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**Optics and optical instruments —
Preparation of drawings for optical
elements and systems —**

Part 7:

Surface imperfection tolerances

ISO 10110-7:1996

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*Optique et instruments d'optique — Indications sur les dessins pour
éléments et systèmes optiques —*

Partie 7: Tolérances d'imperfection de surface

INTERNATIONAL

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10110-7 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 1, *Fundamental standards*.

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ISO 10110 consists of the following parts, under the general title *Optics and optical instruments — Preparation of drawings for optical elements and systems*:

- Part 1: *General*
- Part 2: *Material imperfections — Stress birefringence*
- Part 3: *Material imperfections — Bubbles and inclusions*
- Part 4: *Material imperfections — Inhomogeneity and striae*
- Part 5: *Surface form tolerances*
- Part 6: *Centring tolerances*
- Part 7: *Surface imperfection tolerances*
- Part 8: *Surface texture*
- Part 9: *Surface treatment and coating*

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- *Part 10: Table representing data of a lens element*
- *Part 11: Non-toleranced data*
- *Part 12: Aspheric surfaces*
- *Part 13: Laser irradiation damage threshold*

Annexes A, B, C and D form an integral part of this part of ISO 10110. Annexes E, F and G are for information only.

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Optics and optical instruments — Preparation of drawings for optical elements and systems —

Part 7: Surface imperfection tolerances

1 Scope

ISO 10110 specifies the presentation of design and functional requirements for optical elements and systems in technical drawings used for manufacturing and inspection.

This part of ISO 10110 specifies the indication of the level of acceptability of surface imperfections (scratches, pits, fixture marks, coating blemishes, etc.) within the effective aperture of the optical surfaces of individual optical elements. Also given is the method for indicating the size of allowable edge chips.

It is to be noted that the acceptance level for surface imperfections is specified taking into account functional effects (affecting image formation or durability of the optical element) as well as cosmetic (aesthetic) effects.

It applies to both transmissive and reflecting surfaces and to finished optical elements (including coating), but not to assemblies. It recognizes that allowable surface imperfections may be specified according to either Method I (the surface area obscured or affected by the defects) or Method II (the visibility of the defects). Rules for indicating allowable surface imperfections are given for both cases.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10110. At the time of publication,

the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10110 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 10110-1:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 1: General.*

ISO 10110-8:—¹⁾, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 8: Surface texture.*

3 Definitions

For the purposes of this part of ISO 10110, the following definitions apply.

3.1 surface imperfections: Localized defects within the effective aperture of an optical surface produced by improper treatment during or after the fabrication process.

NOTE 1 Examples of such surface imperfections are scratches, pits, broken bubbles, sleeks, scuffs and fixture marks. Also included are localized coating blemishes such as grey spots and colour sites that absorb or reflect light differently from the bulk of the coating.

3.2 long scratches: Thin surface imperfections longer than 2 mm.

1) To be published.

NOTES

2 These tend to be more visible than shorter defects of the same width because of their length.

3 Long scratches and coating blemishes can only be indicated separately when Method I is used.

3.3 edge chips: Localized defects around the periphery of an element.

NOTE 4 Even if edge chips are outside the optically effective area, they may detrimentally affect the performance of optical systems by disturbing the sealing of elements, being a source of scattered light or being sites of crack propagation.

4 Indication in drawings

The indication of permissible surface imperfections is given by a code number and a numerical term. The code number for surface imperfections is 5.

The numerical term depends on whether Method I or Method II is used, and is described in 4.1 or 4.2.

4.1 Method I — Obscured or affected area method

4.1.1 General surface imperfections

According to Method I, the drawing indication for number and size of general surface imperfections, which are permissible within the effective aperture of a surface, is

$$5/N \times A$$

The indication in the form $N \times A$ specifies the number, N , of allowed surface imperfections of maximal permitted size, and the grade number, A , which is equal to the square root of the surface area of the maximum allowed defect, expressed in millimetres. Preferred values for A are given in the first column of table A.1.

4.1.1.1 Coating blemishes

It is possible to specify the level of acceptability of coating blemishes separately from that of general surface imperfections, if desired.

Following the indication for general surface imperfections and separated from it by a semicolon, the indication for coating blemishes, which are permissible within the effective aperture of a surface, is

$$CN' \times A'$$

where the C is the designation for coating blemishes, N' is the number of allowed blemishes of maximal permitted size and A' is the grade number as defined in 4.1.1.

NOTE 5 In general, if the surface has an anti-reflection coating, the grade number A' will be larger than the grade number A for the bare surface imperfections because of the difficulty in distinguishing between small coating blemishes and surface imperfections.

The surface imperfection indication including coating blemishes is

$$5/N \times A; CN' \times A'$$

If no separate indication for coating blemishes is given, it shall be included in the allowable general surface imperfection indication:

$$5/N \times A$$

4.1.1.2 Long scratches

Following the indication for general surface imperfections (and coating blemishes, if given) and separated from them by a semicolon, the indication for long scratches (longer than 2 mm), which are permissible within the effective aperture of a surface, is

$$5/N \times A; LN'' \times A''$$

where L is the indication for long scratches, N'' is the number of allowed long scratches and the grade number, A'' , specifies the maximum allowed width of the scratches, expressed in millimetres.

The surface imperfection indication including coating blemishes and long scratches is

$$5/N \times A; CN' \times A'; LN'' \times A''$$

4.1.1.3 Edge chips

Following the indication for general surface imperfections (and coating blemishes, and/or long scratches, if given) and separated from them by a semicolon, the indication for permissible edge chips is

$$EA'''$$

where E is the designation for edge chips and the grade number A''' specifies the maximum allowable extent of a chip from the physical edge of the surface, measured parallel to the surface, in millimetres. Any number of edge chips is permissible as long as their extent from the edge does not exceed A''' .

The complete surface imperfection indication including coating blemishes, long scratches and edge chips is

$$5/N \times A; CN' \times A'; LN'' \times A''; EA'''$$

4.1.2 Sub-division

A larger number of general surface imperfections (including coating blemishes) with a smaller grade number is permitted, if the sum of their areas does not exceed the maximum total area

$$N \cdot A^2 \text{ for general surface imperfections;}$$

$$N' \cdot A'^2 \text{ for coating blemishes.}$$

Grade numbers are given in the columns of table A.1, and the corresponding multiplication factors appear in the first line of the table.

Table A.1 indicates, for example, that six surface imperfections of grade number 0,10 have the same area as one imperfection of grade number 0,25.

When determining the number of permissible surface imperfections, those with a grade number of 0,16A or smaller shall not be counted.

A larger number of long scratches is allowed, provided that the sum of their widths does not exceed $N'' \cdot A''$. In calculating this sum, scratches with widths less than $0,3A''$ shall not be counted.

4.1.3 Concentrations

Concentrations of surface imperfections are not allowed. A concentration occurs when more than 20 % of the number of allowed defects is found in any 5 % of the test region. If the total number of surface defects is less than 10, then two or more surface defects falling within a 5 % subarea constitute a concentration.

4.1.4 Scale comparison plate

A scale comparison plate is described in annex E. It may be used as a means for comparing the size of surface imperfections with those of artifacts of known grade numbers.

4.2 Method II — Visibility method

This method requires the inspection of the element using an inspection station described in annex B.

In method II an entire optical element is tested. The defects of all optically effective surfaces, as well as material defects (bubbles and other inclusions), are observed simultaneously. Note that this represents a fundamental difference from Method I, wherein the surfaces are inspected separately.

Although the test does not generally provide a separation of the contributions of the individual surfaces, the surface imperfection tolerances are specified individually, because they provide guidelines for the surface fabrication.

Coating blemishes and long scratches are included as part of the general category of surface imperfections in Method II and thus no special indication is necessary. There is no provision for the treatment of subdivisions and concentrations, since it is not necessary when applying Method II.

4.2.1 General surface imperfections

The drawing indication for the visibility of surface imperfections of an optical element, as determined by Method II, shall be either

$$5/TV$$

or

$$5/RV$$

The T or the R in the indication specifies a transmissive or reflective test and the V is a visibility class number according to annex C. (Both "T" and "R" indications are permissible in the case of a dual function surface such as a beamsplitter.) The number V is an integer from 1 to 5, where 1 indicates the most stringent and 5 the weakest requirements on the element with respect to surface imperfections.

4.2.2 Edge chips

Following the indication for surface imperfections by the visibility method (see 4.2.1) and separated from it by a semicolon, the indication for permissible edge chips is given in the same way as in Method I:

$$EA''$$

where E is the designation for edge chips while the grade number A'' specifies the maximum allowable extent of a chip from the physical edge of the surface, measured parallel to the surface, in millimetres. Any number of edge chips is permissible as long as their extent from the edge does not exceed A'' .

The complete surface imperfection indication including edge chips for Method II is

5/TV; EA''

or

5/RV; EA''

4.3 Location

The indication shall be entered near the surface to which it refers. If necessary, the indication may be connected to the element by a leader. It should pref-

erably be associated with the other indications of surface tolerances (surface form tolerance and centring tolerance). An example of such an indication is given in ISO 10110-1:1996, annex A.

Alternatively, the indication may be given in a table in accordance with ISO 10110-10^[1].

If two or more optical elements are to be cemented (or optically contacted), the surface imperfection tolerances given for the individual elements apply also for the surfaces of the optical sub-assembly, i.e. after cementing (or optically contacting), unless otherwise specified. See ISO 10110-1:1996, subclause 4.8.3.

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Annex A (normative)

Preferred values of grade numbers and sub-division factors for Method I

The preferred range of values for grade number *A* is given in the first column of table A.1. Columns two through four show the connection between grade numbers and their multiplication factors.

The table indicates, for example, that six surface imperfections of grade number 0,25 have the same area as one imperfection of grade number 0,63.

Table A.1 — Preferred size designation and factors for sub-division for surface imperfections according to Method 1

	Multiplication factors			
	1 (preferred values)	2,5	6,3	16
Grade numbers <i>A</i> mm	0,006			
	0,010	0,006		
	0,016	0,010	0,006	
	0,025	0,016	0,010	0,006
	0,040	0,025	0,016	0,010
	0,063	0,040	0,025	0,016
	0,10	0,063	0,040	0,025
	0,16	0,10	0,063	0,040
	0,25	0,16	0,10	0,063
	0,40	0,25	0,16	0,10
	0,63	0,40	0,25	0,16
	1,0	0,63	0,40	0,25
	1,6	1,0	0,63	0,40
	2,5	1,6	1,0	0,63
4,0	2,5	1,6	1,0	

EXAMPLE

If the indication is $5/2 \times 0,25$ (i.e. 2 surface imperfections of grade number 0,25), then $2 \times 2,5 \approx 5$ surface imperfections of grade number 0,16, or $2 \times 6,3 \approx 12$ surface imperfections of grade number 0,1 or $2 \times 16 \approx 32$ surface imperfections of grade number 0,063 are permissible. Alternatively, any corresponding combination of the above is permissible, provided that the total projected area of all surface imperfections with a grade number greater than $0,16 \times 0,25 = 0,04$ does not exceed $2 \times 0,25^2 \text{ mm}^2 = 0,125 \text{ mm}^2$.

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Annex B (normative)

Description of inspection station for Method II

B.1 Principle of operation

Light scattered from the surface imperfections of the sample under test is compared with a reference background illumination. The visibility class is determined by the level of sample illumination at which surface defects become visible; each visibility class corresponds to a particular sample illumination.

In order to guarantee a uniform level of sensitivity, independent of the observer, the reference background illumination shall be adjusted, using a standard sample described in annex D.

Detailed descriptions of the principle of operation regarding physics and physiological optics are given in annex G, references [2] to [4].

B.2 Description of the inspection station

The inspection station for the classification of surface defects includes two paths:

- A path incorporating a uniform hemispherical illumination of the sample, excluding the solid angle determined by the location of the eye of an observer, 30 cm from the sample. (This means that, in the absence of a sample, no light of the illumination reaches the observer's eyes.)
- A reference path which superposes a background of uniform luminance in the observer's field of view by means of a beam splitter. This luminance shall be adjusted until the standard defect described in annex D, when illuminated at a level of 2 500 lx, is just visible to the observer. (It is to be noted that each observer must adjust the inspection station in this manner.)

B.3 Schematic diagram of the station

Figure B.1 shows schematic diagrams of an inspection station for transmissive and reflective tests. By appropriate arrangement of optical fibres, dark-field illumination of the sample under test is achieved. (Further information is given in annex G, reference [4].)