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Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere

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Swedish Standards corresponding to documents referred to in this Standard are listed in ”Catalogue of Swedish Standards”, annually issued by SIS. The Catalogue lists, with reference number and year of Swedish approval, International and European Standards approved as Swedish Standards as well as other Swedish Standards.

Akustik – Dämpning av ljud under utbredning utomhus – Del 1: Beräkning av atmosfärens ljudabsorption

Den internationella standarden ISO 9613-1:1993 gäller som svensk standard. Detta dokument innehåller den officiella engelska versionen av ISO 9613:1993.

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Acoustics — Attenuation of sound during propagation outdoors —

Part 1:
Calculation of the absorption of sound by the atmosphere

Acoustique — Attenuation du son lors de sa propagation à l'air libre —
Partie 1: Calcul de l'absorption atmosphérique

Reference number
ISO 9613-1:1993(E)

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.

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

International Standard ISO 9613-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Sub-Committee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors*:

- *Part 1: Calculation of the absorption of sound by the atmosphere*
- *Part 2: A general method of calculation*

Annexes A, B, C, D, E and F of this part of ISO 9613 are for information only.

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Introduction

The aim of this International Standard is to specify methods of calculating the attenuation of sound propagating outdoors in order to predict the level of environmental noise at distant locations from various sound sources.

Acoustics — Attenuation of sound during propagation outdoors —

Part 1:
Calculation of the absorption of sound by the atmosphere

1 Scope

This part of ISO 9613 specifies an analytical method of calculating the attenuation of sound as a result of atmospheric absorption for a variety of meteorological conditions when the sound from any source propagates through the atmosphere outdoors.

For pure-tone sounds, attenuation due to atmospheric absorption is specified in terms of an attenuation coefficient as a function of four variables: the frequency of the sound, and the temperature, humidity and pressure of the air. Computed attenuation coefficients are provided in tabular form for ranges of the variables commonly encountered in the prediction of outdoor sound propagation:

- frequency from 50 Hz to 10 kHz,
- temperature from −20 °C to +50 °C,
- relative humidity from 10 % to 100 %, and
- pressure of 101,325 kPa (one atmosphere).

Formulae are also provided for wider ranges suitable for particular uses, for example, at ultrasonic frequencies for acoustical scale modelling, and at lower pressures for propagation from high altitudes to the ground.

For wideband sounds analysed by fractional-octave band filters (e.g. one-third-octave band filters), a method is specified for calculating the attenuation due to atmospheric absorption from that specified for pure-tone sounds at the midband frequencies. An alternative spectrum-integration method is described in annex D. The spectrum of the sound may be wideband with no significant discrete-frequency components or it may be a combination of wideband and discrete frequency sounds.

This part of ISO 9613 applies to an atmosphere with uniform meteorological conditions. It may also be used to determine adjustments to be applied to measured sound pressure levels to account for differences between atmospheric absorption losses under different meteorological conditions. Extension of the method to inhomogeneous atmospheres is considered in annex C, in particular to meteorological conditions that vary with height above the ground.

This part of ISO 9613 accounts for the principal absorption mechanisms present in an atmosphere devoid of significant fog or atmospheric pollutants. The calculation of sound attenuation by mechanisms other than atmospheric absorption, such as refraction or ground reflection, is described in ISO 9613-2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2533:1975, *Standard Atmosphere.*

ISO 266:1975, *Acoustics — Preferred frequencies for measurements.*

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

3 Symbols

f	frequency of the sound, in hertz
f_m	midband frequency, in hertz
h	molar concentration of water vapour, as a percentage
p_r	reference ambient atmospheric pressure, in kilopascals
p_i	initial sound pressure amplitude, in pascals
p_t	sound pressure amplitude, in pascals
p_0	reference sound pressure amplitude (20 µPa)
p_a	ambient atmospheric pressure, in kilopascals
s	distance, in metres, through which the sound propagates
T	ambient atmospheric temperature, in kelvins
T_0	reference air temperature, in kelvins
α	pure-tone sound attenuation coefficient, in decibels per metre, for atmospheric absorption

NOTE 1 For convenience, in this part of ISO 9613, the shortened term "attenuation coefficient" will be used for α in place of the full description.

δL_t	attenuation due to atmospheric absorption, in decibels

4 Reference atmospheric conditions

4.1 Composition

Atmospheric absorption is sensitive to the composition of the air, particularly to the widely varying concentration of water vapour. For clean, dry air at sea level, the standard molar concentrations, or fractional volumes of the three principal, normally fixed, constituents of nitrogen, oxygen and carbon dioxide are: 0,780 84; 0,209 476; and 0,000 314, respectively (taken from ISO 2533). For dry air, other minor trace constituents, which have no significant influence on atmospheric absorption, make up the remaining fraction of 0,009 37. For atmospheric absorption calculations, the standard molar concentrations of the three principal constituents of dry air may be assumed to hold for altitudes up to at least 50 km above mean sea level. However, the molar concentration of water vapour, which has a major influence on atmospheric absorption, varies widely near the ground and by over two orders of magnitude from sea level to 10 km.

4.2 Atmospheric pressure and temperature

For the purposes of this part of ISO 9613, the reference ambient atmospheric pressure, p_r, is that of the International Standard Atmosphere at mean sea level, namely 101,325 kPa. The reference air temperature, T_0, is 293,15 K (20 °C), i.e. the temperature at which the most reliable data supporting this part of ISO 9613 were obtained.

5 Attenuation coefficients due to atmospheric absorption for pure-tone sounds

5.1 Basic expression for attenuation

As a pure-tone sound propagates through the atmosphere over a distance s, the sound pressure amplitude p_t decreases exponentially as a result of the atmospheric absorption effects covered by this part of ISO 9613 from its initial value p_i, in accordance with the decay formula for plane sound waves in free space

$$p_t = p_i \exp(-0{,}115\,1\alpha s) \qquad \ldots (1)$$

NOTE 2 The term $\exp(-0{,}115\,1\alpha s)$ represents the base e of Naperian logarithms raised to the exponent indicated by the argument in parentheses and the constant $0{,}115\,1 = 1/[10\lg(e^2)]$.

5.2 Attenuation of sound pressure levels

The attenuation due to atmospheric absorption $\delta L_t(f)$, in decibels, in the sound pressure level of a pure tone with frequency f, from the initial level at $s = 0$ to the level at distance s, is given by

$$\delta L_t(f) = 10\lg(p_i^2/p_t^2)\ \text{dB} = \alpha s \qquad \ldots (2)$$

6 Calculation procedure for pure-tone attenuation coefficients

6.1 Variables

The acoustic and atmospheric variables, i.e. frequency of the sound, ambient atmospheric temperature, molar concentration of water vapour and ambient atmospheric pressure, are listed in clause 3, together with their symbols and units.

NOTES

3 For a specific sample of moist air, the molar concentration of water vapour is the ratio (expressed as a percentage) of the number of kilomoles (i.e. the number of kilogram molecular weights) of water vapour to the sum of the number of kilomoles of dry air and water vapour. By Avogadro's law, the molar concentration of water vapour is also the ratio of the partial pressure of water vapour to the atmospheric pressure.

4 Molar concentrations of water vapour range from about 0,2 % to 2 % for commonly encountered meteorological conditions at altitudes near mean sea level, but decrease to well below 0,01 % at altitudes above 10 km.

6.2 Formulae

As described in annex A, the attenuation due to atmospheric absorption is a function of two relaxation frequencies, f_{rO} and f_{rN}, the oxygen and nitrogen relaxation frequencies, respectively. Values of f_{rO} and f_{rN}, in hertz, shall be calculated from

$$f_{\mathrm{rO}} = \frac{p_{\mathrm{a}}}{p_{\mathrm{r}}}\left(24 + 4{,}04 \times 10^{4} h \frac{0{,}02 + h}{0{,}391 + h}\right) \qquad \ldots (3)$$

and

$$f_{\mathrm{rN}} = \frac{p_{\mathrm{a}}}{p_{\mathrm{r}}}\left(\frac{T}{T_0}\right)^{-1/2} \times \left(9 + 280h \exp\left\{-4{,}170\left[\left(\frac{T}{T_0}\right)^{-1/3} - 1\right]\right\}\right) \qquad \ldots (4)$$

The attenuation coefficient α, in decibels per metre, for atmospheric absorption shall be calculated from

$$\alpha = 8{,}686 f^{2}\left(\left[1{,}84 \times 10^{-11}\left(\frac{p_{\mathrm{a}}}{p_{\mathrm{r}}}\right)^{-1}\left(\frac{T}{T_0}\right)^{1/2}\right] + \left(\frac{T}{T_0}\right)^{-5/2} \times \left\{0{,}012\,75\left[\exp\left(\frac{-2\,239{,}1}{T}\right)\right]\left[f_{\mathrm{rO}} + \left(\frac{f^{2}}{f_{\mathrm{rO}}}\right)\right]^{-1} + 0{,}106\,8\left[\exp\left(\frac{-3\,352{,}0}{T}\right)\right]\left[f_{\mathrm{rN}} + \left(\frac{f^{2}}{f_{\mathrm{rN}}}\right)\right]^{-1}\right\}\right) \qquad \ldots (5)$$

Values for f_{rO} and f_{rN} are taken from equations (3) and (4).

In equations (3) to (5), $p_{\mathrm{r}} = 101{,}325$ kPa and $T_0 = 293{,}15$ K.

Equations (3) to (5) combine, in a condensed form suitable for computations, formulae giving contributions from the individual physical mechanisms described in annex A.

6.3 Computation of the attenuation coefficient

Equations (3) to (5) are all that is needed to calculate the pure-tone attenuation coefficient for atmospheric absorption for selected values of the variables. Although air temperature and air pressure data may not be supplied in the units of measure given in clause 3, conversion factors are readily available to convert the given unit to kelvins or kilopascals respectively. Humidity data, on the other hand, are rarely supplied in terms of molar concentration of water vapour. Annex B provides information on conversion of humidity data that are supplied in terms of relative humidity, dewpoint and other measures, to corresponding values of molar concentration.

The means by which a real inhomogeneous atmosphere may be approximated by the uniform atmosphere assumed in the formulae of 6.2 are discussed in annex C.

6.4 Tabular values of the attenuation coefficient

For selected values of T, h and f at a pressure of one standard atmosphere (101,325 kPa), table 1 lists pure-tone attenuation coefficients for atmospheric absorption calculated by use of equations (3) to (5), but using the unit "decibels per kilometre" for convenience in applications to sound propagation outdoors over path lengths of the order of a few kilometres. Tabular values are presented in scientific notation to preserve accuracy at low frequencies. Users of table 1 should not interpolate between the entries, or extrapolate beyond the table range, but should use equations (3) to (5) to calculate the specific pure-tone attenuation coefficients for desired conditions.

NOTES

5 For convenience, the frequencies shown in table 1 are the preferred frequencies for one-third-octave band filters (see ISO 266 and IEC 225). However, the attenuation coefficients in table 1 were calculated for the exact midband frequencies f_{m}, in hertz, using the general expression according to the base 10 system

$$f_{\mathrm{m}} = (1\,000)\,(10^{3b/10})^{k} \qquad \ldots (6)$$

where 1 000 Hz is the exact reference frequency and b is a rational fraction that serves as the bandwidth designator for any fractional-octave band filter (e.g. with $b = 1/3$ for one-third-octave band filters, and so on for other bandwidths). For table 1, index k is an integer from − 13 to + 10, corresponding to preferred frequencies from 50 Hz to 10 kHz. For exact ultrasonic frequencies at one-third-octave-band intervals from 10 kHz to 1 MHz, equation (6) may be used with k ranging from + 10 to + 30.

6 Relative humidities given as column headings in table 1 are with respect to saturation over a surface of liquid water at all temperatures; see annex B. The saturated vapour

pressure was calculated from the formulae used to generate the International Meteorological Tables[2]. See annex B.

7 Accuracy of calculated pure-tone attenuation coefficients for various ranges of the variables

7.1 Accuracy of ± 10 %

The accuracy of the calculated pure-tone attenuation coefficients for atmospheric absorption is estimated to be ± 10 % for variables within the following ranges:

molar concentration of water vapour: 0,05 % to 5 %

air temperature: 253,15 K to 323,15 K (– 20 °C to + 50 °C)

atmospheric pressure: less than 200 kPa (2 atm)

frequency-to-pressure ratio: 4×10^{-4} Hz/Pa to 10 Hz/Pa (40 Hz/atm to 1 MHz/atm)

NOTE 7 Combinations of molar concentration of water vapour and temperature which imply a relative humidity greater than 100 % in 7.1 to 7.3 are excluded from the corresponding accuracy estimates.

7.2 Accuracy of ± 20 %

The accuracy of the calculated pure-tone attenuation coefficients for atmospheric absorption is estimated to be ± 20 % for variables within the following ranges:

molar concentration of water vapour: 0,005 % to 0,05 %, and greater than 5 %

air temperature: 253,15 K to 323,15 K (– 20 °C to + 50 °C)

atmospheric pressure: less than 200 kPa (2 atm)

frequency-to-pressure ratio: 4×10^{-4} Hz/Pa to 10 Hz/Pa

7.3 Accuracy of ± 50 %

The accuracy of the calculated pure-tone attenuation coefficients due to atmospheric absorption is estimated to be ± 50 % for variables within the following ranges, which include environmental conditions encountered at altitudes up to 10 km:

molar concentration of water vapour: less than 0,005 %

air temperature: greater than 200 K (– 73 °C)

atmospheric pressure: less than 200 kPa (2 atm)

frequency-to-pressure ratio: 4×10^{-4} Hz/Pa to 10 Hz/Pa

8 Calculation of attenuation by atmospheric absorption for wideband sound analysed by fractional-octave-band filters

8.1 Description of the general problem and calculation methods

8.1.1 Previous clauses of this part of ISO 9613 have considered the effects of atmospheric absorption on the reduction in the level of a pure tone during propagation through the atmosphere. In practice, however, the spectrum of most sounds covers a wide range of frequencies, and spectral analysis is normally performed by fractional-octave-band filters that yield sound pressure levels in frequency bands.

Table 1 — Pure-tone atmospheric-absorption attenuation coefficients, in decibels per kilometre, at an air pressure of one standard atmosphere (101,325 kPa)

(a) Air temperature: −20 °C

Preferred frequency, Hz	Relative humidity, %										
	10	15	20	30	40	50	60	70	80	90	100
50	5,89 × 10^{-1}	5,09 × 10^{-1}	4,18 × 10^{-1}	2,85 × 10^{-1}	2,11 × 10^{-1}	1,68 × 10^{-1}	1,42 × 10^{-1}	1,25 × 10^{-1}	1,14 × 10^{-1}	1,05 × 10^{-1}	9,92 × 10^{-2}
63	7,56 × 10^{-1}	7,04 × 10^{-1}	6,02 × 10^{-1}	4,21 × 10^{-1}	3,08 × 10^{-1}	2,41 × 10^{-1}	2,00 × 10^{-1}	1,73 × 10^{-1}	1,55 × 10^{-1}	1,42 × 10^{-1}	1,33 × 10^{-1}
80	9,24 × 10^{-1}	9,35 × 10^{-1}	8,46 × 10^{-1}	6,19 × 10^{-1}	4,55 × 10^{-1}	3,52 × 10^{-1}	2,86 × 10^{-1}	2,43 × 10^{-1}	2,14 × 10^{-1}	1,94 × 10^{-1}	1,79 × 10^{-1}
100	1,08	1,18	1,15	9,02 × 10^{-1}	6,75 × 10^{-1}	5,21 × 10^{-1}	4,19 × 10^{-1}	3,50 × 10^{-1}	3,03 × 10^{-1}	2,69 × 10^{-1}	2,45 × 10^{-1}
125	1,20	1,43	1,49	1,28	9,98 × 10^{-1}	7,76 × 10^{-1}	6,22 × 10^{-1}	5,14 × 10^{-1}	4,39 × 10^{-1}	3,84 × 10^{-1}	3,44 × 10^{-1}
160	1,30	1,64	1,83	1,77	1,45	1,16	9,30 × 10^{-1}	7,86 × 10^{-1}	6,48 × 10^{-1}	5,61 × 10^{-1}	4,96 × 10^{-1}
200	1,37	1,82	2,15	2,33	2,06	1,70	1,39	1,15	9,70 × 10^{-1}	8,34 × 10^{-1}	7,31 × 10^{-1}
250	1,43	1,95	2,42	2,93	2,83	2,46	2,06	1,73	1,46	1,26	1,09
315	1,46	2,05	2,63	3,49	3,70	3,43	3,00	2,57	2,20	1,90	1,65
400	1,49	2,12	2,79	3,99	4,60	4,59	4,23	3,74	3,27	2,85	2,50
500	1,52	2,17	2,91	4,38	5,45	5,86	5,72	5,29	4,76	4,23	3,76
630	1,55	2,22	3,00	4,68	6,17	7,10	7,39	7,19	6,71	6,13	5,55
800	1,59	2,27	3,08	4,92	6,75	8,22	9,07	9,31	9,09	8,60	7,98
1 000	1,65	2,34	3,16	5,11	7,21	9,14	1,06 × 10	1,15 × 10	1,17 × 10	1,16 × 10	1,11 × 10
1 250	1,74	2,43	3,27	5,28	7,57	9,86	1,19 × 10	1,35 × 10	1,44 × 10	1,48 × 10	1,47 × 10
1 600	1,88	2,58	3,42	5,48	7,90	1,05 × 10	1,30 × 10	1,52 × 10	1,69 × 10	1,80 × 10	1,86 × 10
2 000	2,10	2,80	3,65	5,73	8,24	1,10 × 10	1,39 × 10	1,66 × 10	1,90 × 10	2,10 × 10	2,24 × 10
2 500	2,44	3,15	4,00	6,10	8,66	1,16 × 10	1,47 × 10	1,78 × 10	2,08 × 10	2,35 × 10	2,58 × 10
3 150	2,99	3,69	4,55	6,66	9,26	1,23 × 10	1,55 × 10	1,90 × 10	2,24 × 10	2,57 × 10	2,88 × 10
4 000	3,86	4,56	5,42	7,54	1,02 × 10	1,32 × 10	1,66 × 10	2,02 × 10	2,40 × 10	2,78 × 10	3,14 × 10
5 000	5,24	5,94	6,80	8,92	1,16 × 10	1,46 × 10	1,81 × 10	2,19 × 10	2,59 × 10	3,00 × 10	3,41 × 10
6 300	7,42	8,12	8,98	1,11 × 10	1,38 × 10	1,69 × 10	2,04 × 10	2,42 × 10	2,83 × 10	3,27 × 10	3,71 × 10
8 000	1,09 × 10	1,16 × 10	1,24 × 10	1,46 × 10	1,72 × 10	2,03 × 10	2,39 × 10	2,78 × 10	3,20 × 10	3,65 × 10	4,11 × 10
10 000	1,64 × 10	1,71 × 10	1,79 × 10	2,01 × 10	2,27 × 10	2,58 × 10	2,94 × 10	3,33 × 10	3,76 × 10	4,22 × 10	4,70 × 10

(b) Air temperature: −15 °C

Preferred frequency, Hz	Relative humidity, %										
	10	15	20	30	40	50	60	70	80	90	100
50	5,73 × 10^{-1}	4,25 × 10^{-1}	3,21 × 10^{-1}	2,12 × 10^{-1}	1,64 × 10^{-1}	1,39 × 10^{-1}	1,24 × 10^{-1}	1,14 × 10^{-1}	1,07 × 10^{-1}	1,02 × 10^{-1}	9,68 × 10^{-2}
63	7,93 × 10^{-1}	6,18 × 10^{-1}	4,72 × 10^{-1}	3,05 × 10^{-1}	2,28 × 10^{-1}	1,88 × 10^{-1}	1,66 × 10^{-1}	1,52 × 10^{-1}	1,42 × 10^{-1}	1,35 × 10^{-1}	1,30 × 10^{-1}
80	1,06	8,85 × 10^{-1}	6,93 × 10^{-1}	4,46 × 10^{-1}	3,24 × 10^{-1}	2,60 × 10^{-1}	2,24 × 10^{-1}	2,02 × 10^{-1}	1,87 × 10^{-1}	1,77 × 10^{-1}	1,70 × 10^{-1}
100	1,34	1,23	1,01	6,60 × 10^{-1}	4,71 × 10^{-1}	3,68 × 10^{-1}	3,08 × 10^{-1}	2,71 × 10^{-1}	2,48 × 10^{-1}	2,32 × 10^{-1}	2,21 × 10^{-1}
125	1,62	1,65	1,44	9,79 × 10^{-1}	6,95 × 10^{-1}	5,32 × 10^{-1}	4,35 × 10^{-1}	3,74 × 10^{-1}	3,34 × 10^{-1}	3,08 × 10^{-1}	2,89 × 10^{-1}
160	1,88	2,11	1,99	1,45	1,04	7,86 × 10^{-1}	6,30 × 10^{-1}	5,31 × 10^{-1}	4,64 × 10^{-1}	4,18 × 10^{-1}	3,86 × 10^{-1}
200	2,08	2,57	2,63	2,10	1,55	1,17	9,32 × 10^{-1}	7,72 × 10^{-1}	6,63 × 10^{-1}	5,87 × 10^{-1}	5,32 × 10^{-1}
250	2,24	2,99	3,32	2,97	2,30	1,76	1,40	1,15	9,73 × 10^{-1}	8,47 × 10^{-1}	7,56 × 10^{-1}
315	2,35	3,33	3,98	4,05	3,34	2,64	2,11	1,73	1,45	1,25	1,10
400	2,43	3,59	4,56	5,27	4,73	3,89	3,17	2,61	2,19	1,88	1,65
500	2,50	3,78	5,03	6,52	6,43	5,61	4,70	3,93	3,32	2,85	2,49
630	2,55	3,93	5,39	7,67	8,35	7,81	6,83	5,85	5,01	4,33	3,78
800	2,61	4,05	5,66	8,65	1,03 × 10	1,04 × 10	9,62	8,53	7,46	6,53	5,74
1 000	2,67	4,15	5,87	9,44	1,21 × 10	1,32 × 10	1,30 × 10	1,21 × 10	1,09 × 10	9,69	8,63
1 250	2,77	4,28	6,07	1,01 × 10	1,37 × 10	1,60 × 10	1,67 × 10	1,63 × 10	1,53 × 10	1,40 × 10	1,28 × 10
1 600	2,92	4,44	6,28	1,06 × 10	1,49 × 10	1,84 × 10	2,05 × 10	2,11 × 10	2,07 × 10	1,97 × 10	1,83 × 10
2 000	3,14	4,67	6,54	1,10 × 10	1,59 × 10	2,05 × 10	2,39 × 10	2,60 × 10	2,67 × 10	2,64 × 10	2,54 × 10
2 500	3,49	5,03	6,92	1,15 × 10	1,68 × 10	2,22 × 10	2,69 × 10	3,05 × 10	3,27 × 10	3,37 × 10	3,37 × 10
3 150	4,04	5,59	7,49	1,22 × 10	1,78 × 10	2,37 × 10	2,95 × 10	3,45 × 10	3,84 × 10	4,10 × 10	4,25 × 10
4 000	4,92	6,47	8,38	1,31 × 10	1,89 × 10	2,52 × 10	3,18 × 10	3,79 × 10	4,34 × 10	4,78 × 10	5,11 × 10
5 000	6,31	7,86	9,78	1,46 × 10	2,04 × 10	2,71 × 10	3,41 × 10	4,12 × 10	4,79 × 10	5,40 × 10	5,91 × 10
6 300	8,52	1,01 × 10	1,20 × 10	1,68 × 10	2,27 × 10	2,96 × 10	3,70 × 10	4,47 × 10	5,24 × 10	5,98 × 10	6,65 × 10
8 000	1,20 × 10	1,36 × 10	1,55 × 10	2,03 × 10	2,63 × 10	3,32 × 10	4,09 × 10	4,90 × 10	5,74 × 10	6,58 × 10	7,39 × 10
10 000	1,75 × 10	1,91 × 10	2,10 × 10	2,59 × 10	3,19 × 10	3,89 × 10	4,67 × 10	5,51 × 10	6,40 × 10	7,30 × 10	8,21 × 10