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

**Part 1:  
General**

*Optique et photonique — Indications sur les dessins pour éléments et  
systèmes optiques —*

*Partie 1: Généralités*





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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

This third edition cancels and replaces ISO 10110-1:2006 and ISO 10110-10:2004, which have been technically revised and merged into one single document.

The main changes compared to the previous edition are as follows:

- a) Drawing scale and the reference wavelength are required to be included on the drawing;
- b) provisions have been added to allow coordinate systems to be defined for each surface and for the part as a whole;
- c) new tabular formats have been added to allow more surfaces on a tabular drawing, partially tabulated drawings, and new types of assembly drawings;
- d) a new notation for special surfaces has been added;
- e) in addition, many more examples of drawings and notations have been provided;
- f) and various detailed notes have been added, and corrections and modifications have been made for improved clarity;
- g) GSP defaults by definition no longer apply, they have to be specifically invoked.

A list of all parts in the ISO 10110 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Optics and photonics — Preparation of drawings for optical elements and systems —

## Part 1: General

### 1 Scope

This document specifies the general layout of drawings and provides examples of indications in the ISO 10110 series, which standardizes drawing indications for optical elements and systems.

This document specifies the presentation in drawings of the characteristics, including the tolerances, of optical elements and systems. This document also includes the popular tabular format, formerly presented in ISO 10110-10. This tabular format, now described in [5.1](#), is the preferred format for ISO 10110 drawings.

Rules for preparation of technical drawings as well as for dimensioning and tolerancing are given in various ISO Standards. These general standards apply to optical elements and systems only if the necessary rules are not given in the various parts of ISO 10110.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 128-24, *Technical drawings — General principles of presentation — Part 24: Lines on mechanical engineering drawings*

ISO 10110-6, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 6: Centring tolerances*

ISO 10110-11, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 11: Non-toleranced data*

ISO 10110-12, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 12: Aspheric surfaces*

ISO 10110-18, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae*

ISO 10110-19, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 19: General description of surfaces and components*

ISO 12123, *Optics and photonics — Specification of raw optical glass*

ISO 80000-1, *Quantities and units — Part 1: General*

### 3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 4 Fundamental stipulations

All indications in drawings for optical elements and systems shall apply to the finished optical component or assembly, i.e., to its final form as described on the drawing, except where other parts of ISO 10110 stipulate otherwise or if explicitly stated on the drawing.

Whenever details or symbols specified in this document are found to be inadequate to clearly define the requirement, the information should be supplemented by a note or special instruction (see 5.1.2).

All linear dimensions are in millimetres, unless otherwise stated.

All units shall be shown using either a decimal comma or a decimal point, in accordance with ISO 80000-1. One or the other format should be used; the two conventions shall not be mixed on one drawing. Delimiters for the thousands place shall never be used, regardless of the decimal format.

All optical and dimensional data refer to the reference temperature of 20 °C<sup>1)</sup>, unless specified otherwise.

Unless specified elsewhere, the omission of a permissible deviation or material imperfection from the drawing shall indicate that the provisions of ISO 10110-11 apply. By definition none of the GPS defaults, including the decision rules, apply unless specifically invoked in ISO 10110.

Surface form and transmitted wavefront deviation shall be specified in units of nanometers or, if preferred, micrometers or fringe spacings. Because of the existence of older (national) standards for optical drawings, a possibility of incorrect interpretation of data exists. For this reason, a reference to ISO 10110 shall appear on each drawing. In addition, as described in ISO 7944, wavelengths other than e-line or d-line may be used as the reference wavelength. Therefore if waves or fringe spacings are used, the reference wavelength shall always be indicated<sup>2)</sup>. For example:

“Indications in accordance with ISO 10110;  $\lambda = 546,07 \text{ nm}$ ”

or

“Ind. acc. ISO 10110;  $\lambda = 632,8 \text{ nm}$ ”.

These indications should preferably be together and associated with the title field of the drawing (see Annex A as well as Figures 1 and 2).

While it is preferred to only use one wavelength in an optical element drawing, the usage of other wavelengths is permitted, e.g. a reference wavelength of 546,07 nm but indicating a different wavelength for refractive index and Abbe number ( $n_e$ ,  $v_d$ , etc.). In those cases, the different wavelength strictly applies only to the property indicated with the different wavelength. Any other value not separately indicated shall be considered using the reference wavelength.

NOTE For legacy drawings created prior to the publication of this revision, the default wavelength was 546,07 nm.

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1) 20 °C is the reference temperature in accordance with ISO 1. In the 1996 edition of ISO 10110-1, the default value for the reference temperature was 22 °C.

2) In earlier editions of ISO 10110-1, the default value for the reference wave length was 546,07 nm.

## 5 Presentation and dimensioning

### 5.1 Drawing format

#### 5.1.1 General

The preferred layout of a drawing of optical elements or subassemblies is the tabular format. It was originally described in ISO 10110-10, but has been incorporated here for ease of use. All of the rules regarding line type, notation and symbology given below apply to drawings in a tabular format, unless they are explicitly contradicted by this part of the standard.

The tabulated drawing shall consist of the following three fields (see [Figures 1](#) and [2](#) for sample layouts):

- drawing field in accordance with [5.1.2](#);
- table field in accordance with [5.1.3](#);
- title field in accordance with [5.1.4](#).

#### 5.1.2 Drawing field

In this field, a schematic drawing of the optical element (e.g. lens, mirror, or prism) or cemented assembly shall be given, together with all information not given in the table field. A drawing scale shall be indicated and the drawing shall be a true-to-scale technical drawing.

It is sometimes desirable to exaggerate the surface deviations for non-spherical surfaces for clarity. If this is desired, a separate inset drawing not-to-scale is permitted. It shall be indicated that the inset drawing is not-to-scale; e.g. by giving an exaggeration factor along the z-axis.

The definition of a local coordinate system for each surface is possible. In this case, for every surface on the drawing the coordinate system shall be indicated in the table field. Centring tolerances and (if applicable) the datum axis for centring specification shall be indicated on the drawing as applicable per ISO 10110-6. Additionally, the surface texture specification (see ISO 10110-8) may be shown either in the drawing or the table field.

Notes, instructions and additional information are allowed within the drawing field using a leader line, or may be numbered and tabulated, with a notes table placed in the drawing field in any convenient location. Each note shall have a number for ease of reference.

#### 5.1.3 Table field

This field contains dimensions, tolerances, surface treatment and coating references, permissible material imperfections of the optical element or cemented assembly, and local coordinate system references, if any. The table field is subdivided into subfields.

The number and contents of the subfields depend on the type of component or assembly being specified. Whenever possible, the table subfields should follow the path of the light. [Table 1](#) lists detailed descriptions of the properties which may be indicated. In the event that the local coordinate system for each surface is provided, it shall be indicated directly below the surface label. See [5.3](#) for more information and [Figures A.16](#) and [A.17](#) for examples of local coordinates.

- a) In the case of a single element with two optical surfaces:
- the left subfield refers to the left surface (or, if desired, surface 1) of the optical element;
  - the central subfield refers to the material specification;
  - the right subfield refers to the right surface (or, if desired surface 2) of the optical element.

See [Figures A.1](#), [A.2](#), [A.3](#) and [A.4](#).

- b) In the case of a single element with three or more optical surfaces:
- each surface subfield (e.g. A1, A2, etc.) shall be labelled, and the surface indicated in the drawing;
  - the subfield labelled “Material” shall be for the material specifications;
  - the subfields can be horizontally or vertically aligned;
  - whenever possible, the table subfields should follow the path of the light.

See [Figures A.5, A.6, A.7 and A.8](#).

- c) In the case of a cemented assembly:
- the minimum number of subfields equals the number of surfaces;
  - additional subfields may be included which identify the element information such as element number, drawing number, or part number, either in the same row as the surface subfields or above the surface subfields. For clarity, a label for these additional subfields is recommended;
  - cemented or contacted surfaces are counted as one surface, and information about the interface such as tolerances on the thickness and wedge of the cement or contact area may be given in the surface field.

See [Figures A.9 and A.10](#).

- d) In the case of a cemented assembly without individual element drawings; fully tabulated:
- the number of subfields depends upon the number of elements;
  - each element has a subfield for a left surface, a material, and a right surface;
  - each interface between elements has a subfield where information about the interface such as tolerances on the thickness and wedge of the cement or contact area are shown.

See [Figure A.11](#).

- e) In the case of a cemented assembly without individual element drawings; partially tabulated:
- the number of subfields depends upon the number of elements;
  - each element has a subfield for each surface;
  - the subfields shall be ordered left to right, or as numbered on the drawing
  - each interface between elements has a subfield where information about the interface such as tolerances on the thickness and wedge of the cement or contact area are shown;
  - the materials tolerances are indicated with a leader line in the drawing field.

See [Figure A.12](#).

- f) In the case of a system (e.g. an assembly with air spaces) with individual element drawings; partially tabulated:
- the number of subfields depends upon the number of elements;
  - an additional table of system attributes may also be shown.

See [Figure 35](#).



**5.1.4 Title field**

This field is provided for general indications. This shall include a reference to ISO 10110, the reference wavelength, and other indications such as name, type and/or reference number of the optical element or cemented assembly, part number, designer and/or approver's name, and company name and logo, if desired.

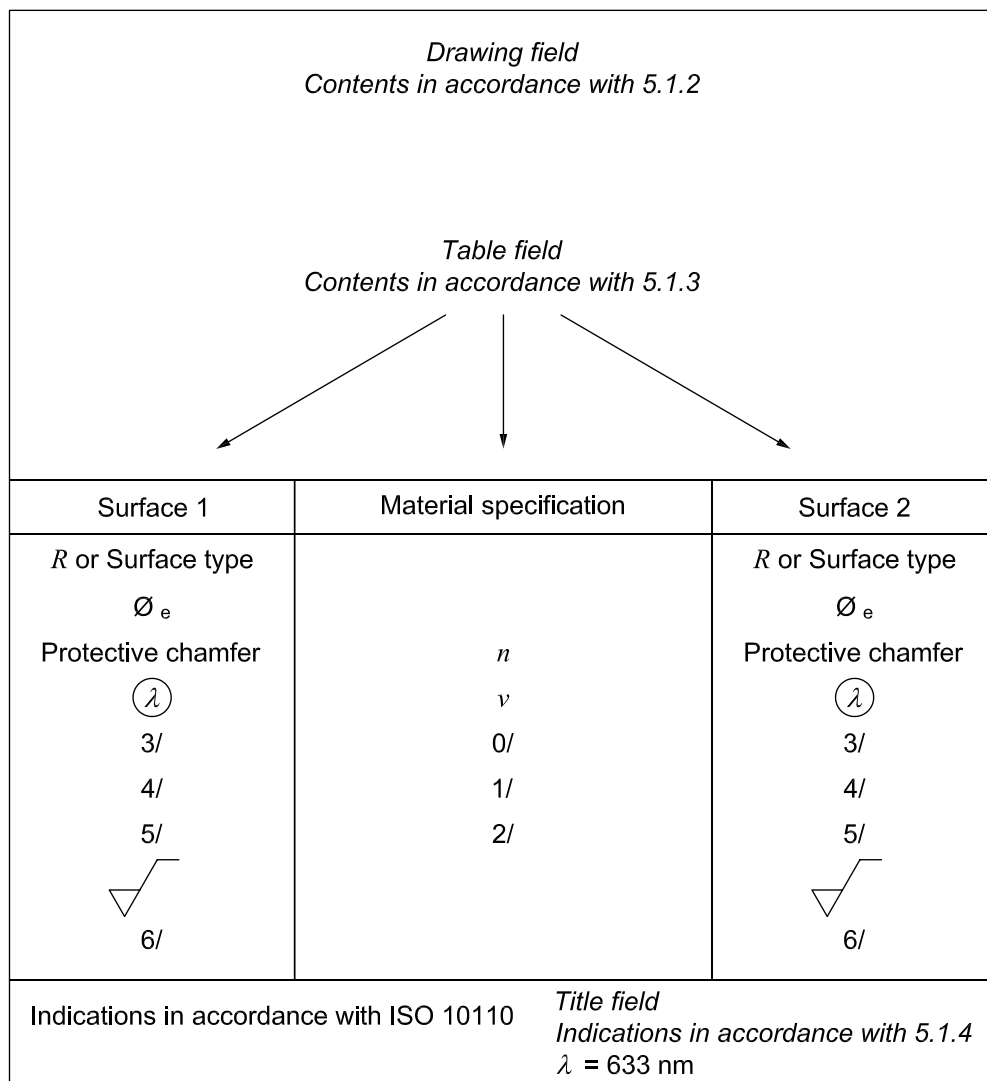
**5.1.5 Alternative drawing layout**

While the tabular format is preferred, it is not required. An alternative layout is allowed which has only a drawing field and a title field. In this case, all surface and materials tolerances are indicated in the drawing field with leader lines to the appropriate material or surface.

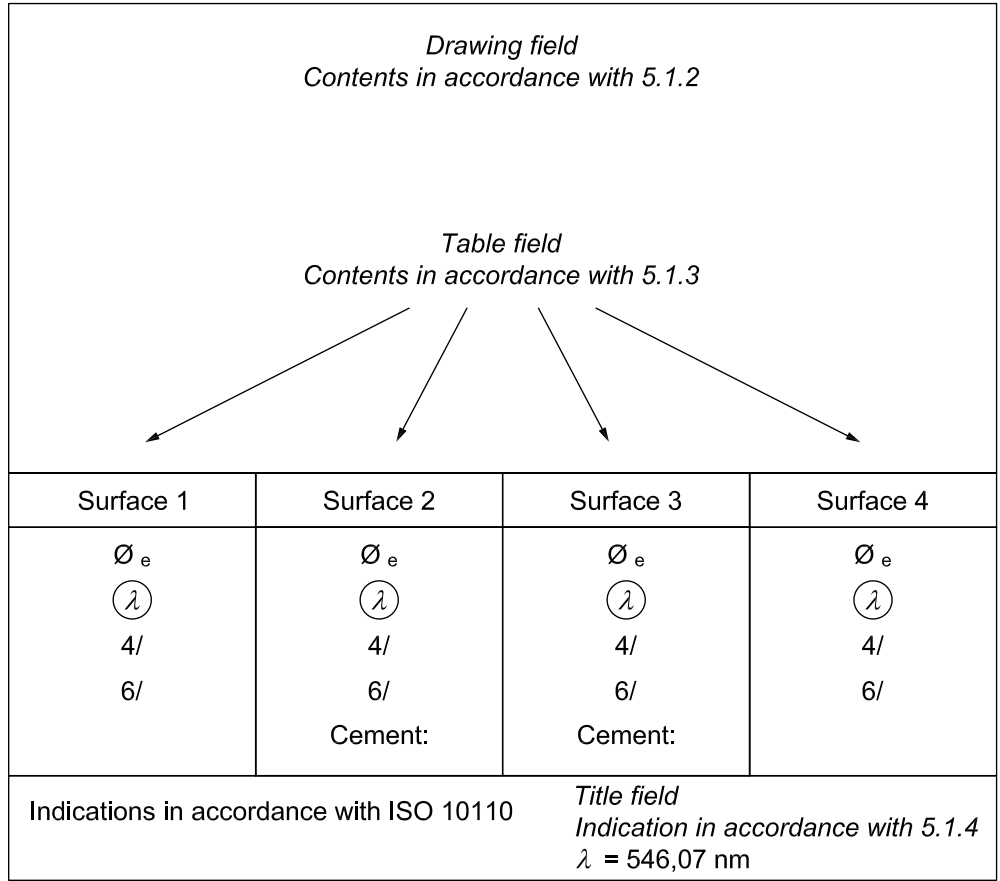
See [Figures A.13, A.14](#) and [A.15](#).

**5.1.6 Examples**

[Annex A](#) gives examples of indications for optical elements and cemented assemblies.



**Figure 1 — Tabular indication of data for a single element**



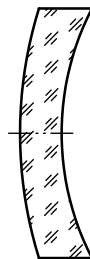
NOTE 5/, 13/ and/or 15/ specifications can be added to the table field if appropriate.

**Figure 2 — Tabular indication of data for a cemented assembly (triplet)**

**5.2 Views**

Optical elements shall be shown with incident light entering from the left and the optical axis horizontal, unless otherwise specified. Rotationally invariant parts and assemblies may be shown with just one cross section drawing.

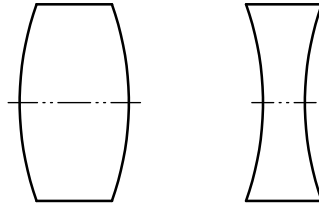
The preferred method is that components be drawn in cross section and hatched with short-long-short strokes in accordance with ISO 128-50, as shown in [Figure 3](#). Back edges and hidden lines should normally be omitted. However, for the sake of clarity, such lines may be included.



**Figure 3 — Hatching**

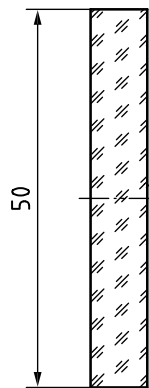
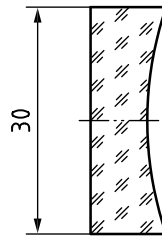
Components of subassemblies, such as cemented components, shall be hatched in alternate directions.

For the purpose of simplification, optical parts may be drawn without hatching, as shown in [Figure 4](#). Mixing of hatched and unhatched parts in one drawing shall not be used.



**Figure 4 — Simplified drawings of lens elements**

Lens elements with surfaces having two meridians of symmetry, such as cylindrical and toric surfaces, shall be drawn in two cross sections corresponding to these meridians (see [Figures 5](#) and [6](#)).



**Figure 5 — Rectangular cylindrical lens element**

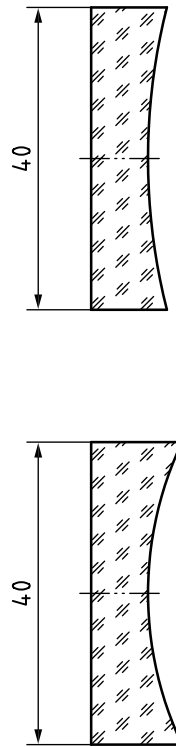


Figure 6 — Square toric lens element

### 5.3 Global and Local Coordinate Systems

It is sometimes necessary to indicate local coordinate systems to describe complex surface shapes. This is often the case with parts that are drawn using the generalized surface descriptions given in ISO 10110-12 and ISO 10110-19. When required, a right-hand orthogonal Cartesian coordinate system shall be drawn as follows: two lines with line type 01.2, ISO 128-24 perpendicular to each other shall indicate two of the three axes (typically the Z and Y axes). The positive direction of each axis shall be indicated by an arrowhead which is labelled by an axis identifier ("z", "y"). The missing X axis which either points into or onto the plane of projection should be indicated in the form of a circle with either a centred point (out of the page) or a cross (into the page) (see Figure 7). If only one coordinate system is shown in the drawing field, it shall be the global coordinate system. If additional coordinate systems are shown in the drawing, the global coordinate system axes shall be indicated with a subscript G, and other coordinate system axes shall be indicated with a subscript by surface (e.g. "z<sub>1</sub>", "z<sub>2</sub>" for surface 1 and 2).

It is recommended that all three axes be indicated, however it is important to note that, since all coordinate systems are right-handed, it is possible to indicate only two of the three axes, and the direction of the third axis can be inferred. Examples of this are shown in Figures 8 and 9.

If local coordinate systems are used, and the global coordinate system is not the coordinate system of the first surface, the global coordinate system shall be indicated in the drawing field.

All local coordinate systems shall be indicated with respect to the global coordinate system. The local coordinate systems shall be indicated by coordinate transformations between the global coordinate system and the local coordinate systems of the individual surfaces. In these cases the local coordinate system for each surface is illustrated in the drawing field. Each surface shall have a set of global reference values, which describe the position of the local coordinate system with respect to the global one. Each set consists of six values; a, b, c,  $\alpha$ ,  $\beta$ , and  $\gamma$ . To move from the global coordinate system to the local coordinate system, one has to first translate along the x, y, and z axes by the indicated translation amounts a, b, and c (the order of translation is irrelevant because they are orthogonal). Secondly rotate around the new x axis by the angle  $\alpha$ . Then rotate around the new y axis by the angle  $\beta$  and finally around the new z axis by the angle  $\gamma$ . The rotations are right-handed. When they are required, the

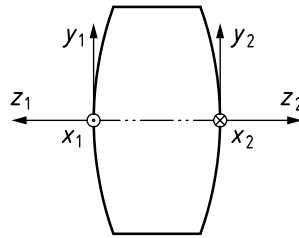
specifications of the local coordinate system shall be the first entry in each surface description in the tabular field. The entry shall be in the following form:

(a, b, c),  $\alpha$ ,  $\beta$ ,  $\gamma$

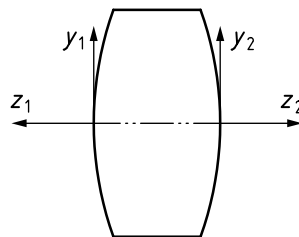
The units for  $\alpha$ ,  $\beta$ , and  $\gamma$  are degrees and the units for a, b, and c in the declared unit for dimensions. References should be used in order to link the surfaces to measurable datums of the part.

If the global coordinate system is the coordinate system of the first surface, the local coordinate system of the first surface shall be indicated as (0, 0, 0) 0°, 0°, 0°.

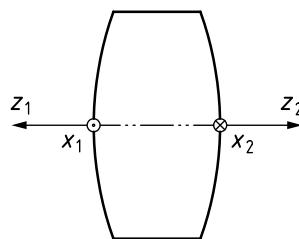
ISO 10110-19 includes more information on local and global coordinate systems and how they relate.



**Figure 7 — Coordinate systems with all axes**



**Figure 8 — Coordinate systems without X axis**



**Figure 9 — Coordinate systems without Y axis**

## 5.4 Axes

Axes shall be drawn as follows:

Rotation axes, axes of symmetry, and centre lines: Line type 04.1, ISO 128-24

Optical axis, beamline or base ray: Line type 05.1, ISO 128-24

If an optical axis coincides with a rotation axis or centre line, the optical axis shall be drawn. An intentional displacement or tilt of axes (e.g. of the centre line of an element with respect to the optical axis) shall be indicated and dimensioned (see [Figure 10](#)). Very small shifts may be drawn out of scale to exaggerate the displacement. Exaggerated dimensions shall be underlined.

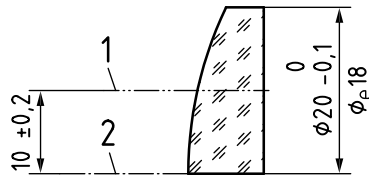


Figure 10 — Axes

### 5.5 Leader lines

Leader lines shall have a dot at the end for leaders terminating within the outline of a part (see [Figure 11](#)), and an arrowhead for leaders terminating on the outline (see [Figure 12](#)). Arrowheads shall touch the edge or surface in order to prevent misunderstanding.

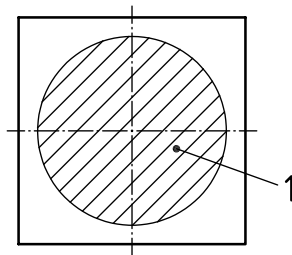


Figure 11 — Leader line to an area

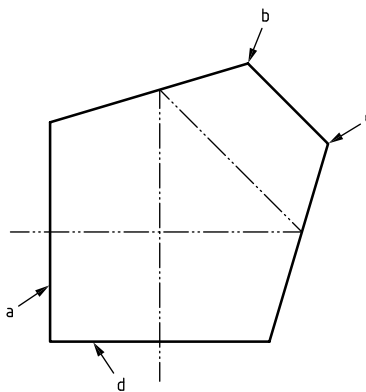
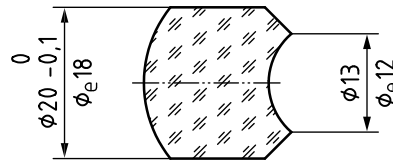


Figure 12 — Leader lines to edges and surfaces

### 5.6 Test regions

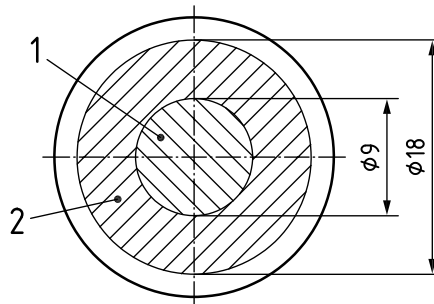
If testing of a complete surface or volume is not required, the test regions or optically effective surfaces shall be shown on the drawings. If no test region is indicated, but an effective aperture is indicated, then the test region shall be the effective aperture. For example, in the case of circular parts if the diameter of the circular test region is not otherwise defined, the “effective diameter”, indicated by “ $\phi_e$ ” shall be the diameter of the test region. (see [Figures 13, 23, A.1](#) and [A.2](#)). It defines the region of the component surface that has optical significance<sup>3)</sup>.

3) Former practice (and specification of the 1996 edition of ISO 10110-1) has been to assign the effective diameter to a surface by a leader line. This former practice could be misinterpreted as an indication for the radius of curvature.



**Figure 13 — Test regions**

The boundaries of test regions shall be drawn in continuous narrow lines (line type 01.1, ISO 128-24) and the regions themselves shall be hatched in continuous lines of the same type. They may be subdivided into sub-regions to which different tolerances apply, if required. In such cases, the sub-regions shall be numbered to clarify their relationship. The sub-region number shall be indicated by a leader to the appropriate area (see [Figure 14](#)).



**Figure 14 — View showing test regions**

Where necessary, special views entitled “test regions” shall be added showing optically effective regions and provided with appropriate dimensional data. If symmetrical components have different test regions (e.g. due to the path of the rays being divergent or convergent) then the regions in question shall be suitably identified to prevent incorrect assembly. The same requirement applies if dissimilar test specifications are to be applied to similar test regions. The method of identification should be explained in the drawing (see [Figure 15](#)).

**NOTE** Since effective diameters and test regions are not per se geometrically tolerated, the designer may have to add further definitions, if necessary.

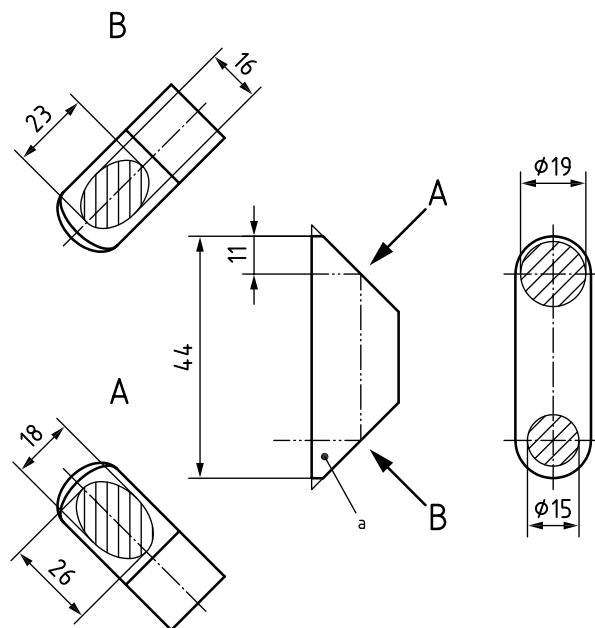
If a test region or effective diameter is not shown, the surface counts in its full extent as the test region. Note that bevels and chamfers do not count as part of this test region.

## 5.7 Test fields

A test field can be defined in any shape (e.g. circular, rectangular) and shown in any position within the test region as a dimensioned area defined by a thin continuous line. Appropriate requirements indicated by a leader to this test field shall apply to all possible positions of the test field within the test region. In this case the geometric shape of the test field shall be appended to the appropriate tolerance indication as follows: “...(all  $\emptyset$ ...) or (all ... x ...) (see [Figure 16](#)).

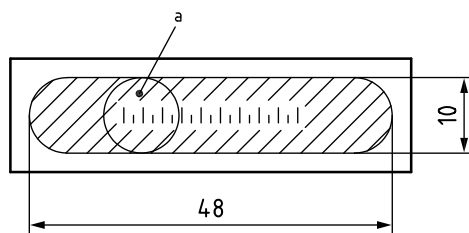
## 5.8 Test volumes

A test volume shall be indicated if a volume of defined extent has to fulfil higher requirements than the rest of the optical element. The boundaries shall be drawn in continuous narrow lines, line type 01.1, ISO 128-24 (see [Figure 17](#)).



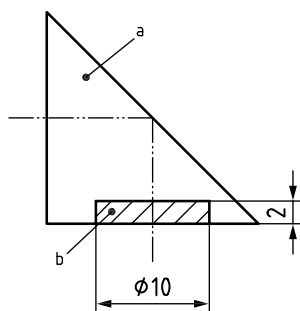
a Mark for identification.

**Figure 15 — Different test regions for a prism**



a Tolerance (all  $\varnothing$  10 mm).

**Figure 16 — Test field within a test region**



a Normal tolerance for bubbles.

b Special tolerance for bubbles.

**Figure 17 — Test volume**



## 5.9 Dimensioning

### 5.9.1 General

Fundamentally, the dimensions for optical elements relate to the finished state and therefore include surface treatment such as painting and/or coating. However, in certain cases the dimensions of a part before the application of surface treatments are important. In such cases it shall be explicitly indicated in the drawing that these dimensions refer to the untreated part.

### 5.9.2 Radius of curvature

Spherical surfaces are defined by stating the radius of curvature with a dimensional tolerance (see [Figures 18](#) to [20](#)).

To distinguish between a convex and a concave surface, especially in the case of a weak curvature, the arrow on the leader for the radius indication shall always appear to start from the centre of curvature. Alternatively, a convex surface may be indicated by the letters CX following the radius of curvature indication, and a concave surface by the letters CC. This tolerance shall indicate the range within which the actual surface shall be contained. If the radius of curvature and its tolerance are not indicated in the drawing field, they shall be indicated in the table field.

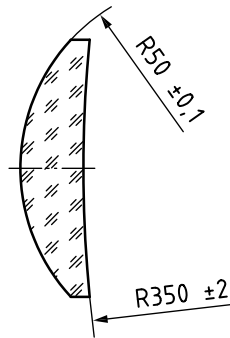


Figure 18 — Radii for a meniscus lens element

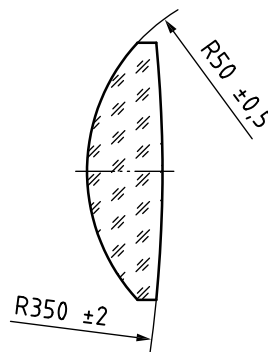


Figure 19 — Radii for a biconvex lens element

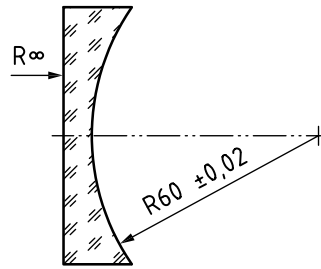


Figure 20 — Radii for a plano concave lens element

Alternatively, the radius of curvature tolerance may be given in whole or in part in interferometric terms as defined in ISO 10110-5.

If the total permissible variation of the radius of curvature is given in interferometric terms, the dimensional tolerance of the radius is zero and need not be included in the indication of the radius of curvature.

For plane surfaces (i.e. infinite radius of curvature) the radius shall be indicated by the symbol “R∞” or “PL”. The tolerance on flatness shall be indicated in interferometric terms (see ISO 10110-5).

For toric and cylindrical surfaces, two views are required, as described in 5.2.

For cylindrical surfaces, the radius shall be indicated by the term as "CYL".

NOTE In prior versions of this document, a cylindrical surface was indicated by the term R<sub>cyl</sub>.

For aspheric surfaces, the surface shall be indicated by the term “ASPH” and the surface description, including the base radius, shall be written in accordance with ISO 10110-12.

For conic surfaces, such as paraboloid, ellipsoid, or hyperboloid surfaces, or for other surfaces of second order, the surface shall be indicated by its canonical shape (e.g. “hyperboloid”, or “toroid”) followed by the radius, conic constant or other terms required to define the surface. The surface equation shall be given in a note. For more information, see ISO 10110-12.

For other surfaces, the surface shall be indicated by the term "GS" and the surface description shall be written in accordance with ISO 10110-19.

### 5.9.3 Thickness

The thickness shall be indicated as a nominal size with a tolerance. In the case of lens elements having concave surfaces, the overall thickness should be indicated in addition to the axial thickness (see Figures 21 and 22). If either the center thickness or overall thickness is given as reference only, it shall be shown in brackets.



Figure 21 — Thickness indication for a biconvex lens element

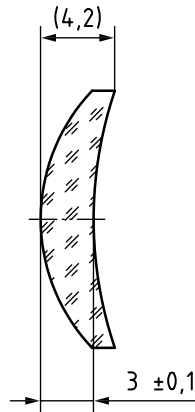


Figure 22 — Thickness indications for a meniscus lens element

#### 5.9.4 Diameter

The diameter of optical parts shall be indicated together with tolerances. The optically effective diameter “ $\phi_e$ ” shall be added, if required (see [Figure 23](#)).

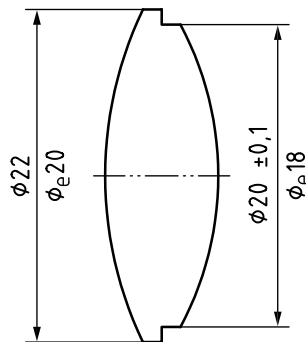


Figure 23 — Diameters and optically effective diameters

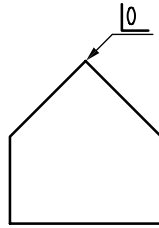
#### 5.9.5 Presentation of shapes of edges, bevels and chamfers

##### 5.9.5.1 General

The shape of edges, bevels and chamfers is either determined for design (functional) reasons, or for protective purposes to prevent chipping of sharp edges and corners during production and handling.

##### 5.9.5.2 Sharp edges

An edge that has to remain sharp for functional reasons is shown by the symbol “0” (see [Figure 24](#)). Imperfections in this edge are usually controlled with the edge chip requirement in the 5/ notation of the adjoining surfaces. Alternately the designer shall indicate the explicit allowed burr or undercut allowance for the edge in a note.



NOTE Sharp edge imperfections shall be less than 0,02.

Figure 24 — Sharp edge

5.9.5.3 Functional bevels

A bevel is a functional surface replacing a sharp edge, and shall be completely specified with respect to dimension, tolerance, inclination and, if necessary, centring (see Figure 25).

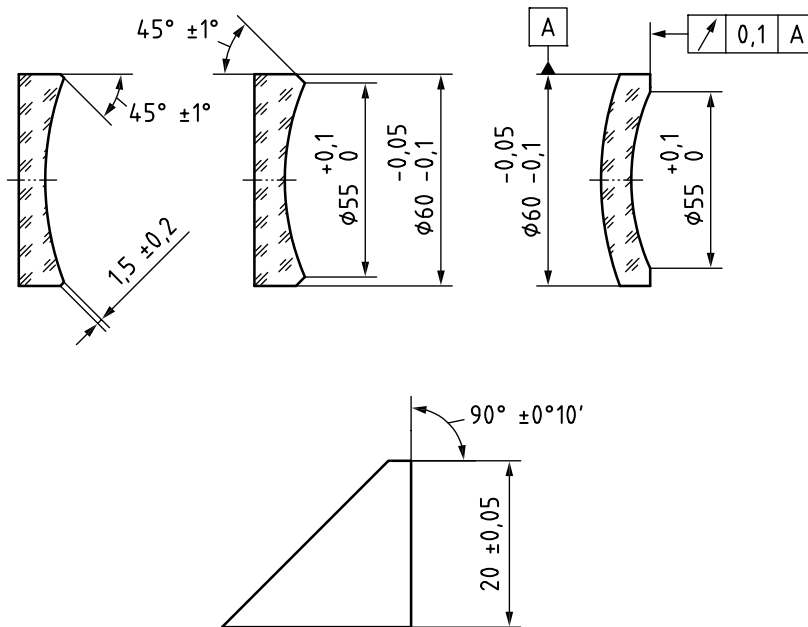


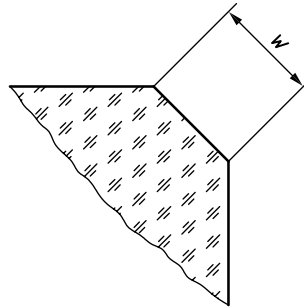
Figure 25 — Dimensioning of bevels

5.9.5.4 Non-functional edges and corners

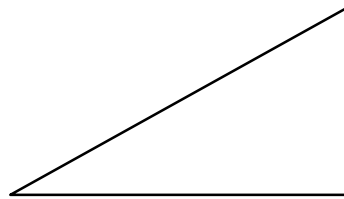
A protective chamfer is a small surface replacing an edge or corner, approximately equally inclined to the surfaces forming the edge or corner. This surface does not need to be individually drawn.

The indication “protective chamfers” shall be included as a note on the drawing to cover all edges and corners that are not individually specified, see Figure 27. The width, *W*, of a chamfer is shown in Figure 26. The minimum and maximum permissible widths of the chamfers shall be indicated in a note.

Inside edges: because a perfectly sharp inside edge cannot be produced, it is often necessary to specify the maximum (and occasionally the minimum) permissible width of the edge surface (see Figures 28 and 29). If only one value is indicated, it shall be interpreted as the maximum permissible width.

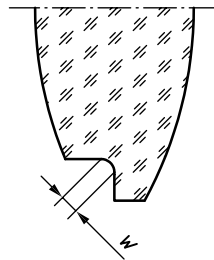


**Figure 26 — Width,  $W$ , of a protective chamfer**

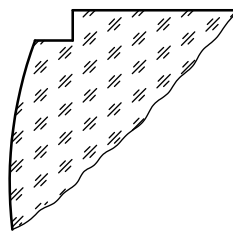


NOTE Protective chamfers 0,2-0,5.

**Figure 27 — Indication of protective chamfers**



**Figure 28 — Width,  $W$ , of inside edge**



NOTE Inside edge 0,2-0,5.

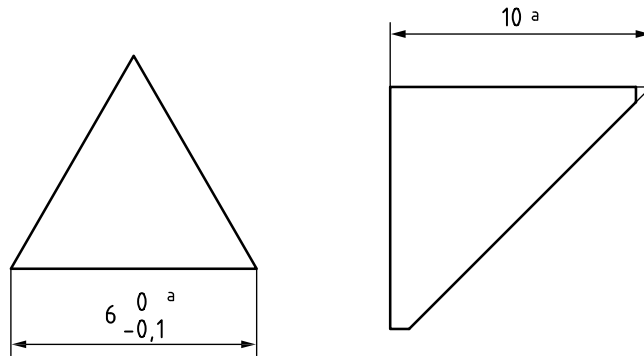
**Figure 29 — Indication of inside edge**

### 5.9.6 Linear dimensions

The nominal dimensions for length, width and height (or diameter and thickness) of a part shall be stated with permissible tolerances. Parts specified to have protective chamfers or small bevels shall be dimensioned without regard to the chamfers or bevels.

On prisms with surface edges that are not 90 degrees, i.e. where the linear dimension cannot be measured, the dimensions refer to the theoretical intersection of the surfaces ("sharp edge condition").

Such dimensions shall be identified by adding the word “theoretical”, or the abbreviation “theor.” to the indication (see [Figure 30](#)).



<sup>a</sup> Theoretical.

**Figure 30 — Linear dimensions for prisms**

### 5.9.7 Angles

The nominal values with tolerances shall be stated in the drawing. The surfaces in question shall be indicated by capital Roman letters (see [Figure 31](#)).

[Figure 31](#) also shows an example of the indication of angles and their tolerances. The angle between a plane containing the normals of two surfaces and the normal to any other surface is called a “pyramidal deviation”. Pyramidal deviation is specified in the form

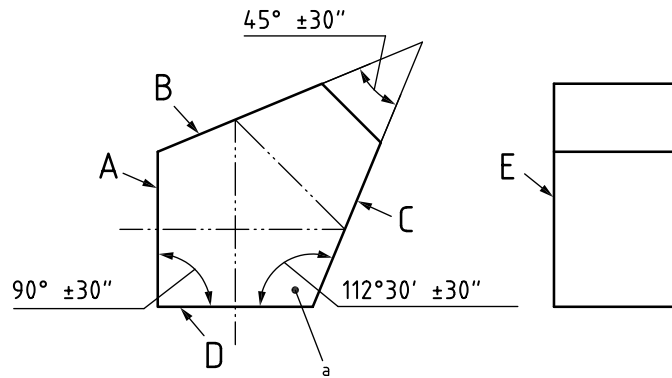
$$\text{pyr AB, C} < n$$

where pyr indicates a pyramidal deviation, n is the allowed angular deviation from the surface normal of surface C to reference plane which contains the surface normals for A and B.

The optical ray path and deflection angle may be shown. The deflection angle is the angle between the directions of the incident and emergent rays. Unless otherwise specified, the incident ray shall be perpendicular to the entrance surface. If specified, the deflection angle shall be given with a  $\pm$  tolerance (see [Figure 32](#)).

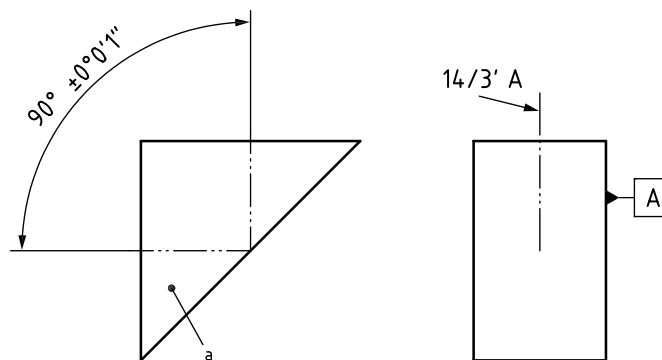
A tolerance in the ray deviation with respect to the datum plane or axis may be indicated using the 14/ notation of ISO 10110-6 as shown in [Figure 32](#).

NOTE This use of the 14/ notation is not fully described in the current edition of ISO 10110-6, however it is a clear and unambiguous way to indicate the ray deviation tolerance. The notation will be described more fully in a future revision of Part 6.



- ∠ A, E = 90° ± 10'
- ∠ D, E = 90° ± 10'
- pyr AD, C < 1'
- a Mark for identification.
- ∠ B, E = 90° ± 3'
- ∠ C, E = 90° ± 3'
- pyr AD, B < 1'

**Figure 31 — Angles with tolerances**



- a Mark for identification.

**Figure 32 — Prism deflection angles**

### 5.9.8 Special surfaces

Special optical surfaces shall be indicated by a special surface symbol (see [Figure 33](#)) tangentially placed at the surface and a note field in a box which identifies the special surface type and the special surface information necessary (e.g. diffractive order number, period, blaze), or a reference to a separate document that describes the special surface. The box, circle and connection line shall all be a continuous thin line type 01.1 in ISO 128-24. See [Figure A.4](#). Additionally, the special surface symbol and information can be tabulated, similar to the method used for coatings. See for example [Figure A.1](#).



**Figure 33 — Special surface symbol**

## 5.10 Material specification

### 5.10.1 General

The information required to define the material shall be entered in a box on the drawing.

The following information shall be given, as appropriate:

- a) Indication of material, e.g.:
  - manufacturer, material type; or
  - international glass code number; or
  - refractive index and Abbe number, including an indication of the reference wavelength; or
  - chemical description (for example for crystalline material);
- b) material requirements, such as:
  - specifications and/or tolerances for refractive index and dispersion (especially important for optical glass), transmission (versus wavelength), birefringence, fluorescence, coefficient of thermal expansion (CTE), raw glass specifications defined in ISO 12123, crystal properties (e.g. mono- or polycrystalline) and orientations with respect to the optical axis (see [5.10.2](#) for more information); and
  - specifications and/or tolerances for “chemical characteristics or properties” (important for climatic, acid, alkali, stain resistance, etc.), and mechanical properties (like hardness) that are sometimes important for processing.

Material properties and tolerances that refer to homogeneity, striae, bubbles, and stress birefringence in the individual optical element shall be specified in accordance with ISO 10110-18.

### 5.10.2 Crystallographic axes

When the optical material is crystalline it may be necessary to indicate the crystallographic axes directions on the drawing. Examples of ways of indicating the axes can be found in IEC 60758:2016 Figures 1, 3 and 9.

When using Miller indices to indicate axis direction, the Miller indices are specified with square brackets e.g. [110] or  $[2\bar{1}1]$ . Alternatively miller indices can indicate the crystallographic plane of a surface of the element, in which case round brackets are used e.g. (110).

## 5.11 Indication of optical tolerances and various properties

### 5.11.1 Tolerances for the position of the local coordinate systems

The rules for indicating tolerances for the position of local coordinate systems are given in ISO 10110-6.

### 5.11.2 Optical properties and tolerances

Optical properties and tolerances shall be indicated using the symbols shown in [Table 1](#) and the other parts of ISO 10110, and either the tabular format described in [5.1](#), or with a leader line to the appropriate surface or volume. Instructions for the indication of numerous properties and tolerances specific for optical parts are given in the various parts of ISO 10110.



**Table 1 — Properties to be listed if applicable**

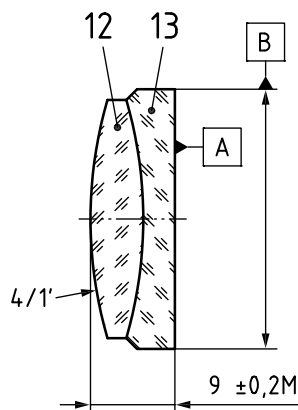
Items	Description
Material	Type, name and manufacturer or identification number of the material
Surface type: ASPH CYL GS Ⓢ toroid, etc.	Indication of the type of surface being specified: — asphere — cylinder — general surface — special surface — other designations per ISO 10110-12
$n$ $v$	If appropriate, refractive index and Abbe number including an indication of the reference wavelength (and tolerances).
$R$	Radius of curvature with tolerance, if desired <sup>a</sup> . The direction of curvature shall be indicated as follows: — convex surface: CX — concave surface: CC — plano surface: $R^\infty$ or PL
$\emptyset_e$	Optically effective diameter
Protective chamfer	Minimum and maximum permissible widths of the protective chamfer
Ⓐ	Surface treatment and coating (i.e. ISO 10110-9)
0/	Stress birefringence tolerance (i.e. ISO 10110-18)
1/	Indication of permissible bubbles and inclusions (i.e. ISO 10110-18)
2/	Homogeneity and striae classes (i.e. ISO 10110-18)
3/	Surface form tolerance (i.e. ISO 10110-5)
4/	Centring tolerance (i.e. ISO 10110-6)
5/	Surface imperfection tolerance (i.e. ISO 10110-7)
6/	Laser irradiation damage threshold indication (i.e. ISO 10110-17)
13/	Transmitted wavefront deviation (i.e. ISO 10110-14)
15/	Assembly surface imperfections (i.e. ISO 10110-7)
√	Surface texture (i.e. ISO 10110-8)
	If appropriate, the words “To be cemented” or “To be contacted” and information about the surface interface such as bondline thickness tolerance shall be added.
NOTE Aspheres, cylinders, and other optical surfaces can require additional information to define the surface shape. See ISO 10110-12 and ISO 10110-19 for further guidance.	
<sup>a</sup> Other ISO symbols are defined for the radius of curvature. In particular, ISO 129-1 uses “SR” as such a symbol, which shall not be used according to ISO 10110.	

### 5.11.3 Optical subassembly

An optical subassembly drawing shall include, as appropriate, the following items (see [Figure 34](#)):

- a) element part numbers (or parts list reference numbers);
- b) details of cement or other method of bonding;
- c) dimensions, tolerances and necessary datums that are additional to those given in detail drawings (e.g. centring tolerance and datums);

- d) focal length and/or other requirements;
- e) special notes regarding assembly and test procedures.



NOTE 1 Cement, according to specification # XXXX.

NOTE 2 Focal length  $100 \pm 0,5$ .

**Figure 34 — Optical subassembly**

The drawings of parts of subassemblies shall contain references to the assembling process, e.g. “to be cemented”.

If a subassembly drawing does not contain tolerances for surface form or surface imperfections, the tolerances given in ISO 10110-11 apply after cementing (or optical contacting), where appropriate<sup>4)</sup>.

If the thickness tolerance of a compound (e.g. cemented) subassembly is smaller than the sum of the thickness tolerances of the elements forming the subassembly, so that the elements have to be matched, the thickness tolerance of the subassembly shall be identified with the capital letter “M” (see [Figure 34](#)).

## 6 Additional indications for optical layout drawings

### 6.1 General

An optical layout drawing shall show the relative positions of all components of a complete optical system and shall specify, as appropriate, the following items (see [Figure 35](#)):

- a) item references (or parts list reference numbers);
- b) datum (reference) axis for element tilt and decenter tolerances;
- c) separations, including tolerances;
- d) magnification (total and/or partial, as applicable);
- e) object distance, or range of object distances;
- f) full field of view in object space;
- g) numerical aperture or  $f$ -number;
- h) position and sizes of field stops;
- i) position(s) and size(s) of image plane(s);

4) Imperfection tolerances for cemented surfaces taken from element drawings can need adjustment to consider the enlarged or reduced view of the imperfections through an optical element.

- j) position and sizes of pupils;
- k) dimensions of clear apertures and physical sizes of parts;
- l) position(s) and size(s) of focal plane(s);
- m) spectral passband;
- n) movements required for magnification and focus adjustment;
- o) mounting interface data;
- p) element tilt and decenter tolerances; see ISO 10110-6;
- q) special notes regarding assembly and test procedures;
- r) other performance requirements.

NOTE 1 For the sake of clarity, it is sometimes useful to indicate certain data in tabular form.

NOTE 2 In cases where optical systems have complex, folded paths it can be necessary to show isometric views.

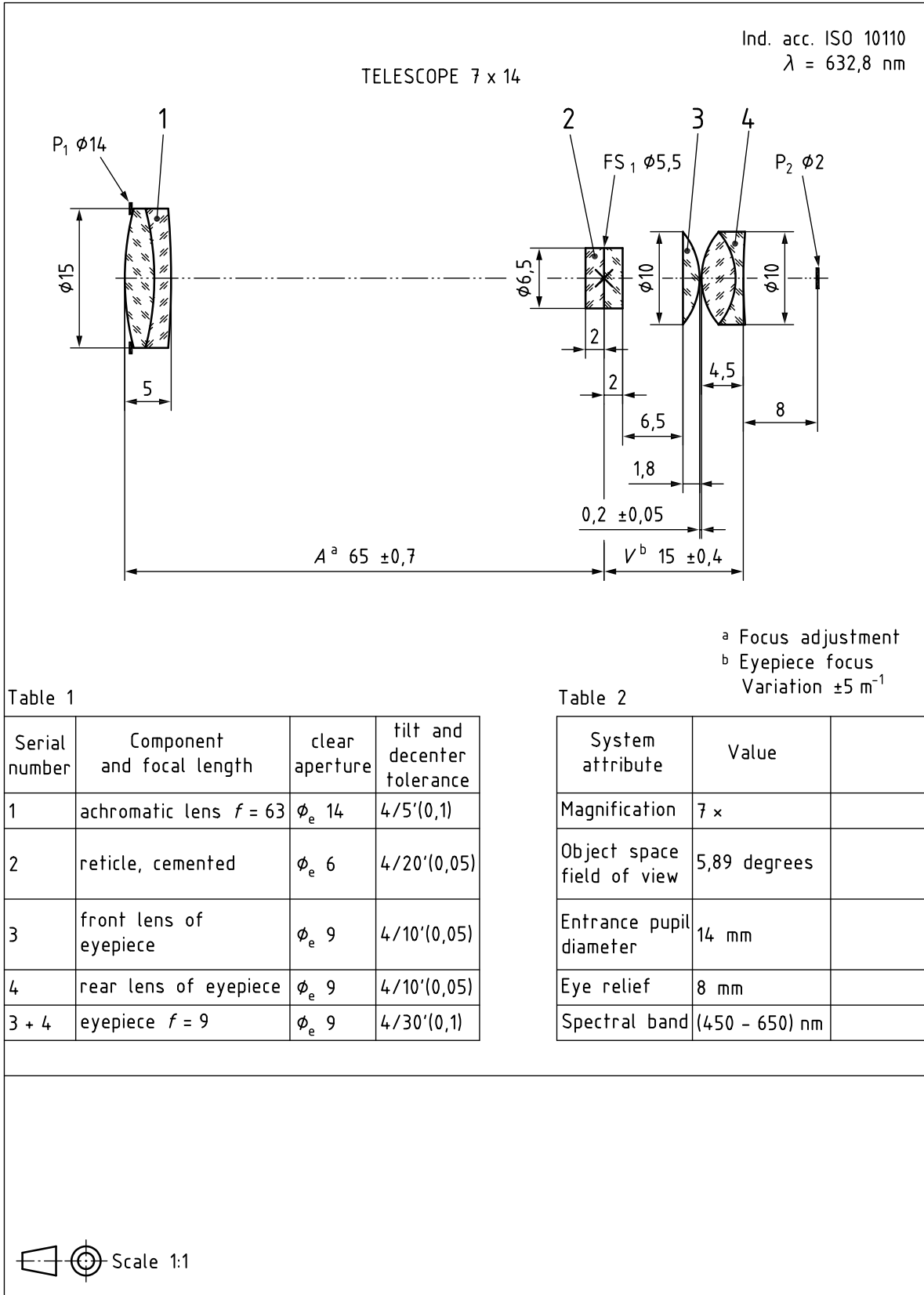


Figure 35 — Optical layout drawing

## 6.2 Axial separations

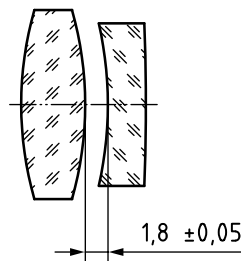
### 6.2.1 General

Separations between the elements shall be indicated along the datum axis (see ISO 10110-6). For axially symmetric systems this axis is the centre line.

Distances that are to be adjusted during assembly, or varied during use, shall be indicated on the optical layout drawing, together with a short explanatory note giving the reasons for the adjustment or variation.

### 6.2.2 Fixed axial separations

Fixed separation distances shall be shown by the nominal design dimension with the permitted tolerance (see [Figure 36](#)).

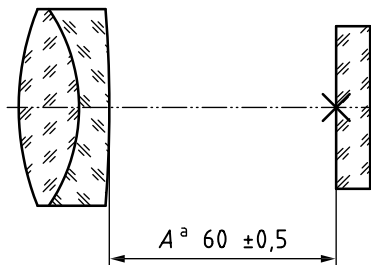


**Figure 36 — Air space between lens elements**

### 6.2.3 Adjustable axial separations

During assembly, some axial separations may be varied within predetermined limits in order to achieve a specific condition or requirement. Such adjustable distances shall be identified with the capital letter “A”, and the reason for the adjustment shall be given in a note. If necessary, the required accuracy of adjustment shall also be given. The dimensional information shall be shown on the drawing in the following order (see [Figure 37](#)):

- the letter “A” to identify that the distance is to be adjusted;
- the nominal distance;
- the permissible limits of adjustment from the nominal value.

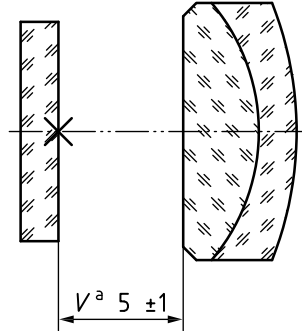


<sup>a</sup> Adjust for best focus, accuracy of adjustment  $\pm 0,02$ .

**Figure 37 — Adjustable axial separation**

6.2.4 Variable axial separations

Some axial distances may need to be varied by the user of the complete system. These shall be identified by the letter “V”. The extent of variation together with the reason for the variation shall be shown in the drawing (see Figure 38). If necessary, the required accuracy shall also be given.



<sup>a</sup> Eyepiece focus variation  $\pm 3 \text{ m}^{-1}$ .

Figure 38 — Variable axial separation

6.3 Images, pupils, field stops and other apertures

Positions and sizes of images, pupils, field stops and other apertures in optical layout drawings shall be drawn as follows:

- a) the position of an image shall be drawn as a cross (line type 01.2, ISO 128-24) on the optical axis (see Figures 39 and 40);
- b) the position of a pupil shall be drawn as a short continuous thick line (line type 01.2, ISO 128-24) across the optical axis (see Figure 41);
- c) physical apertures shall be drawn as continuous thick lines (line type 01.2, ISO 128-24) defining position (see Figures 42 and 43);
- d) sizes of physical apertures should be drawn as continuous narrow lines (line type 01.1, ISO 128-24) perpendicular to the axis (see Figures 42 and 43);
- e) other apertures shall be drawn in a similar manner, but in dashed thick lines (line type 02.2, ISO 128-24) (see Figure 44).



Figure 39 — Indication of image position (in space)

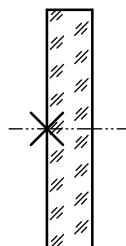
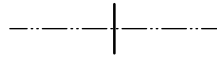


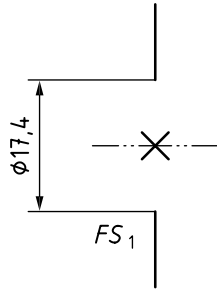
Figure 40 — Indication of image position (on a surface)



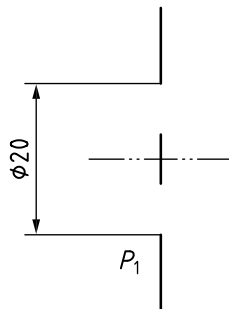
**Figure 41 — Pupil position**

If required, field stops shall be marked  $FS_1$ ,  $FS_2$ , etc., pupils shall be marked  $P_1$ ,  $P_2$ , etc., following the path of the incident light (see [Figures 42](#) and [43](#)).

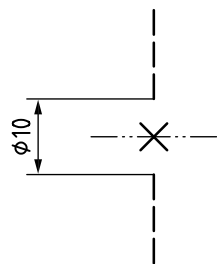
Dimensions of field stops, pupils and images shall be shown adjacent to the stop, pupil or image (see examples in [Figures 42](#) to [44](#)).



**Figure 42 — Physical aperture (field stop)**



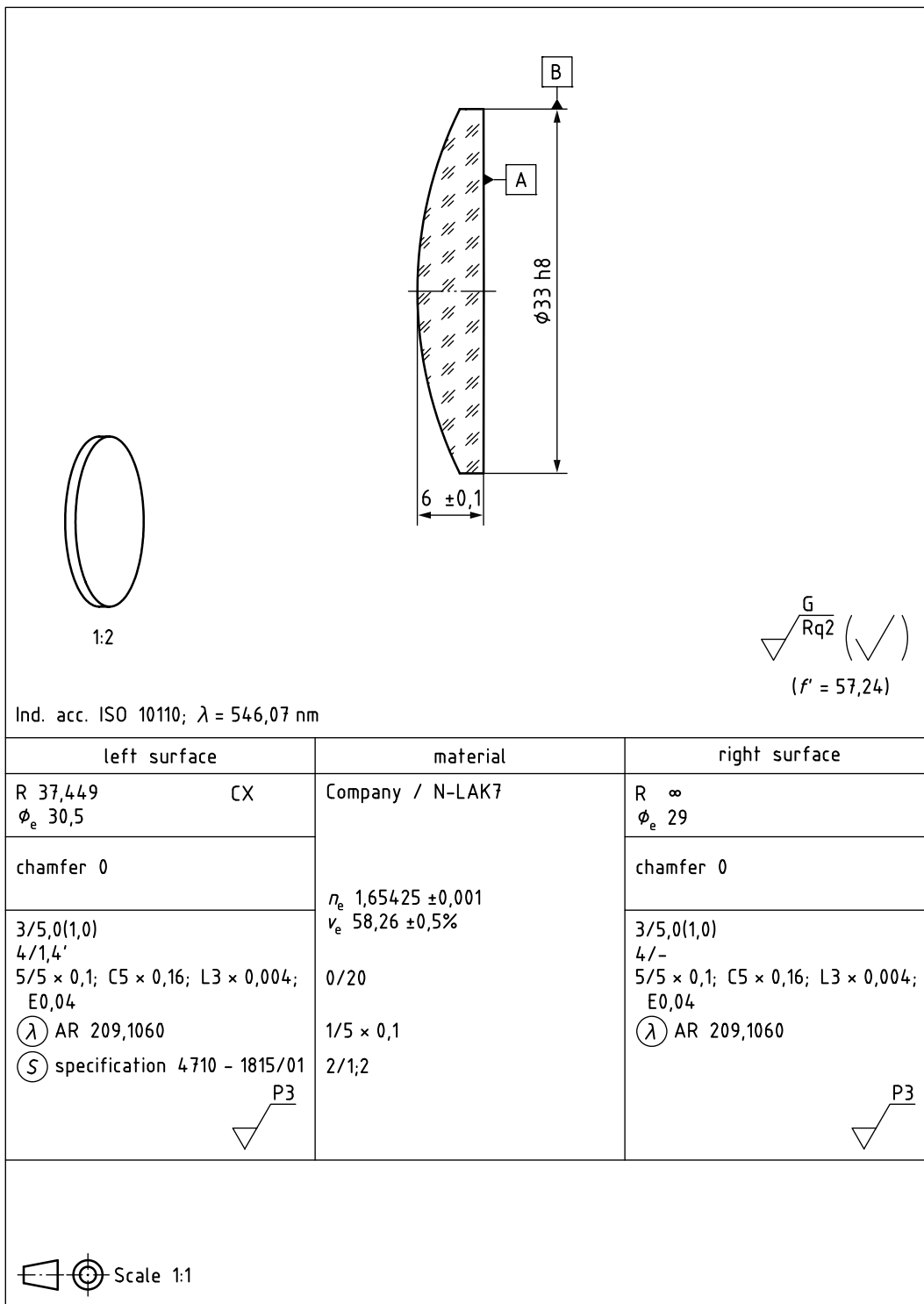
**Figure 43 — Physical aperture located at the pupil  $P_1$**



**Figure 44 — Image without physical aperture**

## Annex A (informative)

### Examples of drawings of optical elements



**Figure A.1 — Example of lens element drawing**



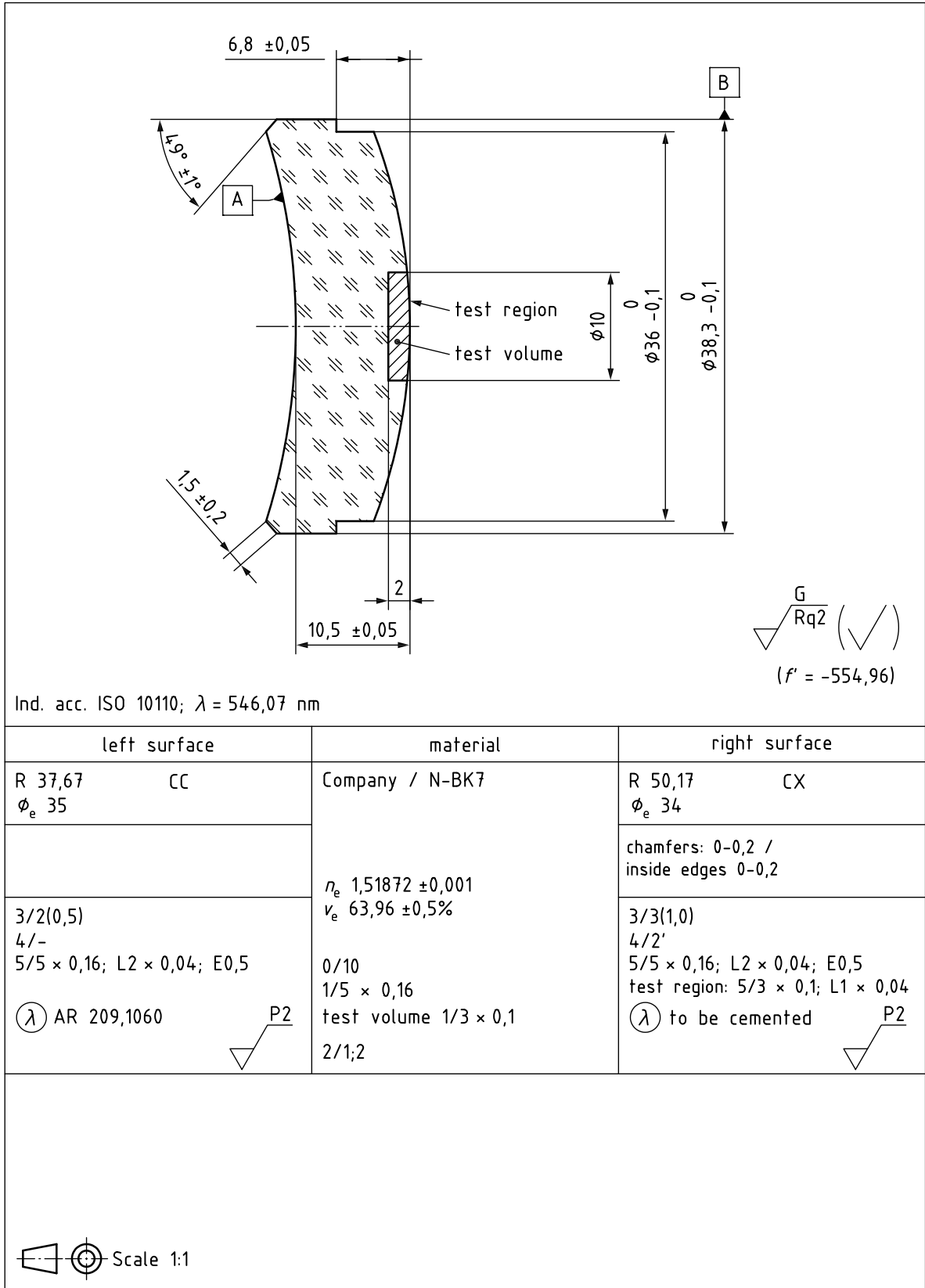


Figure A.2 — Example of lens element drawing

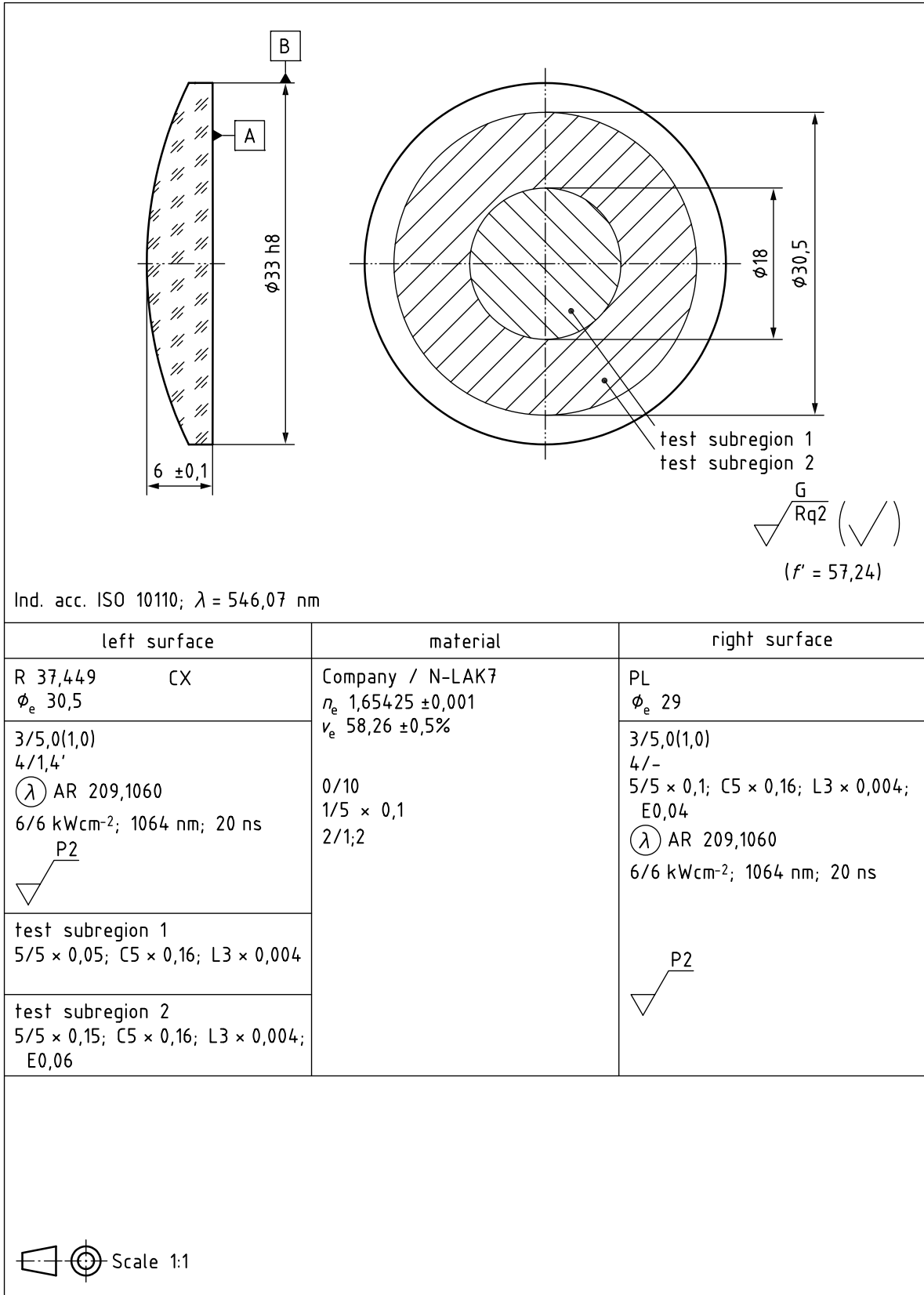


Figure A.3 — Example of lens element drawing

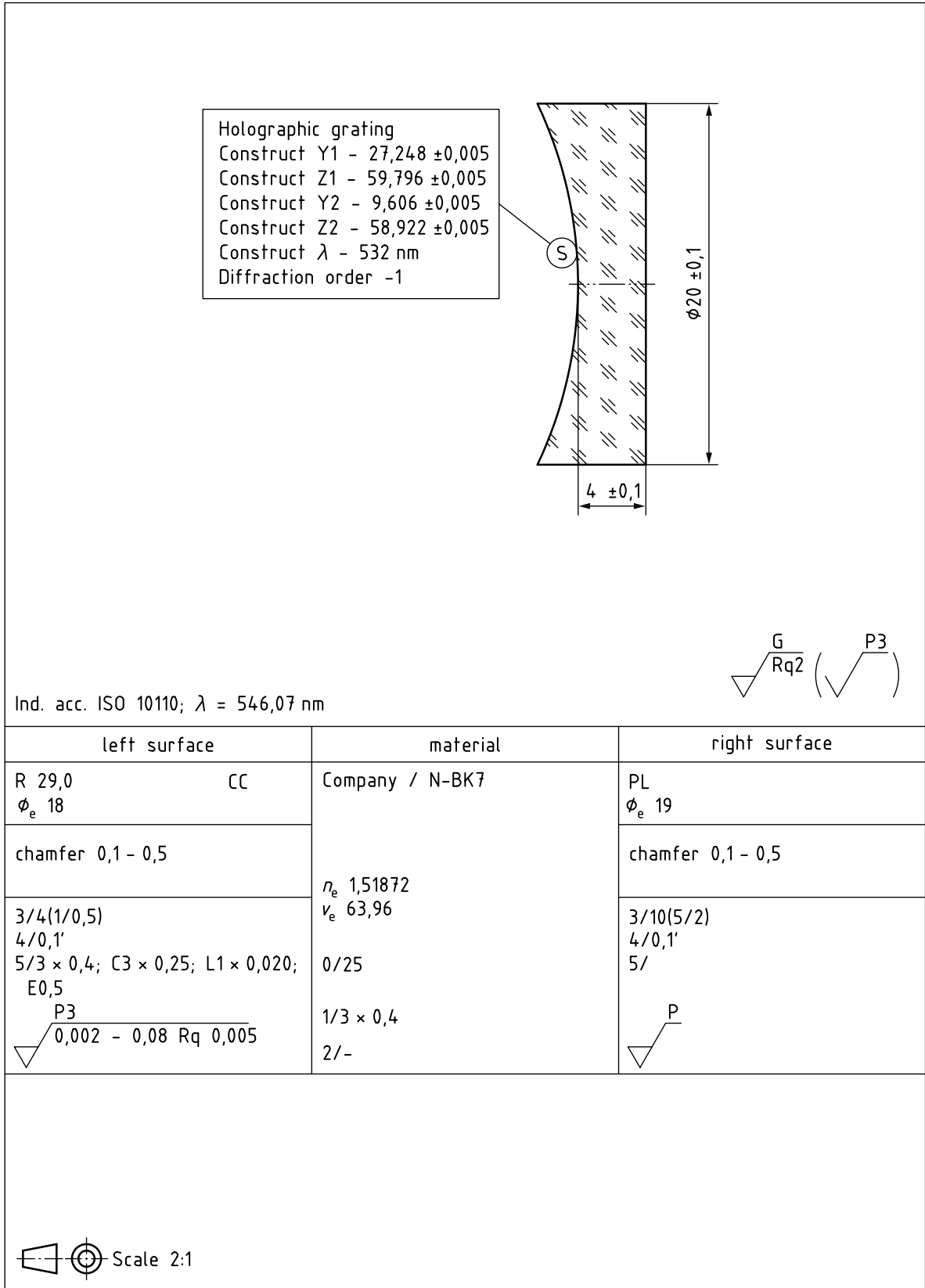


Figure A.4 — Example of a lens element drawing with a special surface indication

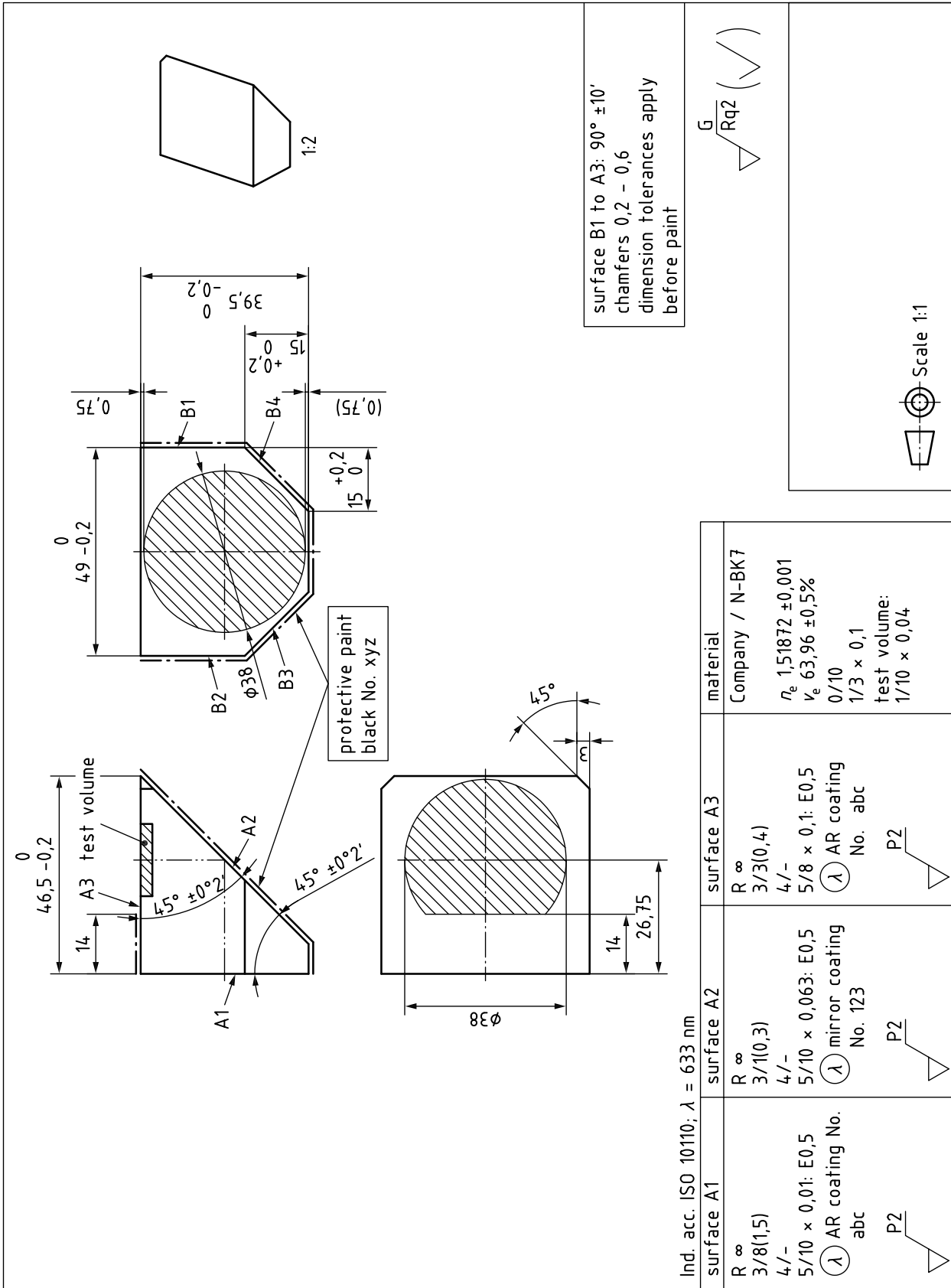


Figure A.5 — Example of a tabular element drawing with more than two surfaces; vertically aligned

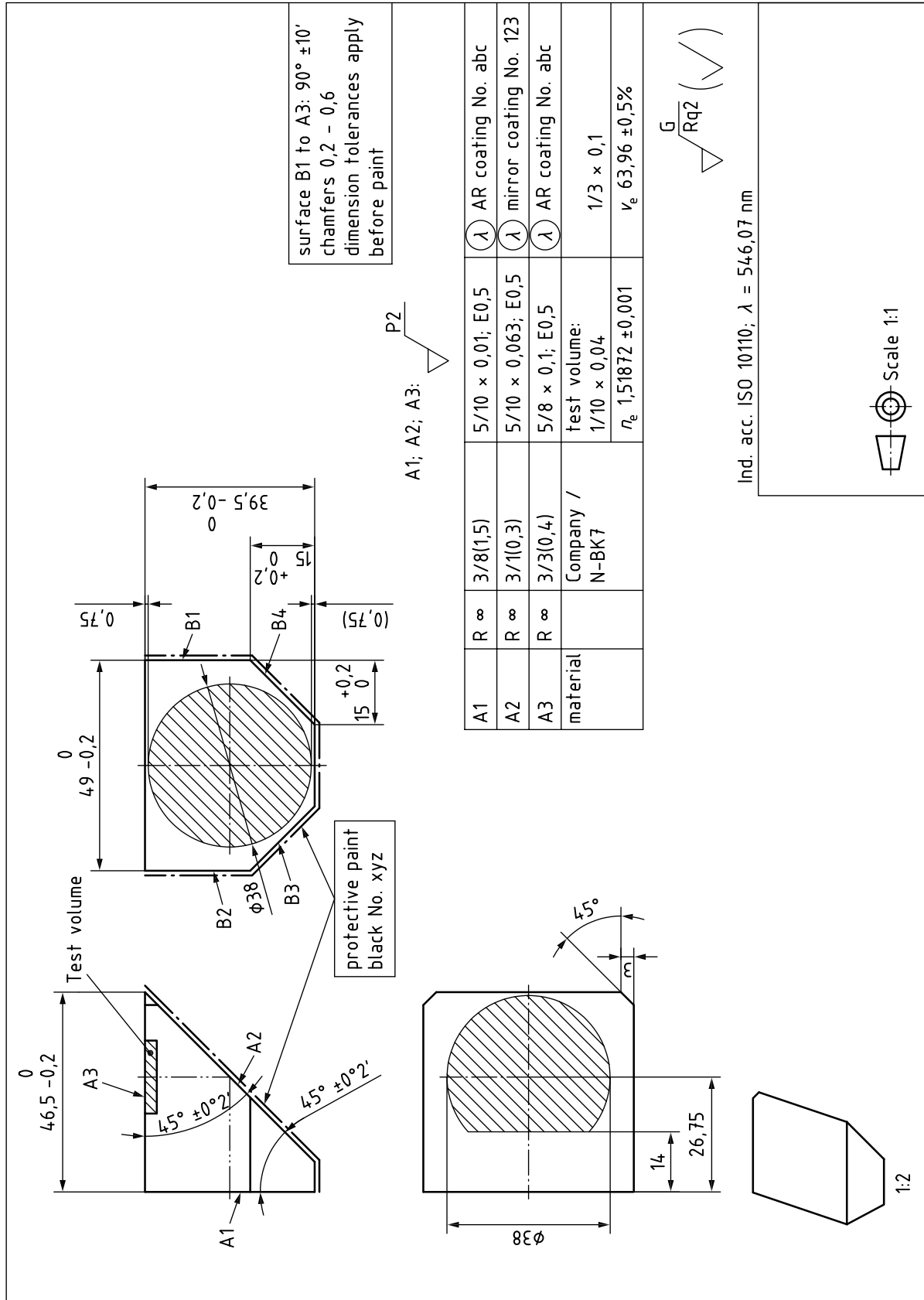


Figure A.6 — Example of a tabular element drawing with more than two surfaces; horizontally aligned

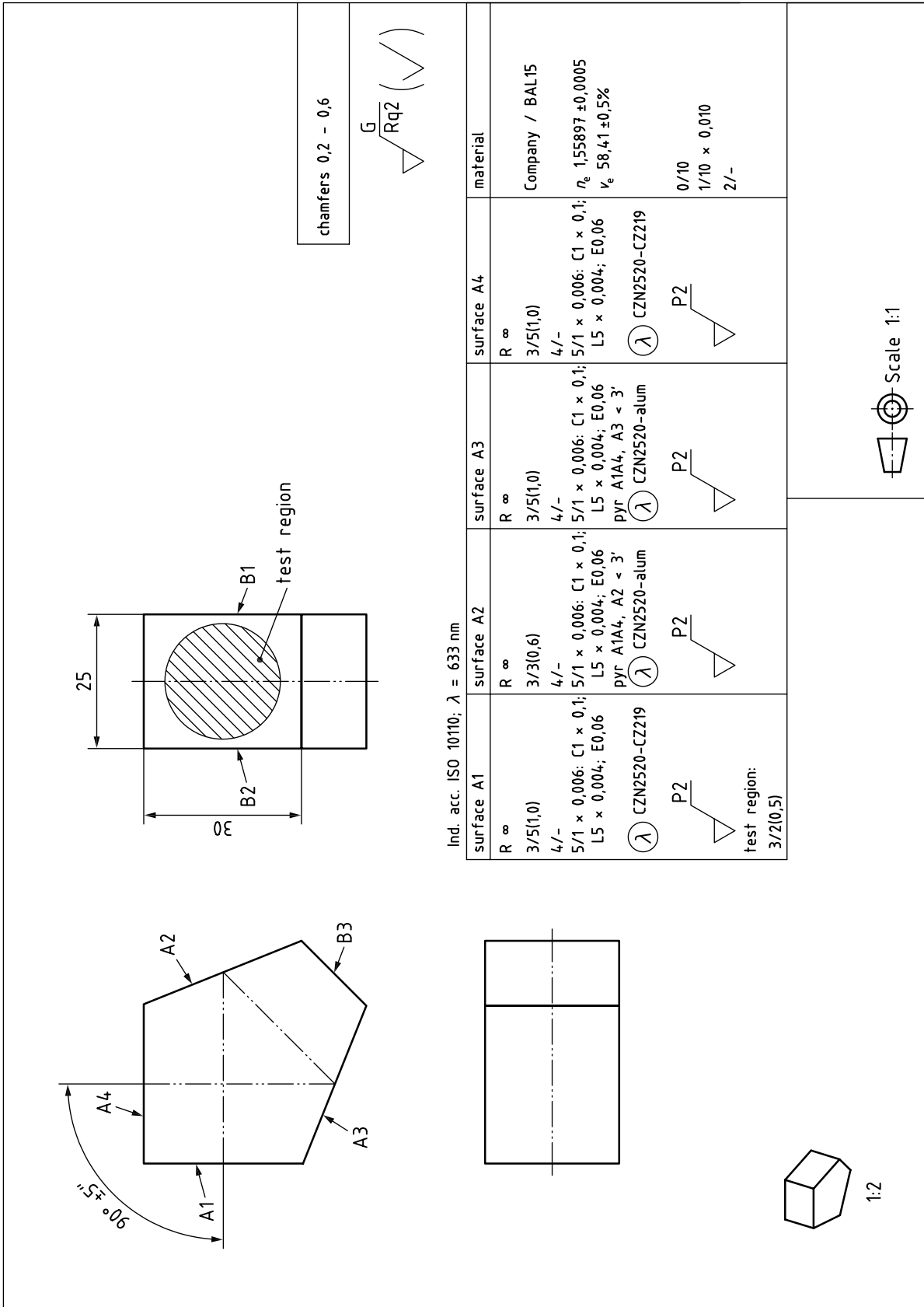


Figure A.7 — Example of a tabular element drawing with more than two surfaces; vertically aligned

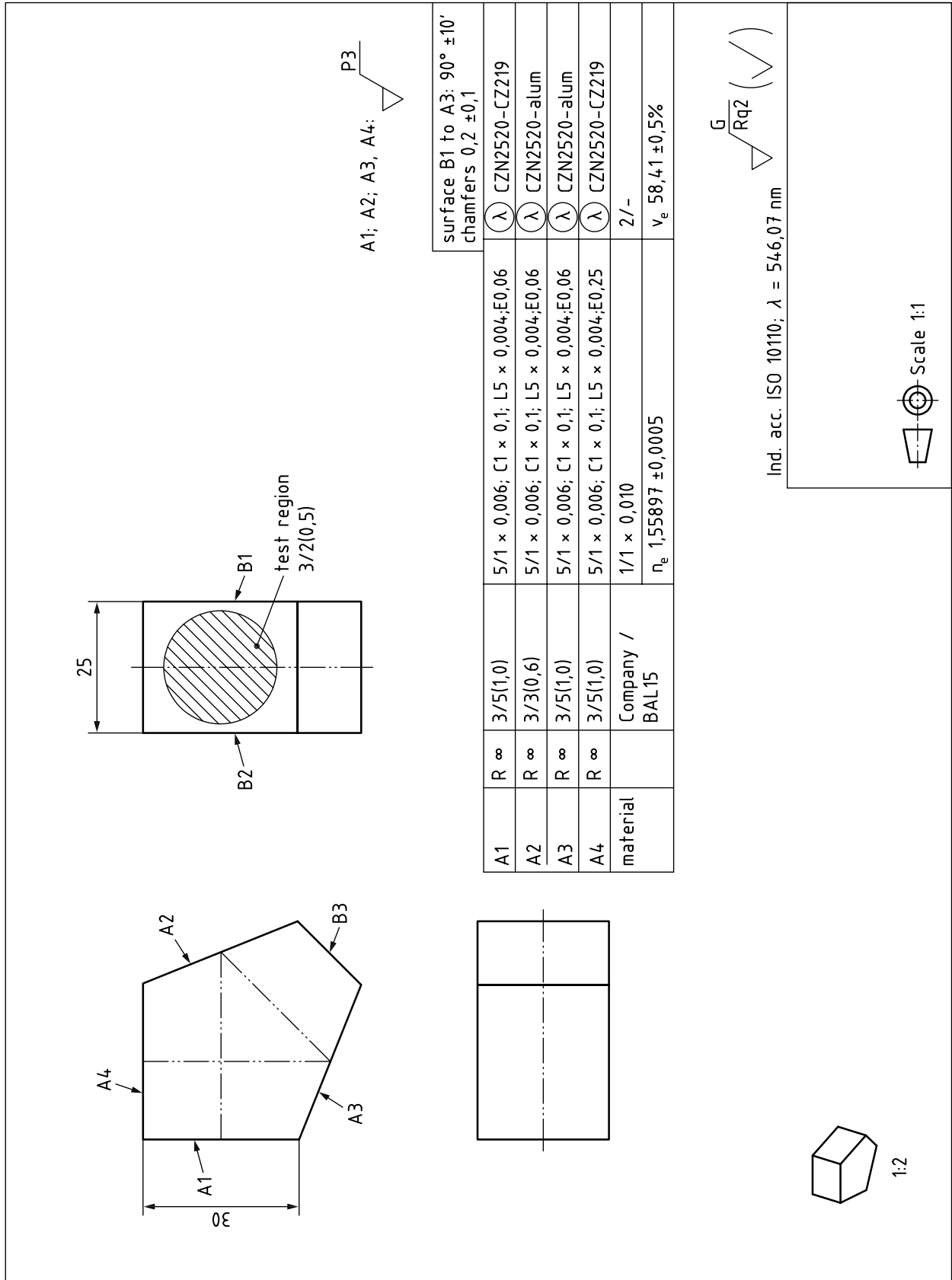


Figure A.8 — Example of a tabular element drawing with more than two surfaces; horizontally aligned

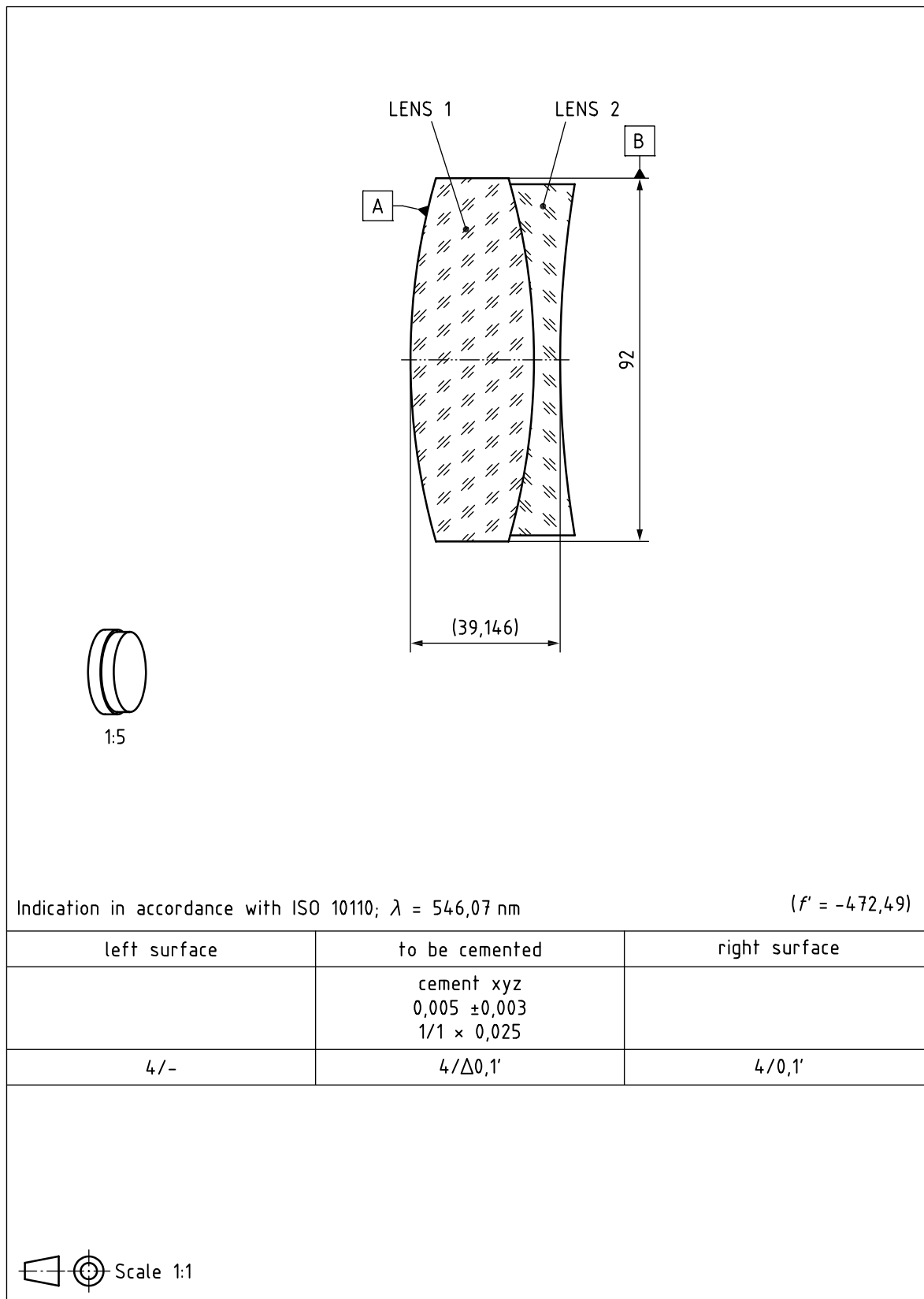


Figure A.9 — Example of tabular indication of data for a cemented assembly (doublet)



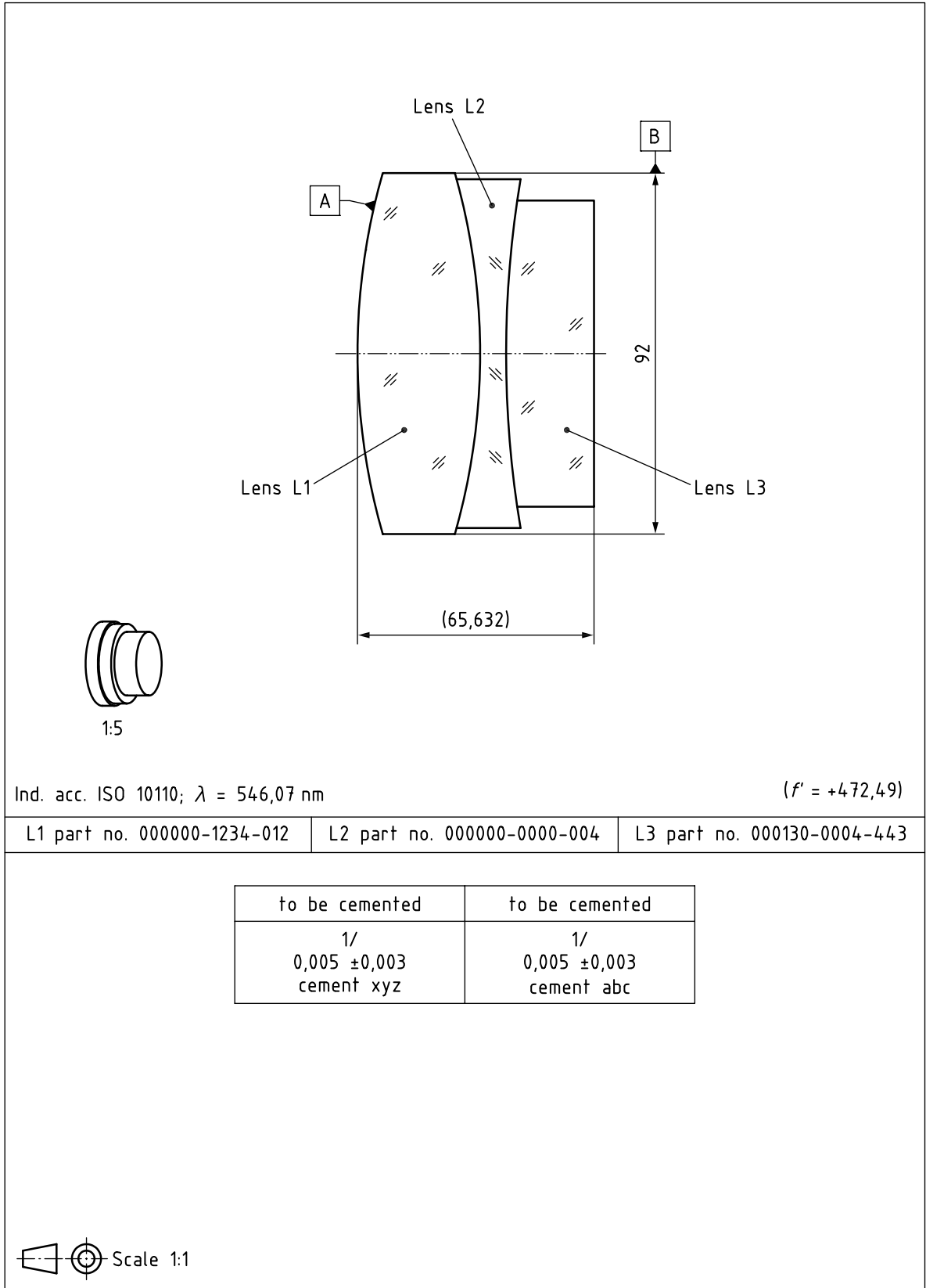


Figure A.10 — Example of tabular indication of data for a cemented assembly (triplet)

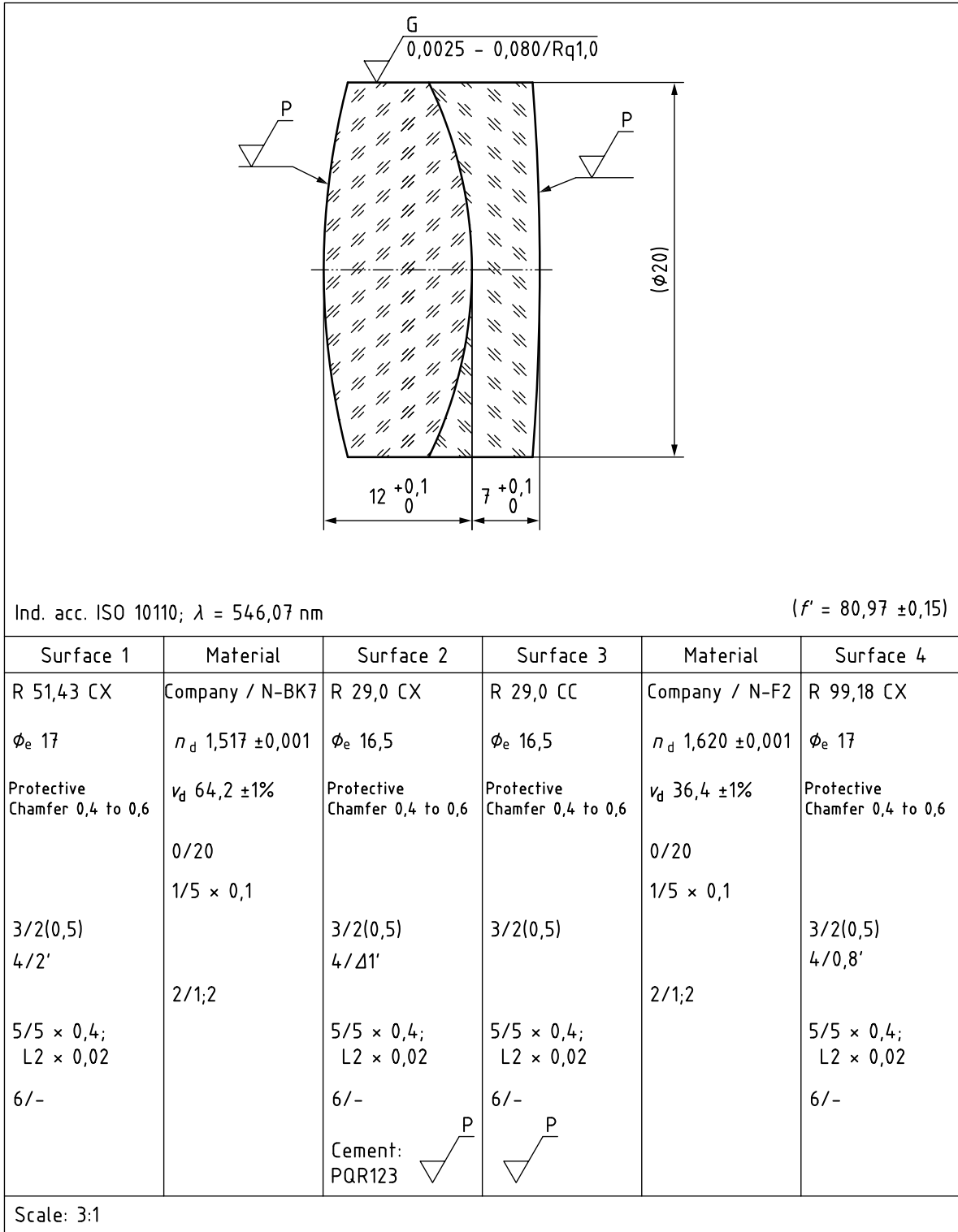
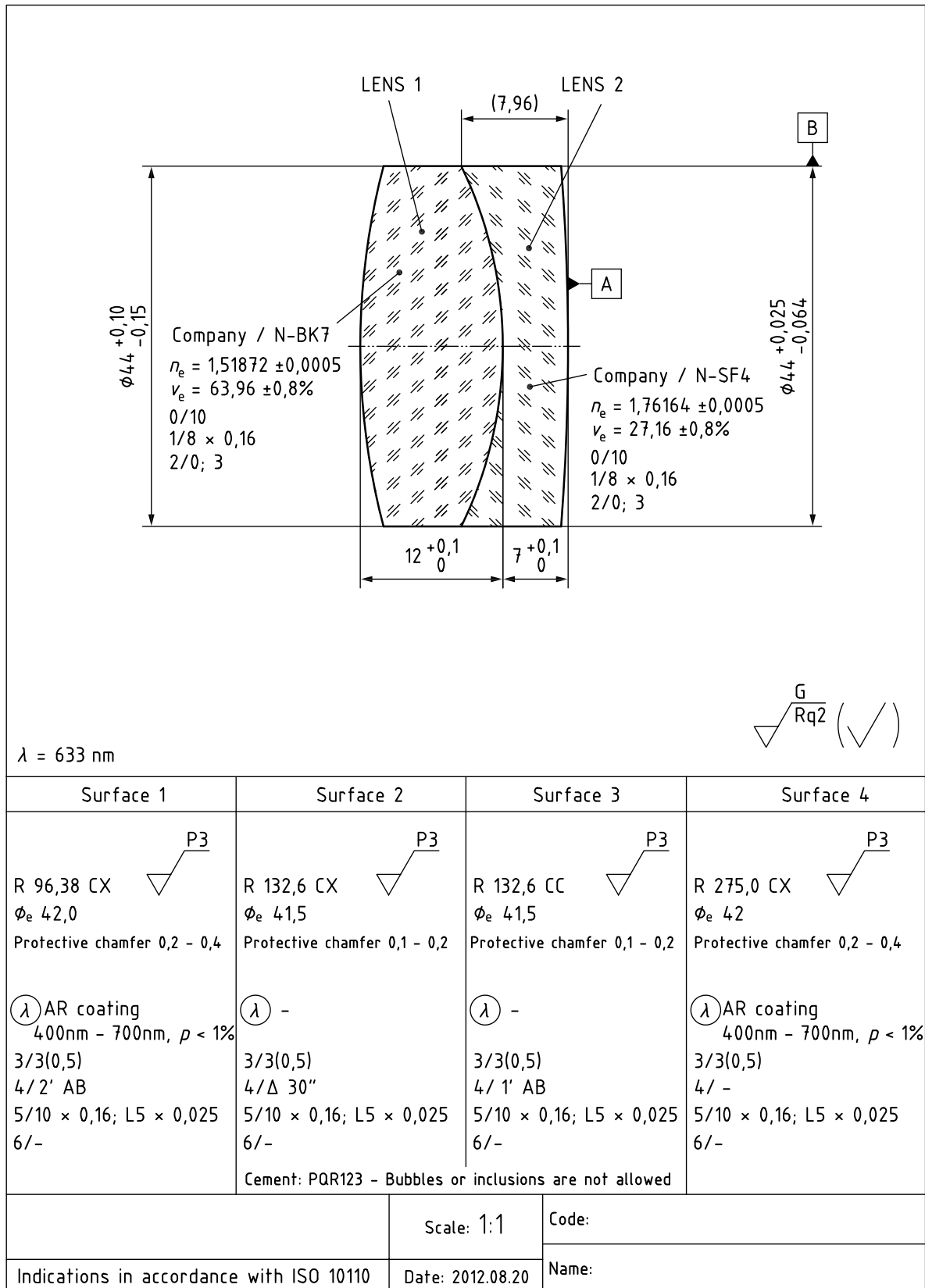


Figure A.11 — Example of tabular indication of data for the cemented assembly, when no detail element drawings are used; fully tabulated



**Figure A.12 — Example of tabular indication of data for the cemented assembly, when no detail element drawings are used; partially tabulated**

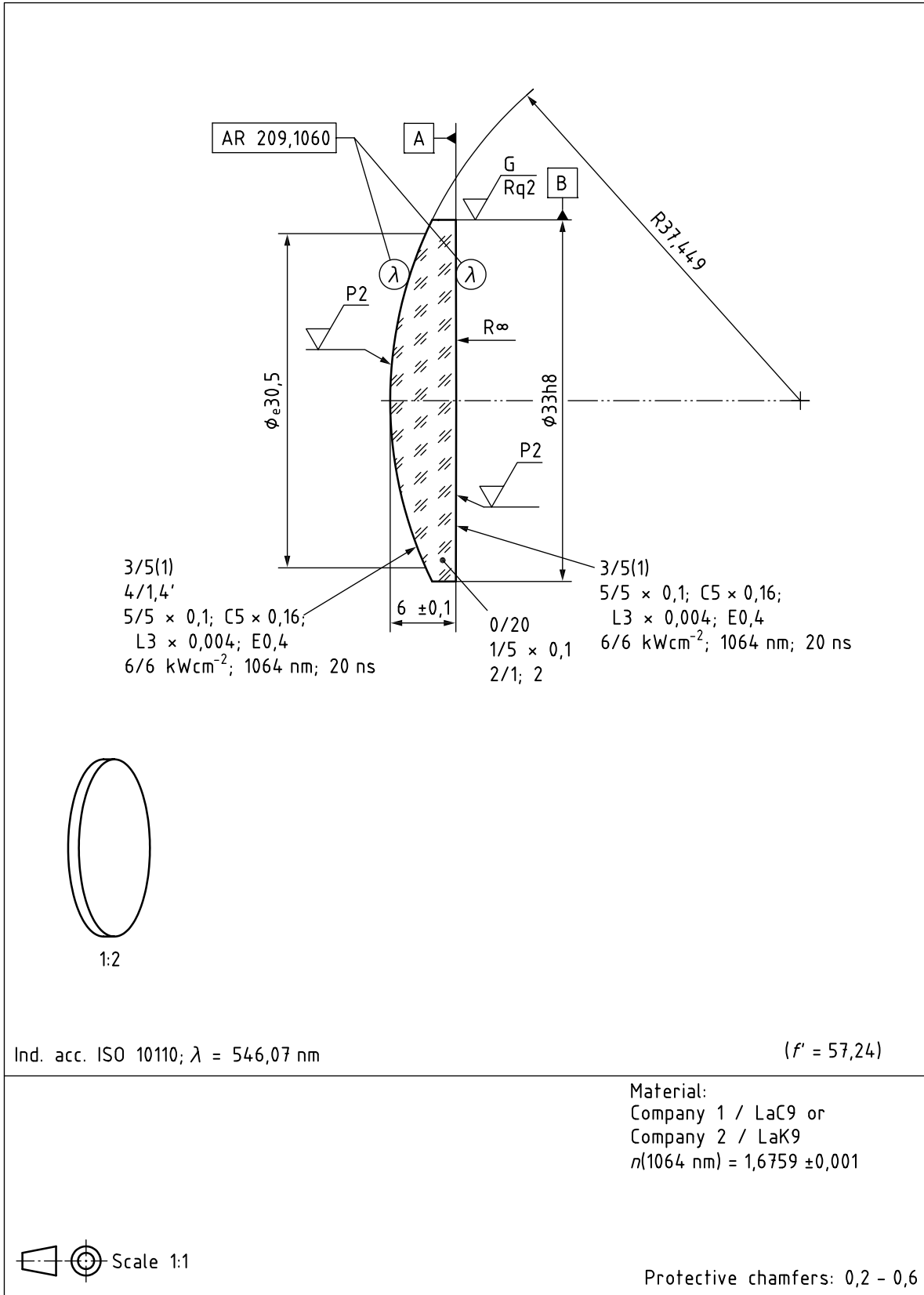


Figure A.13 — Example of a lens element drawing in the alternative layout

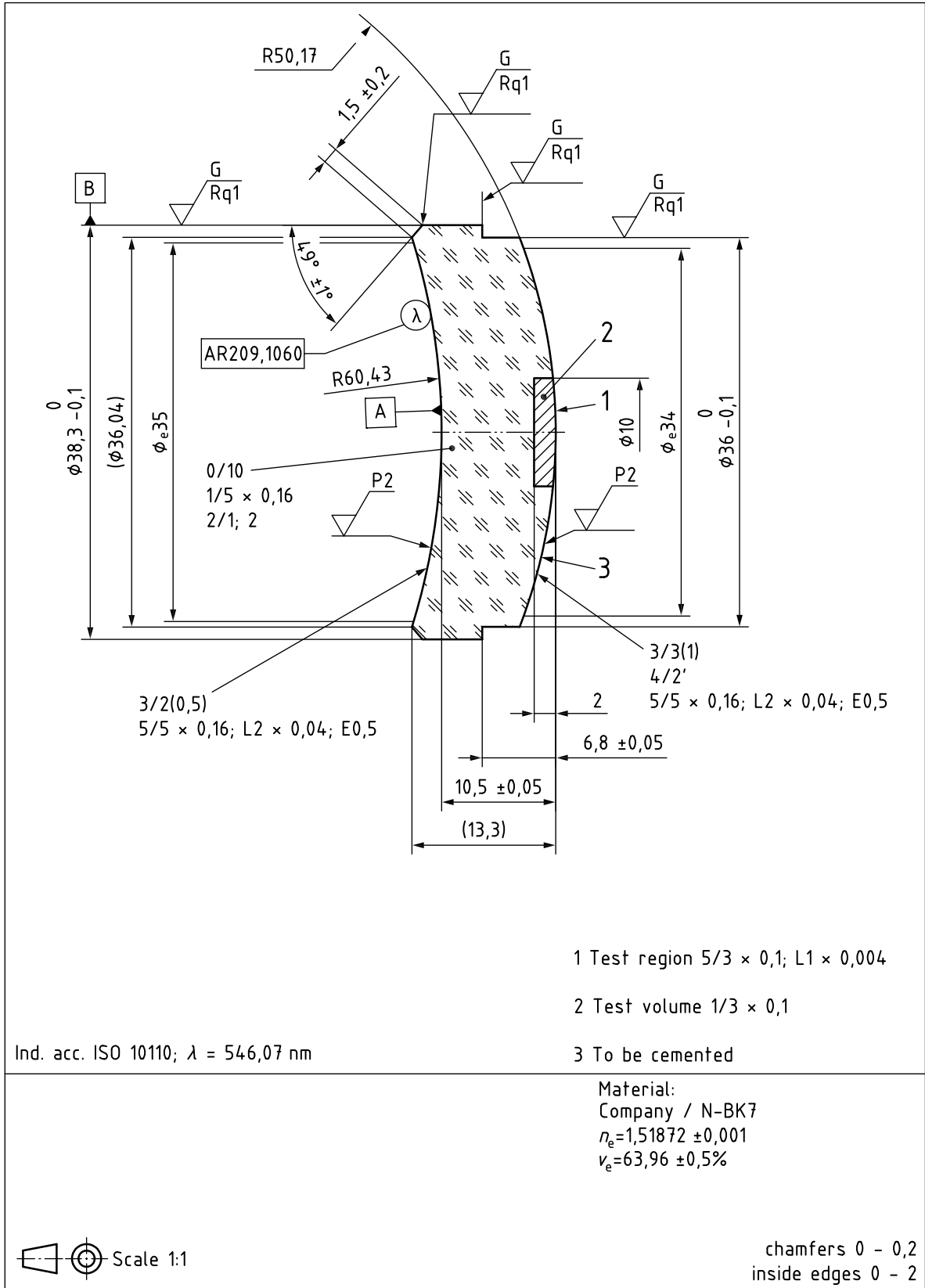


Figure A.14 — Example of a lens element drawing in the alternative layout

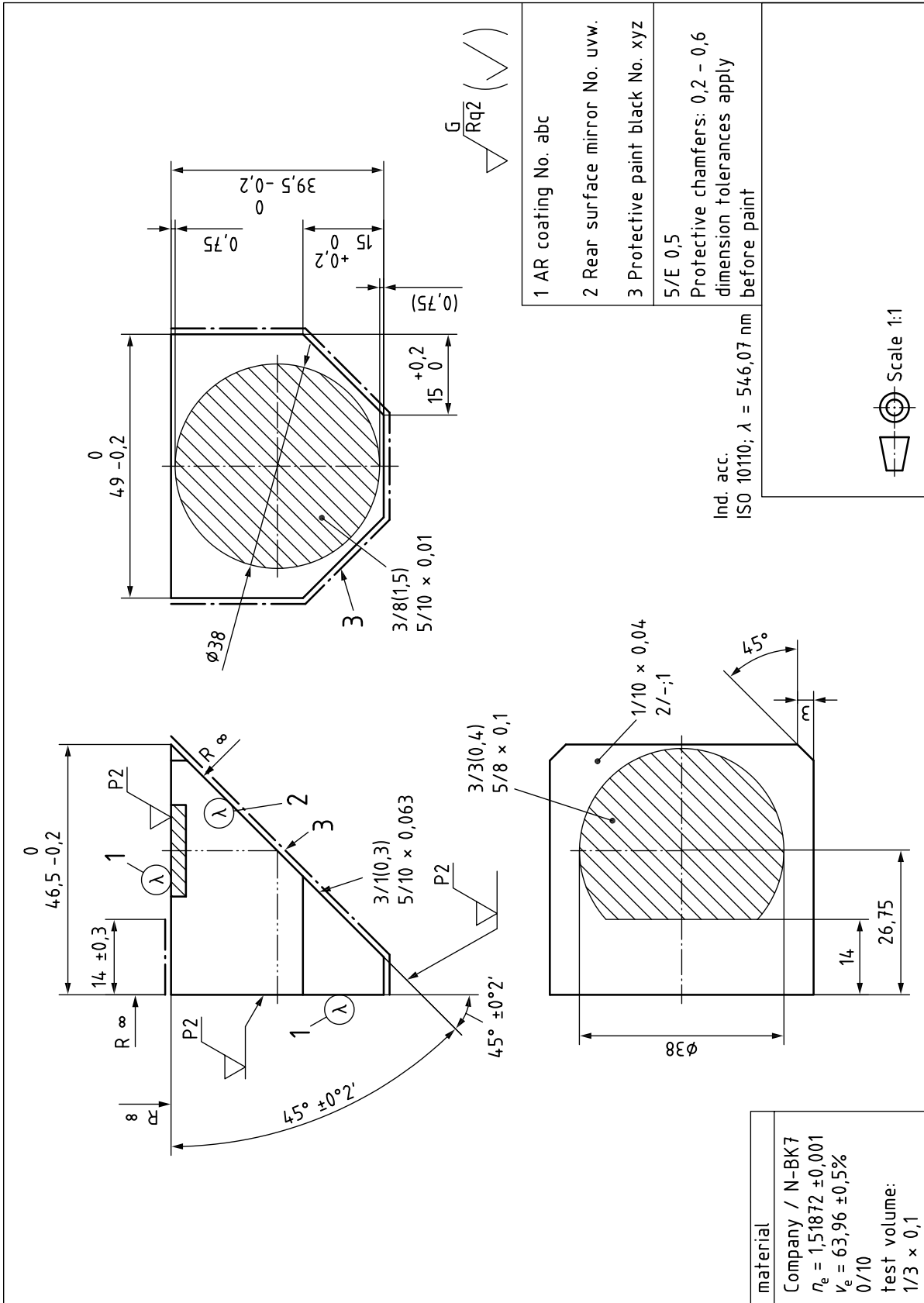


Figure A.15 — Example of a lens element drawing in the alternative layout

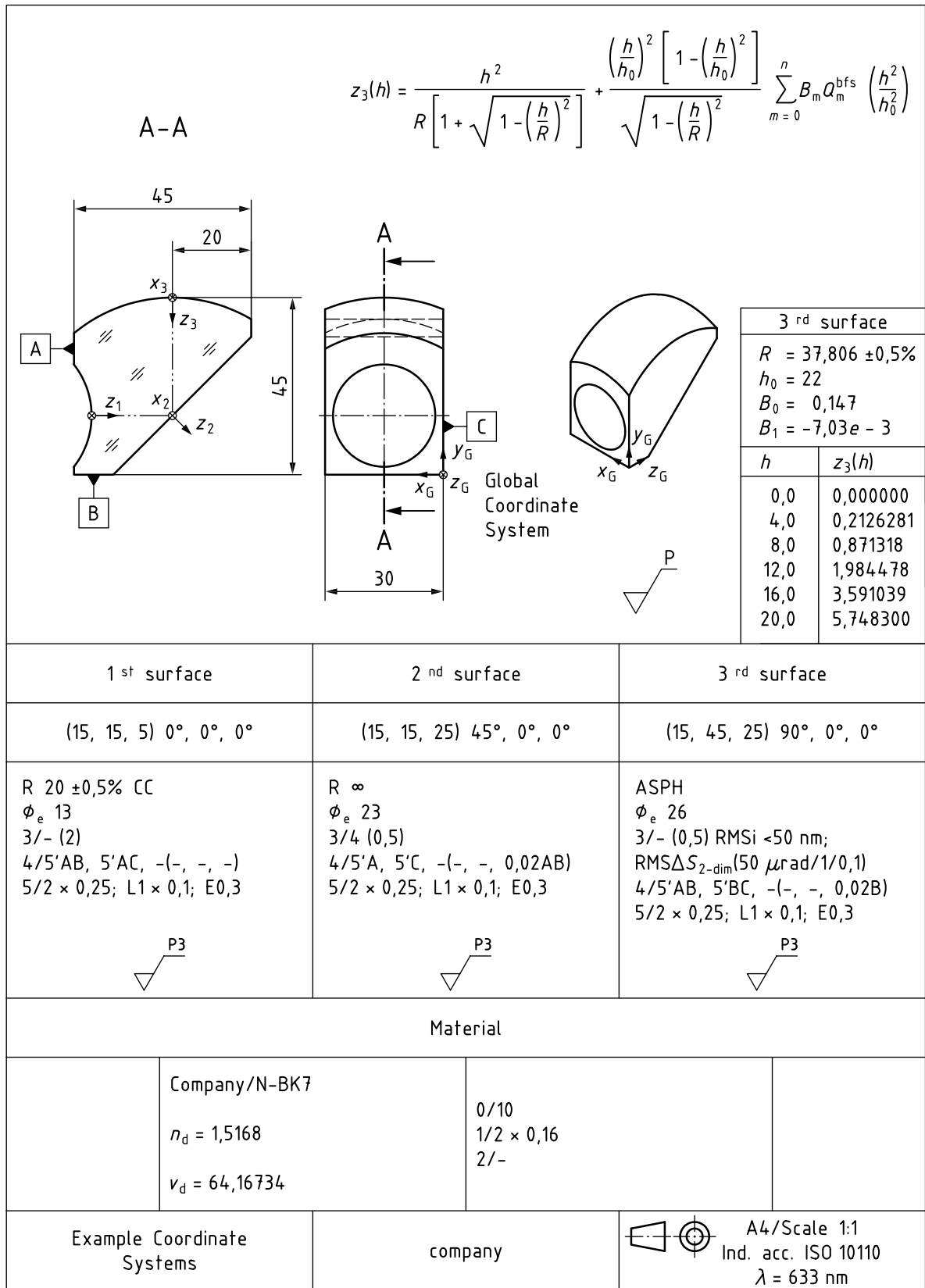


Figure A.16 — Example of an optical prism with local coordinate systems

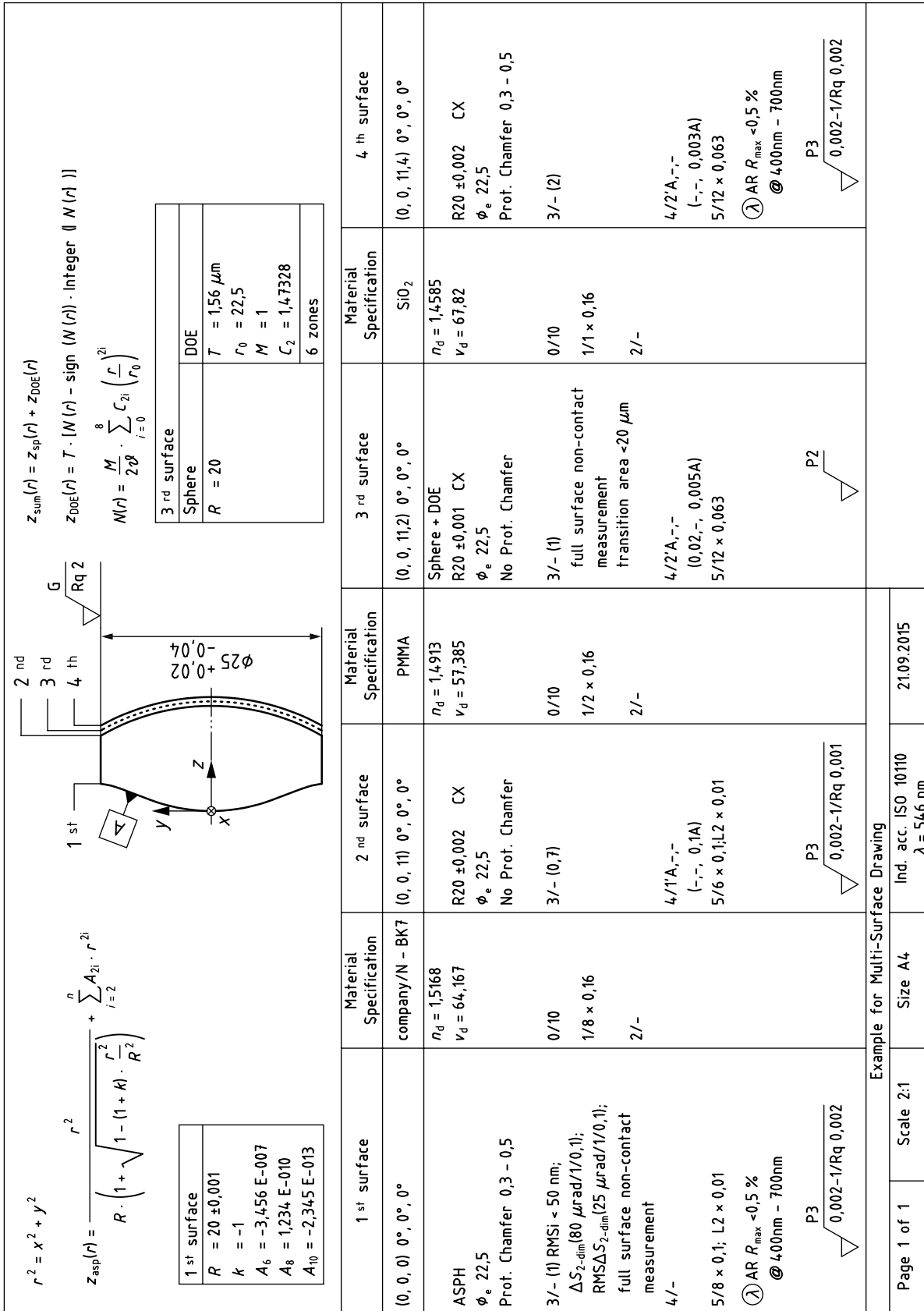


Figure A.17 — Example of a multi-surface element with local coordinates



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