



**International
Standard**

ISO 6760-1

**Optics and photonics — Test
method for temperature coefficient
of refractive index of optical
glasses —**

**Part 1:
Minimum deviation method**

*Optique et photonique — Méthode d'essai pour déterminer le
coefficient de température de l'indice de réfraction des verres
optiques —*

Partie 1: Méthode de la déviation minimale

**First edition
2024-05**

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Foreword

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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

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Introduction

Optical glass is widely used in optical devices such as cameras, telescopes, and microscopes, and its refractive index is measured by the minimum deviation method (see ISO 21395-1) and the V-block refractometer method (see ISO 21395-2^[4]). Here, when designing an optical apparatus that requires high resolution, it is necessary to consider the temperature change of the refractive index of the optical glass in the usage environment, however up until now, there is no International Standard. In view of the above situation, this document proposes a method for measuring the temperature coefficient of refractive index of optical glass with high accuracy, aiming to help mutual understanding of measured value users and contribute to efficiency and fairness.

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Optics and photonics — Test method for temperature coefficient of refractive index of optical glasses —

Part 1: Minimum deviation method

1 Scope

This document specifies the measurement method used for calculating the temperature coefficient of the refractive index by measuring the refractive index, which changes with the temperature of the optical glass using the minimum deviation method.

The intended temperature range for the specified measurement method is -40 °C to $+80\text{ °C}$.

The intended wavelength range for the specified measurement method is 365 nm to 1 014 nm.

The intended accuracy for the specified measurement method is $1 \times 10^{-6}\text{ K}^{-1}$.

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 21395-1:2020, *Optics and photonics — Test method for refractive index of optical glasses — Part 1: Minimum deviation method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology 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/>

3.1

temperature coefficient of refractive index

ratio of refractive index change to temperature change at a selected wavelength

Note 1 to entry: Similar to ISO 9802^[2].

3.2

temperature coefficient of absolute refractive index

$\Delta n_{\text{abs}}/\Delta T$

ratio of refractive index change in vacuum to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022^[2], 3.4.2.3]

3.3 temperature coefficient of relative refractive index

$$\Delta n_{rel}/\Delta T$$

ratio of refractive index change at an air pressure of $1,013\ 3 \times 10^5$ Pa and a relative humidity of 0 % to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[2], 3.4.2.4, modified — $1,013\ 3 \times 10^5$ Pa and a relative humidity of 0 %.]

Note 1 to entry: This definition of $\Delta n_{rel}/\Delta T$ is for a specific pressure and humidity. $\Delta n_{rel}/\Delta T$ can be calculated for any other pressure and humidity by understanding the index of air in those conditions.

3.4 thermal chamber

chamber where the temperature of the specimen can be changed and maintained to a preset temperature

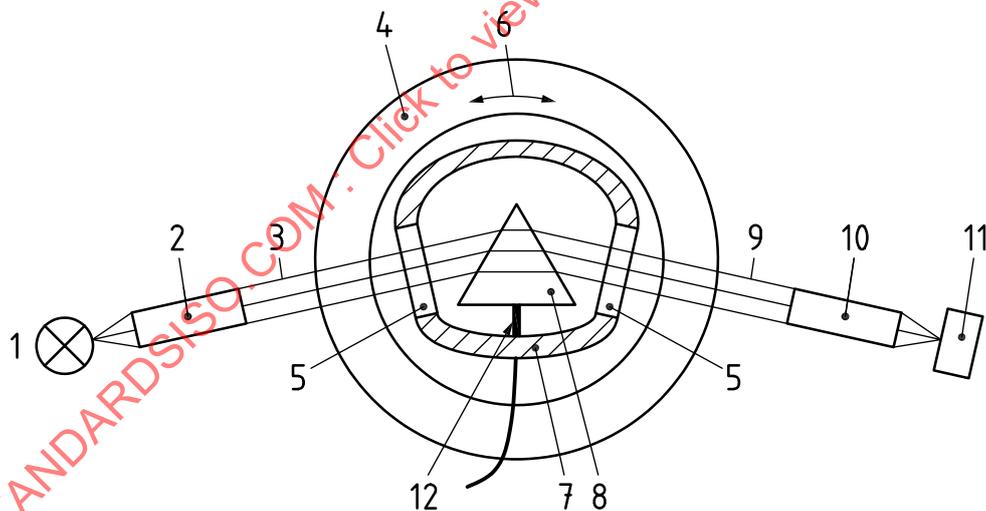
4 Principle

As shown in [Figure 1](#), a specimen prism is placed in a thermal chamber. The temperature of the specimen prism is changed from T_1 to T_2 or from T_2 to T_1 , and the refractive index of the specimen prism is measured at the temperatures of T_1 and T_2 respectively, in accordance with the method described in ISO 21395-1 to find the temperature coefficient of refractive index. [Figure 2](#) shows the concept of calculating this temperature coefficient of refractive index.

NOTE 1 In this document the term “light” is used to describe not only optical radiation visible to the human eye but also radiation in the infrared and ultraviolet spectrum.

NOTE 2 In this document, all temperature symbols are represented by “T”. The original symbol for temperature in ISO 80000-5 is “t” or “θ” for temperature in Celsius degrees, and “T” for absolute temperature.

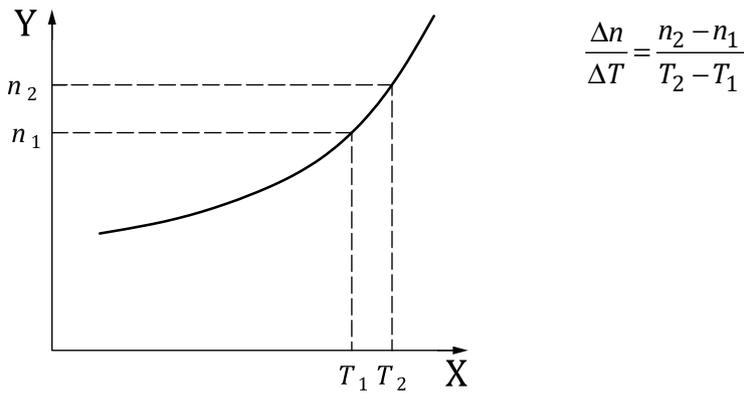
NOTE 3 Alternatively the measurement principle according to [Annex C](#) can be applied.



Key

- | | |
|--|---|
| 1 light source | 7 thermal chamber containing the specimen prism |
| 2 collimator | 8 specimen prism |
| 3 incident light | 9 transmitted light |
| 4 goniometer containing the telescope and detector | 10 telescope |
| 5 window | 11 detector |
| 6 rotating stage containing the thermal chamber | 12 thermometer |

Figure 1 — Measurement set-up with thermal chamber

**Key**

X	temperature
Y	refractive index
T_1, T_2	temperature of specimen prism
n_1	refractive index of specimen prism at temperature T_1
n_2	refractive index of specimen prism at temperature T_2

Figure 2 — Conceptual diagram for calculation of temperature coefficient of refractive index

5 Measuring apparatus

5.1 Goniometer

The goniometer shall be in accordance with ISO 21395-1:2020, 5.2.

5.2 Light source

The light source shall be in accordance with ISO 21395-1:2020, 5.3.

5.3 Detector

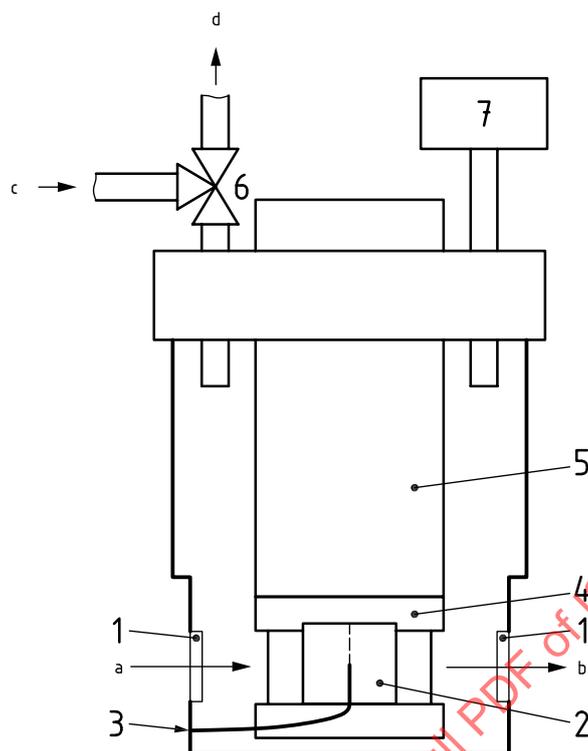
The detector shall be in accordance with ISO 21395-1:2020, 5.4.

5.4 Thermal chamber

The thermal chamber shall follow the requirements below. An example of a thermal chamber is shown in [Figure 3](#). The thermal chamber shall

- have the ability to change the temperature of the specimen prism between the temperatures to be measured,
- have a structure that can maintain the temperature distribution in the specimen within the range of 1,0 K during raising and lowering of the temperature,
- have a thermometer to measure the temperature of the specimen prism with an accuracy of $\pm 0,2$ K or better,
- have the ability to provide a vacuum with a residual pressure of less than 10 Pa for the purpose of having a negligible influence of the refractive index of air and of preventing condensation, and
- have windows made of a parallel plate of quartz glass polished on both sides. The wedge angle between the parallel polished faces shall not exceed 5 arc sec, the flatness of the parallel polished faces shall be $\lambda/10$ or better.

NOTE Quartz glass is used because it has a high transmittance over a wide wavelength range, a high durability against temperature changes, and is resistant to breakage.



Key

- | | | | |
|---|-----------------------------------|---|-----------------|
| 1 | window | 7 | vacuum gauge |
| 2 | specimen prism | a | Incident light. |
| 3 | thermometer | b | Outgoing light. |
| 4 | thermal conductor specimen holder | c | Leak inlet. |
| 5 | heating and cooling unit | d | To vacuum pump. |
| 6 | three-way valve | | |

Figure 3 — Example of thermal chamber

6 Specimen prism

The specimen prism shall be in accordance with ISO 21395-1:2020, Clause 6.

7 Measurement

7.1 Measurement of apex angle

The apex angle of the specimen prism shall be measured in accordance with ISO 21395-1:2020, 8.2.

7.2 Measurement of the angle of minimum deviation

The angle of minimum deviation of the specimen prism shall be measured at two or more temperatures in accordance with ISO 21395-1:2020, 8.3.

The bisector of the apex angle, α , is parallel to the bisector of the angle, β , formed by the opposite two-surface window of the thermal chamber. (See [Figure 4](#))

The degree of vacuum around the specimen prism shall be less than 10 Pa. The minimum deviation angle should be measured at a temperature within $\pm 0,5$ °C with respect to the target temperature.

NOTE 1 Allowable measurement error is an error in the measurement of the refractive index. When the allowable measurement error is smaller than $0,5 \times 10^{-6}$, the allowable angle difference between the bisectors of α and β is within 2° ; when the allowable measurement error is smaller than $0,5 \times 10^{-5}$, the allowable angle difference between the bisectors of α and β is within 6° .

NOTE 2 The temperature to be measured is arbitrary. Allow sufficient time for the specimen prism to reach a uniform temperature throughout. In most cases, the temperatures measured are -40 °C, -20 °C, 0 °C, 20 °C, 40 °C, 60 °C and 80 °C.

8 Calculation

8.1 Absolute refractive index

The absolute refractive index at each temperature of the specimen prism shall be calculated by [Formula \(1\)](#) (adaptation of ISO 21395-1:2020, Clause 4).

$$n_{\text{abs}}(T) = \frac{\sin\left[\frac{\alpha + \delta_{\text{min,vac}}(T)}{2}\right]}{\sin\left(\frac{\alpha}{2}\right)} \quad (1)$$

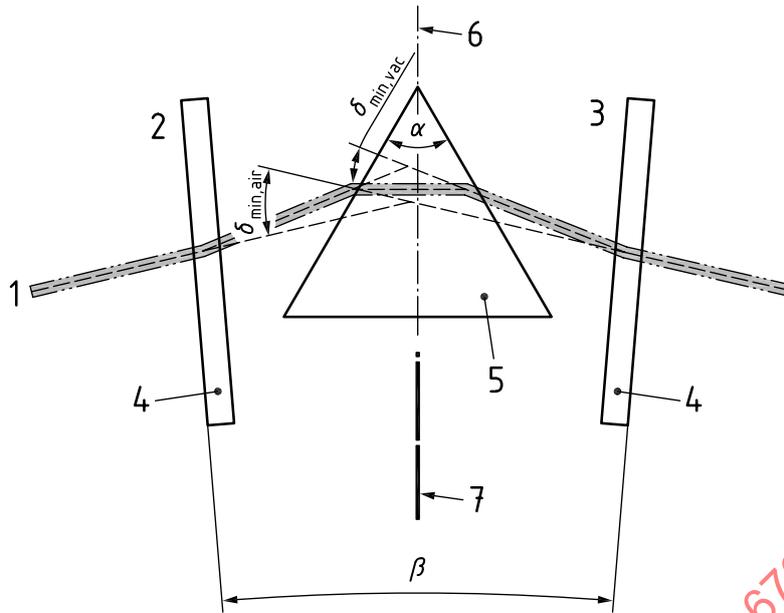
where

- $n_{\text{abs}}(T)$ is the absolute refractive index of specimen prism at temperature T ;
- α is the apex angle of the specimen prism;
- $\delta_{\text{min,vac}}(T)$ is the minimum deviation angle at temperature T ;
- T is the temperature (°C) of the specimen prism during the measurement (°C).

NOTE In ISO 21395-1 the measurements are performed in air, therefore the refractive index n obtained is the relative refractive index. In this document, the measurements are performed in vacuum, and therefore the result obtained by [Formula \(1\)](#) is the absolute refractive index.

[Figure 4](#) shows a schematic drawing of the light path through the thermal chamber windows and the specimen prism. The internal and external environments are air and vacuum respectively. As a consequence, light transmitted through a parallel window at non-normal incidence will be deflected.

Consequently the minimum angle of deflection in vacuum $\delta_{\text{min,vac}}$ must be calculated using the correction [Formula \(2\)](#) to the observed angle of minimum deflection in air $\delta_{\text{min,air}}$.



Key

- | | | | |
|---|------------------|------------|--|
| 1 | light beam | 6 | bisector of the specimen prism apex angle |
| 2 | air condition | 7 | bisector of angle formed by the opposite two-surface window of thermal chamber |
| 3 | vacuum condition | α | apex angle |
| 4 | window | β | angle formed by the opposite two-surface window of thermal chamber |
| 5 | specimen prism | δ_1 | $\delta_{\min,air}$ apparent minimum deviation angle in air |
| | | δ_2 | $\delta_{\min,vac}$ minimum deviation angle in vacuum |

Figure 4 — Schematic drawing of light path through, input window, prism and output window

The angle of minimum deflection in vacuum $\delta_{\min,vac}$ shall be calculated from the observed angle of minimum deflection in air $\delta_{\min,air}$ using [Formula \(2\)](#).

$$\delta_{\min,vac} = 2 \times \arcsin \left[n_{air} \times \sin \left(\frac{\delta_{\min,air}}{2} - \frac{\beta}{2} \right) \right] + \beta \quad (2)$$

where

n_{air} is the refractive index of air;

$\delta_{\min,vac}$ is the minimum deviation angle in vacuum;

$\delta_{\min,air}$ is the apparent minimum deviation angle in air;

β is the angle formed by the opposite two-surface window of the thermal chamber.

8.2 Temperature coefficient of absolute refractive index

The temperature coefficient of the absolute refractive index between the temperatures of specimen prism T_1 and T_2 shall be calculated by [Formula \(3\)](#).

$$\frac{\Delta n_{abs}}{\Delta T} = \frac{n_{abs}(T_2) - n_{abs}(T_1)}{T_2 - T_1} \quad (3)$$

where

- $\frac{\Delta n_{\text{abs}}}{\Delta T}$ is the temperature coefficient (K^{-1}) of absolute refractive index of the specimen prism;
- $n_{\text{abs}}(T_1), n_{\text{abs}}(T_2)$ is the absolute refractive index of the specimen prism at temperature T_1, T_2 ;
- T_1, T_2 are the temperatures of the specimen prism ($^{\circ}\text{C}$).

NOTE 1 T_1, T_2 and $T_2 - T_1$ (ΔT) are arbitrary. In most cases T_1 and T_2 are the temperatures at 6 points shown in 7.2, and ΔT is 20 K.

NOTE 2 Alternatively, the absolute temperature coefficient of the absolute refractive index can be calculated using Formula (D.3).

8.3 Temperature coefficient of relative refractive index

The temperature coefficient of the relative refractive index of the specimen prism between the temperatures T_1 and T_2 shall be calculated by Formula (4).

For the calculation of the temperature coefficient of the relative refractive index of the specimen, the temperature coefficient of the refractive index of air at a pressure of $1,013\,25 \times 10^5$ Pa a relative humidity of 0 % and the individual temperatures T_1 and T_2 should be used.

Temperature coefficients of relative refractive index for a number of well-known spectral wavelength lines are shown in Table 1. For additional wavelengths, the temperature coefficient of relative refractive index can be calculated using the refractive index of air, obtained by Formula (A.1).

NOTE 1 Formula (4) is an approximation. The derivation and a proof that the approximation is of negligible influence is given in Annex E.

NOTE 2 The calculation method for determining the relative refractive index of glass at any given temperature, pressure, and relative humidity is shown in Annex B.

$$\frac{\Delta n_{\text{rel}}}{\Delta T} = \frac{\Delta n_{\text{abs}}}{\Delta T} - \frac{n_{\text{abs}}(T_1) + n_{\text{abs}}(T_2)}{2} + \frac{\Delta n_{\text{air}}}{\Delta T} \quad (4)$$

where

- $\frac{\Delta n_{\text{rel}}}{\Delta T}$ is the temperature coefficient (K^{-1}) of relative refractive index of the specimen prism;
- $\frac{\Delta n_{\text{abs}}}{\Delta T}$ is the temperature coefficient (K^{-1}) of absolute refractive index of the specimen prism;
- $\frac{\Delta n_{\text{air}}}{\Delta T}$ is the temperature coefficient (K^{-1}) of refractive index of air.

Table 1 — Temperature coefficient of refractive index of air (air pressure $1,013\,25 \times 10^5$ Pa, relative humidity 0 %)

Spectral line	Wavelength nm	$\Delta n_{\text{air}}/\Delta T(10^{-6}/\text{K})$ in the temperature range of					
		-40 °C to 20 °C	-20 °C to 0 °C	0 °C to 20 °C	20 °C to 40 °C	40 °C to 60 °C	60 °C to 80 °C
i	365,01	-1,40	-1,19	-1,03	-0,90	-0,79	-0,70
h	404,66	-1,38	-1,18	-1,02	-0,89	-0,78	-0,69
g	435,83	-1,38	-1,17	-1,01	-0,89	-0,78	-0,69
F'	479,99	-1,37	-1,17	-1,01	-0,88	-0,77	-0,69
F	486,13	-1,37	-1,17	-1,01	-0,88	-0,77	-0,69

Table 1 (continued)

Spectral line	Wavelength nm	$\Delta n_{\text{air}}/\Delta T(10^{-6}/\text{K})$ in the temperature range of					
		-40 °C to 20 °C	-20 °C to 0 °C	0 °C to 20 °C	20 °C to 40 °C	40 °C to 60 °C	60 °C to 80 °C
e	546,07	-1,36	-1,16	-1,00	-0,88	-0,77	-0,68
d	587,56	-1,36	-1,16	-1,00	-0,87	-0,77	-0,68
He-Ne	632,8	-1,35	-1,16	-1,00	-0,87	-0,77	-0,68
C'	643,85	-1,35	-1,16	-1,00	-0,87	-0,77	-0,68
C	656,27	-1,35	-1,15	-1,00	-0,87	-0,77	-0,68
r	706,52	-1,35	-1,15	-1,00	-0,87	-0,76	-0,68
t	1 013,98	-1,34	-1,15	-0,99	-0,86	-0,76	-0,67

9 How to express the temperature coefficient of refractive index

The temperature coefficient of the absolute refractive index and that of the relative refractive index as calculated in 8.2 and 8.3 shall be rounded to 1 decimal place in the unit of 10^{-6} K^{-1} . An example is shown in Table 2.

Table 2 — Example of how to express the temperature coefficient of refractive index

Spectral line	Wavelength nm	$\Delta n/\Delta T(10^{-6}/\text{K})$ in the temperature range of					
		-40 °C to -20 °C	-20 °C to 0 °C	0 °C to 20 °C	20 °C to 40 °C	40 °C to 60 °C	60 °C to 80 °C
d	587,56	3,8	3,8	3,9	4,0	4,1	4,2

10 Test report

The test report shall include following items:

- method used (minimum deviation);
- a reference to this document, e.g. ISO 6760-1:2024;
- melt number, lot number or alternative means of indicating the specific test sample;
- date of measurement;
- the temperature coefficient of absolute refractive index obtained by calculation;
- the temperature coefficient of relative refractive index obtained by calculation;
- any deviations from the procedure;
- any unusual features observed.

Annex A (informative)

Formula for calculating the refractive index of air

The refractive index of air can be obtained from [Formulae \(A.1\) to \(A.7\)](#) based on the formulae shown in References [\[6\]](#) and [\[7\]](#). Using the following [Formulae \(A.1\) to \(A.7\)](#), the refractive index of air can be determined with the precision required for this specification in the wavelength range of 300 nm to 1,700 nm, temperature range of -40 °C to 100 °C, air pressure range of 10 kPa to 140 kPa, and relative humidity range of 0 % to 100 %.

NOTE 1 The formula shown in Reference [\[6\]](#) is the Edlén formula.

NOTE 2 The formula shown in Reference [\[1\]](#) describes the term related to the relative humidity in a non-temperature-dependent format. [Formulae \(A.1\) to \(A.7\)](#) represent modifications to the term related to relative humidity of the shown in Reference [\[1\]](#) to improve calculation accuracy over a wide temperature range.

NOTE 3 This value can also be calculated using the Ciddor formula as per Reference [\[7\]](#).

$$n_{\text{air}} = n(T, p, h) - 10^{-10} \times \frac{292,75}{t + 273,15} \times (3,7345 - 0,0401 \times S) \times p_V \quad (\text{A.1})$$

$$n(T, p, h) = 1 + \frac{p(n_s - 1)X}{D} \quad (\text{A.2})$$

$$n_s = 1 + 10^{-8} \left(A + \frac{B}{130 - S} + \frac{C}{38,9 - S} \right) \quad (\text{A.3})$$

$$X = \frac{1 + 10^{-8} (E - F \times t)p}{1 + G \times T} \quad (\text{A.4})$$

$$S = \frac{1}{\lambda^2} \quad (\text{A.5})$$

$$p_V = h \times p_{\text{sv}} \quad (\text{A.6})$$

$$p_{\text{sv}} = 6,112 \times 10^2 \times \exp\left(\frac{17,62 \times T}{243,12 + T}\right) \quad (\text{A.7})$$

where

n_{air} is the refractive index of air at temperature, T , air pressure, p , and relative humidity (P_V/P_{SV}) %;

p_V is the vapour partial pressure (Pa);

$n(T, p, h)$ is the refractive index of air at temperature, T , air pressure is p , and relative humidity, h ;

T is the temperature (°C);

p is the air pressure (Pa);

S is $1/\lambda^2$ (μm^{-2});

λ is the wavelength of light in vacuum (μm);

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h	is the relative humidity of air (%);
p_{sv}	is the saturated water vapour pressure of air at temperature t (Pa);
A	= 8 342,54
B	= 2 406 147
C	= 15 998
D	= 96 095,43
E	= 0,601
F	= 0,009 72
G	= 0,003 661

As an example, [Table A.1](#) shows the refractive index values of air in the representative spectral lines calculated by the actual values in these formulae.

Table A.1 — Refractive index of air (air pressure $1,013\ 25 \times 10^5$ Pa, relative humidity 0 %)

Spectral wavelength nm	Temperature						
	-40 °C	-20 °C	0 °C	20 °C	40 °C	60 °C	80 °C
i 365,01	1,000 352 35	1,000 324 45	1,000 300 63	1,000 280 07	1,000 262 13	1,000 246 34	1,000 232 35
h 404,66	1,000 349 34	1,000 321 68	1,000 298 07	1,000 277 68	1,000 259 89	1,000 244 24	1,000 230 36
g 435,83	1,000 347 57	1,000 320 05	1,000 296 55	1,000 276 27	1,000 258 57	1,000 243 00	1,000 229 19
F' 479,99	1,000 345 66	1,000 318 29	1,000 294 92	1,000 274 75	1,000 257 15	1,000 241 67	1,000 227 93
F 486,13	1,000 345 44	1,000 318 08	1,000 294 73	1,000 274 57	1,000 256 98	1,000 241 51	1,000 227 79
e 546,07	1,000 343 66	1,000 316 44	1,000 293 22	1,000 273 16	1,000 255 66	1,000 240 27	1,000 226 61
d 587,56	1,000 342 74	1,000 315 60	1,000 292 43	1,000 272 43	1,000 254 98	1,000 239 63	1,000 226 01
He-Ne 632,8	1,000 341 95	1,000 314 87	1,000 291 76	1,000 271 80	1,000 254 39	1,000 239 07	1,000 225 49
C' 643,85	1,000 341 78	1,000 314 72	1,000 291 61	1,000 271 67	1,000 254 27	1,000 238 95	1,000 225 38
C 656,27	1,000 341 60	1,000 314 55	1,000 291 46	1,000 271 52	1,000 254 13	1,000 238 83	1,000 225 26
r 706,52	1,000 340 98	1,000 313 97	1,000 290 93	1,000 271 03	1,000 253 67	1,000 238 39	1,000 224 85
t 1 013,98	1,000 338 97	1,000 312 13	1,000 289 22	1,000 269 44	1,000 252 18	1,000 236 99	1,000 223 53

Annex B (informative)

Calculation method for obtaining the relative refractive index of glass at an arbitrary temperature, air pressure and relative humidity

B.1 General

Since the refractive index of air depends on temperature, air pressure, and humidity, the value of the relative refractive index of optical glass in air varies depending on these environmental conditions. In ISO 21395-1, the desirable relative humidity of the measurement condition is 50 % to 65 % and the relative refractive index is often reported under this environment. However, in this document, the relative humidity of air in the determination of the temperature coefficient of relative refractive index was set at 0 %. This is to unify the environmental conditions across all temperature ranges. Because the saturated vapour pressure varies with temperature, the same relative humidity cannot be achieved over the entire temperature range if the relative humidity is not 0 % unless the amount of vapour in the air is intentionally adjusted. The calculation method when the user obtains the relative refractive index for air at an arbitrary temperature, air pressure and relative humidity is as follows. When the relative refractive index $n_{\text{rel}}(T_1, p_1, h_1)$ at temperature T_1 , air pressure p_1 and relative humidity h_1 is known, the relative refractive index $n_{\text{rel}}(T_2, p_2, h_2)$ at temperature T_2 , air pressure p_2 and relative humidity h_2 is calculated.

B.2 If a temperature coefficient of absolute refractive index is given

Calculate the refractive index of air $n_{\text{air}}(T_1, p_1, h_1)$ with reference to A.1 and determine the absolute refractive index $n_{\text{abs}}(T_1)$ at temperature T_1 from $n_{\text{rel}}(T_1, p_1, h_1)$. Determine the absolute refractive index $n_{\text{abs}}(T_2)$ at temperature T_2 using the temperature coefficient for the absolute refractive index. Then, calculate the refractive index of air $n_{\text{air}}(T_2, p_2, h_2)$ to obtain $n_{\text{rel}}(T_2, p_2, h_2)$.

$$\begin{aligned} n_{\text{rel}}(T_2, p_2, h_2) &= \frac{n_{\text{abs}}(T_2)}{n_{\text{air}}(T_2, p_2, h_2)} = \frac{1}{n_{\text{air}}(T_2, p_2, h_2)} \left\{ n_{\text{abs}}(T_1) + (T_2 - T_1) \frac{\Delta n_{\text{abs}}}{\Delta T} \right\} \\ &= \frac{1}{n_{\text{air}}(T_2, p_2, h_2)} \left\{ n_{\text{rel}}(T_1, p_1, h_1) \times n_{\text{air}}(T_1, p_1, h_1) + (T_2 - T_1) \frac{\Delta n_{\text{abs}}}{\Delta T} \right\} \end{aligned} \quad (\text{B.1})$$

B.3 If a temperature coefficient of relative refractive index is given

Calculate the refractive index of air $n_{\text{air}}(T_1, p_1, h_1)$ and refractive index of dry air at standard atmosphere $n_{\text{air}}(T_1, p_0, 0)$ with reference to A.1 and determine the relative refractive index corresponding to dry air at standard atmosphere $n_{\text{rel}}(T_1, p_0, 0)$ at temperature T_1 from $n_{\text{rel}}(T_1, p_1, h_1)$. Determine the relative refractive index for dry air at standard atmosphere $n_{\text{rel}}(T_2, p_0, 0)$ at temperature T_2 using the temperature coefficient of relative refractive index. Then, calculate the refractive index of air $n_{\text{air}}(T_2, p_2, h_2)$ and refractive index of dry air at standard atmosphere $n_{\text{air}}(T_2, p_0, 0)$ to obtain $n_{\text{rel}}(T_2, p_2, h_2)$.

$$\begin{aligned} n_{\text{rel}}(T_2, p_2, h_2) &= \frac{n_{\text{rel}}(T_2, p_0, 0) \times n_{\text{air}}(T_2, p_0, 0)}{n_{\text{air}}(T_2, p_2, h_2)} \\ &= \frac{n_{\text{air}}(T_2, p_0, 0)}{n_{\text{air}}(T_2, p_2, h_2)} \left\{ n_{\text{rel}}(T_1, p_0, 0) + (T_2 - T_1) \frac{\Delta n_{\text{rel}}}{\Delta T} \right\} \\ &= \frac{n_{\text{air}}(T_2, p_0, 0)}{n_{\text{air}}(T_2, p_2, h_2)} \left\{ \frac{n_{\text{rel}}(T_1, p_1, h_1) \times n_{\text{air}}(T_1, p_1, h_1)}{n_{\text{air}}(T_1, p_0, 0)} + (T_2 - T_1) \frac{\Delta n_{\text{rel}}}{\Delta T} \right\} \end{aligned} \quad (\text{B.2})$$

In both cases of (B.1) and (B.2), when t_1 and t_2 are not within the same temperature range ΔT in which the temperature coefficient of refractive index is given, calculate the temperature coefficient of refractive index

$\frac{\Delta n_{\text{abs}}}{\Delta T}$ or $\frac{\Delta n_{\text{rel}}}{\Delta T}$ from the temperature range including T_1 to T_2 using the value obtained by integrating the coefficient of each temperature range according to the temperature width within the temperature range. For example, if $T_1 < T_c < T_2$ when the temperature coefficient of the refractive index changes at T_c between t_1 and t_2 , substitute the term related to the temperature coefficient of refractive index $(T_2 - T_1) \frac{\Delta n_{\text{abs}}}{\Delta T}$ in (B.1) with:

$$(T_2 - T_c) \left(\frac{\Delta n_{\text{abs}}}{\Delta T} \right)_{T_c, T_2} + (T_c - T_1) \left(\frac{\Delta n_{\text{abs}}}{\Delta T} \right)_{T_1, T_c}$$

and the term related to the temperature coefficient of refractive index $(T_2 - T_1) \frac{\Delta n_{\text{rel}}}{\Delta T}$ in (B.2) with respectively:

$$(T_2 - T_c) \left(\frac{\Delta n_{\text{rel}}}{\Delta T} \right)_{T_c, T_2} + (t_c - t_1) \left(\frac{\Delta n_{\text{rel}}}{\Delta T} \right)_{T_1, T_c}$$

where

$\left(\frac{\Delta n_{\text{abs}}}{\Delta T} \right)_{T_c, T_2}$	is temperature coefficient of absolute refractive index over the temperature range including T_2 °C;
$\left(\frac{\Delta n_{\text{abs}}}{\Delta T} \right)_{T_1, T_c}$	is temperature coefficient of absolute refractive index over the temperature range including T_1 °C;
$\left(\frac{\Delta n_{\text{rel}}}{\Delta T} \right)_{T_c, T_2}$	is temperature coefficient of relative refractive index over the temperature range including T_2 °C;
$\left(\frac{\Delta n_{\text{rel}}}{\Delta T} \right)_{T_1, T_c}$	is temperature coefficient of relative refractive index over the temperature range including T_1 °C.

If there are multiple temperature ranges in which the temperature coefficient of refractive index is given between T_1 and T_2 , calculate in the same manner.

NOTE For "standard atmosphere", refer to ISO 2533^[1].

Annex C (informative)

Half prism method

C.1 General

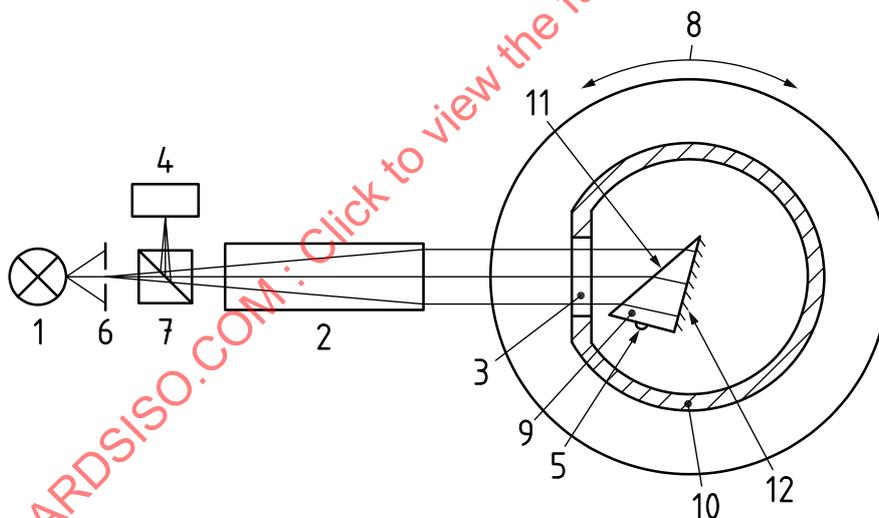
In order to have a simpler thermal chamber than described in [Clause 4](#) and [5.4](#), the half prism method may be employed likewise.

C.2 Principle

In the case of minimum deflection, the light beam passes the specimen prism perpendicular to the apex bisector as illustrated in [Figure 4](#).

For the measurement of the half prism method, a prism similar to the specimen prism of ISO 21395-1 is used. But, it is cut in half along the apex bisector, and the surface comprising the bisector is covered with a reflective coating, e.g., Silver.

When the prism is rotated to the minimum deviation position, the incident light to the prism and the outgoing light from the prism pass through the same path.



Key

1	light source	7	beam splitter
2	collimator	8	goniometer containing the specimen prism (9)
3	window	9	specimen prism
4	detector	10	thermal chamber
5	thermometer	11	incident surface
6	slit	12	reflective surface

Figure C.1 — Schema of measurement device with thermal chamber

C.3 Principle

C.3.1 Goniometer

The goniometer shall be in accordance with [5.1](#).

C.3.2 Light source

The light source shall be in accordance with [5.2](#).

C.3.3 Detector

The detector shall be in accordance with [5.3](#).

C.3.4 Thermal chamber

The thermal chamber shall be in accordance with [5.4](#), subclause a) to e).

Additionally,

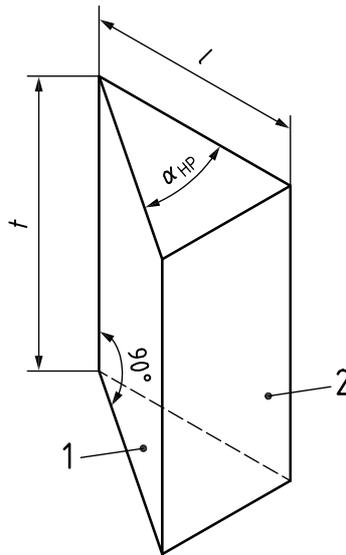
- a) The thermal chamber shall include a vacuum-sealed rotary feedthrough coupling to rotate the goniometer, 8, with the specimen prism, 9, on it.
- b) Alternatively, the thermal chamber can be filled with a dry gas at a pressure close to the ambient air pressure. In this case, it is not necessary that the rotary feedthrough mentioned in a) is vacuum sealed.

C.4 Specimen prism

C.4.1 General

An example of the shape of the specimen prism is shown in [Figure C.2](#). The reflective back surface shall be coated with a reflective coating, e.g., Silver.

NOTE The measurement is possible even without a metallic coating on the reflective surface.



Key

l	length	1	incident surface
t	thickness	2	reflective surface
α_{HP}	apex angle		

Figure C.2 — Shape of the specimen prism

C.4.2 Dimensions

The dimensions shall be in accordance with ISO 21395-1:2020, 6.2.

C.4.3 Apex angle

The apex angle α_{HP} is a function of the refractive index and the angle of incidence θ .

$$\alpha_{HP} = \arcsin\left[\frac{\sin(\theta)}{n}\right] \tag{C.1}$$

α_{HP} is typically between 17° and 40°.

C.4.4 Flatness

The flatness shall be in accordance with ISO 21395-1:2020, 6.4.

C.5 Measurement

C.5.1 Measurement of apex angle

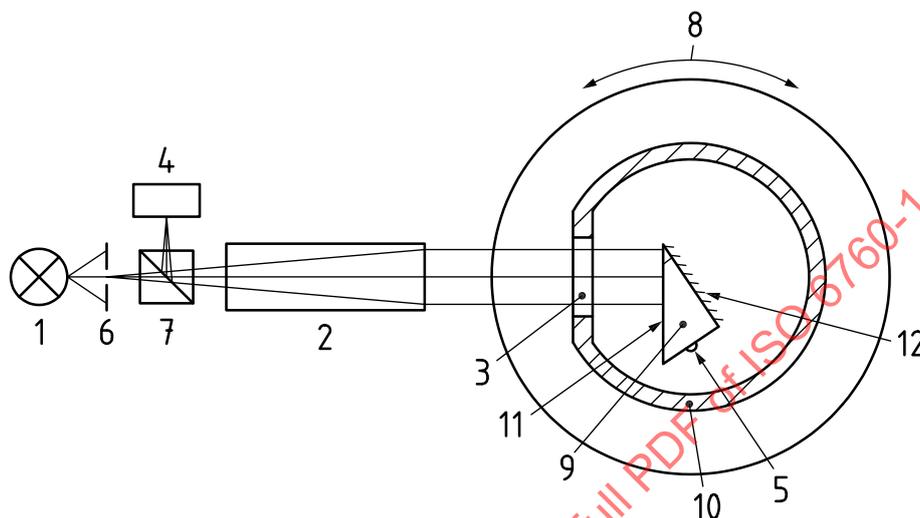
The apex angle of the specimen prism shall be measured in accordance with 7.1.

NOTE As the reflection coefficients of the incident surface (11) and the reflective surface (12) are very different, it might be necessary to take care that the light flux to the detector (4) is within the operating range for the detector (4). Depending on the type of the light source (1) it might be possible to regulate the intensity of the light source. If attenuator elements, e.g. neutral density glass filters, are used, they should be placed between the light source (1) and the slit (6) in order not to distort the imaging part of the beam path. If a camera is used as detector (4), experience shows that in most cases it is sufficient to adapt the shutter time of the camera.

C.5.2 Measurement of the angle of minimum deviation

The angle of minimum deviation shall be obtained by the difference of two readings from the goniometer, 26:

- Reading 1 is obtained when the prism is in auto collimation position for the reflected light from the incident surface, 11, as illustrated in [Figure C.3](#)
- Reading 2 is obtained when the prism is in auto collimation position for the refracted light at the desired wavelength. This light is reflected light from the reflective surface, 12, of the specimen prism as illustrated in [Figure C.1](#).



Key

- | | | | |
|---|--------------|----|--|
| 1 | light source | 7 | beam splitter |
| 2 | collimator | 8 | goniometer containing the specimen prism (9) |
| 3 | window | 9 | specimen prism |
| 4 | detector | 10 | thermal chamber |
| 5 | thermometer | 11 | incident surface |
| 6 | slit | 12 | reflective surface |

Figure C.3 — Measurement device, specimen prism in auto collimation position for reflection from incident surface

C.6 Calculation

C.6.1 Absolute refractive index

- calculate the angle of incidence θ as the difference between Reading 1 and Reading 2.
- calculate the absolute refractive index

$$n_{\text{abs}}(T, \lambda) = n_m(T, \lambda) = \frac{\sin[\theta(T, \lambda)]}{\sin(\alpha_{\text{HP}})} \tag{C.2}$$

In the case the atmosphere around the specimen prism is dry air:

- calculate the relative refractive index

$$n_{\text{rel}}(T, \lambda, p) = n_m(T, \lambda, p) = \frac{\sin[\theta(T, \lambda)]}{\sin(\alpha_{\text{HP}})} \tag{C.3}$$

- calculate the refractive index $n_{\text{air}}(T, \lambda, p)$ as described in [Annex A](#)
- calculate the absolute refractive index

$$n_{\text{abs}}(T, \lambda) = n_{\text{rel}}(T, \lambda, p) \times n_{\text{air}}(T, \lambda, p) \quad (\text{C.4})$$

where

- $\Delta n_{\text{abs}}(T, \lambda)$ is the absolute refractive index of specimen prism at temperature T and wavelength λ ;
- $n_{\text{m}}(T, \lambda)$ is the absolute refractive index measured at temperature T and wavelength λ ;
- $n_{\text{rel}}(T, \lambda, p)$ is the relative refractive index measured at temperature T , wavelength λ and air pressure P ;
- $n_{\text{air}}(T, \lambda, p)$ is the refractive index of air at temperature T , wavelength λ and air pressure P ;
- $\theta(T, \lambda)$ is the angle of incidence at temperature T and wavelength λ ;
- α_{HP} is the apex angle of the specimen prism;
- T is the measurement specimen prism temperature (°C);
- p is the measurement air pressure in the thermal chamber (Pa);
- λ is the wavelength of the observed light.

C.6.2 Temperature coefficient of the refractive index

The temperature coefficients of the absolute and the relative refractive index shall be calculated in accordance with [8.2](#) and [8.3](#).

The temperature coefficient of the refractive index shall be expressed in accordance with [Clause 9](#).

The test report shall be created in accordance with [Clause 10](#).

Annex D (informative)

Interpolation formula for $\Delta n/\Delta T$

A formula describing the temperature coefficient of absolute refractive index as a function of temperature and wavelength can easily be derived from the formula given in ISO 12123:2018^[3], A.3:

$$\Delta n_{\text{abs}}(\lambda, T) = \frac{n_{\text{abs}}^2(\lambda, T_0) - 1}{2 \times n_{\text{abs}}(\lambda, T_0)} \times \left[D_0 \Delta T + D_1 \Delta T^2 + D_2 \Delta T^3 + \frac{E_0 \Delta T + E_1 \Delta T^2}{\lambda^2 - \lambda_{\text{TK}}^2} \right] \quad (\text{D.1})$$

with

$$\Delta T = T - T_0 \quad (\text{D.2})$$

Dividing by ΔT yields

$$\frac{\Delta n_{\text{abs}}(\lambda, T)}{\Delta T} = \frac{n_{\text{abs}}^2(\lambda, T_0) - 1}{2 \times n_{\text{abs}}(\lambda, T_0)} \times \left[D_0 + D_1 \Delta T + D_2 \Delta T^2 + \frac{E_0 + E_1 \Delta T}{\lambda^2 - \lambda_{\text{TK}}^2} \right] \quad (\text{D.3})$$

where

$\Delta n_{\text{abs}}(\lambda, T)$ is the change of absolute refractive index at wavelength λ between a specific temperature T and the standard temperature T_0 ;

D_0, D_1, D_2
 E_0, E_1
 λ_{TK} are glass type specific constants;

T_0 is standard temperature 20 °C.

In order to reduce statistical errors of $\Delta n/\Delta T$ values, one can proceed as follows:

- measure refractive indices at various temperatures and wavelengths
- create value triplets $\lambda, \Delta T, \Delta n_{\text{abs}}$
- determine the glass type specific constants $D_0 \sim \lambda_{\text{TK}}$ by an approximation method

NOTE In case multiple measurements at several spectral lines and several temperatures have been carried out, the glass type specific constants $D_0, D_1, D_2, E_0, E_1, \lambda_{\text{TK}}$ can be calculated for best approximation of the measurement results. The absolute temperature coefficient of the absolute refractive index can be calculated using [Formula \(D.3\)](#).