NATIONAL BUREAU OF STANDARDS REPORT

5184

COLOR RECONNAISSANCE STUDIES

(1952 - 1957)

By

Harry J. Keegan

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

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
0201-20-2325	December 1957	5184

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Harry J. Keegan
Photometry and Colorimetry Section
Optics and Metrology Division

To

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

Contract No. AF 33(616) 52-21
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Preface

This is the last of a series of NBS reports of spectrophotometric and colorimetric work done under NBS Project 0201-20-2325 entitled Color Reconnaissance Studies, financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; Air Force Contract No. AF 33 (616) 52-21. It was coordinated with Air Force Contract No. AF 33 (616)-262 under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland. It also was coordinated with some work on Cereal Crop Diseases of the National Research Council under Dr. Robert N. Colwell, University of California, Berkeley, California.

Harry J. Keegan
Project Leader

Color Reconnaissance Studies (1952 - 1957)

Harry J. Keegan

Abstract

A review of a color reconnaissance studies project at the National Bureau of Standards sponsored by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, between July 1952 and December 1957. This report is intended to serve a four-fold purpose: (1) A summary of the technical reports resulting from this investigation; (2) A bibliography of the subject of spectrophotometry and colorimetry applicable to aerial and ground photographic reconnaissance; (3) A listing of the requests for work made during the course of the project; and (4) A ready reference index to the quarter-year reports made of the progress of this five and one-half years color reconnaissance studies project.

Contents

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 particular report is a summary of the accomplishments of this color reconnaissance project which resulted in thirteen NBS technical reports, which are listed in the bibliography of this report [1 to 13] *, and four volumes of spectrophotometric curves on transparent plastic foil which may serve as a working set of curves of natural backgrounds and of object-targets for study over a "light-table" [14].

II. Color Contrast, NBS Reports 3773, 3774, and 4408

Three of the NBS reports issued to the Wright Air Development Center on these color reconnaissance studies project resulted from six work requests received from Dr. H. T. O'Neill on the subject of color contrast. These requests are WADC 2.1-16/53, -22/53, -24/53(A), -24/53(B), -29/53(A) and -39/53 included in Appendix A of this report. These reports are: NBS 3773 "Determination of color of maximum contrast", November 12, 1954 [1], NBS 3774 "The detection of objects from photographic transparencies", November 12, 1954 [2], and NBS 4408 "Chromaticities exhibiting maximal contrast", November 1955 [5]. These three reports consisting of a total of 24 pages and one illustration were prepared by Dr. D. B. Judd of the Photometry and Colorimetry Section of the National Bureau of Standards, and were bound in a single issue.

These three reports discuss the properties of color contrast as follows: 1. A formula for calculating for any given color whose chromaticity coordinates are known, the chromaticity coordinates of that color which will give the greatest visual contrast. 2. Are two such colors calculated according to this formula properly or conventionally called "complementary colors"? 3. A formula for calculating how much greater the contrast is between the darker complementary color and black than between its lighter complementary color and white. 4. Information on the difference between two systems of increasing the degree of contrast between an object and its immediate surrounding on a color transparency. 5. Which two hues give the greatest contrast visible to the eye; which the least contrast; and which chromaticity diagram to use to plot these differences in contrast.

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* Numbers in brackets refer to the bibliography on page 12 of this report.

III. NBS Report 4322, Spectrophotometric and Colorimetric Change in the Leaf of a White Oak Tree Under Conditions of Natural Drying and Excessive Moisture

This 104 page report entitled "Spectrophotometric and colorimetric change in the leaf of a white oak tree under conditions of natural drying and excessive moisture" by H. J. Keegan, J. C. Schleter, and W. A. Hall, Jr. [3], containing sixty illustrations and twenty-seven tables of data of a common natural background in an aerial scene, the leaf of a White Oak tree, was issued in September 1955. It resulted from a request for work from Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland. This work request 2.1 WADC-1/52 is included in Appendix A.

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. H. T. O'Neill requested the determination of 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 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 on a General Electric recording spectrophotometer for both the visible and near infrared spectrum, 400 to 1080 millimicrons. For the visible spectrum, 400 to 750 millimicrons, CIE chromaticity coordinates and daylight reflectances are reported as well as Munsell renotations, ISCC-NBS (Inter-Society Color Council - National Bureau of Standards) color designations, and color differences in NBS units based on the Godlove formula [15], 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.

IV. NBS Report 4370, Spectrophotometric and Colorimetric Study of Foliage Stored in Covered Metal Containers

This 113 page report entitled "Spectrophotometric and colorimetric study of foliage stored in covered metal containers" by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and Gladys M. Haas [4], containing thirty-nine illustrations and thirty-seven tables of data showing what happens to specimens in the type containers that naturalists all over the world use for transporting vegetation from one part of the world to another for study, was issued in November 1955.

The report resulted from a work request, 2.1 WADC - 3/52, from Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland, included in Appendix A of this report.

Measurements of spectral directional reflectance for the visible and near infrared spectral regions, 400 to 1080 millimicrons, were made on a General Electric recording spectrophotometer for the leaves of three species of trees (Beech, Dogwood, and White Oak), one shrub (Mountain Laurel), and one herb (Milkweed), stored in metal containers with tightly fitting metal covers for intervals of 17 hours to 12 days. From the spectral directional reflectance data of the visible spectral region, 400 to 750 millimicrons, were derived the CIE chromaticity coordinates, daylight reflectances, Munsell renotations, and color differences based on the Balinkin formula [16] . All of the other reports of this series were based on the Godlove formula of color difference as it was found that the Balinkin formula for small color difference was inadequate for use in the determination of large color differences.

This work was done to determine the color variations that occur in these representative types of foliage during storage and to predict, if possible, the color variations that may occur in similar and other types of foliage during periods of shipment in similar covered metal containers.

The practice of shipping and storing leaves in well capped metal containers for subsequent spectrophotometric study would appear from the results of this report to be satisfactory for tough leathery leaves, such as the Mountain Laurel, and also for storage of White Oak leaves for not more than two days; but it is unsatisfactory for Beech and Dogwood leaves. It is possible that the practice of dry shipment and storage of leaves should be supplanted by the practice of shipping them immersed in water.

V. NBS Report 4438, Spectrophotometric and Colorimetric Study of the Fading of Dyed Papers and Cardboards Under Natural Daylight

This 181 page report entitled "Spectrophotometric and colorimetric study of the fading of dyed papers and cardboards under natural daylight" by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and Gladys M. Haas, dated December 1955 [6] , contains 122 illustrations and 35 tables of data.

It resulted from work requests from Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland. These work requests were 2.1 WADC - 7/52 and -9/52. These requests are listed in Appendix A of this report.

In the study of color photographs, either taken on the ground or in the air, some indication of the control of the color reproduction must be maintained. Accordingly, in the beginning of these color reconnaissance studies, and possibly before that time, Dr. H. T. O'Neill purchased a quantity of each of 22 dyed papers and cardboards of this test for use as working standards of color to supplement other more accurate standards as a guide of "color registers" on the aerial color film.

A spectrophotometric and colorimetric study was made of the permanence of these color standards kept in dark storage and of the fading of these standards when exposed behind glass to natural North skylight and South sunlight for periods of two and of ten months. Measurements of spectral directional reflectance were made for the visible spectrum 400 to 750 milli-

microns on a General Electric recording spectrophotometer for each of these seven conditions of storage or of time of exposures. From these measurements there were derived CIE chromaticity coordinates, daylight reflectances, Munsell renotations, ISCC-NBS color designations, and color differences in NBS units. From this information, predictions may be made of the time change of these paper colors from the day that they are removed from dark storage to the day that they are discarded in the field as being unfit to serve as reference standards.

This study suggests that most dyed papers available commercially are sufficiently resistant to fading to serve as reference standards to obtain a register of color on a color photograph. It is recommended that railroad tag board should not be used for this purpose.

VI. NBS Report 4528, Spectrophotometric and Colorimetric Record of Some Leaves of Trees, Vegetation, and Soil

This 162 page report entitled "Spectrophotometric and colorimetric record of some leaves of trees, vegetation, and soil" by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., Gladys M. Haas, dated April 1956 [7] , contains 63 illustrations and 34 tables of data. The report resulted from five work requests from Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland: 2.1 WADC - 4/52(A), -4/52(B), -5/52, -8/52, -19/53, and -20/53. Copies of Dr. O'Neill's work requests are included in Appendix A of the present report. The reduction of the data published by Dr. E. L. Krinov, USSR, Academy of Sciences [24] , was made at the request of Dr. D. B. Judd.

Visible and near infrared measurements of spectral directional reflectance have been made, on a General Electric recording spectrophotometer for the spectral region 400 to 1080 millimicrons, of some selected leaves of deciduous trees from the Annapolis, Maryland, and the Washington, D. C. areas of the United States of America submitted by Dr. O'Neill, and from the Ottawa, Ontario, area of the Dominion of Canada submitted by Dr. J. M. Robinson, Department of Resource and Development, Ottawa, Ontario, Canada, in the late fall of 1952 and early spring of 1953. These recordings have been illustrated and tables of data are included as well as graphs and tables of CIE chromaticity coordinates, daylight reflectances, Munsell renotations and ISCC-NBS color designations. In addition, color differences determined in terms of the NBS unit of color difference have been made between the ventral and the dorsal sides of the same leaf specimens. Similar reductions are reported and illustrated for some natural formations in the USSR as reported in the literature.

VII. NBS Report 4544, Spectral Transmissive and Colorimetric Properties of Several Aerial and Hand Camera Lenses and Filters

This 163 page report entitled "Spectral transmissive and colorimetric properties of several aerial and hand camera lenses and filters", by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and G. M. Haas, dated October 1956 [8] , contains 69 illustrations and 28 tables of data.

It resulted from three work requests from Dr. H. T. O'Neill, O'Neill

Associates, Annapolis, Maryland: 2.1 WADC - 17/53(A), -17/53(B), and -17/53(C), for measurements of the hand camera lenses and filters, except for the two camera lenses from Mr. J. C. Schleter's camera. The work on the aerial camera lenses and filters was done at the request of Captain Robert J. Fisher, Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Copies of Dr. O'Neill's work requests are included in Appendix A of the present report.

Measurements of spectral transmittance have been made for the visible and near infrared spectral region 400 to 1080 millimicrons on a General Electric recording spectrophotometer at the National Bureau of Standards for three components of two aerial-camera lenses, five hand-camera lenses, one yellow anti-vignetting aerial camera filter, ten color temperature correcting hand camera filters, and thirteen selective absorbing hand camera filters. This report contains copies of the spectrophotometric curves of these photographic lenses and filters, tables and graphs of spectral transmittance and the CIE chromaticity coordinates and daylight transmittances derived from the visible spectral data; the Munsell renotations; ISCC-NBS color designations; and Lovibond notations of the lenses and filters and a comparison study of the conventional photographic color temperature correcting filters commercially recommended to be used for exposure of color film when the light source differs from that for which the film was manufactured.

VIII. NBS Report 4591, Spectrophotometric and Colorimetric Study of Diseased and Rust Resisting Cereal Crops

This 128 page report entitled "Spectrophotometric and colorimetric study of diseased and rust resisting cereal crops" by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and G. M. Haas, dated July 1956 [9] , contains 53 illustrations and 21 tables of data showing the visible and near infrared spectral directional reflectance of some healthy and of some diseased wheat plants inoculated either manually or infected naturally in the field. Also shown are the CIE chromaticity coordinates derived from the visible spectrum of these specimens, together with their Munsell renotations, ISCC-NBS color designations, and color differences between similar specimens.

This study involves the development of a method for the detection and for the evaluation of wheat rust and of other cereal crop diseases in the field by means of ground or aerial photography based on spectrophotometric and colorimetric analyses of specimens of healthy and diseased cereal crops. To develop this method, measurements of the visible and the near infrared spectral directional reflectance, or spectral transmittance, of thirty specimens of diseased and non-diseased cereal crop plants and of six specimens of rust were made on a General Electric recording spectrophotometer for the spectral range 400 to 1080 millimicrons. Three of these samples of rust were measured for spectral transmittance and three for spectral directional reflectance. All of the thirty specimens of diseased and rust resisting cereal crop plants were measured for spectral directional reflectance; fourteen specimens, of which nine were young wheat plants, two mature heads of wheat, and three young rye plants were grown in pots under controlled conditions at the Plant Industry Station, USDA, Beltsville,

Maryland; the remaining sixteen samples were the leaves, heads, and stalks of three species of wheat grown in the field at Stillwater, Oklahoma, and flown to Washington, D. C. for measurement at the National Bureau of Standards.

This report resulted from work that began before the formulation of the objective of the Air Force investigation, but which carried over beyond July 1, 1952 when the WADC financed NBS Color Reconnaissance Studies project began. In April 1952, the Committee on Plant and Crop Ecology of the National Research Council, Dr. E. F. Davis, Executive Secretary, invited a representative of the National Bureau of Standards to attend a conference to assist in the development of methods for the detection of wheat rust in a field of growing wheat. With the approval of the Director of the National Bureau of Standards, arrangements were made to perform preliminary spectrophotometric determinations on controlled specimens of rust-resisting young wheat plants and susceptible young wheat plants that had been manually inoculated with wheat rust. The results of these initial determinations appeared promising and further preliminary investigations were made resulting in the recommendations of the present method. The pertinent events leading to this investigation are listed in chronological order in Appendix B of this report. In 1954, the Air Force became interested in these studies and the preparation of NBS Report 4591 was made possible by their support of this work.

Two companion reports on the aerial photographs of the wheat fields by the use of the film-filter method developed in this report are given by Keith [17] , and by Colwell [18] .

IX. NBS Report 4794, Spectrophotometric and Colorimetric Study of Color Transparencies of Some Natural Objects

This 139 page report entitled "Spectrophotometric and colorimetric study of color transparencies of some natural objects" by H. J. Keegan, J. C. Schleter, G. M. Haas, and W. A. Hall, Jr., dated March 1957 [10] , contains 52 illustrations and 39 pages of tables of data. It resulted from six work requests from Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland: 2.1 WADC - 23/53, -28/53(A), -28/53(B), -31/54, -35/55, and -42/55. Copies of these work requests are included in Appendix A of the present report.

This report compares the effects that exposures to natural formations or objects have upon the various emulsion layers that comprise color positive and color negative photographic films. Spectral transmittance measurements and colorimetric computations are made and reported on these effects. In addition, visible and near infrared spectral directional reflectance measurements are reported for one of these photographed natural objects; namely sand, together with several other soils, sands, and barks of trees. The spectrophotometric data, obtained on a General Electric recording spectrophotometer for the visible spectral region, 400 to 750 millimicrons, or the visible and near infrared spectral regions, 400 to 1080 millimicrons, are reported and illustrated for these objects and color transparencies, together with the CIE chromaticity coordinates, Munsell renotations, daylight reflectances or daylight transmittances, ISCC-NBS color designations, Lovibond notations, and color differences between wet and dry sand and their corresponding color transparencies.

X. NBS Report 4953, Spectrophotometric and Colorimetric Study of Color Transparencies of Some Man-Made Objects

This 251 page report entitled "Spectrophotometric and colorimetric study of color transparencies of some man-made objects" by H. J. Keegan, J. C. Schleter, G. M. Haas, and W. A. Hall, Jr., dated November 1957 [11] , contains 100 illustrations and 70 pages of tables of data. It resulted from ten work requests from Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland: 2.1 WADC - 6/52, -28/53(A), -28/53(B), -31/54, -32/54, -33/54, -34/55(A), -34/55(B), -36/55, and -37/55. Copies of these work requests are included in Appendix A of the present report.

The effects that a few man-made reflecting objects have upon the various emulsion layers that comprise color positive photographic films, when these films are exposed to the objects, are described. Spectral transmittance measurements and colorimetric computations are made and reported on these effects as well as spectral directional reflectance measurements and colorimetric computations for the objects; namely a U. S. Army shirt and several dyed papers and cardboards. The spectrophotometric data, obtained on a General Electric recording spectrophotometer for the visible spectral region, 400 to 750 millimicrons, or the visible and near infrared spectral regions, 400 to 1080 millimicrons, are reported and illustrated for these materials, their transparencies, a number of other transmitting and reflecting materials, and some color transparencies of other objects, together with the CIE chromaticity coordinates, Munsell renotations, daylight reflectances or daylight transmittances, ISCC-NBS color designations, and Lovibond notations. Color differences between the dyed papers and cardboards and the color transparencies of the dyed papers and cardboards and between the U. S. Army shirt and color transparencies of the U. S. Army shirt are reported and illustrated.

XI. NBS Report 5183, An Index to Spectrophotometric Curves of Color Reconnaissance Project

This 58 page report entitled "An index to spectrophotometric curves of color reconnaissance project" by H. J. Keegan and J. C. Schleter, dated December 1957 [12] , comprises 11 illustrations and 29 pages of tables of sample description and cross reference tables to spectrophotometric graph sheets of all of the specimens studied during the five and one-half years of this color reconnaissance studies project.

This index pertains to the data on the 250 spectrophotometric curve sheets of the 717 specimens studied. Its main purpose is to serve as a guide in the location and use of a collection of spectrophotometric curves contained in nine of the thirteen reports issued to the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, on this color reconnaissance studies project. There are spectrophotometric curves of 104 color transparencies of man-made objects, 85 color transparencies of natural objects, 290 man-made objects, and 238 natural objects. The data on each of these samples have been previously reported in its original form except for eleven spectrophotometric graph sheets including seven German photographic filters which were considered important enough to be included in this spectrophotometric summary.

This report resulted from two work requests of Dr. H. T. O'Neill, O'Neill Associates, Annapolis, Maryland: 2.1 WADC - 10/53 and -17/53(B). The additional samples included in this report that had not been previously reported were requested by (1) Dr. R. N. Colwell for the glass filters and the rock and soil samples; (2) Mr. F. G. Jacocks for the German and the Russian camera lenses; (3) Dr. D. B. Judd for the Göttinger Farbfilters (Muster-Schmidt K.G., Göttingen, West Germany); and (4) Dr. H. T. O'Neill for the curves of photopic and scotopic vision.

XII. Working Set of Spectrophotometric Curves

This set of four volumes of 250 graph sheets of spectrophotometric curves on 11 x 15 inch transparent plastic foil and on opaque paper, together with 33 pages of identification tables of all of the measurements made on this color reconnaissance studies project, comprises Appendix B of NBS Report 5183 entitled "An index to spectrophotometric curves of color reconnaissance project" by H. J. Keegan and J. C. Schleter. Each of the four 11-1/2 x 16-1/2 inch black loose-leaf binders are engraved "Spectrophotometric curves of color reconnaissance project", and either "Volume I, II, III, or IV" [13] .

The desired spectrophotometric curves on a continuous wavelength scale from 400 to 1080 millimicrons reproduced either on opaque paper or on transparent plastic acetate foil may be removed from the loose leaf three ring binder, used over a light table with other papers or films, and refiled in their proper place by means of identifiable volume and page reference numbers. An index of these reference numbers as well as a reference index according to the GE graph sheet serial number are contained in Volume I of the working set of spectrophotometric curves. Only ten sets of these working volumes of graphs were prepared. Information on the distribution of these volumes and of the NBS reports referred to in this report may be obtained from the Aerial Reconnaissance Laboratory, Attn: WCLRD-1, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

XIII. Summary

In the five and one-half years duration of a color reconnaissance studies project financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, sixty-three requests for spectrophotometric and colorimetric work were made to the Spectrophotometry Unit of the Photometry and Colorimetry Section, Optics and Metrology Division, National Bureau of Standards. Fifty-eight of these requests were received from Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, under a coordinated WADC contract; two requests were received directly from WADC; one request from the National Research Council; one from the University of California; and one request from the National Bureau of Standards. All of these requests have been fulfilled, completely or in part, except seven requests on which for one reason or another, no measurements were made. Dr. O'Neill's work requests form Appendix A of this report, and the chronology of the events of the NRC request form Appendix B.

Nineteen progress reports were prepared and issued to WADC, Dr. O'Neill, and Dr. F. W. H. Mueller, Director of Research, General Aniline and Film Corporation, Binghamton, N. Y., who supplied Dr. O'Neill with all of the experimental film that was used to photograph the natural and man-made objects of this investigation. An index to these progress reports and minutes of meetings are included in Appendix C of this report.

As a result of these requests, thirteen NBS reports were prepared and issued together with four volumes of all of the spectrophotometric curves obtained and reported for this color reconnaissance studies project. Three of the reports were on color contrast; eight of them on the spectrophotometry and colorimetry of objects; one was on the spectrophotometric curves; and the present one serves as a summary of the entire project.

During this period, an analog curve computer was developed and built under a separate WADC contract, by the Ansco Division of the General Aniline and Film Corporation, Binghamton, N. Y., for the electronic reduction of the spectrophotometric curves of this investigation into colorimetric terms by means of mathematical integration. Unfortunately, this instrument was delivered to the National Bureau of Standards, Washington, D. C., after the thousands of computations of this investigation had been manually made with a desk computer and graphically checked. Also during this period of these color reconnaissance studies project, two reports were issued to WADC by Dr. H. T. O'Neill [19] and [20] , and three papers were published by him, two of them with Mr. Wm. J. Nagel of Ansco [21] , [22] , and [23] , on subjects of techniques or apparatus resulting from contracts coordinated with this color reconnaissance studies project.

In conclusion, this color reconnaissance studies project has resulted in a basic spectrophotometric study on certain natural and man-made objects; on color transparencies of some of these natural and man-made objects on one-, two-, and three-emulsion films that comprise commercially available color film; on some aspects that comprise the photography of a scene, including some American, German, and Russian camera lenses, and some photographic filters and color-temperature conversion filters; on diseased and rust-resisting cereal crops; and on some targets. This basic spectrophotometric study when combined with the work of Krinov [24] , the annotated bibliography on photo-interpretation issued by the Library of Congress [25] , and several papers of Colwell [18] and [26] , Truesdell [27] , and others [28] , and [29] , should prove to serve as a fundamental base of operation for future investigators to proceed in their quest for the solution of other problems similar, possibly, to some of the unanswered questions that will be noted in some of the requests listed in Appendix A of this report; such as, (1) Measurements of natural formations in the ultraviolet region of the spectrum, 186 to 400 millimicrons; (2) Gloss measurements of natural formations; (3) Color fidelity studies of photographs of natural objects; (4) Measurements of ice, snow, smoke, and other phases of water and particles; (5) Measurements on photographs for contrast of object and background; (6) Measurements on the causes of the death of a tree leaf by Cicada, blight, wood smoke, grading by heavy machinery, and so forth; (7) Spectrophotometric measurements on dying or dead tree leaves stored between blotters, with and without heat; (8) Similar spectrophotometric

measurements on autumn tree leaves stored as in (7) above; (9) Measurements on targets of fluorescent materials; (10) Measurements on photographs made on x-ray, orthochromatic, panchromatic, infrared, and color films of objects taken from the air; (11) Studies of spectrophotometric measurements made in the visible spectrum, 400 to 750 millimicrons, converted to colorimetric terms by integration on the Ansco analog curve computer; and (12) Measurements on the degree of contrast of objects and backgrounds.

There probably are many, many more problems that could be benefited from these color reconnaissance studies; these are a few that were presented by Dr. H. T. O'Neill during the course of this investigation for which no answers were given.

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XIV. Bibliography

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[5] D. B. Judd. Chromaticities exhibiting maximal contrast. NBS Report 4408 to WADC, November 1955.

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[8] H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and G. M. Haas. Spectral transmissive and colorimetric properties of several aerial and hand camera lenses and filters. NBS Report 4544 to WADC, October 1956.

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(Note: The following references pertain to the index and the remarks following Dr. H. T. O'Neill's work requests in Appendix A of this report.)

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Appendix A. Work Requests

Copies of the work requests received from Dr. Hugh T. O'Neill during the course of these Color Reconnaissance Studies project. When reports were issued on the requests, the report numbers are listed together with reference numbers to the bibliography of this report. This collection will serve to follow the reasoning behind some of the requests, to indicate how some of the requests are linked together, and to show that this project is terminated before all of the questions have been studied regarding color aerial photoreconnaissance. The index to these work requests contains the given serial number, the date of the request, the NBS Report and the literature reference numbers, and a letter symbol indicating the status of the request: whether it was completed (C), partially completed (P), or that no measurements were made (N).

Index to Dr. H. T. O'Neill's Work Requests

Serial Number 2.1 WADC	Date of Request	NBS Report No. or Comment	Ref. No.	Status
-1/52	September 1952	4322	[3]	(C)
-2/52	" "	(No measurements)	--	(N)
-3/52	" "	4370	[4]	(C)
-4/52-(A)	October 1952	4528	[7]	(P)
-4/52-(B)	" "	4528	[7]	(P)
-5/52	" "	4528	[7]	(P)
-6/52	" "	4953	[11]	(C)
-7/52	" "	4438	[6]	(C)
-8/52	November 1952	4528	[7]	(C)
-9/53	February 1953	4438	[6]	(C)
-10/53	March 1953	5183	[12]	(P)
-11/53	" "	(RP 2505)	[30]	(P)
-12/53	" "	(No measurements)	--	(N)
-13/53	" "	(No measurements)	--	(N)
-14/53	" "	2254	[31]	(P)
-15/53	April 1953	(Oral information)	--	(P)
-16/53	" "	3774	[2]	(C)
-17/53-(A)	" "	4544	[8]	(C)
-17/53-(B)	July 1953	4544	[8]	(C)
" "	" "	5183, Appendix B	[13]	(C)
-17/53-(C)	February 1954	4544	[8]	(C)
-18/53	April 1953	(Oral information)	--	(P)
-19/53	" "	4528	[7]	(C)
-20/53	May 1953	4528	[7]	(C)
-21/53	June 1953	(No measurements)	--	(N)
-22/53	" "	3774	[2]	(C)
-23/53	" "	4794	[10]	(C)
-24/53-(A)	" "	3773	[1]	(C)
-24/53-(B)	November 1954	4408	[5]	(C)
-25/53	June 1953	(No measurements)	--	(N)
-26/53	" "	(No measurements)	--	(N)
-27/53	" "	(No measurements)	--	(N)
-28/53-(A)	July 1953	4794	[10]	(C)
" "	" "	4953	[11]	(C)
-28/53-(B)	" "	4794	[10]	(C)

Index to Work Requests (continued)

Serial Number 2.1 WADC	Date of Request	NBS Report No. or Comment	Ref. No.	Status
-28/53-(B)	July 1953	4953	[11]	(C)
-29/53-(A)	September 1953	3773	[1]	(P)
" "	" "	3774	[2]	(P)
" "	" "	4408	[5]	(P)
-29/53-(B)	July 1953	(No measurements)	--	(N)
-30/53	September 1953	(NRC-NBS Infrared cards)	[32]	(C)
-31/54	February 1954	4794	[10]	(P)
"	" "	4953	[11]	(C)
-32/54	" "	4953	[11]	(C)
-33/54	September 1954	4953	[11]	(C)
-34/55-(A)	July 1953	4953	[11]	(C)
"	" "	5183, Appendix B	[13]	(C)
-34/55-(B)	" "	4953	[11]	(C)
-35/55	April 1955	4794	[10]	(C)
-36/55	" "	4953	[11]	(C)
-37/55	June 1955	4953	[11]	(C)
-38/55	" "	(Oral information)	--	(C)
-39/55	November 1955	3774	[2]	(C)
"	" "	(Letter of Nov. 14, 1955)	--	(C)
-40/55	" "	(" " " " ")	[33]	(C)
"	" "	(" " " " ")	[34]	(C)
-41/55	" "	(Letter of Nov. 23, 1955)	[20]	(C)
-42/55	March 1956	4794	[10]	(C)

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Copies of the fifty-eight work requests received from Dr. Hugh T. O'Neill during the course of these Color Reconnaissance Studies Project. Following each request is a statement of the report or publication that either resulted from the request or from which information on the request may be obtained. If no information was available or if no measurements could be made at that time, it is so stated.

* * * * *

Request Number 2.1 WADC - 1/52 September 24, 1952

"To determine the spectrophotometric change in white oak leaves under conditions of natural drying and excessive moisture. One set of leaves remains immersed in water at all times, the other set is allowed to dry at room temperature and humidity. Spectrophotometric measurements are made weekly to determine the change."

(Result.....NBS Report 4322, September 1955 [3].)

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Request Number 2.1 WADC - 2/52 September 25, 1952

"Spectrophotometric study of ice and snow."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 3/52 September 29, 1952

"To determine the suitability of air-tight metal containers for collecting foliage for subsequent spectrophotometric determinations. How much does sunlight change the color of leaves in contrast to leaves of the same species kept in the shade or in complete darkness?"

"The metal container was a five gallon metal can, lines with tin, the air inside it was evidently approximately saturated as shown by the moisture condensing on the top."

"Incidental information to be obtained is: Do thick leathery leaves (coriaceous) and thin (membranous) leaves go through different color changes in dying when kept in such a metal container? Is the rate of change the same or different for different types of leaves? Do leaves which show incipient coloring (beech) or leaves which show advanced fall coloration change at the same rate and in the same stages as green leaves which have not yet shown visible fall coloration (white oak) or evergreen leaves (laurel)?"

(Result.....NBS Report 4370, November 1955 [4].)

* * * * *

Request Number 2.1 WADC - 4/52 (A) October 15, 1952

"Spectrophotometric measurements of leaves of Mockernut Hickory, Beech, Dogwood, White Oak, and Black Oak. These leaves have been photographed with Ansco color film tricolor, magenta only, and cyan only. Photographs of the leaves will be spectrophotometered when processed."

(Result.....The data on the leaves of the trees were included along with those of other trees in NBS Report 4528, April 1956 [7]. The images of the photographed leaves of trees were too small to measure conveniently and were returned to Dr. O'Neill.)

* * * * *

Request Number 2.1 WADC - 4/52 (B) October 16, 1952

"Determine spectrophotometric curves of leaves to match with or compare with color fidelity and gray tones of the same leaves as registered on Ansco, Magenta, and Cyan by overcast skylight:

1. Green white oak leaves (Quercus alba L.) cf. exposures 83, 84, and 85, i.e. as registered on tricolor, magenta, and cyan films.

2. Red dogwood leaves (Cornus florida L.) cf. exposures 86, 87, and 88.

3. Brown glossy black oak leaves (Quercus velutina Lam.) typical of thick, deciduous, coriaceous leaves when browned cf. exposures 89, 90, and 91.

4. Bright yellow hickory leaves (Carya tomentosa (Lam.) Nutt.) cf. exposures 92, 93, and 94.

5. Russet beech leaves (Fagus grandifolia Ehrh.) cf. exposures 95, 96, and 97."

"To enable us to set up a standard objective procedure for judging films for intelligence and reconnaissance. One factor and a fundamental factor is color fidelity. The series of photographs mentioned above 83 - 97 shows the field entirely taken up by a single or a very few leaves of as uniform a color as could be found at this time. The curve of each leaf can then be compared with that curve shown on the film. Preceding this set of photographs are numbers 50 to 82 which also shows the performance of the same films on this cloudy day when registering our standard color patches."

(Result.....The data on the leaves of the trees were included with those of other trees in NBS Report 4528, April 1956 [7]. The images of the photographed leaves of trees were too small to measure conveniently and were returned to Dr. O'Neill.)

* * * * *

Request Number 2.1 WADC - 5/52 October 17, 1952

"Determine spectrophotometric curves of Red Dogwood leaves corresponding

to photographs 131 tricolor, 132 magenta in emulsion, and 133 cyan in emulsion, taken in direct sunlight at 8-inch focus so as to show only the leaves in the entire field. Similarly yellow hickory leaves in the same series comparable in every detail Nos. 134, 135, and 136. Also green white oak leaves photographed on exposures 137, 138, and 139. Also reddish white oak leaves photographed on exposures 140, 141, and 142. Also brown glossy black oak leaves photographed on exposures 143, 144, and 145. These are the leaves actually photographed so that this affords a means of testing color fidelity on Ansco Daylight (tricolor or three-dye) emulsion, and special emulsion with magenta only and special emulsion with cyan only."

"This will enable us not only to check or estimate color fidelity as to leaves but also by comparison with photographs, of the series 98 to 132 to fit in with data on the color patches set up as standards for judging any future films to be tested in this or any other similar research. Yesterday's studies enable the whole series to be compared with similar series made with overcast sky. In this way comparisons as to effect of skylight and of sunlight can be made at numerous points. A table showing all the data of the films, etc. will be supplied separately as soon as the films have been processed."

(Result.....The data on the leaves of the trees were included with those of other trees in NBS Report 4528, April 1956 [7] . The images of the photographed leaves of trees were too small to measure conveniently and were returned to Dr. O'Neill.)

* * * * *

Request Number 2.1 WADC - 6/52 October 14, 1952

"Determine color fidelity as well as other characteristics of set of photographs numbers 1 to 45, showing the performance on a clear cloudless day with only very moderate haze, of Ansco tricolor film, magenta film, cyan film, and Ansco Supreme with and without filters. Pictures were taken on October 13, 1952, processing to be done as soon as possible by Mr. Wm. Nagel of Ansco (probably done within a few days of date). This series is to be studied along with the two succeeding requests which should be consulted in this connection."

(Result.....NBS Report 4953, November 1957 [11] .)

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Request Number 2.1 WADC - 7/52 October 28, 1952

"Determine the reflectance curve spectrophotometrically and the Munsell Scale reading and give the correct name according to some of the most widely used terminology for each of the samples submitted:

6 differently colored onion skin paper all of the same weight.
4 differently colored bond (13 lb) paper.
7 differently colored mimeo bond paper.
5 differently colored Railroad Tag Board (6 ply)."

"It is requested in so far as feasible that samples of each be stored in darkness, in diffused daylight and in sunlight so that information as to the fading of these colors can be obtained over periods of a half year or similar appropriate periods. Spectrophotometric curves are also requested for the transmittance of the paper samples if this is feasible."

"A quantity of each of the above colored papers has been bought and will be used in various ways as rough color standards along with other more accurate color standards when such is possible. The railroad board is to be used to lay flat on the ground in strips 12 to 24 feet long in order to see how such a color registers on aerial color film. Various other uses in photo-interpretation are planned for these colored papers."

(Result.....NBS Report 4438, December 1955 [6].)

* * * * *

Request Number 2.1 WADC - 8/52 November 3, 1952

"Spectrophotometric study (400 to 1080 millimicrons) of colored leaves."

"These leaves are the "last leaves of Autumn" and were picked after there was a killing frost."

(Result.....NBS Report 4528, April 1956 [7].)

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Request Number 2.1 WADC - 9/53 February 4, 1953

"This is the permanence study of the papers exposed to North skylight and to South sunlight and daylight of 7 weeks and for 42 weeks."

"Permanence study of 22 colored papers of 2.1 WADC - 7/52."

(Result.....NBS Report 4438, December 1955 [6].)

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Request Number 2.1 WADC - 10/53 March 27, 1953

"Reproduce on Ozachrome film the spectrophotometric curves 400 to 750 millimicrons of all Corning glass filters. Also the near infrared and ultraviolet spectral transmittance of these glasses, if available."

"Look into the possibility of having the spectrophotometric curves of Wratten filters reproduced. Also other sets of glass filters such as those of Kopp Glass, Houze, Bausch and Lomb, Chance (England) and Jena (West Germany)."

(Result.....All of the Corning glasses were reproduced by Dr. Alan Werner (Corning Glass Works, Corning, N. Y.) on Lithofoil plastic intermediate film; however, they were overexposed and could not be reproduced

again. None of the other sets of glasses or filters were measured, except the Göttinger, West Germany, photographic filters. NBS Report 5183, December 1957 [12] .)

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Request Number 2.1 WADC - 11/53 March 27, 1953

"Spectrophotometric curves of transparent materials; such as optical glass, commercial glass, plastics and gelatins."

"These transparent materials are for use as viewing screens on light-table."

(Result.....The optical glass properties were reported in Research Paper 2505, J. Research NBS 52, 305; 1954 [30] .)

* * * * *

Request Number 2.1 WADC - 12/53 March 27, 1953

"Spectrophotometric curves of 2-1/4 inch squares of photographs of commonest backgrounds on color aerial vertical films; White (snow and ice), Green and Brown (vegetation and soil), Gray (smoke and vapors), and possibly others."

"For purpose of determining contrasts of object and backgrounds."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 13/53 March 27, 1953

"Goniophotometric curves of the leaves of magnolia, Japanese cane, Norway maple, and others with glossy, semi-matte, and matte surfaces."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 14/53 March 27, 1953

"Information of spectral properties of light sources, daylight, sunlight, incandescent lamps, fluorescent lamps, carbon arcs, photo-flash lamps, and others."

"Does anyone know of the spectral properties as well as the photometric properties of lights reflected from low clouds at night."

(Result.....NBS Report 2254, February 1953 [31] .)

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Request Number 2.1 WADC - 15/53 April 20, 1953

"Information, advice, literature references, and reprints on the performance of fluorescent, incandescent, and Geisler-principle lamps (e.g. Neon lights) as to the candlepower of any light units, the laws involved and any information of use in building a "light" or "viewing-table" for purposes of photo-intelligence and photo-reconnaissance."

(Result.....Oral information given by Mr. R. P. Teele to Dr. H. T. O'Neill.)

* * * * *

Request Number 2.1 WADC - 16/53 April 20, 1953

"A discussion of the difference between the results obtained by studying color transparencies: a) by means of filters attached to a frame, such as a spectacle frame, and therefore held between the eye and the transparency, and b) by means of a filter placed between the source of light and the transparency."

(Result.....NBS Report 3774, November 1954 [2] .)

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Request Number 2.1 WADC - 17/53 (A) April 20, 1953

"Spectrophotometric curves of filters, lens, etc., for use with Hasselblad, Karomat, Speedex, Viking, and other camera accessories."

(Result.....NBS Report 4544, October 1956 [8] .)

* * * * *

Request Number 2.1 WADC - 17/53 (B) July 13, 1953

"Spectrophotometric curves of the filters accompanying Fr. Dutilly's Hasselblad camera on clear Ozachrome cellulose acetate. These filters are: UV16, UV17, Aero 2 (yellow), Wratten A (red), Green B, Green N, and Blue C-5. Also on Ozachrome cellulose acetate clear, a considerable number of spectrophotometric curves which you have already determined and which are of sufficient importance to justify making duplicates on this transparent medium for the purpose of comparison on a light-table."

"This request may be considered as duplicating a previous request. It is sent to make clearer what we need, if such clarification is necessary. If not, this request should be destroyed."

(Result.....NBS Report 4544, October 1956, and NBS Report 5183 Appendix B, December 1957 [13] .)

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Request Number 2.1 WADC - 17/53 (C) February 25, 1954

"Please determine the spectrophotometric curves of the following filters which will be used in experimental photography for WADC in the near future: Two conversion filters No. 10 Ansco, Series V and VI; and two conversion filters No. 11 Ansco, Series V and VI. These are herewith. They are for using Ansco Color Daylight film in tungsten-light illumination and Ansco Color tungsten-light film used in daylight. As these conversion filters differ very notably, even to the eye, from similar conversion filters for Eastman's Kodachrome, we also wish to have similarly studied the Kodak conversion filters which we will deliver next week but in size Series VI only. It is believed the curves resulting from these studies will enable us to understand the different results obtained when using the two corresponding films, at least to some extent."

(Result.....NBS Report 4544, October 1956 [8] .)

* * * * *

Request Number 2.1 WADC - 18/53 April 20, 1953

"Information, advice, literature references and reprints on the different kind of lamps for use in building a light or viewing table for purposes of photo-intelligence and photo-reconnaissance. Published spectro-radiometric curves of various phosphorescent tubes, line sources and emission spectra."

(Result.....Oral information.)

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Request Number 2.1 WADC - 19/53 April 22, 1953

"Spectrophotometric study of Spring red leaves. Measure the spectral directional reflectance of leaves of Spanish Hazelnut and Purpleleaf Plum (including 'green sport' and intermediate leaves of the Hazelnut)."

(Result.....NBS Report 4528, April 1956 [7] .)

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Request Number 2.1 WADC - 20/53 May 14, 1953

"Study of early foliage in the subarctic deciduous forest, also dead overwintered leaves on the ground."

(Result.....This request was followed by four pages of descriptive data on two shipments of leaves of trees from Canada. See Appendix F, NBS Report 4528, April 1956 [7] .)

* * * * *

Request Number 2.1 WADC - 21/53 June 11, 1953

"Photographs of foliage, killed by the 17 year cicada, by wood smoke, by chestnut blight, by grading with heavy machinery at the roots of a tree which slowly killed it so that the leaves turned color in June, etc., have been taken with black and white and color film. Similar pictures will be taken with some of special one-color and two-color sensitive film just received from the Ansco Company. This is in an effort to determine in an exploratory way, if there is any possibility of determining what kind of injury causes the death of the leaf."

"We are therefore requesting that as soon as convenient, spectrophotometric curves be made on leaves killed in various ways. These leaves will be supplied with data on notification when it is feasible to make these curves."

"Obviously, it is of importance in forestry, agriculture, military reconnaissance to be able to decide what caused the browning of the leaves of a dying tree. It is the purpose of this study to determine if there is any reasonable hope of differentiating the type of death of the tree on the basis of the color change as shown by the spectrophotometric curves."

"This leads to the further request for information as to how much of a difference of chromaticity is it feasible to detect a) by eye alone, and b) by color film. Any general statement on this subject, together with any literature references will be gratefully acknowledged."

"To facilitate further answering of requests like this, the project-director proposes to file with the Bureau of Standards, a list of his books and cards in this field."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 22/53 June 12, 1953

"Information in the shape of a short report or memorandum discussing the difference between the two following systems of increasing the degree of contrast between an object and its immediate surroundings on a color transparency: System No. 1. Eye, Colored filter, Color film, Source of light. System No. 2. Eye, Color film, Colored filter, Source of light. In system No. 1, the eye adjusts itself gradually to a certain degree at least and thus the contrast becomes less sharp. Any summary and literature references pertinent to this topic will be appreciated."

"Mr. Wm. Nagel and the writer are now building an illuminating table where this information will be of use in designing it, as well as planning its method of use."

"In this connection reprint No. 40 of "Object-Color Changes from Daylight to Incandescent Filament Illumination" by Helson, Judd, and Warren, given to the writer by Mr. Keegan last week was very much apropos and seems

sure to be dealing with a phenomenon which must be closely analogous with the problem stated above."

(Result.....NBS Report 3774, November 1954 [2] .)

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Request Number 2.1 WADC - 23/53 June 13, 1953

"Information on the effect on the color of soil, subsoils, and rocks of wetting. The color of soils, subsoils, and rocks is generally much darker while wet than when dry. Changes in hue, chromaticity, etc., also occur. An example is the marble of the Lincoln Memorial which turns distinctly green to the eye when wet. Is this caused by what? What spectrophotometric data is available for this phenomenon? Colors of subsoils, wet and dry, are important in the detection of fox-holes, excavations, etc., on color film. Eocene and other soils in our area resulting from weathering of glauconite (ferrous potassium silicate) turn from dull greenish to a rich raw umber. Some of the Patuxent gravels turn to rich burnt umber, others are various shades of ochre."

(Result.....NBS Report 4794, March 1957 [10] .)

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Request Number 2.1 WADC - 24/53 (A) June 15, 1953

"Information (if and in so far as it exists): 1) A formula for calculating for any given color whose chromaticity coordinates are known, the chromaticity coordinates of that color which will give the greatest contrast to the eye (including non-spectral colors?). 2) Are two such colors calculated according to this formula properly or conventionally called "complementary colors"? 3) A formula for calculating how much greater is the contrast between the darker complementary color and black than with its lighter complementary color. Also the same for the darker complementary color and white."

(Result.....NBS Report 3773, November 1954 [1] .)

* * * * *

Request Number 2.1 WADC - 24/53 (B) November 16, 1954

"Which two hues will give the greatest contrast visible to the eye? Which will give the least contrast, and is there any table, chart, graph published, or unpublished, which would give this information in terms of the CIE chromaticity diagram? Could we have a large scale copy of such a diagram showing areas of color contrast?"

(Result.....NBS Report 4408, November 1955 [5] .)

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Request Number 2.1 WADC - 25/53 June 16, 1953

"Previous spectrophotometric curves made to determine the feasibility of keeping green leaves relatively unchanged by various means and thus determining definitely practical means of shipping vegetation without significant change. These studies have shown that shipment in an air-tight container (can) is satisfactory and that over a period of several days such leaves change only slightly, in so far as their spectrophotometric curve of the chlorophyll A and B are concerned."

"From his thirty years' experience, the writer believes that samples of leaves that are dying or dead can be dried in the conventional way between blotters, with or without heat and that such browned leaves are quite stable. Hence he wishes to have spectrophotometric curves made of undried brown leaves and as well of dried brown leaves under approximate regulation of the factors such as time and temperature; e.g. the author wishes to ascertain what if any change takes place in the chromaticity of leaves killed by the 17 year cicada when picked fresh from the tree, when such a leaf is dried between blotters and studied after 8 hours drying and then after long periods of time in storage in darkness and in light. The permanency of pigments of plants when dried and kept in the dark is astonishing; e.g. Schweinfurth's experiments in 1890 (?) on leaves and flowers taken from the Egyptian sarcophagi after 3000 years showed an amazing permanency of purple pigment of Delphinium (larkspur)."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 26/53 June 23, 1953

"Spectrophotometric curves of leaves sent herewith in order to determine the possibility of collecting leaves in the conventional manner of taxonomists and pressing and drying them and storing in the dark and using such leaves, particularly autumn leaves as a permanent record (for at least several years) and in order to obviate the expensive method of shipping in air tight containers. Submitted herewith are leaves of the scarlet oak (red) (Quercus coccinnea Wang.) which have been kept under average herbarium conditions from November 1952 to June 1953. These leaves are part of the same batch, collected from the same tree of leaves submitted in the fresh condition to the Bureau of Standards and of which spectrophotometric curves have been made. This should enable inferences to be made as to the suitability of collecting and preserving in this manner, leaves for spectrophotometric study without the necessity of immediately measuring their reflectance, now thought to be necessary but believed to be unnecessary by us. Submitted at the same time are a few other leaves of other trees with colors having a more or less special significance in this study."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 27/53 June 22, 1953

"Information, references, and any readily available bibliography on the 'Spectrophotometry or Fluorescent Pigments'. May we borrow or have a photostat of a paper with this title given by R. Donaldson, National Physical Laboratory, at the Imperial College, South Kensington, London SW 7, and mentioned on page 1, Inter-Society Color Council Newsletter, No. 105, March 1953. Also the names of two or more companies manufacturing fluorescent paints, is requested. Information is needed in connection with the projectiles photographed at Dahlgren for us on special films made by Ansco for our WADC project. All the projectiles photographed were coated with fluorescent paint."

(Result.....No measurements made.)

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Request Number 2.1 WADC - 28/53 (A) July 17, 1953

"Please make spectrophotometric curves for several hundred 2-1/4 by 2-1/4 inch color transparencies, showing color fidelity of eight types of color (Ansco color reversal or color negative) films, as well as the spectrophotometric curves of such important military backgrounds as: sky, haze, water, vegetation, soil, airplanes, army uniforms, effect of water on the chromaticity of soil, etc."

"To enable us to compare the efficiency of the various types of color photography and of the individual layers, alone or collectively, with or without filters in the field of military reconnaissance and intelligence. Also, to make use of these (color transparencies) in conjunction with filters for increasing contrast with background when viewing such color transparencies on a light-table."

(Result.....NBS Reports 4794 and 4953 [10 and 11] .)

* * * * *

Request Number 2.1 WADC - 28/53 (B) July 23, 1953

"Spectrophotometric curves and Munsell notations are requested on samples of film (2-1/4 x 2-1/4) whose purpose and function are more or less explained on the tabulation sheet herewith."

"Film numbers W-132 to W-236 are sent herewith with tabulation sheet. In a sense when these curves have been made, it will enable a series of comparisons to be made of many of the factors involved in this study on the principle of solving for a series of simultaneous equations."

"To test color fidelity: 1. Over a range of underexposure and overexposure of seven types of color reversal film; 2. The possibility of making suitable filters by overexposure, i.e., securing in this convenient and inexpensive way, a filter sufficiently thin but really exactly repre-

senting on any particular film used, objects of military importance; 3. When such a filter exactly representing a military object is compared with a similarly prepared filter for any of the various backgrounds, the following can be deduced with fair accuracy: a) degree of contrast between object and background on the seven types of films studied, b) a filter can be plotted that will best serve to give maximum contrast between object and background when used in photographing such a pair on any kind of photographic film studied, and c) a similar filter or filtering system can be planned that will give the maximum contrast between the background and the military object showing on a color transparency when this filter is interposed between the eye of the observer and transparency or between the source of light and the transparency."

"Note: The Project Director would like to have these films for further study at some later date."

(Result.....As a result of requests 28 (A) and 28 (B), the spectrophotometric and colorimetric study of the color transparencies were reported in NBS Reports 4794 and 4953 [10, 11] .)

* * * * *

Request Number 2.1 WADC - 29/53 (A) September 29, 1953

"Various means of calculating degree of contrast: 1. On basis of total light or light energy reflected; 2. On basis of sensitivity of the eye; 3. On basis of sensitivity of various types of photographic films or plates, e.g., orthochromatic, panchromatic, X-ray, commercial, infrared, color, tricolor, unicolor, etc.; 4. Influence of gloss; 5. Influence of hue, brightness, etc.; 6. Contrast with results from Sweet's curve computer; and 7. Contrast on the basis of complementary colors, so-called."

(Result.....A few of these problems were answered in NBS Reports 3773, 3774, and 4408 [1, 2, and 5] .)

* * * * *

Request Number 2.1 WADC - 29/53 (B) July 11, 1953

"Several hundred or more determinations of the degree of contrast between a minute image of an object of military importance and a military background on various selected photographs made by us on special Ansco color films. Possibly the word 'contrast' is somewhat vague used in this connection. The long word 'recognizability' or even visibility may be better. Such semantics can be decided later. We wish to have data on any factor involved that can be measured at the Bureau of Standards, e.g., on the 'Color Densitometer' of the Ansco Company. It has been used in this kind of estimating the degree of contrast."

(Result.....No measurements made.)

* * * * *

Request Number 2.1 WADC - 30/53 September 29, 1953

"A preliminary or outline - report on substances or classes of substances that absorb in the infra-red region from 700 to 2000 mμ. Literature references, chemical formulae, graphic but more especially structural formulae requested. Especially those substances suitable for incorporating in the photographic film. See for example: Photography in infrared by Walter Clark ed. 2, Wiley, 1946, Chapt. V, pp 72-103. NB No need to repeat bibliography given at end of this chapter by Clark unless for some special reason."

"This is an exploratory study. Would like to have any general principles or formulations. Would appreciate getting information piecemeal, i.e. a few cards or notes at a time."

(Reference.....NBS-NRC Infrared Spectra [32] .)

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Request Number 2.1 WADC - 31/54 February 11, 1954

"Determine spectrophotometric curve and Munsell notation on: 34 models, toys, and (#34) aluminum lacquer or bronze or paint on a 4 x 4 inch sheet of aluminum. 1/16 inch gage, as per list appended herewith. All articles are numbered in india ink. Index cards 3 x 5 inches in five colors, red, yellow, green, blue, salmon or orange. Part of a lot of 8 M each. Also the following used in series W-1 to W-1588 photographed on ten kinds of color film and several black and white: Top soil, 'A' horizon, Collington sandy loam, rolling phase Yellow sand, Upper Cretaceous, Roger's quarry, 6 ton sample lot, Vermiculite (commercial Zonalite), part of 50 lb. bag. Used in other photography and to be used later, white quartz sand, Upper Cretaceous, Roger's quarry, Gray-green reindeer moss (Cladonia). Also used in series W-1 to W-1588, 9 color patches, 7 red saturated scale, 14 degrees of gray scale."

(Result.....NBS Reports 4794 and 4953 [10 and 11] . There were no measurements made on the toys.)

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Request Number 2.1 WADC - 32/54 February 10, 1954

"Please determine spectrophotometric curves of: Quartermaster uniforms, olive drab jacket, and khaki shirt. (Olive drab trousers and cap match jacket by eye. Can bring them in if you think necessary.) Please give Munsell color notations also unless this seems unnecessary. Please determine spectrophotometric curve, if necessary, and note if already duplicated by other objects, and/or the Munsell color reading of the following: Marine clothing: Fatigue cap, trousers, and jacket. Khaki shirt and trousers (slightly different shades on each). Khaki tie and overseas cap. Olive drab cap, trousers, and jacket. These have not yet been photographed but it is proposed to use them very soon on dummies."

"To obtain the spectrophotometric curves for these uniforms, also later for any films, filters, sources of light, and how each of these records the color, etc. as shown on the spectrophotometer. The spectrophotometric curves for any of these are requested as soon as convenient so that they can be used on clear plastic for superposing over a source of light. This superposing method should show to what extent this procedure will be practical for photographers to decide what film, filter, source of light, etc. is best for photographing and later studying such photographs, where it is proposed to detect these objects by photographic means."

(Result.....NBS Report 4953, November 1957 [11] .)

* * * * *

Request Number 2.1 WADC - 33/54 September 21, 1954

"Spectrophotometric study of five paints used for color targets in aerial photography, and the following Munsell samples prepared by the Tobey Press, St. Louis, Missouri: 18 samples of the gray series; 7 samples of the red scale; and 9 samples of the most saturated chromatic scale."

(Result.....NBS Report 4953, November 1957 [11] .)

* * * * *

Request Number 2.1 WADC - 34/55 (A) July 22, 1953

"Please determine spectrophotometric curves of the samples submitted herewith as follows: A series of seven 2" by 2" Ansco color films, W-124 to W-130, illustrating six types of film, all elements of the seventh type, the Ansco Color Daylight type.

W-124 Two layers, blue and red sensitive only.
W-125 Two layers, green and red sensitive only.
W-126 Three layers of the complete Ansco color.
W-127 Single layer, blue sensitive only.
W-128 Single layer, green sensitive only.
W-129 Single layer, red sensitive only.
W-130 Double layer, blue and green sensitive only.

Rate and kind of fading tests are requested. All these samples are color-reversal film, all of them unexposed."

"The curves shown by these films are requested to be transferred to clear plastic (Ozachrome) so that they can be used to determine the following: 1. The effect of light on the dye in the emulsion, when this curve of the unexposed but developed film is compared with the curve of the exposed and developed film. 2. The effect of the entire process of the manufacturing and developing by reversal process on the absorbtion spectrum of each dye can be observed by comparison of this curve with the curve of the dye alone in aqueous suspension, with and without gelatin. Mr. Keegan has cited a Russian reference which states that notable differences in the absorbtion spectra of certain dyes occurs in the presence of at least some

kinds of gelatin used in the industry. We wish to determine in a preliminary way the magnitude of this change and other changes. Further: Munsell Notations of each of these samples is requested. P.S. Samples are duplicates of the author's collection and may be kept at the Bureau for purposes of further studies."

(Result.....NBS Report 4953, November 1957 [11] and 5183 Appendix B [13] .)

* * * * *

Request Number 2.1 WADC - 34/55 (B) July 29, 1953

"Determine the total amount of light transmitted by color transparencies which we have submitted to the Bureau of Standards or will submit in the near future, especially Numbers W-124 to W-130, i.e the series of unexposed developed color reversal film modifications, single layers only, double layers, etc. Also W-132 to W-299."

"For obtaining data on the use of normally exposed, overexposed, and even underexposed color-reversal transparencies as filters in a light table or illuminating table. Results can be expressed in absolute units or in the scale of filter factors in use in photography, that is, where a factor of 2 corresponds to 1 full stop in exposure or a reduction of one half of the total amount of light. While it is realized that this figure may be calculated or deduced from the graph of the spectrophotometric curve, it is believed that direct measurement would be much more rapid, more accurate (?), and furnish an excellent means of checking total transmittance and/or reflectance (?) at least sufficiently accurately for the purposes of this research. It is left to the judgment of Mr. Keegan to decide how best to do this."

(Result.....NBS Report 4953, November 1957 [11] .)

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Request Number 2.1 WADC - 35/55 April 20, 1955

"Spectrophotometric curves on color transparencies of wet and dry sand and gravel, W-872 to W-946 (not complete). Total: 51 transparencies."

(Result.....NBS Report 4794, March 1957 [10] .)

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Request Number 2.1 WADC - 36/55 April 20, 1955

"Spectrophotometric curves of color transparencies of three types of light sources used in the O'Neill - Nagel light table. W-1858 to W-1884 inclusive. Total: 27."

(Result.....NBS Report 4953, November 1957 [11] .)

* * * * *

Request Number 2.1 WADC - 37/55 June 3, 1955

"Spectrophotometer samples of Ansco color correcting printing foils on GE. Samples consist of 7 yellows, 7 cyans, 7 magentas, and 10 samples from the old set of filters."

(Result.....NBS Report 4953, November 1957 [11] .)

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Request Number 2.1 WADC - 38/55 June 3, 1955

"Compute and supply as table or nomogram the reduction ratios of four lenses (-40, -20, -10, and -5 diopters) using object distances of 10 cm to 80 cm at each 10 cm interval."

(Result: At a conference held on August 31, 1955, the requested formula prepared by Dr. Robert E. Stephens was given to Dr. O'Neill by Mr. J. C. Schleter.)

* * * * *

Request Number 2.1 WADC - 39/55 November 5, 1955

"Some time ago, Dr. Judd remarked that there was a difference in the effect caused in viewing colored transparencies through a colored filter as to the position of the color filter, i.e. if the color filter was placed between the source of light and the transparency, or, between the transparency and the eye of the observer. This is not clear to us. Any further information on this topic will be of great use to us now and will be much appreciated. An example giving quantitative, if only very roughly, will probably be the best way to make this clear to us. For example, with a light source of 700 foot-candles at the surface of the viewing screen viewing color transparencies showing all colors of the spectrum, an average color transparency reduces the intensity of the source of light to between 25 to 200 foot-candles. When a magenta filter is interposed between the source of light and transparency, before the light reaches the transparency, its intensity is reduced from 700 to 35. If this same filter is now interposed between the transparency and the eye, what differences as to hue will be or can be observed."

(Result: Answered by letter of November 14, 1955 and by NBS Report 3774, November 1954 [2] .)

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Request Number 2.1 WADC - 40/55 November 7, 1955

"Certain information, some of it undoubtedly in the literature of optics, is needed by us in this research, finishing January 1, 1956. Any information which can be supplied should be prefaced or followed by literature citation, or if unpublished, by the author's name cited in precisely the way in which he wishes his name and agency to be worded. On account

of the short time before the expiration of the contract, the information should reach the writer before December 20, 1955 at the latest; much earlier will be much appreciated. From the pleasant discussion with Dr. Stephens and Mr. Keegan a few weeks ago, it seems likely that Dr. Stephens could answer some of these questions readily."

"For the average observer, or any one or any few observers (on record somewhere), please give any general and/or any specification, observation, or measurement on the following: 1) At what intensity of light, or between what approximate intensities of light, does the human eye see best or resolve details best or have best vision or see the lowest contrast in intensity of light between an object and its background? 2) Stated otherwise, man, in common with other diurnal animals, for recognition of his enemies or of his prey, would seem by adaptation, to have best vision most acute when average reflected light from landscape, waterscape, and sky is roughly between 200 to 400 on the Weston meter or ASA 250 to 500 (i.e. blue sky 400, white clouds 1200 to 1600, green vegetation 100, yellowed vegetation 175, on Weston meter cited here as common readings from common elements of common photographs, landscapes, etc.) Animals and races of men long habituated to dense forest might see best between Weston reading 25 to 50. Whether this assumption is correct or not, it is stated here in order to show what is the information for which we are groping. We need much better information than we have. 3) Presuming a small black object against a white background at such distance that it can be just seen (disregard psychological factors for the present) at a distance of 50 meters, for example, when the white reflects about 1600 on Weston meter, please state: Can this minute target be seen more or less clearly when the reflected light reads from the white background 800, 400, 200, 100, 50, 25, 10, 5, and 1 Weston reading or ASA readings or in foot-candles, respectively? Can you state how much more or less clearly in any terms whatsoever (?) e.g. in terms of the longer or shorter distance (?) or larger or smaller black dot (?) (Presume the white background is dull and has negligible gloss or lustre.) 4) Mr. Teele kindly gave us the information that northern blue sky free of clouds and notable haze reads 400 on the Weston (450 ASA) meter between 10 and 2 o'clock. Can you refer us to a table giving average intensities of daylight and sunlight, at dawn, sunrise, phases of the moon, or should we seek this information from the Weather Bureau? 5) Regarding visibility. Presume a black line, 1 mm thick and 3.1416 mm long on a white background, as well as a circle made of a line 1 mm thick and 3.1416 mm in circumference. Which of these will be visible at the greatest distance."

(Result: Answered by letter of November 14, 1955 with the following references: (a) Tufts College Institute for Applied Experimental Psychology for the Department of the Navy, Office of Naval Research entitled "Handbook of Human Engineering Data for Design Engineers", Technical Report No. SDC 199-1-1, NavExosP-643, 1949 [33] ; (b) G. M. Byram "The physical and photochemical basis of visual resolving power. Part I. The distribution of illumination in retinal images" J. Opt. Soc. Am. 34, 571-591; 1944 [34] .)

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Request Number 2.1 WADC - 41/55 November 10, 1955

"Enclosed herewith is an English translation (16 pages) of the Introductory Chapter of Krinov's Russian text on Spectral Reflectance. This part was omitted from the Canadian National Research Council's translation by Belkov. In my opinion this is by far the most important part so far as we are concerned and, I may add, the most difficult part to translate. This translation is mailed to you so that you can substitute the correct or most commonly used technological terms used in the United States in the field of optics and photography. If you will read the translation, you will readily see what I have in mind and what is necessary. In some cases, I have penciled a word which I believe is better than the typed word. Undoubtedly yourself, and your conferees, such as Mr. Teele, Dr. Judd, Dr. Stephens can also offer valuable suggestions. The translator is unfamiliar with the technology of optics but has translated successfully where more general types of technology were involved. Please note that we will supply you with as many copies of this as you wish; also copies will be sent to the Canadian National Research Council; and it will be incorporated in our Final Report. On account of the short time at our disposal for completing the Final Report, it will be a great help to us and will be greatly appreciated if this MS can be returned as soon as convenient, within a week if possible. It must be referred back to the translator, I must go over it once more and then it must be stenciled, the stencils to be sent to WADC."

"Later if you can combine a critical appraisal with mine, I believe, we can give a very important insight as to what the Russians use in the way of photo-interpretation and how they think along these lines. My own critique points out some very important corrections to be made in the English translation by the Canadian National Research Council."

(Result: Answered by letter of November 23, 1955, together with typed copies of "Translation of Introduction and Chapter I, Part I of Krinov's spectral reflectance, Optical Terminology by Dr. Deane B. Judd. This translation was used in Dr. O'Neill's final report [20] .)

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Request Number 2.1 WADC - 42/56 March 3, 1956

"Spectrophotometry of bark specimens, 400 to 1080 millimicrons. Two samples of tree bark:- Scrub pine (Pinus Virginiana Mill.) and White Oak (Quercus alba L.). Measure inner and outer sides of the tree bark specimens."

(Result.....Part of NBS Report 4794, March 1957 [10] .)

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Appendix B.

Chronology of pertinent events of the NRC Wheat Rust Work from the first meeting in which NBS personnel participated in April 1952 to the preparation of the present report in December 1957.

April 2, 1952. Meeting to initiate this study called by Dr. Everett F. Davis, Executive Secretary, Committee on Plant and Crop Ecology, National Research Council. Meeting held in the laboratory of Dr. Robert B. Withrow, Director, Division of Radiation of Organisms, Smithsonian Institution, Washington, D. C. Those present were: Dr. E. F. Davis, Dr. R. B. Withrow, Mrs. R. B. Withrow, Miss B. B. Britton, Dr. H. T. O'Neill, Lt. Cmdr. R. N. Colwell, Mr. R. C. Heller, Mr. R. H. Moyer, Dr. W. S. Benninghoff, and Mr. H. J. Keegan.

May 1, 1952. The second planning meeting was held in Dr. Davis' offices in the Dupont Circle Building, Washington, D. C. Those present were: Dr. E. F. Davis, Miss B. B. Britton, Lt. Cmdr. R. N. Colwell, Lt. J. W. Hallstead (USN), Mr. R. H. Moyer, Dr. L. O. Quam, Dr. R. B. Withrow, Dr. H. A. Rodenhiser, and Mr. H. J. Keegan. At this meeting, a National Research Council memo, dated May 1, 1952, entitled "Guide to photography and field work" was prepared by Lt. Cmdr. Colwell, Mr. Keegan, and Dr. Rodenhiser, on flight instructions, spectrophotometry, and plant culture, respectively.

May 7, 1952. Initial spectral directional reflectance curves were made on some of Dr. Rodenhiser's young wheat plants, that were grown in pots under controlled conditions at Beltsville, Maryland, which he brought to the NBS for measurement.

May 15, 16, and 26, 1952. Additional specimens of cut wheat leaves and pure spore were brought from Beltsville for measurement at the NBS.

May 29, 1952. Lt. Cmdr. Colwell brought to the NBS for measurement, specimens of diseased and rust-resisting field-grown wheat plants flown to Washington, D. C. from Stillwater, Oklahoma. Spectrophotometric curves of the leaves of specimens of Westar wheat having high and low rust severity were given to Lt. Cmdr. Colwell after the completion of the measurements that day.

June 3, 1952. Additional specimens of cut wheat leaves from inoculated plants and specimens of pure stem and leaf rust were brought to the NBS for measurement by Dr. Rodenhiser and Dr. C. V. Lowther.

September 3, 1952. Spectrophotometric curves of the heads and stalks of high and low rust severity Westar wheat plants were given to Lt. Cmdr. Colwell for his talk before the Optics Division, Armed Services Research and Development Board.

September 5, 1952. Lt. Cmdr. Colwell informally presented the data obtained on May 29, 1952, together with photographs of fields of growing wheat, to the members of the Seventh Congress of the International Society of Photogrammetry, sponsored by the American Society of Photogrammetry, at the Shoreham Hotel, Washington, D. C.

September 7, 1952. Lt. Cmdr. Colwell presented the same material to the NRC Committee on Plant and Crop Ecology, Dr. R. E. Cleland, Chairman, at Cornell University, Ithaca, N. Y.

December 1, 1952. Mr. Keegan was thanked by the Executive Secretary, Dr. E. F. Davis, by letter, for the "spectral analysis of the plant materials from Beltsville, and those involved in photographic work done this summer in Oklahoma". The whole matter was dropped temporarily with the following statement "while the resulting interpretation by the Subcommittee on Crop Geography and Vegetation Analysis was not altogether conclusive, it has given a good indication of the present limitations in this field, and the value of continuing research".

January 16, 1953. H. J. Keegan presented a paper at the Nineteenth annual meeting of the American Society of Photogrammetry on the "Use of reflection spectra for photointerpretation purposes" by H. J. Keegan and J. C. Schleter. The abstract of this paper was published in Photogrammetric Engineering XIX, 107 (1953).

January 30, 1953. Cmdr. L. W. Keith, Officer in Charge, U. S. Naval Photographic Interpretation Center (U. S. Naval Receiving Station, Washington 25, D. C.), issued Report No. 102-53 "Aerial photographic interpretation of diseased and healthy cereal crops". (This report contains a graph of the spectral directional reflectance of the leaves of Westar based on NBS measurements but with wrong labeling of the wavelength scale.)

June 1953. In the issue of Photogrammetric Engineering (vol. XIX, 468 to 472) there appeared a "Report of unclassified military terrain studies section" by Page E. Truesdell, U. S. Navy Photographic Interpretation Center, Washington, D. C. This report was a part of the report of the Photo Interpretation Committee of the American Society of Photogrammetry. This paper contained the spectral directional reflectance curves of the leaves of Westar wheat plants, having high and low rust severity, that had been given to Lt. Cmdr. Colwell on May 29, 1952. The wrongly labeled graph from the Keith report was used for this illustration. The error was drawn to the attention of Mr. Truesdell by telephone on August 17, 1953, who arranged to have the corrected graph published (Photogrammetric Engineering, XIX, 851; December 1953).

November 20, 1953. At a closed meeting in the Pentagon, Dr. Colwell again presented the series of photographs which were taken over Stillwater, Oklahoma, on May 27 or 28, 1952, Langdon, North Dakota on August 14, 1952, and over Davis, California in the fall of 1953.

January 19, 1954. Drs. Colwell and Davis brought specimens of diseased and non-diseased rye plants to the NBS for spectrophotometric measurements to see if rye plants infected with rust behaved in the same way as wheat plants infected with rust.

March 12, 1954. Messrs. W. Paul Brandenburg and H. J. Keegan met with Dr. Davis in his offices in the Dupont Circle Building, Washington, D. C. to discuss the continuation of the work of the subcommittee on Crop Geography and Vegetation Analysis by Dr. Colwell, Associate Professor of Forestry, University of California, Berkeley, California.

March 31, 1954. The Committee on Plant and Crop Ecology of the National Research Council was terminated.

May 26, 1954. Dr. Colwell agreed to continue his studies of this method of photo interpretation with support by WADC.

August 19, 1954. Dr. Colwell presented his aerial photographs taken with color, black and white, infrared, and camouflage detecting films at a meeting at the NBS. Those present: Messrs. Brandenburg, Jacocks, and Warren of WADC; Dr. Judd, Messrs. Keegan, Schleter, and Denne of NBS.

December 31, 1954. A looseleaf notebook containing the prepublication draft of a paper entitled "The identification of cereal crop diseases on aerial photographs", by Dr. R. N. Colwell was received.

May 4, 1955. The notebook and prepublication paper by Dr. Colwell, received at the NBS December 31, 1954, was returned to him at his request.

March 27, 1956. Dr. Colwell gave Mr. Keegan a "ditto" copy of his paper "Determining the prevalence of certain cereal crop diseases by means of aerial photography" for review.

July 1956. NBS Report 4591, entitled "Spectrophotometric and colorimetric study of diseased and rust resisting cereal crops" by H. J. Keegan, J. C. Schleter, W. A. Hall, Jr., and G. M. Haas, was issued to the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Copies were also sent to Dr. H. T. O'Neill and to Dr. R. N. Colwell.

November 1956. A paper entitled "Determining the prevalence of certain cereal crop diseases by means of aerial photography" by Robert N. Colwell was published in Hilgardia 26, 223 to 286, No. 5, University of California, Berkeley, California.

October 1957. A paper entitled "Spectrophotometry and aerial photoreconnaissance by H. J. Keegan and J. C. Schleter was presented to the members of the Optical Society of America. The abstract was published in the J. Optical Soc. Am. 47, 1050, November 1957.

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Appendix C

An Index to NBS Progress Reports and Dates of the Periods Reported or Minutes of Meeting

Sequence No.	Reported Period or Comment
1	Quarter-year ending September 30, 1952
2	" " " December 31, 1952
3	" " " March 31, 1953
4	" " " June 30, 1953
-	(No report was issued for September 30, 1953)
5	Half-year ending December 31, 1953
6	Quarter-year ending March 31, 1954
7	" " " June 30, 1954
-	(No report was issued for September 30, 1954)
8	Half-year ending December 31, 1954
-	(No report was issued for March 31, 1955)
9	Half-year ending June 30, 1955
10	Quarter-year ending September 30, 1955
11	" " " December 31, 1955
12	" " " March 31, 1956
13	" " " June 30, 1956
-	(Minutes of meeting of July 18, 1956)
14	Quarter-year ending September 30, 1956
15	" " " December 31, 1956
16	" " " March 31, 1957
17	" " " June 30, 1957
18	" " " September 30, 1957
19	" " " December 31, 1957

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major laboratories in Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside front cover.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.


NBS