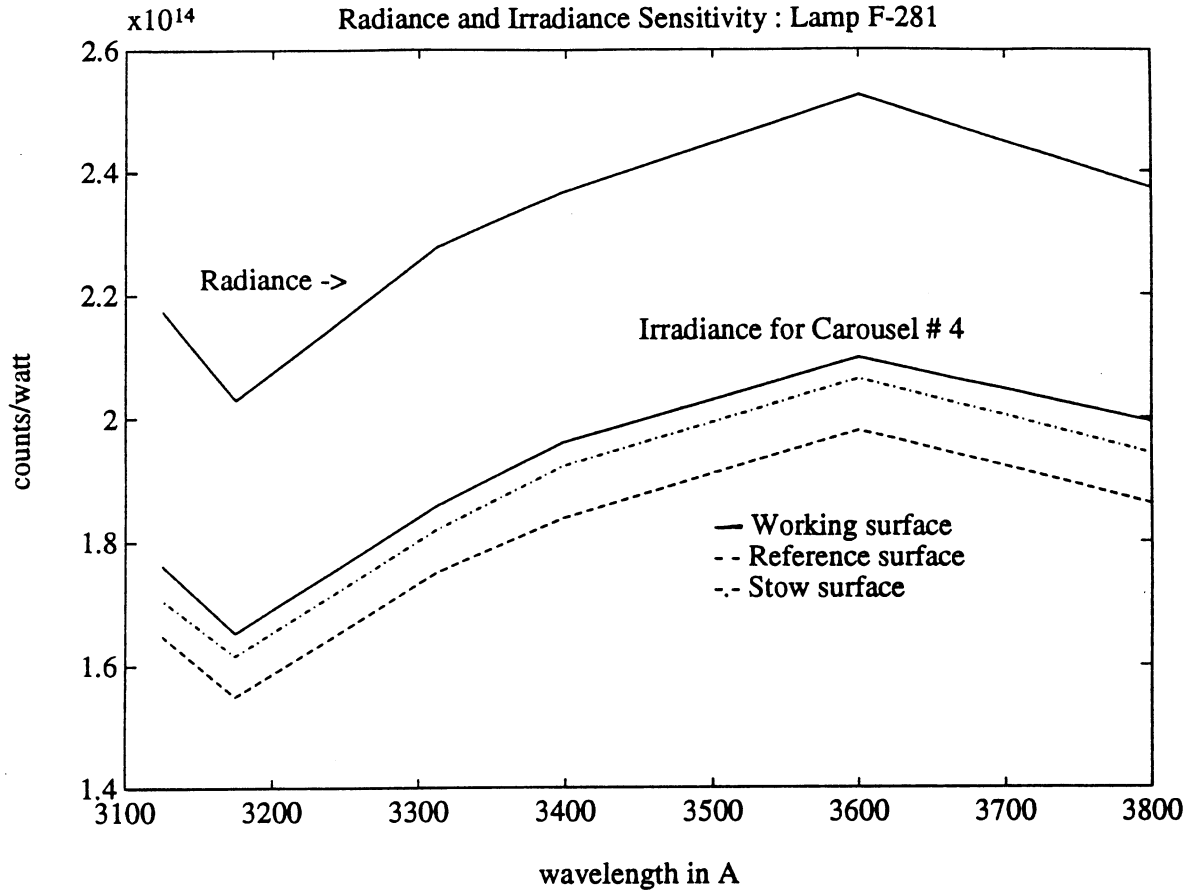

x10^14
Radiance and Irradiance Sensitivity : Lamp F-281
2.6
2.4
2.2
2
1.8
1.6
1.4
counts/watt
Radiance ->
Irradiance for Carousel # 4
— Working surface
- - Reference surface
-.- Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 10c

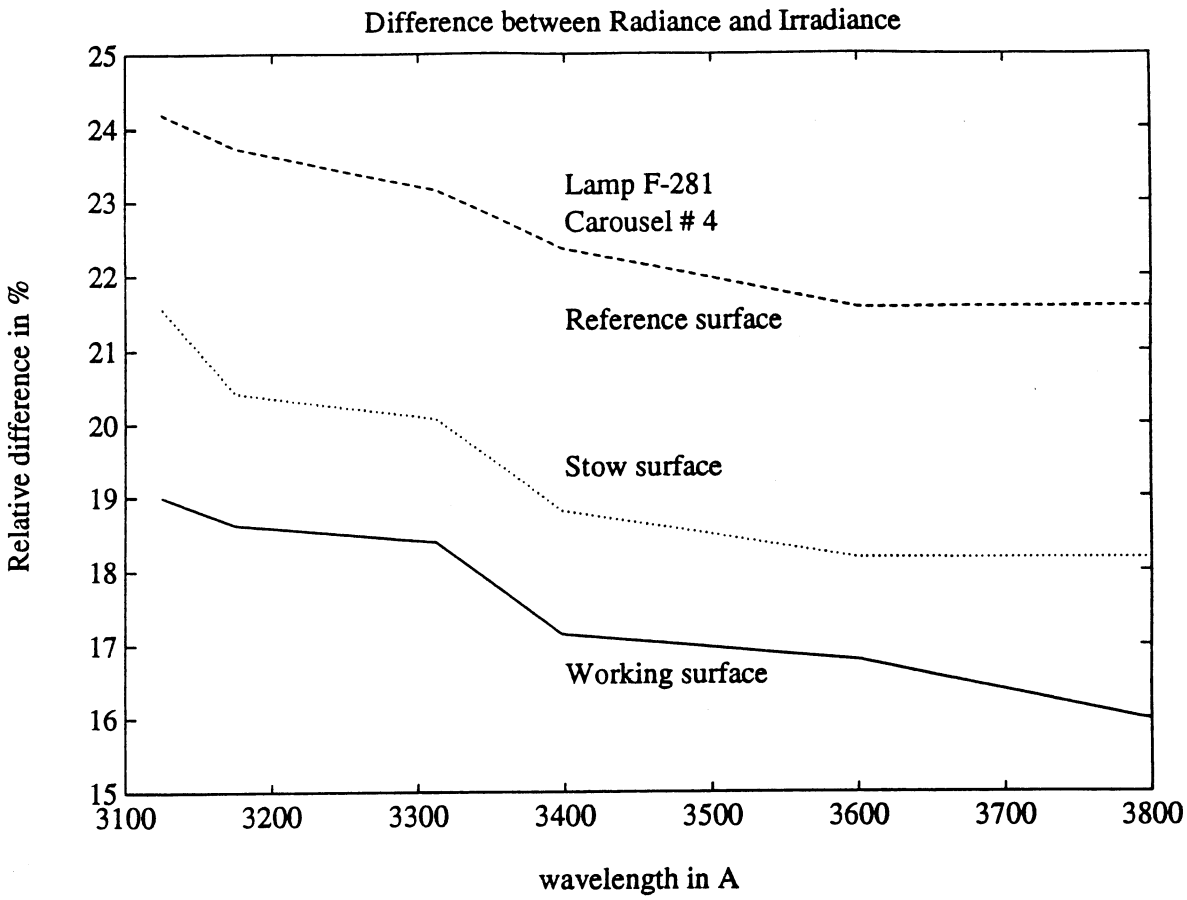

Difference between Radiance and Irradiance
Relative difference in %
25
24
23
22
21
20
19
18
17
16
15
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A
Lamp F-281
Carousel # 4
Reference surface
Stow surface
Working surface

Fig. 11

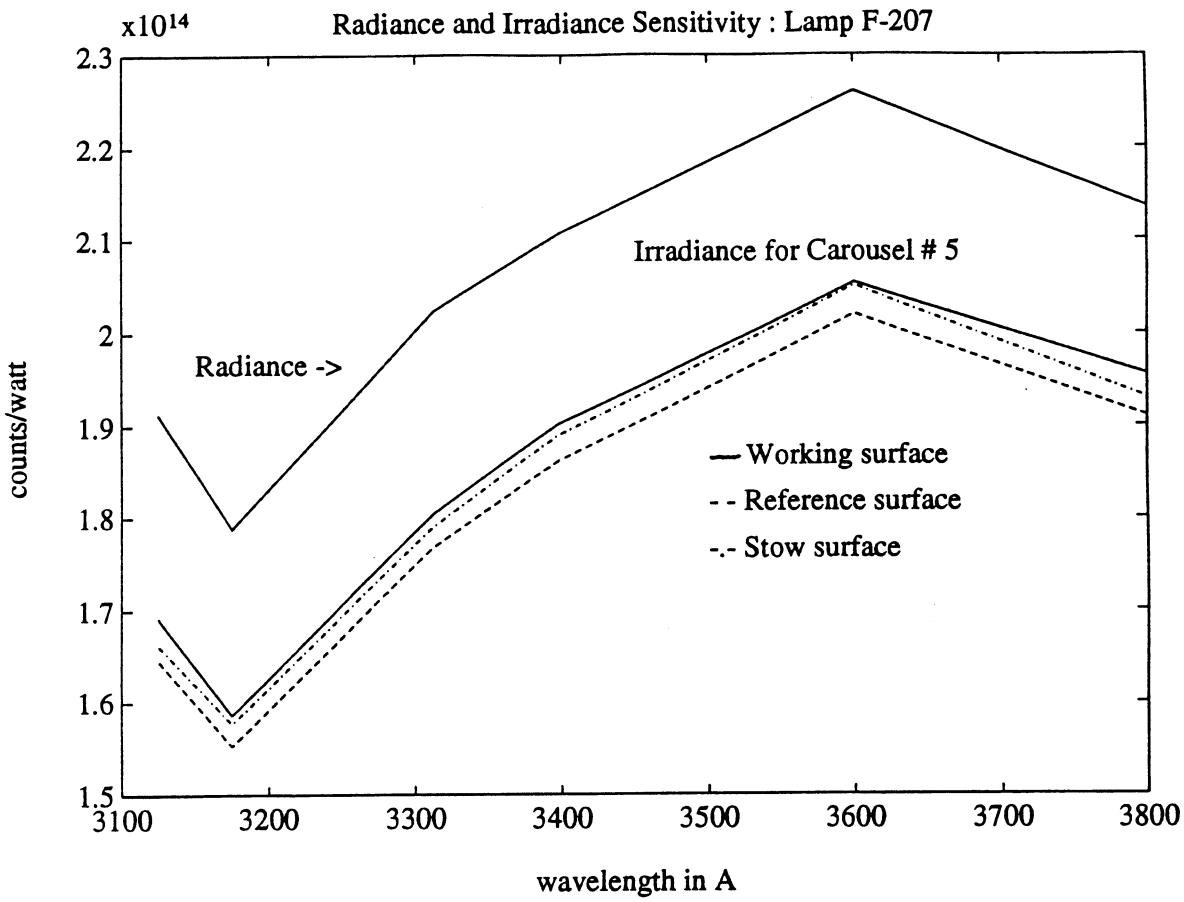

Radiance and Irradiance Sensitivity : Lamp F-207
x10^14
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
counts/watt
Radiance ->
Irradiance for Carousel # 5
— Working surface
- - Reference surface
-.- Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 12a

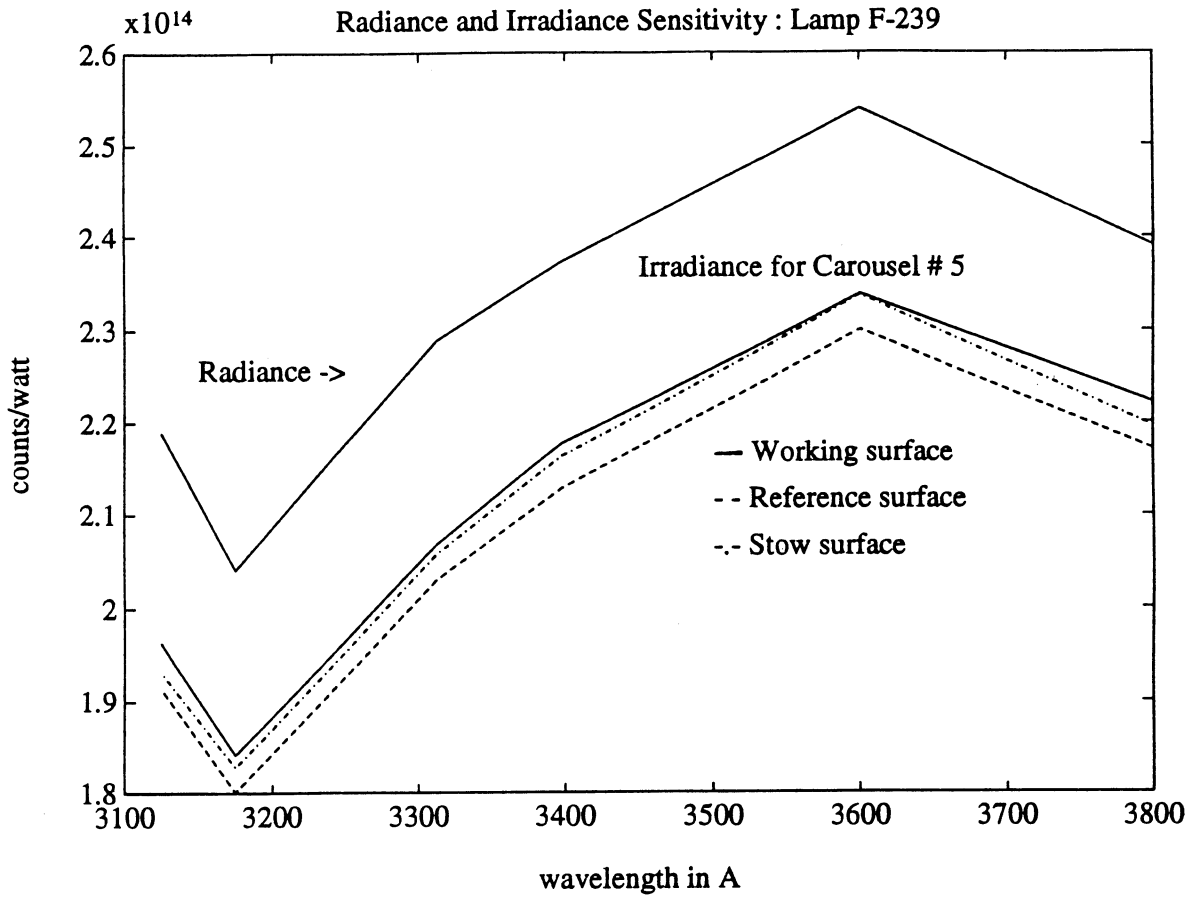

x10^14
Radiance and Irradiance Sensitivity : Lamp F-239
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
counts/watt
Irradiance for Carousel # 5
Radiance ->
— Working surface
- - Reference surface
-.- Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 12b

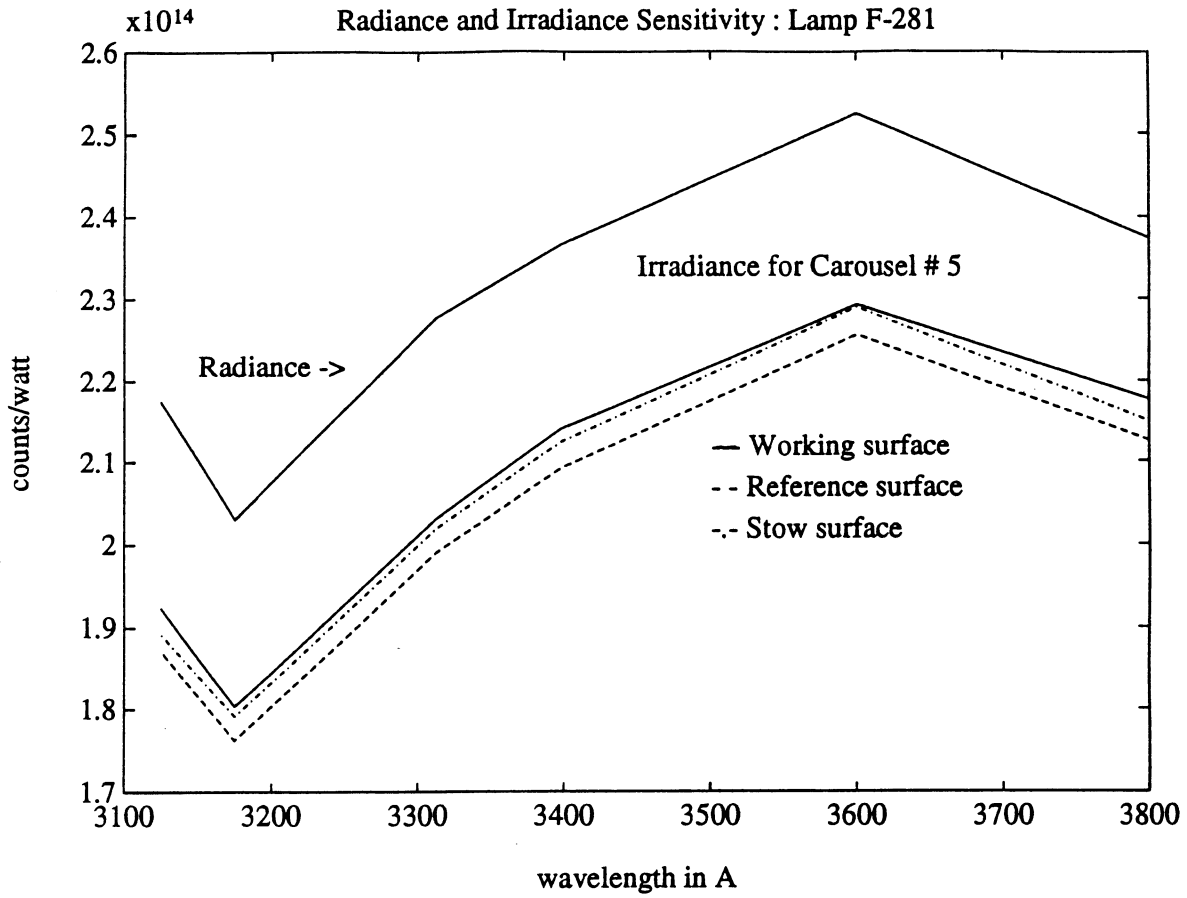

x10^14
Radiance and Irradiance Sensitivity : Lamp F-281
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
counts/watt
Irradiance for Carousel # 5
Radiance ->
— Working surface
- - Reference surface
-.- Stow surface
3100
3200
3300
3400
3500
3600
3700
3800
wavelength in A

Fig. 12c

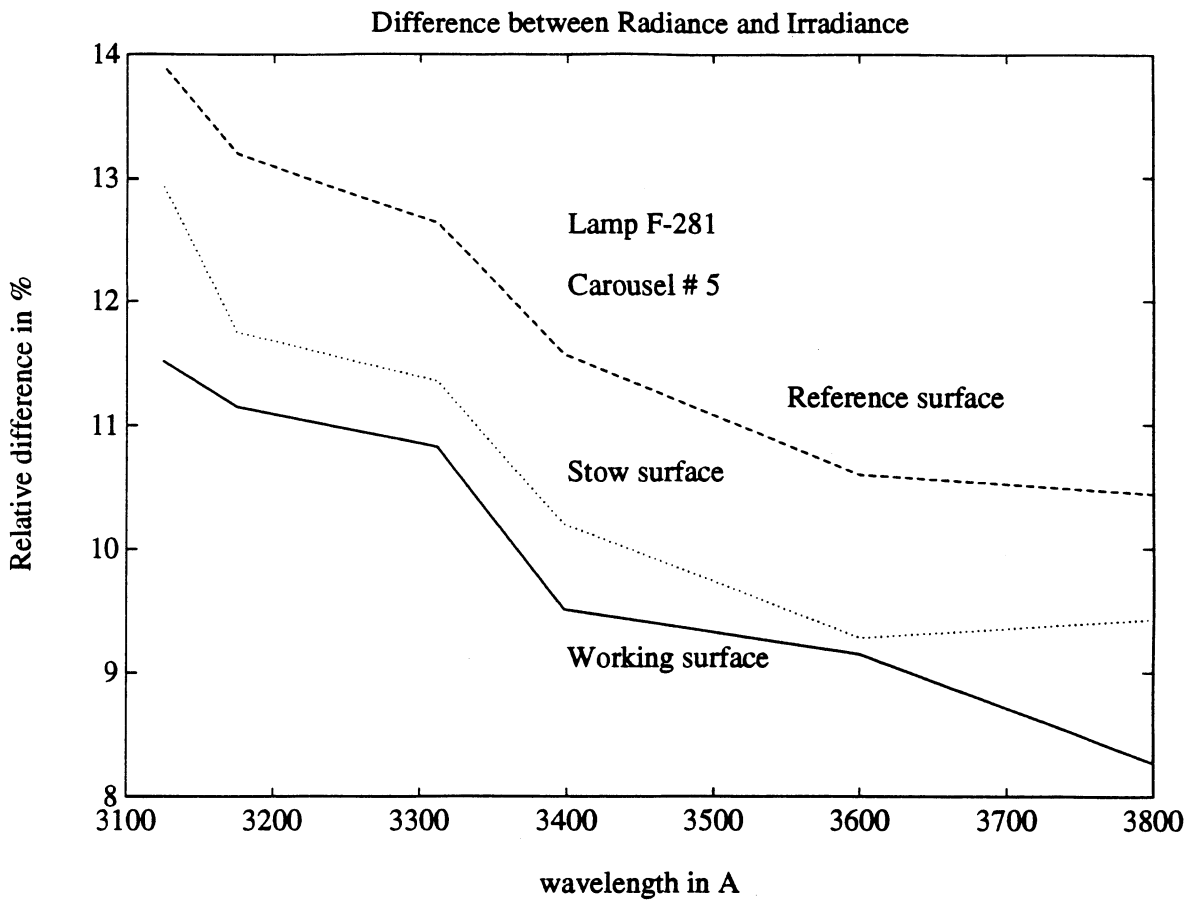

Difference between Radiance and Irradiance
Lamp F-281
Carousel # 5
Reference surface
Stow surface
Working surface
Relative difference in %
wavelength in A
14
13
12
11
10
9
8
3100
3200
3300
3400
3500
3600
3700
3800

Fig. 13

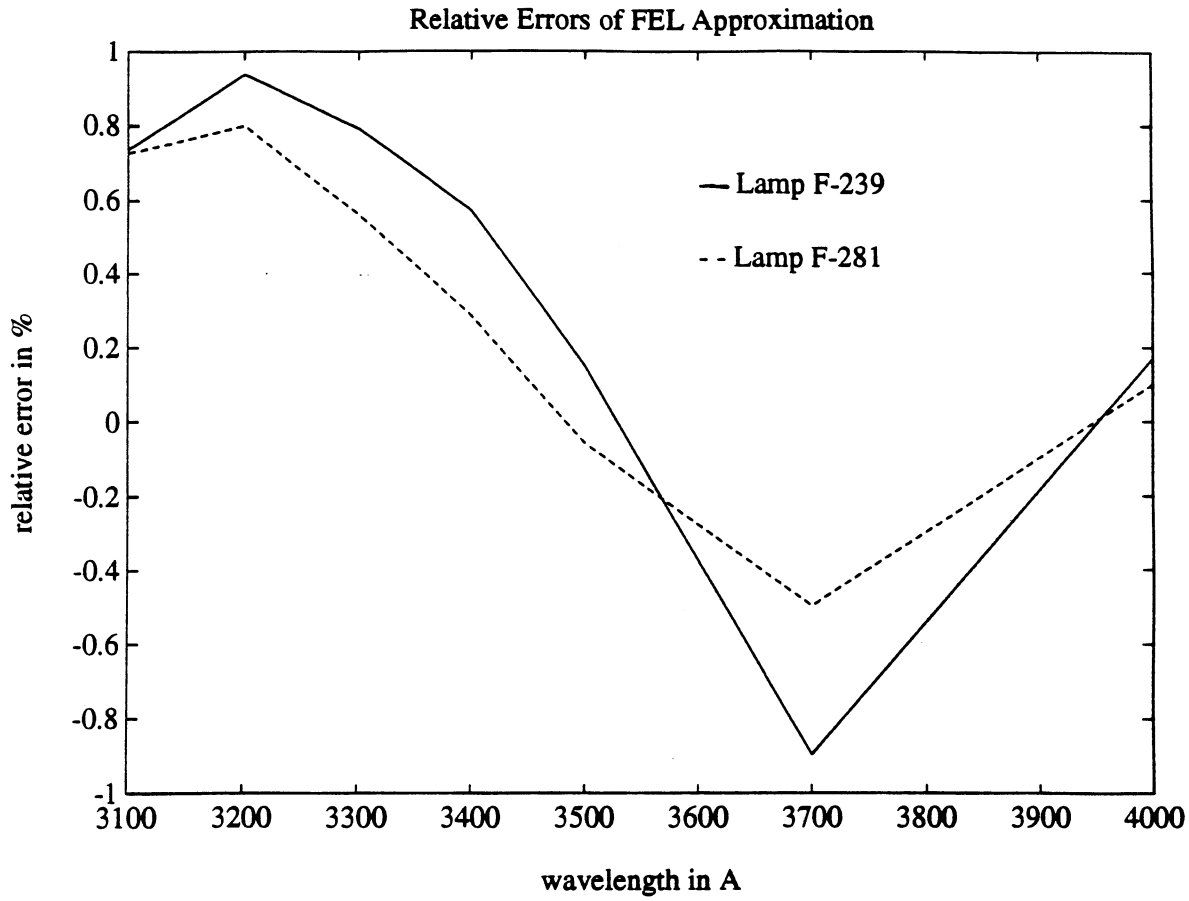

Relative Errors of FEL Approximation
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
relative error in %
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
wavelength in A
— Lamp F-239
- - Lamp F-281

Fig. 14

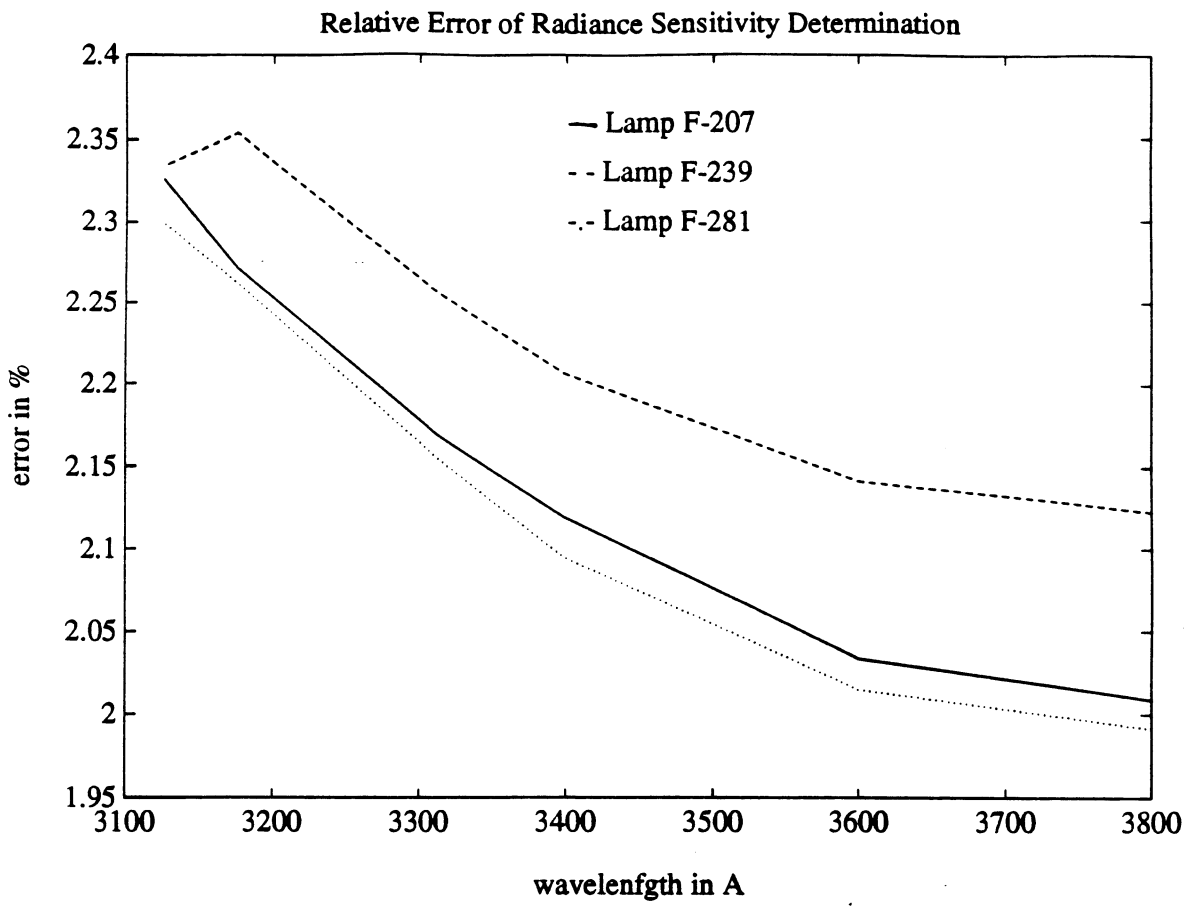

Relative Error of Radiance Sensitivity Determination
— Lamp F-207
- - Lamp F-239
-.- Lamp F-281
error in %
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
3100
3200
3300
3400
3500
3600
3700
3800
wavelenfgth in A

Fig. 15

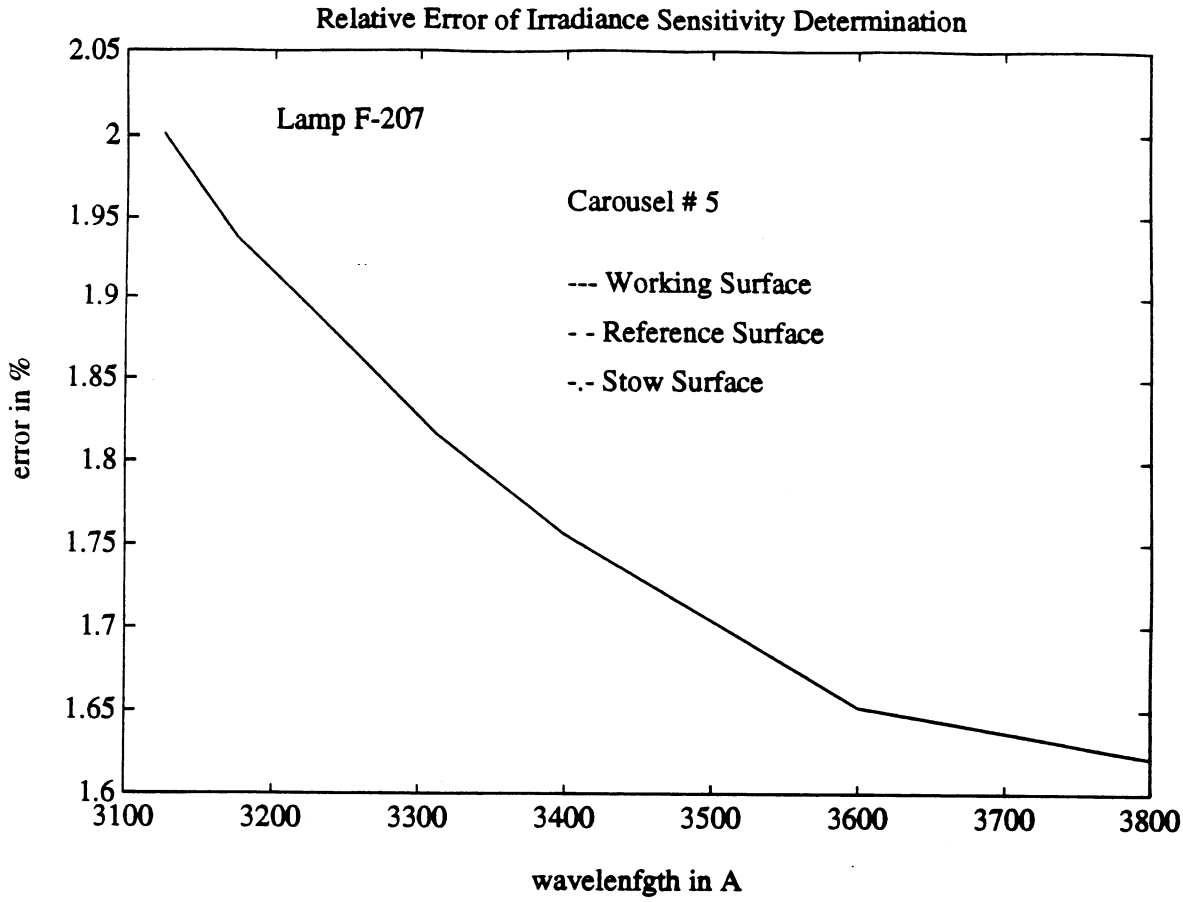

Relative Error of Irradiance Sensitivity Determination
Lamp F-207
Carousel # 5
--- Working Surface
- - Reference Surface
-.- Stow Surface
error in %
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
3100
3200
3300
3400
3500
3600
3700
3800
wavelenfgth in A

Fig. 16.a

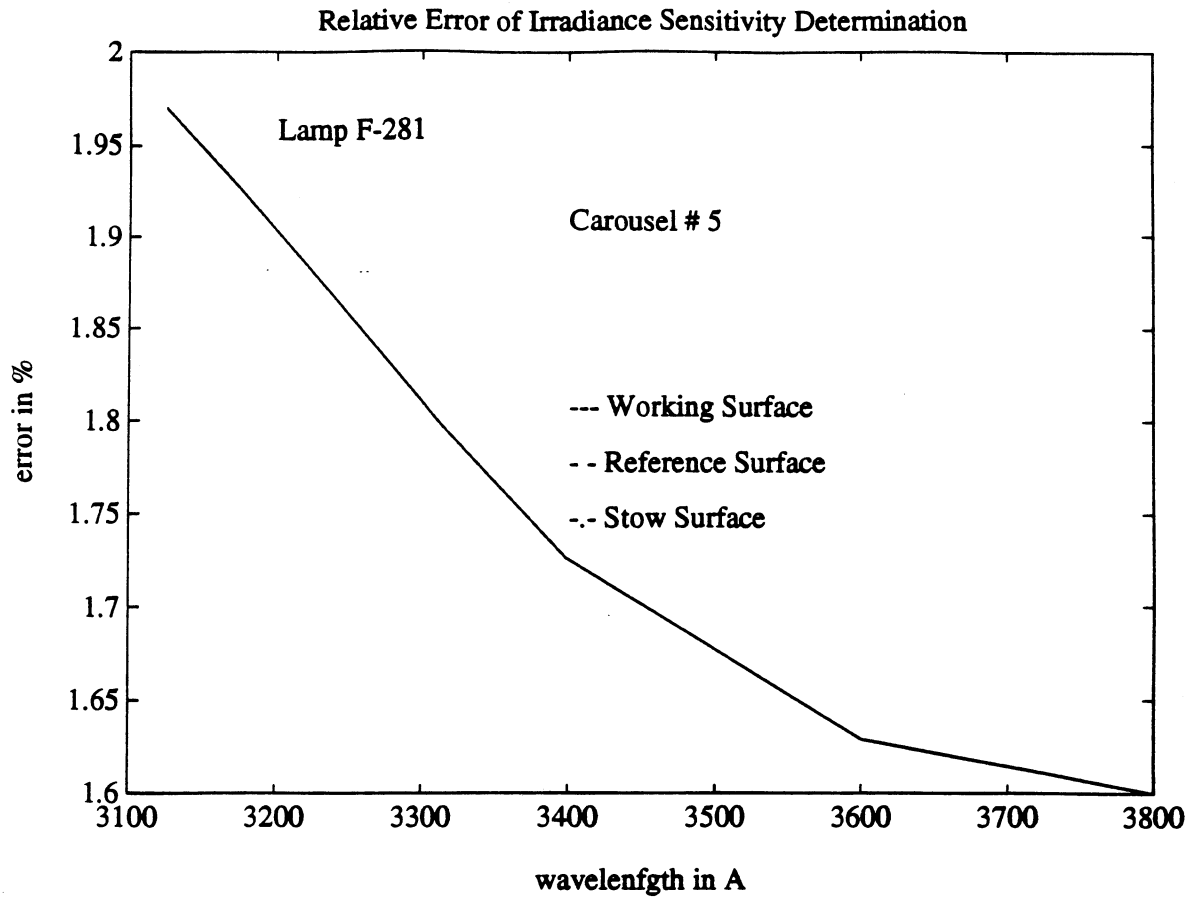

Relative Error of Irradiance Sensitivity Determination
Lamp F-281
Carousel # 5
--- Working Surface
- - Reference Surface
-.- Stow Surface
error in %
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
3100
3200
3300
3400
3500
3600
3700
3800
wavelenfgth in A

Fig. 16.c

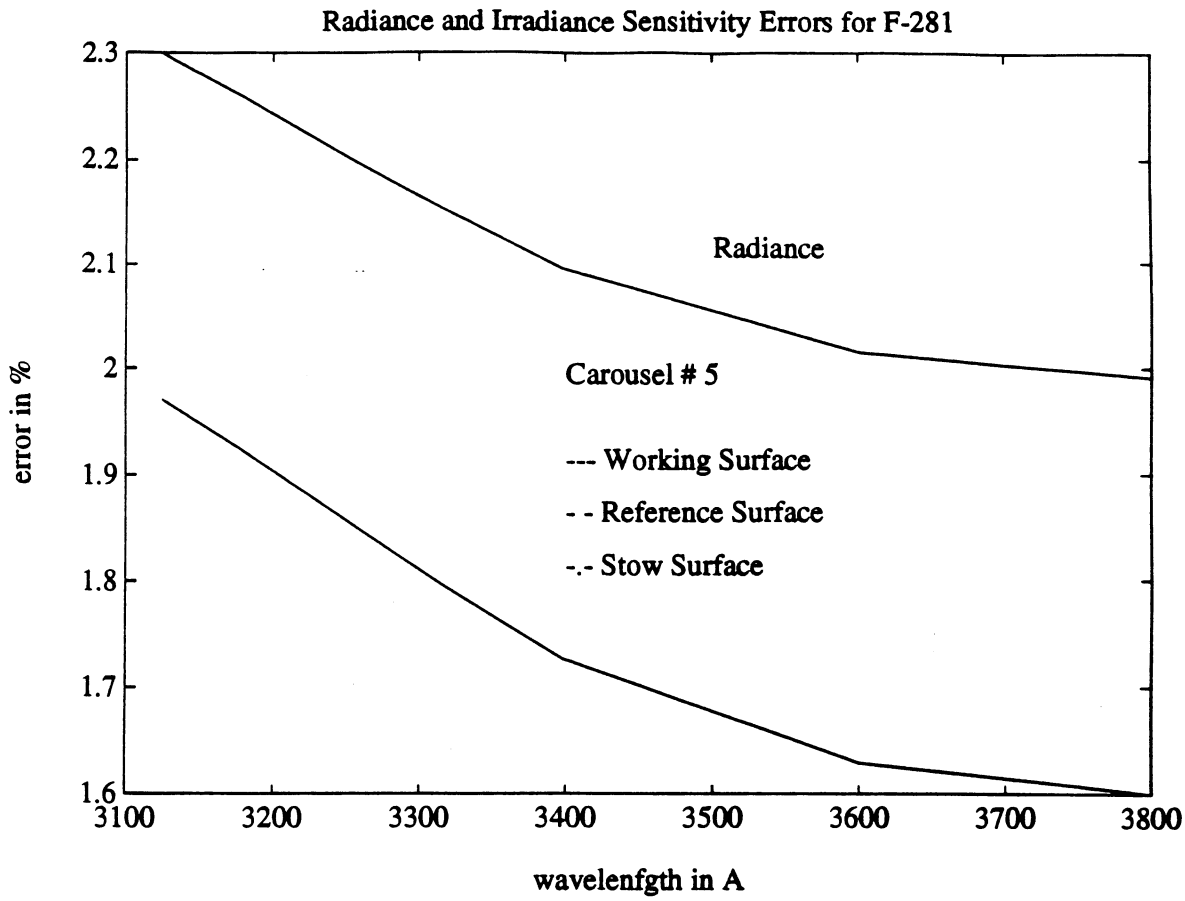

Radiance and Irradiance Sensitivity Errors for F-281
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
error in %
3100
3200
3300
3400
3500
3600
3700
3800
wavelenfgth in A
Radiance
Carousel # 5
--- Working Surface
- - Reference Surface
-.- Stow Surface

Fig. 17

Appendix I

APPENDIX I
DATA SHEET

for 10.2 b

TOMS Module DESCRIPTION Bandpass and Resolution

S/N 001 TEST OPERATOR Robert E Haring DATE 12-13-90

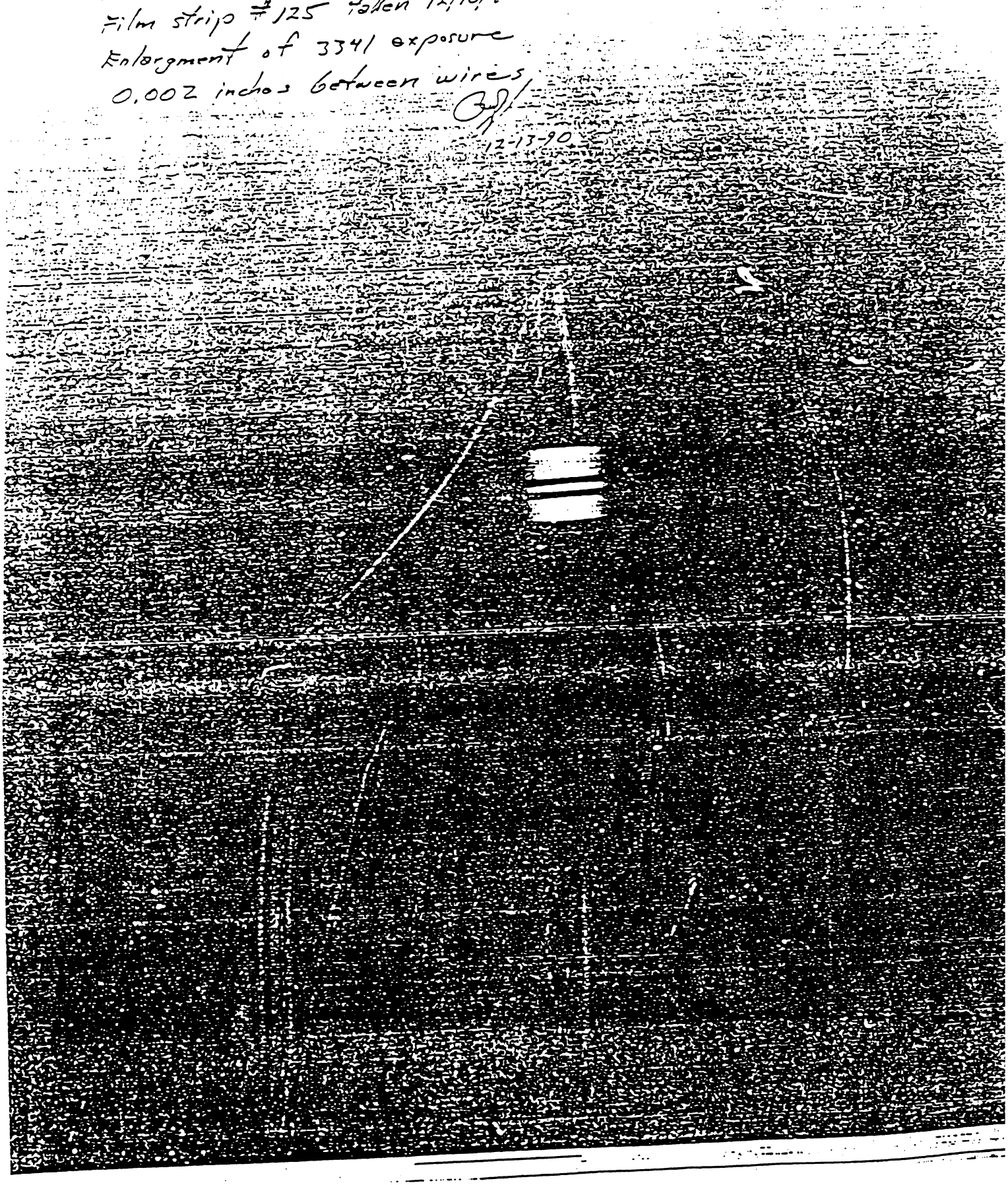
QA [illegible] DATE 12-13-90

TEST PARA		DESCRIPTION		ACCEPTANCE CRITERIA	TEST RESULTS	QA
			λ			
8.1		Bandpass	3125 Å	9 Å to 13 Å	9.4	
			3312 Å	9 Å to 13 Å	10.0	
			3175 Å	10 Å to 13 Å	10.4	
			3398 Å	10 Å to 13 Å	10.2	
			3600 Å	10 Å to 13 Å	10.3	
			3800 Å	10 Å to 13 Å	10.6	
8.2		Resolution		2 Å or Better	Pass	
8.3		Accuracy (and coverage per para. 6.1)	3125 Å	±1.5 Å	-1.5	
			3312 Å	±1.5 Å	-0.5	
			3175 Å	±1.5 Å	-0.6	
			3398 Å	±1.5 Å	-0.6	
			3600 Å	±2.5 Å	0.0	
			3800 Å	±2.5 Å	+1.5	

BECKMAN® Advanced Technology Operations Beckman Instruments, Inc.	CODE IDENT NO. 53110	SIZE A	DATA SHEET 552960	REV
			SHEET 6 of 6	

X27-73.38

TOMS FM-2
Resolution and Bandpass
Performance Test Procedure #55-960
Film strip #125 taken 12/10/90
Enlargment of 3341 exposure
0.002 inches between wires
12-13-90



12/13/90
file dn901213.wks
R. Haring

Table II. Wavelength & Bandpass Summary

Film strip 118

	Actual Wavelength	Bandwidth	
3125	3123.29	9.38	
3175	3174.38	10.41	2
3312	3311.47	10.50	3
3398	3397.45	10.14	4
3600	3600.00	10.32	5
3800	3801.40	10.58	6

Film strip 119

Actual Wavelength	Bandwidth
3123.64	9.44
3174.42	10.47
3311.48	9.56
3397.38	10.21
3600.05	10.27
3801.67	10.61

$= \frac{1}{2}$ (strip 118 + strip 119)

Spec.	Actual Wavelength	delta
3125	3123.5	-1.5
3175	3174.4	-0.6
3312	3311.5	-0.5
3398	3397.4	-0.6
3600	3600.0	0.0
3800	3801.5	1.5

Spec.	Bandwidth	delta
10.0	9.4	-0.6
10.0	10.4	0.4
10.0	10.0	0.0
10.0	10.2	0.2
10.0	10.3	0.3
10.0	10.6	0.6

Appendix II

MATLAB programs : data listings

MATLAB PROGRAMS USED FOR CALIBRATION

```
%%% fm_cal2.m
%%
%%%  summary of FM-2 calibration
%%
%%   update version according to IOM from R.Haring 10/2/91
%%
%%   added data from lost file : Diff # 5, F-281, RCL320

%%  wavelenth in A

     L=[3800 3600 3312 3125 3398 3175];

%%  sort wavelength in increasing order

    [L2,Lk] = sort(L);

%% Irradiance values for different diffusers and different lamps

%%!!  IC.. files use aluminum diffuser
%%!!  there are two carousels #4 and #5
%%!!  (#5 is used for the flight set )
%%!!   in each IC... file
%%!!   the first row corressponds to carousel # 4
%%!!   the second row             to carousel # 5

%%  for all file ...vc stands for std in %

ICR_239 = [15884.94 10823.22  4561.26 2266.17 6184.45 2793.03
           18347.06 12462.14  5264.32 2611.68 7099.33 3219.51];

ICR_239vc = [0.65 0.79 1.17 1.69 1.02 1.50
             0.59 0.73 1.06 1.53 0.98 1.39];

ICR_281 = [14161.20  9573.21 3998.26 1966.34 5419.49 2425.09
           16174.20 10912.46 4545.24 2233.21 6171.66 2759.63];

ICR_281vc = [0.68 0.82 1.27 1.77 1.11 1.65
             0.66 0.79 1.19 1.66 1.02 1.52 ];

ICR_207 = [12002.47 8021.94 3299.45 1604.67 4494.60 1985.59
           13658.15 9134.19 3756.49 1821.66 5112.06 2256.75];

ICR_207vc = [0.74 0.90 1.36 2.04 1.22 1.75
             0.70 0.82 1.22 1.84 1.12 1.62];

ICS_239 = [16421.93 11160.46 4694.64 2330.63 6353.31 2874.90
           18688.70 12712.28 5359.47 2660.22 7228.92 3273.67];


ICS_239vc = [0.64 0.76 1.13 1.67 1.02 1.53
```

```
            0.59 0.72 1.09 1.53 0.94 1.41];

ICS_281 = [14880.28 10028.43 4176.54 2052.97 5677.34 2534.78
           16469.94 11118.63 4632.10 2278.61 6279.13 2811.22];

ICS_281vc = [0.69 0.79 1.24 1.62 1.10 1.56
             0.64 0.77 1.23 1.64 1.02 1.45];

ICS_207 = [12586.91  8396.07 3450.51 1674.98 4706.37 2074.51
           13895.83  9306.63 3820.29 1856.93 5199.58 2296.26];

ICS_207vc = [0.72 0.84 1.31 1.90 1.16 1.68
             0.70 0.85 1.23 1.82 1.10 1.62];

ICW_239 = [16754.08 11395.87 4807.63 2389.95 6504.48 2944.87
           18481.51 12576.17 5309.24 2640.31 7169.64 3252.39];

ICW_239vc = [0.64 0.76 1.14 1.69 1.02 1.47
             0.62 0.68 1.09 1.55 0.99 1.38];

ICW_281 = [14929.19 10082.88 4203.10 2070.73 5708.88 2556.26
           16299.31 11010.10 4592.41 2261.87 6235.10 2790.97];

ICW_281vc = [0.70 0.81 1.21 1.73 1.03 1.56
             0.66 0.76 1.18 1.71 1.03 1.52];

ICW_207 = [12638.95  8442.72 3471.12 1691.23 4728.11 2089.42
           13754.81  9216.49 3794.58 1845.12 5157.66 2278.00];

ICW_207vc = [0.70 0.86 1.35 1.85 1.20 1.76
             0.71 0.84 1.33 1.86 1.10 1.68];

%%% rearrange

    ICR_239   = ICR_239(:,Lk);
    ICR_239vc = ICR_239vc(:,Lk);
    ICR_281   = ICR_281(:,Lk);
    ICR_281vc = ICR_281vc(:,Lk);
    ICR_207   = ICR_207(:,Lk);
    ICR_207vc = ICR_207vc(:,Lk);

    ICS_239   = ICS_239(:,Lk);
    ICS_239vc = ICS_239vc(:,Lk);
    ICS_281   = ICS_281(:,Lk);
    ICS_281vc = ICS_281vc(:,Lk);
    ICS_207   = ICS_207(:,Lk);
    ICS_207vc = ICS_207vc(:,Lk);

    ICW_239   = ICW_239(:,Lk);
    ICW_239vc = ICW_239vc(:,Lk);
    ICW_281   = ICW_281(:,Lk);
    ICW_281vc = ICW_281vc(:,Lk);
```

```
    ICW_207    = ICW_207(:,Lk);
    ICW_207vc = ICW_207vc(:,Lk);

%%%%%%%%%%%%

%%  All RCL files used the same BaS diffuser

RCL_239 = [19193.97 13161.21 5625.07 2830.37 7572.67 3468.77
           19071.72 13080.19 5598.17 2812.38 7528.89 3448.32
           19030.19 13045.45 5581.00 2807.61 7507.90 3439.19
           19318.32 13241.93 5657.52 2833.43 7615.41 3486.72];

RCL_239vc  =[0.58 0.69 1.06 1.53 0.95 1.34
             0.58 0.70 1.05 1.51 0.92 1.36
             0.61 0.70 1.04 1.46 0.90 1.35
             0.58 0.70 1.04 1.49 0.92 1.32];

RCL_207 = [14439.38 9736.23 4059.36 1997.79 5511.47 2460.88
           14419.10 9727.82 4057.17 1995.73 5505.14 2460.09
           14508.72 9792.23 4080.06 2010.91 5544.48 2474.87
           14504.87 9770.33 4066.62 1994.36 5522.25 2463.35];

RCL_207vc =  [0.70 0.81 1.22 1.71 1.06 1.61
              0.70 0.79 1.19 1.73 1.07 1.61
              0.71 0.81 1.17 1.73 1.11 1.57
              0.70 0.82 1.15 1.75 1.06 1.60];

%!! the last row for RCL_281 came from the lost file RCL320

RCL_281 = [17141.24 11672.54 4930.33 2455.73 6674.72 3023.01
           17094.89 11638.63 4916.91 2451.86 6654.58 3013.47
           17092.56 11630.04 4917.84 2448.63 6654.17 3009.83
           17147.95 11668.81 4923.62 2445.09 6660.42 3014.65];

RCL_281vc = [0.63 0.76 1.11 1.59 0.93 1.40
             0.63 0.76 1.13 1.63 0.94 1.38
             0.64 0.75 1.16 1.61 0.92 1.45
             0.62 0.76 1.12 1.59 0.97 1.46];

     RCL_239 = RCL_239(:,Lk);
     RCL_207 = RCL_207(:,Lk);
     RCL_281 = RCL_281(:,Lk);

     RCL_239vc = RCL_239vc(:,Lk);
     RCL_207vc = RCL_207vc(:,Lk);
     RCL_281vc = RCL_281vc(:,Lk);

%%%% data for reflectance curve fitting

%%      L2 = [3125 3175 3312 3398 3600 3800];

%% Bandpass in A as function of L2
```

```
    BW1 = [9.38 10.41 10.50 10.14 10.32 10.58];     % film 118
    BW2 = [9.44 10.47  9.56 10.21 10.27 10.61];     % film 119

    BW  = [9.4 10.4 10.0 10.2 10.3 10.6];           %
%%     BW=(BW1+BW2)/2;

%%% Goniometric Reflectance for Pitch=0
%%%  Surfaces R W and S for case 5

     Yaw = [120 100 80 60 50 40];

%%% wavelength across rows Yaw along column

     R5 = [0.45866 0.46430 0.47603 0.47789 0.48244 0.48918
           0.36999 0.37774 0.38556 0.38768 0.39290 0.39914
           0.24591 0.25037 0.25585 0.25757 0.26137 0.26536
           0.17313 0.17682 0.18086 0.18185 0.18461 0.18726
           0.15417 0.15739 0.16059 0.16149 0.16395 0.16630
           0.14262 0.14521 0.14835 0.14933 0.15136 0.15353];

     W5 = [0.46539 0.47225 0.48135 0.48426 0.48990 0.49433
           0.37154 0.37853 0.38655 0.38948 0.39531 0.39979
           0.24551 0.25025 0.25590 0.25830 0.26239 0.26515
           0.17405 0.17698 0.18125 0.18292 0.18567 0.18755
           0.15462 0.15745 0.16077 0.16210 0.16473 0.16614
           0.14194 0.14447 0.14741 0.14854 0.15084 0.15191];

     S5 = [0.46781 0.47385 0.48404 0.48541 0.49039 0.49827
           0.37478 0.37985 0.38893 0.39064 0.39629 0.40367
           0.24749 0.25005 0.25636 0.25796 0.26169 0.26649
           0.17448 0.17655 0.18112 0.18204 0.18512 0.18806
           0.15494 0.15721 0.16118 0.16199 0.16435 0.16710
           0.14122 0.14367 0.14699 0.14792 0.15022 0.15246];

%%% correct using absolute values for Yaw=50 dg

 W5_abs = [0.15517 0.15754 0.16105 0.16215 0.16471 0.16556];

 R5_abs = [0.15701 0.15935 0.16261 0.16410 0.16583 0.16838];

 S5_abs = [0.15777 0.15925 0.16309 0.16420 0.16616 0.16907];

%%
%%% FEL lamp Calibration Data
%%
LH = [250 260 270 280 290 300 310 320 330 340 350 370 400];  %% wavelength
LH=10*LH;

%%%   FEl in micro watt/(cm^2*nm)
%%    F-207   F-239   F-281
H = [0.017   0.0227  0.019
     0.0302  0.0393  0.0332
```

```
     0.0503  0.0645  0.055
     0.0792  0.1     0.0863
     0.1193  0.15    0.13
     0.1739  0.216   0.188
     0.2451  0.301   0.263
     0.3353  0.41    0.36
     0.448   0.545   0.481
     0.5862  0.708   0.628
     0.7526  0.903   0.804
      NaN    1.4     1.25
     2.049   2.39    2.17];

H = H*1.e-6;        % now H is in watt/(cm^2*nm)

%%% error in H
    LH_err =[2500 3500 6546];
    He_239 = [ 2.23 1.35 1.01      % in %
               1.0  0.7  0.4];
    He_239 = He_239/100;

    He_281 = [2.23 1.35 1.01        % in %
              1.0  0.7  0.4];
    He_281 = He_281/100;
%%

%%%   BRDF
%%%  each row corresponds to a wavelength
%%%   [ msr_avg at 100%, msr_avg(1),...,msr_avg(3),msr_avg at 100%]
%%%%
%%     y_corr=y_msr*exp(y_corr*a)) --> log(z)=z*a*y_msr
%%     where z=y_corr/y_msr
%%
%%     BRDF = (y_corr/y_corr100%)*g

       g = 78.7424;      %% geometry factor
       a = 9.5e-9;       %% pulse dead time

    p3 = [5667083.2 22907.901 22985.718 22957.692 5662637.2
          7935912.8 33952.708 33327.764 33290.559 7943591.2
          5382316.2 22775.852 22896.197 22861.674 5395686.6
          6304242.4 26901.008 26930.944 26955.422 6310966.6
          6208617.6 26908.385 26762.843 26880.980 6217236.0
          7292168.2 32159.863 32215.127 32289.431 7283978.4];

%!!  dark current : need to be subtracted wrom the measurements

     dc3 = [284.1 362.2
            301.0 281.2
            436.1 556.2
            249.5 228.2
            238.1 215.1
            249.2 486.9];
```

```
 dc3 = mean(dc3')';     % average between start and end

for i=1:6
   y_msr(i)  = mean(p3(i,2:4))-dc3(i);
   y_full(i) = 0.5*(p3(i,1)+p3(i,5))-dc3(i);
   z1(i) = myfzero('lgroot',a*y_msr(i),1);
   z2(i) = myfzero('lgroot',a*y_full(i),1);
end;

BRDF3 = (y_msr.*z1)./(y_full.*z2);
BRDF3 = g*BRDF3;                          % geometry correction

p6 = [5689256.2 22477.891 22464.290 22421.580 5684048.6
      7655081.2 31220.564 31158.998 31227.708 7634126.8
      7477739.8 31111.848 31069.087 31041.768 7458408.8
      6811106.8 29110.353 29032.591 29075.480 6875381.4
      6255831.0 26512.860 26582.337 26549.906 6243352.0
      7385619.0 31977.927 32039.914 32013.386 7386142.0 ];

%!!  dark current : need to be subtracted wrom the measurements

dc6 = [251.7 246.3
       269.4 311.1
       431.3 336.8
       496.0 273.5
       364.9 362.4
       325.7 322.6];
dc6 = mean(dc6')';


for i=1:6
   y_msr(i) = mean(p6(i,2:4))-dc6(i);
   z1(i) = myfzero('lgroot',a*y_msr(i),1);
   y_full(i) = 0.5*(p6(i,1)+p6(i,5))-dc6(i);
   z2(i) = myfzero('lgroot',a*y_full(i),1);
end;

BRDF6 = (y_msr.*z1)./(y_full.*z2);
BRDF6 = g*BRDF6;                          % geometry correction

%%%%
%%%%%%    end of file
```

```
%%%% ref_cal2.m
%%
%%  calibrate reflectance using fm_calib.m data
%%
%%  update according to IOM from R.Haring, 10/2/91
%%
%%  all correctins are marked as % !!

%%  define constants

%!!    CF = cos(50*pi/180);          % cos of diffuser view angle
    CF = cos(40*pi/180);          % cos of diffuser view angle
    OMEGA=(3*pi/180).^2;          % field of view in sterad
    A = (0.26)^2;                 % entrance pupil area in cm^2

%% correct goniometric reflectance into absolute
%% using absolute reflectance at Yaw=50

    i50 = find(Yaw==50);

    cR5 = R5_abs./R5(i50,:);
    cW5 = W5_abs./W5(i50,:);
    cS5 =  S5_abs./S5(i50,:);            % correction is a function of
wavelength

    n=length(Yaw);
    for i=1:n
       R5ref(i,:) = R5(i,:).*cR5;
       W5ref(i,:) = W5(i,:).*cW5;
       S5ref(i,:) = S5(i,:).*cS5;
    end;

%%  we need reflectance at yaw=90 which was not measured
%%  therefore,  fit cubic spline into these data

   yaw = 40:120;
    for i=1:6
      Y=R5ref(:,i);
      R5all(:,i) = spline(Yaw',Y,yaw');
      Y=W5ref(:,i);
      W5all(:,i) = spline(Yaw',Y,yaw');
      Y=S5ref(:,i);
      S5all(:,i) = spline(Yaw',Y,yaw');
   end;

%% find absolute reflectance at yaw=90 (function of wl)
%% these data will be used as BRDF for irradiance calibration

   i90 = find(yaw==90);
   BRDFr=R5all(i90,:);
   BRDFw=W5all(i90,:);
   BRDFs=S5all(i90,:);
```

```
%%
%%%  Now reduce H(l) data
%%%  FEL was measured for several frequencies but not for L2
%%%   Fit 3d order polinomial into FEL data

     yH=H(find(~isnan(H(:,1))),1);
     xH=LH(find(~isnan(H(:,1))));
     pH_207=polyfit(xH,yH',3);

     yH=H(:,2);
     pH_239 = polyfit(LH,yH',3);

     yH=H(:,3);
     pH_281 = polyfit(LH,yH',3);

%% now compute FEL for each lamp for needed wavelengths

     H_207 = polyval(pH_207,L2);
     H_239 = polyval(pH_239,L2);
     H_281 = polyval(pH_281,L2);

%%  now find relative error of approximation.
%%  do not use lamp F-207 since it does not have all the frequencies

    h_239 = polyval(pH_239,LH);
    h_281 = polyval(pH_281,LH);

    dH_239 = (h_239-H(:,2)')./H(:,2)';
    dH_281 = (h_281-H(:,3)')./H(:,3)';

%%  retain only data for the wavelengths of interest

    dH_239 = dH_239(7:13);
    dH_281 = dH_281(7:13);

%%
%%%%%%%% Radiance Calibration %%%%%%%%%%%%
%%%
%%%     Rs(lambda) = I(lambda)/[BRDF(l)*cos(F)*H(l)*BW(l)*A*OMEGA]
%%%
%%%   convert BW into nm

        BW = 0.1*BW;

        BRDF = 0.5*(BRDF6+BRDF3);
        Rs_239 = mean(RCL_239)./(BRDF.*BW.*H_239*CF*A*OMEGA);
        Rs_281 = mean(RCL_281)./(BRDF.*BW.*H_281*CF*A*OMEGA);
        Rs_207 = mean(RCL_207)./(BRDF.*BW.*H_207*CF*A*OMEGA);

%%%
%%%%%%%%%% Iradiance Calibration  %%%%%%%%%%%
%%%
```

```
%%%     Ri(lambda) = I(lambda)/[BRDF(l)*cos(F)*H(l)*BW(l)*A*OMEGA]
%%%
%%!!  compute irradiance separately for car. #4 and #5
%%!!  car.#4 is in the first row of IC..
%%!!  car.#5 is in the second row of IC..

%%!!  carousel # 4

        Ri_239_4 = ICR_239(1,:)./(BRDFr.*BW.*H_239*CF*A*OMEGA);
        Ri_281_4 = ICR_281(1,:)./(BRDFr.*BW.*H_281*CF*A*OMEGA);
        Ri_207_4 = ICR_207(1,:)./(BRDFr.*BW.*H_207*CF*A*OMEGA);

        Wi_239_4 = ICW_239(1,:)./(BRDFw.*BW.*H_239*CF*A*OMEGA);
        Wi_281_4 = ICW_281(1,:)./(BRDFw.*BW.*H_281*CF*A*OMEGA);
        Wi_207_4 = ICW_207(1,:)./(BRDFw.*BW.*H_207*CF*A*OMEGA);

        Si_239_4 = ICS_239(1,:)./(BRDFs.*BW.*H_239*CF*A*OMEGA);
        Si_281_4 = ICS_281(1,:)./(BRDFs.*BW.*H_281*CF*A*OMEGA);
        Si_207_4 = ICS_207(1,:)./(BRDFs.*BW.*H_207*CF*A*OMEGA);

%%% compute difference between radiance and irradiance
%%% for the lamp 281 only

    dw_281_4 = 100*(Rs_281-Wi_281_4)./Rs_281;
    dr_281_4 = 100*(Rs_281-Ri_281_4)./Rs_281;
    ds_281_4 = 100*(Rs_281-Si_281_4)./Rs_281;
    d_281_4  = [dw_281_4; dr_281_4; ds_281_4];

%%%!!  carousel # 5

        Ri_239_5 = ICR_239(2,:)./(BRDFr.*BW.*H_239*CF*A*OMEGA);
        Ri_281_5 = ICR_281(2,:)./(BRDFr.*BW.*H_281*CF*A*OMEGA);
        Ri_207_5 = ICR_207(2,:)./(BRDFr.*BW.*H_207*CF*A*OMEGA);

        Wi_239_5 = ICW_239(2,:)./(BRDFw.*BW.*H_239*CF*A*OMEGA);
        Wi_281_5 = ICW_281(2,:)./(BRDFw.*BW.*H_281*CF*A*OMEGA);
        Wi_207_5 = ICW_207(2,:)./(BRDFw.*BW.*H_207*CF*A*OMEGA);

        Si_239_5 = ICS_239(2,:)./(BRDFs.*BW.*H_239*CF*A*OMEGA);
        Si_281_5 = ICS_281(2,:)./(BRDFs.*BW.*H_281*CF*A*OMEGA);
        Si_207_5 = ICS_207(2,:)./(BRDFs.*BW.*H_207*CF*A*OMEGA);

%%% compute difference between radiance and irradiance
%%% for the lamp 281 only

    dw_281_5 = 100*(Rs_281-Wi_281_5)./Rs_281;
    dr_281_5 = 100*(Rs_281-Ri_281_5)./Rs_281;
    ds_281_5 = 100*(Rs_281-Si_281_5)./Rs_281;
    d_281_5  = [dw_281_5; dr_281_5; ds_281_5];

%%
%%%%   end of file
```

```
%% cal_plt2.m
%%%
%%%  make all the plots for FM-2
%%   use results of fm_cal2.m, ref_cal2.m
%%

%%% Fig.1 BRDF(3) and BRDF(6)


y1=BRDF3; y2=BRDF6; y3=0.5*(y1+y2);
plot(L2,y1,'--r',L2,y1,'*',L2,y2,'--g',L2,y2,'o',L2,y3,'-b')
title('BaSO4 BRDF for Area 3 and Area 6');
xlabel('wavelength A')
ylabel('BRDF str-1');
text(3500,0.306,'Area 6');
text(3200,0.310,'Area 3');
text(3500,0.313,'Average');
pause;
if DOMETA meta brdf.met; end;


%%% Fig.2  bandwidth

plot(L2,BW,'-r',L2,BW,'o')
title('Measured Bandwidth ');
xlabel('wavelength A')
ylabel('Bandwidth in A');
%%text(3350,9.6,'Film 119');
%%text(3350,10.5,'Film 118');
pause;
if DOMETA meta bandwidz.met; end;

%%% Fig.3 cubic fit for lamp FEL

ll=LH(1):2:LH(13);
y1=polyval(pH_207,ll);
y2=polyval(pH_239,ll);
y3=polyval(pH_281,ll);

yH=H(find(~isnan(H(:,1))),1);
plot(ll,y1,'-r',xH,yH,'*',ll,y2,'--g',LH,H(:,2),'o',ll,y3,'-.w',LH,H(:,3
),'x')
title('Cubic Fit into FEL Lamp Data');
ylabel('Spectral Irradiance w/cm-2*nm')
xlabel('wavelength in A');
text(2600,2.0e-6,'--- F-207');
text(2600,1.8e-6,'- - F-239');
text(2600,1.6e-6,'-.- F-281');
pause;
if DOMETA meta fel_lamp.met; end;

%%% Fig. 4 Radiance for different lamps
```

```
I1=mean(RCL_207);
I2=mean(RCL_239);
I3=mean(RCL_281);
plot(L2,I1,'-r',L2,I2,'--g',L2,I3,'-.w')
title('Average Normalized Radiance Counts');
ylabel('Spectral Radiance in normalized counts')
xlabel('wavelength in A');
text(3200,1.60e+4,'--- F-207');
text(3200,1.45e+4,'- - F-239');
text(3200,1.30e+4,'-.- F-281');
pause;
if DOMETA meta radians.met; end;


%%%% Fig... Radiance measured during different sessions

plot(L2,RCL_207')
title('Measured Radiance for F-207 at Different Sessions');
ylabel('Spectral Radiance in normalized counts')
xlabel('wavelength in A');
pause;
if DOMETA meta rad207.met; end;

plot(L2,RCL_239')
title('Measured Radiance for F-239 at Different Sessions');
ylabel('Spectral Radiance in normalized counts')
xlabel('wavelength in A');
pause;
if DOMETA meta rad239.met; end;

plot(L2,RCL_281')
title('Measured Radiance for F-281 at Different Sessions');
ylabel('Spectral Radiance in normalized counts')
xlabel('wavelength in A');
pause;
if DOMETA meta rad281.met; end;


%%% Fig. 6a  Cubic spline fit for Absolute Reflectance vs yaw
%%% at l=3125 A.

x=yaw; y1=R5all(:,1); y2=W5all(:,1); y3=S5all(:,1);
x0=Yaw; y10=R5ref(:,1); y20=W5ref(:,1); y30=S5ref(:,1);
plot(x,y1,'--r',x0,y10,'*',x,y2,'-g',x0,y20,'o',x,y3,'-.w',x0,y30,'x')
title('Cubic Spline Fit into Reflectance Data');
ylabel('Absolute Reflectance  str-1')
xlabel('Yaw in dg');
text(50,0.46,'Carousel ser. num. 5');
text(75,0.43,'Pitch  = 0 dg');
text(75,0.40,'lambda = 3125 A')
text(50, 0.35,'--- Working Surface');
text(50, 0.32,'- - Reference Surface');
```

```
text(50, 0.29,'-.- Stow Surface');
pause;
if DOMETA meta abs_ref.met; end;

%%% Fig. 6b. Abs refl for working surface for all temperature

plot(yaw,W5all);
title('Cubic Spline Fit into Reflectance Data for Working Surface');
ylabel('Absolute Reflectance  str-1')
xlabel('Yaw in dg');
text(50,0.46,'Carousel ser. num. 5');
text(75,0.40,'Pitch  = 0 dg');
text(75,0.37,'all lambda')
pause;
if DOMETA meta ref_work.met; end;

%%%%%   radiance sensitivity for all lamps
plot(L2,Rs_207,'-r',L2,Rs_239,'--g',L2,Rs_281,'-.w')
title('Radiance Sensitivity for All Lamps');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3500,2.00e14,'--- Lamp F-207');
text(3500,1.95e14,'- - Lamp F-239');
text(3500,1.90e14,'-.- Lamp F-281');
text(3200,2.45e14,'Working surface');
pause;
if DOMETA meta radsens.met; end;

%%
%%%%%%%    carousel # 4  %%%%%%%%%%%%%%%%%%%%

%%%% Fig. 7a, 7b, 7c  Irradiance for F-207, F-239, 281

y1=ICW_207(1,:); y2=ICR_207(1,:); y3=ICS_207(1,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-207 ');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,13000,'Carousel ser. num. 4');
text(3200,11000,'--- Working Surface');
text(3200,10000,'- - Reference Surface');
text(3200,9000,'-.- Stow Surface');
pause;
if DOMETA meta irr207_4.met; end;

y1=ICW_239(1,:); y2=ICR_239(1,:); y3=ICS_239(1,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-239 ');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
```

```
text(3200,16000,'Carousel ser. num. 4');
text(3200,13000,'--- Working Surface');
text(3200,12000,'- - Reference Surface');
text(3200,11000,'-.- Stow Surface');
pause;
if DOMETA meta irr239_4.met; end;

y1=ICW_281(1,:); y2=ICR_281(1,:); y3=ICS_281(1,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-281');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,14000,'Carousel ser. num. 4');
text(3200,11000,'--- Working Surface');
text(3200,10000,'- - Reference Surface');
text(3200, 9000,'-.- Stow Surface');
pause;
if DOMETA meta irr281_4.met; end;

y1=ICW_207(1,:); y2=ICW_239(1,:); y3=ICW_281(1,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for Working Surface for all Lamps');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,16000,'Carousel ser. num. 4');
text(3200,12000,'--- Lamp F-207');
text(3200,11000,'- - Lamp F-239');
text(3200,10000,'-.- Lamp F-281');
pause;
if DOMETA meta irr_w_4.met; end;

%%%%% resulted plots of radiance and irradiance for each lamp

plot(L2,Rs_207,'-r',L2,Wi_207_4,'-g',L2,Ri_207_4,'--b',L2,Si_207_4,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-207');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3200,2.05e14,'Radiance ->');
text(3450,1.90e14,'Irradiance for Carousel # 4');
text(3500,1.60e14,'--- Working surface');
text(3500,1.55e14,'- - Reference surface');
text(3500,1.50e14,'-.- Stow surface');
pause;
if DOMETA meta rir207_4.met; end;

plot(L2,Rs_239,'-r',L2,Wi_239_4,'-g',L2,Ri_239_4,'--b',L2,Si_239_4,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-239');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3180,2.25e14,'Radiance ->');
```

```
text(3450,2.15e14,'Irradiance for Carousel # 4');
text(3500,1.80e14,'--- Working surface');
text(3500,1.75e14,'- - Reference surface');
text(3500,1.70e14,'-.- Stow surface');
pause;
if DOMETA meta rir239_4.met; end;

plot(L2,Rs_281,'-r',L2,Wi_281_4,'-g',L2,Ri_281_4,'--b',L2,Si_281_4,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-281');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3150,2.2e14,'Radiance ->');
text(3450,2.12e14,'Irradiance for Carousel # 4');
text(3500,1.80e14,'--- Working surface');
text(3500,1.75e14,'- - Reference surface');
text(3500,1.70e14,'-.- Stow surface');
pause;
if DOMETA meta rir281_4.met; end;


%%% plot relative difference between radiance and irradiance

plot(L2,d_281_4)
title('Difference between Radiance and Irradiance ')
xlabel('wavelength in A')
ylabel('Relative difference in %')
text(3400,23.0,'Lamp F-281');
text(3400,22.5,'Carousel # 4')
text(3400,21.2,'Reference surface')
text(3400,19.2,'Stow surface')
text(3400,16.4,'Working surface')
pause
if DOMETA meta rad_ir_4.met; end


%%
%%%%%%%    carousel # 5  %%%%%%%%%%%%%%%%%%%

%%%% Fig. 7a, 7b, 7c  Irradiance for F-207, F-239, 281

y1=ICW_207(2,:); y2=ICR_207(2,:); y3=ICS_207(2,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-207 ');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,13000,'Carousel ser. num. 5');
text(3200,11000,'--- Working Surface');
text(3200,10000,'- - Reference Surface');
text(3200,9000,'-.- Stow Surface');
pause;
if DOMETA meta irr207_5.met; end;
```

```
y1=ICW_239(2,:); y2=ICR_239(2,:); y3=ICS_239(2,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-239 ');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,18000,'Carousel ser. num. 5');
text(3200,14000,'--- Working Surface');
text(3200,13000,'- - Reference Surface');
text(3200,12000,'-.- Stow Surface');
pause;
if DOMETA meta irr239_5.met; end;

y1=ICW_281(2,:); y2=ICR_281(2,:); y3=ICS_281(2,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for All Surfaces : Lamp F-281');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,16000,'Carousel ser. num. 5');
text(3200,12000,'--- Working Surface');
text(3200,11000,'- - Reference Surface');
text(3200,10000,'-.- Stow Surface');
pause;
if DOMETA meta irr281_5.met; end;

y1=ICW_207(2,:); y2=ICW_239(2,:); y3=ICW_281(2,:);

plot(L2,y1,'-r',L2,y2,'--g',L2,y3,'-.w');
title('Irradiance for Working Surface for all Lamps');
ylabel('Irradiance in normalized counts')
xlabel('Wavelength in A');
text(3200,16000,'Carousel ser. num. 5');
text(3200,12000,'--- Lamp F-207');
text(3200,11000,'- - Lamp F-239');
text(3200,10000,'-.- Lamp F-281');
pause;
if DOMETA meta irr_w_5.met; end;

%%%%% resulted plots of radiance and irradiance for each lamp

plot(L2,Rs_207,'-r',L2,Wi_207_5,'-g',L2,Ri_207_5,'--b',L2,Si_207_5,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-207');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3150,1.95e14,'Radiance ->');
text(3450,2.07e14,'Irradiance for Carousel # 5');
text(3500,1.85e14,'--- Working surface');
text(3500,1.80e14,'- - Reference surface');
text(3500,1.75e14,'-.- Stow surface');
pause;
if DOMETA meta rir207_5.met; end;
```

```
plot(L2,Rs_239,'-r',L2,Wi_239_5,'-g',L2,Ri_239_5,'--b',L2,Si_239_5,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-239');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3150,2.24e14,'Radiance ->');
text(3450,2.35e14,'Irradiance for Carousel # 5');
text(3500,2.15e14,'--- Working surface');
text(3500,2.10e14,'- - Reference surface');
text(3500,2.05e14,'-.- Stow surface');
pause;
if DOMETA meta rir239_5.met; end;

plot(L2,Rs_281,'-r',L2,Wi_281_5,'-g',L2,Ri_281_5,'--b',L2,Si_281_5,'-.w')
title('Radiance and Irradiance Sensitivity : Lamp F-281');
ylabel('counts/watt')
xlabel('wavelength in A');
text(3150,2.2e14,'Radiance ->');
text(3450,2.32e14,'Irradiance for Carousel # 5');
text(3500,2.10e14,'--- Working surface');
text(3500,2.05e14,'- - Reference surface');
text(3500,2.00e14,'-.- Stow surface');
pause;
if DOMETA meta rir281_5.met; end;


%%% plot relative difference between radiance and irradiance


plot(L2,d_281_5)
title('Difference between Radiance and Irradiance')
xlabel('wavelength in A')
ylabel('Relative difference in %')
text(3400,12.5,'Lamp F-281');
text(3400,12.0,'Carousel # 5')
text(3550,11.1,'Reference surface')
text(3400,10.5,'Stow surface')
text(3400,9.0,'Working surface')
pause
if DOMETA meta rad_ir_5.met; end

%%%%%%% end of file
```

MATLAB PROGRAMS FOR ERRORBAR COMPUTATION

```
%%% error2.m
%%  error bars for TOMS FM-2 calibration
%%
%%  corrected from errors.m taking into account IOM R.Haring 10/2/91
%%
%%  all corrections are marked as %!!

%%%  H errors are common for radiance and irradiance
%%%  According to NBS relative errors are the same for F-239 and F-281
%%%  Therefore, we use the same values for all lamps

%%%  first linearly interpolate errors for the frequencies of interest

%%  for wavelength < 3500
    dL=LH_err(2)-LH_err(1);
    dE=He_239(:,2)-He_239(:,1);
    for i=1:4
      Herr(:,i) = He_239(:,1)+dE*(L2(i)-LH_err(1))/dL;
    end;

%% for wavelength > 3500
    dL=LH_err(3)-LH_err(2);
    dE=He_239(:,3)-He_239(:,2);
    for i=5:6
      Herr(:,i) = He_239(:,2)+dE*(L2(i)-LH_err(2))/dL;
    end;

%%%  there is some error associated with cubic interpolation
%%%  use average for all frequencies

     Herr_interp_239 = mean(dH_239.*dH_239);
     Herr_interp_281 = mean(dH_281.*dH_281);

%%%  add NBS uncertainty and Transfer Uncertainty and interpolation errors
%%%  use lamp F-281 only

    Herr_full = Herr(1,:).^2 + Herr(2,:).^2 + Herr_interp_281;

%%% radiance sensitivity
%%
%%  there are 4 sets of samples each set has 20 major frames
%%  each major frame has 70 samples (minot frames)
%%  RCL_XXXvc is a std over whole data set = 20x70 points
%%  therefore, one could expect that err(RCL_XXX) = RCL_XXXvc/sqrt(70*20)
%%  However, the differences between averages of 4 sets
%%  are much larger than this number
%%    sigma/sqrt(70*20) = 0.04%
%%    max(RCL)-min(RCL) = 0.6 %
%%  this is from other factors such as
```

```
%%  lamp stability, temperature, bearing accuracy, etc.
%%  therefore, for RCL error use 0.5*(max(RCL)-min(RCL)) between the sets.

ss1 = 0.01*mean(RCL_207vc)/sqrt(70*20);
ss2_207 = 0.5*(max(RCL_207)-min(RCL_207))./mean(RCL_207);
RCL_207err = max([ss1;ss2_207]);

ss1 = 0.01*mean(RCL_239vc)/sqrt(70*20);
ss2_239 = 0.5*(max(RCL_239)-min(RCL_239))./mean(RCL_239);
RCL_239err = max([ss1;ss2_239]);

ss1 = 0.01*mean(RCL_281vc)/sqrt(70*20);
ss2_281 = 0.5*(max(RCL_281)-min(RCL_281))./mean(RCL_281);
RCL_281err = max([ss1;ss2_281]);
ss = ss/3;

BRDF_err = abs(BRDF3-BRDF6)/(BRDF3+BRDF6);
BRDF_err = BRDF_err.^2;

Rs_err = [ RCL_207err.^2+BRDF_err+Herr_full
           RCL_239err.^2+BRDF_err+Herr_full
           RCL_281err.^2+BRDF_err+Herr_full];

Rs_err  = sqrt(Rs_err)*100;     %% in per cent
Rs_ebar = 0.01*Rs_err.*[Rs_207;Rs_239;Rs_281];

%%%% irradiance sensitivity

%%  for itrradiance we have only one set of measurements
%%  therefore we cannot estimate long term variations
%%  we assume that they are the same as for the radiance

%% use carousel # 5 only

ss1 = 0.01*ICR_207vc(2,:)/sqrt(70*20);
ICR_207err = max([ss1;ss2_207]);
ss1 = 0.01*ICR_239vc(2,:)/sqrt(70*20);
ICR_239err = max([ss1;ss2_239]);
ss1 = 0.01*ICR_281vc(2,:)/sqrt(70*20);
ICR_281err = max([ss1;ss2_281]);

ss1 = 0.01*ICW_207vc(2,:)/sqrt(70*20);
ICW_207err = max([ss1;ss2_207]);
ss1 = 0.01*ICW_239vc(2,:)/sqrt(70*20);
ICW_239err = max([ss1;ss2_239]);
ss1 = 0.01*ICW_281vc(2,:)/sqrt(70*20);
ICW_281err = max([ss1;ss2_281]);

ss1 = 0.01*ICS_207vc(2,:)/sqrt(70*20);
ICS_207err = max([ss1;ss2_207]);
ss1 = 0.01*ICS_239vc(2,:)/sqrt(70*20);
ICS_239err = max([ss1;ss2_239]);
```

```
ss1 = 0.01*ICS_281vc(2,:)/sqrt(70*20);
ICS_281err = max([ss1;ss2_281]);

BRDFi_err = (0.3/100)^2;

Wi_207err = sqrt(ICW_207err.^2+BRDFi_err+Herr_full)*100;     % in per cent
Ri_207err = sqrt(ICR_207err.^2+BRDFi_err+Herr_full)*100;
Si_207err = sqrt(ICS_207err.^2+BRDFi_err+Herr_full)*100;

Wi_239err = sqrt(ICW_239err.^2+BRDFi_err+Herr_full)*100;     % in per cent
Ri_239err = sqrt(ICR_239err.^2+BRDFi_err+Herr_full)*100;
Si_239err = sqrt(ICS_239err.^2+BRDFi_err+Herr_full)*100;

Wi_281err = sqrt(ICW_281err.^2+BRDFi_err+Herr_full)*100;     % in per cent
Ri_281err = sqrt(ICR_281err.^2+BRDFi_err+Herr_full)*100;
Si_281err = sqrt(ICS_281err.^2+BRDFi_err+Herr_full)*100;

Ri_207ebar = 0.01*Ri_207err.*Ri_207_5;
Ri_239ebar = 0.01*Ri_239err.*Ri_239_5;
Ri_281ebar = 0.01*Ri_281err.*Ri_281_5;

Wi_207ebar = 0.01*Wi_207err.*Wi_207_5;
Wi_239ebar = 0.01*Wi_239err.*Wi_239_5;
Wi_281ebar = 0.01*Wi_281err.*Wi_281_5;

Si_207ebar = 0.01*Si_207err.*Si_207_5;
Si_239ebar = 0.01*Si_239err.*Si_239_5;
Si_281ebar = 0.01*Si_281err.*Si_281_5;


%%%
```

```
%% errtab.m
%%
%%  print out values for error bars of radiance and irradiance
%%
%%   use data generated by error2.m
%%

%%  error bars for Radiance sensitivity

str='Estimation error of Radiance Sensitivity in %'
% rows are for F-207, F-239, F-281
Rs_err

%%
str='Estimation error of Irradiance Sensitivity in %'
str='Carousel # 5'

% rows are for W R S
L2
str='F-207'
[Wi_207err;Ri_207err;Si_207err]
str='F-239'
[Wi_239err;Ri_239err;Si_239err]
str='F-281'
[Wi_281err;Ri_281err;Si_281err]

%%
```

```
%%% plt_err.m

%%% error of FEL approximation

ll=LH(7:13);
plot(ll,dH_239*100,'-r',ll, dH_281*100,'--g')
title('Relative Errors of FEL Approximation');
xlabel('wavelength in A');
ylabel('relative error in %');
text(3600,0.6,'--- Lamp F-239');
text(3600,0.4,'- - Lamp F-281');
pause;
if META meta fel_err.met; end;

%%% plot all relative errors for radiance

plot(L2,Rs_err);
title('Relative Error of Radiance Sensitivity Determination')
xlabel('wavelenfgth in A')
ylabel('error in %')
text(3400,2.35,'--- Lamp F-207')
text(3400,2.32,'- - Lamp F-239')
text(3400,2.29,'-.- Lamp F-281');
pause;
if META meta rad_err.met; end;


%%% irradiance errors

plot(L2,Wi_207err,'-r',L2,Ri_207err,'--g',L2,Si_207err,'-.w');
title('Relative Error of Irradiance Sensitivity Determination')
xlabel('wavelenfgth in A')
ylabel('error in %')
text(3200,2.00,'Lamp F-207');
text(3400,1.95,'Carousel # 5');
text(3400,1.90,'--- Working Surface')
text(3400,1.87,'- - Reference Surface')
text(3400,1.84,'-.- Stow Surface');
pause;
if META meta i207_err.met; end;

plot(L2,Wi_239err,'-r',L2,Ri_239err,'--g',L2,Si_239err,'-.w');
title('Relative Error of Irradiance Sensitivity Determination')
xlabel('wavelenfgth in A')
ylabel('error in %')
text(3400,2.05,'Lamp F-239');
text(3400,2.0,'Carousel # 5');
text(3500,1.950,'--- Working Surface')
text(3500,1.925,'- - Reference Surface')
text(3500,1.900,'-.- Stow Surface');
pause;
if META meta i239_err.met; end;
```

```
plot(L2,Wi_281err,'-r',L2,Ri_281err,'--g',L2,Si_281err,'-.w');
title('Relative Error of Irradiance Sensitivity Determination')
xlabel('wavelenfgth in A')
ylabel('error in %')
text(3200,1.95,'Lamp F-281');
text(3400,1.9,'Carousel # 5');
text(3400,1.8,'--- Working Surface')
text(3400,1.77,'- - Reference Surface')
text(3400,1.74,'-.- Stow Surface');
pause;
if META meta i281_err.met; end;

%% both radiance and irradiance

plot(L2,Rs_err(3,:),'-r',L2,Wi_281err,'-r',L2,Ri_281err,'--g',L2,Si_281e
rr,'-.w');
title('Radiance and Irradiance Sensitivity Errors for F-281')
xlabel('wavelenfgth in A')
ylabel('error in %')
text(3500,2.1,'Radiance');
text(3400,1.98,'Carousel # 5');
text(3400,1.9,'--- Working Surface')
text(3400,1.85,'- - Reference Surface')
text(3400,1.80,'-.- Stow Surface');
pause;
if META meta rad_irad.met; end;
```

Appendix III

Appendix I

Radiance & Irradaince Calibration Data Sheet

Test Conductor Robert E. Horing

Quality Control _____

Date 4-29-91

Radiance Calibration

Paragraph	Item	
8.4	BaSO4 Diffuser calibration completed	✓
8.6 a	Test configuration per figure 2	✓
	BaSO4 diffuser angle (degrees)	50 1/4°
	FEL target to diffuser distance	19.685
8.6 d	Setup & interconnections verified	✓
	Enter Test Log Book number & page reference for power up.	15.54 ✓ Log Book 8 pg 98
8.6 e	Perkin Elmer reference lamp serial number	F-239
	GFSC standard lamp serial number	207
	Calibrated FEL lamp serial number	281
8.6 f	83 DS current setting at 8.000 amps	_____

Note: Enter recorded radiance file information on the data file index sheets provided in appendix III.

Appendix III

Data File Index From: Radiance Calibration

REFER TO TEST PARAGRAPH 9.6 J TDIC ~~77536~~ 77536 sheet 1 of ___

P.E. 11/27/91 Paragraph 9.2

	DATE	TIME	LAMP	~~SURFACE~~	FILE NAME	DISK	FRAME NUMBERS
DEWKG	4/29/91		F-239		RCL300		20
GSFC	4/29/91		F-207		RCL301		20
PECM	4/29/91		F-281		RCL 302		20
	4/29/91		F-239		RCL 303		20
	4/29/91		F-207		RCL 304		20
	4/29/91		F-281		RCL 305		20
	4/29/91		F-239		RCL 306		20
	4/29/91		F-207		RCL 307		20
	4/29/91		F-281		RCL 308		20

Test Conductor [signature]
Quality Control ___
Date 4/29/91

WITNESSED P.E.

Appendix III

Data File Index From: Radiance Calibration

REFER TO TEST PARAGRAPH 9.6 J

sheet__of___

DATE	TIME	LAMP	SURFACE	FILE NAME	DISK	FRAME NUMBERS
~~5-3-91~~	~~22:20~~					
5-3-91	22:06	F-281	BaSO4	RCL 320		20
	~~22:48~~	~~F-207~~	~~BaSO4~~	~~RCL 321~~		~~20~~
	~~23:40~~	~~F-235~~	~~BaSO4~~	~~RCL 322~~		~~20~~
5-3-91	23:02	F-207	BaSO4	RCL 321		20

"D" Cluster
Robert
Crew Journal
TDR 77571

Test Conductor RCJ
Quality Control
Date 5/3/91
WITNESSED

Appendix III

Data File Index Form: Irradiance Calibration

Sheet 1 of __

Diffuser Carousel Serial Number (par. 9.7 b) #0100 (#4)

DATE	TIME	LAMP	SURFACE	FILE NAME	DISK	FRAME NUMBERS
~~5-3-91~~		~~F-239~~	~~Stow~~	~~ICS300~~		
~~"~~	~~14:03~~	~~"~~	~~"~~	~~ICS301~~		~~1-20~~
5-3-91		F-239	"	ICS302		1-20
"	14:20	"	Working	ICW303		1-20
"	14:27		Reference	ICR304		1-20
"	15:18	F-281	Stow	ICS305		1-20
"	15:24	"	Working	ICW306		1-20
"	15:35	"	Reference	ICR307		1-20
"	16:20	F-207	Stow	ICS308		1-20
"	16:26	F-207	Working	ICW309		1-20
"	16:33	F-207	Reference	ICR310		1-20

Test Conductor [signature]
Quality Control [signature] #47
Date 5/3/91

Appendix III

Data File Index Form: Irradiance Calibration

Sheet 2 of __

Diffuser Carousel Serial Number (par. 9.7 b) 0101 (#s)

DATE	TIME	LAMP	SURFACE	FILE NAME	DISK	FRAME NUMBERS
5-3-91	1820	F-239	STOW	ICS 320		20
	18:26	F-239	WORKING	ICW 321		20
	18:33	F-239	REF.	ICR 322		20
	19:13	F-281	STOW	ICS 323		20
	19:19	F-281	WORKING	ICW 324		20
	19:25	F-281	REF	ICR 325		20
	20:05	F-207	STOW	ICS 326		20
	20:11	F-207	WORKING	ICW 327		20
5-3-91	20:18	F-207	REF	ICR 328		20

Test Conductor [signature]
Quality Control [signature]
Date 5/3/91

Appendix III

Data File Index Form: Response Verification

	NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
	-50,0	-50,0	IO	IRV001		3
	-50,0		B			8
	-40,0	-40,0	IO			12
	-40,0		B			17
	-30,0		IO			22
	-30,0		B			27
	-20,0		IO			32
	-20,0		B			37
	-10,0		IO			45
	-10,0		B			51
	0,0		IO			57
	0,0		B			62
	+10,0		IO			68
	+10,0		B			73
	+20,0		IO			79
	+20,0		B			84
	+30,0		IO			89
	+30,0		B			95
(38°)	+MAX,0		IO	↓		99 - END
	+MAX,0		IO	IRV002		1
	+MAX,0		B	↓		5
				↓		TC: 10 - END

Test Conductor [signature]
Quality Control _____
Date 5-2-91

WITNESSED [signature]

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
-30°, -20°	I_0	21:09	IRV003		1
-30°, -20°	B				6
-40°, -20°	I_0				12
-40°, -20°	B				17
-50°, -20°	I_0				22
-50°, -20°	B				29
-20°, -20°	I_0				34
-20°, -20°	B				39
-10°, -20°	I_0				43
-10°, -20°	B				46
0°, -20°	I_0				53
0°, -20°	B				59
+10°, -20°	I_0				63
+10°, -20°	B				67
+20°, -20°	I_0				72
+20°, -20°	B				78
+30°, -20°	I_0				83
+30°, -20	B				88
					99 END

Lamp Height
Set to 20.637" for -20° nominal pitch
(just grazing earthshade @ 0° yaw)

Test Conductor [signature]
Quality Control _____
Date 5-2-91

WITNESSED [signature]

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
+30°, -20°	Io		IRVC04		1
+30°, -20°	B				8
+20°, -20°	Io				15
+20°, -20°	B				20
+10°, -20°	Io				26
+10°, -20°	B				31
0°, -20°	Io				36
0°, -20°	B				41
-10°, -20°	Io				45
-10°, -20°	B				49
-20°, -20°	Io				53
-20, -20°	B				57
-30, -20°	Io				61
-30, -20°	B				65
-40, -20°	Io				69
-40, -20°	B				74
-50, -20°	Io				79
-50, -20°	B				85
					90 - 99
					~~[illegible]~~ lamp to
					+30, +20

Lamp Height
Set to 22.06 @ actual -20° pitch

Test Conductor P.W.
Quality Control
Date 5/2/91
WITNESSED

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
+30°, -10°	Io	23:10	IRV005		1
+30°, -10	B				9
+20°, -10	Io				14
+20°, -10°	B				19
+10°, -10°	Io				24
+10°, -10°	B				29
0°, -10°	Io				34
0°, -10°	B				39
-10°, -10°	Io				45
-10°, -10°	B				50
-20°, -10°	Io				55
-20°, -10°	B				60
-30°, -10°	Io				65
-30°, -10°	B				70
-40°, -10°	Io				75
-40°, -10°	B				80
-50°, -10°	Io				85
-50°, -10°	B				90
		23:35	IRV005		99 (END)

Lamp Height 28'
Set To 18.37 (-10°) pitch

Test Conductor KW
Quality Control
Date 5/2/92

WITNESSED

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
+30°, -5°	Io	23:56	IRU006		1
+30°, -5°	B				8
+20°, -5°	Io				13
+20°, -5°	B				18
+10°, -5°	Io				23
+10°, -5°	B				28
0°, -5°	Io				33
0°, -5°	B				38
-10°, -5°	Io				43
-10°, -5°	B				48
-20°, -5°	Io				53
-20°, -5°	B				58
-30°, -5°	Io				63
-30°, -5°	B				68
-40°, -5°	Io				73
-40°, -5°	B				78
-50°, -5°	Io				83
-50°, -5°	B				88
			IRU006		92
		00:23			Lamp off

Lamp Height
set to 16.62 (-5°) pitch

Test Conductor R Wade
Quality Control
Date 5/2/91
WITNESSED

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
+30°, +5°	I_0	00:58	IRU007		1
+30°, +5°	B				9
+20°, +5°	I_0				16
+20°, +5°	B				22
+10°, +5°	I_0				28
+10°, +5°	B				33
0°, +5°	I_0				38
0°, +5°	B				43
-10°, +5	I_0				48
-10°, +5	B				53
-20°, +5	I_0				58
-20°, +5	B				63
-30°, +5	I_0				68
-30°, +5	B				74
-40°, +5	I_0				79
-40°, +5	B				84
-50°, +5	I_0				89
-50°, +5	B				94
			IRU007		99 END

LAMP HEIGHT
SET TO 13.18" (+5°) PITCH

Test Conductor FW
Quality Control
Date

WITNESSED

Appendix III

Data File Index Form: Response Verification

NUMBER	PARAGRAPH	TIME	FILENAME	DISK	FRAME NUMBERS
+30°, +15°	I₀		IRV008		1 – 4
+30°, +15°	B				8
+20°, +15°	I₀				13
+20°, +15°	B				18
+10°, +15	I₀				23
+10°, +15	B				28
0°, +15	I₀				33
0°, +15	B				38
-5° { -10, +15	I₀				43 } WE BUT TO -5°
-10, +15	B				48
-20, +15	I₀				55
-20, +15	B				60
-30, +15	I₀				65
-30, +15	B				70
-40, +15	I₀				75
-40, +15	B				80
-50, +15	I₀				85
-50, +15	B				90
		2:06	IRV009		95
					END

LAMP HEIGHT
SET TO 9.62" (+15°) PITCH

Test Conductor RW
Quality Control
Date 5/3/91
WITNESSED

Appendix IV

Test Equipment Calibration Log

Item Description	Indent Number	Last Cal Date	Cal Due Date
Bench Checkout Unit NIMBUS Simulator	N/A	N/A	N/A
FEL Lamp Supply Model 83DS	70170	3-19-91	9-19-91
Calibrated FEL-A Lamp	F-281	3/11/91	3/11/92
Indinometer	91766	Extended	5/15/91
Digital Calipers	91843	4/29/91	10/29/91
Precision Scale	~~91843~~	~~4/29/91~~	~~10/29/91~~

Test Conductor_____
Quality Control_____

Appendix V Point 6

Diffuser Calibration Matrix
Absolute Calibration

Date 4/5/91 Operator GUERRERO

Diffuser S/N _____ QA _____ Date 4/5/91

Diffuser Part Number 358467-001 Figure ref. _____

Pitch	Yaw	Done	Notes

Wavelength: 312.5 nm File 1F120405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0	180	✓	REPEAT COMPUTER MALFUNCTION. 310NM

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	✓	
0	90	✓	
0	90	✓	

(F5) Repeat Source Intensity:

0	180	✓	

Wavelength: 317.5 nm File 1F170405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

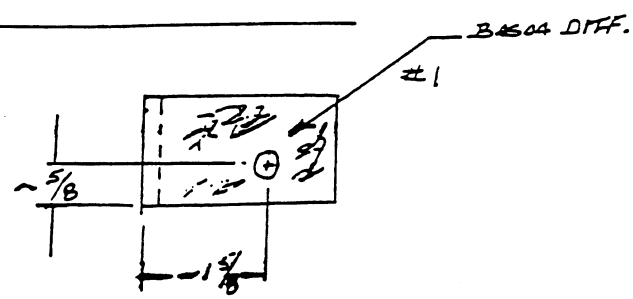
0	180	✓	

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	✓	
0	90	✓	
0	90	✓	

(F5) Repeat Source Intensity:

0	180	✓	



Wavelength: 331.2 nm File 1E310405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0 180 H _____

(F6) Diffuser Measurement: Install Diffuser Under Test

0 90 H _____
0 90 H _____
0 90 H _____

(F5) Repeat Source Intensity:

0 180 H _____

Wavelength: 339.8 nm File 1E390405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0 180 H _____

(F6) Diffuser Measurement: Install Diffuser Under Test

0 90 H _____
0 90 H _____
0 90 H _____

(F5) Repeat Source Intensity:

0 180 H _____

Wavelength: 360.0 nm File 1E600405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0 180 H _____

(F6) Diffuser Measurement: Install Diffuser Under Test

0 90 H _____
0 90 H _____
0 90 H _____

(F5) Repeat Source Intensity:

0 180 H _____

Wavelength: 380.0 nm File 1E800405

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0	180	HT	

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	HT	
0	90	HT	
0	90	HT	

(F5) Repeat Source Intensity:

0	180	HT	

TF910325.WP
REV.A

```
GFIB-PC\IF120405.RTM                    RTM VER 3.00      GUERRERO
05/91                          10:14:08
EEN 80PCO
UARTZ DIFFUSERS @ ENTRANCE SLIT
SUREMENTS ON 312.5NM
04 DIFFUSER MOUNTED AT THE HORIZONTAL POSITION
IDE BY 10
erance              =      .1000
METRIC FACTOR       =      75.7954
EGRATION PERIOD     =      1.00
BER OF WAVELENGTHS  =      1.00
ELENGTHS =          312.50
TER VALUES=         .0000
F FACTORS=          1.0000

                            ------------100% Filter Reference-------------
                                   AVG      ERR    MEAS       PPUC       PPUC       PPUC   PPUC       PPUC       INT
 RAW       TIME      WL     CNT   SM       SM     AVG        AVG        SDEV       STDERR LOW        HIGH       FAC
7.3        10:15:52  310.0  5     2528.2   .0231  4762713.6  4940767.5  1672.      .0151  4937855.1  4941877.5  10.

                            ------------100% Filter Reference-------------
                                   AVG      ERR    MEAS       PPUC       PPUC       PPUC   PPUC       PPUC       INT
 RAW       TIME      WL     CNT   SM       SM     AVG        AVG        SDEV       STDERR LOW        HIGH       FAC
1.7        10:17:17  312.5  5     2526.8   .0148  5689256.2  5942393.0  3143.      .0237  5938768.3  5946160.5  10.

lter Reference Measurement
--ANGLE----                        AVG      STDERR MEAS       PPUC       NORM       SDEV   STDERR     PPUC       PPUC            INT
W    PITCH TIME      WL     CNT   SM       SM     AVG        AVG        AVG        PPUC   PPUC       LOW        HIGH       BRDF FAC
.0   .000  10:19:00  312.5  5     2527.4   .00969 22477.891  22481.933  22224.923  39.684 .0789      22421.094  22532.103  .2835 10.

lter Reference Measurement
--ANGLE----                        AVG      STDERR MEAS       PPUC       NORM       SDEV   STDERR     PPUC       PPUC            INT
W    PITCH TIME      WL     CNT   SM       SM     AVG        AVG        AVG        PPUC   PPUC       LOW        HIGH       BRDF FAC
.0   .000  10:19:12  312.5  57    2528.1   .00572 22464.290  22468.327  22205.521  168.60 .0994      22128.666  22920.999  .2832 10.

lter Reference Measurement
--ANGLE----                        AVG      STDERR MEAS       PPUC       NORM       SDEV   STDERR     PPUC       PPUC            INT
W    PITCH TIME      WL     CNT   SM       SM     AVG        AVG        AVG        PPUC   PPUC       LOW        HIGH       BRDF FAC
.0   .000  10:20:24  312.5  51    2528.1   .00585 22421.580  22425.602  22162.588  157.46 .0983      22094.690  22853.647  .2827 10.

                            ------------100% Filter Reference-------------
                                   AVG      ERR    MEAS       PPUC       PPUC       PPUC   PPUC       PPUC       INT
 RAW       TIME      WL     CNT   SM       SM     AVG        AVG        SDEV       STDERR LOW        HIGH       FAC
6.3        10:23:26  312.5  5     2529.2   .0194  5684048.6  5936727.4  2129.      .0160  5933181.3  5938293.3  10.
```

C:\SPIB-PC\1F390405.RTM RTM VER 3.00 GUERRERO
04/05/91 11:24:51
SCREENS 100RCO & 100SPEQ.NI
MEASUREMENTS ON 339.8NM
BQSO4 DIFFUSER MOUNTED AT THE HORIZONTAL POSITION

DIVIDE BY 10
Tolerance = .1000
GEOMETRIC FACTOR = 75.7954
INTEGRATION PERIOD = 1.00
NUMBER OF WAVELENGTHS = 1.00
WAVELENGTHS = 339.80
FILTER VALUES= .0000
BRDF FACTORS= 1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
496.0	11:32:37	339.8	5	2528.8	.0148	6811106.8	7172306.2	2202.	.0137	7168494.4	7173868.4	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:32:53	339.8	12	2527.9	.0103	29110.353	29117.132	28631.258	99.358	.0985	28892.985	29266.558	.3026	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:33:27	339.8	35	2527.7	.00561	29032.591	29039.333	28556.415	168.07	.0978	28672.183	29480.709	.3018	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:34:54	339.8	21	2527.6	.00799	29075.480	29082.242	28600.330	131.41	.0986	28886.181	29286.538	.3022	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
273.5	12:37:42	339.8	5	2528.2	.0291	6875381.4	7243336.3	3721.	.0230	7238934.6	7247970.5	10.

C:\GPIB-PC\1F600405.RTM RTM VER 3.00 GUERRERO
04/05/91 12:43:47
SCREENS 40WCO & 60SPEC,NI
MEASUREMENTS ON 360.0NM
BASO4 DIFFUSER MOUNTED AT THE HORIZONTAL POSITIONB

DIVIDE BY 10
Tolerance = .1000
GEOMETRIC FACTOR = 75.7954
INTEGRATION PERIOD = 1.00
NUMBER OF WAVELENGTHS = 1.00
WAVELENGTHS = 360.00
FILTER VALUES= .0000
BRDF FACTORS= 1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
364.9	12:45:48	360.0	5	2527.6	.00969	6255831.0	6561209.1	3667.	.0250	6557530.7	6566841.6	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:47:38	360.0	36	2528.1	.00752	26512.860	26518.483	26148.216	156.39	.0983	26099.817	26826.994	.3021	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:49:06	360.0	43	2527.5	.00549	26582.337	26587.990	26224.013	172.76	.0991	26171.847	26860.079	.3029	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:50:52	360.0	47	2527.7	.00619	26549.906	26555.545	26189.119	181.53	.0997	26137.412	26991.845	.3025	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
362.4	12:54:42	360.0	5	2527.8	.0148	6243352.0	6547528.0	2705.	.0185	6544532.1	6551699.3	10.

C:\GPIB-PC\1F310405.RTM RTM VER 3.00 GUERRERO
04/05/91 11:00:50
SCREEN 60RCO
2 QUARTZ DIFFUSERS @ ENTRANCE SLIT
MEASUREMENTS ON 331.2NM
BASO4 DIFFUSER MOUNTED AT THE HORIZONTAL POSITION
DIVIDE BY 10

Tolerance	=	.1000
GEOMETRIC FACTOR	=	75.7954
INTEGRATION PERIOD	=	1.00
NUMBER OF WAVELENGTHS	=	1.00
WAVELENGTHS =		331.20
FILTER VALUES=		.0000
BRDF FACTORS=		1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
431.3	11:04:21	331.2	5	2528.8	.0148	7477739.8	7911955.4	4580.	.0259	7905571.2	7917399.6	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	11:07:12	331.2	29	2528.2	.00892	31111.848	31119.590	30695.150	163.92	.0978	30805.587	31434.320	.2941	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	11:08:24	331.2	31	2528.0	.00734	31069.087	31076.308	30655.326	167.45	.0979	30829.058	31418.462	.2937	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	11:09:40	331.2	16	2528.2	.00900	31041.768	31049.476	30625.682	120.89	.0973	30890.919	31324.255	.2934	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
336.8	11:12:25	331.2	5	2528.0	.0125	7458408.8	7890415.3	3263.	.0185	7886094.9	7894116.7	10.

:\GPIB-PC\1F170405.RTM RTM VER 3.00 GUERRERO
4/05/91 10:27:24
CREEN 125PCO
QUARTZ DIFFUSERS @ ENTRANCE SLIT
EASUREMENTS ON 317.5NM
ASOR DIFFUSER MOUNTED AT THE HORIZONTAL POSITION
IVIDE BY 10
olerance = .1000
EOMETRIC FACTOR = 75.7954
NTEGRATION PERIOD = 1.00
UMBER OF WAVELENGTHS = 1.00
AVELENGTHS = 317.50
ILTER VALUES= .0000
RDF FACTORS= 1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
169.4	10:31:08	317.5	5	2529.4	.0202	7655081.2	8109817.1	3989.	.0220	8105601.4	8115012.2	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	10:32:54	317.5	47	2528.4	.00585	31220.564	31228.361	30971.256	212.30	.0992	30729.030	31679.594	.2895	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	IN FAC
90.0	.000	10:34:50	317.5	26	2527.8	.00822	31158.998	31166.764	30916.994	158.01	.0994	30840.835	31422.724	.2890	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	10:35:59	317.5	40	2527.9	.00699	31227.708	31235.508	30984.331	196.16	.0993	30723.737	31591.339	.2896	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
311.1	10:39:39	317.5	5	2528.6	.0321	7634126.8	8086414.1	1385.	.00766	8084361.8	8087871.6	10.

C:\GPIB-PC\1F800405.RTM RTM VER 3.00 GUERRERO
04/05/91 12:59:36
SCREENS 40WCO & 100SPEQ.NI
MEASUREMENTS ON 380.0NM
BAS04 DIFFUSER MOUNTED AT THE HORIZONTAL POSITION

DIVIDE BY 10
Tolerance = .1000
GEOMETRIC FACTOR = 75.7954
INTEGRATION PERIOD = 1.00
NUMBER OF WAVELENGTHS = 1.00
WAVELENGTHS = 380.00
FILTER VALUES= .0000
BRDF FACTORS= 1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
325.7	13:07:35	380.0	5	2527.6	.0158	7385619.0	7809356.5	2973.	.0170	7804193.1	7811381.1	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:09:39	380.0	32	2528.4	.0100	31977.927	31986.107	31650.166	176.86	.0977	31583.815	32397.751	.3072	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:10:59	380.0	38	2528.0	.00707	32039.914	32048.126	31717.647	193.71	.0981	31484.825	32459.233	.3078	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:12:35	380.0	17	2528.2	.0142	32013.386	32021.584	31687.796	130.16	.0986	31666.447	32259.090	.3076	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
322.6	13:16:09	380.0	5	2527.8	.00791	7386142.0	7809938.6	2449.	.0140	7805800.2	7812318.4	10.

#3

Diffuser Calibration Matrix
Absolute Calibration

Date 4-2-91

Operator GUERRERO

Diffuser S/N _____

QA _____ Date 4-2-91

Diffuser Part Number 358467-001

Figure ref. PAGE 3

Pitch	Yaw	Done	Notes
Wavelength: 312.5 nm		File 1F120402.RTM	
(F5) Source Intensity: DO NOT INSTALL ND3 FILTER ~~[illegible]~~ F.G.			
0	180	✓	
(F6) Diffuser Measurement: Install Diffuser Under Test BA904			
0	90	✓	
0	90	✓	
0	90	✓	
(F5) Repeat Source Intensity:			
0	180	✓	
Wavelength: 317.5 nm		File 1F170402.RTM	
(F5) Source Intensity: DO NOT INSTALL ND3 FILTER			
0	180	✓	
(F6) Diffuser Measurement: Install Diffuser Under Test			
0	90	✓	
0	90	✓	
0	90	✓	
(F5) Repeat Source Intensity:			
0	180	✓	

Wavelength: 331.2 nm File 1F310402.RTM

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0	180	✓	REPEAT SHUTTER CLOSED

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	✓	
0	90	✓	
0	90	✓	

(F5) Repeat Source Intensity:

0	180	✓	

Wavelength: 339.8 nm File 1F390402.RTM

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0	180	✓	

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	✓	REPEAT INCORRECT YAW ANGLE
0	90	✓	
0	90	✓	

(F5) Repeat Source Intensity:

0	180	✓	

Wavelength: 360.0 nm File 1F600402.RTM

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

0	180	✓	

(F6) Diffuser Measurement: Install Diffuser Under Test

0	90	✓	REPEAT INCORRECT YAW ANGLE
0	90	✓	
0	90	✓	

(F5) Repeat Source Intensity:

0	180	✓	

Wavelength: 380.0 nm File 1F800402.BTM

(F5) Source Intensity: DO NOT INSTALL ND3 FILTER

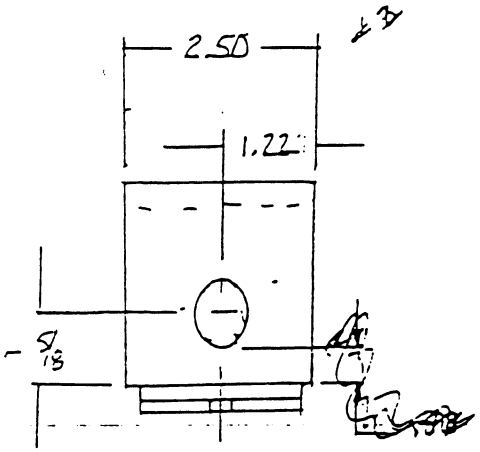
0	180	M	

(F6) Diffuser Measurement: Install Diffuser Under Test

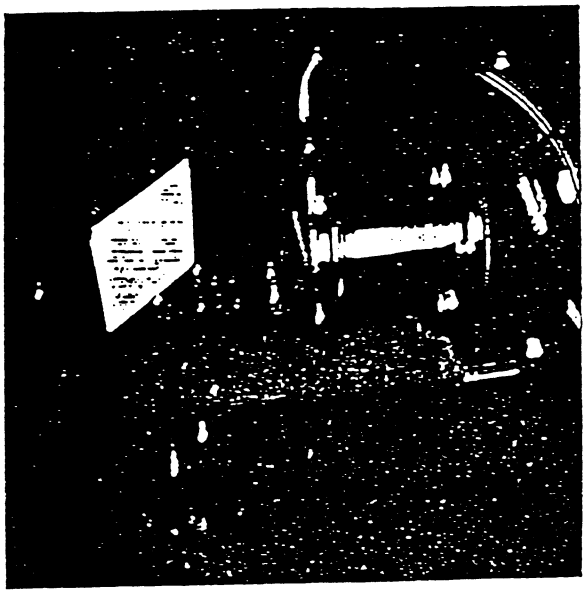
0	90	M	
0	90	M	
0	90	M	

(F5) Repeat Source Intensity:

0	180	M	



BEAM OFF CENTER X ~.03 @ 90° & 50°



90° YAW

TF910325.WP
REV.A

:B-PC\1F120402.RTM RTM VER 3.00 GUERRERO
'91 08:34:59
(80PCO
RTZ DIFFUSERS @ ENTRANCE SLIT
REMENTS ON 312.5NM

E BY 10
ance = .1000
TRIC FACTOR = 75.7954
RATION PERIOD = 1.00
R OF WAVELENGTHS = 1.00
ENGTHS = 312.50
R VALUES= .0000
FACTORS= 1.0000

			----------100% Filter Reference----------									
				AVG	ERR	MEAS	PPUC	PPUC	PPUC	PPUC	PPUC	INT
AW	TIME	WL	CNT	SM	SM	AVG	AVG	SDEV	STDERR	LOW	HIGH	FAC
(	08:41:54	312.5	5	2526.4	.0202	5667083.2	5918272.9	4694.	.0355	5911299.9	5922964.8	10.

er Reference Measurement

ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC		INT
PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
.000	08:46:15	312.5	51	2526.2	.00512	22907.901	22912.099	22629.643	162.61	.0994	22488.104	23261.187	.2898	10.

er Reference Measurement

ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC		INT
PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
.000	08:48:33	312.5	23	2526.7	.00841	22985.718	22989.945	22703.127	110.06	.0998	22753.810	23154.807	.2908	10.

er Reference Measurement

ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC		INT
PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
) .000	08:49:31	312.5	67	2526.8	.00574	22957.692	22961.908	22674.227	187.54	.0998	22528.128	23565.391	.2904	10.

			----------100% Filter Reference----------									
				AVG	ERR	MEAS	PPUC	PPUC	PPUC	PPUC	PPUC	INT
RAW	TIME	WL	CNT	SM	SM	AVG	AVG	SDEV	STDERR	LOW	HIGH	FAC
.3	08:55:07	312.5	5	2526.4	.00970	5662637.2	5913437.3	1923.	.0145	5910167.8	5915168.5	10.

:B-PC\1F170402.RTM RTM VER 3.00 GUERRERO
'91 09:44:14
(125PCO
RTZ DIFFUSERS @ ENTRANCE SLIT
REMENTS FOR 317.5NM

E BY 10
ance = .1000
TRIC FACTOR = 75.7954
RATION PERIOD = 1.00
R OF WAVELENGTHS = 1.00
ENGTHS = 317.50
R VALUES= .0000
FACTORS= 1.0000

			----------100% Filter Reference----------									
AW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
0	09:46:01	317.5	5	2527.0	.0177	7935912.8	8424082.3	3334.	.0177	8419622.9	8428852.9	10.

er Reference Measurement
ANGLE----

PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
.000	09:48:39	317.5	36	2526.9	.00722	33952.708	33961.934	33661.647	853.26	.419	32984.038	36323.347	.3029	10.

:er Reference Measurement
-ANGLE----

PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
0 .000	09:50:11	317.5	52	2526.8	.00686	33327.764	33336.649	33038.913	237.66	.0989	32960.115	34025.456	.2973	10.

ter Reference Measurement
-ANGLE----

PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
0 .000	09:52:13	317.5	39	2526.2	.00515	33290.559	33299.424	33009.544	205.85	.0990	32837.361	33726.584	.2970	10.

			----------100% Filter Reference----------									
RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
1.2	10:00:40	317.5	5	2526.8	.00792	7943591.2	8432691.0	3040.	.0161	8429839.5	8437375.2	10.

IB-PC\1F310402.RTM RTM VER 3.00 GUERRERO
/91 10:17:48
N 60RCO & 60SPEQ.NI
RTZ DIFFUSERS @ ENTRANCE SLIT
REMENTS FOR 331.2NM

E BY 10
ance = .1000
TRIC FACTOR = 75.7954
RATION PERIOD = 1.00
R OF WAVELENGTHS = 1.00
LENGTHS = 331.20
R VALUES= .0000
FACTORS= 1.0000

SHUTTER CLOSED

				----------100% Filter Reference----------								
~~AW~~	~~TIME~~	~~WL~~	~~CNT~~	~~AVG SM~~	~~ERR SM~~	~~MEAS AVG~~	~~PPUC AVG~~	~~PPUC SDEV~~	~~PPUC STDERR~~	~~PPUC LOW~~	~~PPUC HIGH~~	~~INT FAC~~
~~0~~	~~10:19:42~~	~~331.1~~	~~5~~	~~2526.8~~	~~.0148~~	~~1856276.8~~	~~1883639.3~~	~~1710.~~	~~.0406~~	~~1882051.3~~	~~1886523.2~~	~~10.~~

				----------100% Filter Reference----------								
AW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
1	10:21:33	331.2	5	2526.2	.0194	5382316.2	5609152.2	2944.	.0235	5605172.8	5612928.7	10.

er Reference Measurement													
-ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC	INT
	PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
)	.000	10:23:32	331.2	56	2526.2	.00535	22775.852	22780.002	22344.072	168.94	.0991	22328.677	23238.558	.3019	10.

ter Reference Measurement													
-ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC	INT
	PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
0	.000	10:25:49	331.2	56	2526.0	.00557	22896.197	22900.391	22465.920	170.87	.0997	22555.328	23249.842	.3036	10.

ter Reference Measurement													
-ANGLE----				AVG	STDERR	MEAS	PPUC	NORM	SDEV	STDERR	PPUC	PPUC	INT
	PITCH	TIME	WL	CNT	SM	SM	AVG	AVG	AVG	PPUC	PPUC	LOW	HIGH	BRDF	FAC
0	.000	10:28:40	331.2	83	2525.9	.00472	22861.674	22865.855	22432.634	207.22	.0995	22357.217	23404.720	.3031	10.

				----------100% Filter Reference----------								
RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
5.2	10:34:51	331.2	5	2525.8	.00792	5395686.6	5623638.9	3680.	.0293	5618910.6	5628396.4	10.

.6PIB-PC\1F390402.RTM RTM VER 3.00 6UERRERO
'02/91 11:27:01
REENS 100RCO & 100SPEQ.NI
)UARTZ DIFFUSERS @ ENTRANCE SLIT
ASUREMENTS FOR 339.8NM

VIDE BY 10
lerance = .1000
OMETRIC FACTOR = 75.7954
TESRATION PERIOD = 1.00
MBER OF WAVELENGTHS = 1.00
VELENGTHS = 339.80
LTER VALUES= .0000
OF FACTORS= 1.0000

----------100% Filter Reference----------

: RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
.9.5	11:28:33	339.8	5	2525.8	.00792	6304242.4	6614305.7	4060.	.0275	6609493.3	6618862.8	10.

INCORRECT YAW ANGLE

~~ilter Reference Measurement~~
~~---ANGLE---~~

~~AW~~	~~PITCH~~	~~TIME~~	~~WL~~	~~CNT~~	~~AVG SM~~	~~STDERR SM~~	~~MEAS AVG~~	~~PPUC AVG~~	~~NORM AVG~~	~~SDEV PPUC~~	~~STDERR PPUC~~	~~PPUC LOW~~	~~PPUC HIGH~~	~~BRDF~~	~~INT FAC~~
~~0.0~~	~~.000~~	~~11:29:51~~	~~339.8~~	~~14~~	~~2525.9~~	~~.00877~~	~~496.8597~~	~~496.8617~~	~~247.3451~~	~~23.495~~	~~1.26~~	~~452.4978~~	~~541.8232~~	~~.00283410~~	

ilter Reference Measurement
---ANGLE----

AW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
0.0	.000	11:32:27	339.8	23	2526.4	.00819	26901.008	26906.797	26650.545	128.23	.0994	26674.079	27122.322	.3054	10.

'ilter Reference Measurement
---ANGLE----

'AW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	11:33:26	339.8	44	2526.2	.00708	26930.944	26936.746	26683.183	178.28	.0998	26482.788	27368.979	.3058	10.

Filter Reference Measurement
---ANGLE----

YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	11:35:13	339.8	41	2525.8	.00690	26955.422	26961.235	26711.431	170.31	.0987	26554.658	27360.295	.3061	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
228.2	12:37:17	339.8	5	2525.8	.0148	6310966.6	6621683.3	2226.	.0150	6618092.6	6623846.4	10.

C:\GPIB-PC\1F600402.RTM RTM VER 3.00 GUERRERO
04/02/91 12:44:35
SCREENS 40WCO & 60SPEO.NI
2 QUARTZ DIFFUSERS @ ENTRANCE SLIT
MEASUREMENTS FOR 360.0NM

DIVIDE BY 10

Tolerance	=	.1000
GEOMETRIC FACTOR	=	75.7954
INTEGRATION PERIOD	=	1.00
NUMBER OF WAVELENGTHS	=	2.00
WAVELENGTHS =	360.00	.0000
FILTER VALUES=	1.0000	.0000
BRDF FACTORS=	.0000	.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
238.1	12:46:23	360.0	5	2527.6	.0202	6203763.2	6504141.1	1566.	.0108	6501516.8	6505559.7	10.
	12:46:34	360.0	5	2527.0	.000	6208617.6	6509460.0	2626.	.0180	6506859.2	6512748.7	10.

Filter Reference Measurement

INCORRECT YAW ANGLE

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
.000	.000	12:48:57	360.0	5	2527.8	.0148	2671.1460	2671.3172	2432.9995	13.897	.233	2660.0608	2691.4728	.2835	1.0
		12:49:08	360.0	22	2526.9	.00949	2687.1914	2687.3647	2449.4034	15.276	.121	2665.4615	2719.6345	.02[illegible]	1.0

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:50:20	360.0	49	2526.5	.00555	26908.385	26914.177	26688.115	186.12	.0988	26570.945	27408.246	3.110	10.
		12:52:16	360.0	42	2526.5	.00636	26797.565	26803.310	26570.760	173.24	.0997	26334.705	27190.381	.3094	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:54:08	360.0	48	2526.6	.00496	26762.843	26768.572	26541.016	184.58	.0995	26317.288	27207.969	3.093	10.
		12:56:02	360.0	42	2526.5	.00622	26776.300	26782.035	26549.481	173.01	.0997	26408.726	27134.087	.3091	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	12:57:49	360.0	51	2526.8	.00643	26880.980	26886.760	26656.916	189.32	.0986	26513.161	27381.925	3.106	10.
		12:59:50	359.9	51	2526.6	.00576	26835.988	26841.749	26607.600	188.09	.0981	26357.715	27222.775	.3098	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
215.1	13:03:50	360.0	5	2527.4	.00969	6214507.0	6515913.4	4179.	.0287	6510072.9	6519496.7	10.
	13:04:01	360.0	5	2526.8	.0148	6217236.0	6518903.9	4141.	.0284	6514933.7	6524887.4	10.

:\GPIB-PC\1F800402.RTM RTM VER 3.00 GUERRERO
4/02/91 13:20:17
CREENS WOTCO & 100SPEQ.NI
QUARTZ DIFFUSERS @ ENTRANCE SLIT
EASUREMENTS FOR 380.0NM

IVIDE BY 10
olerance = .1000
EOMETRIC FACTOR = 75.7954
NTEGRATION PERIOD = 1.00
UMBER OF WAVELENGTHS = 1.00
AVELENGTHS = 380.00
ILTER VALUES= .0000
RDF FACTORS= 1.0000

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
249.2	13:21:49	380.0	5	2527.2	.0148	7292168.2	7705403.3	2766.	.0161	7702652.7	7708766.0	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:23:39	380.0	33	2527.4	.00706	32159.863	32168.136	31916.878	182.93	.0990	31860.856	32538.875	.3140	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:25:05	380.0	10	2527.0	.00834	32215.127	32223.429	31976.803	101.27	.0994	32058.787	32415.020	.3145	10.

Filter Reference Measurement

---ANGLE---- YAW	PITCH	TIME	WL	CNT	AVG SM	STDERR SM	MEAS AVG	PPUC AVG	NORM AVG	SDEV PPUC	STDERR PPUC	PPUC LOW	PPUC HIGH	BRDF	INT FAC
90.0	.000	13:25:35	380.0	47	2527.0	.00670	32289.431	32297.771	32051.695	219.63	.0992	31959.665	32709.133	.3153	10.

----------100% Filter Reference----------

DC RAW	TIME	WL	CNT	AVG SM	ERR SM	MEAS AVG	PPUC AVG	PPUC SDEV	PPUC STDERR	PPUC LOW	PPUC HIGH	INT FAC
486.9	13:30:10	379.9	5	2526.0	.0250	7283978.4	7696299.2	2756.	.0160	7693797.7	7699511.2	10.

Appendix IV

OPTRONIC LABORATORIES, INC.

A Subsidiary of Kollmorgen Corporation

Emphasizing Precision and Accuracy

REPORT OF CALIBRATION

of

One Standard of Spectral Irradiance

Model FEL-A, S/N: F-239

Project No: 900-502

Date: April 13, 1989

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OPTRONIC LABORATORIES, INC.
A Subsidiary of Kollmorgen Corporation
Emphasizing Precision and Accuracy

REPORT OF CALIBRATION

of

One Standard of Spectral Irradiance

Customer: Perkin Elmer
Pomona, CA 91767

Purchase Order No: 13369 BC

1. Material.

One 1000-Watt (FEL) quartz-halogen tungsten coiled-coil filament lamp Standard of Spectral Irradiance (Model FEL-A) was supplied by Optronic Laboratories and bears the designation F-239.

2. Method of Calibration and Standards.

See "Instructions for Using the Optronic Laboratories 1000-Watt FEL Tungsten-Halogen Lamp Standards of Total and Spectral Irradiance", a copy of which is enclosed. See particularly the paragraphs relating to the alignment and operation of the standard.

3. Results.

The spectral irradiance of Standard F-239 at a distance of 50 cm when operated at 8.00 amperes dc is given in attached Table 1. Information pertaining to the accuracy and long term stability is given in the attached instructions.

Calibration Certified by:

OPTRONIC LABORATORIES, INC.

Deborah Griffith
Radiometrist

Project No: 900-502
Date: April 13, 1989

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OPTRONIC LABORATORIES CALIBRATION REPORT

TABLE 1

Spectral Irradiance of Standard F-239 in Microwatts/cm² per Nanometer Wavelength Interval at a Distance of 50 cm when Operated at 8.00 Amperes DC.

Wavelength (nm)	Spectral Irradiance (μW/cm² nm)
* 250	.0227
* 260	.0393
* 270	.0645
* 280	.100
* 290	.150
* 300	.216
* 310	.301
* 320	.410
* 330	.545
* 340	.708
* 350	.903
370	1.40
* 400	2.39
* 450	4.75
* 500	7.77
550	11.1
* 555	11.4
* 600	14.3
650	17.2
* 654.6	17.4
* 700	19.5
750	21.2

* Actual NIST wavelengths.

Project No: 900-502
Date: April 13, 1989

OPTRONIC LABORATORIES, INC.
A Subsidiary of Kollmorgen Corporation
Emphasizing Precision and Accuracy

March 1987

Instructions for Using the Optronic Laboratories 1000-Watt FEL Tungsten-Halogen Lamp Standards of Total and Spectral Irradiance

General

These instructions cover the use of tungsten-filament quartz-halogen lamps issued as standards of total and spectral irradiance. The lamps employed are commercial G.E. type FEL 1000-Watt lamps having a tungsten coiled-coil filament enclosed in a small quartz envelope. (Figure 1) The lamp bases have been converted to a medium bipost base which can be used with a kinematic lamp holder (see Figure 2), allowing the lamps to be removed and replaced repeatably in the same position.

Spectral irradiance values are given for the wavelength range of 0.25 to 2.5 µm. The radiant intensity of the entire lamp as mounted in the manner prescribed below is measured and reported. The totalirradiance of these lamps is based on the radiance of a blackbody asdefined by the Stefan-Boltzman radiation law. The assigned values of total irradiance have estimated uncertainties of ±1%.

The spectral irradiance from these lamps over the wavelength range of 250 nm to 1600 nm is based on the National Bureau of Standards 1973 scale of spectral irradiance. Values of spectral irradiance from 1600 nm to 2400 nm are based on the NBS 1986 spectral irradiance scale and the value at 2500 nm is based on the modified NBS 1963 spectral irradiance scale. The reported uncertainty of the NBS irradiance scales along with uncertainty associated with the transfer from the NBS standard to the issued 1000-Watt lamp standard is given below:

Wavelength (nm)	NBS Uncertainty (%)	Transfer Uncertainty (%)
250	2.23	1.0
350	1.35	0.7
654.6	1.01	0.4
900	1.34	0.5
1300	1.42	0.5
1600	1.89	0.5
2000	3.29	0.75
2400	6.51	1.0
2500	6.50	1.0

Alignment and Orientation

The following procedure should be carefully followed when setting up the standard for calibration purposes:

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OPTRONIC LABORATORIES, INC.

A Subsidiary of Kollmorgen Corporation

Emphasizing Precision and Accuracy

REPORT OF CALIBRATION

of

One Standard of Spectral Irradiance

Model FEL-A, S/N: F-281

Project No: 901-397

Date: 11 March 1991

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OPTRONIC LABORATORIES, INC.
A Subsidiary of Kollmorgen Corporation
Emphasizing Precision and Accuracy

REPORT OF CALIBRATION

of

One Standard of Spectral Irradiance

Customer: Perkin Elmer
Pomona, CA 91767

Purchase Order No: 26738 BH

1. Material.

One 1000-Watt (FEL) quartz-halogen tungsten coiled-coil filament lamp Standard of Spectral Irradiance (Model FEL-A) was supplied by Optronic Laboratories and bears the designation F-281 .

2. Method of Calibration and Standards.

See "Instructions for Using the Optronic Laboratories 1000-Watt FEL Tungsten-Halogen Lamp Standards of Total and Spectral Irradiance", a copy of which is enclosed. See particularly the paragraphs relating to the alignment and operation of the standard.

3. Results.

The spectral irradiance of Standard F-281 at a distance of 50 cm when operated at 8.00 amperes dc is given in attached Table 1. Information pertaining to the accuracy and long term stability is given in the attached instructions.

Calibration Certified by:

OPTRONIC LABORATORIES, INC.

Deborah Griffith
Deborah Griffith
Radiometrist

Project No: 901-397
Date: 11 March 1991

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OPTRONIC LABORATORIES CALIBRATION REPORT

TABLE 1

Spectral Irradiance of Standard F-281 in Microwatts/cm² per Nanometer Wavelength Interval at a Distance of 50 cm when Operated at 8.00 Amperes DC.**

Wavelength (nm)	Spectral Irradiance (μW/cm² nm)
* 250	.0190
* 260	.0332
* 270	.0550
* 280	.0863
* 290	.130
* 300	.188
* 310	.263
* 320	.360
* 330	.481
* 340	.628
* 350	.804
370	1.25
* 400	2.17
* 450	4.36
* 500	7.22
550	10.4
* 555	10.7
* 600	13.5
650	16.3
* 654.6	16.5
* 700	18.6
750	20.4

* Actual NIST wavelengths.

** Effective July 1, 1990, the International Temperature Scale of 1990 has been implemented in NIST calibration services for optical radiometry. This has resulted in small changes in the spectral irradiance scale. Values given in Table 1 reflect these changes.

Project No: 901-397
Date: 11 March 1991

OPTRONIC LABORATORIES, INC.
A Subsidiary of Kollmorgen Corporation
Emphasizing Precision and Accuracy

March 1987

Instructions for Using the Optronic Laboratories 1000-Watt FEL Tungsten-Halogen Lamp Standards of Total and Spectral Irradiance

General

These instructions cover the use of tungsten-filament quartz-halogen lamps issued as standards of total and spectral irradiance. The lamps employed are commercial G.E. type FEL 1000-Watt lamps having a tungsten coiled-coil filament enclosed in a small quartz envelope. (Figure 1) The lamp bases have been converted to a medium bipost base which can be used with a kinematic lamp holder (see Figure 2), allowing the lamps to be removed and replaced repeatably in the same position.

Spectral irradiance values are given for the wavelength range of 0.25 to 2.5 μm. The radiant intensity of the entire lamp as mounted in the manner prescribed below is measured and reported. The total irradiance of these lamps is based on the radiance of a blackbody as defined by the Stefan-Boltzman radiation law. The assigned values of total irradiance have estimated uncertainties of ±1%.

The spectral irradiance from these lamps over the wavelength range of 250 nm to 1600 nm is based on the National Institute of Standards and Technology 1973 scale of spectral irradiance. Values of spectral irradiance from 1600 nm to 2400 nm are based on the NIST 1986 spectral irradiance scale and the value at 2500 nm is based on the modified NIST 1963 spectral irradiance scale. The reported uncertainty of the NIST irradiance scales along with uncertainty associated with the transfer from the NIST standard to the issued 1000-Watt lamp standard is given below:

Wavelength (nm)	NIST Uncertainty (%)	Transfer Uncertainty (%)
250	2.23	1.0
350	1.35	0.7
654.6	1.01	0.4
900	1.34	0.5
1300	1.42	0.5
1600	1.89	0.5
2000	3.29	0.75
2400	6.51	1.0
2500	6.50	1.0

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Appendix VII Spline Fit Analysis

Carousel 4 Summary

4 R Goniometric Reflectivity, f(yaw), fixed pitch = 0

Rho_f(yaw)	125	124	122	120	100	90	80	60	50	40
312.5	0.41807	0.41394	0.40419	0.39503	0.31780	0.26322	0.21437	0.15985	0.14697	0.13643
317.5	0.41726	0.41209	0.40278	0.39396	0.31722	0.26253	0.21408	0.15938	0.14672	0.13626
331.2	0.42905	0.42488	0.41455	0.40505	0.32733	0.27110	0.22091	0.16459	0.15129	0.14040
339.8	0.43433	0.43022	0.41967	0.40987	0.33147	0.27471	0.22395	0.16666	0.15352	0.14224
360	0.44985	0.44489	0.43435	0.42447	0.34287	0.28328	0.22951	0.17061	0.15652	0.14545
380	0.46740	0.46223	0.45088	0.44034	0.35394	0.29088	0.23440	0.17319	0.15854	0.14700

Rel_std

312.5	0.00072	0.00225	0.00152	0.00153	0.00338	0.00320	0.00112	0.00259	0.00357	0.00160
317.5	0.00088	0.00226	0.00120	0.00241	0.00303	0.00279	0.00168	0.00313	0.00398	0.00236
331.2	0.00060	0.00265	0.00052	0.00275	0.00194	0.00228	0.00161	0.00189	0.00241	0.00312
339.8	0.00117	0.00229	0.00076	0.00163	0.00229	0.00329	0.00171	0.00156	0.00211	0.00345
360	0.00084	0.00119	0.00240	0.00228	0.00231	0.00252	0.00227	0.00189	0.00199	0.00272
380	0.00074	0.00103	0.00190	0.00162	0.00220	0.00140	0.00227	0.00270	0.00218	0.00265

4 S Goniometric Reflectivity, f(yaw), fixed pitch = 0

Rho_f(yaw)	125	124	122	120	100	90	80	60	50	40
312.5	0.43432	0.42985	0.41962	0.40919	0.33036	0.27411	0.22157	0.16108	0.14560	0.13535
317.5	0.43500	0.43028	0.41933	0.40980	0.33067	0.27454	0.22204	0.16140	0.14560	0.13529
331.2	0.44786	0.44262	0.43155	0.42212	0.34098	0.28314	0.22879	0.16616	0.15010	0.13940
339.8	0.45395	0.44911	0.43765	0.42793	0.34589	0.28723	0.23214	0.16861	0.15202	0.14116
360	0.46951	0.46411	0.45284	0.44319	0.35693	0.29579	0.23830	0.17228	0.15508	0.14404
380	0.48941	0.48370	0.47194	0.46140	0.36946	0.30461	0.24368	0.17497	0.15712	0.14567

Rel_std

312.5	0.00088	0.00173	0.00318	0.00266	0.00252	0.00217	0.00275	0.00085	0.00000	0.00147
317.5	0.00243	0.00188	0.00427	0.00264	0.00220	0.00279	0.00062	0.00085	0.00216	0.00130
331.2	0.00064	0.00201	0.00345	0.00190	0.00220	0.00304	0.00164	0.00154	0.00037	0.00145
339.8	0.00130	0.00153	0.00278	0.00117	0.00261	0.00284	0.00172	0.00074	0.00156	0.00037
360	0.00074	0.00071	0.00109	0.00111	0.00091	0.00125	0.00054	0.00074	0.00047	0.00023
380	0.00106	0.00091	0.00110	0.00112	0.00091	0.00109	0.00112	0.00112	0.00085	0.00027

4 W Goniometric Reflectivity, f(yaw), fixed pitch = 0

Rho_f(yaw)	125	124	122	120	100	90	80	60	50	40
312.5	0.43587	0.43010	0.42033	0.40975	0.32431	0.26803	0.21714	0.16004	0.14489	0.13550
317.5	0.43486	0.42935	0.41885	0.40875	0.32347	0.26794	0.21722	0.16014	0.14482	0.13515
331.2	0.44670	0.44101	0.43046	0.41966	0.33295	0.27611	0.22427	0.16566	0.14944	0.13931
339.8	0.44990	0.44413	0.43361	0.42320	0.33675	0.27894	0.22664	0.16752	0.15108	0.14123
360	0.45147	0.44599	0.43460	0.42461	0.33910	0.28152	0.22936	0.16901	0.15270	0.14209
380	0.45671	0.45128	0.44011	0.42965	0.34450	0.28612	0.23318	0.17150	0.15486	0.14417

Rel_std

312.5	0.00089	0.00263	0.00168	0.00211	0.00159	0.00342	0.00200	0.00090	0.00290	0.00157
317.5	0.00240	0.00202	0.00214	0.00163	0.00228	0.00080	0.00307	0.00187	0.00429	0.00031
331.2	0.00160	0.00137	0.00051	0.00229	0.00110	0.00177	0.00043	0.00198	0.00257	0.00100
339.8	0.00102	0.00162	0.00167	0.00127	0.00104	0.00097	0.00195	0.00112	0.00354	0.00150
360	0.00074	0.00050	0.00068	0.00083	0.00119	0.00089	0.00041	0.00168	0.00192	0.00182
380	0.00105	0.00083	0.00102	0.00073	0.00066	0.00091	0.00038	0.00124	0.00133	0.00123

file: dif4fit.mcd
date: 11 November, 1991

This file extends the cubic spline fit comparison of the 4W, 380nm example to cover the three surfaces at all wavelengths. No surprises are expected here; the fits are all expected to agree within a percent of the measured rho(90) reflectivities. Two complete cubic spline interpolations are performed for each diffuser surface - one employing the complete set of yaw data to predict rho(90), the other using only yaw values between 40 and 120 degrees inclusive.

The abbreviated yaw range was used to be consistent with the earlier Matlab cubic spline interpolation reported for the irradiance response calibrations.

IMPORT DIFFUSER REFLECTIVITY DATA AND ARRANGE IN COLUMNS....
4W SPLINE INTERPOLATION.....

$M := \text{READPRN}(W4DATA)$

$M := (M^T)$

$$M = \begin{bmatrix} 0.43587 & 0.43486 & 0.4467 & 0.4499 & 0.45147 & 0.45671 \\ 0.4301 & 0.42935 & 0.44101 & 0.44413 & 0.44599 & 0.45128 \\ 0.42033 & 0.41885 & 0.43046 & 0.43361 & 0.4346 & 0.44011 \\ 0.40975 & 0.40875 & 0.41966 & 0.4232 & 0.42461 & 0.42965 \\ 0.32431 & 0.32347 & 0.33295 & 0.33675 & 0.3391 & 0.3445 \\ 0.26803 & 0.26794 & 0.27611 & 0.27894 & 0.28152 & 0.28612 \\ 0.21714 & 0.21722 & 0.22427 & 0.22664 & 0.22936 & 0.23318 \\ 0.16004 & 0.16014 & 0.16566 & 0.16752 & 0.16901 & 0.1715 \\ 0.14489 & 0.14482 & 0.14944 & 0.15108 & 0.1527 & 0.15486 \\ 0.1355 & 0.13515 & 0.13931 & 0.14123 & 0.14209 & 0.14417 \end{bmatrix}$$

BUILD A MODIFIED ARRAY, MISSING YAW 90 DATA

$i := 0 ..8 \quad k := 0 ..5$

$$Mpr_{8-i,k} := \text{if}\left[i \geq 5, M_{i+1,k}, M_{i,k}\right]$$

$$Mpr = \begin{bmatrix} 0.1355 & 0.13515 & 0.13931 & 0.14123 & 0.14209 & 0.14417 \\ 0.14489 & 0.14482 & 0.14944 & 0.15108 & 0.1527 & 0.15486 \\ 0.16004 & 0.16014 & 0.16566 & 0.16752 & 0.16901 & 0.1715 \\ 0.21714 & 0.21722 & 0.22427 & 0.22664 & 0.22936 & 0.23318 \\ 0.32431 & 0.32347 & 0.33295 & 0.33675 & 0.3391 & 0.3445 \\ 0.40975 & 0.40875 & 0.41966 & 0.4232 & 0.42461 & 0.42965 \\ 0.42033 & 0.41885 & 0.43046 & 0.43361 & 0.4346 & 0.44011 \\ 0.4301 & 0.42935 & 0.44101 & 0.44413 & 0.44599 & 0.45128 \\ 0.43587 & 0.43486 & 0.4467 & 0.4499 & 0.45147 & 0.45671 \end{bmatrix}$$

These data are then fit to cubic splines against the following yaw vector (for 'full yaw' spline interpolations).

$$Yaw := \begin{bmatrix} 40 \\ 50 \\ 60 \\ 80 \\ 100 \\ 120 \\ 122 \\ 124 \\ 125 \end{bmatrix}$$

The abbreviated, or short set, uses only 40 < yaw < 120, as was originally used in the cubic spline fits.

$is := 0 ..5$

$Yaw_short_{is} := Yaw_{is}$

$$Yaw_short = \begin{bmatrix} 40 \\ 50 \\ 60 \\ 80 \\ 100 \\ 120 \end{bmatrix}$$

file: 4w.mcd
date: 11 November, 1991

This file fits diffuser 4W goniometric reflectivity to a cubic spline to determine a fit value of rho(90). This value is then compared to a measured value of rho(90).

diffuser data for pitch = 0, lambda = 380nm.

$$yaw1 := \begin{bmatrix} 125 \\ 124 \\ 122 \\ 120 \\ 100 \\ 90 \\ 80 \\ 60 \\ 50 \\ 40 \end{bmatrix} \qquad rho1 := \begin{bmatrix} .456711 \\ .451284 \\ .44011 \\ .429645 \\ .344504 \\ .286116 \\ .23318 \\ .171499 \\ .154862 \\ .144167 \end{bmatrix}$$

truncated data.

$$yaw3 := \begin{bmatrix} 40 \\ 50 \\ 60 \\ 80 \\ 100 \\ 120 \\ 122 \\ 124 \\ 125 \end{bmatrix} \qquad rho3 := \begin{bmatrix} .144167 \\ .154862 \\ .171499 \\ .23318 \\ .344504 \\ .429645 \\ .44011 \\ .451284 \\ .456711 \end{bmatrix}$$

$i := 0 ..9$

Rearrange the data, in MathCAD splines require x in increasing values.....

$yaw2_i := yaw1_{9-i}$

$rho2_i := rho1_{9-i}$

Set up another array to fit spline to 40 < yaw < 120. This abbreviated yaw fit is analogous to that performed in the original irradiance response test, when rho(90) was computed from goniometric data.

$k := 0 ..5$

$rho4_k := rho3_k \qquad yaw4_k := yaw3_k$

Interpolate using truncated data set, 40 < yaw < 120 degrees.

vc_short := cspline(yaw4,rho4)

rho_short(x) := interp(vc_short,yaw4,rho4,x)

rho_short(90) = 0.28586

$$rel_err_short := \frac{rho_short(90) - rho2_4}{rho2_4}$$

$rel_err_short = -9.0904 \cdot 10^{-4}$

The cubic spline yields a 0.1% error in the computed value of rho_90 if yaw values between 40 and 120 are used in the cspline interpolation.

==========

Compute a relative error based on fitting a cubic spline to the full Yaw set. (ie, if the extended region around Yaw=90 is fit, does this improve the prediction of Yaw 90?)

Long data set interpolation.....

vc_long := cspline(yaw3,rho3) build a coefficient array on long data set.

rho_long(x) := interp(vc_long,yaw3,rho3,x)

rho_long(90) = 0.28845 Interpolate a rho(90) based on the extended yaw set.

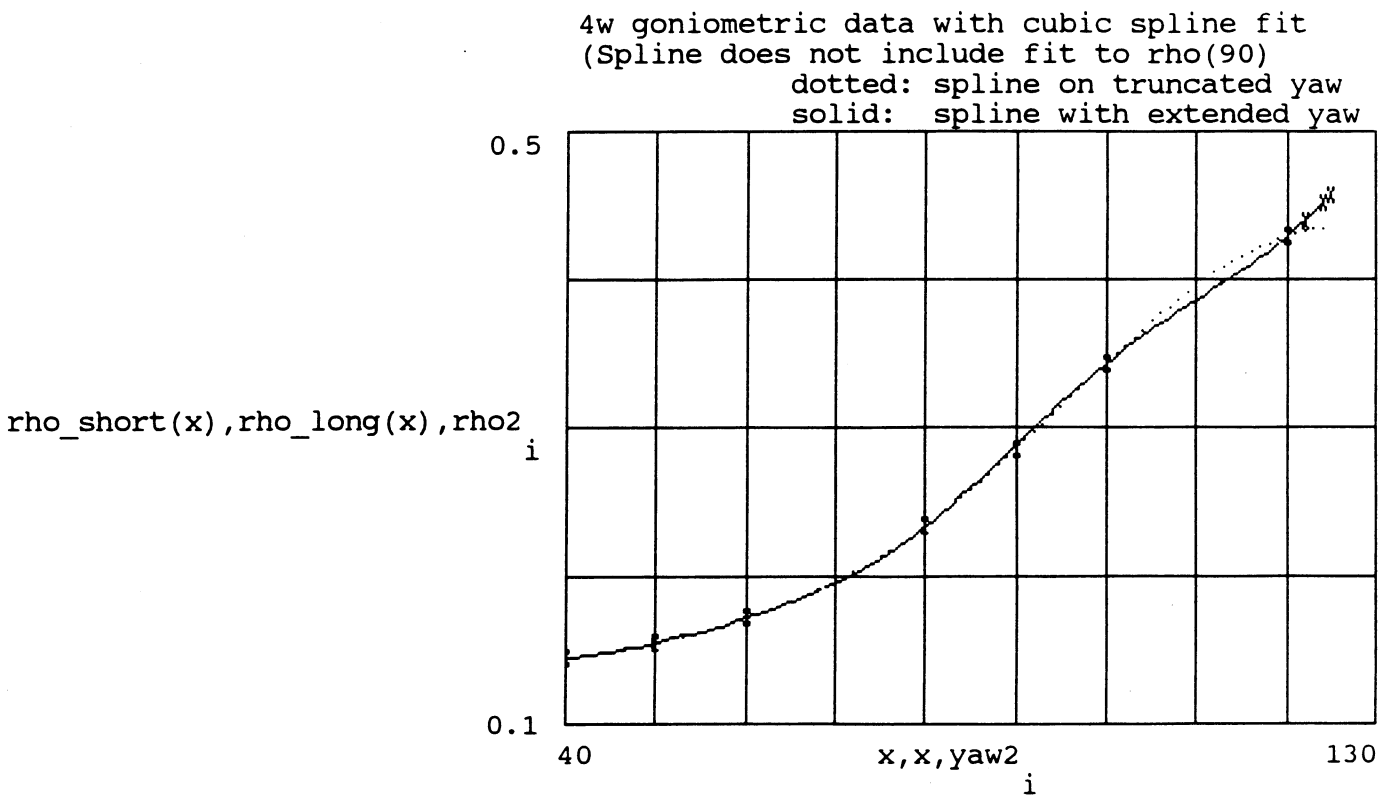
$$\text{rel_err_long} := \frac{\text{rho_long}(90) - \text{rho2}_4}{\text{rho2}_4}$$

rel_err_long = 0.00816 Using the longer yaw set to predict rho(90) results in a 0.8% error.

==========

Set up plot to compare fit to measured reflectivities.....

x := 40 ..124



4W SPLINE INTERPOLATION.....

$$Mpr_short_{is,k} := Mpr_{is,k}$$

Now, compute the spline fits for each wavelength (k) and determine the percent deviation from the observed rho(90)'s at the 6 wavelengths. This process is repeated for both long yaw (ly) and short yaw (sy) data sets.

$$cv_sy(k) := cspline\left[Yaw_short, Mpr_short^{\langle k \rangle}\right]$$

$$cv_ly(k) := cspline\left[Yaw, Mpr^{\langle k \rangle}\right]$$

$$rho_90_fit_sy_k := interp\left[cv_sy(k), Yaw_short, Mpr_short^{\langle k \rangle}, 90\right]$$

$$rho_90_fit_ly_k := interp\left[cv_ly(k), Yaw, Mpr^{\langle k \rangle}, 90\right]$$

$$rho_90_act_k := M_{5,k}$$

$$pct_error_sy := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_sy}{rho_90_act} \cdot 100\right]}$$

$$pct_error_ly := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_ly}{rho_90_act} \cdot 100\right]}$$

==========

Results:

==========

Full Yaw Spline $pct_error_ly_k$	Abbrev. Yaw $pct_error_sy_k$	Wavelength
-0.78303	0.22008	312.5
-0.55018	0.31104	317.5
-0.67291	0.28945	331.2
-0.71961	0.20247	339.8
-0.67128	0.12764	360
-0.81249	0.09321	380

note: positive errors indicate that the spline underestimated the diff-user reflectivity.

==========

==========

4W SPLINE INTERPOLATION.....

Plot the fit against the measured reflectivity data.

$k := 5$ the plot will only consider λ=380nm.

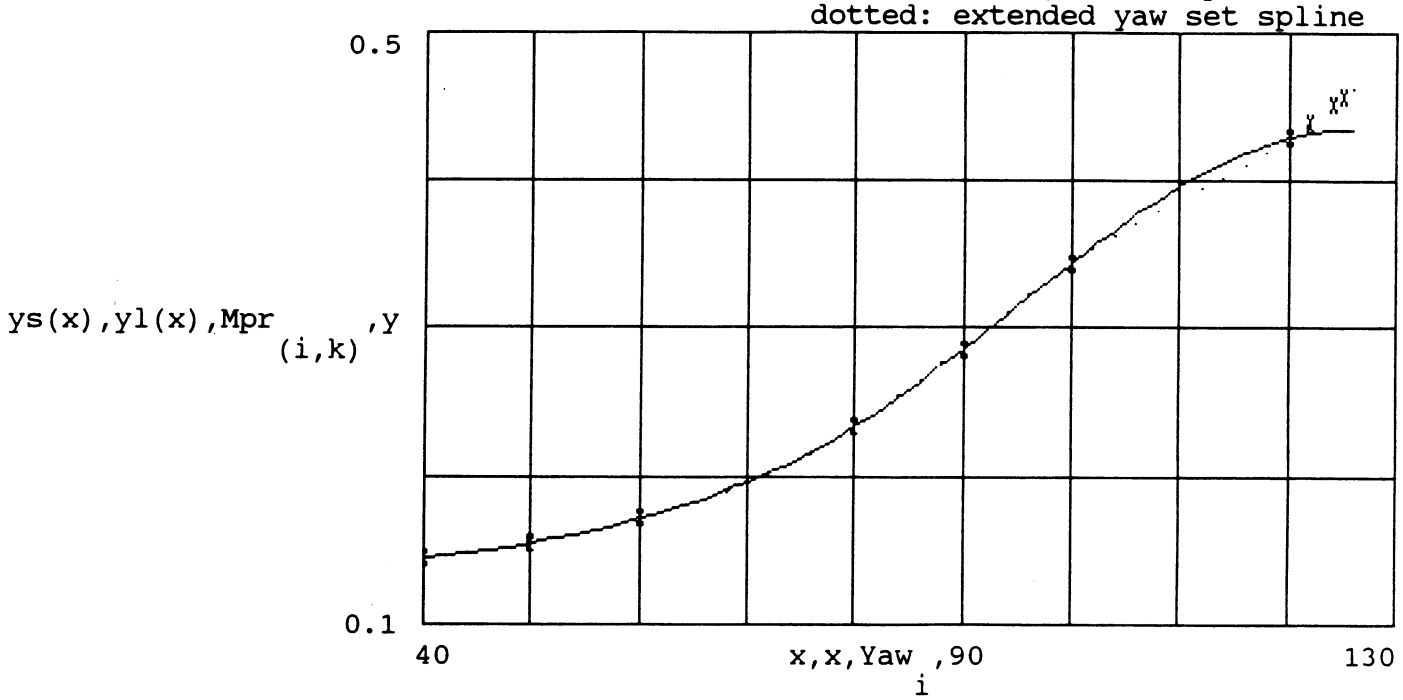
$ys(x) := interp\left[cv_sy(k), Yaw_short, Mpr_short^{<k>}, x\right]$ short yaw set

$yl(x) := interp\left[cv_ly(k), Yaw, Mpr^{<k>}, x\right]$ this is for the long yaw set fit

$x := 40, 42 .. 126$

$y := rho_90_act_k$

DIFFUSER REFLECTIVITY vs CUBIC SPLINE
INTERPOLATION at λ = 380nm,
solid: short yaw set spline
dotted: extended yaw set spline



4R SPLINE INTERPOLATION.....

$Mpr_short_{is,k} := Mpr_{is,k}$

Now, compute the spline fits for each wavelength (k) and determine the percent deviation from the observed rho(90)'s at the 6 wavelengths. This process is repeated for both long yaw (ly) and short yaw (sy) data sets.

$$cv_sy(k) := cspline\left[Yaw_short, Mpr_short^{<k>}\right]$$

$$cv_ly(k) := cspline\left[Yaw, Mpr^{<k>}\right]$$

$$rho_90_fit_sy_k := interp\left[cv_sy(k), Yaw_short, Mpr_short^{<k>}, 90\right]$$

$$rho_90_fit_ly_k := interp\left[cv_ly(k), Yaw, Mpr^{<k>}, 90\right]$$

$$rho_90_act_k := M_{5,k}$$

$$pct_error_sy := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_sy}{rho_90_act} \cdot 100\right]}$$

$$pct_error_ly := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_ly}{rho_90_act} \cdot 100\right]}$$

==========

Results:

==========

Full Yaw Spline $pct_error_ly_k$	Abbrev. Yaw $pct_error_sy_k$	Wavelength
-0.89541	-0.00289	312.5
-1.00937	-0.13046	317.5
-1.0051	-0.06879	331.2
-1.03986	-0.08099	339.8
-0.91632	0.07172	360
-0.98234	0.04012	380

note: positive errors indicate that the spline underestimated the diff-user reflectivity.

==========

==========

4R SPLINE INTERPOLATION.....

Plot the fit against the measured reflectivity data.

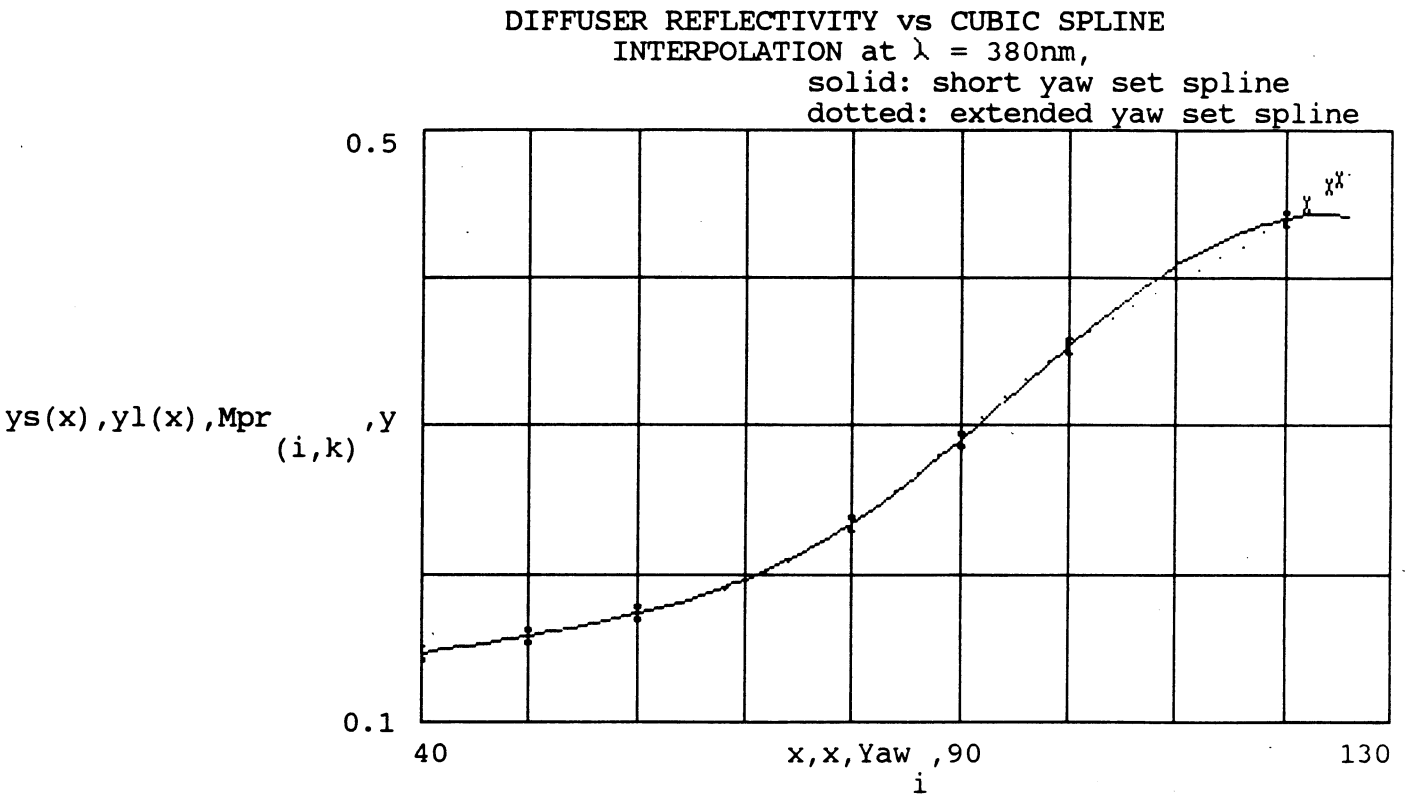
$k := 5$ the plot will only consider λ=380nm.

$ys(x) := interp\left[cv_sy(k), Yaw_short, Mpr_short^{\langle k \rangle}, x\right]$ short yaw set

$yl(x) := interp\left[cv_ly(k), Yaw, Mpr^{\langle k \rangle}, x\right]$ this is for the long yaw set fit

$x := 40, 42 .. 126$

$y := rho_90_act_k$



file: dif4fit.mcd
date: 11 November, 1991

This file extends the cubic spline fit comparison of the 4W, 380nm example to cover the three surfaces at all wavelengths. No surprises are expected here; the fits are all expected to agree within a percent of the measured rho(90) reflectivities. Two complete cubic spline interpolations are performed for each diffuser surface - one employing the complete set of yaw data to predict rho(90), the other using only yaw values between 40 and 120 degrees inclusive.

The abbreviated yaw range was used to be consistent with the earlier Matlab cubic spline interpolation reported for the irradiance response calibrations.

IMPORT DIFFUSER REFLECTIVITY DATA AND ARRANGE IN COLUMNS....
4S SPLINE INTERPOLATION.....

M := READPRN(S4DATA)

$M := (M^T)$

$$M = \begin{bmatrix} 0.43432 & 0.435 & 0.44786 & 0.45395 & 0.46951 & 0.48941 \\ 0.42985 & 0.43028 & 0.44262 & 0.44911 & 0.46411 & 0.4837 \\ 0.41962 & 0.41933 & 0.43155 & 0.43765 & 0.45284 & 0.47194 \\ 0.40919 & 0.4098 & 0.42212 & 0.42793 & 0.44319 & 0.4614 \\ 0.33036 & 0.33067 & 0.34098 & 0.34589 & 0.35693 & 0.36946 \\ 0.27411 & 0.27454 & 0.28314 & 0.28723 & 0.29579 & 0.30461 \\ 0.22157 & 0.22204 & 0.22879 & 0.23214 & 0.2383 & 0.24368 \\ 0.16108 & 0.1614 & 0.16616 & 0.16861 & 0.17228 & 0.17497 \\ 0.1456 & 0.1456 & 0.1501 & 0.15202 & 0.15508 & 0.15712 \\ 0.13535 & 0.13529 & 0.1394 & 0.14116 & 0.14404 & 0.14567 \end{bmatrix}$$

BUILD A MODIFIED ARRAY, MISSING YAW 90 DATA

$i := 0 ..8 \quad k := 0 ..5$

$$Mpr_{8-i,k} := if\left[i \geq 5, M_{i+1,k}, M_{i,k}\right]$$

$$Mpr = \begin{bmatrix} 0.13535 & 0.13529 & 0.1394 & 0.14116 & 0.14404 & 0.14567 \\ 0.1456 & 0.1456 & 0.1501 & 0.15202 & 0.15508 & 0.15712 \\ 0.16108 & 0.1614 & 0.16616 & 0.16861 & 0.17228 & 0.17497 \\ 0.22157 & 0.22204 & 0.22879 & 0.23214 & 0.2383 & 0.24368 \\ 0.33036 & 0.33067 & 0.34098 & 0.34589 & 0.35693 & 0.36946 \\ 0.40919 & 0.4098 & 0.42212 & 0.42793 & 0.44319 & 0.4614 \\ 0.41962 & 0.41933 & 0.43155 & 0.43765 & 0.45284 & 0.47194 \\ 0.42985 & 0.43028 & 0.44262 & 0.44911 & 0.46411 & 0.4837 \\ 0.43432 & 0.435 & 0.44786 & 0.45395 & 0.46951 & 0.48941 \end{bmatrix}$$

These data are then fit to cubic splines against the following yaw vector (for 'full yaw' spline interpolations).

$$Yaw := \begin{bmatrix} 40 \\ 50 \\ 60 \\ 80 \\ 100 \\ 120 \\ 122 \\ 124 \\ 125 \end{bmatrix}$$

The abbreviated, or short set, uses only 40 < yaw < 120, as was originally used in the cubic spline fits.

$is := 0 ..5$

$Yaw_short_{is} := Yaw_{is}$

$$Yaw_short = \begin{bmatrix} 40 \\ 50 \\ 60 \\ 80 \\ 100 \\ 120 \end{bmatrix}$$

4S SPLINE INTERPOLATION.....

$$Mpr_short_{is,k} := Mpr_{is,k}$$

Now, compute the spline fits for each wavelength (k) and determine the percent deviation from the observed rho(90)'s at the 6 wavelengths. This process is repeated for both long yaw (ly) and short yaw (sy) data sets.

$$cv_sy(k) := cspline\left[Yaw_short, Mpr_short^{<k>}\right]$$

$$cv_ly(k) := cspline\left[Yaw, Mpr^{<k>}\right]$$

$$rho_90_fit_sy_k := interp\left[cv_sy(k), Yaw_short, Mpr_short^{<k>}, 90\right]$$

$$rho_90_fit_ly_k := interp\left[cv_ly(k), Yaw, Mpr^{<k>}, 90\right]$$

$$rho_90_act_k := M_{5,k}$$

$$pct_error_sy := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_sy}{rho_90_act} \cdot 100\right]}$$

$$pct_error_ly := \overrightarrow{\left[\frac{rho_90_act - rho_90_fit_ly}{rho_90_act} \cdot 100\right]}$$

==========

Results:

==========

Full Yaw Spline $pct_error_ly_k$	Abbrev. Yaw $pct_error_sy_k$	Wavelength
-0.8083	0.28298	312.5
-0.59001	0.30034	317.5
-0.52322	0.32954	331.2
-0.54005	0.32734	339.8
-0.45458	0.36386	360
-0.47602	0.42215	380

note: positive errors indicate that the spline underestimated the diff-user reflectivity.

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4S SPLINE INTERPOLATION.....

Plot the fit against the measured reflectivity data.

$k := 5$ the plot will only consider λ=380nm.

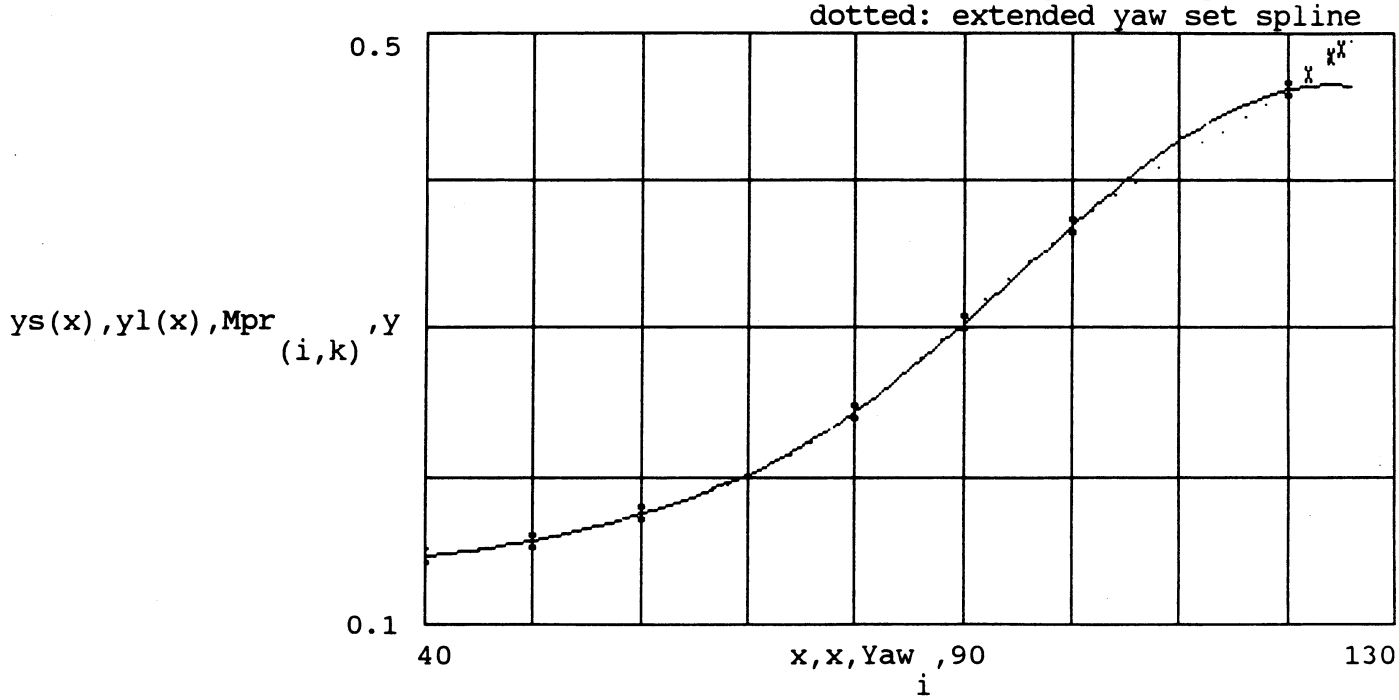
$ys(x) := interp\left[cv_sy(k), Yaw_short, Mpr_short^{<k>}, x\right]$ short yaw set

$yl(x) := interp\left[cv_ly(k), Yaw, Mpr^{<k>}, x\right]$ this is for the long yaw set fit

$x := 40, 42 .. 126$

$y := rho_90_act_k$

DIFFUSER REFLECTIVITY vs CUBIC SPLINE
INTERPOLATION at λ = 380nm,
solid: short yaw set spline
dotted: extended yaw set spline



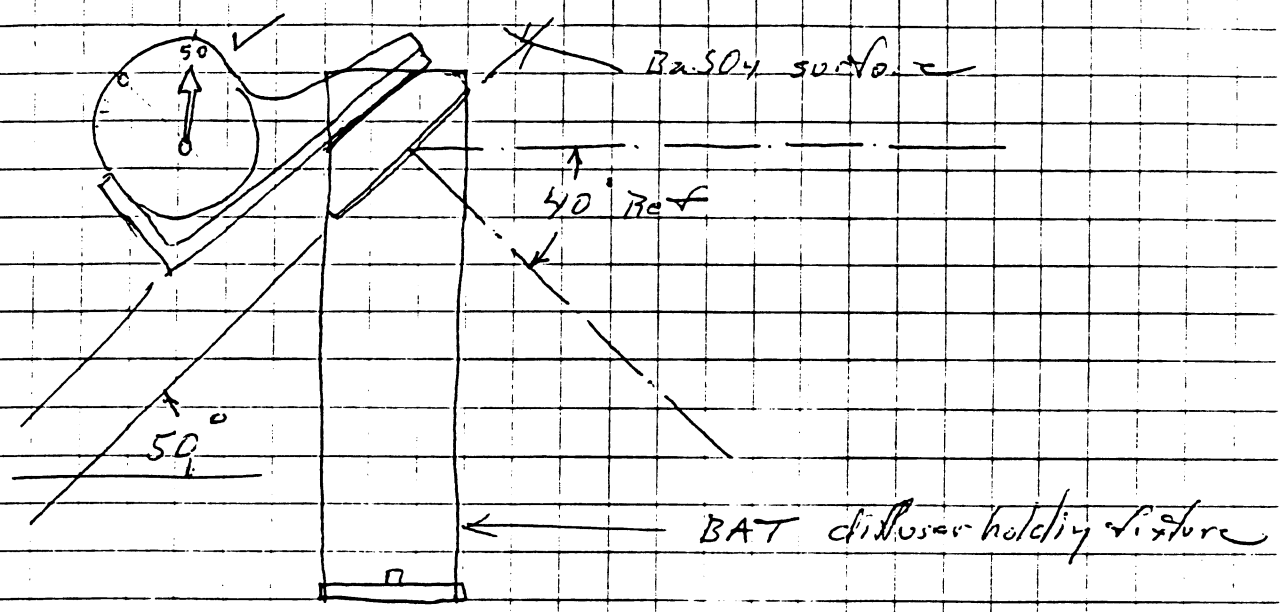
Appendix VIII

Notebook No. _____

PROJECT TOMS FM-2, Calibration Diffuser Angle

Continued From Page _____

Task: Check the $BaSO_4$ diffuser angle used for the TOMS FM-2 Radiance Calibration.



Note measurement made using Dasco Pro Inclinometer PE # 91766 last cal 6-3-91, cal due 12/3/91

Task performed 11-4-91 @ 2:10 pm BN

Note: This confirms the angle of incidence for the radiance calibration was 40°.

Continued on Page

Signed

4 Nov. 1991 Date

Read and Understood By Benjamin C. Cone Q.A.

Signed

Date