

The responsibility was accepted on behalf of the SMPTE by Engineering Vice-President Wintringham.

Subsequent to the meeting, K. B. Benson accepted appointment as Chairman of this Ad Hoc Committee. Invitations to appoint members to the Committee have gone to the Electronic Industries Association, the Groups on Broadcasting and on Broadcast and Television Receivers of the Institute of Electrical and Electronics Engineers, the National Association of Broadcasters,

and to the SMPTE Engineering Committees on Color, on Television, and on Video-Tape Recording. These four organizations are represented in the JCIC. In addition, invitations have been extended to the National Cable Television Association, and to the American Telephone and Telegraph Company as a common carrier responsible for long distance networking of color television programs. The Broadcast Bureau and Chief Engineer's Office of the Federal Communications Commission have been

invited to appoint observers to the Committee.

At the date this is written (September 4, 1968), each of these organizations has named its representatives to the Color Television Study Committee. (An organization meeting was held late in September and a preliminary plan-of-attack was established.) Interested persons are invited to send their suggestions to Chairman K. B. Benson at 23 Park Lane, South Norwalk, Conn. 06854.

Recent Agreements Reached by the Colorimetry Committee of the Commission Internationale de l'Eclairage Technical Notes

Note: The following is published to acquaint SMPTE members with recent decisions reached by the CIE on new standard daylight sources, new colorimetric and other terms, and a variety of revised colorimetric formulas that have been found important in present-day color technology. They are reprinted here from the *Journal of the Optical Society of America*, pp. 290-292, February 1968, by permission granted by Dr. David L. MacAdam, Editor.—*Pierre Mertz*, Chairman, SMPTE Board of Editors.

Just prior to and during the 16th Session of the Commission Internationale de l'Eclairage (CIE) held in Washington in June, 1967, the Colorimetry Committee (E-1.3.1) met and discussed a variety of acute problems in color measurement with the purpose of arriving at improved or new colorimetric standards and procedures. Much of the preparatory work of the committee is conducted by correspondence and in informal meetings between the chairman and the members located in different countries. Official meetings of the whole committee (its present roster consists of 10 experts, 14 corresponding members, and 42 consultants from 24 countries) usually take place every two years and at these meetings formal agreements are reached by the members.

The most important agreements reached at the Washington meetings may be summarized as follows:

1. CIE Document on Colorimetry

The chairman of the committee will revise his second draft of a document on colorimetry in accordance with a number of amendments agreed upon at the meeting. This document will contain all official CIE recommendations on colorimetry. The wording of the original recommendations, some of which date back to 1931, will be altered to be consistent with modern nomenclature, and in some cases, the original recommendations will be modified in content to bring them into line with present-day thinking and practice. The document will constitute the official CIE recommendations in force as of the date of publication and will supersede all previous recommendations published in the CIE Proceedings. It is anticipated that in all subsequent CIE Proceedings an official statement will be made regarding the recommendations given in the document, and, if required, amendments will be announced at that time.

Present plans call for completion of the third draft of the CIE document in January, 1968. A formal vote by letter ballot will then be taken on the document and if the committee votes in favor of it we hope that it can be published (in English, French, and German) sometime early in 1969.

Among the various amendments to the document agreed upon by the committee, the following are of particular interest:

It was agreed to change the recommendation regarding the **Standard of Reflectance**. The new recommendation reads: The perfect diffuser is recommended as the reference standard. It supersedes magnesium oxide as of 1 January 1969.

It was further agreed to amend the recommendation regarding **Illuminating and Viewing Conditions**. It may be recalled that in 1931 the recommendation specified the "45°/normal" condition, but colorimetric practice since that time has required and used also other conditions, particularly some that involve an integrating sphere. The new recommendation takes account of the developments and states that the colorimetric specifications of opaque specimens should be given so as to correspond to one of the following illuminating and viewing conditions:

45°/normal;	normal/45°
diffuse/normal;	normal/diffuse.

The recommendation gives rather detailed specifications of the angles involved in each case and angular limitations imposed on the illuminating beams and beams selected for viewing.

The Committee also agreed to include in the document new tables of the color-matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ of the **CIE 1931 standard observer** from 360 to 830 nm at 1-nm intervals. These tables were developed by interpolating and extrapolating the original 1931 tables. Some smoothing was also done. However, when the new tables are cut back to four decimal figures they agree with the original 1931 tables in all but three instances. The three discrepancies were the result of smoothing but are insignificant for all practical purposes.

2. Degree of Metamerism

The committee agreed to set up a subcommittee dealing with the specific problem of assembling data to study metameric indices. Wyszecki was asked to draft a proposal for a working program.

3. Measurement and Specification of Whiteness

The committee agreed to take a serious look at this problem of long standing and has asked Dr. Anni Berger of Germany to prepare a report on the principles involved and to recommend two or three selected formulas for study.

4. Terminology

Mr. Tonnquist of Sweden was appointed chairman of a subcommittee to study the present status of colorimetric terminology and propose, if necessary, improved terms and definitions with the aim to have them available when the CIE decides to bring out the 4th edition of the CIE Vocabulary: The 3rd edition is to be published soon.

5. Correlated Color Temperature

Jointly with the CIE committee on Color Rendering (E-1.3.2) the Colorimetry Committee agreed to study the problem of evaluation of the correlated color temperature of light sources. A subcommittee was formed with Dr. Robertson of Canada as chairman:

6. CIE Standard Daylight Sources (D)

Presently, the CIE has recommended standard daylight illuminants (D) defined by relative spectral power distributions from 300 to 830 nm. The next, a most desirable step is to develop actual artificial sources which realize the D illuminants, particularly those having correlated color temperatures 7500°K, 6500°, 5500°K. A request for relevant data and information has been sent by the chairman to all National Committees of the CIE. We hope that the material supplied by the various National Committees will aid us in specifying standard sources for colorimetric use. These specifications will include tolerance specifications which might take the form of a minimum value of color rendering index with maximum percentage deviations from the target spectral power distribution.

7. Color-Difference Formulas

In view of the great industrial importance of predicting perceived color differences from colorimetric data such as CIE tristimulus values and because the present CIE method of calculating color differences is not considered satisfactory in some important applications, the committee agreed to initiate further work on the problem and proposed the following recommendations:

It is recommended to the various National Committees that they collect data on the perceived sizes of color differences under the following conditions:

- (1) Size of color differences: 0.5 to 2.0 CIE units.
- (2) Angular subtense of field: approximately 10°.
- (3) Surround color: either white (Y_s about 90), gray (Y_s about 30), or approximately the average of the two colors being compared (realizable by using samples so large that the actual surround makes no difference in the judgments).
- (4) Angular separation of the two colors: zero.
- (5) Illumination: daylight (natural or artificial) of correlated color temperature about 6500°K, and of illuminance 1000 lm m⁻² or greater.
- (6) Selection of observers: experienced or inexperienced, but the nature and extent of the experience of each observer should be recorded.

These data on the perceived sizes of color difference should be used to check not only the formula recommended provisionally in 1964 but also three other formulas currently under consideration as improvements of the 1964 CIE formula.

1964 CIE Formula (Proc. 15th CIE Session, Vol. A, p. 113):

$$\Delta E_{CIE} = [(U_1^* - U_2^*)^2 + (V_1^* - V_2^*)^2 + (W_1^* - W_2^*)^2]^{\frac{1}{2}}$$

where:

$$\begin{aligned} W^* &= 25Y^{\frac{1}{3}} - 17, 1 \leq Y \leq 100; \\ U^* &= 13W^*(u - u_0), \text{ and } V^* = 13W^*(v - v_0), \\ u &= 4X/(X + 15Y + 3Z), v = 6Y/(X + 15Y + 3Z), \end{aligned}$$

and u_0, v_0 refers to the nominally achromatic color.

Cube-Root Formula [L. G. Glasser, A. H. McKinney, C. D. Reilly, and P. D. Schnelle, *J. Opt. Soc. Am.* **48**, 736 (1958)]. The transformation of X, Y, Z to R, G, B was proposed by Reilly at the Colorimetry Committee meeting in Vienna in 1963 as an improvement of the Adams chromatic-value formula:

$$\Delta E_{CR} = [(a_1 - a_2)^2 + (b_1 - b_2)^2 + (L_1 - L_2)^2]^{\frac{1}{2}}$$

where:

$$\begin{aligned} L &= 25.29G^{\frac{1}{3}} - 18.38, \\ a &= 106.0(R^{\frac{1}{3}} - G^{\frac{1}{3}}), \text{ and } b = 42.34(G^{\frac{1}{3}} - B^{\frac{1}{3}}), \end{aligned}$$

and:

$$\begin{aligned} R &= 1.1084X + 0.0852Y - 0.1454Z, \\ G &= -0.0010X + 1.0005Y + 0.0004Z, \\ B &= -0.0062X + 0.0394Y + 0.8192Z. \end{aligned}$$

Munsell Renotation Formula (Proposed by Judd at the Colorimetry Committee meeting in June 1967 in Washington):

$$\Delta E_{GM} = f_s \{ 2f_h C_1 C_2 [1 - \cos 3.6 (H_1 - H_2)] + (C_1 - C_2)^2 + 16(V_1 - V_2)^2 \}^{\frac{1}{2}}$$

where: $H, V,$ and C are Munsell renotation hue, value, and

chroma, respectively, $(H_1 - H_2)$ is the hue difference expressed in percent of the hue circuit; $3.6 (H_1 - H_2)$ expresses the same angle in degrees; f_h is a hue-weighting factor; f_s is a surround factor. For the surround color equal approximately to the average of the two colors being compared, $f_h = 1$, and $f_s = 3$. For a white to middle-gray surround,

$$f_h = \{ 4/[3 - \cos 3.6 (H_1 - H_2)] \}^2,$$

and

$$f_s = \frac{15 + [\bar{C}^2 + 16(\bar{V} - V_s)^2]^{\frac{1}{2}}}{5 + [\bar{C}^2 + 16(\bar{V} - V_s)^2]^{\frac{1}{2}}}$$

where: $\bar{V} = (V_1 + V_2)/2$, $\bar{C} = (C_1 + C_2)/2$, and V_s is the Munsell value of the gray or white surround. For $f_h = 1$, the formula becomes the Godlove formula [I. H. Godlove, *J. Opt. Soc. Am.* **41**, 760 (1951)]. For a white to middle-gray surround, f_h weights hue differences by twice the weight specified by the Godlove formula. The factor, f_s , expresses the reduction of perceived size of the color difference caused by use of a surround that differs in color from the average of the two colors being compared.

MacAdam-Modified Friele Formula [K. D. Chickering, *J. Opt. Soc. Am.* **57**, 537 (1967)]. The introduction of the additional parameters, K_1 and K_2 , was proposed by Chickering at the Colorimetry Committee meeting in June 1967 in Washington as an improvement on the published formula. These parameters are functions of Y :

$$\Delta E_{FC} = [(\Delta C)^2 + (\Delta L)^2]^{\frac{1}{2}},$$

where:

$$\Delta C = K_1 \Delta C_1, \text{ and } \Delta L = K_2 \Delta L_2,$$

$$\Delta C_1 = [(\Delta C_{r0}/a)^2 + (\Delta C_{yb}/b)^2]^{\frac{1}{2}}, \text{ and } \Delta L_1 = (P\Delta P + Q\Delta Q)/(P^2 + Q^2)^{\frac{1}{2}}$$

$$\Delta C_{r0} = (Q\Delta P - P\Delta Q)/(P^2 + Q^2)^{\frac{1}{2}}, \text{ and } \Delta C_{yb} = S\Delta L_1/(P^2 + Q^2)^{\frac{1}{2}} - \Delta S,$$

$$\Delta L_2 = 0.279\Delta L_1/a,$$

$$K_1 = 0.55669 + 0.049434Y - 0.82575 \cdot 10^{-3}Y^2 + 0.79172 \cdot 10^{-5}Y^3 - 0.30087 \cdot 10^{-7}Y^4,$$

$$K_2 = 0.17548 + 0.027556Y - 0.57262 \cdot 10^{-3}Y^2 + 0.63893 \cdot 10^{-5}Y^3 - 0.26731 \cdot 10^{-7}Y^4,$$

$$a^2 = 17.3 \cdot 10^{-8}(P^2 + Q^2)/[1 + 2.73P^2Q^2/(P^4 + Q^4)],$$

$$b^2 = 3.098 \cdot 10^{-4}(S^2 + 0.2015Y^2),$$

$$P = 0.724X + 0.382Y - 0.098Z,$$

$$Q = -0.48X + 1.37Y + 0.1276Z,$$

$$S = 0.686Z,$$

X, Y, Z being the tristimulus values for either of the two colors constituting the difference to be evaluated, and $\Delta P, \Delta Q, \Delta S$ being the differences between the values of $P, Q,$ and S for these two colors.

Sometime after the above recommendation was made by the committee, MacAdam (following a suggestion made by F. T. Simon) proposed, in a private communication to the chairman, simpler alternatives for the recommended polynomials K_1 and K_2 in the MacAdam-modified Friele formula. These are as follows:

$$K_1 = 0.054 + 0.46Y^{\frac{1}{2}},$$

$$K_2 = 0.465K_1 - 0.062.$$

All formal recommendations, such as that on color-difference formulas, proposed by the Committee require the approval of the CIE as a whole and before this is obtained and published in the official *CIE Proceedings*, many months go by. Thus, this can be only an informal report, prepared primarily for the benefit of those who have a keen interest in the developments of colorimetry and wish to participate actively in them, but who are not members of the Colorimetry Committee.

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Committee (E-1.3.1)