Journal of the
Colour Group
Number 2 January, 1965

Survey of Industrial Needs for Measurement of Colour

This survey has been carried out to investigate the needs of various sectors of industry for colour measurement, their particular problems and the current research and development work directed towards solving these. Some 20 Research Associations and other Research Organisations have been approached for their views. This report has been prepared by the Scientific Instrument Research Association on behalf of the Research and Development Panel of the United Kingdom Automation Council, and ediied for publication in the Journal of the Colour Group. The U.K.A.C. is indebted to the various contributors for their ready co-operation in producing very detailed statements.

The object of the report is to summarise the information obtained to present a picture of industrial needs with clarification of common problems, so that an assessment may be made of the possibility of joint action in research and development in colour measurement technology. The first part of this edited version of the report deals with the problems under general headings. Most of the problems listed in the replies to the survey were of interest to more than one of the Research Associations. The second part of the report lists the research in progress at the Associations.

A similar study has been made by an Institute of Packaging Discussion Group, and published as " The Colour Matching of Packaging Materials," Institute of Packaging Journal 10 (77) 1964,5-6.

PART 1: PROBLEMS

Existing colorimeters came in for a considerable amount of criticism. The filter-photocell spectral response is not sufficiently close to the C.I.E. functions in most instruments. This results in discrepancies between instruments of different makes and even between those of the same make. Differences in viewing geometry also give rise to discrepancies. This criticism is linked with a need for a calibration service which will provide permanent sub-standards of known colour so that differential rather than absolute measurements can be made. There is also need for further control in the preparation of magnesium oxide standards.

A further criticism was the difficulty of deriving the required parameters from the instrument readings. This applied to both the derivation of C.I.E. co-ordinates and to the figures needed for input to computers. The derivation of tolerance specifications from colorimetric measurements is particularly difficult, and there was a call for both simple methods of fixing tolerances and also for a simple explanation of the C.I.E. system. Evaluation of Uniform Colour Systems was also required.

Additional problems concerned with colorimeters were the difficulty of measuring non uniform samples, such as wood grains, and the need was also expressed for colorimeters calibrated in terms of the new C.I.E. 10/ field data.

The main interest in the specification of fluorescent colours was among the Research Associations working with near white materials containing fluorescent bleaching agent. At present there is no C.I.E. standard for an illuminant in a colorimeter suitable for measuring fluorescent colours. Allied to this requirement was the need for an agreed method of measuring " whiteness." One-dimensional colour scales were also required in association with ageing tests. Research Associations dealing with natural materials were particularly interested in this problem.

The application of colorimetric measurements to formulation is linked to the derivation of suitable parameters from the instrument readings. The need to predict a colour match is importantin many industries in addition to the Paint and Dye Industries where considerable research has already been carried out. Metameric colour matches introduce special problems.

PART 2: RESEARCH IN PROGRESS

The Glass Industry Research Association is working on instrumental methods of measurement of colourlessness of glass and making tests on the Colormaster colorimeter.

The Ceramic Research Association is making an assessment of colorimeters for use in the Ceramic Industry. They are including the Colormaster, the Hilger 740 and the Colorcord and are using crystal glasses and pastel wall tiles as samples. (These samples are available to any interested laboratory.) The application of the Colormaster to batch-matching of glazes and to research into causes of colour variation in ceramic bodies and glazes is being investigated. Work on visual assessment of colour includes the comparison of the colour differences readily identifiable with those which can be reliably measured. Specifications of tolerances and the colour rendering properties of lamps are also being investigated. Future research will include measurement of metameric colours and measurement of whiteness. It is also

hoped to establish colour standards. If permanent standards can be made these may be of interest to many other industries.

The Rubber and Plastics Research Association is correlating accelerated tests using the Xenotest with normal service ageing.

The reply from *The Leather Manufacturers Research Association* said that the Colour Committee of the Society of Leather Trades Chemists is considering a revision of the system suggested by Wyszecki at the 1963 C.I.E. Conference in connection with an official test method for determination of colour tolerances.

The Wool Industries Research Association is connected with the proposal by the, Society of Dyers and Colourists to consider problems of evaluation of different instruments and techniques.

The Hosiery and Allied Trades Research Association is carrying out research on the colour measurement of knitted fabrics.

The Launderers Research Association is developing a simple battery-operated portable reflectometer.

Imperial Chemical Industries have carried out a considerable amount of research over a number of years on colour measurement techniques and their correlation with visual discrimination, on the specification of parameters and the accuracy of the match attainable. Much of the work has been directed towards the setting up of the Instrumental Match Prediction service to dyers which allows a dyer to send in C.I.E. co-ordinates of a sample and to have computed the recipe for a match to the sample.

Recent work by *The Printing, Packaging and Allied Trades Research Association* has included a comparison of the results given by different colorimeters under industrial conditions and also the effect of the optical geometry of a reflectometer on the measurements obtained. The Association has recently published a description of a simple transmission measuring instrument which can be built and used in schools. Surveys have been made of the factors to be taken into account when assessing primary colours for three-colour subtractive reproduction processes and of methods of measuring whiteness.

A literature survey on measurements of colour of wood is being prepared by *The Furniture Industry Research Association*. They are using colour measurements in connection with ageing tests and also working on the problem of making measurements on non-uniform colours.

The main recent work by *The Paint, Colour and Varnish Manufacturers Research Association* is on the instrumental formulation of mixtures of pigments or tinting pastes. At present they are working with a Davidson and Hemmendinger Colorant Mixture Computer. They are also studying the application of analogue and digital methods to colour formulation. (Digital methods are more suitable for working from colorimetric measurements while analogue methods can produce a non-metameric match.) Future work at the Paint Research Station will include a study of the effects of variation in the type of medium, the effect of dispersion of the pigment on colour strength and the extension of the colourmatching theory to partly transparent films, such as printing inks.

The Technical Optics Department of *Imperial College* under Professor W. D.

Wright listed the following research projects already carried out or in progress:—

(i) The development of a tristimulus colorimeter using spectrum templates instead of filters.

(ii) The development of a differential spectrophotometer.

(iii) The development of a visual differential colorimeter.

(iv) The calibration of a series of grey tiles and an inter-laboratory comparison of these.

Future work is likely to include an extension of the calibration of the grey tiles to a study of matt grey and coloured tiles and their use as sub-standards.

The *National Physical Laboratory* also has several projects in their current research programme : —

(i) Measurement of absolute spectral luminance factor of primary standard surfaces of the highest possible permanence and also of secondary standard surfaces for industrial use.

(ii) To increase by a factor of at least 10 the accuracy of spectrophotometry by the use of time-ratio photometry and by the building of a high precision double monocromator of suitable design.

(iii) A close investigation of the visual factors involved in setting up the colour matching functions to define a mean standard observer; this involves particular difficulties with large fields of view.

(iv) Design of a prototype template colorimeter for commercial production.

(v) The study of variation of differential colour sensitivity with luminance and adaptation and other aspects of subjective colour measurement.

The N.P.L. also pointed out that a very considerable amount of work has been carried out over the last few years on the colour rendering properties of light sources and the associated problems of visual tolerance.

Reports of Science Meetings by the Secretary

DAYLIGHT

The twentieth Science meeting was held at Imperial College, London, on May 20th, 1964, and consisted of a lecture given by Dr. G. Wyszecki, of the National Research Council of Canada, who was on a visit to this country. The subject, " The Spectral Distribution of Typical Daylight as a Function of Correlated Colour Temperature," was one in which Dr. Wyszecki had personally taken an active part.

After reminding the meeting of the shortcomings of the International Sources B and C as representations of daylight—low illumination levels, insufficient ultraviolet content and the inconvenience of liquid filters— Dr. Wyszecki described the recent measurements of the spectral quality of various phases of daylight carried out by Budde in Canada, Condit in U.S.A. and Henderson in England. All these data had been collected together and represented the spectral curves of 622 samples of daylight. This set of curves had been subjected to eigenvector analysis and it had been found possible to characterise the complete set by

only two eigenvectors in addition to the average curve. Thus if E_λ and $\underline{E}_\lambda$ were the individual and the average spectral distribution curves and $V_{1\lambda}$ and V_2 were the eigenvectors with scalar multiples M_1 and M_2 then

$$E_\lambda = E_\lambda + M_1V_{1\lambda} + M_2V_{2\lambda}$$

In explaining the principles of eigenvector analysis the lecturer pointed out that the small number of eigenvectors required indicated a high degree of correlation between the individual curves of the set.

A second analysis of the set of spectral curves showed that the chromaticities derived from them all lay on a curve parallel to but slightly on the green side of the Black Body locus.

Isotemperature lines from the Black Body locus such as those computed by Kelly may then be used to find the correlated colour temperature of points on the daylight curve.

Finally Dr. Wyszecki explained that there was a direct relationship between the scalar multiples of the eigenvectors describing a particular phase of daylight and the chromaticity co-ordinates of the daylight.

A report of this work by Judd, Mac-Adam and Wyszecki was published in J. Opt. Soc. Amer. 54 (8), August 1964, 1031-1040.

During the discussion the following points were made :—

1 The use of co-ordinate axes along the Black Body locus and the isotemperature lines would probably not be a simplification since the Vector loci are straight lines on the present diagram.

2. The correlated colour temperature of the mean spectral distribution is about 6,500/ K.

3 The data presented show more ultraviolet content and a greener colour than Source C.

4 A third eigenvector (V3) might be capable of giving the U.V. variation in daylight which is to some extent independent of the visual colour. The variation of the relative content of U.V. in various phases of daylight was about 2: 1.

5 The eigenvector analysis of the logarithm of the daylight curves might give vectors which when reconverted to energy units were multiplicative instead of additive. These would be much more useful when considering the filters necessary to reproduce phases of daylight. It was emphasised, however, that the analysis assumes a normal distribution of the family of curves which may not be true for log curves.

At the end of the meeting there was some discussion of the disagreements which had arisen between representatives of America and Britain on the 10/ field data presented to the C.I.E. at Vienna in 1963. Dr. F. J. J. Clarke reported that in conversations with Dr. Wyszecki during his visit the disagreements had been reduced to matters of fact which would be answered by a new set of field trials which had been proposed. Dr. Wyszecki explained that the new trials would be based on new calibrations of the Donaldson colorimeter using new spectro-radiometric techniques which enable calibration in situ.

PHOTOGRAPHY

At the 21st Science Meeting of the Group, held on October 7th, 1964, Dr. J. E. Pinney,

of the Eastman Kodak Company, addressed the Group on " Computational Colour Photography."

In describing his work Dr. Pinney said that the main bases for forecasting the results to be expected from a specific colour photographic process had been laid down by Evans, Hanson and Brewer in their book, " Principles of Color Photography " (Wiley, 1953). Each stage of the process was analysed separately and its properties described mathematically. It was then possible by computation to synthesise the results to be expected from the process as a whole.

The process could be broken down into the following stages: properties of object colours, spectral sensitivities of the layers, interimage effects during development, basic sensitometric properties and finally properties of the dye systems used for the final reproduction. Dr. Pinney emphasised the difficulties of the second and third stages, the latter being capable of only incomplete mathematical treatment as yet. In the examination of the dye systems the process was set up mathematically to give good reproduction of one standard object colour and the resulting reproduction of other common colours was computed.

TEACHING METHODS

The second part of the October meeting was a demonstration of " Colour Teaching Methods ' by Miss M. Hayward, Miss A. M. Mitchell and Mr. D. A. Pavey, of Hayward, Mitchell and Pavey, Ltd., colour consultants.

The demonstration included examples of films and film-strips, and also the use of the overhead projector.

TELEVISION

The 22nd Science Meeting of the Group was held on November 4th, 1964.

Mr. K. Hacking, of the B.B.C. Research Department, Kingswood Warren, described his work on " The Relative Visibilities of Spatial Variations in Luminance and Chromaticity " which was directed towards a better understanding of the requirements in colour television. He reminded the audience of the work on the constant luminance principle which had been done using noise signals on a colour television tube. His own approach was, however, to present either luminance or chromaticity variations as pure sinusoidal spatial patterns and to determine the visual threshold under various conditions. The apparatus was a purely optical one in which light from two sources of light with different colour filters in front of them passed through a sinusoidal grating to produce a pattern on a screen. Suitable adjustments of distances could give patterns in or out of phase from the two sources; in the former case giving luminance changes with constant chromaticity and in the latter chromaticity changes at constant luminance. A method was available to vary the contrast of the resultant patterns continuously so that visual threshold values could be measured.

The general conclusion reached was that in progressing from threshold to super-threshold the rate of change of chromaticity perceptability was greater than that for luminance.

COLORIMETRY

The second paper in the November meeting was given by Mr. A. R. Robertson, of Imperial College, on " High Accuracy Colorimetry,"

An account was given of the international intercomparison of spectrophotometric and colorimetric measuring instruments using a series of four grey ceramic tiles.

The effects of differences in the magnesium oxide standards, the measurement systems in the instruments, and the properties of the grey tiles themselves were discussed at some length. It was concluded that accuracy was not as high as was needed for many purposes, and that improved working standards, in place of magnesium oxide, would lead to considerable improvement in accuracy.

Who Needs to Know What About Colour

M. Hayward, A. M. Mitchell and D. A. Davey

Many members of the Colour Croup are concerned with producing accuracy and quality of colour for some commercial purpose at a distance from the point of sale. More directly concerned with marketing are all sorts of other people: manufacturers, technologists, designers, wholesale and retail buyers, advertising and display people and various types of salesman. How much do they know about colour and how much do they need to know? This is far too big a question to answer without research, but we can make some observations from our own experience.

First, the technologists who deal with such matters as the fastness to light of the dyestuffs required, the ability to determine a finished colour effect from colourless raw materials, or the problems of batch matching: the basic scientific knowledge they need is acquired at university or technical college, but the extent to which colour is included will vary from one institution to another. When they come to build up a specialist knowledge in their own industry they will find mechanical aids available for measuring, checking and formulating colour. All the same they have to learn to take into account their own subjective response to colour and other people's, whether this means reckoning with a colleague's personal reactions or the tendency of the public to like colours which are brighter than life, as in colour photography. Further, they need to be able to describe the results they get in terms understandable to employer or customer. They meet the problem of identifying colours in words which runs right through industry and commerce.

The designers bring to their work what they have learnt of colour at an art school and also their intuitive capacity for handling colours. Their intuitive knowledge may be great, that is to say they may have a seeing eye and an innate understanding of the way in which colours can be manipulated to obtain a desired effect. This may have been developed by their training, but the amount of direct teaching about colour at art schools varies and we know of no art school in this country where colour is regularly treated as an area of study in itself. Plainly a designer must know enough of the technology of the industry in which he works not to specify technically unsuitable colours, and this he learns from training and experience. However, sometimes he may ask the research side to produce a colour or colour effect previously unobtainable in the material specified. More important in some

ways is his knowledge of the requirements of the market for which he is designing, and this comes to him in greater or less degree from the marketing side of the organisation he works for. Colours often need to be forecast months or even years ahead, and any expertise in forecasting colour trends which he can acquire for himself may be very useful.

These are generalisations — and about manufacturers it is specially difficult to generalise, having regard to the diversified nature of British industry, the number of small units even in these days of mergers, and the varying forms of organisation. However, the plain fact is that anything which any manufacturer sells has colour. Some things are sold in such a range of colours that one can only marvel at the stocking problems which must ensue. If the manufacturer is in one of the major colour-using industries such as textiles, plastics, paint or floor-coverings, he may well employ colourists as well as other technologists. Elsewhere he may give little serious attention to colour even though it is of great importance in his marketing. If he does think about it he may make his own exploration of the subject or call in consultants. If, lacking expert help, he is ever at a loss to decide upon colours it is with good reason : public colour preferences are forever changing, and the reasons for individual choice lie in hitherto uncharted realms of psychology. They are usually emotional reasons, expressed by people who may not know that some colours are mixtures of other colours or that colour has anything to do with light, but do know that for their own purposes some colours are attractive and some not to be tolerated.

If the manufacturer is not selling direct to the public there are such intermediaries as wholesalers and retailers. What their buyers need to know about colour is which colours will sell at a fairly precise time. They need to know fashion trends and they may also build up a knowledge of those colours which continue in demand, in season and out, in their own line of business. But they must be ready for change. At present, for example, the leadership in trend-setting in the clothing trades is changing hands, and we may see the day when the public buys with much greater understanding of what suits the individual personality, within a general trend.

People with a special need for colour knowledge are those in advertising and display work who use colour deliberately to convey an attractive impression of the goods they publicise. If they have had an art training this should have given them the necessary understanding of the relations between colours, both as surface colours and in terms of light, plus the ability to marshal colours into a total effect, creating accents where appropriate. But they will have to gather their own knowledge of colour trends, and their use of colour psychology, which would seem fundamental, can only be personal and eclectic.

The work of everybody so far mentioned will stand or fall at the point of sale. The salesman has to know enough about colour to talk about it convincingly and correctly, making use of it as an important selling factor. The retail salesman of furnishing or fashion goods will clearly need to know more about colour than some other salesmen. In our viewhe needs to know the main facts of colour classification and how to select " something to go with " a particular colour; and at least to be aware of

the effects on colour of different kinds of lighting. These things he learns almost entirely on the job, if it is in him to do so, putting them into practice in on-the-spot interpretations of customers' requirements.

Few of the people we have mentioned will, if they want to learn more about colour for their own purposes, find it easy to do so. Knowing this, we are trying to bring together information about colour from art, science and psychology, to relate it to practice in such spheres as interior decoration, fashion marketing and retail distribution, and to make the results available in acceptable form. We have studied the factors which make up human responses to colour based on feeling and sensation, and we have to keep abreast of trends and events to recognise the changes in mass attitudes to colour which reflect social change—which, for example, make it impossible to sell a product in a particular colour one year and easily possible the next. But what our brief survey would seem to suggest is lacking is a research project to determine more exactly " Who needs to know what about colour in industry and commerce." Is this, we wonder, something which the Colour Group would consider?

Physics Exhibition

The Colour Group has accepted an invitation to exhibit at the 1965 Physics Exhibition, to be held in the Renolds Building of the Manchester College of Science and Technology from April 5th to 8th. The theme chosen is " Recent International Recommendations in Colonmetry," based on the decisions of the C.I.E. Committee E-1.3.1 (Vienna, 1963). The exhibits will introduce the basis for new standard sources, colour matching functions for a 10/ field, and a three-dimensional uniform spacing co-ordinate system.

DIN Atlas

The Colour Group has been presented with a copy of the DIN Farbenkarte (DIN 6164) by Professor Manfred Richter of the Fachnormenausschuss Farbe, Berlin.

The DIN colour atlas, which supplements the original gelatine colour standards, contains 585 matt-surface detachable cardboard chips, arranged in 25 separate folders, all housed in a well-padded plastic case and accompanied by a great deal of graphic and numerical data, including Munsell renotation values for each colour, conversion tables to and from the C.I.E. system, and a slide rule for reckoning colour differences.

The atlas itself is very well produced, and designed foil ease in handling. The smoothness of progression of the colour series is very evident, showing the great care that has been taken to match the samples to the required colorimetric specifications.

Ultimately the usefulness of the atlas will not depend on the excellence of manufacture but on the appropriateness of the system on which it is based; in other words, on the thinking that has gone into it. In many ways the DIN system seems to be an Ostwald derivative; the number of steps in the hue circuit (24) and the order in which they are taken (yellow, red, blue, green), the logarithmic basis of the grey scale, the way that the colour solid has been

built up from the outer limits towards the centre, the use of " shadow series " and, most fundamental of all, the fact that the system is presented as a set of standard colours to be copied by manufacturers, rather than as a means of describing simply and accurately any colour one may happen to have or want.

But Richter has been to a great deal of trouble to improve on Ostwald and remove the anomalies. The hue steps are much more nearly equal, since the requirement that additive complementariesmust come opposite has been abandoned. Constant hue series, however, are not represented, and each chart shows samples with the same dominant wavelength; some variation in hue is noticeable (especially in oranges and reds 4, 5, 6 and 7, and in blues 15 and 16) even with the small range of saturation covered. The grey scale (on the 25th chart) has been fixed at ten steps from 0 (white) to 10 (absolute black), of which 16 half-steps (from 0.5 to 8.0) are shown; the spacing is more even than Ostwald's, though still decreases towards the dark end.

The colour solid now used (Luther-Nyberg) is based on the maximum theoretical limits for reflecting surfaces—similar to the MacAdam limits but plotted in X, Y, Z space instead of x, y, Y space. Thus the " shadow series," or lines of constant chromaticity, converge on the black point, giving smaller steps between the darker samples, though the saturation steps have been chosen to be visually equal at any one level of constant darkness. Levels of constant darkness, however, are not the same as levels of constant lightness, since they remain parallel to the upper surface of the colour solid; that is to say, horizontal series in the DIN charts get darker as the saturation increases, and at a steeper rate in some hues (e.g., blues) than in others (e.g., yellows). The absence of constant lightness levels in the DIN atlas is the most obvious difference from the Munsell charts, and may prove to be its biggest drawback in practical use, as far as the design of the system is concerned. Graphs for each hue, plotting loci of saturation and darkness-degree in a framework of lightness against " colourfulness " (Buntmoment, much the same as Munsell chroma), help to overcome this difficulty, but if lightness plays an important part in the specification, a good deal of work on the tables will be needed.

Academically, this is a fascinating product, the result of years of detailed work on the part of Professor Richter and his colleagues, and well worth study. Practically, one suspects that its greatest value in this country will lie with those who need to work to German colour specifications. R. W. BROCKLEBANK.

Printed by the Woodbridge Press Ltd.. Onslow Street. Guildford, and published by The Colour Group (Great Britain), Institute of Optthalmology, Judd Street. London. W.C.I.