



# Technical Report

**ISO/TR 11797**

## **Ophthalmic optics – Spectacle lenses – Power and prism measurements**

*Optique ophtalmique – Verres de lunettes – Mesures de puissance  
et de prisme*

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CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
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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 document 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)).

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ISO/TR 11797 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments*.

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).

## Introduction

This document work undertaken by TC172/SC7/WG3 during the systematic review of ISO 21987<sup>[6]</sup> commencing in 2014. The appropriateness and relevance of the prism and power tolerances and methodologies in ISO 8980-1<sup>[1]</sup> and ISO 8980-2<sup>[2]</sup> and ISO 21987 were investigated to help determine whether these spectacle lens standards remain relevant.

Two specific power and prism task groups were established. These two groups were tasked with reviewing tolerances and test methods with respect to current industry practices, as well as conducting a systematic review of the literature. This search of the scientific literature used the keywords 'tolerances', 'prism', 'power', 'spectacle' to identify and cross-reference studies/findings in relation to the then current tolerances used in the ISO 21987, ISO 8980-1 and ISO 8980-2, and to investigate what appropriate values might be considered to satisfy spectacle lens wearer requirements. Because the results of this literature survey were inconclusive, it was decided to launch a survey into Australian laboratory practice and yields (see [5.3](#)).

After the review of the available literature, both groups decided that a global survey of the industry into tolerances and measuring methods (see [5.4](#) and [5.5](#)) would help better to understand current industry practice, thus informing a future review of ISO 8980-1 and ISO 8980-2 and ISO 21987. Its findings could assist in harmonization as to the preferred methodology for measuring power and prism when verifying uncut lenses and finished eyewear.

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# Ophthalmic optics – Spectacle lenses – Power and prism measurements

## 1 Scope

This document describes the methods currently used in applying tolerances to the focal powers of spectacle lenses and methods that can be considered for adoption in the future; it also describes methods of measuring the prism imbalance (relative prism error) between the lenses of a mounted pair. The results of a 2014 survey of manufacturing capability for lens power and a 2018 international web survey are discussed, as are possible new methods for applying tolerances to the focal power of spectacle lenses.

## 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 13666, *Ophthalmic optics — Spectacle lenses — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13666 apply.

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

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

## 4 Background/Technical introduction

### 4.1 General

Tolerances and methodology for lens power and prism assessment in standards have varied between countries resulting in different criteria for local country standards and international standards. This can lead to potential issues and barriers to trade as globally distributed product can be assessed and qualified against different quality criteria to that applied in the manufacturing country of origin.

During the revision of ISO 21987<sup>[6]</sup> in 2014 with the edition that was published in 2017, the appropriateness and relevance of the prism and power tolerances and methodologies was discussed. To help identify how relevant spectacle lens standards are, specific power and prism task groups were established. These two groups were tasked with reviewing tolerances and test methods in the light of current practices as well as conducting a systematic review of the literature with a view to informing future revisions.

### 4.2 Power

Historically the lens power tolerances in ISO standards and regional country standards have not been harmonized. The tolerance values allowed and the methodology of their application to measured lens powers varies internationally. There have been numerous attempts to harmonize this in the past without success.

There are primarily two different methodologies currently used when measuring and applying tolerances for back vertex power assessment of spectacle lenses. To understand these methodologies, it is important to first understand the expression of lens power and the two different cylinder conventions that are applied/used in the industry. This is discussed in detail in [Clause 6](#).

The two different methodologies for assessing lens power and applying tolerances are as follows.

- Three-parameter methodology (sphere meridian 1 value, sphere meridian 2 value, and cylindrical power value).

This method establishes the two principal lens powers/meridians and applies a tolerance of  $\pm X$  to each principal spherical power separately, e.g.,  $F_1 \pm X$  tolerance and  $F_2 \pm X$  tolerance. Assuming a lens has passed these criteria, a secondary level of tolerance is then applied to the Cylinder value (or absolute difference between  $F_1$  and  $F_2$ ),  $ABS(F_1 - F_2) \pm Y$  tolerance, or expressed as Cyl  $\pm Y$  tolerance.

- Two-parameter methodology (Sphere meridian value and Cylinder magnitude value)

This method applies a tolerance of  $\pm U$  to only one of the principal lens power meridians. It is applied to the Sphere power meridian (determined by the cylinder convention being used as described in [Clause 6](#)), e.g. Sph meridian  $\pm U$  tolerance. It then applies a tolerance to the Cylinder value (or absolute difference between  $F_1$  and  $F_2$ ), e.g. Cyl  $\pm V$  tolerance. This means that the tolerance on the power in the secondary principal meridian is effectively  $U + V$ , which is greater than that in the three-parameter method.

It is important to note that when verifying lens power, the pass/fail results are affected by the lens power tolerance methodology used and, for the two-parameter methodology, the cylinder convention applied during measurement. It is also important to note that since spectacle lens powers are ordered by a spherical and a cylindrical power, it is logical that these two parameters are those that are verified. [Annex A](#) highlights specific examples where given lenses are either passed or failed depending on the methodology and the cylinder convention used.

### 4.3 Prism

When ISO 21987<sup>[6]</sup> was first being developed, only the UK with BS 2738-1<sup>[7][8]</sup> and ANSI Z80.1<sup>[9]</sup> had standards on mounted lenses. Consequently, when 5.3.5 was written, the majority of the project group, who were familiar with the application of ISO 8980-1 to uncut lenses, wished to copy its philosophy in that the standard, ISO 21987:2017, 6.6 a), effectively specified that the prismatic imbalance should be verified by checking the prismatic effects at the reference points, which in this case are the centration points.

The tolerances in ISO 21987:2017 Table 5 and illustrated in its [Figures 1](#) and [2](#), are written in two forms. There are constant prismatic imbalance values for lower value principal focal powers and for higher focal powers, prismatic powers indicated by Prentice's Rule. This is, effectively, a positioning error given by the multiplier (in cm), i.e., 2 mm (0,2 cm) horizontally and 1 mm (0,1 cm) vertically. Conversely, in ISO 21987:2017, Annex C, the tolerances are expressed directly as a prismatic imbalance error or a centration distance/vertical alignment error.

## 5 Ad hoc work group activity summary

### 5.1 Background

This clause discusses the activities undertaken by the Ad Hoc work group and the major outcomes. The three main areas of effort were in conducting a literature search, analysing a surfacing/fitting (edging and mounting) laboratory capability and undertaking a global industry survey/questionnaire as discussed below.

### 5.2 Literature search

The articles found in the literature search were used as the basis for the revised and extended [Annex C](#).

### 5.3 Initial spectacle lens surfacing laboratory practice survey

#### 5.3.1 General

A limited study was undertaken commencing in July 2014 in Australia to review the current tolerances/practices applied within a typical spectacle lens surfacing laboratory to determine if the tolerance values applied were appropriate in relation to process capability. The impact of reducing or increasing the tolerances was also evaluated – see [Annexes A](#) and [B](#). This work was primarily done to look at the effect of harmonizing the ANSI and ISO power tolerances applied to the sphere power and cylinder values, not specifically looking at the differences in methodology. The data could be re-evaluated for other methods of applying tolerances, but it would be sensible to obtain new data since manufacturing processes have changed significantly since the original data was collected.

#### 5.3.2 Observations and conclusions from the limited study

See [Annex B](#) for the data and full conclusions. A summary of the conclusions is given here.

A yield of 96 % was achieved using the ISO tolerances but with the two-parameter method of checking the spherical and cylindrical powers when in the negative-cylinder transposition – see [Clause 6](#).

The reject analysis shows that in the lower power ranges (0 to  $\pm 6$ D), the very small change to the power tolerance from 0,12D in ISO to 0,13D in ANSI would recover approximately 46 % of the rejects in this category (refer to [Annex B](#) results, [Table B.3](#)).

The graphs in the results [B.4](#) of [Annex B](#) show that yield is significantly affected by tightening the tolerances.

Sphere power rejects were more prevalent than Cylinder power rejects (75 % to 25 %).

The significant gap in the cylinder graph analysis reflects the absence of surfaced to prescription jobs in the laboratory in the low power/low cylinder prescription area which are largely filled by Finished Stock Lens product types.

#### 5.3.3 Historical comment

Spectacle lenses are typically available in 0,25 D steps, so it is logical that the tolerance on power was chosen to be half this interval, i.e., 0,125 D. Since the industry works to only two places of decimals, many countries and the ISO standards have used 0,12 D as the tolerance on most spherical and cylindrical powers, though in the USA, 0,13 D has generally been used. [Annex B](#) gives some data on the increase in yields that this extra 0,01 D would make.

### 5.4 Global survey/questionnaire (see [Annex D](#))

The review of the available literature gave no firm conclusions on either the methodology to measure focal power and prismatic imbalance or the tolerances to be applied. Hence the ISO spectacle lens working group decided that a survey of the industry (optometric, dispensing, retail optical and manufacturing) would help it to better understand current industry practice, thus informing this Technical Report to be considered in future revision of the relevant standards used by the industry, specifically ISO 21987 (mounted spectacle lenses) and ISO 8980-1 and ISO 8980-2.

The questionnaire was produced to gather data on actual 'industry practice', standards awareness and interpretation, with a specific focus on the areas of lens power and prism assessment. The questionnaire was sent out world-wide in 2018. There were a number of limitations associated with conducting and analysing the survey. These includes the disproportionate representation of ISO countries and the very large representation of some countries. Some of these limitations were overcome by normalising the data.

The results, which are presented in [Annex D](#), were reviewed at the ISO TC 172/SC7/WG3 meetings in Dallas in November 2019.

The Working Group (WG) decided that an executive summary (see below) be prepared to provide the basis for recommendations for this technical report.

## 5.5 Executive summary of the global survey sent to ISO/TC172/SC7/WG3

Over 70 % of industry practice use a two-parameter (Spherical and Cylindrical) power tolerance methodology.

A large proportion of respondents use increments of 0,25 D or 0,25 Δ when measuring lenses, (81 % for power and 60 % for prism).

The survey results show that 95 % of the industry now works in minus cylinder convention.

(The two-parameter methodology gives rise to the situation where some specific jobs pass power tolerance requirements when assessed applying the Minus cylinder convention but fail the tolerance requirements when assessed in the Plus cylinder convention (see [Annex A](#)). This can be managed by clearly stating the cylinder convention used. Historically with a larger percentage of the industry working in plus cylinder convention, the two-versus three-parameter power methodology had a larger impact. Now that 95 % of the industry work in the minus cylinder convention, the occurrence of these contrary pass/fail situations is minimal).

In general, practice and methodology for prism verification varied significantly with a variety of procedures and 'interpretations' of the standard performed, the majority of which, employing a methodology that differed from the reference method in the standard.

A significant section (41 %) of the marketplace demonstrated a lack of understanding of 'compensated' verification power and prism check off values. (This is likely to cause many more correctly manufactured jobs to be rejected for power compliance than jobs rejected because of a two-parameter power methodology being implemented.)

The survey suggests that for the next revision, the ISO spectacle lens working group could consider the following points:

- For the focal power tolerancing clauses in the Standards, based on the general practice occurring in the industry, a discussion on changing the methodology to a two-parameter (Spherical and Cylindrical power) tolerancing approach would be worthwhile. The fact that 95 % of the manufacturing and dispensing industries now work in minus cylinder convention helps support this.
- For the prism imbalance methodology in ISO 21987, given that most users did not follow the current reference method in ISO 21987, it is clear that a different approach is required. It is understood that agreement on this approach is unlikely to be easy to achieve and therefore having a single reference method might not be possible. However, it would be logical if the reference method in the standard reflected the majority's practice method in the industry.
- Given the confusion still evident in the industry on verifying powers against ordered or verification (supplied compensated) values, development of appropriate educational materials would be helpful while any future revision of the standard could seek to make this clearer.
- The survey conducted has generated a database of useful information that can be accessed and used by WG3 for reference as other standards are revised/created. A more detailed survey result report for all the 18 questions is given in [Annex D](#).

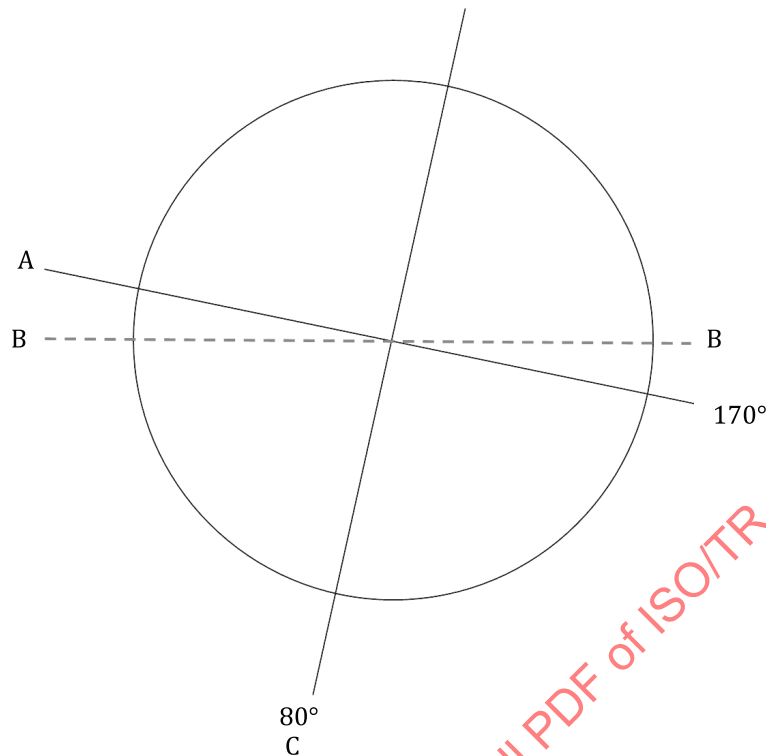
## 6 Detailed lens power assessment methodologies

### 6.1 Two-parameter and three-parameter methods

#### 6.1.1 General

When describing spectacle lens powers, the lens is considered to have two principal meridians with back vertex powers of  $F_1$  and  $F_2$  and their orientations in relation to a horizontal reference axis line. (In the case of spherical lens powers,  $F_1$  and  $F_2$  are always nominally the same). There are two principal conventions used

in the industry to do this; these depend upon which of these two meridians is used as reference. The example used below is for a lens that has back vertex principal powers of +3,00 and +1,00 along 170° and 80°<sup>1)</sup>.



#### Key

- A power along 170° meridian = +3,00 D
- B 0 to 180 reference meridian
- C power along 80° meridian = +1,00 D

**Figure 1 — Diagram showing principal power meridians**

- **“Minus” cylinder convention** – This convention takes the more positive (or less negative) powered principal meridian as the “Sphere” meridian and the less positive (or more negative) powered meridian as the secondary principal meridian. The cylindrical value is the difference between the power in this secondary principal meridian and the power in the sphere meridian, and hence has a negative power.

In this example, the two principal powers are +3,00 and +1,00 with the +3,00 meridian considered as the “Sphere” power meridian; its power is along the 170-degree reference meridian – see [Figure 1](#). The lens power is therefore expressed as Sph +3,00/Cyl -2,00, together with a cylinder axis of 170, which is at right angles to the orientation of the second principal meridian and parallel to the sphere principal meridian.

- **“Plus” cylinder convention** – This convention takes the more negative (or less positive) powered meridian as the “Sphere” meridian and the secondary principal meridian as the more positive or less negative powered meridian. The cylindrical value is the difference between the power in this secondary principal meridian and the power in the sphere meridian, and hence has a positive power.

In this example, the two principal powers are +3,00 and +1,00 with the +1,00 meridian considered as the “Sphere” power meridian; its power is along the 80-degree reference meridian – see [Figure 1](#). The lens power is therefore expressed as Sph +1,00/Cyl +2,00, together with a cylinder axis of 80, which is also at right angles to the axis in the “minus” cylinder convention.

The two current different methodologies for assessing lens power and applying tolerances have been described in [Clause 4](#). Depending on the method chosen (two- or three-parameter methodology) and

1) The degree sign is often omitted, to avoid possible confusion between, say, a badly written 10° and 100 or vice-versa.

the cylinder convention used, the pass/fail criteria is affected, and specific lenses assessed for power that pass under one set of conditions can fail when the alternative methodology is applied. [Annex A](#) highlights specific examples where this occurs.

### 6.1.2 Impact of the differences in the power assessment methodologies

- The requirements of spectacle lens standards vary from country to country depending on the methodology used in a particular standard.
- Implications on yield and processing cost: the three-parameter tolerance method has the potential to fail a small percentage of lenses that would pass the two-parameter method. Lenses that were manufactured and checked using the two-parameter approach and passed a manufacturing Quality criterion could be rejected by an end user who applies a three-parameter methodology on incoming inspection quality assessments. (Some examples of this are illustrated in [Annex A](#)).
- Differences in instrumentation used to determine lens power: some instruments can measure and resolve lens power results using either of the two methodologies above. These instruments can record and display results in either the two- or three-parameter formats. Such instruments are usually more sophisticated and expensive. Many instruments measuring lens power (focimeters or lens meters) are configured to determine and report lens power using the “two-parameter” approach, i.e. Sphere and Cylinder values. Typically, these instruments are simpler in operation and more affordable. Often, multiple units are implemented in a lens processing facility and these types of instruments are also more likely to be used in an Eye Care Professional's or Retail store's environment.
- Interpretation and ‘ease of use’: where instrumentation does not support the three-parameter approach, it is a more complicated process to compute and apply this methodology if the referenced standard requires it.
- Where manual focusing focimeters are used, the ability to determine the lens power for each meridian precisely might be difficult due to the marked scale increment and resolution typically used by such instruments and the subjective interpretation of the two focal endpoints by the operator. For historical reasons, the simpler two-parameter approach is often applied with such instruments.

### 6.1.3 Power assessment methodologies considered in the survey

Although the two-parameter and three-parameter verification methods are the ones in common use, and hence investigated in the world-wide survey and in detail in this document, other methods of applying tolerances that could be considered in future revisions of the relevant standards are summarised and presented in [6.2](#) to [6.5](#). [6.1.4](#) includes a comparison of the tolerance ranges applicable to most lenses under the two- and three-parameter methods and a method based on the mean spherical and cylindrical powers. This shows that the two-parameter method has a more relaxed tolerance for the secondary principal meridian.

### 6.1.4 Numerical comparison of the two- and three-parameter methods

In the three-parameter method, the same tolerance is applied to the powers in both principal meridians. – see the top rows of [Table 1](#) for an example of a lens of nominal power Sph +3,00 D/Cyl -2,00 D, which has a nominal power of +1,00 D in the second principal meridian.

**Table 1 — Comparison of three and two-parameter methods and effects on the mean sphere**

|                        |        | Primary principal power | Cylindrical power | Secondary principal power | Mean sphere  |
|------------------------|--------|-------------------------|-------------------|---------------------------|--------------|
| <b>Nominal</b>         |        | <b>+3,00</b>            | <b>-2,00</b>      | <b>+1,00</b>              | <b>+2,00</b> |
| <b>Three-parameter</b> | Error  | +0,12                   | correct           | +0,12                     | +0,12        |
|                        | giving | +3,12                   | -2,00             | +1,12                     | +2,12        |
| <b>Two-parameter</b>   | Error  | +0,12                   | +0,12             | <b>+0,24</b>              | <b>+0,18</b> |
|                        | giving | +3,12                   | -1,88             | +1,24                     | +2,18        |

The two-parameter method can, however, be criticized for allowing cumulative errors on the second principal meridian if the errors in both the spherical and cylindrical powers are in the same direction. (The permissible error in the second meridian is the tolerance on sphere plus tolerance on cylinder.) Thus, in the example above, the lens could be made as Sph +3,12 DS/Cyl -1,88 DC giving a power of +1,24 D in the second principal meridian, an error of 0,24 D; see the lower rows of [Table 1](#). Moreover, as the cylindrical power increases, the permissible tolerance increases, allowing the power in the second meridian (and therefore also in the mean sphere) to deviate even further from its intended value.

Furthermore, because the two-parameter method specifies that the minus cylinder convention is used, the method can give rise to different tolerances when a cylinder is present for positive and negative lenses of the same absolute powers (i.e. when the + or - signs are ignored). In the example in [Table 2](#), the positive lens has a higher spherical or primary principal power. Taking table 1 from ANSI Z.80 as an example, the plus lens falls into the >6,50 D category, the minus lens in the <6,50 D category. The three-parameter method on the other hand always chooses the tolerance band on the meridian with the higher absolute value.

**Table 2 — Tolerances for plus and minus lenses of the same absolute powers**

|                   |         | Primary principal power | Cylindrical power | Secondary principal power | Mean sphere |
|-------------------|---------|-------------------------|-------------------|---------------------------|-------------|
| <b>Plus lens</b>  | Nominal | <b>+7,50</b>            | -4,00             | +3,50                     | +5,50       |
| <b>Minus lens</b> | Nominal | <b>-3,50</b>            | -4,00             | -7,50                     | -5,50       |

Summing up, the two-parameter method does not only allow for increased blur but also introduces asymmetric distribution between the two meridians and a difference in tolerances between plus and minus powered lenses of the same absolute power. Neither of these has any technological nor any physiological justification but only originates from the sign convention for writing prescriptions and orders.

## 6.2 A mean sphere (spherical equivalent power) and cylinder method

Rather than applying the tolerances to one or both principal powers, a tolerance could be applied to the mean sphere<sup>2)</sup>. This gives a result that is between those for the two- and three-parameter methods. If the tolerances are applied to the two principal meridians, the mean sphere therefore also cannot deviate by more than this tolerance, as in the top example of [Table 1](#). For the lens at the bottom of [Table 1](#), the principal powers are +3,12 D and +1,24 D, giving a mean sphere of +2,18 D instead of the ordered +2,00 D, which is outside the tolerance if the same value of 0,12 D is applied. (For the mean sphere, the two-parameter method gives a permissible error of the tolerance for the sphere plus half of the value of the tolerance for cylinder.) If the present 0,12 tolerance is applied to the mean sphere and the cylindrical power, then the powers with the largest error are Sph +3,12 D/Cyl -2,00 D or Sph +3,18 D/Cyl -2,12 D (or the opposite error equivalents) – See [Tables 1](#) and [3](#).

Thus, when the tolerances are applied to the mean sphere and the cylindrical power, the potential blur on the wearer's retina is better controlled than with the two parameter methods while at the same time relaxing tolerances on the individual meridians.

2) The mean sphere is half the algebraic sum of the two principal powers.

Table 3 — Comparison of the mean sphere method on the principal and cylindrical powers

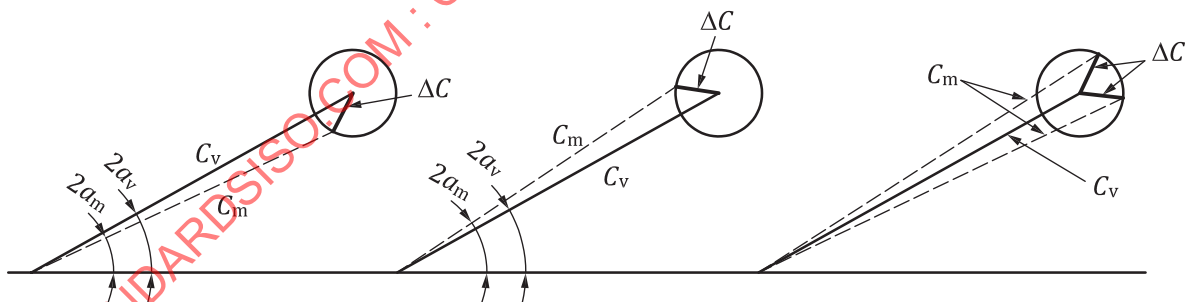
|         |         | Primary principal power | Cylindrical power | Secondary principal power | Mean sphere |
|---------|---------|-------------------------|-------------------|---------------------------|-------------|
| Nominal |         | +3,00                   | -2,00             | +1,00                     | +2,00       |
|         | Error   | +0,18                   | -0,12             | +0,06                     | +0,12       |
|         | giving: | +3,18                   | -2,12             | +1,06                     | +2,12       |
|         | Error   | +0,06                   | +0,12             | +0,18                     | -0,12       |
|         | giving: | +3,06                   | -1,88             | +1,18                     | +2,12       |
|         | Error   | -0,18                   | +0,12             | -0,06                     | -0,12       |
|         | giving: | +2,82                   | -1,88             | +0,94                     | +1,88       |
|         | Error   | -0,06                   | -0,12             | -0,18                     | -0,12       |
|         | giving: | +2,94                   | -2,12             | +0,82                     | +1,88       |

Calculating the mean sphere for this example of ordered power is relatively simple. For other ordered powers, such as Sph +3,25/Cyl -1,75 or verification powers or measured powers such as Sph +3,21/Cyl -1,83 is somewhat more difficult and requires a pen and paper or a calculator<sup>3)</sup>.

### 6.3 A mean sphere (spherical equivalent power) and astigmatic difference method

Another issue is the tolerance on astigmatism. At present, cylindrical power and cylinder axis are tolerated as separate entities although they act together, errors in either or both giving rise to an unwanted astigmatic error. This can be demonstrated with a focimeter or lens meter, any two cylindrical powers at any orientation with respect to each other except for a 0° or 90° angle compound to a spherocylindrical power. This applies also to differences between cylindrical powers or axes. Moreover, the greater the cylindrical power, the greater the unwanted astigmatic error for the same error in cylinder axis. To take this into account, the tolerance on axis is stricter for higher cylindrical powers than for lower ones.

A more systematic way might be to tolerance the difference in astigmatic effects<sup>4)</sup> directly. Geometrical and mathematical methods of calculating this difference are given in E.2 in the Annex. Using the geometrical method described there, Figure 2 shows a verification cylindrical power of  $-1,00 \times 15$ , with measured powers of, from left to right,  $-0,90 \times 13$ ,  $-0,90 \times 17$  and  $-1,10 \times 13$  and  $\times 17$ .



#### Key

- $C_v$  is the verification or ordered power  
 $C_m$  is the measured power  
 $\Delta C$  is the induced unwanted cylindrical power

3) However, even with the two-parameter method today, more complex calculations can be necessary, e.g., when using ANSI tolerances for a single vision lens with +2,50 D sph and 4,75 D cyl, obtaining the tolerance in the cylindrical power requires the calculation of 4 % of +4,75D (= 0,19 D).

4) The astigmatic effect is the combination of the cylindrical power and cylinder axis.

$a_v$  is the verification or ordered axis

$a_m$  is the measured axis

The radius of the circle represents a possible value for the tolerance

**Figure 2 — Schematic illustration of the graphical method for calculating the difference between the verification power  $C_v$  and the measured power  $C_m$**

In these examples, the unwanted induced cylindrical power or astigmatic difference,  $\Delta C$  is 0,120 D for the cases where the measured cylindrical power is 0,90 D and is 0,124 D for the cases when the measured power is 1,10 D. The radius of the circles centred at the end of the line indicating the verification value represents a possible tolerance. Any measured astigmatic effect that, when plotted as in [Figure 2](#), falls within the circle is within tolerance. The appropriate value of this tolerance will need to be determined.

#### 6.4 Scalar or root mean square (RMS) power error

To take the approach of [6.3](#) even further, the error in spherical power as well as the spherical error from the unwanted cylindrical error can be included in the Thibos<sup>[11]</sup> calculation to compute a number (RMS) summing up all errors leading to blur – see [F.2](#).

If the mean sphere is regarded as varying the height of the plane containing the cylindrical powers, the two spherocylindrical powers can be regarded as vectors in 3-dimensional space. The distance between the ends of these two vectors can also be represented as a scalar value. A single value,  $u$ , could then be applied to the total error – see [Formula F.3](#).

If this method is considered for applying a tolerance to spectacle lens powers, its appropriate value will need to be determined.

Admittedly, the methods of calculation in [6.3](#) and [6.4](#) requires some more computation than the methods described in [6.1](#) or [6.2](#). However, the application can be simplified by providing the required calculation software. The verification or ordered and measured values can either be entered directly or via a communication link to the measurement equipment or the ordering software. However, given, that most practices use practice management software, this could be easily included, possibly even selecting and applying the tolerances.

#### 6.5 Introduce a tiered approach with different optical classes

This approach, which is used in the ISO standard for eye and face protectors (ISO 16321-1<sup>[4]</sup>), would allow the use of different grades or classes of product. It could use the stricter three-parameter method to be the tolerance for optical class 1 and the two-parameter or mean sphere methods to be the tolerance for optical class 2.

Discussion would be required to consider:

- The general approach of standards to set a minimum performance level;
- The application by country/region of different classes of product.

### 7 Detailed lens prism assessment methodologies

#### 7.1 General

The result of the survey showed that only 31 % of the respondents world-wide adopted the reference test method, although this average masked the 50 % of respondents in Europe who used this method. This is not surprising because of the number of steps:

- the need to identify the highest principal power of the two lenses;

- the need to mark the centration points on the lenses, and the potential uncertainties in the marking and the subsequent positioning of the spectacles on the lens support;
- the need to record the left and right readings, then calculate the prism imbalance.

A method similar to that in ISO 21987:2017, Annex C, was adopted by about 54 % of respondents world-wide, 64 % in North America. The [Annex C](#) method is both more ergonomic and physiologically more appropriate in that it automatically considers the powers along the horizontal and vertical meridians of the weaker or second lens rather than taking the highest<sup>5)</sup> principal power of the two lenses in the reference test method. The combination, however, of prismatic and centration tolerances can appear confusing until the method is tried practically. The method is also criticized for not providing any control over yoked prisms, i.e., matching prisms with bases in the same direction, e.g. base left or base up (see [C.3.3](#)). However, although it measures them, the reference test method does not specify any control over the prism at the centration points, while yoked prism in the form of vertical prism thinning has been used successfully on power-variation lenses since the 1970s. Moreover, single vision lenses are usually mounted for the edging process by the position of their optical centres rather than geometrical considerations so that unwanted prism is unlikely to occur; also, compliance with ISO 8980-1 ensures that there is no large unwanted prism at the geometrical centre of the blank. With low power lenses, it is possible that unwanted prism at the geometrical centre is not able to be eliminated by mounting a lens sufficiently away from its geometrical centre. For example, a spherical lens of power 1,00 D with 0,35 Δ of unwanted prism would require 3,5 mm of decentration to cancel it, while if the power in the base-apex meridian were only 0,25 D, 14 mm of decentration would be required.

A further criticism of the [Annex C](#) method is the use of the higher power lens as the reference. In cases of significant difference, e.g.  $R+5,00$  DS and  $L+2,00$  DS, a 1,0 mm positioning error will induce 0,5 prism dioptres instead of 0,2 prism dioptres displacement in the field of view if the lower power lens had been used as reference. However, this difference is small in comparison to the change in relative prism before the two eyes when viewing away from the reference points; a 5 mm rotation across the lenses (about 10,5° change in angle of gaze) will result in approximately 1,5 prism dioptres difference, which might be base left for the right eye when looking to the right, base right when looking to the left, base up when looking down and base down when looking up.

Another criticism is that the method is more difficult to apply when there is ordered prism, but the lens is either moved sideways until the ordered prism is shown in the display or neutralizing prism is added by the prism compensator before marking the centration point with the focimeter.

However, methods similar to those in [Annex C](#) have been used in other countries for many years without problems – for example BS 2738-1:1985<sup>[7][8]</sup>, in the USA ANSI Z80.1<sup>[9]</sup>, since 1964.

## 7.2 Marking of the reference points and uncertainties in positioning

Unless computerized instruments with robotic placement are used, the reference test method in ISO 21987:2017, 6.6, requires the centration points to be marked on the lenses and the lenses placed on the focimeter with these marks centred in aperture of the lens support. The horizontal and vertical prismatic effects at the left and right centration points then have to be recorded and any difference, the prismatic imbalance, calculated and compared with the tolerances, either using Table 5 or Figures 1 and 2 in that standard.

The precision of dotting the optical centres with a focimeter or lens meter is governed by ISO 8598-1, which allows a maximum of 0,4 mm error between the marked dot and the optical centre. Except for cases of significant anisometropia, any displacement of the dot from the optical centre will give rise to similar prismatic errors in both lenses, i.e. a yoked prism.

Results of experiments by one observer on the repeatability of marking and placing a pair of mounted lenses<sup>6)</sup> on a focimeter gave a standard deviation of 10 independent measurements of the prism imbalance of 0,36 Δ horizontally and 0,24 Δ vertically, with similar results from a second experimenter. These are half

5) This was changed from the lowest principal power that was in ISO 21987:2009, because for lenses with large cylindrical components with cylinder axes near vertical when expressed in the minus cylinder form, the tolerances on the positioning in the vertical meridian were tighter than could regularly be achieved.

6) Right lens +4,00 DS, left lens +3,00 DS.

the tolerances for low powered lenses (0,67  $\Delta$  for lenses up to 3,33 D for horizontal measurements, 0,50  $\Delta$  for lenses up to 5,00 D for vertical ones).

The method in [Annex C](#) makes identification of a vertical imbalance very obvious (except in the case of strong oblique cylinders, when use of the current reference method can be easier), while the 2 mm maximum horizontal displacement is easy to apply. Using the same mounted pair of lenses as before, the standard deviation of five independent measurements of the horizontal centration distance was 0,37 mm, which is equivalent on the +3,00 D lens to 0,11  $\Delta$ . Vertically, the standard deviation was 0,04  $\Delta$  which is equivalent to 0,13 mm.

### 7.3 Single-vision position-specific lenses and power-variation lenses

ISO 21987 does not specify additional prism imbalance tolerances for single-vision position-specific lenses or power-variation lenses but relies on the tolerances in the uncut lens standards, ISO 8980-1 and -2 and the positioning tolerance. This is because the consensus view of the project group writing the standard was that accurate positioning of these types of lens in front of the eye was more important than any very small displacement used to try to neutralize unwanted prism in the uncut lens, even though 1 mm of mounting error horizontally was allowed. Conversely, it was felt that with flat and curved top multifocal lenses, there was no significant loss of binocular field of view in near vision by decentring the lenses slightly. Now that the very large majority of these types of lens are made from blanks with spherical front surfaces instead of the less regular power-variation surface, mounting them for surfacing of the complicated back surface is more precise and consistent, resulting in better control of unwanted prism in power-variation lenses than when the front surface with an irregular progressive-power or complex surface shape is used.

The questionnaire asked whether the respondent verified prism imbalance on progressive-power lenses - the most common lens of this class. 80 % of respondents verified the prismatic imbalance; of these, 62 % measured the imbalance at the mounted position of the prism reference points, 33 % at the ordered position. The questionnaire did not ask what tolerance was applied. This might have been the same as for mounted single vision lenses, or as specified in ISO 21987, the uncut unwanted prism tolerance from ISO 8980-2.

## 8 Summary

### 8.1 Power

Even though the current ISO standards include a three-parameter power tolerance methodology, the results of the international survey given in [Annex D](#) showed that it is not used in practice by more than 70 % of the industry, who apply a two-parameter approach.

The literature search given in [Annex C](#) showed that studies found no significant detrimental effect on wearers using spectacle lenses manufactured using the two-parameter methodology.

It is likely that no significant impact on wearers' visual acuity would result from harmonizing the methodologies of power measurement and tolerancing to the simpler two-parameter method. It is also likely that no significant impact on wearers visual acuity would result from harmonizing the actual power tolerance values used in the ISO and ANSI spectacle lens standards.

The advantages of these changes are:

- Reduces the overall cost of manufacture as the first pass yield is greater using the two-parameter method – see [Annexes A](#) and [B](#).
- Simpler method in execution both in measurement and application of the tolerances.
- Reduces operator error in computation of meridional powers which are not directly measured.
- Most lower cost automated focimeter instruments are configured to the two-parameter methodology format. (Note that in the USA, manual focimeters were the majority instrument, and the operator has to calculate the cylindrical power.)

At some stage in the future, other methods of applying tolerances based on a more physiological approach to the potential blur on the retina, could be used– see [Annex F](#).

## 8.2 Prism imbalance

The international survey given in [Annex D](#) showed that the majority of people world-wide do not use the reference method that is in ISO 21987. The adoption of a more ergonomic reference method, probably one based on the method in [Annex C](#) of the standard or the very similar method in ANSI Z80.1 might be worth considering.

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## Annex A

### (informative)

## Example prescription jobs showing three-parameter (ISO) compared with two-parameter (ANSI) power tolerance methodology differences

Tables A.1 and A.2 show the pass/fail results for hypothetical measured powers of two different lenses when verified in minus or plus cylinder convention using the ISO three-parameter method (which applies tolerances to both principal meridians and the cylindrical power and the ANSI two-parameter method which applies the tolerances to the primary principal meridian and the cylindrical power. The 0,12 D ISO tolerance has been applied to one or two of: the primary principal meridian, the secondary principal meridian and the cylindrical power.

**Table A.1 — Example of a lens of nominal power: Sphere +3,00 D, Cylinder -1,00 D when expressed in minus cylinder form (upper) and plus cylinder form (lower)**

| MINUS CYL                       |            | ISO         | Example 1   |          |             |                                 |            | ANSI       | Example 1   |          |             |
|---------------------------------|------------|-------------|-------------|----------|-------------|---------------------------------|------------|------------|-------------|----------|-------------|
| Power ordered +3,00 DS/-1,00 DC |            |             |             |          |             | Power ordered +3,00 DS/-1,00 DC |            |            |             |          |             |
| Tolerance                       | ±0,12      | ±0,12       | ±0,12       |          |             | Tolerance                       | ±0,13      |            | ±0,13       |          |             |
|                                 | Meridian 1 | Meridian 2  | CYL (-)     | Mean pwr | Pass/Fail   |                                 | Meridian 1 | Meridian 2 | CYL (-)     | Mean pwr | Pass/Fail   |
| Lens 1                          | 2,88       | 1,88        | 1,00        | 2,38     | Ok          | Lens 1                          | 2,88       | 1,88       | 1,00        | 2,38     | Ok          |
| Lens 2                          | 2,88       | 2,00        | 0,88        | 2,44     | Ok          | Lens 2                          | 2,88       | 2,00       | 0,88        | 2,44     | Ok          |
| Lens 3                          | 2,88       | 2,12        | <b>0,76</b> | 2,50     | <b>Fail</b> | Lens 3                          | 2,88       | 2,12       | <b>0,76</b> | 2,50     | <b>Fail</b> |
| Lens 4                          | 2,88       | <b>1,76</b> | 1,12        | 2,32     | <b>Fail</b> | Lens 4                          | 2,88       | 1,76       | 1,12        | 2,32     | Ok          |
| Lens 5                          | 3,00       | 1,88        | 1,12        | 2,44     | Ok          | Lens 5                          | 3,00       | 1,88       | 1,12        | 2,32     | Ok          |
| Lens 6                          | 3,00       | 2,00        | 1,00        | 2,50     | Ok          | Lens 6                          | 3,00       | 1,88       | 1,12        | 2,44     | Ok          |
| Lens 7                          | 3,00       | 2,00        | 1,00        | 2,50     | Ok          | Lens 7                          | 3,00       | 2,12       | 0,88        | 2,56     | Ok          |
| Lens 8                          | 3,12       | 1,88        | <b>1,24</b> | 2,50     | <b>Fail</b> | Lens 8                          | 3,12       | 1,88       | <b>1,24</b> | 2,50     | <b>Fail</b> |
| Lens 9                          | 3,12       | 2,00        | 1,12        | 2,56     | Ok          | Lens 9                          | 3,12       | 2,00       | 1,12        | 2,56     | Ok          |
| Lens 10                         | 3,12       | 2,12        | 1,00        | 2,62     | Ok          | Lens 10                         | 3,12       | 2,12       | 1,00        | 2,62     | Ok          |
| Lens 11                         | 3,12       | <b>2,24</b> | 0,88        | 2,68     | <b>Fail</b> | Lens 11                         | 3,12       | 2,24       | 0,88        | 2,68     | Ok          |

| PLUS CYL           |             | ISO        | Example 1   |          |             |                    |             | ANSI       | Example 1   |          |             |
|--------------------|-------------|------------|-------------|----------|-------------|--------------------|-------------|------------|-------------|----------|-------------|
| Script +2,00/+1,00 |             |            |             |          |             | Script +2,00/+1,00 |             |            |             |          |             |
| Tolerance          | ±0,12       | ±0,12      | ±0,12       |          |             | Tolerance          | ±0,13       |            | ±0,13       |          |             |
|                    | Meridian 1  | Meridian 2 | CYL (+)     | Mean pwr | Pass/Fail   |                    | Meridian 1  | Meridian 2 | CYL (+)     | Mean pwr | Pass/Fail   |
| Lens 1             | 1,88        | 2,88       | 1,00        | 2,38     | Ok          | Lens 1             | 1,88        | 2,88       | 1,00        | 2,38     |             |
| Lens 2             | 2,00        | 2,88       | 0,88        | 2,44     | Ok          | Lens 2             | 2,00        | 2,88       | 0,88        | 2,44     |             |
| Lens 3             | 2,12        | 2,88       | <b>0,76</b> | 2,50     | <b>Fail</b> | Lens 3             | 2,12        | 2,88       | <b>0,76</b> | 2,50     | <b>Fail</b> |
| Lens 4             | <b>1,76</b> | 2,88       | 1,12        | 2,32     | <b>Fail</b> | Lens 4             | <b>1,76</b> | 2,88       | 1,12        | 2,32     | <b>Fail</b> |
| Lens 5             | 1,88        | 3,00       | 1,12        | 2,44     | Ok          | Lens 5             | 1,88        | 3,00       | 1,12        | 2,44     |             |
| Lens 6             | 2,00        | 3,00       | 1,00        | 2,50     | Ok          | Lens 6             | 2,00        | 3,00       | 1,00        | 2,50     |             |
| Lens 7             | 2,12        | 3,00       | 0,88        | 2,56     | Ok          | Lens 7             | 2,12        | 3,00       | 0,88        | 2,56     |             |
| Lens 8             | 1,88        | 3,12       | <b>1,24</b> | 2,50     | <b>Fail</b> | Lens 8             | 1,88        | 3,12       | <b>1,24</b> | 2,50     | <b>Fail</b> |
| Lens 9             | 2,00        | 3,12       | 1,12        | 2,56     | Ok          | Lens 9             | 2,00        | 3,12       | 1,12        | 2,56     |             |
| Lens 10            | 2,12        | 3,12       | 1,00        | 2,62     | Ok          | Lens 10            | 2,12        | 3,12       | 1,00        | 2,62     |             |
| Lens 11            | <b>2,24</b> | 3,12       | 0,88        | 2,68     | <b>Fail</b> | Lens 11            | <b>2,24</b> | 3,12       | 0,88        | 2,68     | <b>Fail</b> |

**Table A.2 — Example of a lens of nominal power: Sphere -1,00 D, Cylinder -2,00 D when expressed in minus cylinder form (upper) and plus cylinder form (lower)**

| MINUS CYL          |            | ISO        | Example 2 |          |           |                    |            | ANSI       | Example 2 |          |           |
|--------------------|------------|------------|-----------|----------|-----------|--------------------|------------|------------|-----------|----------|-----------|
| Script -1,00/-2,00 |            |            |           |          |           | Script -1,00/-2,00 |            |            |           |          |           |
| Tolerance          | ±0,12      | ±0,12      | ±0,12     |          |           | Tolerance          | ±0,13      |            | ±0,13     |          |           |
|                    | Meridian 1 | Meridian 2 | CYL (-)   | Mean pwr | Pass/Fail |                    | Meridian 1 | Meridian 2 | CYL (-)   | Mean pwr | Pass/Fail |
| Lens 1             | -0,88      | -2,88      | 2,00      | -1,88    | Ok        | Lens 1             | -0,88      | -2,88      | 2,00      | -1,88    | Ok        |
| Lens 2             | -0,88      | -3,00      | 2,12      | -1,94    | Ok        | Lens 2             | -0,88      | -3,00      | 2,12      | -1,94    | Ok        |
| Lens 3             | -0,88      | -3,12      | 2,24      | -2,00    | Fail      | Lens 3             | -0,88      | -3,12      | 2,24      | -2,00    | Fail      |
| Lens 4             | -0,88      | -2,76      | 1,88      | -1,82    | Fail      | Lens 4             | -0,88      | -2,76      | 1,88      | -1,82    | Ok        |
| Lens 5             | -1,00      | -2,88      | 1,88      | -1,94    | Ok        | Lens 5             | -1,00      | -2,88      | 1,88      | -1,94    | Ok        |
| Lens 6             | -1,00      | -3,00      | 2,00      | -2,00    | Ok        | Lens 6             | -1,00      | -3,00      | 2,00      | -2,00    | Ok        |
| Lens 7             | -1,00      | -3,12      | 2,12      | -2,06    | Ok        | Lens 7             | -1,00      | -3,12      | 2,12      | -2,06    | Ok        |
| Lens 8             | -1,12      | -2,88      | 1,76      | -2,00    | Fail      | Lens 8             | -1,12      | -2,88      | 1,76      | -2,00    | Fail      |
| Lens 9             | -1,12      | -3,00      | 1,88      | -2,06    | Ok        | Lens 9             | -1,12      | -3,00      | 1,88      | -2,06    | Ok        |
| Lens 10            | -1,12      | -3,12      | 2,00      | -2,12    | Ok        | Lens 10            | -1,12      | -3,12      | 2,00      | -2,12    | Ok        |
| Lens 11            | -1,12      | -3,24      | 2,12      | -2,18    | Fail      | Lens 11            | -1,12      | -3,24      | 2,12      | -2,18    | Ok        |

| PLUS CYL           |            | ISO        | Example 2 |          |           |                    |            | ANSI       | Example 2 |          |           |
|--------------------|------------|------------|-----------|----------|-----------|--------------------|------------|------------|-----------|----------|-----------|
| Script -3,00/+2,00 |            |            |           |          |           | Script -3,00/+2,00 |            |            |           |          |           |
| Tolerance          | ±0,12      | ±0,12      | ±0,12     |          |           | Tolerance          | ±0,13      |            | ±0,13     |          |           |
|                    | Meridian 1 | Meridian 2 | CYL (+)   | Mean pwr | Pass/Fail |                    | Meridian 1 | Meridian 2 | CYL (+)   | Mean pwr | Pass/Fail |
| Lens 1             | -2,88      | -0,88      | 2,00      | -1,88    | Ok        | Lens 1             | -2,88      | -0,88      | 2,00      | -1,88    | Ok        |
| Lens 2             | -3,00      | -0,88      | 2,12      | -1,94    | Ok        | Lens 2             | -3,00      | -0,88      | 2,12      | -1,94    | Ok        |
| Lens 3             | -3,12      | -0,88      | 2,24      | -2,00    | Fail      | Lens 3             | -3,12      | -0,88      | 2,24      | -2,00    | Fail      |
| Lens 4             | -2,76      | -0,88      | 1,88      | -1,82    | Fail      | Lens 4             | -2,76      | -0,88      | 1,88      | -1,82    | Fail      |
| Lens 5             | -2,88      | -1,00      | 1,88      | -1,94    | Ok        | Lens 5             | -2,88      | -1,00      | 1,88      | -1,94    | Ok        |
| Lens 6             | -3,00      | -1,00      | 2,00      | -2,00    | Ok        | Lens 6             | -3,00      | -1,00      | 2,00      | -2,00    | Ok        |
| Lens 7             | -3,12      | -1,00      | 2,12      | -2,06    | Ok        | Lens 7             | -3,12      | -1,00      | 2,12      | -2,06    | Ok        |
| Lens 8             | -2,88      | -1,12      | 1,76      | -2,00    | Fail      | Lens 8             | -2,88      | -1,12      | 1,76      | -2,00    | Fail      |
| Lens 9             | -3,00      | -1,12      | 1,88      | -2,06    | Ok        | Lens 9             | -3,00      | -1,12      | 1,88      | -2,06    | Ok        |
| Lens 10            | -3,12      | -1,12      | 2,00      | -2,12    | Ok        | Lens 10            | -3,12      | -1,12      | 2,00      | -2,12    | Ok        |
| Lens 11            | -3,24      | -1,12      | 2,12      | -2,18    | Fail      | Lens 11            | -3,24      | -1,12      | 2,12      | -2,18    | Fail      |

NOTE 1 In Minus cyl convention, for these two examples, the ANSI two-parameter method passes lens 4 and lens 11 while in Plus cyl Convention these become Fails by the ANSI method. For ISO, these are Fails in both cylinder conventions because the control is on both meridians.

NOTE 2 For ease of comparison, the 0,12 D tolerance value was used in the evaluation across all examples, so the meridian values stayed the same. It is noted that the actual ANSI tolerance is 0,13 D.

## Annex B (informative)

### Australian spectacle lens surfacing laboratory — Tolerance capability study

#### B.1 Aim

A limited study was undertaken in July 2014 to review the current tolerances applied within a typical spectacle lens surfacing laboratory to determine if the tolerance values applied were appropriate in relation to process capability. The impact of reducing or increasing the tolerances was also evaluated. The purpose of this work was to provide input to the "Power tolerance task force team" then involved with the revision of ISO 21987, ISO 8980-1 and ISO 8980-2.

#### B.2 Method

A database sample of approximately 192,000 records was sourced and analysed from an Australian surfacing laboratory reflecting a 4-month manufacturing period.

Data was obtained from a Microsoft Access database populated by data from the "first pass" inspection station using an A & R Focovision SPV2 instrument.

The data was analysed to review the yield and distribution of resultant powers against the target Rx to determine current capability. The data was also analysed to review the impact of tightening or relaxing the tolerance values.

Power rejects were divided into the relevant categories as defined by the tolerance tables in ISO 21987.

Due to the limited timeframe for the analysis and the smaller reject percentage due to cylinder power error, the cylinder power rejects were analysed as a total group looking at deviation from target cylinder power.

#### B.3 Conclusions and observations

Given the first pass yield of 96 %, the current ISO standards appear to be achievable with current manufacturing processes and measurement capability (see [Table B.3](#) for the results).

The reject analysis shows that in the lower power ranges (0 to  $\pm 6$ ) D a very small incremental change to the power tolerance from 0,12 D in ISO to 0,13 D in ANSI would recover approximately 46 % of the rejects in this category (see [Table B.3](#) for the results). It is noted that this small change of tolerance value would have no significant effect on visual acuity of the end user of the spectacle lens and would not be discernible with a manual focimeter.

The graphs in the results in [B.4](#) show that yield is significantly affected if the tolerances are tightened.

The rejects breakdown in [Table B.2](#) highlights that Sphere power rejects were more prevalent than Cylinder power rejects (75 % to 25 %).

The instrument setup and data capture mode in the raw database suggests the criteria for qualification was based on sphere power and cyl measurement consistent with the methodology used in the ANSI Z80.1.

The significant gap in the cylinder graph analysis reflects the absence of surfaced jobs in the lab in the low power/low cylinder prescription area which is largely filled by Finished Stock Lens product types.

The cylinder rejects reflect the total population spanning all the tolerance brackets. A more detailed analysis would be required to quantify the magnitude of error over the tolerance for each specific power/cyl brackets, as defined in the current tolerance tables of ISO 21987.

## B.4 Results

### B.4.1 Overview of data

The total number of lenses, of lens power rejects as being outside tolerance and invalid records is given in [Table B.1](#), while [Table B.2](#) gives a breakdown of the type of power causing the rejection. [Table B.3](#) shows the change to the yield with different tolerance values.

**Table B.1 — Data statistics**

|                                   |         |
|-----------------------------------|---------|
| Database records                  | 192 200 |
| Rejects against current standards | 8 001   |
| Invalid records                   | 3 014   |
| Total Valid for analysis          | 189 186 |

**Table B.2 — Reject statistics**

|                         |       |       |
|-------------------------|-------|-------|
| Fail for Sphere and Cyl | 690   | 0,4 % |
| Fail for Sphere only    | 6 290 | 3 %   |
| Fail for Cyl only       | 2 401 | 1 %   |
| TOTAL Failures          | 8 001 | 4 %   |

**Table B.3 — Reject recovery vs the Tolerance setting for spherical power**

| 0 D to 6 D power range (n = 5551) |       |             | 6 D to 9 D power range (n = 859) |       |             | 9 D to 12 D power range (n = 97) |       |             |
|-----------------------------------|-------|-------------|----------------------------------|-------|-------------|----------------------------------|-------|-------------|
| Tolerance                         | Count | % recovered | Tolerance                        | Count | % recovered | Tolerance                        | Count | % recovered |
| 0,13                              | 2 534 | 46 %        | 0,13                             | 265   | 31 %        | 0,19                             | 21    | 22 %        |
| 0,15                              | 3 748 | 68 %        | 0,15                             | 411   | 48 %        | 0,2                              | 27    | 28 %        |
| 0,16                              | 4 138 | 75 %        | 0,16                             | 476   | 55 %        | 0,25                             | 61    | 63 %        |
| 0,18                              | 4 613 | 83 %        | 0,18                             | 559   | 65 %        | 0,3                              | 79    | 81 %        |
| 0,25                              | 5 255 | 95 %        | 0,25                             | 760   | 88 %        | 0,39                             | 97    | 100 %       |

### B.4.2 Effects on yield of changing the tolerances

[Figures B.1](#) to [B.4](#) show the effects on yield of changing the tolerances for sphere power and cylindrical power of single-vision and multifocal lenses and for progressive-power lenses.

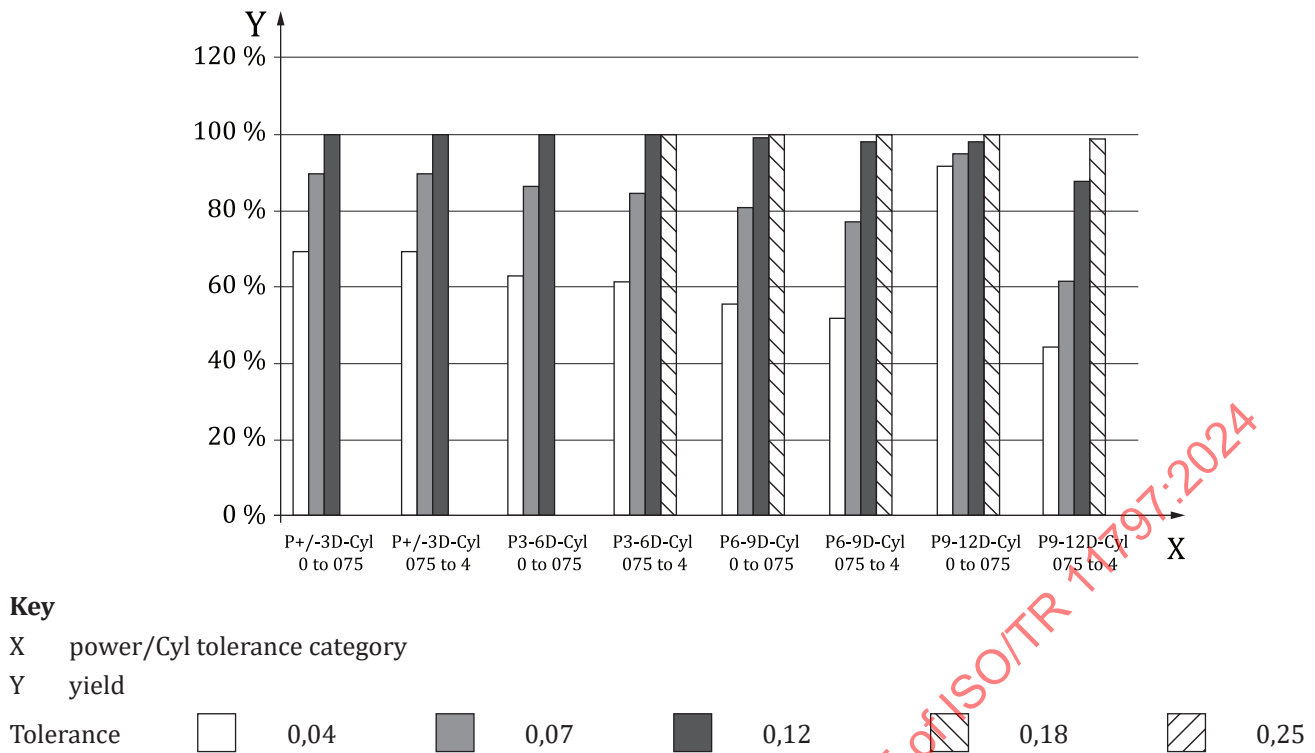


Figure B.1 — Spherical power tolerances for single-vision and multifocal lenses

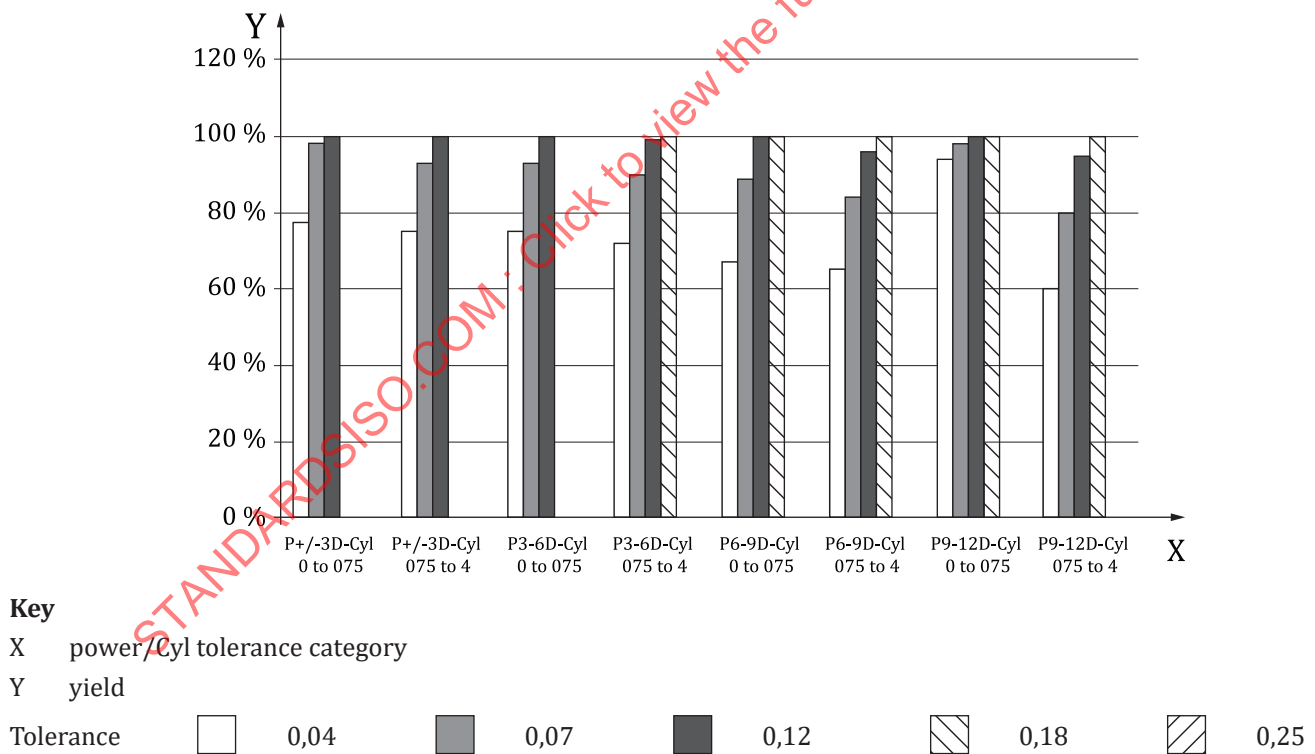


Figure B.2 — Cylindrical power tolerances for single-vision and multifocal lenses

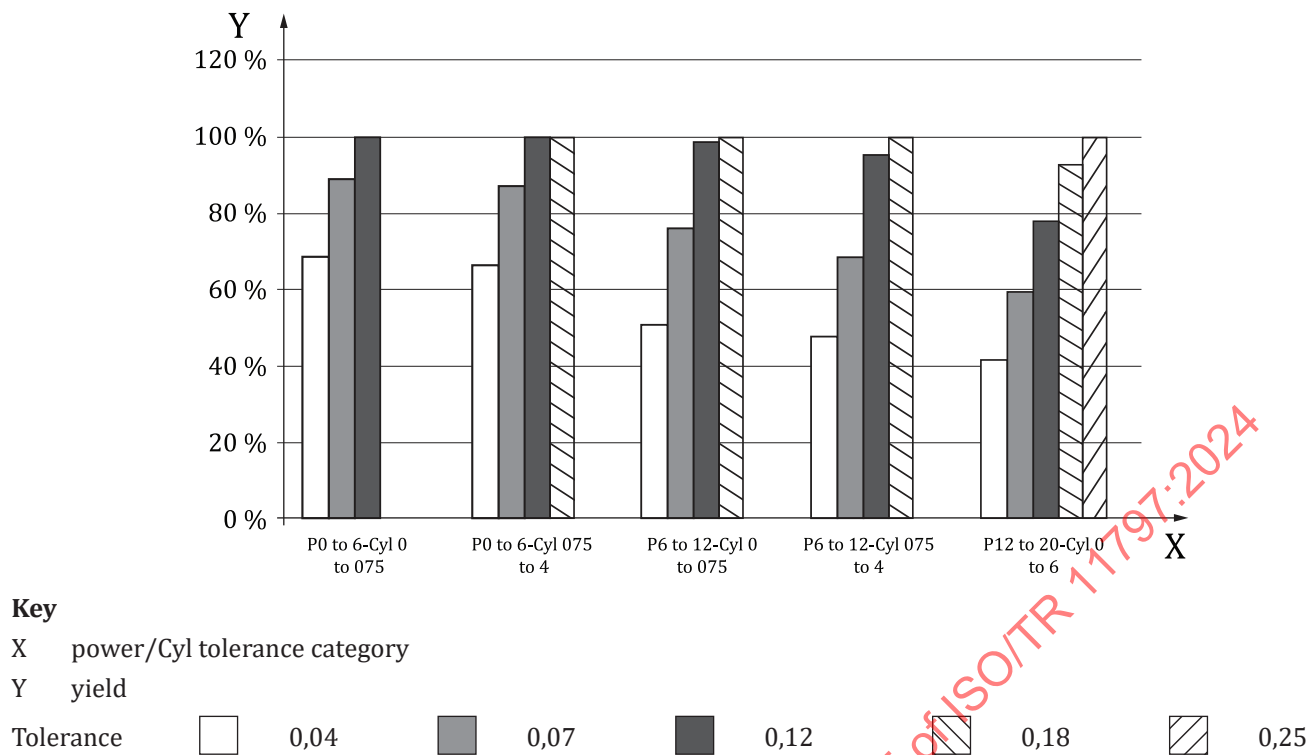


Figure B.3 — Spherical power tolerances for progressive-power lenses

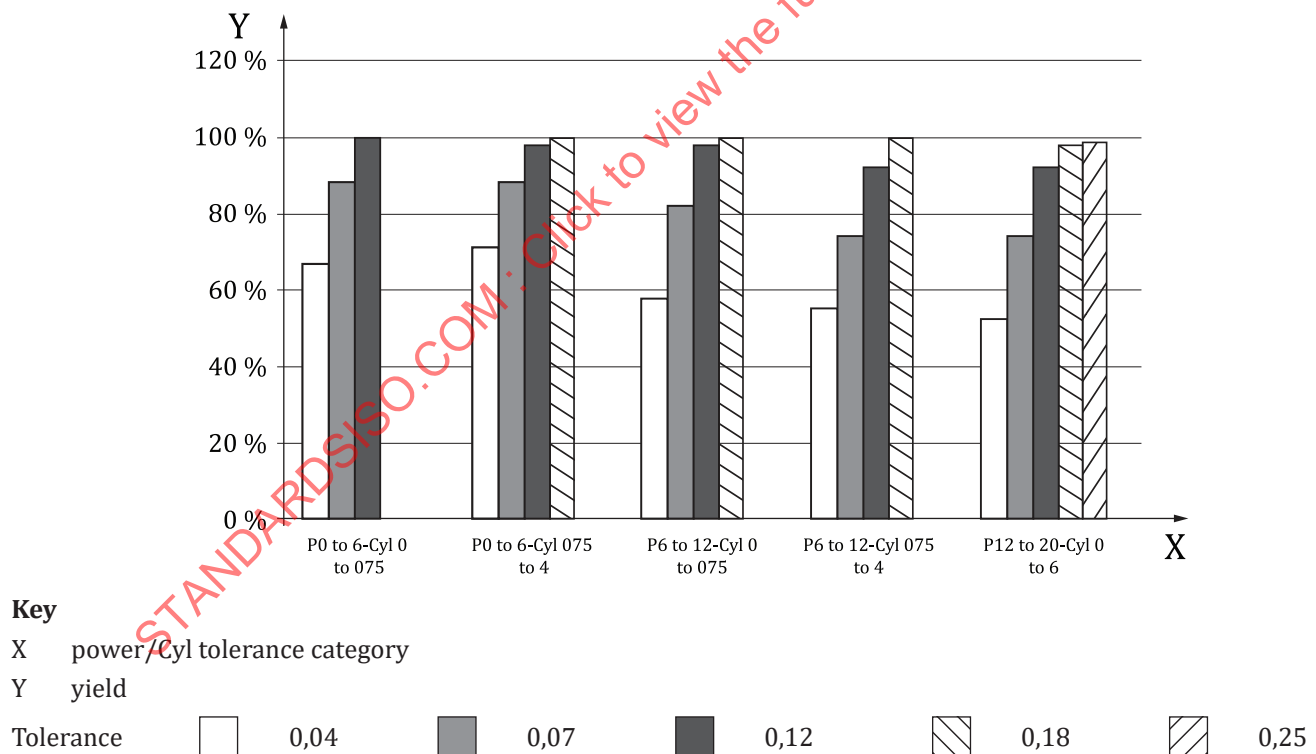


Figure B.4 — Cylindrical power tolerances for progressive-power lenses

### B.4.3 Distributions of the various power rejects

These are shown in [Figures B.5 to B.7](#) for various spherical power ranges and in [Figure B.8](#) for cylindrical power rejects.

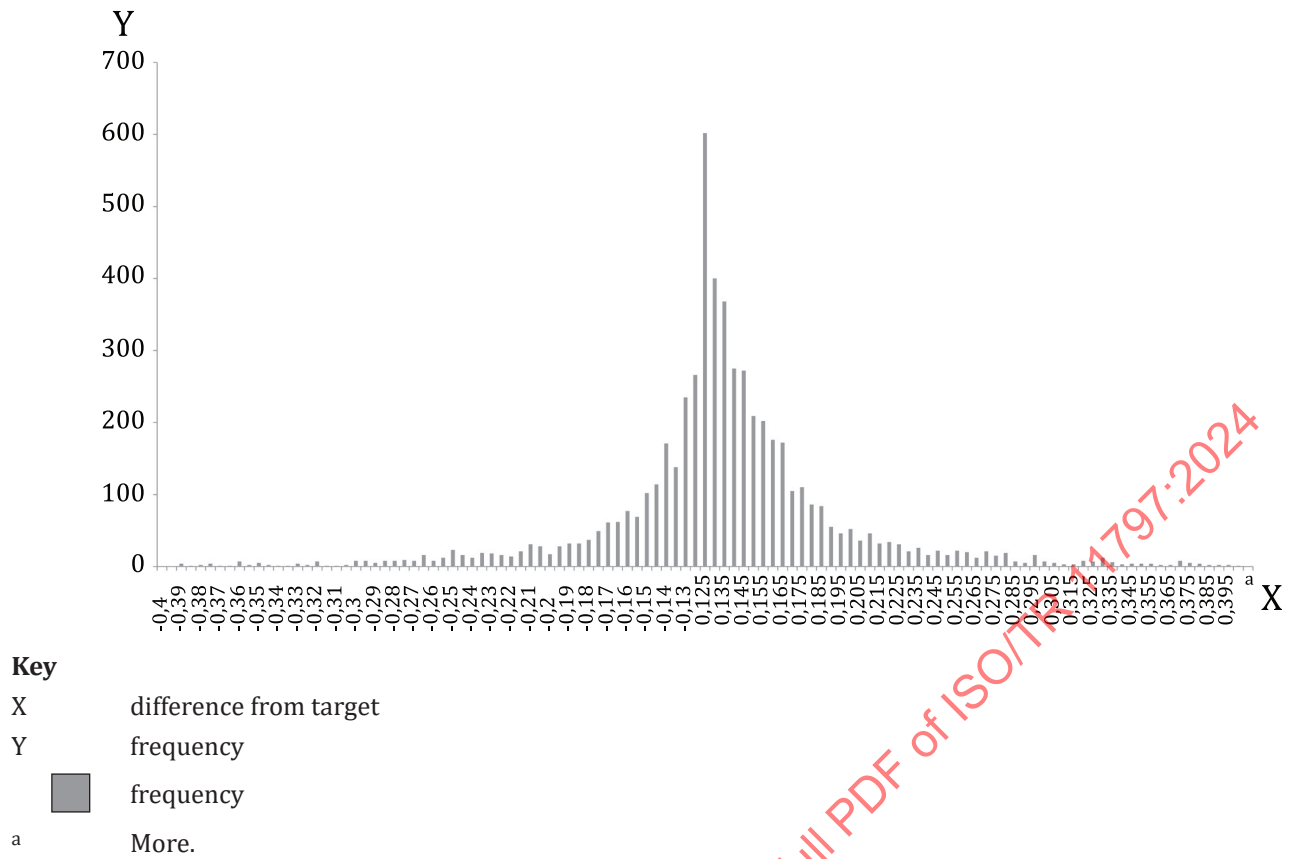


**Figure B.5 — Distribution of spherical power rejects in the 0 D to 6 D power range ( $n = 5\,551$ )**

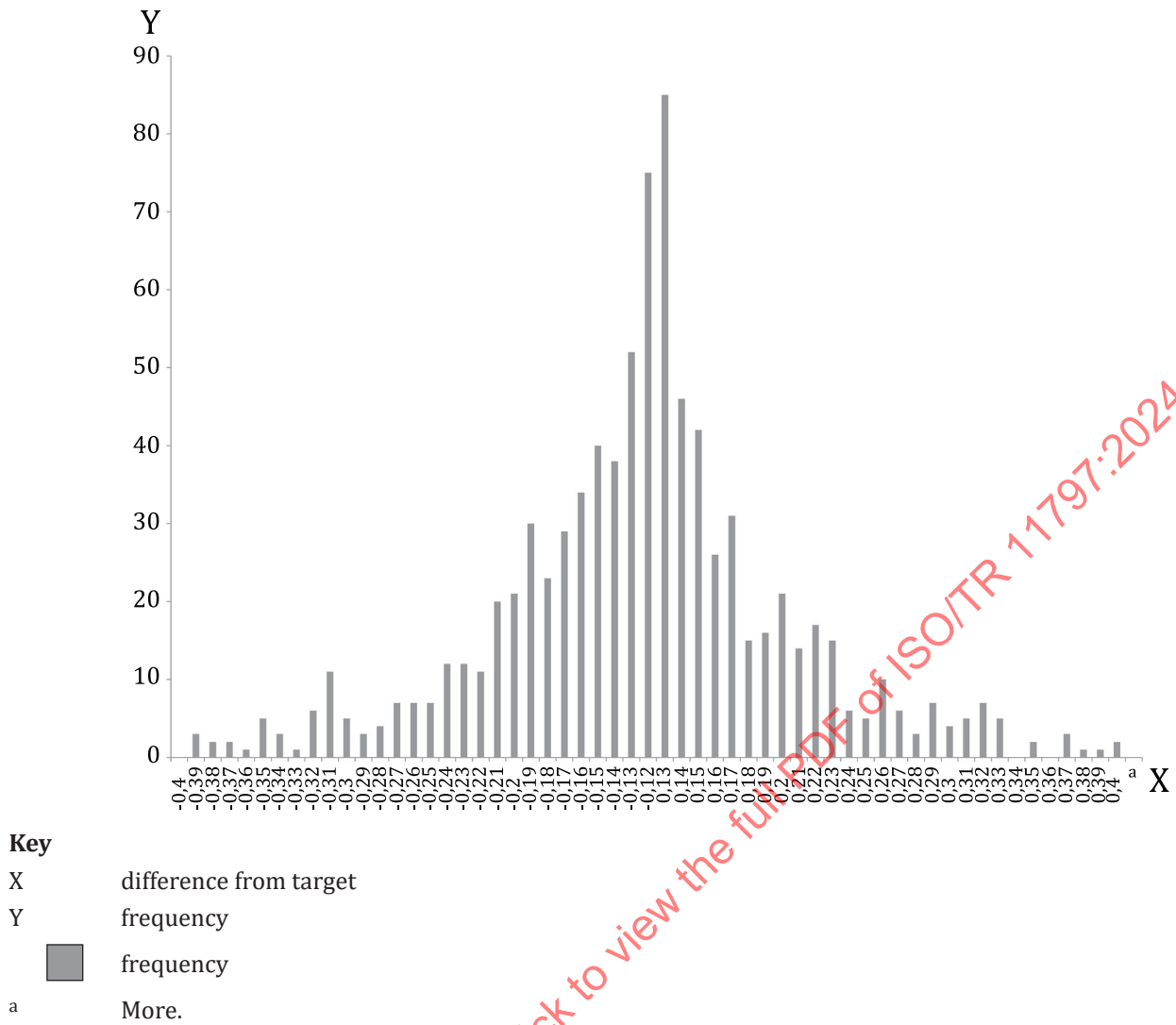


**Figure B.6 — Distribution of spherical power rejects in the 6 D to 9 D power range ( $n = 859$ )**

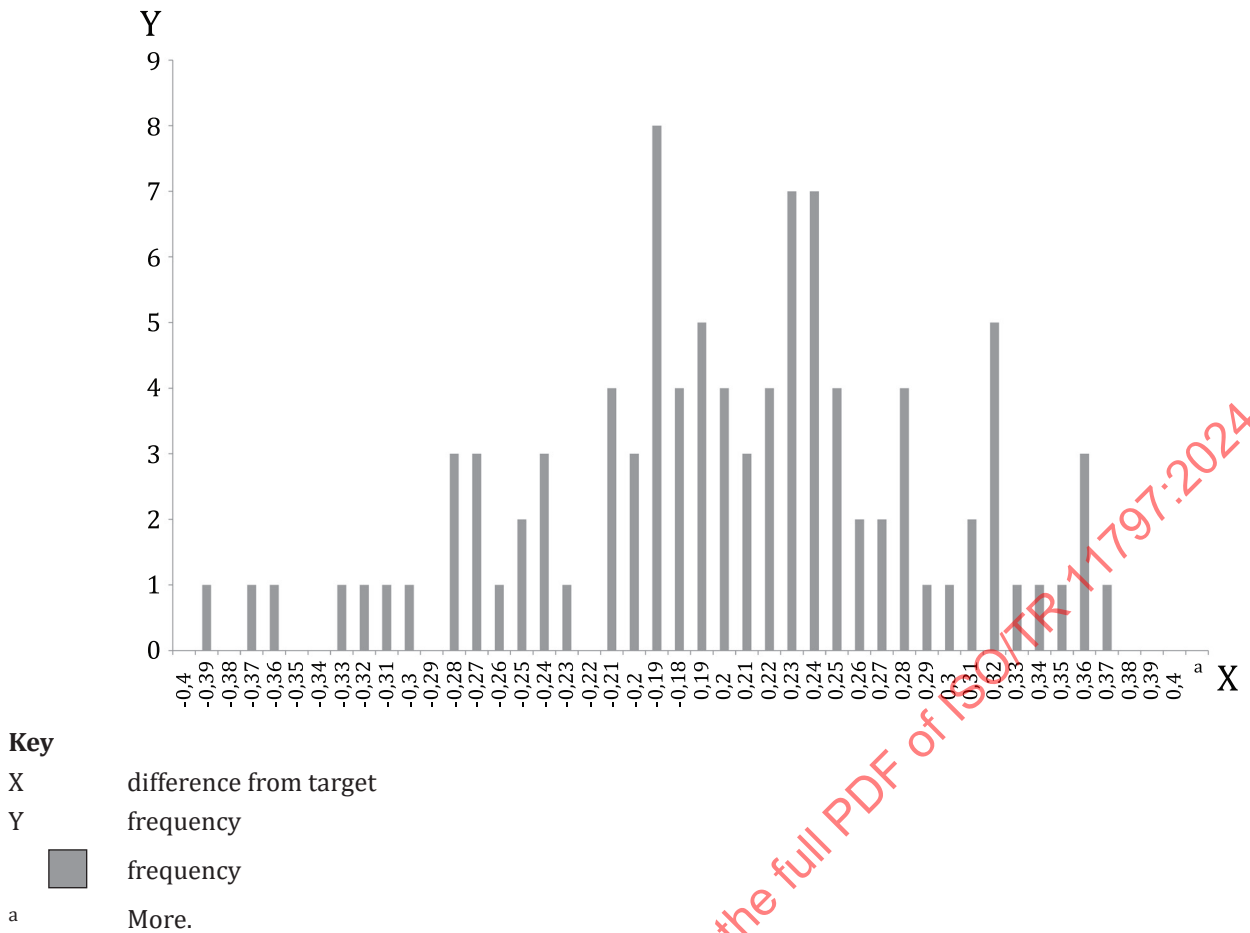


Figure B.7 — Distribution of spherical power rejects in the 9 D to 12 D power range ( $n = 97$ )

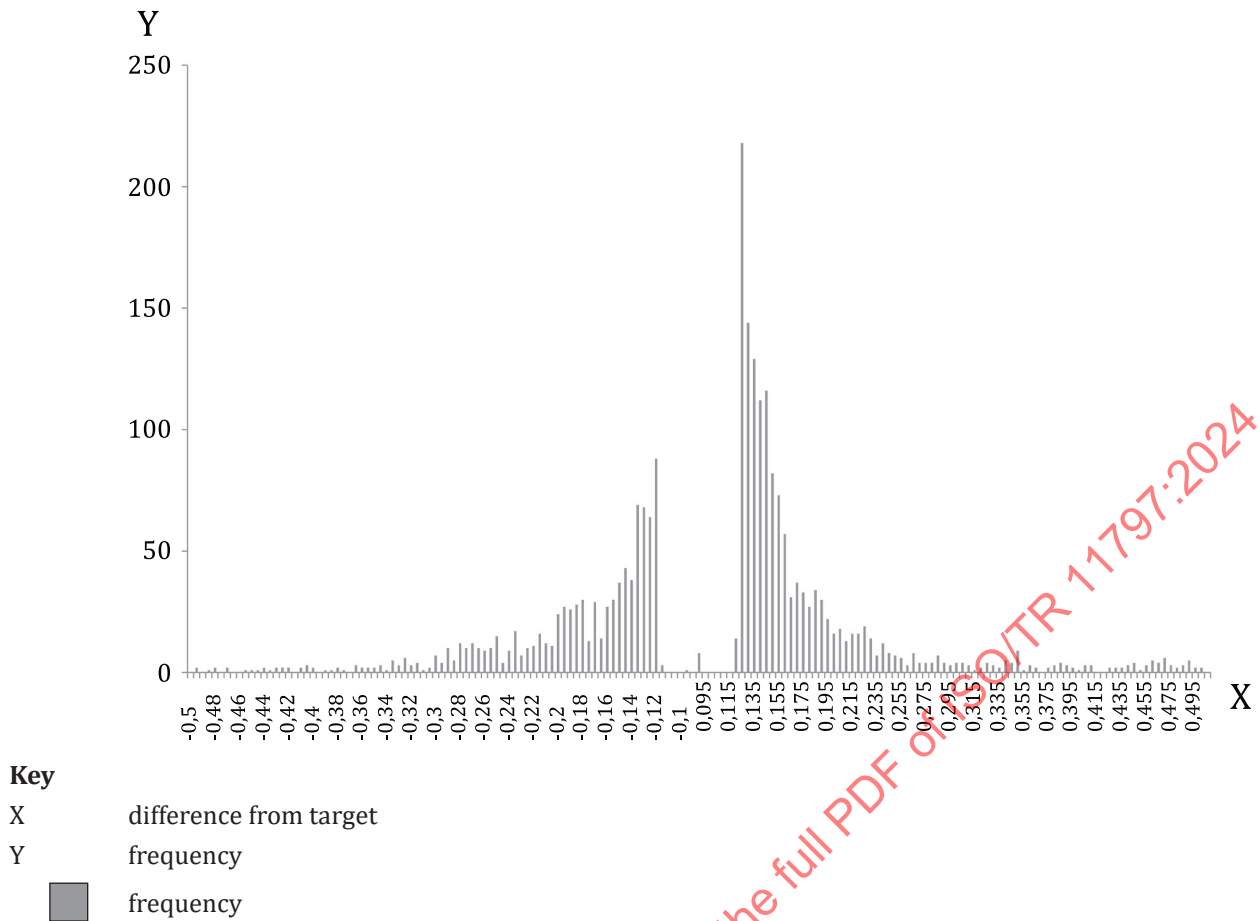


**Figure B.8 — Distribution of cylindrical power rejects for all spherical and cylindrical powers  
( $n = 2\,399$ )**

## Annex C (informative)

### Literature search

#### C.1 Method

A review of the literature revealed a number of papers on or related to the tolerances for spectacle lens powers. The search included the following keywords: 'tolerances', 'prism', 'power', 'spectacle' and additional relevant papers included from those cross referenced in the papers. Some additional papers known to members of the committee are also included.

#### C.2 Key points derived from the literature – focal power

##### C.2.1 Historical note – the unit dioptre and power subdivisions

According to Barnett<sup>[12]</sup>, the use of the metre to measure the focal length was suggested by Donders in 1860, who called it the dioptric, while Nagel introduced the term "dioptre" 6 years later. The use of the power of a lens rather than its focal length resulted from conferences in 1875. The subdivisions into half and quarter unit steps followed soon after, and eighth dioptre steps later.

##### C.2.2 Intolerance to spectacle prescriptions

Patients/subjects can notice discrepancies of 0,25 D, e.g., in intolerance to prescriptions (Howell-Duffey et al)<sup>[13]</sup> with many of the intolerance cases having been prescribed lenses +0,25 D too positive. This would cause blur in the distance out-of-doors; Freeman and Evans<sup>[14]</sup> similarly found the majority of errors in the spherical component were over-plussed (or under-minussed), with 83 % of the 12 wearers being within  $\pm 0,50$  D of the final prescription.

##### C.2.3 Experimental prescription errors

Miller, Kris and Griffiths<sup>[15]</sup> had 20 subjects aged 24 to 40 years wear a reference pair of spectacles with the latest prescription, an identical control pair, and pairs with +0,25 D or +0,50 D sphere or cylindrical power at 180° or 90° and +0,50 DC  $\times$  infero-nasal (right eye  $\times$  135° and left eye  $\times$  45°) added to the prescription in both lenses. A significant number of wearers were dissatisfied in distance vision with errors as small as the +0,25 D spherical or cylindrical change. The majority of subjects found the pairs with 0,50 D added to be unacceptable. A similar study with younger subjects, aged 18 to 30 years, was performed by Atchison et al.<sup>[16]</sup> They used +0,50 DS (sphere) right eye (RE) and binocular (BE), -0,50 DS RE and BE, and {+0,25 DS R, -0,25 DS L}. All lenses, whether monocular or binocular, reduced binocular distance visual acuity, the +0,50 DS BE the worst. Monocular imbalance reduced the stereoscopic acuity on the TNO test worse than a binocular error. Subjectively, all were rejected, even 35 % felt the control was worse than the reference pair though only about 13 % said it was unacceptable.

Rosenfield et al<sup>[17]</sup> measured the rate of reading and number of errors for young people while reading paragraphs of random words (N12) on computer screen wearing their distance correction, or with -1,00  $\times$  45 or -2,00  $\times$  45 over the top. He found a non-significant increase in symptoms for -1,00 DC, very significant increase for -2,00 DC, but no real difference in rate of reading or number of errors for the three conditions. However, they concluded "Therefore, it might be necessary to correct astigmatism in those patients whose visual demands require them to view information on an electronic screen, which is almost everybody, irrespective of age, nowadays".

### C.2.4 Experiments on blur limits

In a series of papers, Atchison and colleagues have investigated the limits of defocus at which cycloplegic subjects noticed blur on logMAR letters; their later papers included neutralising the eye's other aberrations, but this aspect is ignored in this review.

Atchison et al.<sup>[18]</sup> used 15 subjects, a Badal optometer with lines of three high contrast letters as targets and 3 mm to 6 mm artificial pupils. For 0,0 logMAR size, mean "noticeable" blur limits were  $\pm 0,33$  D,  $\pm 0,30$  D and  $\pm 0,28$  D at 3 mm, 4 mm and 6 mm, respectively, but the limits increased by about 70 % for 0,7 logMAR letters.

Atchison, Guo and Fisher<sup>[19]</sup> reported that for the 0,1 logMAR letter size, mean 'noticeable' blur limits were  $\pm 0,30$ ,  $\pm 0,24$  and  $\pm 0,23$  D at 3, 4 and 6 mm, respectively.

Guo and Atchison<sup>[20]</sup> compared the blur limits for spherical and cylindrical errors finding that in dioptric terms, the blur limits for astigmatism when viewing text were about 30 % larger than for spherical errors. They found less influence of the axis of the astigmatic error on blur than expected.

Conversely, Atchison et al.<sup>[21]</sup> found that the blur limits for crossed-cylinder<sup>7)</sup> astigmatic blur were approximately 90 % of those for spherical defocus, but with considerable meridional influences even though the circle of least confusion was kept on the retina with the crossed-cylinder error. With two subjects, the experiments were performed with higher order aberrations of the eye greatly reduced by a deformable mirror in the apparatus.

Despite this, there was still some influence of the eye's residual higher-order aberrations. With the eyes' higher-order aberrations uncorrected, the mean blur limits and their 95 % confidence limits for spherical defocus<sup>[21]</sup> for their six subjects ranged from  $(0,18 \pm 0,08)$  D (just noticeable blur for a letter size of 0,1 logMAR, approximately 6/7,5 or 20/25) to  $(1,01 \pm 0,27)$  D (objectionable blur, 0,6 logMAR, approximately 6/24 or 20/80).

### C.2.5 Repeatability of subjective refraction

Recent surveys of the repeatability of subjective refraction have been given by Goss and Grosvenor<sup>[22]</sup>, Rabbetts<sup>[23]</sup> and Smith<sup>[24]</sup>. Based on previous experimental work, the last author suggested that the expanded uncertainty in refractive measurements was about 0,6 D. Shah et al.<sup>[25]</sup> performed a study in which three subjects had their refractive errors measured in routine eye examinations by a hundred or more optometrists, "The spherical equivalent refractions were found to be within  $\pm 0,25$  D of the benchmark on average 81 % of the time and within  $\pm 0,50$  D 97 % of the time. The spherical power was within  $\pm 0,25$  D 90 % of the time and within  $\pm 0,50$  D 98 % of the time. The cylindrical power agreed within  $\pm 0,25$  D 93 % of the time and within  $\pm 0,50$  D 100 % of the time. Based on reproducibility limits data obtained for all six eyes, any two optometrists would differ in their estimation of spherical equivalent refraction by no more than 0,75 D in 95 % of repeated measures."

## C.3 Key points derived from the literature – prismatic power

### C.3.1 Intolerance to prescriptions

Although this research<sup>[26]</sup> was performed in relation to ready-to-wear spectacles, it is applicable to prescription spectacles. Nine subjects who either did not wear spectacles or who wore contact lenses wore plano spectacles, either a control or pairs with 0,50 or 1,00  $\Delta$  base up, 0,50, 1,00 or 2,00  $\Delta$  base out or 0,50, 1,00 or 2,00  $\Delta$  base in in one of the lenses for periods of up to 8 h. Most of the subjects were not prepared to wear the higher amounts of prism for the required 8 h, while to be visually comfortable, "the induced prism should be less than 1  $\Delta$  base up, 2  $\Delta$  base out and 2  $\Delta$  base in". The authors' recommendation was, however, that tolerances on spectacles would preferably be half these amounts.

7) A crossed-cylinder is a lens in which the surfaces are two cylinders with their axes at right angles. In this paper, the powers were equal and opposite, giving a mean spherical power of zero. A crossed-cylinder power of 1 D is equivalent to a normal cylindrical power of 2 D, so a 1 D crossed-cylinder power of 1 D would normally be regarded as being equivalent to a 1 D spherical power in terms of the blur generated.

### C.3.2 Prism adaptation

Unless there is a manifest deviation (“squint” or heterotropia), people’s eyes align on the object of regard, although most will show a misalignment (heterophoria) when the stimulus to fusion is removed, for example, if one eye is covered or if dissimilar views are presented to the two eyes, e.g., a spot of light for one eye and a streak to the other. Prism adaptation occurs when the angle of misalignment recovers to the initial value when looking through a prism – initially, the angle of misalignment is modified by the deviation of the prism and can recover at different speeds completely or not at all<sup>[27][28][29]</sup>. Tunnaclyffe and Williams<sup>[30][31]</sup> expanded this type of study to evaluate the performance of the ocular system by measuring the binocular contrast sensitivity function, to find that although prism adaptation had occurred, there was a measurable drop in the contrast sensitivity function with 1 Δ base down in photopic conditions, with 0,5 Δ in mesopic conditions, or with 2 Δ outside the zone between the angles of fixation and the dissociated position. One of the subjects reported a continuous headache when wearing the 1 Δ vertical prism. Although no consistent effect on stereopsis, another sensitive binocular function, was found by Reference [26]. Jiménez et al.<sup>[32]</sup> showed a decline in the maximum image disparity that could be seen stereoscopically (termed “range”) when spectacle lenses were decentred from their correct position, thus inducing unwanted prism. They also found<sup>[33]</sup> a poorer range in patients who required an aligning prism (associated heterophoria) on a consulting room fixation disparity test.

In anisometropia (unequal focusing errors of the eyes), the eyes view different sized images at different distances. When gazing away from the centre of the lenses, one eye therefore must move through a larger angle than another – a numerical example is given in Reference [34]; an alternative approach, though giving an over-estimate of the variable prismatic imbalance, can be obtained by regarding the two eyes as viewing through the lenses at the same distance from their reference point. Prentice’s rule therefore gives a differential imbalance of  $c \times \Delta F$  prism dioptres, where  $c$  is the distance from the reference point measured in cm and  $\Delta F$  the difference in power in the direction of gaze. Allen<sup>[35]</sup>, in a study of 20 subjects, found that there was almost complete adaptation to the induced vertical imbalance in about half the subjects, about one third showed less than full adaptation and the remainder over-compensated. Although not part of the study, it would be expected that similar or better adaptation would be made in the horizontal direction since the fusional reserves allowing the eyes to coordinate are greater, and the binocular system more frequently makes such adjustments with the convergence and divergence of the eyes for different viewing distances and the need for sideways movements of the eyes when reading or driving.

### C.3.3 Yoked prisms

Yoked prism is the name given to prisms that are dispensed with the same base direction, e.g., both base down or both base left – see [Clause 7](#). An investigation by Sheedy and Parsons<sup>[36]</sup> of yoked base down prism, as used in prism thinning, found that 4 Δ was rejected by nearly all the 24 subjects, but that 2 Δ was accepted. With the types of lens that incorporate prism thinning, patients will usually be exposed to increases in prismatic power as the addition or variation power is increased with increasing age, whereas in this study, younger subjects were suddenly exposed to the prism.

## Annex D (informative)

# Report of the ISO web survey into lens verification methods — World-wide results

### D.1 Background

During the last systematic review of ISO 21987, the appropriateness and relevance of the prism and power tolerances and methodologies was discussed. To help ensure spectacle lens standards remain relevant, specific power and prism task groups were established in 2014. These two groups were tasked with reviewing tolerances and test methods in the light of current practices as well as conducting a systematic review of the literature. After the review of the available literature, both groups decided that a survey of the industry would help to better understand current industry practice, thus informing a future review. (See survey objectives)

This ad hoc group was set up during the Southbridge meeting of ISO/TC172/SC7 in 2017 to develop a questionnaire on spectacle lens verification methods and then to run a world-wide web survey of optometric practices, retail optical stores and manufacturing opticians and prescription laboratories asking how the person actually verifying spectacles performs the task. The aim was to gather data on actual 'industry practice', standards awareness and interpretation, with specific focus on the areas of lens power and prism assessment. The data from this work will be used in the future revision of the relevant standards used by the industry, specifically ISO 21987 (mounted spectacle lenses) and ISO 8980-1 and -2 (uncut spectacle lenses).

The two main contentious issues are firstly whether the focal power of spectacle lenses is measured by a 2-parameter method (applying the tolerances to the spherical power and the cylindrical power, usually in the minus cylinder transposition), or a 3-parameter method in which the power of the second principal meridian is also to be verified and toleranced, and secondly, whether prism imbalance is measured by the reference method in ISO 21987 or a method more similar to that in [Annex C](#) of the standard. In addition, respondents were asked whether or not they verified the prism imbalance in mounted progressive-power lenses.

The Survey was held in Summer 2018 and the results were reviewed at the ISO TC 172/SC 7/WG 3 meetings in Dallas in November 2019. The WG decided in 2019 to prepare an executive summary that provided the basis for recommendations for the next systematic review of 21987. There were a total of 2090 responses, of which 57,4 % were from the USA, see [D.5](#) for details. To help discussion, the results were available as the normalized overall percentages (where the number of answers in a region was modified in proportion to the number of spectacle lenses made in that region) or subdivided into North America/Europe/Rest of the world.

### D.2 Introductory text provided to participants in the survey

The following introductory text was provided to the participants in the survey.

*"The International Standard for verifying mounted spectacle lenses, ISO 21987, is currently being revised. The committee responsible is interested to know the methods currently used by the spectacle lens community internationally to verify whether a pair of completed spectacles complies with the prescription order, both for power and prism imbalance (relative prism error).*

*"It is very important that the survey is completed by the people who perform the power and prism inspection of the completed spectacles or finished uncut lenses, whether in laboratories or in optical practices. We wish to find out what actually happens, not what you feel should be done. There are no right or wrong answers to this survey, and because this information will be collected anonymously, there are no implications to your responses."*

### D.3 Major findings

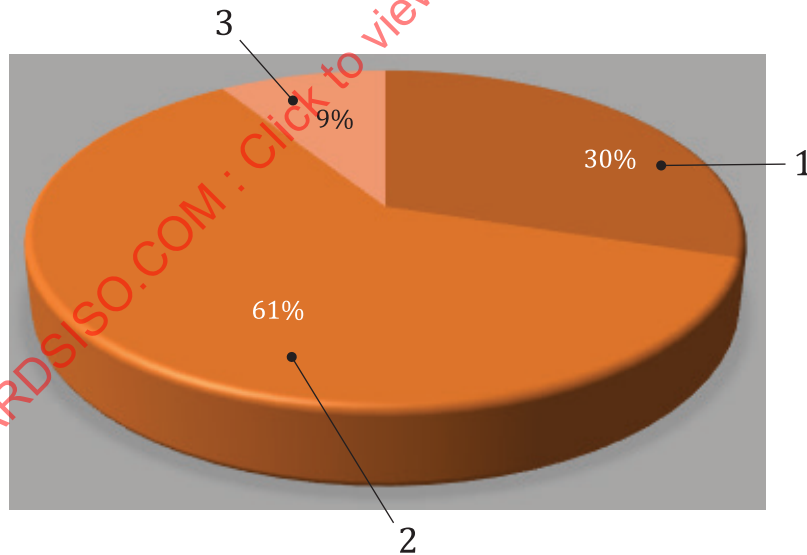
- Over 70 % of industry practice use a 2-parameter (Spherical and Cylindrical) power tolerance methodology.
- A large proportion of respondents use increments of 0,25 D or  $\Delta$  when measuring lenses, (81 % for power and 60 % for prism).
- 95 % of the industry works in minus cylinder convention, (historically with a larger percentage of the industry working in plus cylinder convention, the 2- versus 3-parameter power methodology had a larger impact).
- In general, practice and methodology for prism verification was significantly varied with a variety of procedures and 'interpretations' of the standard performed with the majority employing a methodology that differed from the reference method in the standard.
- A significant section (41 %) of the marketplace demonstrated a lack of understanding of 'compensated' verification power and prism check off values. (This is likely to cause many more correctly manufactured jobs to be rejected for power compliance than jobs rejected because of a 2-parameter power methodology being implemented.)

### D.4 Detailed results

#### D.4.1 Country, focimeter type, use of standards, etc.

The various pie or other charts below are listed for each question on the survey, together with comments where appropriate. Apart from this first plot, the results in the charts to all the following questions have been normalized to the proportion of spectacle lenses supplied in each region.

##### Question 1: What country are you in?



##### Key

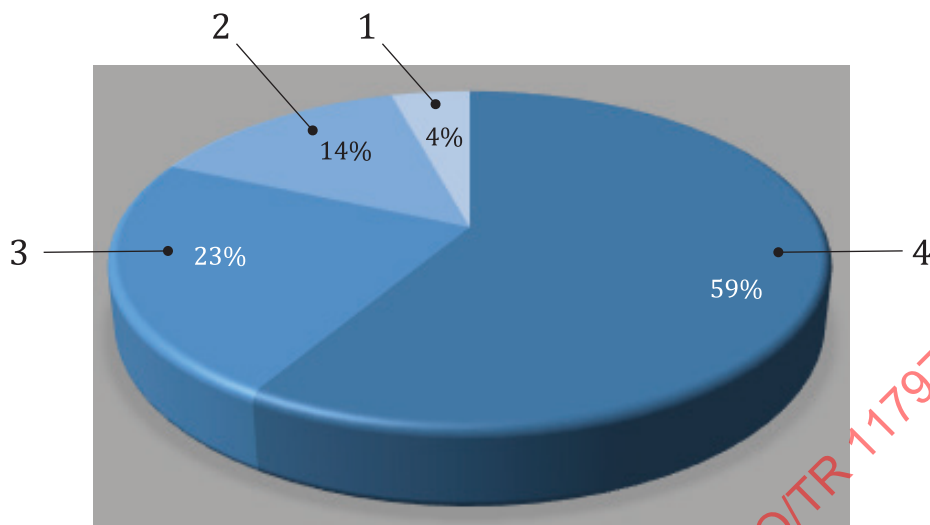
- 1 Europe
- 2 North America
- 3 Rest of the world

**Figure D.1 — Country of the respondent**

Because the replies predominantly came from the USA, the results below have been normalized according to the number of spectacle lenses used in each region.

**Question 2: What type of business do you work in?**

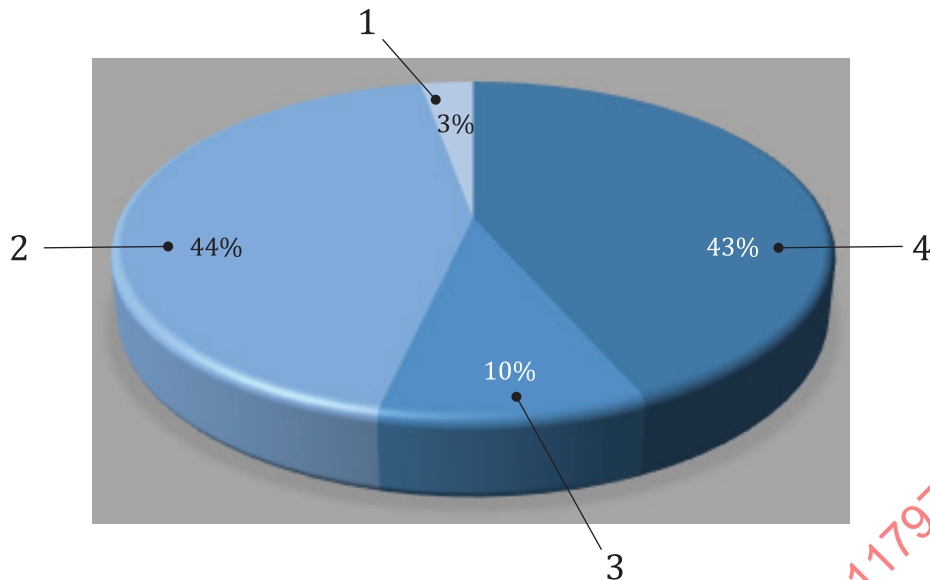
Predominantly, the replies have come from private practices, which might not verify lenses in the same way as retail locations or prescription laboratories and lens manufacturers.

**Key**

- 1 no answer
- 2 prescription laboratory/manufacturer
- 3 retail location
- 4 private practice

**Figure D.2 — Type of business of the respondent**

**Question 3: What quantity of lenses are inspected per week?**

**Key**

- 1 no answer
- 2 < 50
- 3 ≥ 300
- 4 ≥ 50 and < 300

**Figure D.3 — Quantity of lenses inspected each week**

The greater number of responses from private practices is mirrored in the roughly equal numbers that verify < 50 lenses a week and the 50 to < 300 group.

In the UK, the results for the number of lenses inspected per week and type of location could be analysed – see [Table D.1](#).

**Table D.1 — Percentage in the UK only answers on location and number of lenses inspected per week**

| Quantity of lenses inspected per week | Percentage of all UK replies |                 |                          |
|---------------------------------------|------------------------------|-----------------|--------------------------|
|                                       | Private                      | Retail location | Rx Lab/Lens manufacturer |
| <50                                   | 28,4                         | 5,9             | 0                        |
| ≥50 and <300                          | 32,4                         | 12,7            | 0                        |
| ≥300                                  | 0                            | 8,8             | 11,8                     |

As expected, the retail locations or, in the UK, stores belonging to multiple opticians, were more likely to be checking more lenses per week than private practices. There were, however, far more replies from private practices than from the retail locations (60,8 % versus 27,4 % of all UK replies).

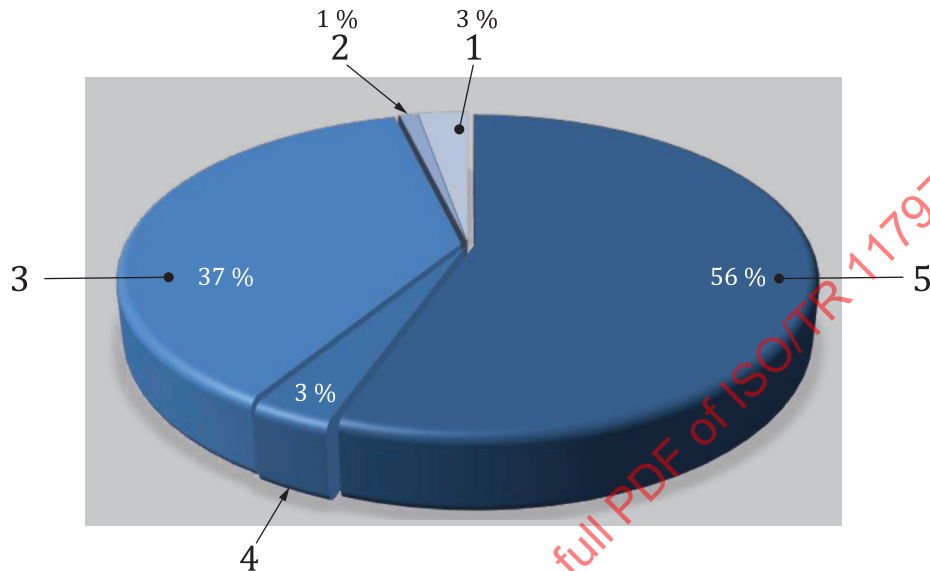
**Question 4: What is the primary type of focimeter/lens meter used when verifying spectacle lenses?**

The preferred type of focimeter varied considerably by region – see [Table D.2](#).

In North America, manual focimeter use was 77 %, while elsewhere it was about 25 % to 35 % with automated instruments being the more popular.

Table D.2 — The preferred type of verification instrument according to the region

| Type of verification instrument | Europe | North America | Rest of the world |
|---------------------------------|--------|---------------|-------------------|
| Manual                          | 26     | 77            | 33                |
| Automated Manual positioning    | 68     | 21            | 59                |
| Automated Robotic positioning   | 5      | 2             | 3                 |
| Mapper                          | 1      | 0             | 1                 |
| Not stated                      | 0      | 0             | 4                 |

**Key**

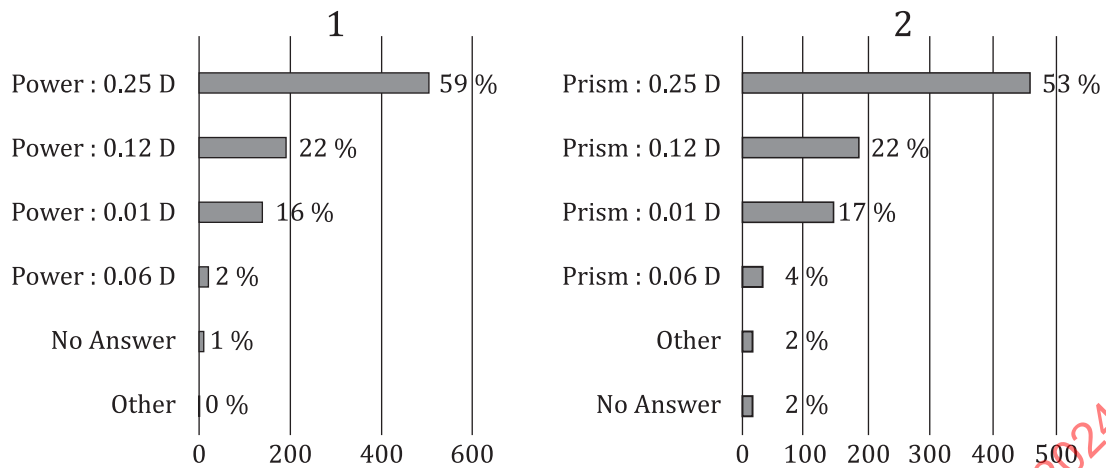
- 1 no answer
- 2 mapping device
- 3 manual focusing
- 4 automated (robotic positioning)
- 5 automated (manual positioning)

Figure D.4 — Preferred type of verification instrument

Overall, automated instruments with manual positioning of the lens were used by 56 %, manual instruments by 37 %.

**Question 5: If your preferred instrument is automated, what power or prism steps were used on the display?**

The display steps used when automated instruments were used are shown below, the majority (59 %) chose 0,25 D display steps, 22 % 0,12D, 2 % 0,06 D and 16 % 0,01 D steps. For prismatic power, the choice was: 53 % 0,25 Δ, 22 % 0,12 Δ, 4 % 0,06 Δ and 17 % 0,01 Δ steps.



**Key**

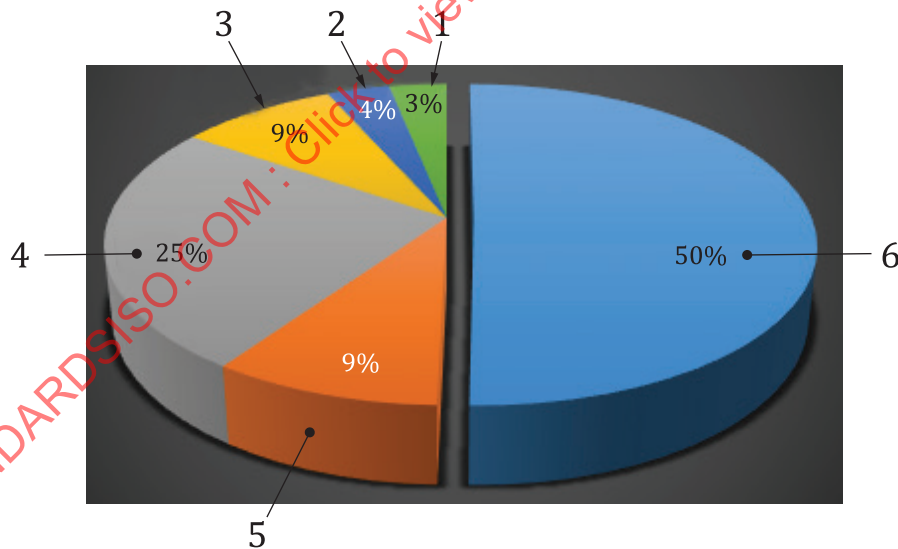
- 1 power step
- 2 prism step

**Figure D.5 — The power or prism step chosen**

The large majority for 0,25 D steps is worrying in that it might not be possible to verify whether a lens is within or outside tolerance when verification powers are not close to the traditional 0,25 D intervals – see Question 11 and [D.6](#) and [D.7](#). [Annex E](#) gives a discussion on the power steps and verification.

The same comment can be applied to measurement of prism imbalance, especially when using the reference test method.

**Question 6: What standard do you use when verifying spectacle lenses?**



**Key**

- 1 other
- 2 no answer
- 3 national
- 4 internal standard
- 5 ANSI
- 6 ISO

A breakdown according to region is given in [Table D.3](#).

**Figure D.6 — Standard used when verifying spectacles**

**Table D.3 — Type of standard used — percentages for each region**

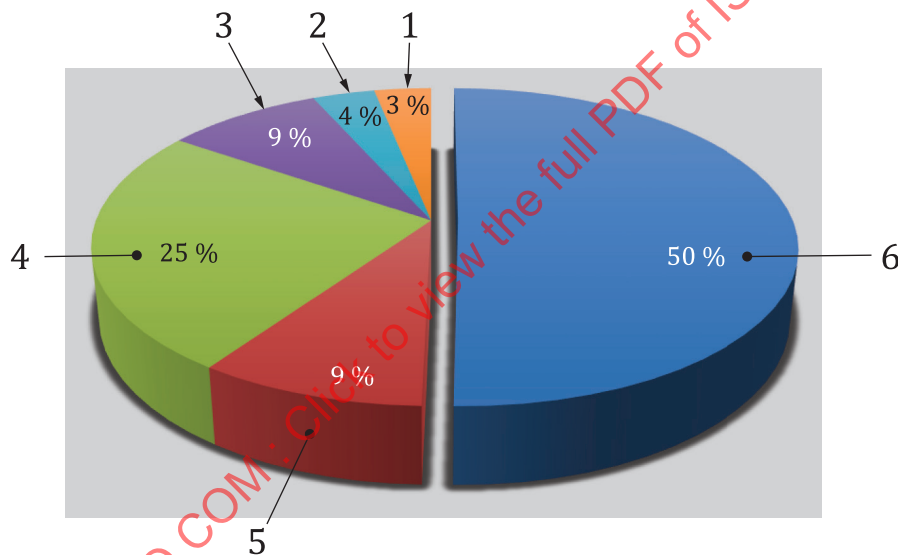
| Type of Standard | Europe | North America | Rest of the world |
|------------------|--------|---------------|-------------------|
| ISO              | 68     | 16            | 63                |
| Internal         | 30     | 8             | 27                |
| National         | 0      | 71 (ANSI)     | 12                |
| Other            | 0      | 4             | 4                 |
| No answer        | 2      | 1             | 4                 |

N.B. Results could include firms marketing internationally. Quebec uses ISO, the rest of Canada uses ANSI.

#### Question 7 What is the name of the standard used?

This plot shows an overall impression. The results vary enormously around the world, with North America showing a 71 % usage of the ANSI standard. The choice of “ISO” could include either edition of ISO 21987, or other ISO lens standards, e.g., 8980.

In the UK, even when ISO 21987 was named, half were using the 2011 edition, not the 2017 edition, 16 % of the total stated that they used ISO 8980, presumably Parts 1 and 2 which are uncut lens standards, some quoted the British Standard that predated ISO 21987. One of the professional bodies in the UK publishes an abstract giving the tolerances, so users can not be sure which Standard was being copied.

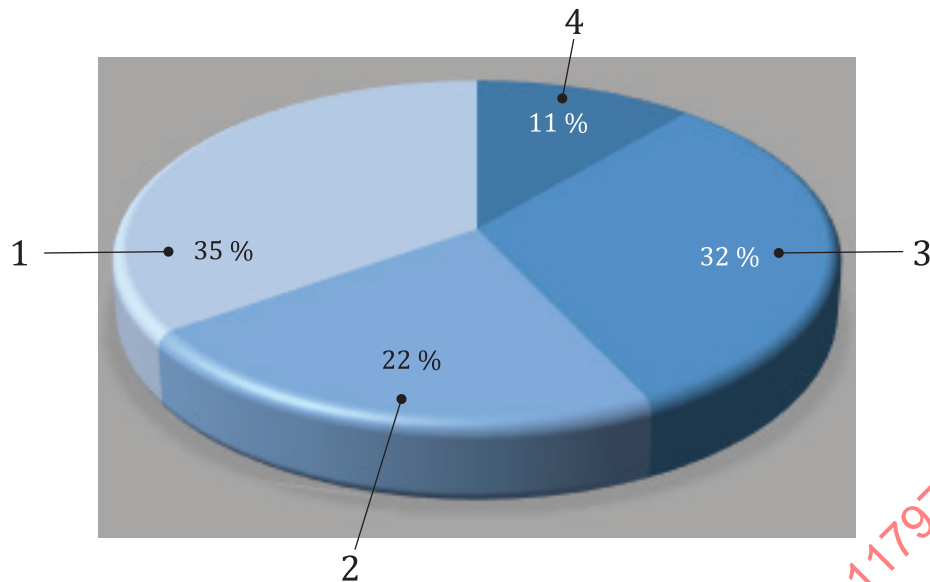


#### Key

- |             |                     |
|-------------|---------------------|
| 1 other     | 4 internal standard |
| 2 no answer | 5 ANSI              |
| 3 national  | 6 ISO               |

**Figure D.7 — Name of the standard used**

**Question 8: If using an internal standard, are your tolerances similar or tighter than those used in (insert local country standard)?**



**Key**

- 1 tighter than the standard listed above
- 2 the same as the National or ISO standard listed above
- 3 similar to the standard listed above
- 4 looser than the standard listed above

**Figure D.8 — Are the tolerances looser, similar to or tighter than the ISO ones?**

Note that only 11 % were using standards with looser tolerances.

**Question 9a: Is the focimeter connected to a computer for data collection?**

**Question 9b: If yes, is final accepting or rejecting a pair of spectacles made with a computer comparing measurements with its pass/fail criteria?**

A very small percentage had focimeters connected to computers, but of that number, a small majority did use the computer's processing for accepting/rejecting a lens. A suggested reason for this is that focimeters' communication protocols differ between manufacturers and even models from a single manufacturer, making interfacing with software difficult. This suggests a task for standardization.

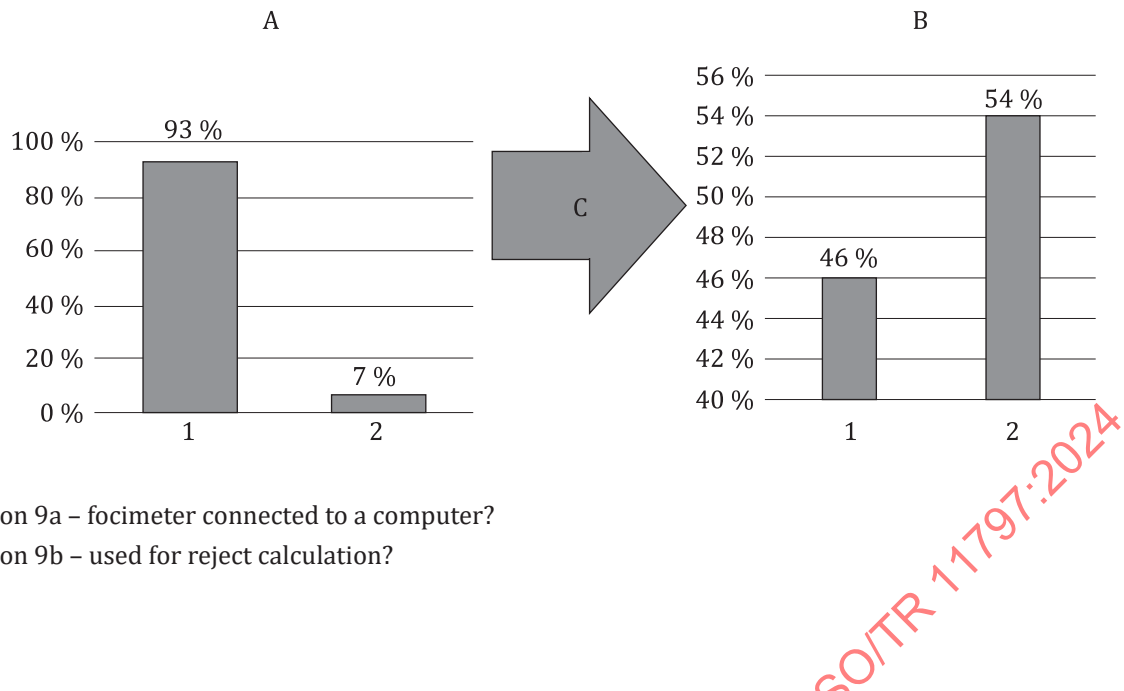
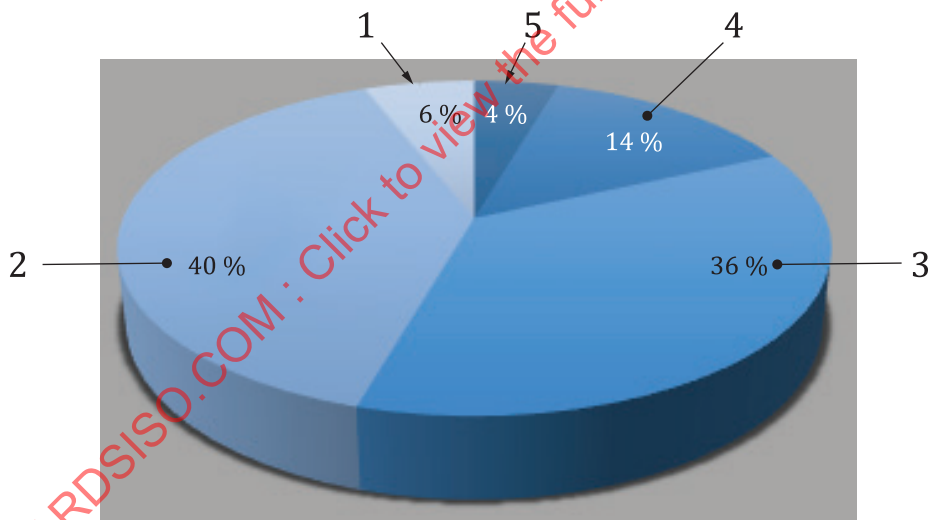


**Figure D.9 — Is the focimeter connected to a computer?**

**Question 10: What do you do when a lens is out of tolerance?**



- Key**
- 1 re-measure on the same instrument without moving the lens
  - 2 re-measure on the same instrument but moving the lens
  - 3 re-measure on a different instrument
  - 4 reject lens without re-measuring
  - 5 other

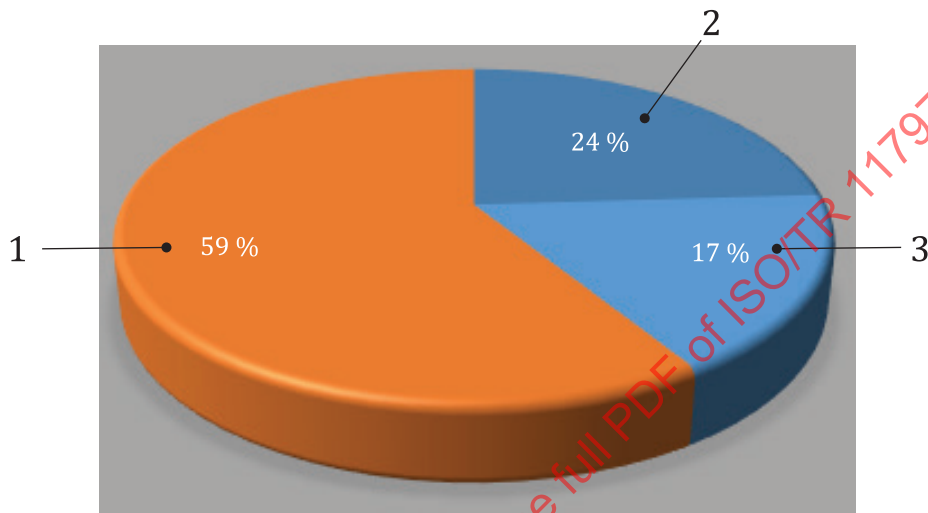
**Figure D.10 — Procedure when a lens is out of tolerance**

The two popular options (remeasure, either after moving the lens or on a different instrument) appear logical, while remeasuring a lens without moving it would be valid only for a manual focimeter. Immediate rejection, especially for a power-variation lens, might reject lenses that were good.

#### D.4.2 Focal power verification

**Question 11: When a manufacturer states both the ordered power and the verification power (compensated power taking into account the as-worn position), do you apply tolerances to the prescribed, ordered or verification power?**

While the majority of replies were for the correct answer of “verification power”, it is disappointing that many did not. For practices that rarely order lenses with powers compensated for the as-worn position, the ordered power is a sensible answer. Similarly, to pick up errors from writing orders manually, checking against the prescribed power on the consulting room’s record is also sensible. The problem arises when a lens’s power has been modified by the manufacturer to take account of the as-worn position, when the lens must be checked against the verification power.



##### Key

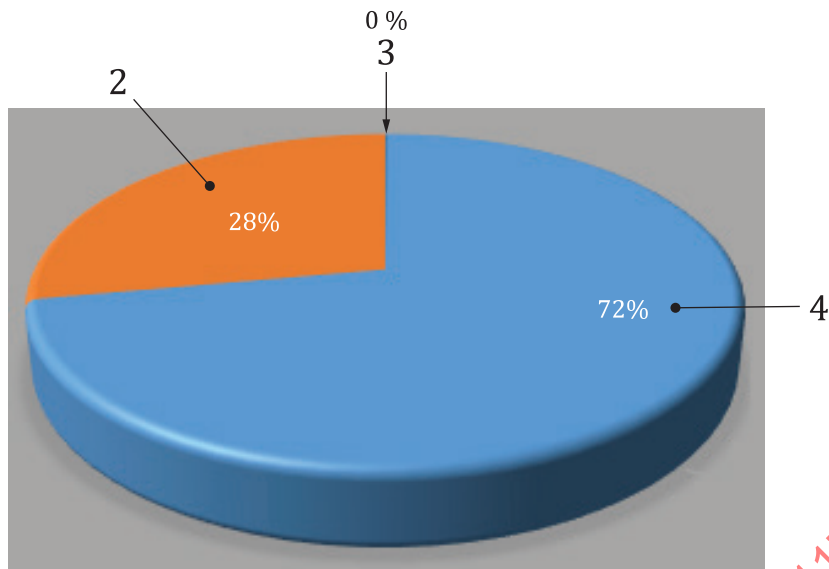
- 1 verification power
- 2 ordered power
- 3 prescribed power

**Figure D.11 — Choice of reference for focal power measurement**

More emphasis is needed on verification power in ISO 21987 and education will need to be done; see also the comments in [D.6](#) and [D.7](#).

**Question 12: When you check the power of a lens with a cylindrical component, do you?**

There is a large majority in favour of a simpler method, such as the 2-parameter method of measuring the spherical and cylindrical powers as used in the ANSI Standard, and not a 3-parameter method such as that specified in the ISO spectacle lens standards. See, however, the discussion related to Question 14, In the UK, trainee dispensing opticians are taught the 3-parameter method but are frequently told in practices that the 2-parameter method is used.



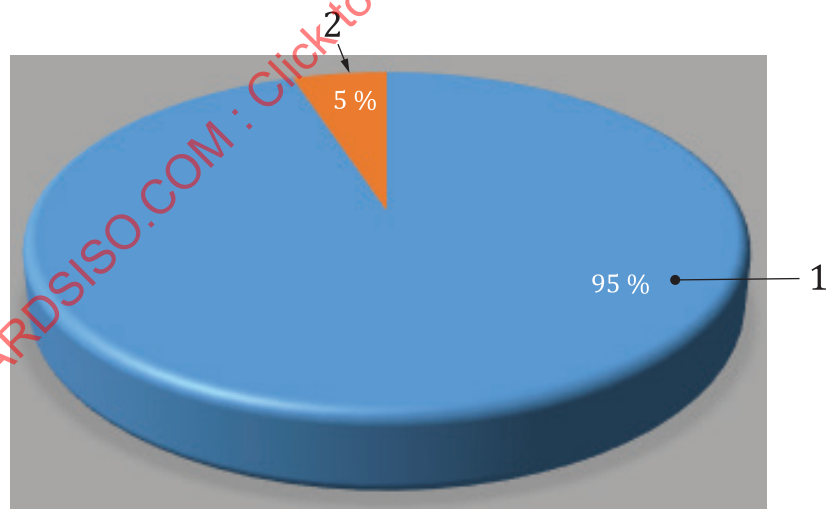
**Key**

- 1 measure the sphere power and cylindrical power i.e. sphere, Cyl
- 2 measure the two principal meridians of focal power and compute the cylindrical difference
- 3 apply your own method

**Figure D.12 — Procedure for verifying a lens with cylindrical power**

**Question 13: Which cylinder convention do you use?**

Note that the very clear-cut majority of people used the minus cylinder. This matches the tooling for conventional back surface toric lenses with their minus cylinder power. See the last paragraph relating to the next question for possible beneficial implications when verifying lenses.



**Key**

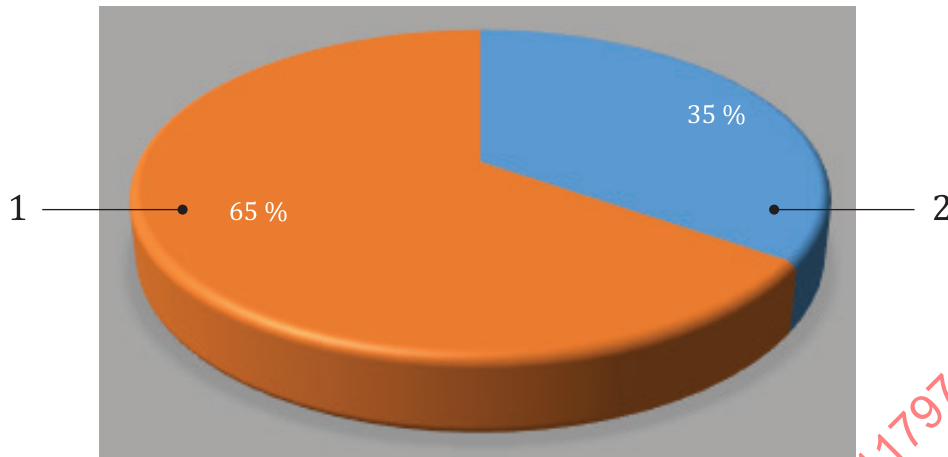
- 1 minus cylinder convention
- 2 plus cylinder convention

**Figure D.13 — Cylinder convention used**

**Question 14: When using the minus cylinder convention, assuming a 0,12 tolerance for sphere and cylinder, would you pass or fail this lens?**

Prescribed = Sphere + 0,25, Cylinder – 3,25 × 103

Measured = Sphere + 0,37, Cylinder – 3,18 × 103



#### Key

- 1 pass
- 2 fail

**Figure D.14 — Pass or fail the lens**

Both the spherical and cylindrical powers of this lens are within the ISO tolerance, but the errors in both are such that the second principal power was outside tolerance (at -2,81 D instead of -3,00 D).

Compared with the answer to Question 12, where only 28 % of replies stated that they used the 3-parameter method, 35 % failed the lens, which implied that they were considering the second principal power. Perhaps more consideration was given because this was a numerical example?

In North America, where the 2-parameter method is normally used, 25 % failed the lens, implying that they would check the second principal power – See [Table D.4](#) below. In Europe and rest of the world, 64 % passed the lens, about 7 % absolute less than the proportion who stated that they used the 2-parameter method. A more detailed breakdown was performed for the UK replies: about 27 % of those who stated that they measured just the spherical and cylindrical powers failed the lens, while approximately equal numbers of those who stated that they used the 3-parameter method passed and failed the lens. Again, were the respondents more careful than they would be when actually verifying a lens because the survey gave them a numerical example?

**Table D.4 — The percentages of replies passing or failing the lens**

| %age passing or failing | Europe | North America | Rest of the world |
|-------------------------|--------|---------------|-------------------|
| Pass                    | 64     | 75            | 64                |
| Fail                    | 36     | 25            | 36                |

The fact that 65 % that passed the lens suggests that the majority of lens verifiers use the 2-parameter method. Users of automated instruments must either calculate the second principal power, or use the transpose button/icon on the instrument to display it. Conversely, users of manual instruments have to calculate the cylindrical power from the two principal powers.

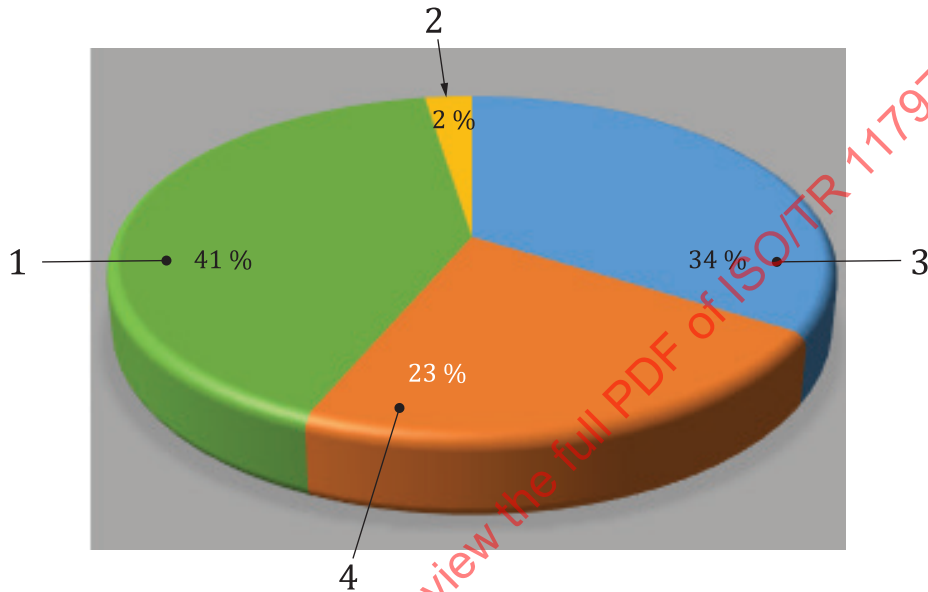
Almost all lenses are now made with the cylindrical component on the back surface, i.e. as minus cylinder lenses. The power in the base curve (i.e. the spherical power) and the cylindrical component are therefore likely to be pretty accurate, but the cumulative error in the power of the second principal meridian could be less accurate; this will not be picked up when the lens is verified using the 2-parameter method in the minus cylinder transposition. Conversely, in the days when the cylindrical component was generally on the front

surface, then the spherical power in the minus cylinder transposition corresponds to the cross curve so out-of-tolerance errors were more likely to be discovered when verifying the lens.

**Question 15: When you measure the addition power of a progressive-power lens, do you?**

It is interesting that 34 % accepted the value in the temporal engraving. The chances of a lens having an incorrect addition power was extremely small when they were made from a progressive-power semi-finished lens blank; the aberrations when verifying this power on a focimeter made measurement somewhat imprecise, making this choice very reasonable.

With free form lenses having the addition power created during the calculation and machining process and in many cases being compensated for the as-worn position, verifying the lens on a focimeter seems much more advisable, especially as the engraved value is usually the ordered and not the verification addition power.



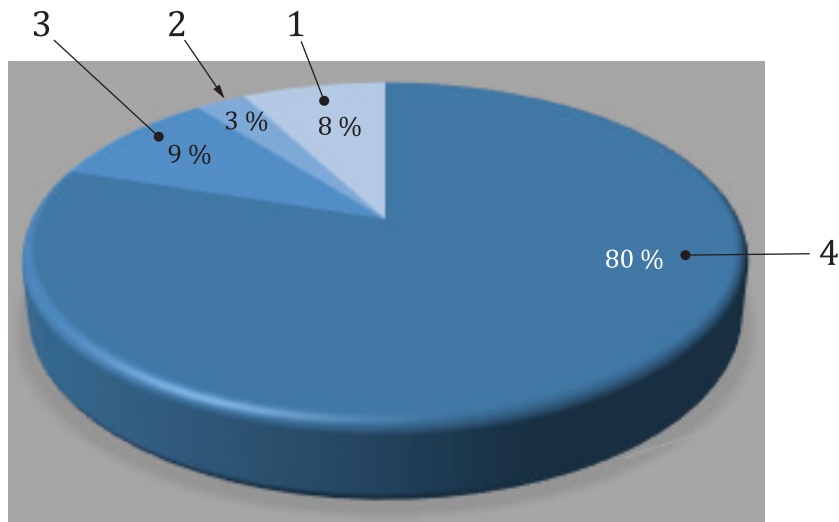
**Key**

- 1 measure the addition power of the lens with the progressive surface against the focimeter's lens support
- 2 other
- 3 look for and accept the value in the engraved temporal marking
- 4 measure according to the instruction supplied by the manufacturer

**Figure D.15 — Verification of the addition power of a progressive-power lens**

#### D.4.3 Prism verification

**Question 16: When you check prism imbalance, what do you check?**

**Key**

- 1 only single vision and multifocal lenses
- 2 only progressive-power lenses
- 3 do not verify prism imbalance
- 4 all single vision, multifocal and progressive-power lenses

**Figure D.16 — What types of lenses are verified for prism imbalance**

[Table D.5](#) shows that there is considerable difference in percentages around the world for verifying all lens types or not verifying at all.

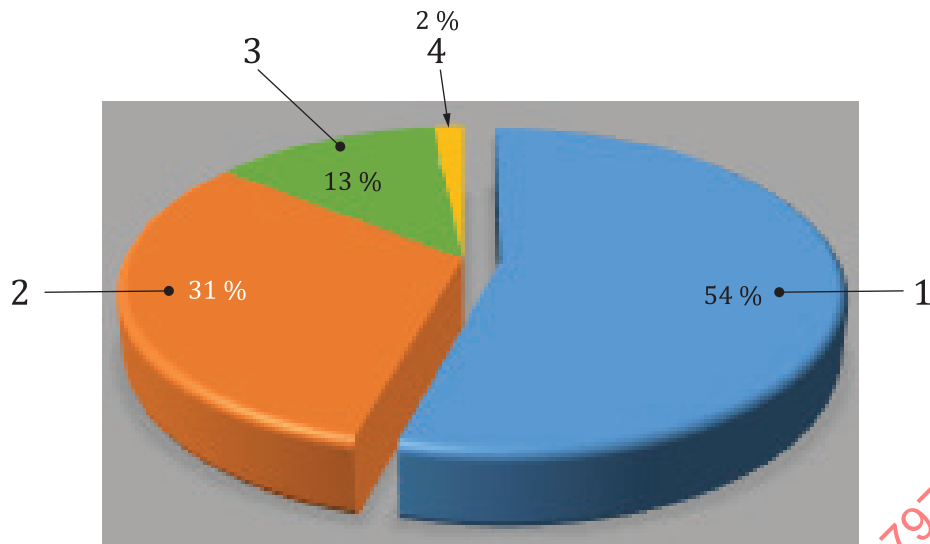
The 9 % overall (in the Figure) that do not verify prism imbalance masks the 24 % in Europe who do not (and this averages the tiny 2 % in Great Britain who do not). The proportion of European answers (see [Table D.5](#)) stating that they did not verify prism imbalance at all (24 %) is somewhat worrying, particularly since the continental European experts on the project group writing ISO 21987 are very strong advocates of the reference method in the standard.

**Table D.5 — Measurement of prism imbalance — percentages for each region**

| Type of lens measured             | Europe | North America | Rest of the world |
|-----------------------------------|--------|---------------|-------------------|
| All lens types                    | 64     | 89            | 82                |
| Only PPL                          | 7      | 1             | 2                 |
| Only single-vision and multifocal | 5      | 4             | 9                 |
| Do not verify                     | 24     | 6             | 7                 |

While the majority verify all lens types, including progressive-addition lenses, the survey did not ask what tolerances were applied. For progressive-addition lenses, see the answer to Question 18.

**Question 17: For single vision and multifocal lenses, which process most closely represents what you do?**

**Key**

- 1 find the optical centre of the stronger of the two lenses and dot it, then slide the pair over to the other lens. then measure the distance between the optical centres (OCD/PD) and check against the ordered centration distance (CD/PD) for accuracy
- 2 mark the ordered position of the centration points, measured any prism at these points, and then determine the horizontal and vertical prism imbalance
- 3 utilizing a focimeter or connected software that has internal prism imbalance calculation capability, we measure the two lenses at their centration points and apply the tolerances to the calculated imbalance values
- 4 other

**Figure D.17 — Method for verifying the prism imbalance of single-vision and multifocal lenses**

The worldwide average masks the choice in Europe where the highest proportion at 50 % marked the centration points and then measured the imbalance, a method similar to the reference test method in Clauses 5.3.5 and 6.6 of ISO 21987. In both North America and the rest of the world, the majority preferred the method of dotting the optical centre, etc., a method similar to that in Annex C of ISO 21987 – see [Table D.6](#), where the most favoured method for each region is shown in bold font.

**Table D.6 — Prism verification method — percentages for each region**

| Prism verification method          | Europe    | North America | Rest of the world |
|------------------------------------|-----------|---------------|-------------------|
| Mark centration points and measure | <b>50</b> | 27            | 28                |
| Dot OC stronger lens, then weaker  | 29        | <b>64</b>     | <b>58</b>         |
| Focimeter with software            | 17        | 7             | 13                |
| Other                              | 4         | 2             | 1                 |

**Question 18: For progressive power lenses, if you are checking the prism imbalance, do you?**