

Recommendations for the presentation of plastics design data —

Part 5: Other properties —

Section 5.3: Optical properties

IMPORTANT NOTE. Before reading this Recommendation it is **essential** to read the General Introduction to this series of Recommendations, issued separately.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 13 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Amendments issued since publication

Amd. No.	Date	Comments

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Introduction

Plastics materials can be used in engineering and related fields for their optical properties in several areas, such as the optical industry, various forms of construction (especially buildings), lighting applications (for illumination and advertising) and packaging. It may not be appreciated that definitive tests are not available in the standards literature for all the properties required. Appendices to this Section give details of some test methods which are known to be suitable.

Each field of application requires a different combination of optical properties for the plastics material, corresponding to its functional role. The properties required in each field can be classified under one or more of the following headings.

- 1) *Refraction* which characterizes those properties of a plastics material of particular interest to the optical industry.
- 2) *Transparency* which describes, in comparison with the object, the contrast and resolution of its image formed by an optical system involving the plastics material.
- 3) *Gloss*, using the word in its more general sense, is a term embracing the reflecting properties of a surface (corresponding to “transparency” in transmission).

This same term is also applied in a more closely defined sense to identify one of the measurable optical characteristics used to evaluate reflection properties of a surface.

- 4) *Light transfer* which covers the characteristics of plastics materials of interest mainly in lighting and advertising.

Each of these can be expressed basically by the optical quantities listed below. Experimental methods are given in appendices. This Section only deals with data based on measurements made with parallel incident light; the effect of diffuse incident light, although important in some applications, is not included in this Section. Data relating to “Colour” are also excluded from this Section.

1 Refraction

The *refractive index*, n , of a material for a certain wavelength, in vacuum, of electromagnetic radiation (or a certain frequency) is defined by the ratio between velocity of the radiation in vacuum and the velocity in the material. For anisotropic materials (e.g. crystals or oriented polymers) both the direction of the radiation and its state of polarization must be defined relative to a reference axis or axes of the sample and the plane of incidence of the radiation (see “Birefringence” below). The variation of refractive index with the wavelength of the light in vacuum is described by the dispersion curve. The spectral lines and their respective wavelengths for which the refractive index n_x is usually measured are:

Identifying suffix for n	Wavelength	Source
(x)	(nm)	(Atomic symbol)
—	780.0	Rb
A'	768.0	K ^a
C	656.3	H
C'	643.8	Cd
D	589.6	Na ^a
d	587.6	He
e	546.1	Hg
F	486.1	H
F'	480.0	Cd
g	435.8	Hg
h	404.7	Hg
^a Mean of the two wavelengths of the doublet.		

Although recommendations have been made to discard both A' and D lines because of their doublet character (International Commission of Optics and NPL), they have been retained here amongst the spectral lines in use for refractometry in view of their ready availability.

The values of the refractive index are assumed to be at 20 °C, unless otherwise stated.

The *reciprocal dispersive power* (sometimes *constringence*), V , of a material is defined by the expression:

$$V_d = \frac{n_d - 1}{n_F - n_C} \quad \left(\text{sometimes } V_e = \frac{n_e - 1}{n_F - n_C} \right)$$

in which all the refractive indices are measured at the same temperature (20 °C unless otherwise specified). The reciprocal dispersive power is generally employed in chromatic aberration calculations.

The *critical angle*, a_d , for total internal reflection of light for the helium yellow line is defined by:

$$a_d = \sin^{-1} \left(\frac{1}{n_d} \right) \text{ and similarly for other spectral lines}$$

The *variation with temperature of the refractive index* (usually n_d) is best described by a curve usually covering the range 0 °C to 50 °C, although it is possible to express it as a temperature

coefficient $\frac{\Delta n_d}{\Delta T}$ at 20 °C which is, in fact, the derivative of the function represented by the above mentioned curve.

Birefringence is a measure of optical anisotropy. The birefringence Δn is defined as the maximum algebraic difference between two refractive indices measured in two perpendicular directions.

Birefringence in bulk plastics is related to the mean orientation of the optically anisotropic molecules. Some materials are isotropic until stressed elastically (see below). Alternatively, permanent birefringence may be induced by processing, e.g. drawing of filament or rolling of sheet materials.

In many practical materials the anisotropy may be more complex than the simple description above (see A.1.1 and A.1.3). For example, colloidal dispersions of isotropic particles in an isotropic matrix can exhibit birefringence if the particles are non-spherical but uniform in shape and are preferentially oriented ("form birefringence" of rods or plates, etc.).

The *relative stress-optical coefficient*, C , measures the ratio between the birefringence in a material and the stress which produces it and is relevant to photoelastic analysis. If n_{ext} and n_{ord} are the refractive indices for the extraordinary and ordinary rays respectively, the difference Δn is proportional to the stress P .

$$n_{\text{ext}} - n_{\text{ord}} = \Delta n = CP$$

or, if l is the thickness of the sample, the path differences introduced is

$$CPl = \Delta nl.$$

The relative stress-optical coefficient is a constant depending only upon the material and the wavelength of light, which should be specified.

2 Transparency

Transparency is a general quality of a plastics material, depending largely upon its optical homogeneity, both in the bulk and at the surfaces. More exactly, the variation in refractive index in the material has a double effect: on the one hand it produces changes in amplitude and phase of a passing wave, in other words a distortion of its wavefront; on the other hand it removes from an incident wave part of its energy, which is scattered within a certain solid angle. The first effect is responsible for aberration of the image formed by any optical system (film, sheet or lens) and the confusion, in the image plane, of two distinct points in the object plane is commonly known as "loss of clarity". The second effect results in the deterioration of contrast in the image formed by the optical system.

The two effects are closely interconnected and constitute in fact the two different aspects of one phenomenon, the propagation of a wave through an inhomogeneous medium; they are two aspects of what is generally understood by "transparency".

Both the loss in clarity and loss in contrast are determined by the variation of refractive index in the material, by the average deviation from the mean value and by the average rate of change of the refractive index with distance. For semi-crystalline polymers this variation is complex and there is no unified theory to explain it completely.