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Ophthalmic optics — Spectacle lenses — Parameters affecting lens power measurement

Optique ophtalmique — Verres de lunettes — Paramètres affectant le mesurage de la puissance de la lentille

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 28980 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments*.

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Ophthalmic optics — Spectacle lenses — Parameters affecting lens power measurement

1 Scope

The purpose of this Technical Report is to explain the changes relating to power measurements in the revised editions of ISO 8980-1 [6] and ISO 8980-2 [7].

In order to illustrate the issues raised, an inter-laboratory power measurement study was conducted on ten different lenses measured by nine organizations worldwide. Twenty-five focimeters of different types were used. The test lenses were spherically powered allyl diglycol carbonate (ADC)1) hard resin lenses surfaced to –4,00 D, –2,00 D, 0,00 D, +2,00 D, and +4,00 D, each with an addition power of 2,50 D. Five were D28 bifocals and five were progressive power lenses. The measurements were front distance power, front near power, back distance power and back near power, for each lens and for each focimeter used. Each lens was measured nine times: five measurements taken without repositioning the lens and four measurements taken with the lens repositioned each time.

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The assessed parameters were divided into three categories:

— discrepancies due to focimeter design and measurement methods;

— systematic errors;

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— random errors.

For each parameter, experimental results are given, as well as theoretical ones when needed. Measurement data include front distance portion power, front near portion power, back distance portion power and back near portion power.

NOTE The results of all measurements are available on the ISOTC Server at the address given in the Bibliography[8].

Unless stated otherwise, in order to show relevant information, the results shown are for the D28 bifocals when no different behaviour was found for the progressive power lenses.

2 Discrepancies due to different focimeter designs and measurement methods

2.1 Focimeter design

Traditional manual focimeters have relied on the user adjusting the instrument to obtain the clearest focus of the test mire. All these instruments are based on the “Focus on Axis” (FOA) design, in which the focal point of the focimeter remains on the axis of the focimeter when the lens under test is measured at a point of the lens where the prism is not zero.

Some automated focimeters also use this optical design, but many use the “Infinity on Axis” (IOA) design, in which the collimated beam coincides with the focimeter axis and the focal point of the focimeter goes off the

1) ADC is often referred to by its original trade name, CR-39®.

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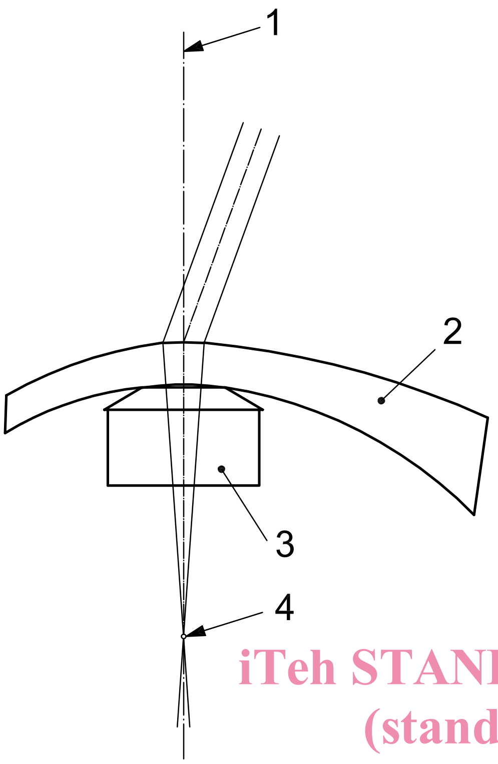
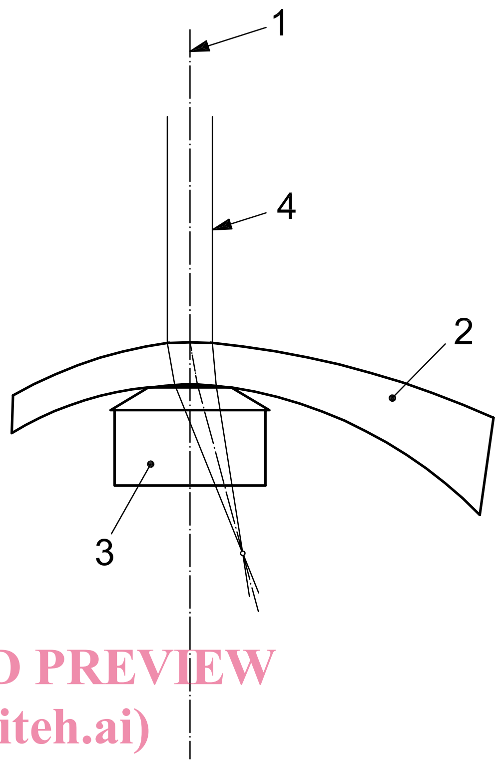
axis of the focimeter when the lens under test is measured at a point of the lens where the prism is not zero (see Figures 1 and 2). As automated focimeters can have either a FOA or IOA design, users should ask the manufacturer what design is employed.





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Key

1 focimeter's optical axis
2 lens
3 focimeter lens support
4 focal point on the optical axis

Figure 1 — FOA focimeter

Key

1 focimeter's optical axis
2 lens
3 focimeter lens support
4 infinite on the optical axis

Figure 2 — IOA focimeter

When there is no prismatic effect, the two designs will give the same results. On the other hand, the results will differ if the prism is not zero, as shown by Coddington's equations for oblique astigmatism (for further details, see textbooks on optics).

Figure 3 is a graph of the results from the inter-laboratory measurements study.

As the lenses used had moderate power and prism, the average FOA-IOA difference remains within the power tolerance for focimeters. Nonetheless, even for these lenses, for near power the discrepancy reaches nearly 2/3 of the lens power tolerance allowed by the ISO standards.

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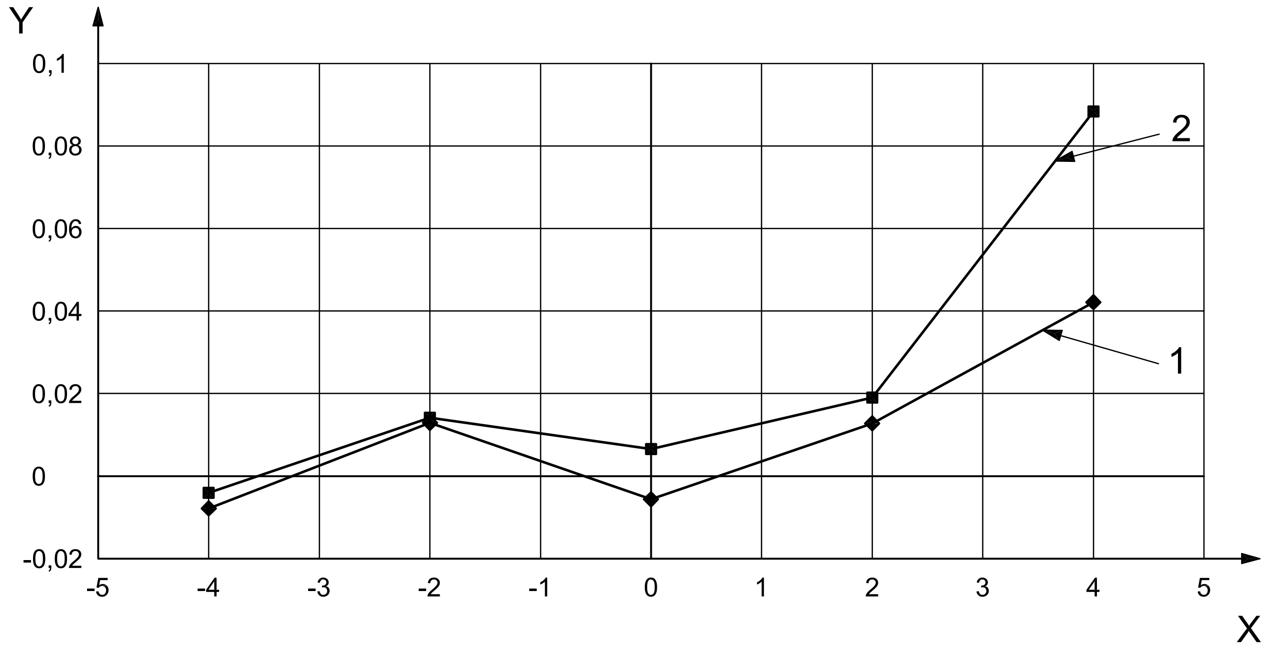

Key

X nominal distance power, in dioptres

Y power difference, in dioptres

1 D28 – differences in distance power

2 D28 – differences in near power

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Figure 3 — Graph of the inter-laboratory measurements showing the difference in power between the FOA and the IOA focimeter design in the presence of prism
(average value of measurements of the back vertex power made at the sagittal focus, addition power 2,50 D)

2.2 Wavelength dependence

The refractive index of the lens material varies with the wavelength. This variation is given by the Abbe number (for further information, see textbooks on optics).

The reference wavelength differs depending on the country. In some countries, the helium d-line (587,56 nm) is used, while in others, it is the mercury e-line (546,07 nm).

Figure 4 shows the effect of the wavelength dependence on the lens power for two materials:

— a material with an Abbe number, ν, of 57,8 and a nominal index, n, of 1,5 (n_d = 1,4977, n_e = 1,4996), and

— a material with an Abbe number, ν, of 30,0 and a nominal index, n, of 1,59 (n_d = 1,5855, n_e = 1,5899).

NOTE n_d is the nominal index at the wavelength of the helium d-line; n_e is the nominal index at the wavelength of the mercury e-line.

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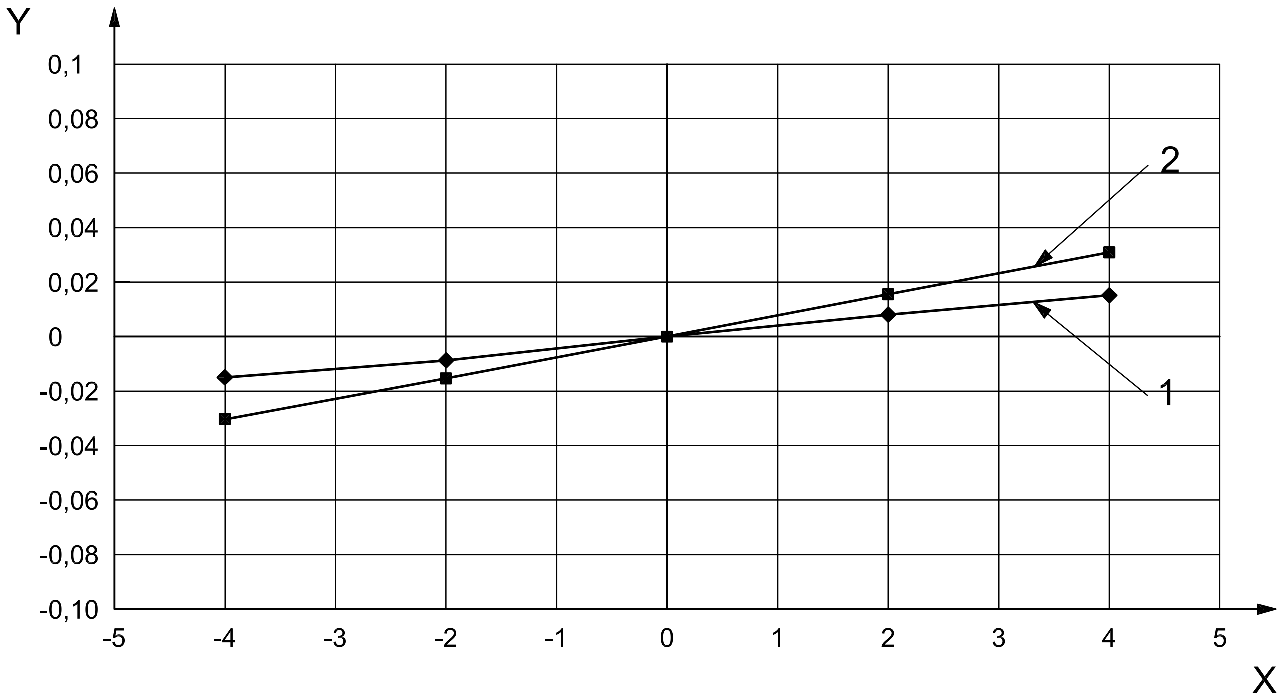

Key

X lens power, in dioptres
Y power difference, in dioptres

1 V = 57,8 and n = 1,5
2 V = 30,0 and n = 1,59

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Figure 4 — Wavelength dependence: Calculated power difference between 546,07 nm and 587,56 nm for two different materials

Hence, the theoretical power discrepancy between the helium d-line and the mercury e-line for a +4,00 D ADC lens with a 2,50 addition would be approximately 0,03 D for a total near power of +6,50 D. It should be noted that reference wavelength dependence is also important in the calibration of focimeters (see 3.4).

Because automated focimeters usually work with red light or infrared radiation, the instrument has a built-in correction for the readings for low dispersion or high Abbe number materials such as ADC. Lenses, especially high powered ones, made from higher index materials with lower Abbe numbers, require the instrument to be adjusted/reset in order to correct for the different Abbe number.

2.3 Target pattern

2.3.1 Manual focimeters

For manual focimeters, the target is a graticule.

2.3.2 Automated focimeters

Automated focimeters have several approaches for the pattern their target uses to determine the focus. Among the most common ones are the “4-rays target pattern” and the “annular pattern”. Note that an annular pattern becomes elliptical when the lens under test is an astigmatic power lens (see Figure 5).

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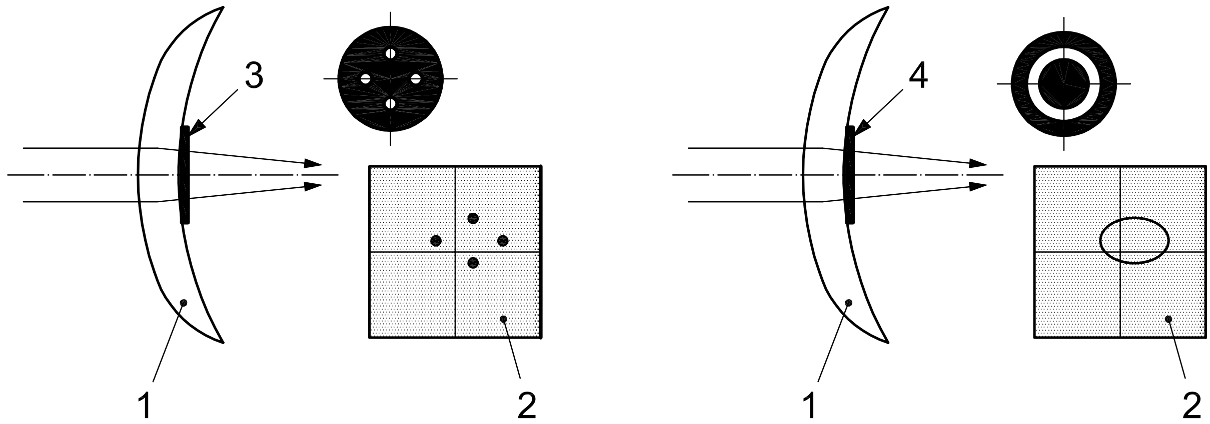

Key

1 measured lens
2 screen
3 aperture with 4 holes
4 annular aperture

a) **4-rays target pattern** b) **Annular target pattern**

Figure 5 — Examples of target patterns commonly used in automated focimeters

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Figure 6 shows the results from the inter-laboratory studies comparing focimeters using the “4-rays target pattern” and the “annular target pattern”.

It is easy to note that there is very little difference between the two patterns. This can be explained by the accuracy and precision of the focimeters.

In these focimeters, the position of the focus is computed. Therefore, when measuring areas of progressive power lenses with built-in aberrations (such as coma), different target patterns can yield significantly different results, and in certain complex cases, some instruments cannot make a measurement and therefore produce an error message.

2.4 Front vertex versus back vertex measurements

ISO 8980-1 and ISO 8980-2 specify for the addition determination that the measurement for near portion power and distance portion power can be made either at the back or the front vertex. This distinction can lead to major discrepancies in power measurements. Indeed, the more the lens differs from the symmetrical biconcave or biconvex shape, the greater this difference will be.

Figure 7 shows the average differences between the back vertex power minus the front vertex power for the distance and near portions of the lenses.

The differences result from the relative surface curvatures and thicknesses and can be significant, especially for positive powered lenses. Consequently, identification of the measurement method is essential.

The distance power of a lens is that given by the back vertex measurement method, while for most multifocal and progressive power lenses, the addition is given by the difference between the two front vertex powers. If the addition power for such a lens is measured as the difference in back surface powers, the error for the addition is the difference between the two lines in Figure 7, i.e. 0,26 D for the +4,00 D distance power lens.

The refractive power at the designed reference point (for distance or near vision) perceived by the viewer is called the “as worn” power of the lens. It cannot be measured with a commercially available focimeter without extensive modifications, and generally differs from both the front and back vertex powers. Some lenses are designed and manufactured to provide the “as worn” power (e.g. “as worn” addition power).

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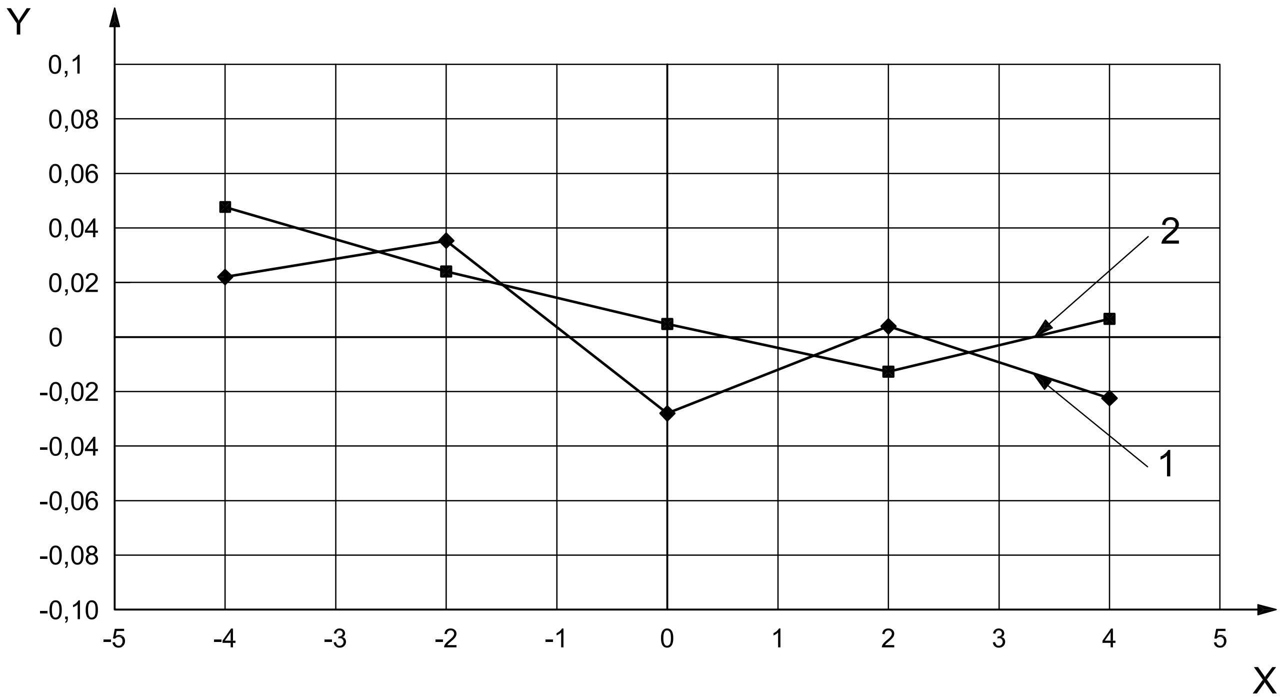

Key

X nominal distance power, in dioptres

Y power difference, in dioptres

1 D28

2 progressive power lens

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Figure 6 — Graph of the inter-laboratory measurements showing the average power difference for distance power between two different target patterns

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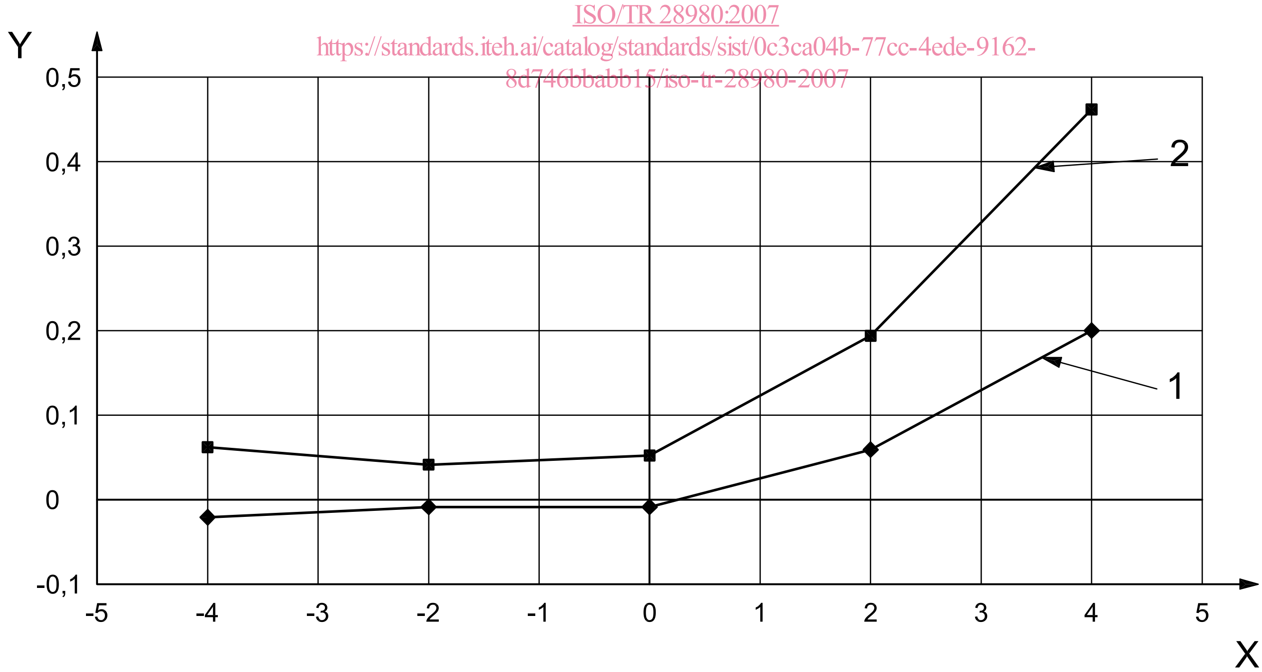

Key

X nominal distance power, in dioptres

Y power difference, in dioptres

1 differences in distance power

2 differences in near power

Figure 7 — Average power differences between front vertex and back vertex measurements on an FOA focimeter using the spherical equivalent for D28 lenses, addition power 2,50 D

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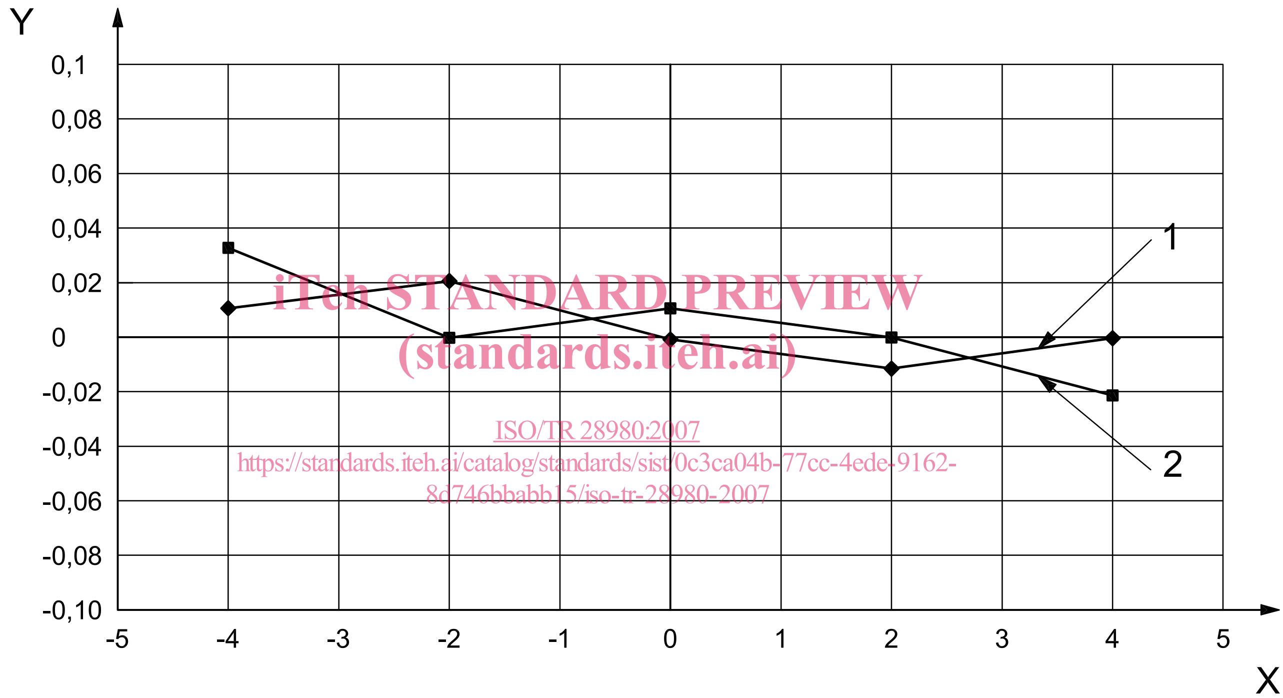
2.5 Choice of focus

ISO 8980-1 and ISO 8980-2 recommend the use of either the nearer to vertical line focus of the target (sagittal focus) or the spherical equivalent which corresponds to the disk of least confusion and to what the human eye perceives. Manual focimeters can use both methods, whereas automated focimeters use the spherical equivalent.

When using the sagittal focus, it is easy to mistake the two focus lines created by astigmatism when the axis is close to 45° and 135°, e.g. using the 45° line for near power and the 135° for distance.

Figure 8 shows the average difference in power measurement between the spherical equivalent power and the power measured at the sagittal focus.

As can be seen, the difference between the two choices of focus point is small and is within the focimeters' accuracy and precision of measurement.



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Key

X nominal distance power, in dioptres

Y power difference, in dioptres

1 differences in distance power

2 differences in near power

Figure 8 — Power difference between sagittal focus and spherical equivalent measurements (average value of measurements of a D28 lens measured at back vertex on FOA focimeters, addition power 2,50 D)

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