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PIGMENT COLOR RESEARCH REPORT

Final Report

TITLE: METHODS AND APPARATUS FOR COLOR SPECIFICATION AND
FOR RATING COLOR DIFFERENCES. LITERATURE SEARCH.

Period Covered: 1920-1941

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Period Covered: 1920-1941

SUBMITTED BY: A. D. Reidinger

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DATE SUBMITTED: July 11, 1944

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INTRODUCTION:

This report covers a literature search made in 1941 on methods and apparatus for color specification and for rating color differences. Possible application to measurement of color in pigmented films was particularly in mind in selecting the references listed below but a number of items on the subject of color theory are also included.

SOURCE OF REFERENCES:

Research File.
Chemical Abstracts Vol. 14-35, 1920-1941.

Subjects for which references were searched included colors, colorimeters, paint, pigments, photometers, spectrophotometers, etc.

SUMMARY:

During the period covered in this search, efforts to represent color in more definite terms than is possible by visual inspection have been directed along several lines.

In the field of classification and nomenclature, Munsell had already published (in 1915) his Atlas describing his color sphere with its use of symbols based on hue, value and chroma. During the next decade considerable attention, some of it adversely critical, was given in the literature to the system proposed by Ostwald, in which selected hues are arranged in a color circle with two adjoining cones to designate value.

For the measurement of color and its representation in definite units, many types of apparatus have been developed. A complete review of these would require more time and study than can be devoted to the subject at present. For such an exposition, the reports of Dr. A. W. Kenney on "The Principles of Color Measurement" and "Instruments for Measuring Color" are referred to.

However, it is interesting to note that in 1921, the types of instruments being used or experimented with, were similar in principle to those which are in use in more refined form at the present time. Colorimeters employing monochromatic and trichromatic light to match a colored sample were just beginning to be used industrially and the application of the spectrophotometer to research and industrial problems was increasing. With the development of the photo-electric cell many improvements were made in these instruments - in particular may be mentioned the Hardy (GE) recording spectrophotometer invented about 1928 which in its present form is considered to be most suitable for measurement of color for control or experimental purposes.

REFERENCES:

- Allen, Frank
J. Optical Soc. Am. 8, 339-41 (1924)
New Tri-color Mixing Spectrometer.
- Barker, S. G.
J. Textile Institute 18, 313-48T (1927)
Standardization of Fastness of Dyestuffs.
Instruments such as tintometer and the Eastman and Guild colorimeters are described.
- Barnard, M. & McMichael, Paul
Paper Trade J. 91, No. 14, 55-8 (1930)
Precision Color Measuring Apparatus.
Discussion of American Photometer Corp. Opacimeter and APC photoelectric spectrophotometer.
- Barnes, N. F.
Tech. Studies Field Fine Arts 7, 120-38 (1939)
Spectrophotometric Study of Artists' Pigments.
Spectrophotometric curves of 52 different artists' pigments are given.
- Bland, N.
Oil & Colour Chemists Assoc. 19, 9-23 (1936)
Color Testing and Recording.
Principles and use of Lovibond tintometer, Guild Trichromatic Colorimeter, and Toussaint photo-electric photo-colorimeter.
- Bawtree, A. E.
J. Oil Colour Chem. Assoc. 11, 61-70 (1919)
Colored Light; simple method of analyzing colors.
Instrument for "chromometric analysis".
- J. Oil Colour Chem. Assoc. 4, 165-88 (1921)
Theory and Practice in Colour Measuring and Recording.
System of designating colour described by Lawrance and measurement with the Bawtree colorimeter.
- J. Oil Colour Chem. Assoc. 5, 353-6 (1922)
Record of Color Research During 1922.
Improvements made to the color circle used in the Bawtree colorimeter.
- Busby, H. S.
Proc. Am. Soc. Testing Materials 22 II 504-14 (1922)
Analysis and Comparison of Systems of Color Measurements;
Proposed Arrangement for Measured Colors.
- Proc. Am. Soc. Testing Materials 21, 1139-43 (1921)
Use of Secondary Reference Standards in Process Problems of Color Measurement.
Colorimeter using rotating sectors of standard colors is described.

- Busby, H. S.
Bulletin Am. Ceramic Soc. 20, 375-402 (1941)
Symposium on Color Standards and Measurements.
Topics discussed are definitions of ideas of colors and terms
used and methods of designating color.
- Campbell, N. R.
J. Sci. Instruments 2, 177-87 (1925)
Photoelectric Color Matching.
- Donaldson, R.
Proc. Phys. Soc. (London) 47, 1068-73 (1935)
Trichromatic Colorimeter.
Use of diffusing sphere.
- Eilers, L.
Farben. Lack 1939, 89-90, 99-100, 111-112
Testing and Evaluating Pigments, Dyes and the Like.
Practical value of various testing methods discussed.
- Fawcett, G. S.
Chemistry & Industry 1005-7, 1933
Color Measurement.

J. Soc. Dyers & Colourists 53, 225-33 (1937)
Application of Colorimetry to the Dyeing and Allied Industries.
Discussion of Lovibond Tintometer.
- Forrest, J. W.
Paper Trade J. 97, No. 22, 38-9 (1933)
New Color Comparator.
Review of Munsell Color System and description of Bausch & Lomb
comparator.
- Gardner, H. A. and Parks, H. C.
Paint Mfrs. Assoc. U.S. Circ. No. 191, 58-140 (Oct. 1923)
A Study of Color Systems, Colorimeters and Spectrophotometers
with Notes on Their Possible Application to Paint Industry.
- Gardner, H. A.
Paint Varnish Prod. Mgr. 14, 30 (1936)
Photoelectric Reflectometer.
Adaptation of Hunter visual reflectometer.
- Gesstacker, L.
Farben-Zeitung 29, 1550 (1924)
Ostwald's "Chrometer"
Modification of Ostwald's color comparator.
- Gibson, K. S. & Harris, F. H.
Bur. Standards Sci Papers No. 547, 46 pp. (1927)
The Lovibond Color System
I.A. Spectrophotometric Analysis of the Lovibond Glasses.

Ginsberg, Ismar

Color Trade J. 11, 93-6 (1922)
Textile World 63, 2615-9, 2645 (1923)
Ostwald's Color Theory, application of

Textile World 65, 2127-32 (1924)
Textile World 64, 1519-21, 1539
Color Measurement by the Ostwald Method.
Directions for constructing apparatus.
Application of Ostwald theory to color analysis.

Godlove, I. H.

Paint, Oil & Chem. Rev. 34, No. 1, 20-3 (1927)
Munsell Color System.
Description and industrial application.

Gordon, H. B.

Color Trade J. 7, 175-180 (1921)
Use of Tint Photometer in Evaluation of Dyestuffs and Pigments.
(e.g. Lovibond, Hess-Ives)

Guild, J.

Trans. Opt. Soc. (London) 27, 106-29 (1925-26)
Trichromatic colorimeter suitable for standardization work.
Description of apparatus.

Proc. Optical Convention 1926 I, 61-146
Critical Survey of Modern Development in the Theory and Technic
of Colorimetry and Allied Sciences.
Properties of illuminants, laws of color mixture and measurement,
etc. are reviewed. Extensive bibliography included.

Hardy, A. C.

J. Opt. Soc. Am. 25, 305-31 (1935)
New Recording Spectrophotometer.
New GE spectrophotometer described.
Principle and operation explained.

Houstoun, R. A.

Phil. Mag (7) 16, 945-53 (1933)
New Method of Colorimetry.
Simple method for describing color presented.

Phil. Mag. (7) 17, 1047-57 (1934)
Colorimetry with a Spectrometer.
Method of measure color coordinates.

Hunter, R. S.

Nat'l. Paint, Varnish & Lacquer Assoc. Circ. #461, 111-28, (1934)
Reflectometer and Color Comparator.
Munsell type photometer is described.

Hunter, R. S. (Bureau of Standards)

Paint & Varnish Prod. Mgr. XXI, No. 8, Aug. 1941, 207-19
Multipurpose Photoelectric Reflectometer.
Developed to measure apparent reflectance, specular gloss, and
trichromatic coefficients.

- Hunter, R. S.
Nat'l. Bureau of Standards Research Paper RP 1345
A Multipurpose Photoelectric Reflectometer.
Description of development, construction, calibration and applications of Multipurpose reflectometers.
- Ingalls, F. P. et al
Proc. Am. Soc. Testing Materials 26, P/1, 347-57 (1926)
Physical Properties of Paint Materials.
Efforts toward establishing method of color measurement are reviewed.
- Ives, H. E.
J. Optical Soc. Am. 5, 469-78 (1921)
Proposed Method of Colorimetry
A spectrophotometric method of color measurement is suggested.
- Jones, L. A.
Am. Dyestuff Reporter 12, 121-31 (1924)
Color Measurements.
Extracts from report of the Colorimetric Committee, Optical Soc. Am. Nutting Monochromatic Analyzer and Eastman universal colorimeter are described.
- Jones, L. A. et al
J. Optical Soc. Ann. 27, 207-13 (1937)
Colorimetry
Preliminary report on nomenclature and definitions.
- Judd, D. B.
J. Optical Soc. Am. 21, 359-74 (1933)
The 1931 ICI Standard Observer and Coordinate System for Colorimetry.
Reports give properties of standard observer. Forms are given for computing linear coordinates.
- Kenny, A. W.
Experimental Station Reports, ESP 37-178, 37-236
I. Principles of Color Measurement.
Discussion of theory. Tristimulus specification of color.

II. Instruments for measuring color.
Colorimeters, photosensitive cells and spectrophotometers.
- Lagaske, H.
Rev. Gen. Mat. Color 23, 69 (1919)
Analytical representation of colors.
Uses the system of rectangular coordinate axes in representing chromatic combinations.
- Lovibond, F. E.
Proc. Optical Conv. 1926 I 211-4
Color tests by means of the Lovibond Tintometer Instrument and standards are described.

- Lowry, T. M. & McHatton, L. D.
J. Oil Colour Chemists Assoc. 4, 189-204 (1921)
A Comparative Study of Methods Used for the Measurement of Colors.
- Ludwig, E. G.
Farben-Zeitung 28, 1257-60, 1323-5 (1923)
Color Designation.
Ostwald system considered inadequate.
- Mayer, Ernest
Farben-Zeitung 41, 31-2 (1936)
The Status of the Theory of Colors.
Application of Ostwald color system to standardization of
paints and pigments.
- Mees, C. E. K.
J. Ind. Eng. Chem. 13, 729-31 (1921)
Measurement of Color.
Brief description of spectrophotometer, colorimeter, monochromatic
analyzer, trichromatic analyzer and their uses.
- Mellon, M. G.
Ind. Eng. Chem. Anal. Ed. 11, 89-5, 1939
Present Status of Colorimetry.
Classified instruments as stimulimeters, comparators, absorptometers.
- Michaelson, J. L. & Tilblafsky, H. A.
Gen. Elec. Rev. 39, 445-50 (1936)
A new spectrophotometer and its applications.
Description of GE recording spectrophotometer apparently the
Hardy design.
- McMullen, E. W. & Ritchie, E. J.
Drugs, Oils & Paints 53, 98, 100 (1938)
New uses of recording spectrophotometer.
Instrument can be used for color matching and determining hiding
power.
- Munsell, A. E. O.
J. Am. Ceramics Soc. 6, 777-82 (1923)
Simple method of measuring color.
Color is measured in three dimensions - hue, value, chroma.
- Nickerson, S. D. & Newhall, S. M.
J. Opt. Soc. Am. 31, 587-9 (1941) No. 9. Sept.
Color Names Central Notations for ISCC-NBS.
A system of color designation based on position in a color solid.
Limits reported in terms of the Munsell system.
- Nutting, R. D.
Textile Research 6, 7-22 (1935)
Objective specification of color.
Spectrophotometric analysis translated into a set of three
numbers to describe color.

Ohe, Fritz

Farbe u Lack, 295, (1940)

New Testing Instruments for the Paint and Varnish Industry.
Thirteen recently developed devices are reviewed briefly.

Ostwald, Wm.

Z. Tech. Physik 1, 173-5, 261-71 (1920)

Fundamentals of the Theory of Color Measurement.
Theory and use of Ostwald's chrometer.

Z. Angew. Chem. 42, 437-9 (1929)

Standardization of Colors.

Comparison of Ostwald's classification and others.

Park, R. H.

Amer. Dyestuffs Reporter 29, No. 11

Proc. Am. Assoc. Textile Chem. Colorists, 272-8 (1940)

Color Comparison Devices.

Spectrophotometers and filter type photometers are described.

Paul, M. R.

Paint Oil & Chem. Rev. 27, No. 8, 16, 18, 20, 4J (1935)

Tolerance in Color Specification.

Different types of color standards and various instruments
are reviewed.

Perry, J.

J. Soc. Dyers & Colourists 42, 159-61 (1927)

Guild Trichromatic Colorimeter.

Instrument and uses described.

J. Sci. Instruments 15, 270-7 (1938)

The Objective Measurement of Color.

Perry, J. W.

Proc. Phys. Soc. (London) 53, 272-287 (1941)

Colors, Its Measurement, Discrimination & Specification.

Principles and tolerances discussed.

Pittsburgh Paint Production Club

American Paint J. 21, Conv. Daily 28, 30 (Nov. 17, 1936)

Standardization and Matching of Opaque Paint Colors.

A study of mechanical means of matching color standards.

Prase, Otto

Farben-Zeitung 25, 855-6 (1920)

Gradation and Meaning of Colors.

Scheme of designating colors similar to Ostwalds.

Rafée, W. G.

Science Progress 20, 662-74 (1926)

Industrial measurement of color.

Use of Lovibond Tintometer and Dewey decimal classification.

- Rawlins, F. I. J.
Tech. Studies Field Fine Arts 9, 3-10 (1940)
Tintometric Comparison of Artist's Pigments.
Color analysis of 55 pigments were carried out with the tintometer.
- Richter, Manfred
Monatsh. Seide-Kunstseide 42, 372-4 (1937)
Development of Measurement of Color During the Last Few Years.
- Rösch, S.
Z. Electrochem. 47, 18-19 (1941)
Practical Color Measurements.
Three dimensional color measuring system.
- Salmony-Karsten, A.
Z. Instruments 55, 502-4 (1935)
New Apparatus for Examining Surfaces.
Diagram and description of apparatus for plant use.
- Schofield, R. K.
J. Sci. Instruments 16, 74-80 (1939)
The Lovibond Tintometer adopted by means of the Rothamsted device to measure colors on the C.I.E. system.
- Scott, Walter M.
Textile World 79, 886-9 (1931)
Photoelectric Cell in Color Measurement.
Applicability of photoelectric cell in various color analyzers is discussed.
- Sheldon, H. H. & Gluck, M.
Amer. Dyestuff Reporter 21, 222-25 (1932)
Colorscope - Recent Developments.
Development of machines for measuring color is traced and methods of operation considered.
- Shelton, E. M. & Emerson, R. L.
Ind. Eng. Chem. Anal. Ed. 4, 248-53 (1932)
Specification of Color on Dyed Fabrics by Spectroanalysis.
A GE recording color analyser gives permanent color records.
- Stuart, A. H.
Paint Manufacture 11, 222-24, No. 11 (Nov. 1941) and 239-244, 252, No. 12 (Dec. 1941).
Paint Color Measurement.
Review of apparatus for comparison and measurement of color for the paint trade.
- Stutz, G. F. A.
J. Opt. Soc. Am. 21, 323-25 (1931)
Reflectance Measurements in the Paint Industry.

- Tenen, H. T.
Am. Dyestuff Reporter 12, 127-32 (1923)
Classifying and Measuring Color by the Ostwald Method.
- Tillard, D. L.
J. Oil Colour Chem. Assoc. 20, 149-163 (1937)
The Colorimetry of Pigments.
Pigments analyzed by means of Guild trichromatic colorimeter.
- Toussaint, René
Chimie & Industrie 21, 924-30 (1929)
Comparison of Colors.
Color matching and use of photocolorimeter.

Recherches & Inventions 16, 251-4 (1935)
Matching Colors & Measuring Fastness.
Use of Toussaint photocolorimeter.
- Trillich, Heinrich
Farben-Zeitung 29, 509-10 (1924)
Measurement of color according to Ostwald.
Color comparator using Ostwald's standards.
- U. S. Bureau of Standards
Publications by Staff for 1939-1940.
Colorimetry and Spectrophotometry.
Letter circular 628, Jan. 1941.
- Van Tussenbroek, M. J.
Chem. Weekblad 24, 270-7 (1927)
Comparative Study of Different Colorimeters.
Comparison of colorimeters and spectrophotometers.
- Vickerstaff, T.
J. Soc. Dyers & Colourists 56, 461-72 (1940)
Color Control.
Review of apparatus and methods of color measurement.
- Vickerstaff, T.
Textile Mfr. 66, 204 (1940)
Color Control by Instruments.
Use and limitations of instruments for color measurement.
- Wagner, Hans
Farben-Zeitung 26, 1505-7 (1921)
Ostwald's Color Circle in Practice.
Color circle of 12 standards gives accurate designation.
- Wales, H.
Am. Dyestuff Reporter 12, 751-5, 791-3 855-8, 863-6 (1923)
The Spectroscope and Spectrophotometer and Their Application
To Identification and Analysis of Dyes.
Construction and use of Kraus, Koenig-Martins and Hilger
wave length spectrometers.

Wallace, Geo.

Textile Colorists 52, 672-4, 676-7 (1930)

Mixing and Matching of Colors.

Application of colorscope is discussed.

Wirth, Alfred

Chem.-Ztg. 44, 737-8 (1920)

Practical significance of Ostwald's color system

Colors are identified with Ostwald's ~~norms~~ by use of an apparatus.

Witte, Martin

Chem. Fabrik 418-20, 1935

Measurement of Body Color for Practical Purposes.

Methods of Munsell and Ostwalds are compared.

Witte, Martin

Farbe u Lack 291-2, 1936

Limits to the Standardization of Pigments.

Practical systems for measuring color are discussed.

Witte, Martin

Farbe u Lack 147-8, 161-2, 1936

Measuring Color of Pigments for Practical Purposes.

Worida, J.

Proc. Acad. Sci. Amsterdam, 38, 585-9 (1935)

New Type of Colorimeter.

Description given.