# Overview

The evaluation of appearance is as broadly based as any subject addressed by ASTM, being applicable to practically every raw material and finished product. While the major focus is on the production of consumer items that must have acceptable appearance as to color and gloss, appearance evaluation is also used with many nonconsumer products. For example, air contamination is graded by the appearance of filters, while contaminants in liquids is judged both by the appearance of filters and of the product itself.

Color is frequently an indicator of some important attribute of a product or material. Many medical laboratory tests are color-related. Color is a critical factor in the assessment of disease or of maturity in numerous agricultural products. The color of skin or tissue is closely related to health in humans and animals. The efficacy of suntanning products is evaluated by color, whether they purport to promote tanning or prevent it. A color test kit tells us if our swimming pool water has been adequately treated.

The industrial and commercial evaluation of appearance is both visual and instrumental. The unaided eye of an experienced observer is a widely used instrument for making color and gloss decisions, especially where photoelectric instruments are not feasible because of cost or portability. Augmenting the eye with material color and gloss standards, or with sets of standards that define acceptable tolerances, greatly improves such visual assessments. ASTM recognizes the value of visual judgments and provides, in ASTM Practice for Visual Evaluation of Color Difference of Opaque Materials (D 1729), guidelines for making such judgments.

Color and gloss measuring instruments continue to be improved in accuracy, precision, and their ability to handle a greater diversity of materials. As our understanding of color vision and visual color space increases, we are able to specify color order systems based upon uniform color scales; the same is now becoming true for visual gloss scales. The capability of instruments, using onboard computers, to transform their responses into these visual color order systems simplifies the setting of acceptability tolerances for product color. This leads to the automatic correction of colorant input and mixture to insure that acceptability is maintained throughout the production run.

Still, with all of our new knowledge, certain aspects of visual perception are not completely understood. Because instruments do only what we tell them to do, further advances in our understanding of perception are necessary before instruments can be designed to address some continuing problems. This STP

may be viewed as the third in a series of ASTM publications designed to provide the reader with a basic knowledge of the specification and evaluation of various appearance phenomena, along with examples of specific application of this knowledge to real-world appearance problems. The first was *Sensory Evaluation of Appearance of Materials, STP 545*, published in 1973. A compilation published in 1984 *ASTM Standards on Color and Appearance Measurement*, references 108 general appearance standards, and actually includes 34 of them. In addition, there are many other ASTM standards that address very specific examples of appearance evaluation that are not of general interest.

Continuing progress in the evaluation of appearance involves both visual and instrumental methods. No matter how sophisticated our instrumental methods become, we are always cautioned to never fail to "look at it." The eye of the skilled observer is unsurpassed for many appearance tasks, and correlates very well with the opinion of the ultimate inspector, the consumer. Progress in technology allows us to continually improve our assessment of traditional materials, while the emergence of new materials (for example, fluorescents and retroreflectors) present challenges to devise ways to deal with new and unusual optical characteristics.

The purpose of this volume is to present the fundamentals of the science of appearance measurement, along with recent research dealing with basic problems that impact upon a broad range of color and gloss specification and measurement efforts. Coupled with this broad-based review and update are papers describing recent applications of both old and new technology to appearance problems in science, industry, and the arts. While the applications cited will be useful to a limited number of readers, the papers describing appearance fundamentals should be of interest to everyone concerned with these broader, more comprehensive matters.

The lead-off paper by Hunter is an all too brief summary of the basic facts of color and gloss evaluation. Many books have been written on this subject, one of the best being by this same author who shares with us his more than 50 years of experience in this field. His comprehensive understanding of the psychophysical aspects of the subject have resulted in the design of many of the workhorse instruments in use today: colorimeters, spectrophotometers, and glossmeters. A knowledge of the interaction of color and gloss is basic to visual and instrumental evaluation. This paper presents it in summary form and allows the reader to determine the direction of further study.

A large part of industrial color work revolves around the specification of color tolerances. How closely should a color match its specification? This question is asked during the design and manufacture of every consumer product and of many others as well. Its answer should result in a product appearance that satisfies the buyer, produced at a cost acceptable to the seller. Robertson has been in the forefront of this work as chairman of the Committee on Color Difference Evaluation of the International Commission on Illu-

mination (CIE), the international body that sets standards in the light and color fields. Such ASTM standards as Methods for Instrumental Evaluation of Color Differences of Opaque Materials (D 2244) and Recommended Practice for Selecting and Defining and Color Gloss Tolerances of Opaque Materials for Evaluating Appearance (D 3134) implement the findings of this and similar committees. Color difference specification and evaluation operate within the field of color order systems. Robertson describes how the several attributes of such systems can be treated mathematically to bring some order to color difference and color tolerance work and shows that we still have a long way to go to bring this order.

Cowan's paper explores the relationship between luminance and perceived brightness. As he discusses the many parameters of this subject one can appreciate its complexity. While Cowan limits his treatise to the theoretical aspects of the matter, there are many important practical concerns relating to the quick and accurate perception of brightness in such critical areas as signals on aircraft instrument consoles and in a variety of military applications where zero error is practically mandatory. A great deal of research continues to be done in this field, and we are gradually increasing our knowledge of this critical relationship.

The complex field of specular reflectance, or gloss, is the subject of the paper by O'Donnell and Billmeyer. Gloss is separated into its many aspects, each are defined, and scales displaying equal visual intervals are derived for each. Just as visual scales for color are important to the work described by Robertson, visual gloss scales are needed to adequately describe gloss differences and to prescribe gloss tolerances. The fundamental ASTM method for gloss measurement is ASTM Test Method for Specular Gloss (D 523), originally approved in 1939; the present work on psychometric gloss scaling represents a major contribution to the work begun so long ago.

In the second part of this volume are reports of specific applications of color technology to industrial and agricultural situations. The last paper describes the modification of a very old color mixture technique to color representation, which could be very useful in the design field. Even though the specific subject matter may be outside the area of interest of a particular reader, the way that color technology has been applied to these problems may have useful ramifications in other areas.

The successful application of instrumental measurements to materials depends upon making the measurements under a regimen that duplicates as nearly as possible the actual use situation. This frequently means that the instrument must have illuminating and viewing geometry and observer conditions identical to some specific combination of light source, object, and human observer. When the product has unusual optical characteristics, this identity of conditions may be of particular importance. Johnson is a specialist in the measurement of retroreflective materials used in highway signs. In his paper he discusses a sophisticated approach to the assessment of the optical

characteristics of this unique material which, as its efficiency is improved, provides a continuing challenge to make the accurate measurements needed to employ it to its full potential for safety purposes.

The report by Jungman et al on color measurement of food involves some current applications of this very old subject. Fruits and vegetables are bought and sold on the basis of color, among other attributes. Color is not only related to consumer preference, but also to disease, maturity, and other factors. Color standards for food products are included in the regulations of many nations as a method of policing the market. Several states (California and Florida) also publish such rules. Government inspectors enforce marketing orders between buyers and sellers, insuring that color and other appearance standards are met. Color is an important marketing factor in the textile industry, and color quality control is basic to a fabric dyeing operation. Hauch describes how colorimetric analysis can be substituted for more expensive and time-consuming analytical methods. The highly competitive nature of this industry, world-wide, continues to inspire research projects resulting in more economical methodology. Safety is also the focus of Cohn's paper on the appearance of escalator treads, and how such appearance can be modified to reduce accidents caused by the visual illusions created by the moving treads. This is a completely different type of appearance evaluation than discussed elsewhere in this volume, and emphasizes the human engineering approach.

The designer faced with the problem of selecting colors for a package or product needs the widest selection of color samples he can find. He often utilizes very expensive collections of color standards and still wishes for more. DeGroff describes how the century-old Maxwell disk-mixture device has been automated to permit the operator to see, under different light sources, an unlimited variety of colors, selected by the operator. Not only can the colors be seen, but they also can be specified in technical terms and communicated to others, whether they also posses the color simulator or not. The designer with 500 or 1000 colors knows he wants more; now that he has millions at his fingertips he can concentrate on how best to use them. Are there other important applications for this million-color generator?

Discussions of theory and fact, delineation of general principles, and product specific applications all generate ideas that may be pertinent to a problem at hand. We hope this book will, for the novice, serve as an introduction to this very interesting subject of appearance evaluation. Those already working in this field will find the new material timely and worthwhile. Committee E-12 on Appearance of Materials hopes to hold future symposia to report further advances in the state-of-the-art.

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