GIMRADA Research Note No. 15

TWO APPROACHES TO A PORTABLE COLOR-MEASURING SYSTEM

by

Kenneth D. Robertson

January 1966

U.S. ARMY
GEODESY, INTELLIGENCE AND MAPPING
RESEARCH AND DEVELOPMENT AGENCY
CORPS OF ENGINEERS

US ARMY ENGINEER
GEODESY, INTELLIGENCE AND MAPPING RESEARCH AND DEVELOPMENT AGENCY
FORT BELVOIR, VIRGINIA

BLANK PAGE

U. S. ARMY ENGINEER
GEODESY, INTELLIGENCE AND MAPPING
RESEARCH AND DEVELOPMENT AGENCY
FORT BELVOIR, VIRGINIA

Research Note No. 15

TWO APPROACHES TO A PORTABLE COLOR-MEASURING SYSTEM

NASA Defense Purchase Request R-47-009-02

January 1966

Distributed by

The Commanding Officer
U. S. Army Engineer
Geodesy, Intelligence and Mapping Research and Development Agency

Prepared by

Kenneth D. Robertson
Research Institute for Geodetic Sciences

SUMMARY

Two approaches to color measurement are presented, the spectrophotometer and the reflectometer. Descriptions are given of two portable instruments, one of each type.

The first instrument was built using a flashlight lamp as light source, a wedge interference filter as monochrometer, and a cadmium sulphide photoresistor as a detector.

The second instrument was built with three filters which provided the tristimulus curves of the CIE standard observer, a flashlight lamp, and three barrier layer cells as detectors.

FOREWORD

The studies of color-measuring techniques employing the two approaches described in this research note were originally performed for the Geographic Intelligence Division of USAEGIMRADA under NASA Defense Purchase Request R-47-009-02. A study of the "Feasibility of Objective Color Sensors" was made. Subsequently, the reflectometer developed during the investigation was used as an aid to color photographic studies.

CONTENTS

ILLUSTRATIONS

TABLES

TWO APPROACHES TO A PORTABLE COLOR-MEASURING SYSTEM

I. INTRODUCTION

Color measurements are usually made in the laboratory. Usually, this is the most satisfactory arrangement; however, on occasion, it becomes necessary or convenient to measure color in the field. The work reported here has been to investigate possible approaches to simple, compact, and portable color-measuring systems and to build working models of such systems. In addition, it has been felt desirable to avoid approaches which require the judgement of a trained color observer, but rather rely as much as possible on objective instrumentation. It is also believed that for the projected use accuracy may be sacrificed, to a degree, in return for portability and low-power consumption. This research note does not describe a rugged finished instrument or a permanent means of recording the instrument output. This work was originally performed for the Geographic Intelligence Division of GIMRADA in response to a NASA request for a study of the "Feasibility of Objective Color Sensors." The desire was for an objective color-measuring system which could be used where abnormal environmental conditions would make human color judgement highly suspect. As work progressed it was determined that the techniques developed might also be useful in the acquisition of certain types of geographic intelligence.

The measurement of color has always been rather difficult because it requires an objective measure of quantities which are psychophysical in nature. Color as seen by the human eye is a complex function, not fully understood, of illumination, texture, color of surrounding objects, and numerous other factors. Because of this, the International Commission on Illumination (CIE) recommended the use of a standard observer which consists of the average of a number of observers considered to have normal color vision. The spectral response of this imaginary observer is defined by the tristimulus values of the spectrum, which are the amounts of each of three primary colors which, when added, are required to reproduce the color of the spectrum at any desired wavelength. This definition makes possible the measurement of color in terms of three numbers which can be derived from instrumentation that does not require use of a color observer. Table I presents the tristimulus values at 10-millimicron intervals weighted for Illuminant C.[1]

There are, in general, two approaches to an instrument based on the standard observer. The first is a device which will produce a curve of the percent reflectance of the sample under study over the range of wavelengths to which the eye is sensitive. A mathematical treatment of the curve will provide the tristimulus values for the sample. A second approach is to manufacture three optical filters, the transmissions of which duplicate the three tristimulus curves of the CIE standard observer. These two approaches have been used in the design of the instruments described as follows.

II. A PORTABLE SPECTROPHOTOMETER

A. APPROACH

In the usual spectrophotometer, white light from an incandescent source is passed through a monochrometer and a narrow band of wavelengths is allowed to fall on the sample. The reflectance of the sample is then compared with the reflectance of a perfectly reflecting, perfectly diffusing standard illuminated in the identical manner. By repeating this procedure at small wavelength intervals, or continuously, throughout the visible spectrum, a curve can be drawn for the sample of percent reflectance versus wavelength. A mathematical treatment of the curve will yield the tristimulus values for the sample.

Components for the instrument were selected and mounted on an optical bench (Fig. 1). Light from a flashlight lamp and reflector was projected at a 45° angle onto the sample. That part of the light which was reflected normal to the plane of the sample passed through a slit, a wedge-type interference filter, and struck the detector. The resistance of the detector changed with the illumination, and the current through the detector was read with a microammeter.

---

[1] In addition to the standard observer, the CIE has also specified the characteristics of three standard light sources used for illuminating the sample, designated CIE Illuminants A, B, and C. Illuminant C is the one generally used and approximates average daylight illumination.

Table I. Tristimulus Values for Spectrum Colors Weighted by Energy Distribution of Illuminant C

Wavelength (millimicrons)	Ec $\bar{x}$	Ec $\bar{y}$	Ec $\bar{z}$
400	0.91	0.02	4.33
410	3.47	0.09	16.57
420	13.18	0.39	63.36
430	31.91	1.30	155.74
440	42.14	2.79	211.43
450	41.68	4.71	219.81
460	35.81	7.38	205.49
470	24.18	11.26	159.45
480	11.84	17.22	100.71
490	3.86	25.10	56.13
500	0.55	36.20	30.49
510	0.95	51.45	16.18
520	6.13	68.79	7.58
530	16.21	84.47	4.13
540	29.64	97.40	2.07
550	45.60	104.67	0.92
560	62.59	104.77	0.40
570	77.97	97.39	0.21
580	89.60	85.08	0.15
590	95.67	70.55	0.10
600	95.25	56.60	0.06
610	88.65	44.46	0.03
620	75.27	33.56	0.01
630	56.53	23.32	0.00
640	39.32	15.36	0.00
650	25.00	9.43	0.00
660	14.49	5.36	0.00
670	7.54	2.76	0.00
680	3.92	1.42	0.00
690	1.81	0.65	0.00
700	0.86	0.31	0.00

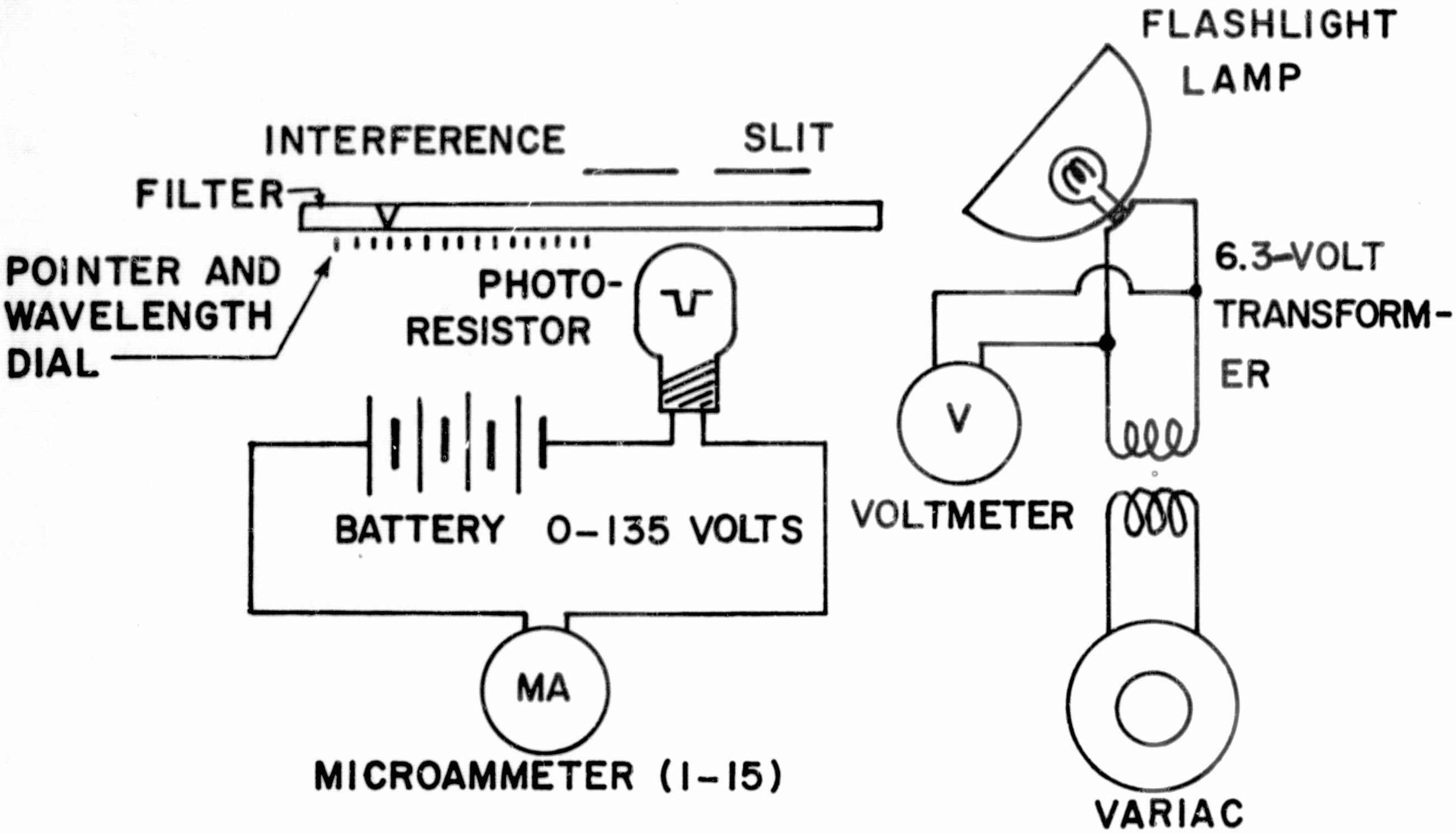

Fig. 1. Wedge interference filter spectrophotometer.

The instrument can be broken down into three basic components, the light source, the monochrometer, and the detector.

The light source was PR 2 lamp in a flashlight reflector. The voltage applied to the lamp was held constant at 2.5 volts through use of a voltmeter, a variable transformer, and a 6.3-volt filament transformer. Because of the angle of projection, the illuminated area of the sample was an oval approximately 2½ inches by 1½ inches.

A wedge-type interference filter was used as a monochrometer. A list of the component characteristics of this filter follow:

Component Characteristics of Wedge Interference Filter

Filter area	20 mm x 65 mm
Useful wavelength range	400-700 millimicrons
Average linear dispersion	5.5 millimicrons/mm
Peak transmittance	35%
Half width	10 millimicrons

In order to use to best advantage the band pass characteristics of the filter, it is necessary to prevent light which passes through the filter at angles other than the normal from being seen by the detector. For this reason, a 2-millimeter slit was placed 5 millimeters in front of the active filter layer. The detector itself is in the form of a narrow rectangle and functions as a second slit placed 5 millimeters in back of the filter. In this configuration, the interference filter is shifted back and forth between the slit and the detector to perform a scan of the visible spectrum (400 to 700 millimicrons).

A cadmium sulphide photoresistor was used as the detector. The characteristics of the detector are given in the following list.

Component Characteristics of Cadmium Sulphide Photoresistor

Wavelength sensitivity	400-800 millimicrons
Temperature range	-40° C to +60° C

Resistance

Ohms	at	Ft-Candles
> 10,000,000		0
1,000,000		1
200,000		10

Table 1. Detectors of this type change resistance on exposure to light and when placed in series with the proper voltage provide a current flow which is a function of the incident illumination. The current, in turn, is measured with a microammeter.

B. CALIBRATION

Two calibrations are necessary before samples can be measured. The first, a wavelength calibration of the wedge interference filter, was performed by illuminating the slit with monochromatic light, then adjusting the wedge for maximum current through the detector. The position of the pointer along the wavelength dial was then marked. The procedure was repeated throughout the spectrum to complete the wavelength calibration.

The wavelength response of the system must also be determined because the current through the detector is dependent upon the spectral distribution in the output of the lamp, the spectral response of the detector, and the band pass and transmission characteristics of the wedge filter as well as the reflectance of the sample. This calibration was performed by recording the apparent reflectance of a well-known white color standard and deriving correction factors for each wavelength of interest to correct the readings to the true reflectance of the standard.

C. USE

In use, the sample to be measured is placed in position and the light is turned on. The interference filter is moved to scan the spectrum, and readings of the meter are made at the desired intervals between 400 and 700 millimicrons. The readings are then corrected through the use of the appropriate multipliers, and a percent reflectance curve is drawn for the sample.

D. RESULTS

Results obtained with two typical samples are given in Table II. Poor results at the ends of the spectrum are felt to be caused by the low response of the detector at these wavelengths. An improved model of the instrument that will use a better detector is planned.

III. A PORTABLE REFLECTOMETER

A. APPROACH

The second approach to color measurements is to manufacture three filters, the transmissions of which duplicate the three tristimulus curves of the CIE standard observer. An additional correction must be built into the filters to compensate for the spectral distribution of the illuminant and the wavelength sensitivity of the detector. Such filters are available for use with an incandescent light and photovoltaic or barrier layer cell (BLC) combination and have been used in the design of the instrument described as follows.

A BLC produces a current which is a function of the incident illumination and has poor sensitivity compared with detectors having large amplification factors. In addition, because of power considerations only a small amount of light is available in this application for illumination of the sample. In order to obtain sufficient signal three barrier layer cells were used instead of the usual one. The resultant configuration is shown in Fig. 2. The end of a flashlight with lens and reflector was used to illuminate the sample normal to its surface. A voltage regulator, a variable transformer, and a filament transformer were used to provide 3 volts of regulated AC to the PR 13 lamp. The illuminated spot on the sample was viewed at 45° by three barrier layer cells wired in parallel. A BLC has an internal

Table II. Spectrophotometer

Wavelength	Spectrophotometer Value (% reflectance)	True Value (% reflectance)
	a. Sample 33538	
450	11.8	3.0
510	21.8	28.0
520	66.2	63.0
630	75.5	76.0
690	54.0	79.0
	b. Sample 27144	
450	30.0	27.0
510	17.0	15.0
520	15.0	11.0
630	22.0	26.0
690	31.0	28.0

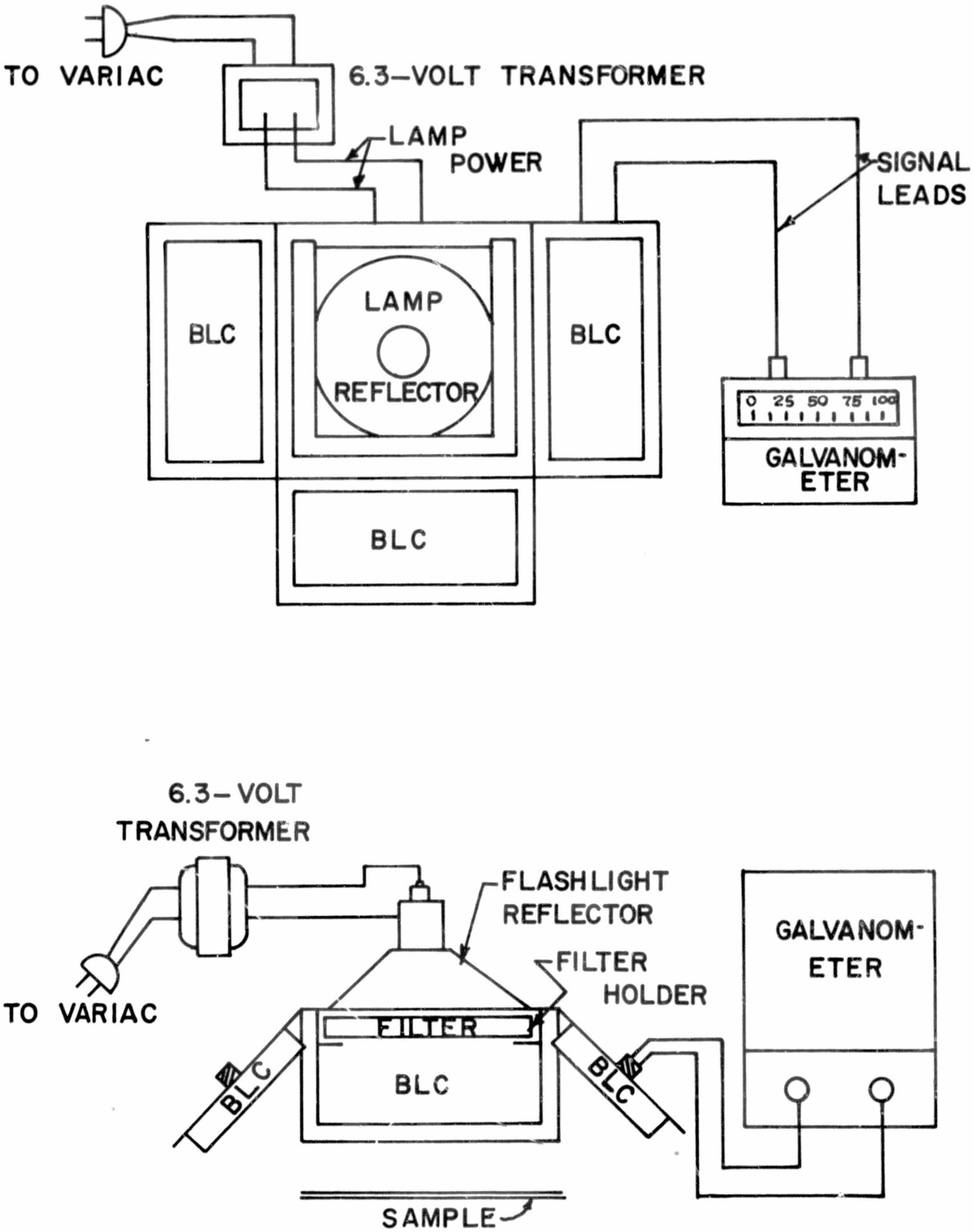

Fig. 2. Portable reflectometer.

resistance which can be taken as also being in parallel with the output and which is a function of the illumination on the cell. Because of this characteristic of the cell it is necessary to use a relatively low-resistance device to measure the output as a linear function of illumination. For this study, an optical galvanometer with a resistance of approximately 100 ohms was used. As can be seen from the Y values for a range of samples, 100 ohms is a low enough resistance value to provide sufficient linearity for the purpose of this instrument. A filter holder was built over the lamp so that each of the three tristimulus filters in turn might be placed over the light source to shape the spectral output of the illumination incident upon the sample. The filters were obtained from the Henry A. Gardner Laboratory, Bethesda, Maryland, as were the barrier layer cells. They were designed for use in their multipurpose reflectometer and represent one of the best efforts to duplicate the CIE standard observer and simultaneously to adjust a lamp to CIE Illuminant C. From Table I it can be seen that the X tristimulus values show a double peak. So far it has proved impossible to find a single filter which has this double peaked response. For this reason, a portion of the Z filter is added to the X to provide the double peak correction.

B. CALIBRATION

No set of filters yet devised follows exactly the contours of the curves for the CIE standard observer. The errors resulting from this mismatch are, in general, a function of the difference in color between the calibration card and the sample. For best results it is important to calibrate with colors in the same range as the samples which are likely to be encountered. It is possible, however, to calibrate the instrument after the samples are read and thus select standards which are a fair color match to the samples already measured.

For the calibration of the laboratory model, ten color cards with known tristimulus values were selected from Federal Standard 595. These cards included grey, blue grey, brown, red brown, and tan colors. The tristimulus values of the cards are given in columns 3, 4, and 5 of Table III.

Measurements were made of each of the ten cards through each of the three tristimulus filters. These values are listed in columns 6, 7, and 8 of Table III. When these values were obtained a multiplier was computed for each of the readings which would correct it to the corresponding true tristimulus

Table III. Filter Correction Factors

(1) Fed Std 595 No.	(2) Color	(3)	(4) Tristimulus Values	(5)	(6) Amber Reading	(7) Green Reading	(8) Blue Reading	(9) Fx*	(10) Fy*	(11) Fz*
36231	Grey	0.2213	0.2300	0.2809	19.5	20.5	13.5	0.861	1.12	2.08
30277	Tan	0.2745	0.2796	0.2129	27.5	26.0	9.5	0.851	.98	2.03
34241	Blue Grey	0.2485	0.2805	0.3383	22.0	26.0	16.5	0.837	1.08	2.04
16307	Grey	0.2751	0.2871	0.3141	27.0	28.5	16.0	0.797	1.01	1.96
20109	Red Brown	0.1403	0.1101	0.0740	15.5	11.0	3.5	0.814	1.00	2.11
30111	Red Brown	0.1152	0.0988	0.0799	11.5	9.0	3.5	0.869	1.10	2.28
30099	Brown	0.0866	0.0834	0.0625	8.5	7.0	2.5	0.878	1.19	2.50**
36307	Grey	0.2949	0.3069	0.3313	27.0	28.5	16.0	0.859	1.08	2.07
36176	Blue Grey	0.1681	0.1750	0.2545	13.5	15.5	11.5	0.886	1.13	2.21
30109	Red Brown	0.1375	0.1052	0.0622	14.5	10.0	2.5	0.866	1.05	2.48**

*Average Values:	Fx	Fy	Fz
	0.852	1.07	2.10

**Not used for computation of Fz.

value. The multipliers are given in columns 9, 10, and 11. Fy is the multiplier to be applied to the reading through the G (green) tristimulus filter to obtain the Y tristimulus value, and Fz is the multiplier to correct the B (blue) filter to the Z tristimulus value. Because the X tristimulus value has a double peak two corrections must be made to readings taken through the A (amber) filter. As can be seen from Table I, the small peak of $Ec\bar{x}$ and the peak of $Ec\bar{z}$ both occur at approximately 450 millimicrons, and the height of the $Ec\bar{x}$ curve is 0.19 that of the $Ec\bar{z}$ curve. Thus, the tristimulus value X is given by:

$$X = A \cdot Fx + 0.19\, B \cdot Fz$$

and the value of Fx is:

$$Fx = \frac{X - 0.19\, B \cdot Fz}{A}$$

The values for Fx, Fy, and Fz were then calculated to provide filter correction factors Fx = 0.847, Fy = 1.07, and Fz = 2.10. The correction factors will remain constant for the instrument until the lamp begins to blacken as a result of evaporation of the filament or the physical dimensions of the instrument are changed. Darkening of the lamp can be checked by measuring a white standard through the green filter. The apparent reflectance of the standard will drop because of darkening.

C. USE

Use of the instrument is simple once it is calibrated. A sample to be measured is placed in position. One of the three filters is placed over the lamp, and the galvanometer deflection is noted. The same procedure is followed for the other two filters, and a set of three readings is obtained for the sample. The tristimulus values can then be computed from these three readings as follows:

$$Z = B \cdot Fz$$

$$Y = G \cdot Fy \text{ and}$$

$$X = A \cdot Fx + (0.19 \cdot B \cdot Fz)$$

where X, Y, and Z are the three tristimulus values of the sample; Fx, Fy, and Fz are the filter correction factors; and B, G, and A are the galvanometer readings taken with the blue, green, and amber filters, respectively.

D. RESULTS

After the instrument was calibrated in the manner described here, the ten color cards of Standard 595 were treated as samples. In addition, four other samples from Standard 595 were measured. The colors of these additional samples were white, purple, yellow, and chartreuse. The values of x, y, and Y were then computed for the 14 samples using the filter corrections of Fx = 0.847, Fy = 1.07, and Fz = 2.10. The results are presented in Table IV, together with the values of the color cards listed in Federal Standard 595.

IV. DISCUSSION

Two feasibility models of color measuring instruments have been built and tested in the laboratory. The first type produces a curve of percent reflectance versus wavelength over the visible portion of the spectrum. Of the two it is the most versatile, because both the tristimulus values and the spectral composition of the light reflected from the sample can be obtained. If the wavelength dial is calibrated an observer is allowed some choice in the data acquired; he may pay particular attention to certain regions of the spectrum which are of interest because of suspected bands of high or low reflection.

If simplicity is more important the second type of instrument which uses tristimulus filters would be a better choice. Only 3 readings are necessary compared with at least 5 and more probably 10, depending on the type of sample, required with the other instrument. Little judgement or skill is required on the part of the operator, and the answers will be reproducible from one observer to another.

It should be understood that the two instruments described here have been built as feasibility models. It is to be expected that additional work would improve the accuracy and particularly the ease with which the instruments could be used. It is felt that both devices demonstrate feasible approaches from the standpoints of compactness, low-power consumption, and accuracy. The first approach allows some choice on the part of the operator of the type and amount of data desired, and the second approach features ease of operation.

Table IV. Measured Values for 14 Color Cards

Fed Std 595 No.	Color	xe	xt	ye	yt	Ye	Yt
37875	White	0.311	0.308	0.320	0.319	0.883	0.889
36231	Grey	0.304	0.302	0.303	0.314	0.219	0.230
30277	Tan	0.362	0.358	0.370	0.365	0.288	0.280
34241	Blue Grey	0.288	0.287	0.317	0.323	0.278	0.281
16307	Grey	0.314	0.314	0.326	0.328	0.305	0.287
20109	Red Brown	0.432	0.433	0.349	0.339	0.118	0.110
37144	Purple	0.304	0.292	0.222	0.230	0.128	0.138
30111	Red Brown	0.397	0.392	0.340	0.336	0.096	0.099
30099	Brown	0.390	0.372	0.357	0.359	0.075	0.083
33481	Yellow Green	0.413	0.426	0.459	0.453	0.492	0.478
33538	Yellow	0.473	0.490	0.468	0.449	0.589	0.543
36307	Grey	0.314	0.316	0.326	0.329	0.305	0.307
36176	Blue Grey	0.283	0.281	0.292	0.293	0.166	0.175
30109	Red Brown	0.454	0.451	0.365	0.345	0.107	0.105

Note: xe, ye, and Ye are the values as measured by the instrument, and xt, yt, and Yt are the values given for the samples by Federal Standard 595.

SELECTED BIBLIOGRAPHY

1. Hardy, Arthur C., Handbook of Colorimetry, Cambridge, Mass.: The Technology Press, MIT, 1936.

2. Judd, Deane B., Color in Business Science and Industry, New York, N. Y.: John Wiley & Sons Inc., 1952.

BLANK PAGE

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Research Institute for Geodetic Sciences	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

TWO APPROACHES TO A PORTABLE COLOR-MEASURING SYSTEM

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Note

5. AUTHOR(S) (Last name, first name, initial)

Robertson, Kenneth D.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1966	15	2

8a. CONTRACT OR GRANT NO. N/A b. PROJECT NO. NASA Defense Purchase Request c. R-47-009-02 d.	9a. ORIGINATOR'S REPORT NUMBER(S) Research Note No. 15 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Intelligence Division, USAEGIMRADA and NASA Request No. R-47-009-02

13. ABSTRACT

Two approaches to color measurement are presented, the spectrophotometer and the reflectometer. Descriptions are given of two portable instruments, one of each type.

The first instrument was built using a flashlight lamp as light source, a wedge interference filter as monochrometer, and a cadmium sulphide photoresistor as a detector.

The second instrument was built with three filters which provided the tristimulus curves of the CIE standard observer, a flashlight lamp, and three barrier layer cells as detectors.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Color Measurement, Reflectometer, Spectrophotometer, portable						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Idenfiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.