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BUREAU OF STANDARDS
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Colorimetry at the National Bureau of Standards.

I.

The National Bureau of Standards has a section devoted to "Colorimetry". It deals with the establishment of color standards and the formulation of color specifications.

Mr. Ordinary American Citizen (provided he is not engaged in a business which requires the maintenance of color standards) often expresses surprise that the standardization of colors should be a matter of governmental concern - worthy of the expenditure of public funds. It may appear to him a very trivial matter - of concern only to artists, women, children and possibly to scientists who may be presumed to entertain an idle curiosity about anything and everything. If he should spend a half day, or even an hour reviewing the correspondence of the colorimetry section, his astonishment would grow by leaps and bounds, but it would be of different nature than his initial surprise. Here are some of the facts and circumstances he would learn.

He would find that manufacturers and dealers all over the country are urgently requesting and demanding the Bureau's advice and assistance in the color-grading of all sorts of materials. On the letter heads of the nation's leading manufacturers, commercial houses, and research laboratories, he would glimpse requests for color standardization of such a multitude of diverse materials that he would weary of listing them. Perhaps he would start a list which might run as follows if merely culled from the letter files as he happened to glimpse them: - glass, cheese, sugar, sirups, butter, vegetable oils, mineral oils, textiles, paper, paints, honey, raw cotton, tobacco, bricks, hardware, chocolate, inks, dyes, pyroxylin materials, teeth, flour, cotton seed meal, meat, clay, yeast, furs, leather, milk, fabrikoid, grease, cement, gypsum, blue-print paper, celluloid, enamels, glycerine, rosin, linoleum, tanning solutions, tomatoes, oleomargarine, soda ash, blood and skin. In a short time he would likely decide it would be easier to list the materials whose color did not concern anyone.

He would learn that specifying the color of illuminants and the testing and standardization of "artificial daylight", equipment was a matter of much concern in many industries. He would notice that the Bureau had developed instruments and methods for this purpose and that requests for such tests were handled in a regular routine manner.

He might notice that the Colorimetry Section had assisted both the Army and the Navy. If he went back to war time records, he would discover volumes of technical reports relating to signaling, camouflage, concealed insignia, invisible writing, searchlights, etc.

And even in peace time he would find the War Department and the Navy Department availing themselves of the technical service of this section. He would find that tests had been made for the following bureaus, divisions or services of the Army and Navy:

War Department

Air Service, McCook Field
Ordnance
General Engineer Depot
Signal Corps
Air Craft Production
Quartermaster's Department

Navy Department

New York Navy Yard
Puget Sound Navy Yard
Washington Navy Yard
Naval Hospital
Aeronautical Division
Bureau of Ordnance
Bureau of Yards and Docks
Bureau of Construction and Repair
Bureau of Steam Engineering

Turning from the military to the civil functions of the government, he would find that many branches had been served either in performing tests or furnishing advice and information. Among these would appear: - The Lighthouse service, the Weather Bureau, the Bureau of Public Roads, the Bureau of Chemistry, the Bureau of Entomology, the Bureau of Plant Industry, the Customs Service, the Post Office Department, the Public Health Service, the Bureau of Foreign and Domestic Commerce, the Interstate Commerce Commission, the Geological Survey, the Forest Service, and the Tariff Commission.

He would find that the Colorimetry Section had performed tests at the request of many applicants, among which any of the following might catch his eye:-

General Electric Company
Westinghouse Lamp Company
General Motors Export Company
Corning Glass Works
Electrical Testing Laboratories
Bausch and Lomb Optical Company
American Institute of Graphic Arts
National Association of Leather Glove and Mitten Manufacturers
American Optical Company
General Optical Company
Pennsylvania Wire Glass Company
E. I. duPont deNemours and Company
National Lead Company
Macbeth Daylighting Company

Keuffel and Esser
Sinclair Refining Company
Munsell Color Company
Garfield Memorial Hospital
United States Envelope Company
Todd Protectograph Company
Brown Company
Spencer Lens Company
Mathieson Alkali Works
Western Electric Company
American Leather Chemists Association
International Pulp Company
Calco Chemical Company
Waltham Watch Company
Pennsylvania Railroad Company
Cheney Brothers
Dennison Manufacturing Company
Cooper-Hewitt Electric Company
Leeds and Northrup Company
American Writing Paper Company
Swift and Company
National Carbon Company
Automobile Club of America
National Tracing Cloth Company

He would see copies of hundreds of letters in which technical advice and assistance relative to color and colorimetric problems had been furnished to applicants of the most diverse interests. He would notice that these applicants included, chemists, physicians, ophthalmologists, astronomers, physicists, biologists, psychologists, railway officials, refiners of oils, paint manufacturers, engineers, packing companies, paper and textile manufacturers, teachers, lithographers, chocolate manufacturers, glass manufacturers, and many others. He would notice kindly letters of appreciation and thanks for service rendered.

Among the prominent firms and organizations which had sought and obtained the Bureau's advice and assistance in colorimetric problems, he might see the following familiar names:

Bausch and Lomb Optical Company
Keuffel and Esser
American Optical Company
American Institute of Baking
Corning Glass Works
Pennsylvania Wire Glass Company
Pennsylvania Railroad
American Oil Chemists Society
Cooper-Hewitt Electric Company
Eastman Kodak Company
Sinclair Refining Company
duPont deNemours and Company
Cheney Brothers

United States Envelope Company
Acme White Lead and Color Works
New York Sugar Trade Laboratory
~~New Haven Pulp and Board Company~~
Devoe and Reynolds, Inc.
National Dairy Union
Valley City Milling Company
Dennison Manufacturing Company
Electrical Testing Laboratories
American Institute of Graphic Arts
Kraft Cheese Company
Southern Cotton Oil Company
Westinghouse Lamp Company
The Glidden Company
Pittsburgh Plate Glass Company
General Motors
National Lamp Works
Macbeth Artificial Daylighting Company
Procter and Gamble
Washburn-Crosby Company
Todd Protectograph Company
Titanium Alloy Manufacturing Company
Edison Lamp Works
American Steel Company
Macbeth-Evans Glass Company
Western Electric Company
General Optical Company
Natural Rock Asphalt Corporation
Forbes Lithograph Company
Calco Chemical Company
Davenport Locomotive Works
American Laundry Machinery Company
Sears, Roebuck and Company
Aluminum Ore Company
Brown Company
National Aniline and Chemical Company
DeZeng Standard Company
Swift and Company
American Lithographic Company
American Leather Chemists Association
General Electric Company
Champion Ignition Company
Munsell Color Company
Raven Screen Corporation
Union Petroleum Company
American Lady Corset Company
Lowe Brothers, Company
Atlantic Dyestuff Company
Welsbach Company
Thomas Nelson and Sons
Central Railway Signal Company
Union Carbide and Carbon Company
Corn Products Refining Company
Leffingwell-Ream Company

Leeds and Northrup Company
Armour and Company
Wilson and Company
Central Scientific Company
Automatic Electric Company
Monsanto Chemical Works
American Writing Paper Company
National Carbon Company
U. S. Conditioning and Testing Company
John Lucas and Company
Baltimore and Ohio Railroad Company
Kimberley-Clark Company
Cluett-Peabody and Company
Electric Arc Cutting and Welding Company
Recording and Computing Machine Company
New Haven Pulp and Board Company
Arthur D. Little Incorporated
Standard Oil Company
Standard Textile Products Company
Ozark Smelting and Mining Company
Lancaster Lens Company
Illinois Paint Works

He would notice that the commercial value of some commodities depends upon their color and that the control and specification of the color of the product is a technical problem of the first magnitude in many industries. For example, he might be impressed with the fact that the price of cotton seed oil is fixed largely by its color. He would learn that very small differences in the color of the oil means thousands of dollars between buyers and sellers in sales of cotton seed oil and that dealers in this commodity are most insistent in their demands that the Bureau make adequate standardization of the glasses which are used in color-grading the oil. He would find in progress fundamental research for the purpose of establishing permanent, universal and unquestionable standards for the service of the vegetable oil industry.

He will also discover that colorimetry has important relations with chemistry, and that these sciences are mutually helpful. Sometimes the chemist is calling on the colorimetric expert for assistance and again colorimetry is dependent on expert advice from the chemist. The very mention of the word "dye" suggests color; but the study of dyes is also a very elaborate and intricate branch of chemistry. So our visitor to the Bureau will find the divisions of optics and chemistry cooperating in the standardizing of dyes, and methods of testing their "fastness". Here he will perceive an important bearing on the textile industry.

Probably the occasion for his greatest astonishment would be the discovery that colorimetry had anything to do with his health and safety.

It would not escape his notice that there were rather frequent instances in which physicians and ophthalmologists sought information and advice of the Colorimetry Section. He might notice tests made for the Rockefeller Institute, Garfield Hospital and the United States Public Health Service. He might learn how investigators at the Mayo Clinic were studying diseases of the skin and blood by colorimetric and photometric methods. He would, perhaps, see how colorimetric research and testing at the Bureau were indirectly contributing to the success of these investigations.

He might notice that the Bureau had published and also supplied by correspondence, a great deal of scientific information relative to "eye-protective glasses" and that much of this information had been obtained by investigations carried on in the Colorimetry Section by the methods used for determining color.

He might see a small disk of yellow glass submitted for test. He would learn that it was a "Newcomer disk", used as a standard in a "hemoglobinometer" in analyses of the blood of patients in the hospital. If curious he would learn the story that some years before, a similar disk had been tested and a report issued by the Bureau. This disk had since been lost, and the new one now being tested, is submitted for test to determine whether it is a duplicate of the lost standard. This question can readily be answered by determining the "spectral transmission" of the new glass and reference to the report on the similar determination for the lost standard. He would appreciate that, by this determination of "spectral transmission" and the record of the previous determination, the Bureau was making it possible for the physician to recover his lost standard for the blood analysis.

He would learn that, in the standardization, specification, and testing of signal colors, the Bureau cooperates with the railways, the lighthouse service, and agencies dealing with street and highway traffic, in making travel safer by land and sea.

II.

Having gained some idea of the demand for colorimetry, Mr. Ordinary Citizen might be curious to learn how the demand is to be satisfied and what scientific and technical problems are involved. It is probably very mysterious to him and he wonders what the Bureau can do about it anyway. How can a color be specified or described adequately in any other way than by exhibiting a sample? If he is a curious citizen and has time, he may linger to ask questions. Here are some of the things he will find out:

Strictly speaking, color is a "sensation". For any individual observer at any given time, the color of any area or "patch" of his field of view depends upon:-

(1) The light entering his eye from that patch.

(2) The light entering his eye from other patches simultaneously present in his field of view (simultaneous contrast).

(3) The light which has entered his eye previous to the moment in question (successive contrast).

(4) The individual nature of his own color sense.

(5) His own conception of the nature of the substance or object occupying that "patch" in his field of view.

Our visitor will at once perceive that colorimetry is a very complex and intricate subject. If he is a man of insight and even some slight acquaintance with the scientific way of viewing problems, he will see that the solution of the problems of colorimetry is to be found in the borderland of physics and psychology - in the study of psychophysics, the science which deals with the relations between "stimulus" and "sensation". He will learn that abnormalities and defects of the color sense are much more frequent than he had supposed, and that colorimetry must perforce concern itself with calibrating and standardizing observers as well as instruments and materials. In fact, it will appear that much of the research in progress is directed toward the goal of establishing the characteristics of the "average normal observer".

It would be pointed out to him, however, that for certain limited purposes a simpler view may be taken of the problem of color specification. That view is that the fundamentally important thing is to specify the "stimulus" in the terms of physics. He will see that, aside from the individual peculiarities of the observer and the accidental circumstances of observation, the thing which determines the color of an object is the light which that object sends to the observer's eye. If he is interested to look about the laboratory, he will find that a great deal of apparatus is devoted to determining the stimulus of color in quantitative terms. He will find everything in readiness to measure the "spectral transmission", or the "spectral reflection" of samples submitted for test. He will find that the essence of these tests is the measurement of the percentage of light transmitted or reflected by the samples and, indeed, the measurement of this percentage for light of different "wavelengths". (A few years ago he would have stalled at this term, but in these days of radio, he will accept it as commonplace). He will learn, for example, that the color of a glass to be used in a railway signal light is specified by a curve showing percentage transmission for the different wavelengths, and he will find that the Bureau is prepared to test glasses in these terms as a regular matter of course.

But, perhaps it may occur to him that the first thing to be thought of should be the specification of the light emitted by sources of light, such as candles, electric incandescent lamps, the sun, etc. He will be shown how this has been attended to by studying the "spectral distribution of energy" and "color temperature". If he wishes to have an ordinary lamp or an "artificial daylight unit" tested, the Bureau can give him its "color temperature", i.e., the temperature which it would be necessary to heat a "blackbody" or "complete radiator" in order to make it emit light which would match the light from his lamp. He may be shown a chart of the color temperatures of all ordinary sources.

Having learned some of the things that can be done and being impressed by the apparatus, he will begin to think it is all very easy - that most any problem in colorimetry can be readily handled. It may occur to him that he has a colorimetry problem in his own business and he will want the assistance of the Bureau in solving it. Perhaps he will be disappointed at least temporarily, for it is more than likely his problem may be a very special one which has not been considered in detail before. It may be that, although the colorimetric experts can see plainly enough how to attack the problem, they can also see that it would take months of research and patient trial to obtain results that would be of practical value. Here the visitor will be given a very frank statement. It will be to the effect that, in spite of all that has been accomplished and all that is being done now, the science of colorimetry is in its infancy as compared with many other branches of the work of the Bureau of Standards. He will be told frankly that there are many instances every month in which the Bureau is quite unable to satisfy the demands which industrial, technical, and scientific interests make upon it for color standardization. He will learn that the problems which have been solved and the things which have been done are insignificant compared with the problems awaiting solution. He will learn that years more of study and research will be required to develop this subject to the stage where most of the expected demands can be met.