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Analysis of Results of Mini Round Robin Reflectance Test

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Thermal Processes Division
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Center for Chemical Engineering
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Introduction

A round-robin test of directional-hemispherical reflectance measurements was conducted by the National Bureau of Standards at the request of the Solar Energy Research Institute. Four national laboratories participated. Measurements were made of the directional-hemispherical reflectance of two samples, having high and low reflectance, respectively, in the wavelength range of 250 to 2500 nm.

Measured directional-hemispherical reflectance is used to compute solar reflectance of materials, and solar absorptance of opaque materials. The overall objective of the round-robin test was to obtain data on the performance of the several laboratories in making such measurements. Since all participants were national laboratories, it is to be expected that the accuracy of such measurements will approach the state of the art for measurements made with commercially available instruments.

Participating Laboratories

The participating laboratories, in alphabetical order are:

1. Battelle Pacific Northwest Laboratories, Richland, Washington

2. National Bureau of Standards, Center for Building Technology, National Engineering Laboratory, Gaithersburg, Maryland (Mail address: Washington, D.C.)

3. Sandia National Laboratory, Albuquerque, New Mexico

4. Solar Energy Research Institute, Golden, Colorado

In addition to the above, the reference measurements on the samples to which the reported values were compared, were made in the Radiometric Physics Division of the Center for Radiation Research, National Measurement Laboratory of NBS. The high-accuracy reflectometer designed and built at NBS was used for these measurements.

Preliminary Discussion

An integrating sphere reflectometer, the instrument used in evaluating directional-hemispherical reflectance, actually measures directional-near-hemispherical reflectance factor. Reflectance is defined as the ratio of reflected flux to incident flux. Reflectance factor is defined as the ratio of the flux reflected by a sample under specified conditions of irradiation and viewing, to that reflected by the ideal completely reflecting, isotropically diffusing surface. Such an ideal surface does not exist, but it is closely approximated by several materials which are near-perfect isotropic diffusers, and have high reflectance. If the reflectance of such a material is known, a correction can be made for its reflectance.

It is physically impossible to design an instrument that has true directional irradiance and hemispherical collection, because the solid angles of irradiance and collection are mutually exclusive. Some of the reflected flux is lost out the entrance aperture of the sphere, and some is lost out the detector aperture. The fraction of the flux lost in this manner is approximately equal to the ratio of the total area of all apertures to the total area of the sphere wall, apertures included. If the diameter of the apertures is small compared to the diameter of the sphere, the fractional losses will be small.

In a reflectance factor measurement in which a comparison standard of known reflectance is used, the flux losses through the ports will be exactly compensated for if the relative geometric (directional) distribution of the reflected flux is the same for sample and standard. If both sample and standard reflect diffusely, the losses will be nearly compensated.

For true geometrical conditions of hemispherical collection, reflectance factor is identically equal to reflectance. For diffusely reflecting samples, the measured directional-hemispherical reflectance factor will be identically equal to the directional-hemispherical reflectance if the ideal comparison standard is used, and the error will be small if a real diffusely reflecting standard is used and a correction is made for the absolute reflectance of the standard.

Measurement of the absolute reflectance of a diffusely reflecting sample is difficult and time-consuming. It is normally done only by a primary standards laboratory, and then only at rather long intervals.

An integrating sphere reflectometer measures only the ratio of the reflectance factor of a sample to that of the comparison standard used in the measurement. The measured value will include uncertainties due to (1) the error, if any, in the reflectance value assigned to the comparison standard, (2) differences in the fractional flux losses out the ports, due to differences in the geometrical distributions of flux by the sample and reference, (3) nonlinearity of the detector-amplifier system, and (4) scattering in double-beam instruments, so that some of the flux in the reference beam is scattered into the sample beam, or vice versa. To this must be added an uncertainty due to the statistical fluctuation in the output of the instrument, usually referred to as noise.

With double-beam instruments, it is customary to run a 100% curve and a zero curve. The 100% curve is obtained with identical samples in the two beams. The zero curve is usually obtained when the sample beam is blocked before entering the sphere. A correction for deviation of the two curves from 100% and 0% respectively is made by use of the following equation.

$$R_\lambda = \frac{S_\lambda - 0_\lambda}{H_\lambda - 0_\lambda} \qquad (1)$$

where R_λ is the corrected directional-hemispherical reflectance factor, S_λ is the sample reading, O_λ is the zero curve reading, and H_λ is the 100% curve reading, all at wavelength λ.

The results of a round-robin test can be analyzed to give an estimate of the fractions of the total error that may be due to bias and random error, respectively, and may give some indication of the source of some of the bias.

Samples for Measurement

The samples sent to the participants were black and white samples, either 50.8x50.8 mm (2x2 inch) or 25.4x25.4 mm (1x1 inch) for the black, and 50.8x50.8 mm (2x2 inch) or 25.4x76.2 mm (1-1/2x3 inch) for the white. The smaller samples were intended for measurement in instruments utilizing an Edwards-type integrating sphere in which the sample is held at the center of the sphere by a rod inserted through an aperture in the top of the sphere. The aperture in these spheres is too small to admit a 50.8x50.8 mm (2x2 inch) sample. The black samples were of black porcelain enamel, with spectral directional-hemispherical reflectance in the range of about 0.06 to 0.11 in the wavelength range of 250 to 2500 nm. The white samples were white ceramic tile, with reflectance generally above 0.8 at wavelengths from about 500 to 2500 nm, dropping from about 0.8 at 500 nm to about 0.15 at 250 nm.

These samples were among those calibrated for directional-hemispherical reflectance in the Radiometric Physics Division of NBS.

Data Requested

The data requested from all participants was the measured directional-hemispherical reflectance for near-normal incidence, including the specular component, and if possible, the same data for angles of incidence of 15, 30, 45 and 60 degrees from normal. Data were requested at 10 nm intervals over as much of the wavelength range of 250 to 2500 nm as the measurement instrument was capable of providing. The instructions for the test are given in Appendix 1.

Results of Measurements

The results reported by the different laboratories are shown in Table 1 for the white samples and Table 2 for the black samples, together with the calibration values for the sample measured in each case.

The values reported for the solar reflectance of the white sample and the solar absorptance of the black sample are given in Table 3. The procedures used to compute the solar properties are given in Table 4.

Because different samples were measured by each laboratory, direct comparison of the reported values is not justified. The calibration values for each sample at each wavelength are included in Table 1 in the column headed "Cal", and the algebraic difference between the calibration value and the reported value is included in the column headed "Diff".

The difference values obtained by subtracting the calibration value from the reported value were plotted as a function of wavelength as shown in figures 1 to 8. The average differences for the white samples were about 0.029 for Lab 1, 0.012 for Lab 2, 0.019 for Lab 3 and 0.010 for Lab 4. The standard deviations associated with these values were about 0.02 for Lab 1, 0.01 for Lab 2, 0.012 for Lab 3 and 0.003 for Lab 4.

A review of figures 1 to 4, where the data for the white samples are plotted, gives some clues to the errors that may be present in the reported values. Figure 1 shows that the data are slightly wavelength dependent. The average value of the difference is about 0.003, and the standard deviation about 0.006. The wavelength dependence and average difference suggests that the values assigned to the halon reference are in error, particularly at wavelengths below 600 nm.

Figure 2, showing the differences for Lab 2, indicates that the values assigned to the Halon reference are high at wavelengths below about 360 nm, and uniformly low by about .0013 at wavelengths beyond about 400 nm.

Figure 3, showing the differences for Lab 3, indicates that the errors are unacceptably high at wavelengths of 800 to 850 nm and at 1380 nm, and at the very short wavelengths in the ultraviolet and at wavelengths beyond 1900 nm in the infrared. The peaks at about 820 nm and 1380 nm may be at the points where detectors were changed, and the signal-tp-noise ratio is small. The signal-to-noise ratio may also be small at the two ends of the spectral range. The comparison standard used for the measurements was not identified.

Figure 4, showing the differences for Lab 4, indicates that the value assigned to the pressed Halon comparison standard may be low by about 0.01. The random error is the lowest of any of the laboratories.

The average differences for the black samples are about 0.0056 for Lab 1, 0.002 for Lab 2, 0.004 for Lab 3 and -.005 for Lab 4, and the standard deviations are about 0.0013 for Lab 1, 0.0028 for Lab 2, 0.0043 for Lab 3 and 0.0037 for Lab 4.

Figure 5 is a plot of the differences for Lab 1 and shows an average difference of 0.0056, and the standard deviation is about 0.0013. The standard deviation is the lowest reported for the black samples, and indicates a very low random error. There is a slight tendency for the error to be greater at the short and long wavelengths. The bias in the data, of about 0.5%, is much too large to be accounted for by an incorrect value for comparison standard, since the value assigned to the comparison standard would have to be about 8% high to account for such a large bias, and the data on the white sample indicates that such a large error is highly unlikely. The bias must be due to a zero line error. The equation used for reducing the data as reported by the investigator, does not show that a zero line correction was made.

Figure 6 shows that the bias in the results reported by Lab 2 is very low, which is also indicated by the average difference of 0.00178, the lowest reported by any of the laboratories for the black samples. The standard deviation is about double that reported by Lab 1. There is no marked variation of the differences with wavelength.

Figure 7 shows that there is an overall trend of increasing difference with wavelength. The peak at about 800 to 850 nm, which is very prominent in figure 3, is still present, but the peak at about 1380 nm, if present, is masked by the random error, which is the largest reported for a black sample, as indicated by the standard deviation of about 0.004.

Figure 8 shows a slight trend toward increasing difference with wavelength. There is a very pronounced peak at about 900 nm and valley at about 1000 nm. This is near the wavelength where detectors are likely to be changed, and may be due to nonlinearity of the detectors in spectral regions where the response is low. The random error appears to be low, and the high standard deviation, 0.00433, appears to be due largely to fluctuations of the difference with wavelength. Again, it appears likely that the observed differences are due to zero line errors.

The coefficient of variation, the ratio of the standard deviation to the mean, may be a more useful measure of the significance of the errors in the measured reflectances. These are shown in Table 5, in which the mean reflectance is taken as the solar reflectance reported by each laboratory. The values for the white samples range from 0.0038 ± 0.0069 for Lab 1 to 0.0225 ± 0.0140 for Lab 3, and for the black samples from 0.0250 ± 0.0399 for Lab 2 to -.0811 ± .0524 for Lab 1. The average of the absolute values is 0.0128 ± .00915 for the white samples, and 0.0456 ± 0.0432. In each case the ± uncertainty is taken as one standard deviation. This is probably much too large for the uncertainty of the average values, for which the individual values vary from 47 to 220, but may be more reasonable for the uncertainty in a single value at one wavelength. The reported data provided essentially no information on which a valid evaluation of the true random error could be based, which would involve multiple measurements at each wavelength with each reflectometer.

Within the limitations of the available data, the figures in Table 5 give an estimate of the state of the art in reflectance measurements in the participating laboratories.

Some general conclusions can be drawn from the results of this round-robin test. The bias in the reported values can be largely eliminated by proper use of the reflectance standards recently made available by the National Bureau of Standards as SRM's 2019, 2020, 2021, and 2022 under the sponsorship of SERI. The errors are due partly to the use of incorrect reflectance values for the reference standards, and partly to 100% line and zero-line errors. The white standards can be used to check the values assigned to the reference standards, and also to evaluate the 100% errors. The black standards can be used to detect, and to help correct the zero line errors. The errors in the values reported by the participating laboratories are larger than were expected, and especially the errors in the measurement of solar absorptance. Such errors introduce rather large errors into the computations of the thermal efficiencies of solar collectors from the measured absorptance of the absorber.

Appendix I

Instructions for Round Robin Test

1. Preparation of Samples

The reflectance of the samples may be significantly affected by dirt or surface films that are not easily seen. They should be cleaned before measurement, using the following procedure.

The white samples are glazed ceramic tiles that have been cut to size. The ceramic body is porous, and would absorb water if not sealed. The back and edges have been sealed with an epoxy base masonry sealant. If this seal is breached, the sample may absorb water, particularly if immersed. Absorbed water will change the reflectance, primarily in the infrared. The samples should be handled gently to avoid chipping or a breach of the seal, and should never be immersed in water. Momentary exposure to water as described in the cleaning procedure will not affect them if the seal is not broken.

The cleaning procedure is as follows for both black and white samples.

1. Rinse with tepid tap water.

2. Wash with a dilute solution of a mild liquid soap, such as Ivory Liquid,[1] using gentle rubbing with a soft cloth or rubber sponge. Never use on abrasive cleaner.

3. Rinse with tepid tap water, to remove soap.

4. Rinse with distilled water.

5. Blot dry with a fresh facial tissue. Do not rub.

6. Allow to air dry for at least 30 minutes before measuring.

[1] Any other noncorrosive liquid soap is also suitable for this use.

Measurement Procedure

The data desired are the spectral directional-hemispherical reflectance for near-normal incidence, including the specular component. In addition, if you have the facilities, also the spectral directional-hemishperical reflectance for angles of incidence of 15, 30, 45 and 60 degrees from normal, including the specular component.

1. Calibrate your reflectometer, using your normal procedure.

2. Measure the samples, using your normal procedure, making corrections as required.

3. Report data at 10 nm intervals over as much of the wavelength range of 250 to 2500 nm as your reflectometer can cover.

4. Compute solar reflectance of the white sample and solar absorptance of the black sample, using your normal procedures, and report the results.

5. Send the data to

   J. C. Richmond
   Room B126 Metrology
   National Bureau of Standards
   Washington, DC 20234

6. Include with the data a detailed description of all procedures used, including the manufacturer and model number of all instruments used, the method of reducing data, and the solar spectral distribution and method of computation used for computing solar properties.

TABLE 1 - RESULTS OF ROUND ROBIN TEST ON WHITE SAMPLES

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
300	.134	.147	-.013	.1470	.147	.0000	.2126	.140	.0726	.1446	.147	-.0024
310				.1940	.190	.0040	.2212	.190	.0312	.1829	.190	-.0071
320				.2025	.238	-.0355	.2630	.238	.0250	.2365	.238	-.0015
330				.3251	.303	-.0221	.3241	.303	.0211	.3063	.303	.0033
340				.3304	.377	-.0466	.3995	.377	.0225	.3082	.377	.0032
350	.437	.451	-.014	.4556	.460	-.0044	.4783	.460	.0183	.4620	.451	.0110
360				.5377	.541	-.0033	.5614	.541	.0204	.5438	.533	.0108
370				.6118	.608	.0038	.6266	.608	.0186	.6119	.601	.0109
380				.6616	.654	.0076	.6739	.654	.0199	.6593	.648	.0113
390				.7025	.690	.0125	.7096	.690	.0196	.6937	.684	.0097
400	.703	.714	-.011	.7347	.720	.0147	.7382	.720	.0182	.7245	.714	.0105
410				.7536	.737	.0166	.7537	.737	.0167	.7427	.731	.0117
420				.7663	.749	.0173	.7743	.749	.0253	.7520	.742	.0100
430				.7755	.757	.0185	.7736	.767	.0166	.7631	.751	.0121
440				.7807	.762	.0187	.7782	.762	.0162	.7665	.756	.0105
450	.755	.761	-.006	.7824	.767	.0154	.7815	.767	.0145	.7716	.761	.0106
460				.7890	.772	.0170	.7858	.772	.0138	.7770	.765	.0120
470				.7934	.776	.0174	.7891	.776	.0131	.7819	.770	.0119
480				.7994	.780	.0194	.7938	.780	.0138	.7867	.774	.0127
490				.8046	.787	.0176	.8010	.787	.0140	.7930	.781	.0120
500	.783	.787	-.004	.8114	.793	.0184	.8074	.793	.0144	.7993	.787	.0123
510				.8177	.799	.0187	.8125	.799	.0135	.8056	.793	.0126
520				.8229	.805	.0179	.8163	.805	.0113	.8111	.799	.0121
530				.8288	.811	.0178	.8217	.811	.0107	.8166	.805	.0116
540				.8339	.816	.0179	.8271	.816	.0111	.8231	.811	.0121
550	.813	.815	-.002	.8379	.820	.0179	.8295	.820	.0095	.8279	.815	.0129
560				.8416	.825	.0166	.8346	.825	.0096	.8322	.819	.0132
570				.8451	.829	.0161	.8383	.829	.0093	.8351	.824	.0111
580				.8464	.831	.0154	.8367	.831	.0057	.8359	.826	.0099
590				.8484	.834	.0144	.8427	.834	.0087	.8402	.829	.0112
600	.832	.833	-.001	.8546	.837	.0176	.8468	.837	.0098	.8451	.833	.0121
610				.8568	.839	.0178	.8484	.839	.0094	.8478	.835	.0128
620				.8591	.842	.0171	.8523	.842	.0103	.8497	.836	.0137
630				.8610	.843	.0180	.8546	.843	.0116	.8503	.838	.0123
640				.8638	.846	.0178	.8561	.846	.0101	.8513	.840	.0113
650	.841	.838	.003	.8629	.844	.0189	.8567	.844	.0127	.8519	.838	.0139
660				.8628	.848	.0148	.8614	.848	.0134	.8561	.842	.0141
670				.8698	.851	.0188	.8646	.851	.0136	.8589	.844	.0149
680				.8722	.851	.0212	.8662	.851	.0152	.8609	.845	.0159
690				.8724	.853	.0194	.8660	.853	.0130	.8618	.847	.0148
700	.853	.851	.002									
700	.854	.851	.003	.8745	.857	.0175	.8717	.857	.0147	.8642	.851	.0132
710							.8768	.858	.0188	.8667	.853	.0137
720							.8801	.859	.0211	.8690	.854	.0150
730							.8842	.860	.0242	.8699	.854	.0159
740				.8718	.861	.0108	.8877	.861	.0267	.8686	.855	.0136
750	.857	.856	.001									
750	.858	.856	.002				.8903	.862	.0283	.8652	.856	.0092
760							.8986	.862	.0366	.8648	.856	.0088
770							.9008	.863	.0378	.8642	.857	.0072
780				.8768	.863	.0138	.9051	.863	.0421	.8628	.856	.0068
790							.9100	.861	.0490	.8636	.855	.0086
800	.856	.854	.002									
800	.858	.854	.004.				.9129	.860	.0529	.8637	.854	.0097
810							.9128	.862	.0508	.8604	.856	.0044
820				.8718	.860	.0118	.9136	.860	.0536	.8610	.854	.0070
830							.9129	.859	.0539	.8606	.853	.0076
840							.9100	.857	.0530	.8591	.852	.0071
850	.851	.850	.001				.9043	.856	.0483	.8588	.850	.0088
860				.8640	.855	.0090	.8977	.855	.0427	.8597	.849	.0107
870							.8860	.853	.0330	.8581	.847	.0111
880							.8780	.852	.0260	.8567	.846	.0107
890							.8692	.852	.0172	.8549	.845	.0099

TABLE 1 - continued

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
900	.847	.845	.002	.8576	.852	.0056	.8645	.852	.0125	.8560	.845	.0110
910							.8590	.853	.0060	.8566	.845	.0116
920							.8584	.853	.0054	.8575	.846	.0115
930							.8566	.853	.0036	.8574	.846	.0114
940				.8644	.853	.0114	.8564	.853	.0034	.8585	.846	.0125
950	.849	.846	.003				.8551	.853	.0021	.8586	.846	.0126
960							.8576	.853	.0046	.8585	.846	.0125
970							.8578	.853	.0048	.8589	.847	.0119
980				.8685	.856	.0125	.8585	.856	.0025	.8595	.849	.0105
990							.8598	.856	.0038	.8624	.849	.0134
1000	.851	.851	.000				.8604	.858	.0024	.8631	.851	.0121
1010							.8618	.859	.0028	.8630	.852	.0110
1020				.8733	.860	.0133	.8652	.860	.0052	.8636	.853	.0106
1030							.8661	.860	.0061	.8631	.854	.0091
1040							.8692	.861	.0082	.8626	.855	.0076
1050	.856	.856	.000				.8703	.861	.0093	.8625	.856	.0065
1060				.8708	.861	.0098	.8692	.861	.0082	.8626	.857	.0056
1070							.8709	.861	.0099	.8627	.857	.0057
1080							.8708	.862	.0088	.8627	.857	.0057
1090							.8698	.862	.0078	.8641	.857	.0071
1100	.860	.857	.003	.8698	.861	.0088	.8686	.861	.0076	.8650	.857	.0080
1110							.8670	.862	.0050	.8655	.857	.0085
1120							.8707	.865	.0057	.8665	.860	.0065
1130							.8742	.868	.0062	.8686	.862	.0066
1140				.8778	.869	.0088	.8748	.869	.0058	.8696	.864	.0056
1150	.867	.865	.002				.8783	.870	.0083	.8710	.865	.0060
1160							.8777	.871	.0067	.8716	.867	.0046
1170							.8795	.871	.0085	.8726	.867	.0056
1180				.8798	.871	.0088	.8812	.871	.0102	.8730	.866	.0070
1190							.8826	.871	.0116	.8740	.867	.0070
1200	.870	.867	.003				.8833	.872	.0113	.8740	.867	.0070
1210							.8823	.872	.0103	.8732	.867	.0062
1220				.8809	.872	.0089	.8828	.872	.0108	.8732	.867	.0062
1230							.8818	.872	.0098	.8737	.867	.0067
1240							.8827	.871	.0117	.8737	.867	.0067
1250	.872	.868	.004				.8826	.872	.0106	.8741	.868	.0061
1260				.8806	.873	.0076	.8852	.873	.0122	.8737	.868	.0057
1270							.8834	.871	.0124	.8736	.867	.0066
1280							.8817	.871	.0107	.8723	.867	.0053
1290							.8798	.871	.0088	.8722	.867	.0052
1300	.870	.866	.004	.8791	.870	.0091	.8806	.870	.0106	.8732	.866	.0072
1310							.8809	.870	.0109	.8726	.866	.0066
1320							.8807	.870	.0107	.8731	.866	.0071
1330							.8800	.870	.0100	.8726	.866	.0066
1340				.8838	.869	.0148	.8806	.869	.0116	.8726	.866	.0066
1350	.870	.865	.005				.8837	.869	.0147	.8727	.865	.0077
1360							.8875	.869	.0185	.8710	.865	.0060
1370							.8916	.869	.0226	.8710	.865	.0060
1380				.8831	.867	.0161	.9116	.867	.0446	.8699	.864	.0059
1390							.9074	.866	.0414	.8711	.862	.0091
1400	.866	.862	.004				.8939	.866	.0279	.8691	.862	.0071
1410							.8859	.867	.0189	.8702	.863	.0072
1420				.8832	.867	.0162	.8848	.867	.0178	.8697	.863	.0067
1430							.8830	.868	.0150	.8707	.863	.0077
1440							.8846	.867	.0176	.8712	.863	.0082
1450	.869	.863	.006				.8836	.867	.0166	.8708	.863	.0078
1460				.8833	.867	.0163	.8826	.867	.0156	.8707	.863	.0077
1470							.8831	.866	.0171	.8707	.862	.0087
1480							.8825	.865	.0175	.8702	.861	.0092
1490							.8806	.863	.0176	.8701	.859	.0111
1500	.864	.859	.005	.8741	.863	.0111	.8770	.863	.0140	.8700	.859	.0110
1510							.8818	.867	.0148	.8722	.864	.0082
1520							.8848	.869	.0158	.8747	.866	.0087
1530							.8851	.871	.0141	.8747	.866	.0087
1540				.8830	.871	.0120	.8858	.871	.0148	.8748	.866	.0088

TABLE 1 - continued

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
1550	.874	.867	.007				.8876	.871	.0166	.8748	.867	.0078
1560							.8874	.871	.0164	.8752	.867	.0082
1570							.8873	.871	.0163	.8752	.867	.0082
1580				.8887	.872	.0167	.8884	.872	.0164	.8766	.867	.0096
1580							.8876	.872	.0156	.8761	.868	.0081
1600	.873	.868	.005				.8877	.872	.0157	.8766	.868	.0086
1610							.8875	.872	.0155	.8766	.868	.0086
1620				.8841	.872	.0121	.8877	.872	.0157	.8761	.868	.0081
1630							.8873	.871	.0163	.8753	.867	.0083
1640							.8884	.872	.0164	.8753	.867	.0083
1650	.873	.867	.006				.8878	.872	.0158	.8753	.867	.0083
1660				.8836	.872	.0116	.8883	.872	.0163	.8757	.867	.0087
1670							.8887	.872	.0167	.8758	.867	.0088
1680							.8899	.872	.0179	.8757	.867	.0087
1690							.8883	.871	.0173	.8749	.867	.0079
1700	.872	.867	.005	.8840	.871	.0130	.8900	.871	.0190	.8753	.867	.0083
1710							.8892	.871	.0182	.8749	.867	.0079
1720							.8894	.871	.0184	.8753	.866	.0093
1730							.8885	.870	.0185	.8743	.866	.0083
1740				.8821	.870	.0121	.8871	.870	.0171	.8744	.865	.0094
1750	.871	.865	.006				.8869	.870	.0169	.8733	.865	.0083
1760							.8856	.870	.0156	.8743	.865	.0093
1770							.8862	.870	.0162	.8742	.865	.0092
1780				.8826	.870	.0126	.8866	.870	.0166	.8738	.865	.0088
1790							.8861	.870	.0161	.8738	.864	.0098
1800	.870	.865	.005				.8871	.870	.0171	.8739	.865	.0089
1810							.8811	.869	.0121	.8738	.864	.0098
1820				.8807	.868	.0127	.8868	.868	.0188	.8738	.863	.0108
1830							.8846	.868	.0166	.8732	.863	.0102
1840							.8858	.867	.0188	.8724	.862	.0104
1850	.869	.861	.008				.8886	.866	.0226	.8709	.861	.0099
1860				.8772	.865	.0122	.8857	.865	.0207	.8723	.861	.0113
1870							.8897	.865	.0247	.8672	.861	.0062
1880							.8844	.861	.0234	.8671	.856	.0111
1890							.8784	.856	.0224	.8659	.852	.0139
1900	.857	.852	.005	.8682	.854	.0142	.8778	.854	.0238	.8606	.852	.0086
1910							.8793	.856	.0233	.8601	.854	.0061
1920							.8830	.860	.0230	.8631	.856	.0071
1930							.8837	.862	.0217	.8650	.858	.0070
1940				.8807	.863	.0177	.8843	.863	.0213	.8686	.859	.0096
1950	.865	.859	.006				.8836	.863	.0206	.8705	.859	.0115
1960							.8862	.865	.0212	.8701	.861	.0091
1970							.8892	.867	.0222	.8729	.862	.0119
1980				.8757	.867	.0087	.8903	.867	.0233	.8733	.863	.0103
1990							.8999	.868	.0319	.8744	.864	.0104
2000	.866	.863	.003				.8921	.869	.0231	.8760	.863	.0130
2010							.8954	.869	.0264	.8776	.864	.0136
2020				.8799	.870	.0099	.8980	.870	.0280	.8777	.865	.0127
2030							.9041	.870	.0341	.8784	.866	.0124
2040							.9038	.870	.0338	.8776	.866	.0116
2050	.870	.865	.005				.9043	.870	.0343	.8791	.865	.0141
2060				.8787	.869	.0097	.9049	.869	.0359	.8781	.865	.0131
2070							.9079	.870	.0379	.8792	.865	.0142
2080							.9131	.870	.0431	.8798	.866	.0138
2090							.9088	.871	.0378	.8808	.867	.0138
2100	.874	.867	.007	.8872	.871	.0162	.9148	.871	.0438	.8804	.867	.0134
2110							.9122	.873	.0392	.8811	.868	.0131
2120							.9156	.872	.0436	.8827	.868	.0147
2130							.9146	.870	.0446	.8798	.866	.0138
2140				.8828	.869	.0138	.9145	.869	.0455	.8775	.864	.0135
2150	.874	.863	.011				.9128	.867	.0458	.8754	.863	.0124
2160										.8751	.861	.0141
2170										.8714	.858	.0134
2180				.8769	.860	.0169				.8682	.855	.0132
2190										.8641	.852	.0121

TABLE 1 - continued

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
2200	.860	.851	.009							.8650	.851	.0104
2210										.8639	.851	.0129
2220				.8637	.858	.0057				.8610	.852	.0090
2230										.8671	.854	.0131
2240										.8649	.855	.0099
2250	.862	.856	.006							.8668	.856	.0108
2260				.8673	.859	.0083				.8653	.856	.0093
2270										.8665	.858	.0085
2280										.8674	.858	.0094
2290										.8657	.859	.0067
2300	.867	.859	.008	.8668	.860	.0068				.8678	.859	.0088
2310										.8744	.860	.0144
2320										.8732	.861	.0122
2330										.8723	.863	.0093
2340				.8804	.863	.0174				.8731	.863	.0101
2350	.869	.862	.007							.8721	.862	.0101
2360										.8715	.861	.0115
2370										.8702	.859	.0112
2380				.8775	.859	.0185				.8669	.859	.0079
2390										.8671	.858	.0091
2400	.866	.852	.014							.8656	.852	.0136
2410										.8623	.854	.0083
2420				.8642	.851	.0132				.8667	.851	.0157
2430										.8611	.848	.0131
2440										.8556	.846	.0096
2450	.858	.843	.015							.8570	.843	.0140
2460				.8521	.842	.0101				.8513	.842	.0093
2470										.8496	.840	.0096
2480										.8518	.839	.0128
2490										.8478	.838	.0098
2500				.8534	.839	.0144						
N			47			86			185			220
ΣX			.146			.9995			3.5086			2.1339
ΣX^2			.001936			2.074143			.09202732			.02284661
$\bar{X}$			.003106			.01162			.01895			.00970
σ			.005677			.01036			.01177			.00313

TABLE 2 - RESULTS OF ROUND ROBIN TEST ON BLACK SAMPLES

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
300	.049	.057	-.008	.0559	.057	-.0011	.0701	.057	.0131	.0534	.057	-.0036
310				.0567	.057	-.0003	.0670	.057	.0100	.0534	.057	-.0036
320				.0573	.059	-.0017	.0658	.059	.0068	.0544	.059	-.0046
330				.0568	.059	-.0022	.0660	.059	.0070	.0574	.059	-.0016
340				.0598	.060	-.0002	.0668	.060	.0068	.0573	.060	-.0027
350	.053	.060	-.007	.0596	.060	-.0004	.0681	.060	.0021	.0563	.060	-.0037
360				.0613	.062	-.0007	.0694	.062	.0074	.0575	.062	-.0045
370				.0632	.063	.0002	.0712	.063	.0082	.0605	.063	-.0025
380				.0653	.065	.0003	.0741	.065	.0091	.0634	.065	-.0016
390				.0686 -	.068	.0006	.0769	.068	.0089	.0643	.068	-.0037
400	.064	.070	-.006	.0706	.070	.0006	.0770	.070	.0070	.0643	.070	-.0057
410				.0709	.071	-.0001	.0767	.071	.0057	.0652	.071	-.0058
420				.0710	.070	.0010	.0759	.070	.0059	.0662	.070	-.0038
430				.0708	.070	.0008	.0754	.070	.0054	.0663	.070	-.0037
440				.0704	.069	.0014	.0749	.069	.0059	.0644	.069	-.0046
450	.063	.069	-.006	.0701	.069	.0011	.0745	.069	.0055	.0645	.069	-.0045
460				.0702	.069	.0012	.0744	.069	.0054	.0645	.069	-.0045
470				.0698	.069	.0008	.0742	.069	.0052	.0635	.069	-.0055
480				.0702	.069	.0012	.0736	.069	.0046	.0645	.069	-.0045
490				.0691	.068	.0011	.0733	.068	.0053	.0634	.068	-.0046
500	.062	.068	-.006	.0689	.068	.0009	.0727	.068	.0047	.0634	.068	-.0046
510				.0687	.068	.0007	.0721	.068	.0041	.0644	.068	-.0036
520				.0680	.067	.0010	.0718	.067	.0048	.0612	.067	-.0058
530				.0681	.067	.0011	.0714	.067	.0054	.0613	.067	-.0057
540				.0681	.066	.0021	.0711	.066	.0051	.0622	.066	-.0038
550	.059	.066	-.007	.0676	.066	.0016	.0708	.066	.0048	.0613	.066	-.0047
560				.0672	.066	.0012	.0704	.066	.0044	.0616	.066	-.0044
570				.0662	.065	.0012	.0692	.065	.0042	.0614	.065	-.0036
580				.0663	.065	.0013	.0685	.065	.0035	.0593	.065	-.0057
590				.0653	.064	.0013	.0683	.064	.0043	.0603	.064	-.0037
600	.058	.064	-.006	.0650	.064	.0010	.0678	.064	.0038	.0614	.064	-.0026
610				.0650	.064	.0010	.0677	.064	.0037	.0625	.064	-.0015
620				.0647	.064	.0007	.0675	.064	.0035	.0615	.064	-.0025
630				.0640	.064	.0000	.0675	.064	.0035	.0605	.064	-.0035
640				.0645	.063	.0015	.0674	.063	.0044	.0605	.063	-.0025
650	.058	.063	-.005	.0642	.063	.0012	.0677	.063	.0047	.0624	.063	-.0006
660				.0644	.063	.0014	.0678	.063	.0048	.0614	.063	-.0016
670				.0651	.063	.0021	.0681	.063	.0051	.0624	.063	-.0006
680				.0645	.064	.0005	.0685	.064	.0045	.0633	.064	-.0007
690				.0655	.064	.0015	.0687	.064	.0047	.0634	.064	-.0006
700	.059	.065	-.006									
700	.059	.065	-.006	.0653	.065	.0003	.0666	.065	.0016	.0614	.065	-.0036
710							.0683	.065	.0033	.0671	.065	.0021
720							.0673	.065	.0023	.0662	.065	.0012
730							.0677	.065	.0027	.0642	.065	-.0008
740				.0660	.065	.0010	.0673	.065	.0023	.0643	.065	-.0007
750	.059	.065	-.006									
750	.059	.065	-.006				.0701	.065	.0051	.0623	.065	-.0027
760							.0652	.065	.0002	.0624	.065	-.0026
770							.0677	.065	.0027	.0624	.065	-.0026
780				.0574	.065	-.0076	.0722	.065	.0072	.0624	.065	-.0026
790							.0716	.065	.0066	.0624	.065	-.0026
800	.060	.065	-.005									
800	.061	.065	-.004				.0740	.065	.0090	.0624	.065	-.0026
810							.0762	.065	.0112	.0622	.065	-.0028
820				.0698	.066	.0038	.0741	.066	.0081	.0643	.066	-.0017
830							.0763	.067	.0093	.0654	.067	-.0016
840							.0759	.067	.0089	.0665	.067	-.0005
850	.065	.068	-.003				.0756	.068	.0076	.0675	.068	-.0005
860				.0676	.069	-.0014	.0745	.069	.0055	.0694	.069	.0004
870							.0729	.070	.0029	.0714	.070	.0014
880							.0729	.072	.0009	.0733	.072	.0013
890							.0776	.073	.0046	.0753	.073	.0023

TABLE 2 - continued

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
900	.071	.074	-.003	.0781	.074	.0041	.0781	.074	.0041	.0773	.074	.0033
910							.0811	.077	.0041	.0812	.077	.0042
920							.0805	.079	.0015	.0842	.079	.0052
930							.0873	.082	.0053	.0872	.082	.0052
940				.0934	.085	.0084	.0920	.085	.0070	.0902	.085	.0052
950	.086	.089	-.003				.0902	.089	.0012	.0922	.089	.0032
960							.0933	.092	.0013	.0931	.092	.0011
970							.0968	.095	.0018	.0941	.095	-.0009
980				.0966	.097	-.0010	.0968	.097	-.0002	.0923	.097	-.0047
990							.1001	.099	.0011	.0923	.099	-.0067
1000	.095	.100	-.005	-			.0984	.100	-.0016	.0912	.100	-.0088
1010							.1010	.100	.0010	.0902	.100	-.0098
1020				.1000	.100	.0000	.1014	.100	.0014	.0892	.100	-.0108
1030							.0961	.099	-.0029	.0872	.099	-.0118
1040							.0943	.098	-.0039	.0852	.098	-.0128
1050	.091	.097	-.006				.0960	.097	-.0010	.0832	.097	-.0138
1060				.0969	.095	.0019	.0953	.095	.0003	.0822	.095	-.0128
1070							.0901	.092	-.0019	.0801	.092	-.0019
1080							.0904	.090	.0004	.0782	.090	-.0108
1090							.0903	.087	.0035	.0762	.087	-.0108
1100	.080	.085	-.005	.0855	.085	.0005	.0828	.085	-.0022	.0743	.085	-.0107
1110							.0838	.083	.0008	.0733	.083	-.0097
1120							.0829	.081	.0019	.0713	.081	-.0097
1130							.0809	.079	.0019	.0683	.079	-.0107
1140				.0771	.077	.0001	.0807	.077	.0037	.0683	.077	-.0087
1150	.071	.076	-.005				.0732	.076	-.0028	.0674	.076	-.0086
1160							.0776	.075	.0026	.0673	.075	-.0077
1170							.0744	.074	.0004	.0674	.074	-.0066
1180				.0763	.073	.0033	.0733	.073	.0003	.0674	.073	-.0056
1190							.0727	.072	.0007	.0684	.072	-.0036
1200	.067	.072	-.005				.0736	.072	.0016	.0684	.072	-.0036
1210							.0720	.072	.0000	.0682	.072	-.0038
1220				.0777	.072	.0057	.0722	.072	.0002	.0682	.072	-.0038
1230							.0734	.072	.0014	.0682	.072	-.0038
1240							.0708	.072	-.0012	.0682	.072	-.0038
1250	.069	.072	-.003				.0762	.072	.0042	.0692	.072	-.0028
1260				.0738	.072	.0018	.0697	.072	-.0023	.0692	.072	-.0028
1270							.0719	.072	-.0001	.0701	.072	-.0019
1280							.0739	.073	.0009	.0711	.073	-.0019
1290							.0733	.073	.0003	.0711	.073	-.0019
1300	.069	.074	-.005	.0774	.071	.0034	.0764	.074	.0024	.0721	.074	-.0019
1310							.0727	.075	-.0023	.0723	.075	-.0027
1320							.0762	.075	.0012	.0733	.075	-.0017
1330							.0749	.076	-.0011	.0742	.076	-.0018
1340				.0832	.078	.0052	.0792	.078	.0012	.0762	.078	-.0018
1350	.075	.079	-.004				.0807	.079	.0017	.0771	.079	-.0019
1360							.0810	.080	.0010	.0790	.080	-.0010
1370							.0871	.081	.0061	.0800	.081	-.0010
1380				.0901	.083	.0071	.0899	.083	.0069	.0810	.083	-.0020
1390							.0916	.084	.0076	.0831	.084	-.0009
1400	.081	.086	-.005				.0939	.086	.0079	.0840	.086	-.0020
1410							.0902	.087	.0032	.0861	.087	-.0009
1420				.0954	.089	.0064	.0929	.089	.0039	.0881	.089	-.0009
1430							.0967	.090	.0067	.0900	.090	.0000
1440							.0922	.092	.0002	.0910	.092	-.0010
1450	.089	.094	-.005				.1000	.094	.0060	.0919	.094	-.0021
1460				.1005	.095	.0055	.0975	.095	.0025	.0919	.095	-.0031
1470							.0997	.097	.0027	.0929	.097	-.0041
1480							.1020	.098	.0040	.0940	.098	-.0040
1490							.1024	.100	.0024	.0949	.100	-.0051
1500	.096	.101	-.005	.1042	.101	.0032	.1029	.101	.0019	.0969	.101	-.0041
1510							.1016	.102	-.0004	.0989	.102	-.0031
1520							.1065	.104	.0025	.0999	.104	-.0041
1530							.1080	.105	.0030	.1009	.105	-.0041
1540				.1075	.106	.0015	.1083	.106	.0023	.1029	.106	-.0031

TABLE 2 - continued

λ	Lab 1			Lab 2			Lab 3			Lab 4		
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
1550	.102	.107	-.005				.1071	.107	.0001	.1037	.107	-.0033
1560							.1077	.108	-.0003	.1057	.108	-.0023
1570							.1107	.108	.0027	.1057	.108	-.0023
1580				.1136	.109	.0046	.1152	.109	.0062	.1058	.109	-.0032
1590							.1103	.109	.0013	.1058	.109	-.0032
1600	.105	.110	-.005				.1124	.110	.0024	.1058	.110	-.0042
1610							.1126	.110	.0026	.1059	.110	-.0041
1620				.1183	.110	.0083	.1144	.110	.0044	.1058	.110	-.0042
1630							.1158	.111	.0048	.1057	.111	-.0052
1640							.1149	.111	.0039	.1057	.111	-.0053
1650	.106	.111	-.005				.1161	.111	.0051	.1057	.111	-.0053
1660				.1186	.111	.0076	.1188	.111	.0078	.1057	.111	-.0053
1670							.1194	.111	.0084	.1067	.111	-.0043
1680							.1156	.111	.0046	.1067	.111	-.0043
1690							.1171	.111	.0061	.1066	.111	-.0044
1700	.107	.111	-.004	.1136	.111	.0026	.1183	.111	.0073	.1056	.111	-.0054
1710							.1198	.111	.0088	.1056	.111	-.0054
1720							.1174	.111	.0064	.1057	.111	-.0053
1730							.1154	.111	.0044	.1046	.111	-.0064
1740				.1155	.111	.0045	.1132	.111	.0022	.1036	.111	-.0074
1750	.105	.110	-.005				.1143	.110	.0043	.1026	.110	-.0074
1760							.1133	.110	.0023	.1017	.110	-.0083
1770							.1118	.110	.0018	.1007	.110	-.0093
1780				.1124	.109	.0034	.1067	.109	-.0023	.1007	.109	-.0083
1790							.1123	.109	.0033	.0997	.109	-.0093
1800	.104	.109	-.005				.1103	.109	.0013	.0996	.109	-.0094
1810							.1093	.108	.0013	.0987	.108	-.0093
1820				.1083	.108	.0003	.1050	.108	-.0030	.0978	.108	-.0092
1830							.1159	.107	.0089	.0978	.107	-.0092
1840							.1113	.107	.0043	.0978	.107	-.0092
1850	.101	.106	-.005				.1052	.106	-.0008	.0969	.106	-.0091
1860				.1096	.106	.0036	.1083	.106	.0023	.0960	.106	-.0100
1870							.1032	.105	-.0018	.0956	.105	-.0094
1880							.1074	.105	.0024	.0966	.105	-.0084
1890							.1015	.104	-.0025	.0965	.104	-.0075
1900	.098	.104	-.006	.1065	.104	.0025	.1085	.104	.0045	.0963	.104	-.0077
1910							.1083	.104	.0043	.0961	.104	-.0079
1920							.0984	.103	-.0046	.0953	.103	-.0077
1930							.1109	.103	.0079	.0943	.103	-.0087
1940				.1043	.102	.0023	.1085	.102	.0065	.0933	.102	-.0087
1950	.095	.102	-.007				.1041	.102	.0021	.0943	.102	-.0077
1960							.1076	.102	.0056	.0943	.102	-.0077
1970							.1083	.102	.0063	.0952	.102	-.0068
1980				.1020	.101	.0010	.1077	.101	.0067	.0951	.101	-.0059
1990							.1017	.101	.0007	.0951	.101	-.0059
2000	.094	.101	-.007				.1045	.101	.0035	.0930	.101	-.0080
2010							.1032	.101	.0022	.0929	.101	-.0081
2020				.1045	.100	.0045	.1087	.100	.0087	.0918	.100	-.0082
2030							.1058	.100	.0058	.0926	.100	-.0074
2040							.0966	.099	-.0024	.0935	.099	-.0055
2050	.093	.099	-.006				.1112	.099	.0122	.0934	.099	-.0056
2060				.1060	.099	.0070	.0857	.099	-.0133	.0933	.099	-.0057
2070							.1024	.099	.0034	.0932	.099	-.0058
2080							.0977	.099	-.0013	.0932	.099	-.0058
2090							.1076	.098	.0096	.0932	.098	-.0048
2100	.092	.098	-.006	.1011	.098	.0031	.1012	.098	.0032	.0922	.098	-.0058
2110							.0960	.098	-.0020	.0920	.098	-.0060
2120							.0988	.098	.0008	.0920	.098	-.0060
2130							.1051	.097	.0081	.0908	.097	-.0062
2140				.0966	.097	-.0004	.1000	.097	.0030	.0907	.097	-.0063
2150	.091	.097	-.006				.1350	.097	.0380	.0890	.097	-.0080
2160										.0894	.096	-.0066
2170										.0895	.096	-.0065
2180				.0991	.095	.0041				.0897	.095	-.0053
2190										.0898	.095	-.0052

TABLE 2 - continued

λ		Lab 1			Lab 2			Lab 3			Lab 4	
nm	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff	ρ	Cal	Diff
2200	.090	.096	-.006							.0889	.096	-.0071
2210										.0892	.096	-.0068
2220				.0947	.096	-.0013				.0894	.096	-.0066
2230										.0894	.096	-.0066
2240										.0895	.096	-.0065
2250	.089	.096	-.007							.0895	.096	-.0065
2260				.0970	.096	.0010				.0895	.096	-.0065
2270										.0904	.096	-.0056
2280										.0901	.096	-.0059
2290										.0908	.096	-.0052
2300	.089	.096	-.007	.1029	.096	.0069				.0908	.096	-.0052
2310										.0908	.096	-.0052
2320										.0889	.096	-.0071
2330										.0888	.096	-.0072
2340				.0902	.096	-.0040				.0885	.096	-.0075
2350	.088	.096	-.008							.0892	.096	-.0068
2360										.0902	.096	-.0058
2370										.0910	.096	-.0050
2380				.0961	.096	.0001				.0908	.096	-.0052
2390										.0918	.096	-.0042
2400	.088	.096	-.008							.0907	.096	-.0053
2410										.0896	.096	-.0064
2420				.1079	.096	.0119				.0881	.096	-.0079
2430										.0880	.096	-.0080
2440										.0879	.096	-.0081
2450	.088	.096	-.008							.0889	.096	-.0071
2460				.0979	.095	.0029				.0887	.095	-.0063
2470										.0888	.095	-.0062
2480										.0878	.095	-.0072
2490										.0898	.095	-.0052
2500				.0923	.095	-.0027						
ΣX		-.262				.1529			.6641			-1.0458
$ΣX^2$		.001538				.0095455			.00583857			.00744336
N		47				86			186			220
$\bar{X}$		-.00557				.00178			.00357			-.00475
σ		-.00130				.00283			.00433			.00366

TABLE 3 - REPORTED VALUES FOR SOLAR PROPERTIES

Property	Lab 1[1]	Lab 2[2]	Lab 3[3]	Lab 4	NBS
	%	%	%	%	
Reflectance of White Sample	82.5	87.1	84.3	81.06[4] 83.66[5] 83.77[6] 80.40[7]	81.94[8] 83.33[9]
Absorptance of Black Sample	93.1	92.9	92.5	93.04[4] 92.98[5] 92.07[7]	92.44

1. Beckman 5270 Spectroreflectometer - Halon powder

2. Beckman 5270 double-beam grating-filter instrument with high intensity source

3. Varian Cary 17D integrating sphere reflectometer

4. Perkin-Elmer 340 - Halon standards

5. Beckman 5420 - Halon standards

6. Beckman 5420 - $BaSO_4$ standard

7. Cary 17 - Halon standard

8. For Comparison to Laboratories 1 and 4

9. For Comparison to Laboratories 2 and 3

TABLE 4 - PROCEDURES USED FOR COMPUTING SOLAR PROPERTIES

Laboratory 1 -	100 Selected Ordinate Method, based on Thekaekara AM 1.5 solar spectral irradiance.
Laboratory 2 -	Weighted Ordinate Method, based on NASA AM 1.5 TDSSID.
Laboratory 3 -	ASTM E-424, Method A, Weighted Ordinate Method based on Parry Moon data.
Laboratory 4 -	Weighted Ordinate Method, based on proposed revision of ASTM E-424.
NBS -	100 Selected Ordinate Method, based on ASTM E-44 direct solar irradiance.

TABLE 5 - DIFFERENCES AS FRACTION OF REPORTED SOLAR VALUES

	Lab 1	Lab 2	Lab 3	Lab 4
	WHITE SAMPLES - SOLAR REFLECTANCE			
Diff	0.0038	0.0133	0.0225	0.0118
σ	0.0069	0.0119	0.0140	0.0038
	BLACK SAMPLES - SOLAR ABSORPTANCE			
Diff	-0.0033	0.0019	0.0039	0.0057
σ	0.0060	0.0030	0.0047	0.0039

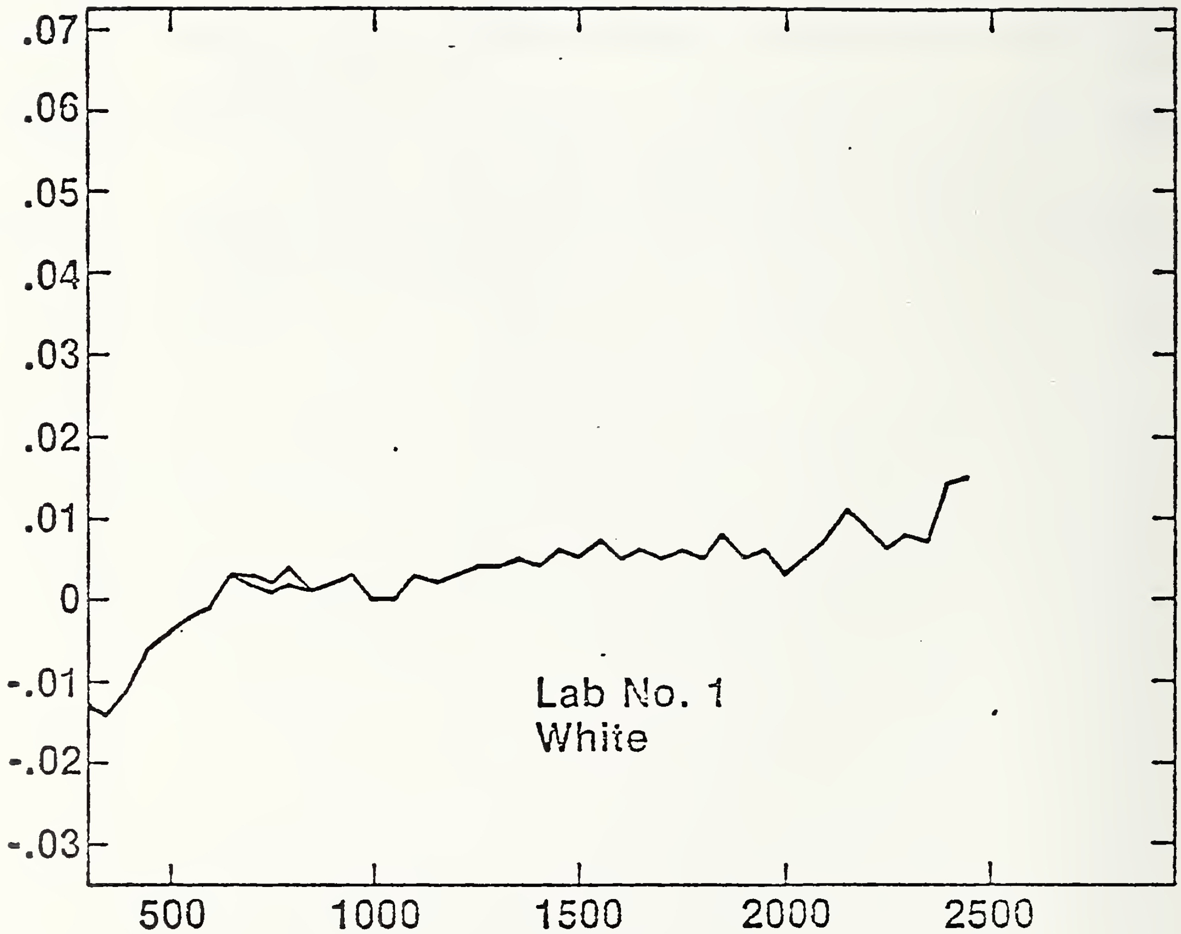

Figure 1 - Difference between the data reported by Laboratory 1 and the calibration data for the white sample, plotted as a function of wavelength.

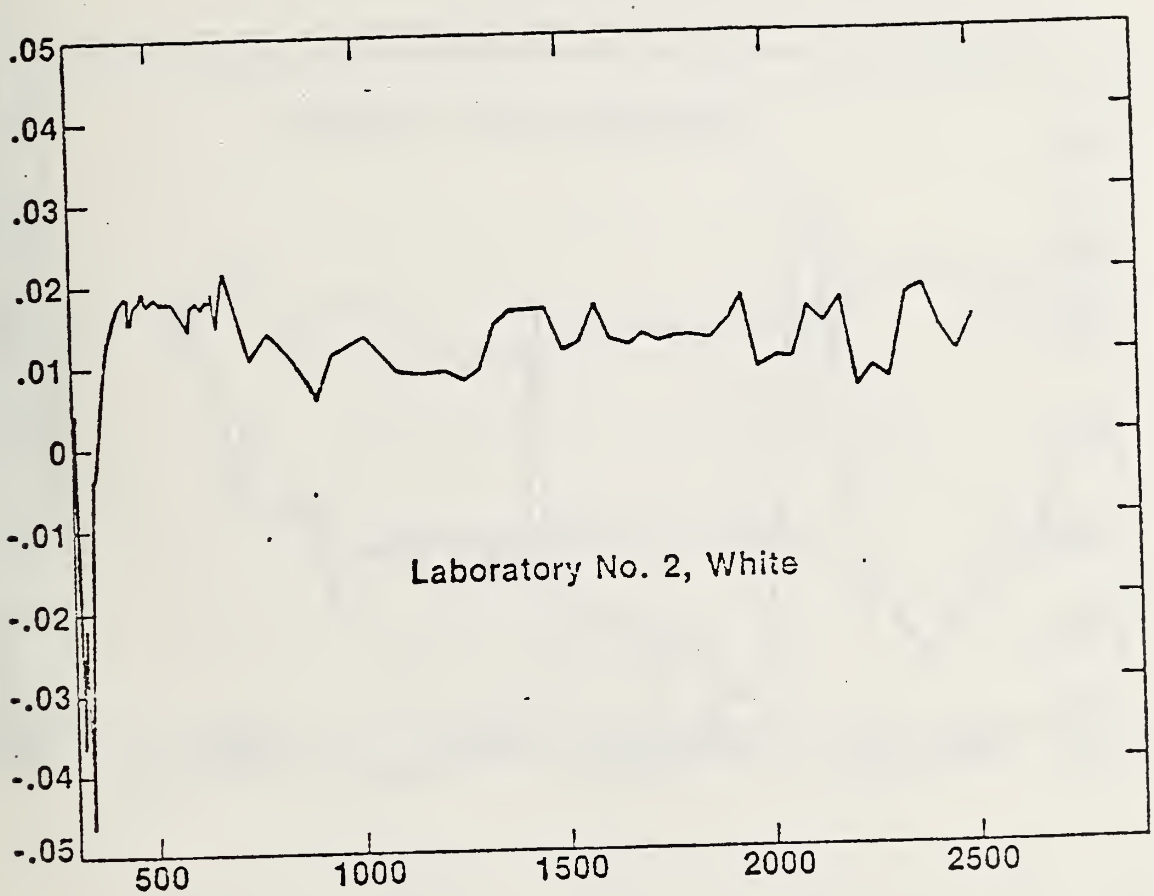

Figure 2 - Difference between data reported by Laboratory 2 and calibration data for the white sample, plotted as a function of wavelength.

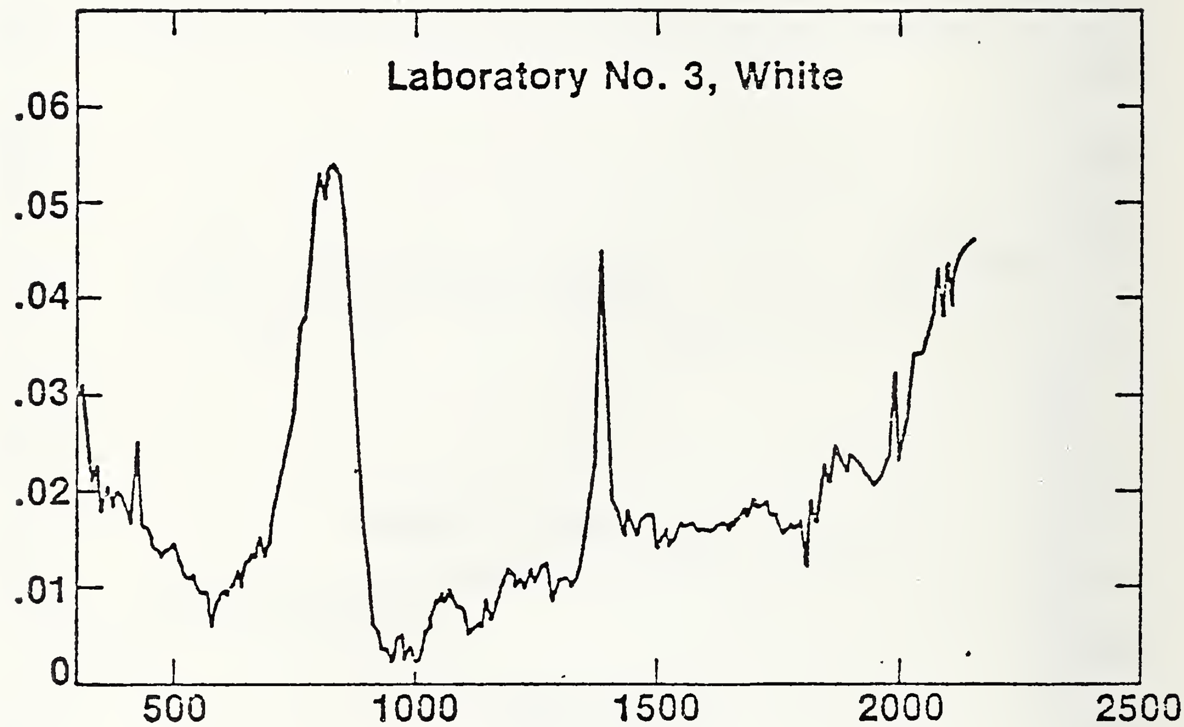

Figure 3 - Difference between data reported by Laboratory 3 and calibration data for the white sample, plotted as a function of wavelength.

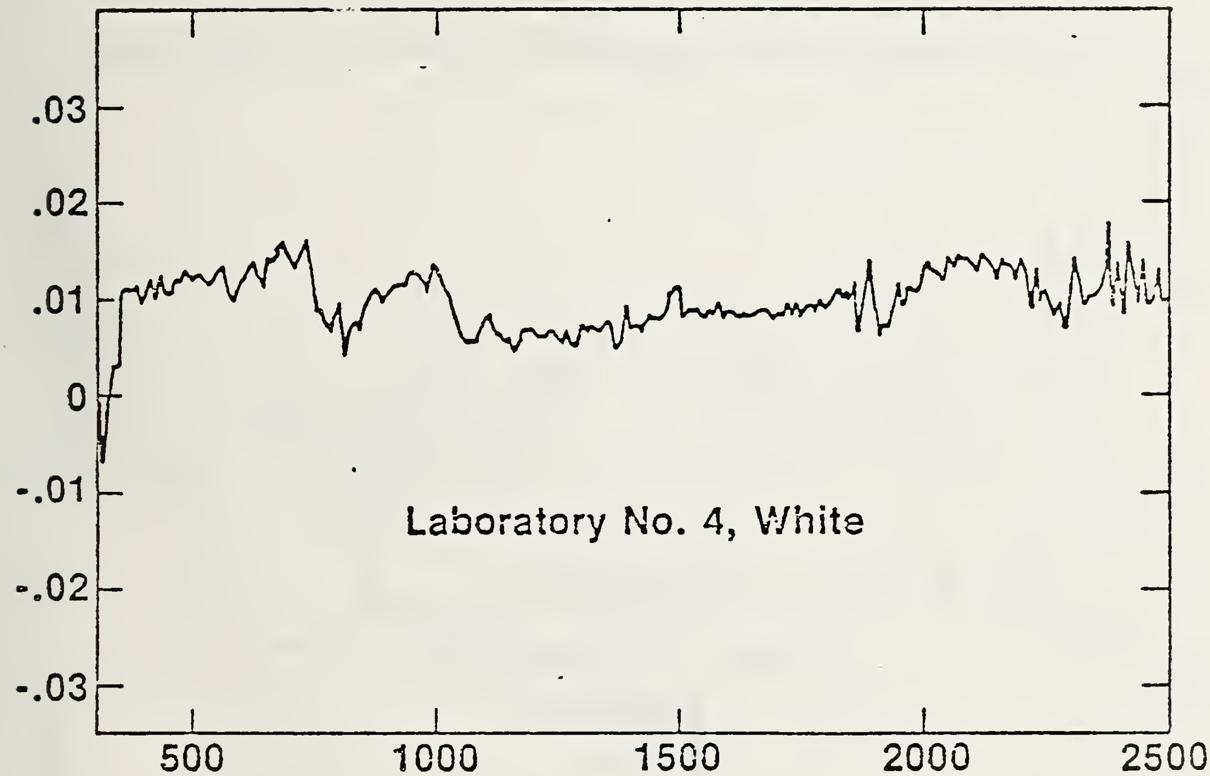

Figure 4 - Difference between data reported by Laboratory 4 and calibration data for the black sample, plotted as a function of wavelength.

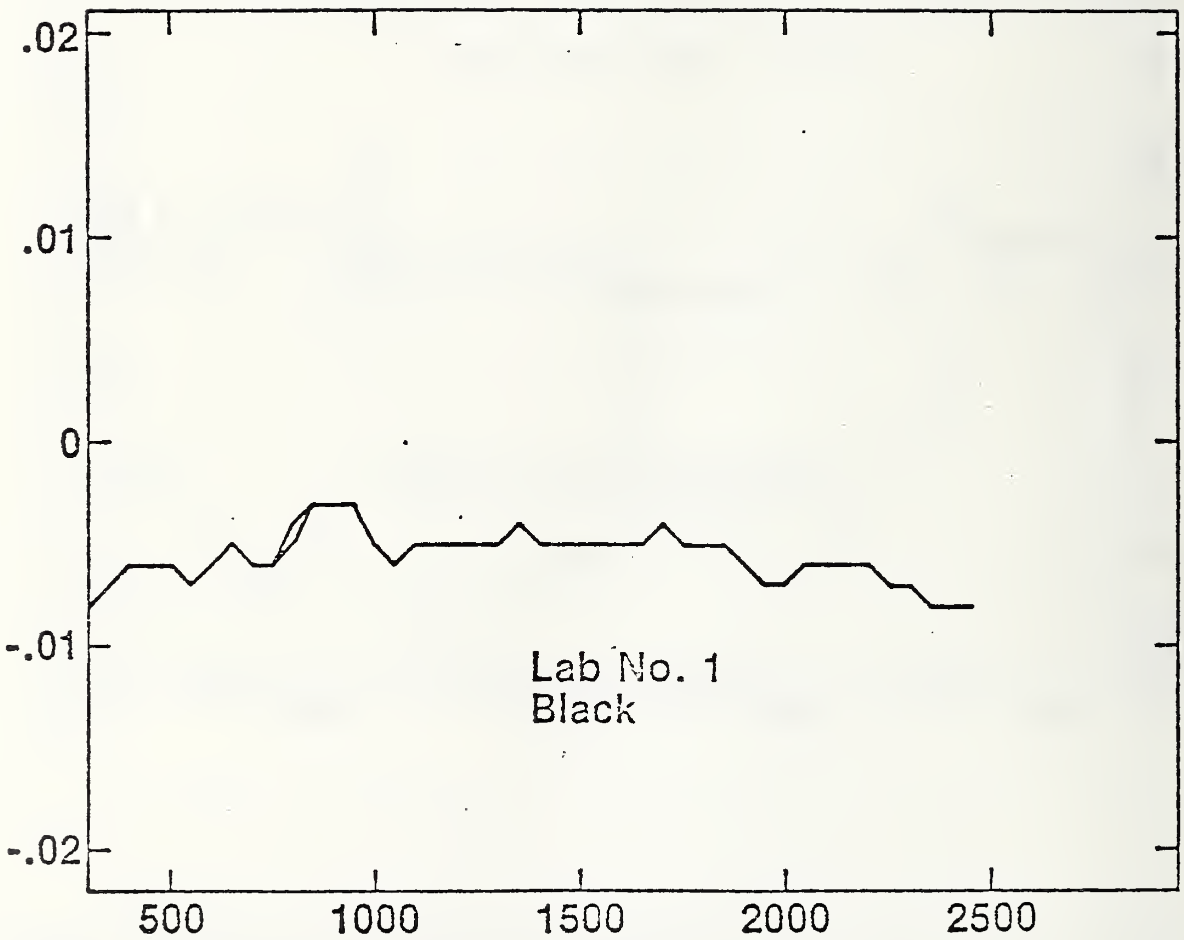

Figure 5 - Difference between the data reported by Laboratory 1 and the calibration data for the black sample, plotted as a function of wavelength.

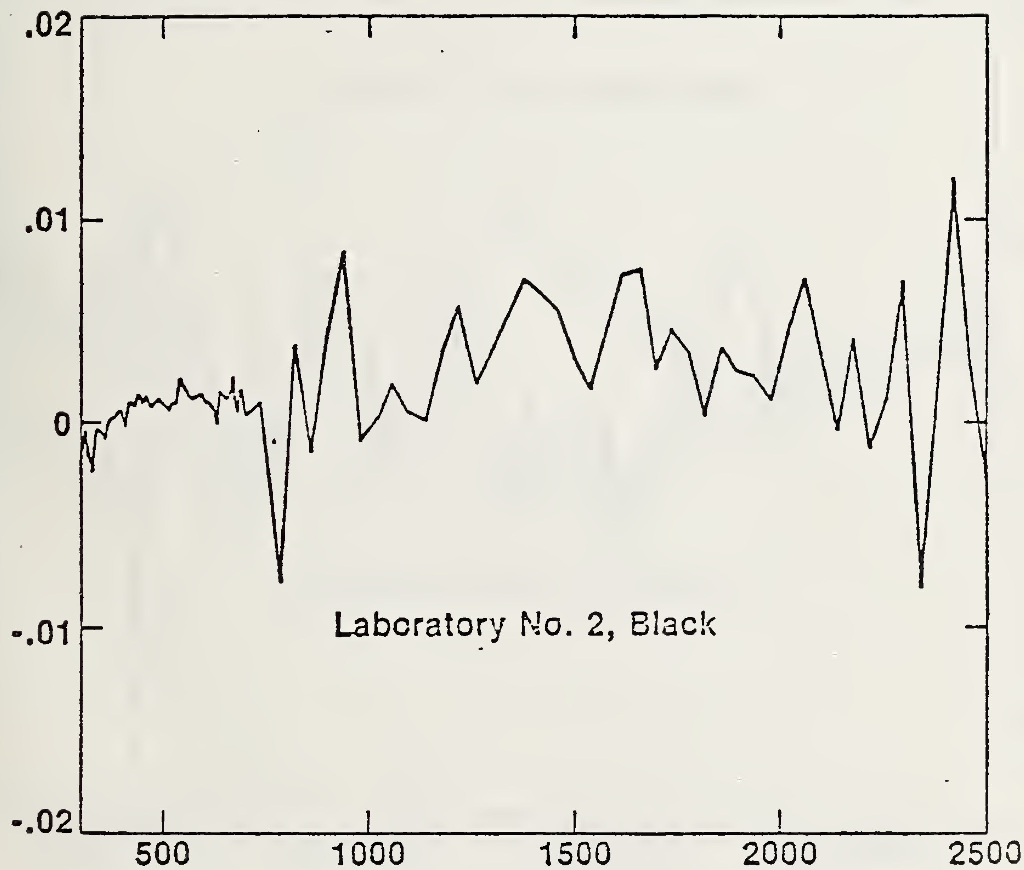

Figure 6 - Difference between the data reported by Laboratory 2 and calibration data for the black sample, plotted as a function of wavelength.

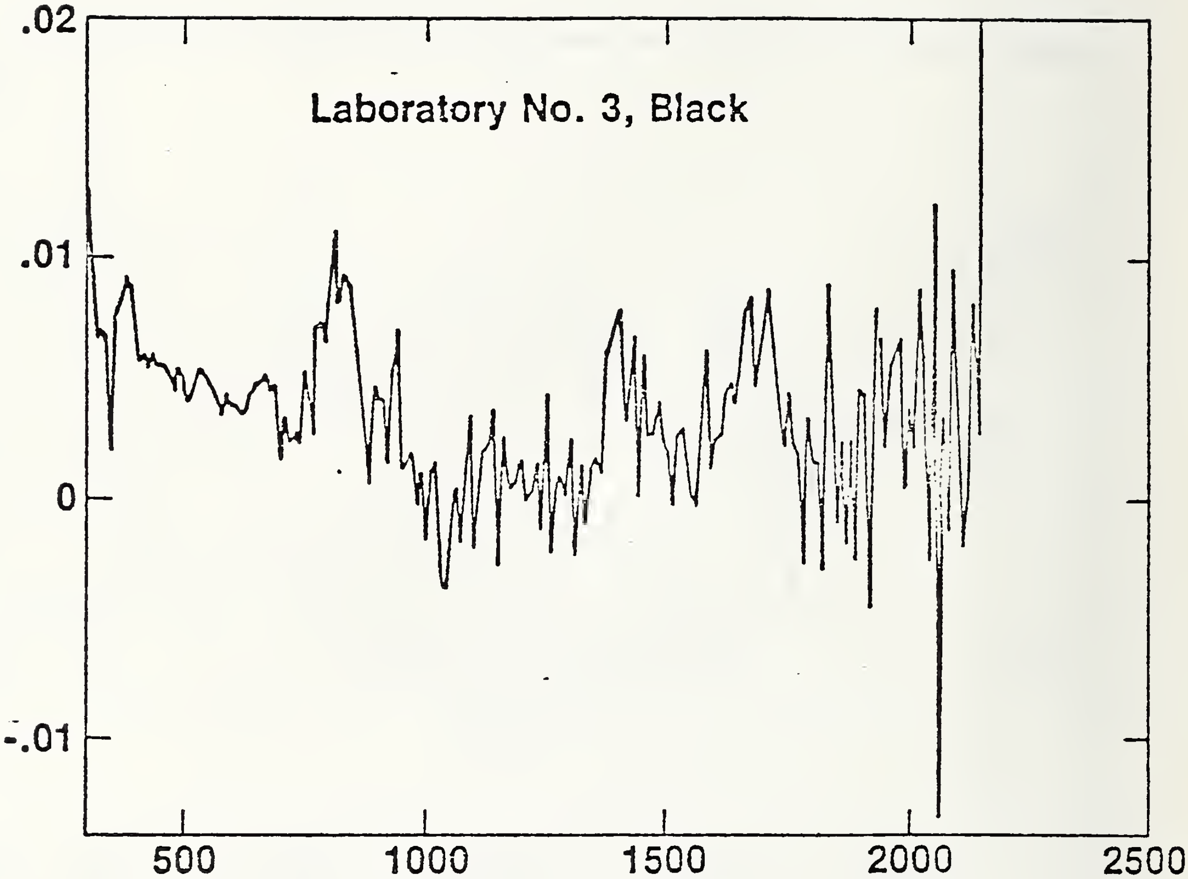

Figure 7 - Difference between the data reported by Laboratory 3 and the calibration data for the black sample, plotted as a function of wavelength.

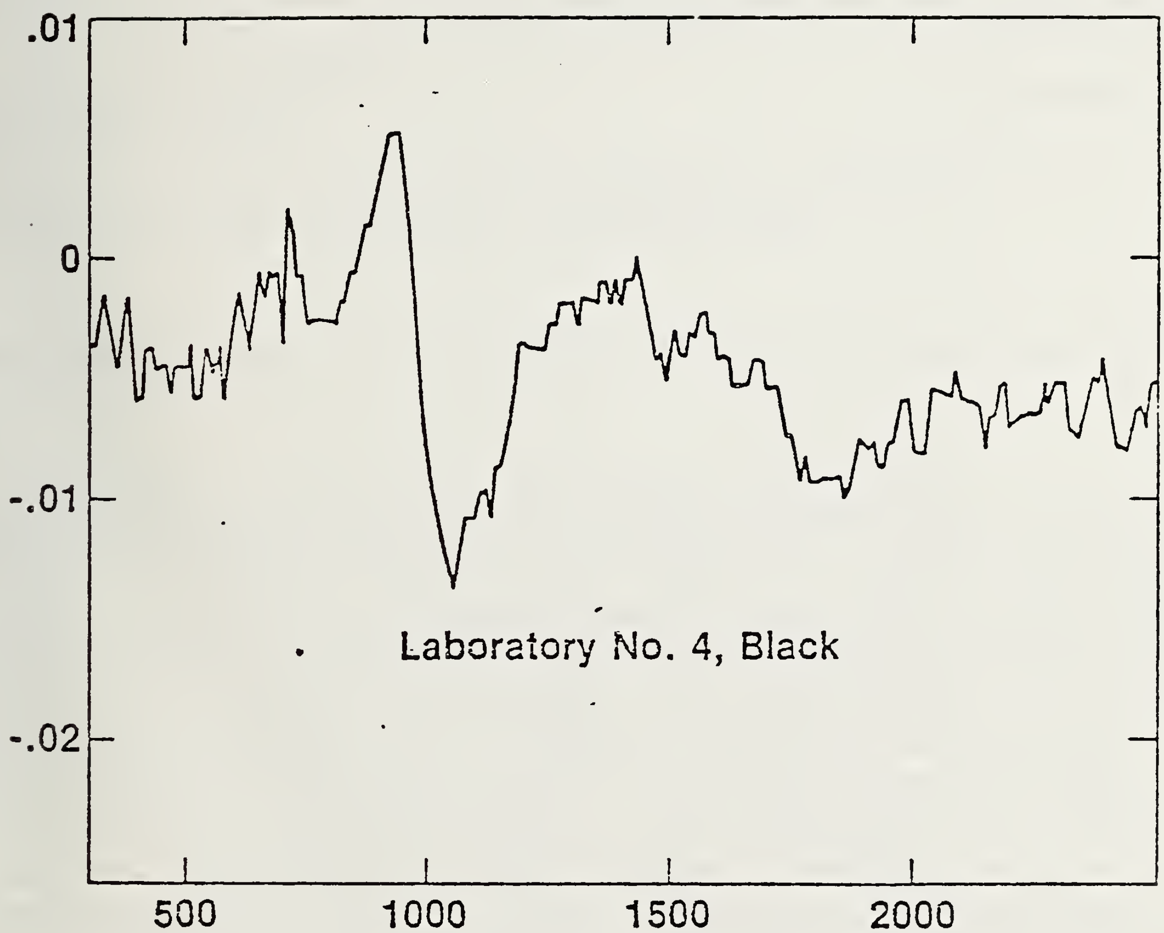

Figure 8 - Difference between data reported by Laboratory 4 and the calibration data for the balck sample, plotted as a function of wavelength.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

A mini round robin test was conducted in which four national laboratories participated. The spectral directional-hemispherical reflectance for near-normal incidence of two samples, one black and one white, was measured in the wavelength range of 250 to 2500 nm. The solar reflectance of the white sample and the solar absorptance of the black sample was then computed. Each laboratory used a different procedure for making the computations. The measured samples had previously been calibrated in the Radiometric Physics Division of the National Bureau of Standards for certification as reflectance standards. The average difference between the reported values and the calibration values varied from +0.0116 $\pm$0.0634 to 0.0386 $\pm$0.0205 for the white samples and from -0.00475 $\pm$0.00366 to +0.00357 $\pm$0.00433 for the black samples. The differences for the white samples were ascribed primarily to errors in the reflectance value assigned to the reference standard used in the measurements. The differences for the black samples were ascribed primarily to zero line errors.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

diffuse reflectance; directional-hemispherical reflectance; integrating spheres; laboratory intercomparisons; reflectance measurements; reflectance standards; solar properties of materials; spectral reflectance measurements.

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