NATIONAL BUREAU OF STANDARDS REPORT

4322

SPECTROPHOTOMETRIC AND COLORIMETRIC
CHANGE IN THE LEAF OF A WHITE OAK TREE
UNDER CONDITIONS OF
NATURAL DRYING AND EXCESSIVE MOISTURE

By

Harry J. Keegan,

John C. Schleter,

and

Wiley A. Hall, Jr.

To

U. S. Department of the Air Force
Aerial Reconnaissance Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base, Ohio

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U. S. DEPARTMENT OF COMMERCE
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PREFACE

This is one of a series of NBS reports of spectrophometric and colorimetric work done under NBS Project No. 0203 - 20 - 2325 entitled Color Reconnaissance Studies, financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; Air Force Contract No. 33 (616) 52-21. It is coordinated with Air Force Contract No. 33 (616) - 262 under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, who requested the NBS to perform this year-long test of leaves of white oak trees.

Harry J. Keegan
Project Leader

SPECTROPHOTOMETRIC AND COLORIMETRIC CHANGE IN THE LEAF OF A WHITE OAK TREE UNDER CONDITIONS OF NATURAL DRYING AND EXCESSIVE MOISTURE

Harry J. Keegan, John C. Schleter, and Wiley A. Hall, Jr.

Abstract

In the detection of an object in a scene from an aerial photograph, it is necessary to know both spectrophotometrically and colorimetrically how the object differs from the surround, and what changes there may be in the common surrounds, such as, leaves of trees, grass, rocks and soils, ice and snow, and water. As the leaves of trees are a common background in many parts of the world, Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, under a coordinated Air Force contract, requested the National Bureau of Standards to determine the spectrophotometric change in White Oak (Quercus alba L.) leaves under conditions of natural drying and excessive moisture. This tree was selected for study because of its prominence, especially in the Eastern part of the United States.

One set of leaves was allowed to dry at room temperature and humidity; another set was immersed in water at all times except during measurements. Measurements of spectral directional reflectance were made periodically at intervals of hours, then weeks, then months for one year. These measurements were made for both the visible and near infrared spectrum, 400 to 1080 millimicrons. For the visible spectrum, 400 to 750 millimicrons, C.I.E. chromaticity coordinates and daylight reflectances are reported as well as Munsell renotations, ISCC-NBS color designations, and color differences in NBS units, (ΔE), for both the wet and dry leaves. From this information predictions may be made of the time change in the leaf of a White Oak tree from the time that it appears on the tree until it is dead either on the tree or on the floor of the forest.

I. Introduction

The overall objective of this Air Force investigation is stated as follows: "To develop by visible, near infrared, and near ultraviolet spectrophotometry, methods for the detection of objects from color reconnaissance; to study the colors, tonal contrast, and color separation necessary in aerial photography to yield maximum information; to determine the wavelength region at which the film manufacturer should strive to obtain maximum sensitivity to yield clear separation of an object from its adjacent area rather than to yield true color fidelity; to determine the characteristics required in a sensitized material for the rapid and accurate extraction of this information".

This report is concerned solely with the spectrophotometric and colorimetric changes that appear in the background of an aerial scene; namely the leaves of trees, and in particular the leaves of the White Oak tree (Quercus alba L.). It is believed that the accumulation of this type of information is a necessary step toward attaining the over-all objection of this investigation.

II. Material.

The white oak tree, from which one of the authors (JCS) picked the leaves on September 24, 1952, is located about 100 feet east of the East Building on the grounds of the National Bureau of Standards in Washington, D. C. The leaves of this tree were selected for their freshness and all of them were taken from the same leaf cluster on the same branch of the one tree. They were separated into two groups and both sets were immediately spectrophotometered. In each case the ventral side of the second leaf, the backing leaf, was stapled to the dorsal side of the first leaf. All measurements were made on the ventral side of the first leaf. Each pair of samples was backed with black paper on a wooden block for all of the measurements. Essentially the same part of each leaf was chosen for the repeat measurements, throughout the year period. Twenty-five sets of measurements were made, three the first day, two the second and third days, then one each on the sixth and eighth days, and one each week until the fifth week, then on tenth, twelfth, and sixteenth weeks, after that one measurement was made each four weeks up to and including the fifty-second week. All this time the "wet" sample was kept immersed in distilled water in a large (4 liter) clear glass beaker, and the "dry" sample was kept in a similar glass beaker without water. The beakers were placed near an east window and were not moved during the year period. Each month or when needed, additional distilled water was added to keep the submerged sample wet.

III. Spectrophotometric Measurements.

Measurements of spectral directional reflectance were made on the NBS General Electric recording spectrophotometer [1, 2]* for the condition of included specular component of the reflected radiant energy and for the spectral range 400 to 1080 millimicrons. Slits of approximately 10 millimicrons of spectral width were used for the measurements in the visible spectrum 400 to 750 millimicrons, and 20 millimicrons of spectral width for the near infrared spectrum 730 to 1080 millimicrons. All recordings were made with calibration curves of standard didymium and Vitrolite glasses for making wavelength and photometric scale corrections [3]; zero curve corrections were also made. Each of the fifty curve sheets were read and corrected at each ten millimicron interval between 400 and 1080 millimicrons.

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* Figures in brackets indicate the index reference pp. 6 and 7 of this report.

As a final run, on the day following the above study, each of the two sets of leaves was unstapled and spectral directional reflectance measurements were made for the ventral side of each of the two measured and the two backing leaves, for the spectral region 400 to 1080 millimicrons.

IV. Spectrophotometric Results.

The results of this spectrophotometric study of the leaf of a white oak tree for the one year period are shown on the 52 Ozalid prints of the original recordings in Appendix A of this report. There are 26 graphs of the visible spectrum and 26 of the near infrared spectrum; for each set of measurements the infrared graph sheet follows its companion visible spectrum graph*.

The numbering system used to designate the time intervals at which the spectrophotometric measurements were made during the one year period and the serial numbers of the graph sheets in Appendix A showing these measurements, for both the visible and near infrared spectrum, are given in Table I.

The corrected values of spectral directional reflectance of 27 sets of determinations of the wet and dry White Oak leaf are listed in the tables of Appendix B. For wavelengths 730, 740, and 750 millimicrons, which spectral region appears on both the visible and on the near infrared graph sheets, the average values for both determinations are reported.

Eight of these sets of spectrophotometric measurements are illustrated in Figure 1, which shows the visible and near infrared spectral directional reflectance curves of the two leaves of the white oak tree, one kept dry (dashed curves) and the other kept immersed in distilled water (solid curve) for one year. The eight pairs of curves were selected from 25 pairs of measurements made on the same specimens over the one-year period.

The same eight sets of spectrophotometric measurements for the visible spectrum only are shown in Figure 2. It is with the visible spectrum that the rest of this report is concerned in the determination of the chromaticity coordinates, daylight reflectances, Munsell renotations, ISCC-NBS color designations and color differences. [4]

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* In a later report, these companion graph sheets will be consolidated and issued with a continuous wavelength scale; they will be issued in the form of transparent foils (11 by 15 inches). These graphs will be issued in specially prepared loose-leaf binders.

V. Colorimetric Computations.

The corrected spectral directional reflectances for the visible spectrum 380 to 750 millimicrons for the 25 determinations made on the wet sample and for the 25 determinations made on the dry sample were integrated into the C.I.E. Standard Observer and Coordinate System [5] for Source C, representative of average daylight. These colorimetric computations yielded the chromaticity coordinates and daylight reflectances listed in Tables II and III.

The area of the C.I.E. chromaticity diagram that the above data occupy is shown in Figure 3, and an enlargement of the indicated area is shown in Figure 4.

VI. Munsell Renotations and ISCC-NBS Color Designations.

By the use of the above C.I.E. chromaticity coordinates and daylight reflectances of the two sets of 25 determinations for the wet and dry leaves, the Munsell renotations were obtained from graphs of conversion from the C.I.E. system to the Munsell system [6]. These Munsell renotations were then converted into terms of the ISCC-NBS color designations [7]. Both the Munsell renotations and the ISCC-NBS color designations of all 50 determinations on the wet and dry leaves are shown in Tables IV and V.

The colorimetric change in these leaves are shown in Figure 5 as a schematic illustration of ideal Munsell space represented as a cylinder with a section of the cylinder removed to show the vertical and horizontal projections of the loci of the leaf changes. These changes are further illustrated in Figure 6, and in the isometric illustration of Figure 7.

VII. Color Difference.

From the Munsell renotations of the 50 determinations of the wet and dry leaves, color differences in terms of NBS units, (ΔE), were computed, by means of the Godlove formula [8], between the initial measurement and each of the succeeding measurements for both the wet and dry leaves. These differences are listed in Table VI, and illustrated in Figure 8.

In addition, and as a final check, the two sets of leaves were unstapled, each leaf was spectrophotometered, and the data was converted into C.I.E. chromaticity coordinates, daylight reflectances, Munsell renotations, ISCC-NBS color designations, and NBS units, (ΔE), of color differences. These data are shown in Tables VII, VIII, and IX.

VIII. Summary.

A series of measurements of spectral directional reflectance have been made on two sets of leaves of the White Oak tree for a period of

one year. One set of leaves was kept at room temperature and humidity, the other set was kept immersed in distilled water at the same room temperature. These measurements were made for both the visible (400 - 750 millimicrons) and the near infrared (730 - 1080 millimicrons) spectral regions.

The data from these visible spectrum measurements were converted into colorimetric terms of the C.I.E. system, the Munsell system, the ISCC-NBS color designations, and NBS units of color differences.

After the one-year study, each leaf (the measured sample and the backing sample, both wet and dry) was spectrophotometered and the data converted into colorimetric terms as used for the other determinations.

IX. Conclusions.

The leaf of the white oak tree in both the wet and dry state gradually ages in color from the green towards the red; that is, from grayish olive green to dark grayish brown and to light brown, respectively.

The daylight reflectance of the dry leaf gradually increases with age from approximately 8% to 19% while the wet leaf gradually decreases in reflectance from approximately 8% to 4% during the one-year period.

The dry leaf becomes more saturated in color for the first 20 hours after picking, then gradually loses saturation until 20 days, and then regains its saturation and is a maximum at the year's end.

Fig. 1 shows that the wavelength region of greatest reflectance change for the dry leaf is in the visible spectrum between 670 and 680 millimicrons (the chlorophyll band). These changes are associated with the disappearance of chlorophyll from the leaf, and they provide the basis for a determination, to the nearest week, of the length of time the dry leaf has been separated from the tree over the range of 1 to 40 weeks. To facilitate such a detection by aerial photography the film should have its sensitivity confined as closely as possible to the wavelength region 500 to 700 millimicrons.

Fig. 1 also shows that the wavelength region of greatest reflectance change for the wet leaf is in the near infrared between 750 and 900 millimicrons. These changes are associated with the penetration of water into the leaf, and they provide a basis for determining whether the leaf has been separated from the tree for two weeks or less, for about three or four weeks, or for six weeks or more; see ozalid prints in Appendix A. To facilitate such a detection by aerial photography the film should have its sensitivity confined as closely as possible to the wavelength region 700 to 1,000 millimicrons. During the first two weeks the leaf rather

successfully resists water penetration, but after six weeks the penetration is substantially complete, the leaf having become water-logged.

Fig. 1 shows two spectral regions (630 and 700 millimicrons) for the wet leaf in which the reflectance is substantially constant with time although in other spectral regions gross changes are evident. Such a crossing point is known as an isosbestic point [9], and it characterizes pigmented structures in which one pigment is converted into another of the same absorption coefficient at that wavelength. Note, however, that the reflectance of the wet leaf does not rise substantially above its original value until the leaf has been separated from the tree for 24 weeks and has become thoroughly waterlogged. It seems likely that this rise is due to physical escape of chlorophyll from the leaf structure, rather than to the formation of another compound, and this view is substantiated by the fact that the water in which the leaf was stored showed a greenish color at this stage.

Fig. 1 also shows a spectral region (about 720 millimicrons) in which the reflectance of the dry leaf is substantially constant. This suggests that the chlorophyll in the dry leaf is changing to a brown pigment, but the absence of an approach to an isosbestic point between 800 and 1,000 millimicrons shows that this simple explanation is untenable. Perhaps, the explanation is that the chlorophyll changes to a brown pigment [10] that is more, though not perfectly, stable.

Fig. 8 supplements the analytical information given in Figs 4 to 7 by showing the noticeability of the color changes in NBS units. The rapid color change of the leaves due to waterlogging after being kept wet for three weeks is particularly striking.

No comparable study to the present one could be found in the scientific literature. The only work related to the spectral reflectance of tree leaves of interest to this project is that of Krinov [11] .

X. Acknowledgments.

The authors wish to acknowledge the assistance of Miss Gladys M. Haas in reading and reducing some of the data in the near-infrared spectrum used in Figure 1, and listed in Appendix B.

XI. Bibliography.

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Figure 1.

Visible and near infrared spectral directional reflectance curves of two sets of white oak leaves, one kept dry (dashed curves) and the other kept immersed in distilled water (solid curves). The eight pairs of curves were selected from the 25 pairs of measurements made on the same specimens over a period of one year. (See Appendixes A and B to this report for all of the curves and data; see Table I for the numbering system.)

Figure 2.

Spectral directional reflectance of the same white oak leaves illustrated in Figure 1, but for the visible spectrum only.

Figure 3.

Chromaticity diagram of the International Commission on Illumination (C.I.E.). The indicated area shows the part of this diagram applying to this report. It also is the area shown in Figure 4.

Figure 4.

Segment of the C.I.E. Chromaticity Diagram showing dominant wavelength, excitation purity, and chromaticity coordinates of the wet and dry white oak leaves (Figures 1 and 2) measured 25 times during one year. The two solid lines illustrate the two paths of the color changes smoothed in Munsell Ideal Space (Figures 6 and 7) and transformed back into C.I.E. space. (For numbering system see Table I.)

Figure 5.

Schematic illustration of Munsell Ideal Space represented as a cylinder with a section of the cylinder removed to show the horizontal and vertical projections of the loci of the color changes of the wet and dry white oak leaves.

Figure 6.

Vertical and horizontal projections of the paths of color change of the wet and dry leaves illustrated in Figure 5. The lower diagram shows the Munsell Hue and Munsell Chroma of the 25 pairs of measurements of these leaves for a period of one year. The upper diagram shows the Munsell Value of these measurements plotted against the Munsell Hue and Munsell Chroma points projected from the lower diagram. (For numbering system, see Table I.) In both segments of the diagram, the closed circles indicate the dry leaf and the open circles the wet leaf.

Figure 7.

Schematic isometric illustration of the paths of color change of the wet and dry white oak leaves in Munsell Ideal Space. The points illustrated were obtained from the eight pairs of spectrophotometric curves shown in Figure 2.

Figure 8.

Color-difference computed by the Godlove [8] color-difference formula, converted into NBS units, and plotted against time for the wet and dry white oak leaves. Each color-difference indicated is relative to the initial measurement.

Table I

Numbering System Used To Designate The Time Intervals At Which Spectrophotometric Measurements Were Made During The One Year Period, And The Serial Numbers Of The Original Recording Sheets.

Run No.	Date Measured	Hours After Picking	Weeks After Picking	GE Graph Sheet Visible Spectrum	Serial Number Near Infrared Spectrum
1	9-24-52	1/2		GE II-1018	GE II-1019
2	9-24-52	3		1020	1021
3	9-24-52	5		1022	1023
4	9-25-52	22		1024	1025
5	9-25-52	27		1026	1027
6	9-26-52	45-1/2		1028	1029
7	9-26-52	51-1/2		1030	1031
8	9-29-52	121		1033	1034
9	10- 1-52	168	1	1043	1044
10	10- 8-52	336	2	1054	1055
11	10-15-52	504	3	1061	1062
12	10-22-52	672	4	1067	1068
13	10-29-52	840	5	1074	1075
14	12- 3-52	1680	10	1091	1092
15	12-17-52	2016	12	1103	1104
16	1-14-53	2688	16	1117	1118
17	2-11-53	3360	20	1126	1127
18	3-11-53	4032	24	1146	1147
19	4- 8-53	4704	28	1182	1183
20	5- 6-53	5376	32	1204	1205
21	6- 3-53	6048	36	1234	1235
22	7- 1-53	6720	40	1245	1246
23	7-29-53	7392	44	1250	1251
24	8-26-53	8064	48	1262	1263
25	9-23-53	8736	52	1269	1270

Table II

White Oak Leaf
(Quercus alba L.)
KEPT WET

Chromaticity Coordinates And Daylight Reflectances Of A Wet White Oak Leaf**
Obtained From Spectrophotometric Measurements.

Run No.	Chromaticity Coordinates x	Chromaticity Coordinates y	Daylight Reflectance Y(%)
1**	0.332	0.388	7.9
2	.332	.388	7.5
3	.332	.385	7.5
4	.333	.384	7.5
5	.333	.386	7.3
6	.335	.391	7.5
7	.331	.384	7.2
8	.342	.405	6.5
9	.331	.386	6.9
10	.333	.383	6.9
11	.330	.378	6.5
12	.324	.338	5.2
13	.317	.323	4.3
14	.331	.332	4.3
15	.328	.328	4.4
16	.330	.332	4.3
17	.338	.340	4.2
18	.340	.336	3.8
19	.346	.336	3.9
20	.341	.330	3.3
21	.346	.334	3.4
22	.350	.339	3.6
23	.342	.332	4.0
24	.339	.331	3.9
25	.341	.331	4.1

**The initial measurement was made on a dry leaf.

Table III

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Chromaticity Coordinates And Daylight Reflectances Of A Dry White Oak Leaf Obtained From Spectrophotometric Measurements.

Run No.	Chromaticity Coordinates x	Chromaticity Coordinates y	Daylight Reflectance Y(%)
1	0.330	0.385	7.7
2	.338	.395	8.7
3	.340	.398	9.3
4	.348	.400	11.4
5	.345	.392	11.7
6	.346	.390	12.4
7	.346	.392	11.4
8	.346	.389	11.8
9	.346	.388	11.2
10	.343	.380	12.5
11	.344	.383	13.1
12	.343	.378	13.7
13	.341	.375	14.0
14	.345	.373	14.6
15	.343	.369	14.9
16	.346	.369	14.9
17	.348	.365	15.5
18	.357	.364	15.9
19	.367	.367	17.2
20	.378	.374	17.5
21	.386	.371	19.1
22	.394	.374	19.7
23	.396	.374	19.2
24	.398	.373	19.0
25	.397	.371	19.3

Table IV

White Oak Leaf
(Quercus alba L.)
KEPT WET

Munsell Renotations And ISCC-NBS Color Designations Of A Wet White Oak Leaf Derived From Chromaticity Coordinates And Daylight Reflectances Computed From Spectrophotometric Data.

Run No.	Munsell Renotations	ISCC-NBS Color Designations
1	5.9GY-3.3/2.5**	Grayish olive green
2	5.8GY-3.2/2.6	Grayish olive green
3	5.6GY-3.2/2.4	Grayish olive green
4	5.5GY-3.2/2.4	Grayish olive green
5	5.6GY-3.2/2.4	Grayish olive green
6	5.5GY-3.2/2.6	Grayish olive green
7	5.7GY-3.1/2.4	Grayish olive green
8	5.2GY-3.0/2.9	Grayish olive green
9	5.8GY-3.1/2.4	Grayish olive green
10	5.4GY-3.1/2.3	Grayish olive green
11	5.5GY-3.0/2.2	Grayish olive green
12	10.0 Y-2.7/0.7	Olive gray
13	4.9 Y-2.4/0.2	Black
14	0.2 Y-2.4/0.6	Brownish black
15	7.7YR-2.4/0.5	Brownish black to black
16	1.1 Y-2.4/0.6	Dark olive brown
17	2.3 Y-2.4/0.8	Dark olive brown
18	9.6YR-2.2/0.8	Dark grayish yellowish brown
19	9.0YR-2.3/1.0	Dark grayish yellowish brown
20	5.1YR-2.1/0.8	Dark grayish brown
21	6.5YR-2.1/0.9	Dark grayish brown
22	7.5YR-2.2/1.1	Dark grayish brown
23	7.8YR-2.3/0.9	Dark grayish brown
24	6.4YR-2.3/0.8	Dark grayish brown
25	5.8YR-2.3/0.9	Dark grayish brown

**Average wet and dry chromaticity coordinates (x,y) and daylight reflectances (Y) used. x = 0.331, y = 0.386, Y = 7.8%.

Table V

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Munsell Renotations And ISCC-NBS Color Designations Of A Dry White Oak Leaf Derived From Chromaticity Coordinates And Daylight Reflectances Computed From Spectrophotometric Data.

Run No.	Munsell Renotations	ISCC-NBS Color Designations
1	5.9GY-3.3/2.5**	Grayish olive green
2	5.4GY-3.4/2.6	Grayish olive green
3	5.3GY-3.6/2.9	Grayish olive green
4	3.7GY-3.9/3.0	Grayish olive green to moderate olive green
5	3.5GY-4.0/2.7	Grayish olive green
6	3.4GY-4.1/2.7	Grayish olive green
7	3.5GY-3.9/2.7	Grayish olive green
8	2.9GY-4.0/2.6	Grayish olive green
9	2.4GY-3.9/2.6	Grayish olive green
10	2.5GY-4.1/2.3	Grayish olive green
11	2.8GY-4.2/2.5	Grayish olive green
12	2.4GY-4.2/2.3	Grayish olive green
13	2.4GY-4.3/2.0	Grayish olive green
14	0.9GY-4.4/1.9	Grayish olive
15	0.5GY-4.4/1.8	Grayish olive
16	9.8 Y-4.4/2.0	Grayish olive
17	7.4 Y-4.5/1.9	Light olive gray to grayish olive
18	3.6 Y-4.5/2.1	Light olive brown to moderate olive brown
19	1.8 Y-4.7/2.5	Light olive brown
20	1.4 Y-4.7/3.0	Light olive brown
21	9.0YR-4.9/3.4	Moderate yellowish brown
22	8.9YR-5.0/3.8	Moderate yellowish brown
23	8.4YR-4.9/3.8	Moderate yellowish brown
24	8.0YR-4.9/3.9	Light brown to moderate yellowish brown
25	7.7YR-4.9/3.9	Light brown

** Average wet and dry chromaticity coordinates (x,y) and daylight reflectances (Y) used. $x = 0.331$, $y = 0.386$, $Y = 7.8\%$.

Table VI

White Oak Leaves
(Quercus alba L.)

Color Differences Between The Initial Measurements And Each Of The 24 Successive Measurements For Both The Wet And Dry White Oak Leaves Taking As Zero The First Determination At 1/2 Hour After The Leaves Were Picked And Considering, For The Purpose Of Color Differences, The First Determination As Zero Hours.

Determinations Between Runs Number:	Color Difference ΔE Wet Leaf	Dry Leaf
1 and 1	0.0	0.0
1 and 2	2.0	2.0
1 and 3	2.0	6.4
1 and 4	2.0	12.4
1 and 5	2.0	14.2
1 and 6	2.0	16.2
1 and 7	4.0	12.2
1 and 8	6.4	14.2
1 and 9	4.0	12.4
1 and 10	4.2	16.2
1 and 11	6.2	18.2
1 and 12	15.2	18.2
1 and 13	21.5	20.3
1 and 14	21.2	22.4
1 and 15	21.4	22.6
1 and 16	21.2	22.6
1 and 17	20.8	24.8
1 and 18	24.6	25.6
1 and 19	22.8	30.0
1 and 20	26.8	30.6
1 and 21	26.7	35.6
1 and 22	24.8	38.0
1 and 23	23.0	36.4
1 and 24	23.2	36.8
1 and 25	23.3	36.8

Table VII

White Oak Leaves
(Quercus alba L.)

Chromaticity Coordinates And Daylight Reflectances Of The Measured Wet White Oak Leaf (Now Dried), The Backing Wet White Oak Leaf (Now Dried), The Measured Dry White Oak Leaf, And The Backing Dry White Oak Leaf Obtained From Spectrophotometric Measurements Made After A Period Of One Year.

Sample	GE Graph Sheet Serial Number: Visible Spectrum	GE Graph Sheet Serial Number: Near Infrared Spectrum	Chromaticity Coordinates x	Chromaticity Coordinates y	Daylight Reflectance Y(%)
Measured Leaf KEPT WET (Now Dried)	GE II-1272	GE II-1273	0.365	0.356	11.3
Backing Leaf KEPT WET (Now Dried)	1272	1273	.366	.354	10.6
Measured Leaf KEPT DRY	1272	1273	.400	.372	18.9
Backing Leaf** KEPT DRY	1272	1273	.353	.365	18.7

**This backing leaf has a chromaticity similar to the measured leaf after 24 weeks of drying thus giving some indication that light is needed to reduce the absorption band of chlorophyll.

Table VIII

White Oak Leaves
(Quercus alba L.)

Munsell Renotations And ISCC-NBS Color Designations Of The Measured Wet White Oak Leaf (Now Dried), The Backing Wet White Oak Leaf (Now Dried), The Measured Dry White Oak Leaf, And The Backing Dry White Oak Leaf Derived From Chromaticity Coordinates And Daylight Reflectances Computed From Spectrophotometric Measurements Made After A Period Of One Year.

Sample	Munsell Renotation	ISCC-NBS Color Designation
Measured Leaf KEPT WET (Now Dried)	9.3YR-3.9/2.0	Grayish yellowish brown
Backing Leaf KEPT WET (Now Dried)	8.7YR-3.8/1.9	Grayish yellowish brown
Measured Leaf KEPT DRY	7.6YR-4.9/3.9	Light brown
Backing Leaf KEPT DRY	5.1 Y-4.9/2.1	Light grayish olive

Table IX

White Oak Leaves
(Quercus alba L.)

Color Differences Between The Initial Measurement And The Measured Wet White Oak Leaf (Now Dried), The Backing Wet White Oak Leaf (Now Dried), The Measured Dry White Oak Leaf, And The Backing Dry White Oak Leaf, Measured After A Period Of One Year, And Taking As Zero The First Determination At 1/2 Hour After The Leaves Were Picked And Considering, For The Purpose Of Color Differences, The First Determination As Zero Hours.

Determinations Between	Color Difference ΔE
Run No. 1 and Measured Leaf, KEPT WET (Now Dried)	16.6
Run No. 1 and Backing Leaf, KEPT WET (Now Dried)	15.3
Run No. 1 and Measured Leaf, KEPT DRY	37.0
Run No. 1 and Backing Leaf, KEPT DRY	33.0

Appendix A

Ozalid prints of the 26 sets of spectral directional reflectance measurements made on two sets of leaves of a White Oak tree; one set kept dry, the other kept immersed for one year in distilled water. Please note that the curves on four of the near infrared graph sheets are erroneous between approximately 950 and 1080 millimicrons, and should not be used in this region of the spectrum. They are: GE II-1235, -1246, -1251, and -1263.

Appendix B

Tables of spectral directional reflectances 400 - 1080 millimicrons of 25 sets of determinations on wet and dry samples of White Oak tree leaves made over a period of one year at the time intervals indicated in Table 1. Also included are the spectral directional reflectances of the two backing leaves after the year's end and reported in Tables VII, VIII, and IX.

The near infrared data on Runs 21, 22, 23, and 24 are given for those portions of the spectrophotometric curves found to be usable. Runs 21 and 22 are given to 940 mμ and Run 24 to 990 mμ. While all of the data on Run 23 is reported the values between 950 and 1080 mμ are extrapolated.

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 1				Run Number 2				Run Number 3			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.041	750	0.489	400	0.040	750	0.472	400	0.041	750	0.477
10	.043	60	.500	10	.043	60	.492	10	.043	60	.499
20	.045	70	.512	20	.043	70	.503	20	.044	70	.510
30	.046	80	.516	30	.044	80	.507	30	.045	80	.514
40	.047	90	.518	40	.045	90	.511	40	.045	90	.519
450	.048	800	.522	450	.045	800	.512	450	.046	800	.522
60	.048	10	.523	60	.046	10	.515	60	.046	10	.525
70	.049	20	.524	70	.046	20	.517	70	.047	20	.528
80	.049	30	.526	80	.046	30	.518	80	.047	30	.529
90	.050	40	.528	90	.046	40	.520	90	.048	40	.531
500	.051	850	.529	500	.048	850	.522	500	.049	850	.532
10	.058	60	.530	10	.054	60	.522	10	.055	60	.534
20	.072	70	.531	20	.067	70	.523	20	.069	70	.536
30	.091	80	.532	30	.086	80	.525	30	.085	80	.537
40	.100	90	.533	40	.095	90	.526	40	.093	90	.538
550	.103	900	.534	550	.098	900	.528	550	.096	900	.540
60	.100	10	.535	60	.095	10	.528	60	.094	10	.540
70	.088	20	.535	70	.084	20	.528	70	.084	20	.541
80	.077	30	.535	80	.073	30	.527	80	.074	30	.540
90	.072	40	.535	90	.068	40	.528	90	.069	40	.540
600	.070	950	.534	600	.065	950	.526	600	.066	950	.540
10	.065	60	.533	10	.062	60	.524	10	.063	60	.536
20	.061	70	.531	20	.057	70	.522	20	.059	70	.533
30	.059	80	.529	30	.055	80	.521	30	.057	80	.532
40	.057	90	.530	40	.054	90	.520	40	.055	90	.532
650	.053	1000	.530	650	.050	1000	.520	650	.052	1000	.533
60	.050	10	.531	60	.048	10	.520	60	.050	10	.534
70	.046	20	.532	70	.045	20	.520	70	.046	20	.536
80	.046	30	.532	80	.044	30	.521	80	.045	30	.536
90	.052	40	.533	90	.049	40	.523	90	.051	40	.537
700	.096	1050	.533	700	.089	1050	.524	700	.096	1050	.537
10	.181	60	.533	10	.169	60	.525	10	.176	60	.537
20	.285	70	.532	20	.269	70	.526	20	.276	70	.538
30	.381	80	.532	30	.368	80	.526	30	.372	80	.538
40	.450			40	.434			40	.440		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained from Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 4				Run Number 5				Run Number 6			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.041	750	0.452	400	0.040	750	0.458	400	0.034	750	0.449
10	.042	60	.470	10	.042	60	.476	10	.036	60	.466
20	.044	70	.479	20	.042	70	.486	20	.039	70	.477
30	.045	80	.484	30	.044	80	.491	30	.041	80	.482
40	.046	90	.488	40	.044	90	.496	40	.042	90	.487
450	.046	800	.490	450	.045	800	.498	450	.044	800	.491
60	.047	10	.492	60	.046	10	.501	60	.045	10	.493
70	.048	20	.494	70	.046	20	.503	70	.046	20	.495
80	.048	30	.496	80	.046	30	.505	80	.047	30	.497
90	.048	40	.498	90	.046	40	.506	90	.048	40	.499
500	.050	850	.498	500	.048	850	.507	500	.049	850	.501
10	.055	60	.499	10	.054	60	.509	10	.055	60	.502
20	.068	70	.500	20	.068	70	.510	20	.068	70	.503
30	.084	80	.502	30	.083	80	.511	30	.084	80	.505
40	.092	90	.502	40	.091	90	.512	40	.093	90	.506
550	.096	900	.504	550	.095	900	.513	550	.096	900	.507
60	.094	10	.504	60	.092	10	.513	60	.094	10	.508
70	.084	20	.504	70	.082	20	.514	70	.084	20	.507
80	.075	30	.503	80	.072	30	.514	80	.074	30	.507
90	.069	40	.503	90	.067	40	.513	90	.068	40	.507
600	.067	950	.500	600	.065	950	.511	600	.066	950	.506
10	.064	60	.498	10	.062	60	.509	10	.062	60	.502
20	.060	70	.496	20	.058	70	.506	20	.058	70	.499
30	.057	80	.494	30	.056	80	.506	30	.057	80	.498
40	.056	90	.494	40	.055	90	.507	40	.055	90	.500
650	.052	1000	.494	650	.051	1000	.507	650	.051	1000	.500
60	.050	10	.494	60	.048	10	.508	60	.048	10	.502
70	.047	20	.494	70	.045	20	.510	70	.046	20	.503
80	.045	30	.494	80	.045	30	.513	80	.045	30	.506
90	.052	40	.495	90	.050	40	.515	90	.051	40	.507
700	.099	1050	.495	700	.095	1050	.516	700	.096	1050	.508
10	.176	60	.495	10	.173	60	.518	10	.175	60	.510
20	.266	70	.496	20	.267	70	.518	20	.271	70	.510
30	.357	80	.496	30	.360	80	.518	30	.355	80	.510
40	.420			40	.423			40	.416		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 7				Run Number 8				Run Number 9			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.039	750	0.440	400	0.025	750	0.438	400	0.037	750	0.438
10	.041	60	.456	10	.028	60	.474	10	.039	60	.457
20	.043	70	.462	20	.029	70	.484	20	.040	70	.465
30	.044	80	.466	30	.031	80	.490	30	.041	80	.471
40	.044	90	.469	40	.032	90	.494	40	.042	90	.476
450	.045	800	.471	450	.034	800	.498	450	.042	800	.479
60	.046	10	.473	60	.035	10	.500	60	.043	10	.482
70	.046	20	.474	70	.036	20	.502	70	.043	20	.485
80	.046	30	.477	80	.037	30	.504	80	.043	30	.487
90	.046	40	.478	90	.039	40	.507	90	.044	40	.489
500	.048	850	.479	500	.040	850	.508	500	.045	850	.491
10	.052	60	.481	10	.046	60	.510	10	.051	60	.492
20	.066	70	.482	20	.059	70	.512	20	.064	70	.494
30	.082	80	.483	30	.074	80	.513	30	.079	80	.497
40	.090	90	.484	40	.082	90	.514	40	.086	90	.498
550	.093	900	.485	550	.085	900	.516	550	.089	900	.501
60	.090	10	.486	60	.082	10	.516	60	.087	10	.503
70	.080	20	.486	70	.073	20	.517	70	.077	20	.503
80	.071	30	.485	80	.064	30	.517	80	.068	30	.505
90	.066	40	.486	90	.059	40	.517	90	.063	40	.506
600	.063	950	.484	600	.057	950	.515	600	.061	950	.504
10	.060	60	.482	10	.054	60	.512	10	.057	60	.502
20	.056	70	.478	20	.050	70	.510	20	.054	70	.501
30	.055	80	.478	30	.049	80	.510	30	.052	80	.503
40	.053	90	.478	40	.047	90	.510	40	.050	90	.505
650	.050	1000	.479	650	.044	1000	.512	650	.046	1000	.507
60	.046	10	.481	60	.042	10	.513	60	.044	10	.501
70	.044	20	.483	70	.040	20	.515	70	.041	20	.503
80	.044	30	.485	80	.039	30	.516	80	.041	30	.506
90	.048	40	.486	90	.044	40	.517	90	.049	40	.510
700	.088	1050	.487	700	.088	1050	.519	700	.093	1050	.512
10	.166	60	.489	10	.160	60	.519	10	.173	60	.514
20	.261	70	.489	20	.242	70	.519	20	.263	70	.514
30	.348	80	.490	30	.343	80	.519	30	.349	80	.515
40	.405			40	.454			40	.406		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 10				Run Number 11				Run Number 12			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.038	750	0.424	400	0.035	750	0.359	400	0.041	750	0.223
10	.039	60	.446	10	.038	60	.371	10	.042	60	.241
20	.041	70	.455	20	.039	70	.380	20	.043	70	.254
30	.042	80	.461	30	.040	80	.386	30	.044	80	.266
40	.043	90	.464	40	.041	90	.391	40	.044	90	.277
450	.043	800	.468	450	.042	800	.395	450	.044	800	.288
60	.044	10	.471	60	.043	10	.400	60	.044	10	.300
70	.044	20	.474	70	.043	20	.405	70	.044	20	.310
80	.044	30	.476	80	.043	30	.409	80	.044	30	.322
90	.044	40	.478	90	.044	40	.414	90	.044	40	.332
500	.046	850	.480	500	.045	850	.417	500	.044	850	.342
10	.051	60	.482	10	.049	60	.421	10	.046	60	.351
20	.064	70	.483	20	.059	70	.425	20	.049	70	.360
30	.077	80	.485	30	.072	80	.430	30	.051	80	.369
40	.085	90	.487	40	.080	90	.433	40	.053	90	.378
550	.088	900	.488	550	.083	900	.437	550	.055	900	.386
60	.086	10	.489	60	.081	10	.441	60	.056	10	.393
70	.078	20	.490	70	.073	20	.444	70	.055	20	.399
80	.069	30	.489	80	.065	30	.446	80	.054	30	.403
90	.064	40	.489	90	.060	40	.448	90	.053	40	.408
600	.062	950	.487	600	.058	950	.448	600	.052	950	.410
10	.060	60	.485	10	.055	60	.448	10	.051	60	.411
20	.056	70	.482	20	.052	70	.447	20	.051	70	.411
30	.055	80	.483	30	.051	80	.447	30	.050	80	.414
40	.052	90	.484	40	.050	90	.447	40	.049	90	.417
650	.049	1000	.484	650	.046	1000	.448	650	.046	1000	.420
60	.046	10	.487	60	.045	10	.450	60	.045	10	.423
70	.043	20	.487	70	.042	20	.452	70	.043	20	.426
80	.043	30	.488	80	.041	30	.452	80	.043	30	.429
90	.052	40	.490	90	.045	40	.452	90	.050	40	.432
700	.100	1050	.490	700	.079	1050	.452	700	.083	1050	.434
10	.171	60	.491	10	.148	60	.452	10	.126	60	.437
20	.260	70	.492	20	.226	70	.452	20	.160	70	.437
30	.340	80	.493	30	.292	80	.452	30	.200	80	.439
40	.393			40	.336			40	.209		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 13				Run Number 14				Run Number 15			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.038	750	0.187	400	0.032	750	0.135	400	0.035	750	0.128
10	.039	60	.202	10	.033	60	.148	10	.037	60	.140
20	.040	70	.214	20	.034	70	.158	20	.038	70	.149
30	.040	80	.228	30	.035	80	.166	30	.039	80	.159
40	.040	90	.238	40	.036	90	.176	40	.039	90	.170
450	.040	800	.253	450	.036	800	.185	450	.039	800	.179
60	.040	10	.264	60	.038	10	.194	60	.039	10	.189
70	.041	20	.275	70	.038	20	.202	70	.040	20	.198
80	.041	30	.287	80	.038	30	.210	80	.040	30	.207
90	.041	40	.298	90	.039	40	.219	90	.040	40	.216
500	.041	850	.309	500	.039	850	.227	500	.040	850	.223
10	.042	60	.318	10	.040	60	.235	10	.041	60	.231
20	.044	70	.328	20	.040	70	.240	20	.042	70	.238
30	.045	80	.337	30	.041	80	.247	30	.042	80	.246
40	.046	90	.344	40	.042	90	.255	40	.043	90	.253
550	.047	900	.354	550	.042	900	.262	550	.043	900	.262
60	.048	10	.363	60	.043	10	.268	60	.044	10	.268
70	.049	20	.369	70	.044	20	.273	70	.045	20	.275
80	.050	30	.374	80	.045	30	.277	80	.046	30	.280
90	.050	40	.379	90	.046	40	.281	90	.046	40	.284
600	.050	950	.382	600	.046	950	.284	600	.047	950	.287
10	.050	60	.384	10	.046	60	.286	10	.047	60	.290
20	.050	70	.387	20	.047	70	.289	20	.048	70	.295
30	.050	80	.390	30	.049	80	.293	30	.049	80	.297
40	.049	90	.394	40	.049	90	.296	40	.049	90	.303
650	.047	1000	.399	650	.048	1000	.300	650	.049	1000	.307
60	.045	10	.403	60	.046	10	.304	60	.048	10	.311
70	.044	20	.407	70	.045	20	.308	70	.047	20	.315
80	.044	30	.412	80	.047	30	.313	80	.049	30	.320
90	.054	40	.416	90	.055	40	.317	90	.056	40	.323
700	.084	1050	.419	700	.070	1050	.320	700	.069	1050	.325
10	.118	60	.423	10	.086	60	.323	10	.084	60	.329
20	.142	70	.425	20	.101	70	.326	20	.098	70	.330
30	.161	80	.428	30	.113	80	.330	30	.107	80	.332
40	.176			40	.124			40	.119		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 16				Run Number 17				Run Number 18			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.031	750	0.127	400	0.028	750	0.115	400	0.026	750	0.107
10	.033	60	.141	10	.029	60	.128	10	.028	60	.120
20	.034	70	.152	20	.030	70	.138	20	.029	70	.129
30	.036	80	.163	30	.031	80	.148	30	.029	80	.138
40	.036	90	.174	40	.033	90	.159	40	.030	90	.147
450	.037	800	.184	450	.033	800	.169	450	.030	800	.156
60	.038	10	.194	60	.034	10	.179	60	.031	10	.165
70	.038	20	.203	70	.035	20	.189	70	.032	20	.174
80	.039	30	.214	80	.036	30	.197	80	.032	30	.183
90	.039	40	.223	90	.037	40	.206	90	.033	40	.191
500	.039	850	.232	500	.038	850	.215	500	.033	850	.198
10	.040	60	.239	10	.038	60	.221	10	.034	60	.205
20	.040	70	.246	20	.040	70	.228	20	.035	70	.211
30	.041	80	.254	30	.040	80	.235	30	.035	80	.218
40	.042	90	.262	40	.041	90	.244	40	.036	90	.226
550	.042	900	.271	550	.041	900	.252	550	.036	900	.236
60	.043	10	.280	60	.042	10	.260	60	.037	10	.244
70	.044	20	.286	70	.043	20	.266	70	.039	20	.251
80	.044	30	.291	80	.044	30	.272	80	.039	30	.257
90	.045	40	.297	90	.044	40	.277	90	.041	40	.261
600	.045	950	.300	600	.045	950	.279	600	.041	950	.264
10	.046	60	.303	10	.046	60	.283	10	.042	60	.267
20	.047	70	.306	20	.047	70	.285	20	.044	70	.270
30	.048	80	.310	30	.049	80	.289	30	.045	80	.273
40	.048	90	.314	40	.049	90	.293	40	.046	90	.277
650	.048	1000	.319	650	.049	1000	.298	650	.047	1000	.281
60	.047	10	.322	60	.049	10	.302	60	.048	10	.285
70	.047	20	.328	70	.049	20	.308	70	.048	20	.290
80	.049	30	.330	80	.051	30	.312	80	.051	30	.292
90	.056	40	.334	90	.058	40	.314	90	.056	40	.295
700	.067	1050	.337	700	.066	1050	.317	700	.063	1050	.299
10	.080	60	.340	10	.075	60	.321	10	.071	60	.300
20	.092	70	.344	20	.086	70	.323	20	.078	70	.301
30	.104	80	.344	30	.094	80	.326	30	.089	80	.304
40	.116			40	.104			40	.098		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 19				Run Number 20				Run Number 21			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.027	750	0.116	400	0.025	750	0.097	400	0.026	750	0.099
10	.028	60	.128	10	.026	60	.100	10	.025	60	.102
20	.029	70	.138	20	.026	70	.109	20	.026	70	.111
30	.030	80	.146	30	.027	80	.117	30	.026	80	.120
40	.030	90	.155	40	.028	90	.126	40	.027	90	.129
450	.031	800	.164	450	.028	800	.136	450	.027	800	.139
60	.032	10	.174	60	.028	10	.145	60	.028	10	.149
70	.032	20	.178	70	.028	20	.153	70	.028	20	.158
80	.032	30	.190	80	.028	30	.162	80	.029	30	.167
90	.033	40	.198	90	.028	40	.171	90	.029	40	.176
500	.033	850	.205	500	.028	850	.178	500	.030	850	.184
10	.034	60	.210	10	.029	60	.183	10	.030	60	.191
20	.034	70	.214	20	.029	70	.189	20	.030	70	.197
30	.035	80	.221	30	.030	80	.196	30	.031	80	.204
40	.036	90	.229	40	.031	90	.204	40	.031	90	.214
550	.037	900	.239	550	.031	900	.215	550	.032	900	.228
60	.038	10	.247	60	.032	10	.225	60	.033	10	.238
70	.040	20	.254	70	.033	20	.232	70	.034	20	.246
80	.041	30	.259	80	.034	30	.238	80	.035	30	.252
90	.042	40	.263	90	.035	40	.242	90	.036	40	.256
600	.044	950	.265	600	.036	950	.246	600	.037	950	-
10	.045	60	.267	10	.037	60	.248	10	.039	60	-
20	.046	70	.270	20	.038	70	.251	20	.041	70	-
30	.049	80	.273	30	.040	80	.255	30	.043	80	-
40	.050	90	.277	40	.043	90	.258	40	.045	90	-
650	.051	1000	.281	650	.044	1000	.262	650	.048	1000	-
60	.054	10	.285	60	.047	10	.267	60	.051	10	-
70	.056	20	.289	70	.050	20	.270	70	.054	20	-
80	.059	30	.292	80	.053	30	.274	80	.058	30	-
90	.064	40	.296	90	.058	40	.277	90	.064	40	-
700	.071	1050	.298	700	.064	1050	.280	700	.070	1050	-
10	.079	60	.302	10	.071	60	.284	10	.077	60	-
20	.087	70	.303	20	.078	70	.286	20	.085	70	-
30	.097	80	.305	30	.082	80	.286	30	.085	80	-
40	.106			40	.090			40	.092		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 22				Run Number 23				Run Number 24			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.023	750	0.116	400	0.028	750	0.115	400	0.029	750	0.113
10	.024	60	.124	10	.030	60	.118	10	.030	60	.121
20	.025	70	.133	20	.032	70	.127	20	.031	70	.130
30	.026	80	.141	30	.032	80	.136	30	.032	80	.138
40	.027	90	.149	40	.033	90	.145	40	.032	90	.148
450	.028	800	.158	450	.033	800	.154	450	.033	800	.157
60	.028	10	.168	60	.034	10	.163	60	.033	10	.167
70	.029	20	.177	70	.034	20	.172	70	.033	20	.176
80	.029	30	.185	80	.034	30	.182	80	.033	30	.184
90	.029	40	.192	90	.034	40	.190	90	.034	40	.192
500	.030	850	.198	500	.035	850	.196	500	.034	850	.198
10	.030	60	.203	10	.036	60	.201	10	.035	60	.205
20	.032	70	.207	20	.036	70	.206	20	.036	70	.211
30	.033	80	.212	30	.037	80	.213	30	.036	80	.217
40	.033	90	.220	40	.037	90	.222	40	.037	90	.227
550	.034	900	.231	550	.038	900	.232	550	.038	900	.237
60	.035	10	.240	60	.040	10	.243	60	.038	10	.247
70	.036	20	.245	70	.040	20	.251	70	.039	20	.256
80	.038	30	.248	80	.041	30	.256	80	.040	30	.262
90	.038	40	.250	90	.043	40	.260	90	.041	40	.267
600	.040	950	-	600	.044	950	.262	600	.042	950	.269
10	.041	60	-	10	.046	60	.264	10	.044	60	.272
20	.043	70	-	20	.048	70	.265	20	.046	70	.274
30	.046	80	-	30	.050	80	.266	30	.048	80	.278
40	.049	90	-	40	.051	90	.268	40	.050	90	.281
650	.051	1000	-	650	.056	1000	.269	650	.052	1000	-
60	.054	10	-	60	.059	10	.270	60	.055	10	-
70	.058	20	-	70	.061	20	.270	70	.058	20	-
80	.062	30	-	80	.066	30	.265	80	.062	30	-
90	.068	40	-	90	.072	40	.257	90	.067	40	-
700	.075	1050	-	700	.080	1050	.248	700	.074	1050	-
10	.082	60	-	10	.087	60	.237	10	.080	60	-
20	.090	70	-	20	.095	70	.223	20	.088	70	-
30	.097	80	-	30	.099	80	.210	30	.096	80	-
40	.104			40	.107			40	.104		

White Oak Leaf
(Quercus alba L.)
KEPT WET

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 25			
Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.031	750	0.118
10	.032	60	.129
20	.033	70	.138
30	.033	80	.147
40	.034	90	.156
450	.034	800	.166
60	.035	10	.174
70	.035	20	.185
80	.035	30	.193
90	.035	40	.201
500	.035	850	.208
10	.036	60	.213
20	.037	70	.217
30	.038	80	.224
40	.038	90	.233
550	.039	900	.244
60	.040	10	.254
70	.041	20	.262
80	.042	30	.267
90	.043	40	.271
600	.045	950	.273
10	.046	60	.276
20	.049	70	.277
30	.050	80	.282
40	.052	90	.285
650	.055	1000	.289
60	.058	10	.292
70	.061	20	.296
80	.066	30	.301
90	.071	40	.305
700	.076	1050	.307
10	.084	60	.312
20	.091	70	.312
30	.101	80	.314
40	.109		

Measured Leaf (Now Dried)			
Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.052	750	0.255
10	.057	60	.266
20	.061	70	.277
30	.066	80	.288
40	.070	90	.299
450	.074	800	.311
60	.078	10	.322
70	.081	20	.332
80	.084	30	.343
90	.087	40	.353
500	.090	850	.362
10	.093	60	.371
20	.097	70	.378
30	.100	80	.386
40	.104	90	.397
550	.108	900	.412
60	.113	10	.426
70	.117	20	.437
80	.121	30	.446
90	.126	40	.455
600	.131	950	.462
10	.136	60	.468
20	.141	70	.476
30	.146	80	.482
40	.153	90	.488
650	.158	1000	.494
60	.166	10	.499
70	.174	20	.503
80	.181	30	.509
90	.190	40	.514
700	.200	1050	.521
10	.210	60	.521
20	.221	70	.524
30	.233	80	.528
40	.244		

Backing Leaf (Now Dried)			
Wave Length mμ	R_λ	Length mμ	R_λ
400	0.049	750	0.268
10	.057	60	.281
20	.061	70	.294
30	.064	80	.308
40	.067	90	.321
450	.070	800	.334
60	.073	10	.348
70	.074	20	.361
80	.078	30	.372
90	.081	40	.384
500	.084	850	.395
10	.087	60	.404
20	.090	70	.414
30	.094	80	.424
40	.098	90	.435
550	.101	900	.447
60	.106	10	.460
70	.110	20	.470
80	.115	30	.480
90	.120	40	.489
600	.125	950	.496
10	.129	60	.503
20	.135	70	.510
30	.141	80	.516
40	.147	90	.521
650	.152	1000	.526
60	.156	10	.531
70	.163	20	.536
80	.172	30	.541
90	.183	40	.544
700	.196	1050	.550
10	.210	60	.552
20	.225	70	.557
30	.240	80	.561
40	.254		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 1				Run Number 2				Run Number 3			
Wave Length $m\mu$	R_λ	Wave Length $m\mu$	R_λ	Wave Length $m\mu$	R_λ	Wave Length $m\mu$	R_λ	Wave Length $m\mu$	R_λ	Wave Length $m\mu$	R_λ
400	0.041	750	0.482	400	0.042	750	0.495	400	0.041	750	0.498
10	.043	60	.500	10	.044	60	.517	10	.044	60	.518
20	.045	70	.512	20	.046	70	.528	20	.046	70	.528
30	.046	80	.516	30	.046	80	.532	30	.048	80	.533
40	.047	90	.518	40	.048	90	.535	40	.049	90	.538
450	.048	800	.522	450	.049	800	.537	450	.051	800	.539
60	.048	10	.523	60	.050	10	.539	60	.052	10	.543
70	.049	20	.524	70	.051	20	.541	70	.053	20	.544
80	.049	30	.526	80	.051	30	.542	80	.054	30	.546
90	.050	40	.528	90	.052	40	.544	90	.055	40	.548
500	.051	850	.529	500	.054	850	.546	500	.058	850	.549
10	.058	60	.530	10	.063	60	.546	10	.068	60	.550
20	.072	70	.531	20	.079	70	.547	20	.087	70	.552
30	.089	80	.532	30	.097	80	.548	30	.106	80	.552
40	.097	90	.533	40	.108	90	.549	40	.115	90	.553
550	.100	900	.534	550	.112	900	.550	550	.119	900	.555
60	.096	10	.535	60	.109	10	.552	60	.115	10	.556
70	.085	20	.535	70	.097	20	.552	70	.104	20	.558
80	.074	30	.535	80	.086	30	.552	80	.092	30	.557
90	.070	40	.535	90	.081	40	.553	90	.086	40	.558
600	.067	950	.534	600	.078	950	.552	600	.084	950	.558
10	.064	60	.533	10	.074	60	.551	10	.079	60	.558
20	.060	70	.531	20	.069	70	.551	20	.074	70	.557
30	.058	80	.529	30	.067	80	.551	30	.072	80	.556
40	.057	90	.530	40	.065	90	.550	40	.069	90	.556
650	.053	1000	.530	650	.060	1000	.550	650	.063	1000	.556
60	.050	10	.531	60	.056	10	.549	60	.059	10	.557
70	.046	20	.532	70	.051	20	.549	70	.052	20	.558
80	.046	30	.532	80	.050	30	.550	80	.051	30	.558
90	.052	40	.533	90	.057	40	.552	90	.062	40	.559
700	.093	1050	.533	700	.099	1050	.552	700	.114	1050	.559
10	.174	60	.533	10	.183	60	.552	10	.200	60	.560
20	.276	70	.532	20	.282	70	.552	20	.300	70	.559
30	.374	80	.532	30	.383	80	.552	30	.395	80	.559
40	.442			40	.453			40	.462		

White Oak Leaf
(Quercus alba L.)
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Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 4				Run Number 5				Run Number 6			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.044	750	0.502	400	0.046	750	0.491	400	0.047	750	0.496
10	.048	60	.519	10	.051	60	.507	10	.053	60	.511
20	.052	70	.528	20	.056	70	.516	20	.060	70	.521
30	.055	80	.534	30	.060	80	.522	30	.064	80	.528
40	.057	90	.540	40	.063	90	.528	40	.067	90	.535
450	.060	800	.544	450	.066	800	.534	450	.070	800	.541
60	.062	10	.549	60	.068	10	.540	60	.073	10	.546
70	.064	20	.553	70	.069	20	.543	70	.074	20	.548
80	.065	30	.557	80	.070	30	.547	80	.076	30	.554
90	.066	40	.562	90	.073	40	.552	90	.078	40	.559
500	.072	850	.565	500	.078	850	.557	500	.084	850	.563
10	.085	60	.569	10	.091	60	.561	10	.097	60	.566
20	.106	70	.572	20	.111	70	.564	20	.117	70	.570
30	.124	80	.574	30	.128	80	.568	30	.134	80	.574
40	.134	90	.578	40	.135	90	.570	40	.142	90	.577
550	.149	900	.581	550	.141	900	.573	550	.147	900	.581
60	.137	10	.582	60	.140	10	.576	60	.147	10	.583
70	.126	20	.584	70	.130	20	.578	70	.137	20	.585
80	.116	30	.586	80	.120	30	.581	80	.128	30	.587
90	.111	40	.588	90	.116	40	.583	90	.124	40	.590
600	.109	950	.589	600	.113	950	.585	600	.121	950	.591
10	.103	60	.591	10	.107	60	.588	10	.115	60	.593
20	.097	70	.591	20	.102	70	.588	20	.110	70	.595
30	.096	80	.591	30	.100	80	.590	30	.108	80	.596
40	.092	90	.591	40	.097	90	.591	40	.104	90	.596
650	.085	1000	.591	650	.090	1000	.592	650	.097	1000	.596
60	.075	10	.591	60	.081	10	.595	60	.089	10	.600
70	.068	20	.592	70	.074	20	.595	70	.080	20	.600
80	.067	30	.593	80	.073	30	.596	80	.080	30	.602
90	.091	40	.593	90	.093	40	.598	90	.103	40	.604
700	.177	1050	.593	700	.177	1050	.599	700	.185	1050	.605
10	.294	60	.593	10	.286	60	.602	10	.291	60	.606
20	.387	70	.593	20	.380	70	.602	20	.387	70	.606
30	.450	80	.593	30	.439	80	.603	30	.442	80	.607
40	.484			40	.472			40	.477		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 7				Run Number 8				Run Number 9			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.044	750	0.483	400	0.045	750	0.480	400	0.044	750	0.474
10	.049	60	.499	10	.052	60	.497	10	.050	60	.490
20	.054	70	.509	20	.057	70	.507	20	.055	70	.500
30	.058	80	.517	30	.061	80	.514	30	.058	80	.508
40	.060	90	.522	40	.064	90	.520	40	.061	90	.515
450	.063	800	.528	450	.068	800	.526	450	.064	800	.520
60	.066	10	.532	60	.070	10	.532	60	.066	10	.526
70	.066	20	.537	70	.071	20	.537	70	.068	20	.531
80	.068	30	.542	80	.073	30	.542	80	.069	30	.536
90	.070	40	.546	90	.075	40	.547	90	.071	40	.542
500	.075	850	.552	500	.081	850	.552	500	.077	850	.547
10	.088	60	.556	10	.093	60	.557	10	.089	60	.552
20	.107	70	.560	20	.111	70	.561	20	.101	70	.555
30	.124	80	.564	30	.127	80	.564	30	.119	80	.560
40	.131	90	.567	40	.133	90	.568	40	.125	90	.563
550	.136	900	.570	550	.139	900	.572	550	.132	900	.567
60	.135	10	.572	60	.140	10	.574	60	.133	10	.570
70	.126	20	.574	70	.131	20	.576	70	.125	20	.572
80	.118	30	.576	80	.124	30	.579	80	.117	30	.576
90	.113	40	.579	90	.119	40	.582	90	.113	40	.578
600	.111	950	.580	600	.116	950	.584	600	.110	950	.581
10	.105	60	.583	10	.111	60	.586	10	.104	60	.584
20	.100	70	.584	20	.106	70	.588	20	.100	70	.584
30	.099	80	.585	30	.104	80	.589	30	.099	80	.586
40	.095	90	.585	40	.100	90	.589	40	.094	90	.588
650	.088	1000	.587	650	.092	1000	.591	650	.086	1000	.590
60	.079	10	.588	60	.083	10	.592	60	.078	10	.591
70	.072	20	.590	70	.076	20	.593	70	.070	20	.592
80	.071	30	.591	80	.076	30	.595	80	.071	30	.593
90	.090	40	.592	90	.100	40	.597	90	.097	40	.596
700	.164	1050	.594	700	.186	1050	.598	700	.176	1050	.599
10	.275	60	.595	10	.288	60	.599	10	.285	60	.599
20	.371	70	.595	20	.375	70	.599	20	.370	70	.599
30	.432	80	.596	30	.429	80	.599	30	.423	80	.599
40	.464			40	.461			40	.454		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 10				Run Number 11				Run Number 12			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.048	750	0.463	400	0.048	750	0.457	400	0.050	750	0.443
10	.057	60	.477	10	.056	60	.475	10	.060	60	.460
20	.064	70	.490	20	.064	70	.486	20	.068	70	.472
30	.069	80	.497	30	.070	80	.495	30	.074	80	.482
40	.073	90	.505	40	.074	90	.502	40	.079	90	.490
450	.077	800	.511	450	.079	800	.508	450	.084	800	.497
60	.079	10	.518	60	.082	10	.514	60	.089	10	.503
70	.080	20	.523	70	.084	20	.520	70	.090	20	.510
80	.082	30	.528	80	.086	30	.525	80	.093	30	.516
90	.086	40	.536	90	.091	40	.531	90	.098	40	.523
500	.092	850	.541	500	.098	850	.537	500	.107	850	.529
10	.104	60	.546	10	.111	60	.543	10	.119	60	.533
20	.119	70	.549	20	.126	70	.547	20	.132	70	.539
30	.131	80	.553	30	.137	80	.550	30	.142	80	.543
40	.136	90	.558	40	.142	90	.554	40	.147	90	.546
550	.142	900	.562	550	.148	900	.558	550	.152	900	.550
60	.143	10	.564	60	.150	10	.561	60	.153	10	.553
70	.138	20	.568	70	.144	20	.564	70	.148	20	.556
80	.131	30	.570	80	.137	30	.566	80	.143	30	.559
90	.128	40	.573	90	.133	40	.570	90	.140	40	.562
600	.124	950	.576	600	.130	950	.573	600	.137	950	.566
10	.120	60	.578	10	.126	60	.574	10	.133	60	.568
20	.115	70	.580	20	.122	70	.575	20	.129	70	.571
30	.114	80	.582	30	.120	80	.577	30	.127	80	.573
40	.109	90	.584	40	.117	90	.578	40	.123	90	.575
650	.101	1000	.586	650	.108	1000	.578	650	.114	1000	.577
60	.092	10	.587	60	.101	10	.579	60	.106	10	.580
70	.085	20	.590	70	.091	20	.580	70	.098	20	.581
80	.084	30	.590	80	.088	30	.580	80	.097	30	.584
90	.114	40	.594	90	.113	40	.580	90	.124	40	.586
700	.192	1050	.595	700	.190	1050	.580	700	.196	1050	.586
10	.289	60	.598	10	.285	60	.580	10	.283	60	.588
20	.366	70	.598	20	.357	70	.580	20	.351	70	.588
30	.413	80	.600	30	.408	80	.580	30	.394	80	.590
40	.443			40	.440			40	.424		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 13				Run Number 14				Run Number 15			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.052	750	0.435	400	0.055	750	0.414	400	0.057	750	0.394
10	.063	60	.452	10	.067	60	.437	10	.068	60	.413
20	.072	70	.464	20	.076	70	.451	20	.079	70	.428
30	.079	80	.474	30	.082	80	.462	30	.086	80	.438
40	.083	90	.482	40	.087	90	.472	40	.092	90	.450
450	.090	800	.491	450	.092	800	.480	450	.097	800	.457
60	.093	10	.498	60	.097	10	.489	60	.102	10	.465
70	.094	20	.504	70	.099	20	.500	70	.104	20	.472
80	.098	30	.511	80	.103	30	.503	80	.109	30	.479
90	.103	40	.516	90	.110	40	.510	90	.115	40	.486
500	.112	850	.522	500	.118	850	.516	500	.123	850	.494
10	.124	60	.528	10	.129	60	.521	10	.133	60	.499
20	.136	70	.533	20	.141	70	.527	20	.143	70	.504
30	.146	80	.537	30	.149	80	.531	30	.150	80	.509
40	.149	90	.540	40	.154	90	.536	40	.155	90	.513
550	.155	900	.545	550	.158	900	.539	550	.159	900	.517
60	.156	10	.548	60	.160	10	.543	60	.162	10	.520
70	.152	20	.552	70	.157	20	.547	70	.159	20	.524
80	.147	30	.555	80	.154	30	.550	80	.157	30	.527
90	.144	40	.557	90	.151	40	.554	90	.156	40	.530
600	.142	950	.561	600	.150	950	.557	600	.154	950	.534
10	.138	60	.563	10	.147	60	.562	10	.152	60	.539
20	.134	70	.567	20	.144	70	.564	20	.150	70	.543
30	.132	80	.570	30	.144	80	.568	30	.149	80	.547
40	.127	90	.573	40	.138	90	.572	40	.145	90	.551
650	.119	1000	.576	650	.129	1000	.576	650	.136	1000	.554
60	.110	10	.580	60	.120	10	.578	60	.128	10	.558
70	.101	20	.583	70	.112	20	.584	70	.120	20	.563
80	.103	30	.585	80	.116	30	.587	80	.124	30	.569
90	.130	40	.590	90	.148	40	.591	90	.151	40	.572
700	.200	1050	.593	700	.206	1050	.593	700	.204	1050	.573
10	.275	60	.597	10	.268	60	.596	10	.260	60	.577
20	.340	70	.598	20	.322	70	.598	20	.309	70	.579
30	.385	80	.599	30	.368	80	.601	30	.349	80	.580
40	.415			40	.396			40	.376		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 16				Run Number 17				Run Number 18			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.056	750	0.392	400	0.058	750	0.374	400	0.058	750	0.363
10	.068	60	.411	10	.073	60	.392	10	.071	60	.379
20	.077	70	.425	20	.083	70	.405	20	.082	70	.392
30	.085	80	.437	30	.091	80	.418	30	.090	80	.404
40	.090	90	.449	40	.097	90	.428	40	.097	90	.414
450	.096	800	.458	450	.102	800	.437	450	.102	800	.422
60	.100	10	.466	60	.106	10	.445	60	.107	10	.432
70	.102	20	.473	70	.110	20	.453	70	.111	20	.438
80	.107	30	.480	80	.114	30	.460	80	.116	30	.444
90	.114	40	.488	90	.120	40	.467	90	.121	40	.450
500	.122	850	.494	500	.127	850	.473	500	.127	850	.457
10	.131	60	.499	10	.136	60	.479	10	.135	60	.463
20	.141	70	.504	20	.144	70	.486	20	.142	70	.469
30	.148	80	.511	30	.151	80	.490	30	.149	80	.473
40	.153	90	.513	40	.156	90	.494	40	.155	90	.478
550	.158	900	.518	550	.160	900	.498	550	.161	900	.482
60	.160	10	.521	60	.164	10	.501	60	.165	10	.486
70	.159	20	.526	70	.164	20	.505	70	.168	20	.490
80	.158	30	.529	80	.165	30	.509	80	.171	30	.494
90	.158	40	.534	90	.166	40	.513	90	.175	40	.498
600	.158	950	.537	600	.167	950	.518	600	.179	950	.504
10	.155	60	.542	10	.167	60	.524	10	.181	60	.510
20	.154	70	.546	20	.166	70	.528	20	.183	70	.515
30	.153	80	.550	30	.167	80	.535	30	.184	80	.521
40	.148	90	.555	40	.163	90	.540	40	.184	90	.526
650	.140	1000	.560	650	.155	1000	.545	650	.179	1000	.534
60	.132	10	.563	60	.148	10	.553	60	.173	10	.539
70	.126	20	.569	70	.142	20	.558	70	.169	20	.545
80	.132	30	.573	80	.149	30	.562	80	.177	30	.550
90	.163	40	.576	90	.178	40	.565	90	.208	40	.555
700	.211	1050	.577	700	.220	1050	.569	700	.238	1050	.560
10	.260	60	.581	10	.261	60	.573	10	.270	60	.564
20	.307	70	.581	20	.302	70	.576	20	.300	70	.567
30	.346	80	.582	30	.334	80	.576	30	.323	80	.570
40	.373			40	.357			40	.348		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 19				Run Number 20				Run Number 21			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.059	750	0.393	400	0.055	750	0.415	400	0.058	750	0.420
10	.072	60	.409	10	.066	60	.431	10	.070	60	.436
20	.082	70	.422	20	.071	70	.442	20	.082	70	.446
30	.092	80	.433	30	.083	80	.454	30	.091	80	.455
40	.097	90	.443	40	.091	90	.464	40	.097	90	.463
450	.104	800	.452	450	.096	800	.471	450	.104	800	.470
60	.108	10	.461	60	.101	10	.480	60	.110	10	.476
70	.114	20	.467	70	.106	20	.487	70	.115	20	.484
80	.119	30	.474	80	.112	30	.493	80	.122	30	.489
90	.125	40	.480	90	.119	40	.499	90	.127	40	.495
500	.132	850	.486	500	.127	850	.506	500	.134	850	.501
10	.140	60	.492	10	.135	60	.510	10	.143	60	.506
20	.148	70	.497	20	.144	70	.515	20	.152	70	.511
30	.156	80	.502	30	.153	80	.520	30	.163	80	.515
40	.163	90	.505	40	.163	90	.522	40	.173	90	.518
550	.170	900	.509	550	.172	900	.526	550	.183	900	.522
60	.177	10	.512	60	.180	10	.530	60	.193	10	.524
70	.183	20	.517	70	.188	20	.533	70	.203	20	.528
80	.188	30	.520	80	.193	30	.536	80	.213	30	.532
90	.194	40	.524	90	.202	40	.539	90	.224	40	.535
600	.200	950	.528	600	.209	950	.543	600	.234	950	-
10	.205	60	.532	10	.215	60	.547	10	.252	60	-
20	.209	70	.537	20	.221	70	.549	20	.260	70	-
30	.213	80	.542	30	.225	80	.552	30	.265	80	-
40	.214	90	.547	40	.227	90	.556	40	.267	90	-
650	.210	1000	.551	650	.224	1000	.558	650	.267	1000	-
60	.206	10	.556	60	.220	10	.560	60	.267	10	-
70	.203	20	.557	70	.218	20	.564	70	.268	20	-
80	.211	30	.563	80	.222	30	.565	80	.278	30	-
90	.235	40	.567	90	.255	40	.566	90	.304	40	-
700	.270	1050	.568	700	.291	1050	.568	700	.331	1050	-
10	.302	60	.573	10	.323	60	.571	10	.354	60	-
20	.332	70	.572	20	.353	70	.572	20	.373	70	-
30	.359	80	.572	30	.380	80	.573	30	.394	80	-
40	.378			40	.400			40	.408		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 22				Run Number 23				Run Number 24			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.055	750	0.449	400	0.056	750	0.455	400	0.058	750	0.462
10	.068	60	.470	10	.067	60	.468	10	.068	60	.472
20	.080	70	.480	20	.078	70	.477	20	.078	70	.482
30	.089	80	.488	30	.086	80	.486	30	.086	80	.490
40	.096	90	.496	40	.092	90	.494	40	.092	90	.497
450	.100	800	.503	450	.097	800	.502	450	.097	800	.506
60	.107	10	.510	60	.104	10	.509	60	.102	10	.511
70	.112	20	.516	70	.108	20	.514	70	.107	20	.519
80	.118	30	.522	80	.114	30	.519	80	.113	30	.523
90	.125	40	.526	90	.120	40	.525	90	.118	40	.530
500	.132	850	.531	500	.128	850	.531	500	.125	850	.534
10	.142	60	.536	10	.135	60	.533	10	.133	60	.539
20	.151	70	.539	20	.146	70	.538	20	.143	70	.542
30	.163	80	.541	30	.157	80	.543	30	.154	80	.545
40	.175	90	.542	40	.169	90	.546	40	.165	90	.549
550	.187	900	.545	550	.181	900	.548	550	.178	900	.554
60	.198	10	.545	60	.193	10	.550	60	.191	10	.555
70	.210	20	.545	70	.206	20	.552	70	.203	20	.559
80	.223	30	.546	80	.219	30	.553	80	.216	30	.560
90	.236	40	.546	90	.232	40	.556	90	.230	40	.564
600	.248	950	-	600	.245	950	.556	600	.244	950	.565
10	.260	60	-	10	.257	60	.557	10	.257	60	.566
20	.272	70	-	20	.270	70	.555	20	.271	70	.567
30	.283	80	-	30	.281	80	.554	30	.284	80	.571
40	.290	90	-	40	.290	90	.555	40	.294	90	.572
650	.293	1000	-	650	.295	1000	.552	650	.300	1000	-
60	.294	10	-	60	.296	10	.550	60	.305	10	-
70	.297	20	-	70	.300	20	.549	70	.310	20	-
80	.311	30	-	80	.314	30	.533	80	.323	30	-
90	.337	40	-	90	.340	40	.528	90	.348	40	-
700	.364	1050	-	700	.367	1050	.512	700	.374	1050	-
10	.388	60	-	10	.391	60	.500	10	.397	60	-
20	.407	70	-	20	.411	70	.494	20	.418	70	-
30	.427	80	-	30	.430	80	.468	30	.436	80	-
40	.440			40	.444			40	.450		

White Oak Leaf
(Quercus alba L.)
KEPT DRY

Spectral Directional Reflectance, R_λ, Obtained From Measurements Made On A General Electric Recording Spectrophotometer (See Appendix A For Copies Of The Original Recording Sheets).

Run Number 25				Measured Leaf				Backing Leaf			
Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ	Wave Length mμ	R_λ
400	0.061	750	0.458	400	0.057	750	0.465	400	0.057	750	0.447
10	.072	60	.468	10	.068	60	.478	10	.076	60	.464
20	.081	70	.478	20	.078	70	.487	20	.093	70	.480
30	.088	80	.486	30	.085	80	.495	30	.107	80	.494
40	.095	90	.494	40	.091	90	.506	40	.116	90	.505
450	.100	800	.501	450	.097	800	.512	450	.121	800	.516
60	.105	10	.508	60	.100	10	.519	60	.127	10	.526
70	.109	20	.514	70	.105	20	.525	70	.131	20	.534
80	.115	30	.520	80	.110	30	.530	80	.136	30	.542
90	.121	40	.526	90	.116	40	.535	90	.143	40	.547
500	.127	850	.531	500	.123	850	.541	500	.150	850	.554
10	.135	60	.535	10	.130	60	.545	10	.159	60	.560
20	.144	70	.537	20	.140	70	.550	20	.168	70	.565
30	.156	80	.543	30	.150	80	.553	30	.177	80	.569
40	.168	90	.544	40	.163	90	.556	40	.184	90	.573
550	.180	900	.549	550	.178	900	.560	550	.192	900	.578
60	.193	10	.552	60	.188	10	.563	60	.198	10	.581
70	.205	20	.554	70	.201	20	.565	70	.201	20	.584
80	.218	30	.557	80	.216	30	.568	80	.204	30	.588
90	.232	40	.561	90	.228	40	.572	90	.205	40	.592
600	.246	950	.562	600	.245	950	.573	600	.207	950	.595
10	.260	60	.564	10	.259	60	.576	10	.206	60	.598
20	.274	70	.566	20	.272	70	.576	20	.206	70	.600
30	.287	80	.567	30	.285	80	.579	30	.207	80	.602
40	.297	90	.569	40	.297	90	.581	40	.203	90	.606
650	.304	1000	.571	650	.304	1000	.583	650	.193	1000	.609
60	.309	10	.573	60	.309	10	.585	60	.182	10	.610
70	.314	20	.575	70	.315	20	.588	70	.174	20	.616
80	.328	30	.577	80	.328	30	.590	80	.181	30	.617
90	.352	40	.579	90	.351	40	.591	90	.214	40	.621
700	.377	1050	.581	700	.378	1050	.596	700	.263	1050	.625
10	.398	60	.584	10	.400	60	.597	10	.313	60	.627
20	.416	70	.585	20	.420	70	.598	20	.360	70	.628
30	.433	80	.586	30	.440	80	.604	30	.395	80	.634
40	.447			40	.453			40	.425		

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

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