PRECISION Though Indefinite

ROBERT J. HUDAK

The Optical Society's Standards Committee is trying to bring useful information on optical standards to the OSA membership. This article is part of the committee's information program. One of the most difficult problems faced by the optics industry is how to specify the visual appearance of optical surfaces. There are many customers who do not believe the old adage that "optics are to be looked through, not at." For these people and also for those who have applications for which surface defects *are* important, there is now an ANSI Standard PH3.617 on the visual appearance of optics. Bob Hudak of Eastman Kodak Company; the author of the following article, was chairperson of the committee that drafted the standard. In his article, Bob describes the philosophy of the standard and tells how to apply it. If you have any comments about the article or about the standard, Bob asks that you direct them to the National Association of Photographic Manufacturers.

Jean M. Bennett
Chairperson, OSA Standards Committee

The American National Standards Institute has published a standard on appearance imperfections in optics. The title of the standard is *Definitions, Methods of Testing, and Specifications for Appearance Imperfections of Optical Elements and Assemblies.* Its designation is ANSI PH3.617. Its purpose is to standardize both objective and subjective methods for the evaluation of macro defects under a variety of illumination and viewing conditions. The emphasis of this standard is solely on the appearance of imperfections. It does not deal with their functional effects.

To devise a standard that defines a quantitative approach, for example, the degree of fit of a nut and a bolt, is often difficult enough. To devise a standard that defines a qualitative approach also has its challenges, i.e., does the scratch on this lens surface exceed the designer's specification? The question can become an economically important one and is often the subject of discussion and debate between vendor and customer. Clouding the issue are the uncomfortable changes that often occur when scratches and some other imperfections appear because of changes in illumination and viewing conditions. It has been suggested that any standard attempting to deal with such a moving target ought to be subtitled *How to be Precise When You Can't be Definite.*

ANSI PH3.617 was promulgated by people concerned with photographic optics. Its principles are applicable, however, to other

The author is with the Eastman Kodak Company, 343 State Street, Rochester, New York 14650.

optics in which the evaluation and effects of visual imperfections are important.

Scratches and digs can be created quite easily and are common artifacts in optical elements and systems. In recognition of these omnipresent defects, Frankford Arsenal, before World War II, offered the industry a series of scratches and digs for use as comparison standards for visually judging these imperfections. These "scratch and dig boxes" went a long way then—and they do now—toward communicating specifications between engineering and manufacturing, between manufacturing and quality control, between buyer and seller. Official scratches and digs are now supplied by ARMCOM, Rock Island, Illinois, by AARADCOM, Dover, New Jersey, and, subject to calibration, by some optics manufacturers.

Owning scratch and dig boxes is a necessary first step in the business of specifying and evaluating imperfections in optics. More than that is needed, however. Although the visual impact of a dig is quite directly related to its actual size, the impact of a scratch is not. Numbers on the dig boxes associated with the graded digs indicate the diameters of the digs. The appearance of a scratch is a function not only of its width but of its depth and the nature of its profile. The numbers on the scratch boxes do not directly indicate the widths of the graded scratches.

Visual comparison of scratches and digs with the standard boxes is widely practiced in the optics industry. PH3.617 retains this basic method and adds standard conditions for inspecting optical elements and assemblies for these defects. In addition, the standard provides other methods of inspection, using a "just-visible" criterion for other imperfections for which no standard comparisons are available. Further, PH3.617 offers a way of specifying imperfections, whether they can be quantitatively evaluated or must be visually inspected and classified.

This American National Standard was created by Subcommittee PH3-5, which is sponsored by National Association of Photographic Manufacturers. The task that PH3-5 undertook at the outset of its work was not an easy one. These were some of the questions the subcommittee faced:

- Which appearance imperfections should be included?
- Which imperfections can be measured and which ones must be visually evaluated?
- Subjective evaluations, especially, are influenced by inspection conditions. What are the conditions? Can they be controlled and standardized?
- How shall imperfections be specified? Can the same system of specifications be applied both to imperfections that can be measured and to those that must be subjectively evaluated?
- A larger number of smaller imperfections can be visually as important as a smaller number of larger imperfections. Can correlation be established between larger imperfections and a subdivision into an equivalent number of smaller ones?

These questions were resolved in PH3.617 with the following conclusions:

- Which imperfections should be included? Thirty-four are listed and described. Most of them are common to glass and to plastic optical elements. Two are specific to molded elements. Several are specific to optical assemblies.

Imperfections are classified into four groups, each identified by a code letter. They are long (L), round (R), edge (E), and area (A) imperfections.

- Which imperfections can be measured and which can be judged only visually? Round and edge imperfections can, in general, be measured. For convenience, the standard also permits visual judging of round and edge imperfections in comparison with the imperfections contained in the standard dig box.

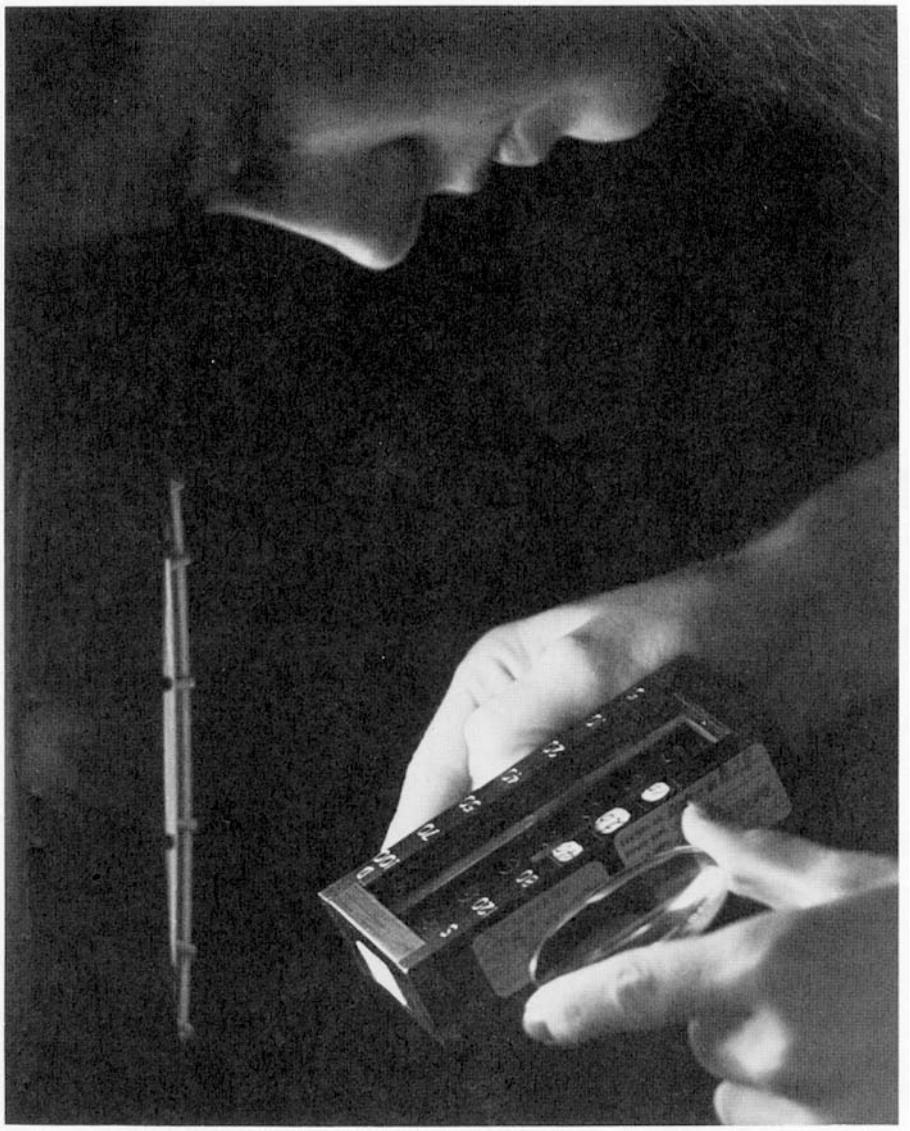
Long and area imperfections can be judged only visually.

- Can inspection conditions be standardized? PH3 defines four illumination conditions: direct light, transmitted (DLT); extended source, transmitted light (EST); reflected specular light source (RSL); and low light level source (LLS). For each kind of illumination the type of light source and its surrounding conditions are described.

Viewing conditions are described: unaided eye, aided eye, magnification to be used.

Inspection methods are defined. The numbers assigned to the scratch box do not represent measured quantities but are related to the apparent intensity of the standard long imperfection. Long imperfections can be judged visually in two ways, by comparison with the scratch box (the EST or the RSL light source is required for this inspection) or by visibility. The visibility method classifies the apparent widths of long imperfections in transmitted or reflected light as a function of the conditions under which the imperfections are just visible. PH3.617 carries a table listing visibility conditions for long imperfections ranging from hairline to extremely coarse.

Round imperfections can generally be measured or, as with long imperfections, can be visually compared under a specified illumination with the standards of the dig box. The numbers assigned to the dig boxes represent diameters of the standard round imperfection in hundredths of a millimeter. Imperfections that are not round are considered as having a diameter half the sum of the length and width. The evaluation of edge imperfections is treated in a similar manner.



Scratch-and-dig defects on a lens surface compared with calibrated standards.

PH3.617 identifies three categories of area imperfections: grayness (G); stain (S), including polishing burn and orange peel stain; other (O) including striae, ripple, and mold marks. Area imperfections are classified by the minimum visibility method.

A typical specification according to PH3.617 might look like this:

L	3 × 80 × 10

The imperfection being specified is a long imperfection (L). Three imperfections are permitted, each no longer than the number 80 of the scratch box and each having a maximum permissible length of 10 mm. EST illumination is required by the standard when the scratch box is used for comparison.

PH3.617 permits subdivision of a long imperfection into equivalent smaller imperfections. The requirement for conversion is that the product of the specification values ($3 \times 80 \times 10 = 2400$) shall not be exceeded. For example, six scratches of number 40 weight, each of 10-mm maximum length, combine also to a product of 2400 ($6 \times 40 \times 10 = 2400$) and are thus equivalent to the specification. So is $6 \times 20 \times 20 = 2400$ or a combination with a sum of products totaling 2400, such as $(4 \times 80 \times 5) + (8 \times 10 \times 10) = 2400$.

Other types of imperfections and inspection procedures are specified in a way similar to the example given above. A more extensive specification is the following, relating to evaluation of imperfections by the visibility method:

A	(30)G-EL	S-L	O-L	+	G-M	S-M	O-M

Translation: This is a specification for area imperfections (A).

A central zone of 30-mm diameter (30) shall have only extremely light (EL) grayness (G) just visible when viewed at 10× magnification under any of the types of illumination described in this standard. Stain types of imperfections (S) and other types (O) shall be of light (L) classification, just visible when viewed with the unaided eye at 60-mm viewing distance under any of the types of illumination described in this standard. For the remainder of the clear aperture (+), grayness (G), stain-type (S) and other (O) imperfections shall be no larger than medium (M) classification, which means that these imperfections shall be just visible when viewed at a distance of 60 cm under fluorescent EST illumination (M). (Table 3 of the standard gives the description of the viewing conditions for the classifications EL, L, and M.)

American National Standard PH3.617 was published in early 1980. It has thus had nearly two years of practical trial. Early indications are that the standard is being favorably received, even though it is the result of a first attempt at a national standard of this type and scope. Copies of PH3.617 can be purchased from American National Standards Institute, 1430 Broadway, New York, New York 10018. Suggestions for improvement of the standard will be welcomed by National Association of Photographic Manufacturers, 600 Mamaroneck Ave., Harrison, New York 10528. Address your remarks to Richard Hittner.