INTERNATIONAL STANDARD

# ISO 3274

Second edition
1996-12-01

# Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments

*Spécification géométrique des produits (GPS) — État de surface: Méthode du profil — Caractéristiques nominales des appareils à contact (palpeur)*



Reference number
ISO 3274:1996(E)

# Contents







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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.

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 3274 was prepared jointly by Technical Committees ISO/TC 57, *Metrology and properties of surfaces*, Subcommittee SC 1, *Geometrical parameters — Instruments and procedures for measurement of surface roughness and waviness*, ISO/TC 3, *Limits and fits*, and ISO/TC 10, *Technical drawings, product definition and related documentation*, Subcommittee SC 5, *Dimensioning and tolerancing*.

This second edition of ISO 3274 cancels and replaces the first edition (ISO 3274:1975) as well as ISO 1880:1979, which have been technically revised.

In particular it takes into account the nominal characteristics of contact (stylus) instruments and their technical development. Modern instruments use phase-correct filters according to ISO 11562.

Annexes A, B, C and D of this International Standard are for information only.

## Introduction

This International Standard is a Geometrical Product Specification (GPS) standard and is to be regarded as a *General GPS standard* (see ISO/TR 14638). It influences chain link 5 of the chain of standards for roughness profile, waviness profile and primary profile.

For more detailed information of the relation of this standard to other standards and the GPS matrix model, see annex C.

Filters for profile meters according to ISO 3274:1975 were realized as a series connection of two analog RC filters. This led to considerable phase shifts in the transition of the profile and therefore to asymmetrical profile distortions. The influence of this distortion on the parameters *Ra* and *Rz* are normally negligible if the sampling lengths (cut-off wavelength) according to ISO 4288:1985 are used. Therefore, analog instruments according to ISO 3274:1975 or instruments using 2RC filters may be used for assessment of *Ra* and *Rz* (see annex A). However, for other parameters the distortion is relevant.

# Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments



## 1 Scope

This International Standard defines profiles and the general structure of contact (stylus) instruments for measuring surface roughness and waviness, enabling existing International Standards to be applied to practical profile evaluation. It specifies the properties of the instrument which influence profile evaluation and it provides the basics of the specification of contact (stylus) instruments (profile meter and profile recorder).

NOTES

1 A data sheet dealing with characteristics of contact (stylus) instruments to be completed by the instrument makers is under preparation and will be introduced in a future standard on calibration procedures.

2 The relationships between the waviness cut-off $\lambda f$, tip radius and waviness cut-off ratio are under consideration and will be added to this International Standard as an amendment.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 4287:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters.*

ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture.*

ISO 5436:1985, *Calibration specimens — Stylus instruments — Types, calibration and use of specimens.*

ISO 11562:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters.*

ISO 12085:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Motif parameters.*

ISO 13565-1:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Surfaces having stratified functional properties — Part 1: Filtering and overall measuring conditions.*

ISO 13565-2:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Surfaces having stratified functional properties — Part 2: Height characterization using the linear material ratio curve.*

ISO 13565-3:—[1], *Geometrical Product Specifications (GPS) — Surface texture: Profile method; Surfaces having stratified functional properties — Part 3: Height characterization using the material probability curve.*

## 3 Definitions

For the purposes of this International Standard, the following definitions apply.

### 3.1 Profiles

**3.1.1 traced profile:** Locus of the centre of a stylus tip which features an ideal geometrical form (conical with spherical tip) and nominal dimensions with nominal tracing force, as it traverses the surface within the intersection plane.

NOTE — This is the profile from which all other profiles defined in this International Standard are derived.

**3.1.2 reference profile**: Trace on which the probe is moved within the intersection plane along the guide.

NOTE — The shape of the reference profile is the practical realization of a theoretical exact profile. Its nominal deviations depend on the deviations of the guide as well as on external and internal disturbances..

**3.1.3 total profile:** Digital form of the traced profile relative to the reference profile, with the vertical and horizontal coordinates assigned to each other.

NOTE — The total profile is characterized by the vertical and horizontal digital steps.

**3.1.4 primary profile:** Total profile after application of the short wavelength filter, $\lambda s$.

NOTES

1 The primary profile represents the basis for digital profile processing by means of a profile filter and calculation of the profile parameters according to ISO 4287. It is characterized by the vertical and horizontal digital steps which may be different from those of the total profile.

2 The best fit least squares form of the type indicated in the specification is not part of the primary profile and should be excluded before filters are applied. For a circle, the radius should also be included in the least squares optimization and not held fixed to the nominal value.

3 The nominal form is removed before the primary profile is obtained.

**3.1.5 residual profile:** Primary profile obtained by tracing an ideally smooth and flat surface (optical flat).

NOTE — The residual profile is composed of the deviations of the guide, external and internal disturbances, as well as deviations in profile transmission. The determination of the causes of the deviations is not normally possible without special equipment and a suitable environment.

**3.2 stylus instrument:** Measuring instrument which explores surfaces with a stylus and acquires deviations in the form of a surface profile, calculates parameters and can record the profile (see figure 1).

NOTE — The diagram as shown represents only the essential operators required in a theoretically exact measuring system. The specific inter-relationship of operators may be subject to design considerations. Therefore figure 1 should not be considered as the only form of theoretically exact configuration.

1) To be published.

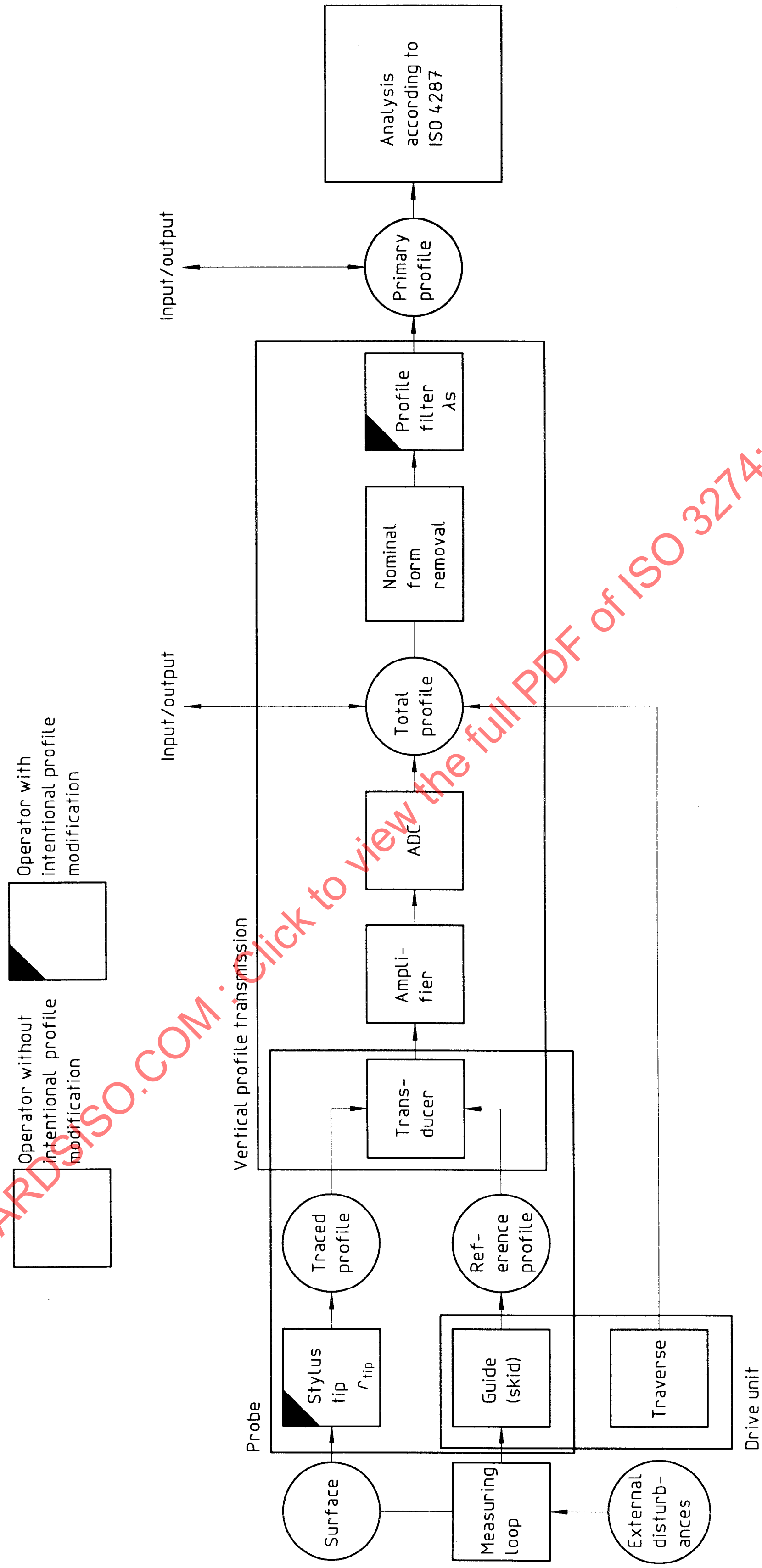


**Figure 1 — Schematic representation of a stylus instrument**

**3.2.1 displacement sensitive, digitally storing stylus instrument:** Stylus instrument whose profile presentation contains deviations including long-wave components and set-up deviations.

NOTE — The profile is digitally stored and, if filtered, is phase-correct filtered. Parameters are digitally calculated and the profile is recorded by means of a graphics system excluding deformation.

## 3.3 Stylus instrument components

**3.3.1 measurement loop:** Closed chain which comprises all mechanical components connecting workpiece and the stylus tip, e.g. positioning means, workholding fixture, measuring stand, drive unit, probe (pick-up). (See figure 2.)

NOTE — The measuring loop is subjected to external and internal disturbances and transmits them to the reference profile. The influence of these disturbances depends on the individual measuring set-up, the measuring environment and the skill of the user. The disturbances influence the residual value to a great extent.

**3.3.2 reference guide:** Component which generates the intersection plane and guides the probe in it on a theoretically exact geometrical trace (reference profile), generally in a straight line.

NOTE — The guide is an essential part of the drive unit; it can be partially included in the probe. For the use of skids, see annex A.

**3.3.3 drive unit:** Component which moves the probe along the reference guide and transmits the horizontal position of the stylus tip in the form of a horizontal profile coordinate.

NOTE — Drive units are characterized by the longest selectable tracing length.

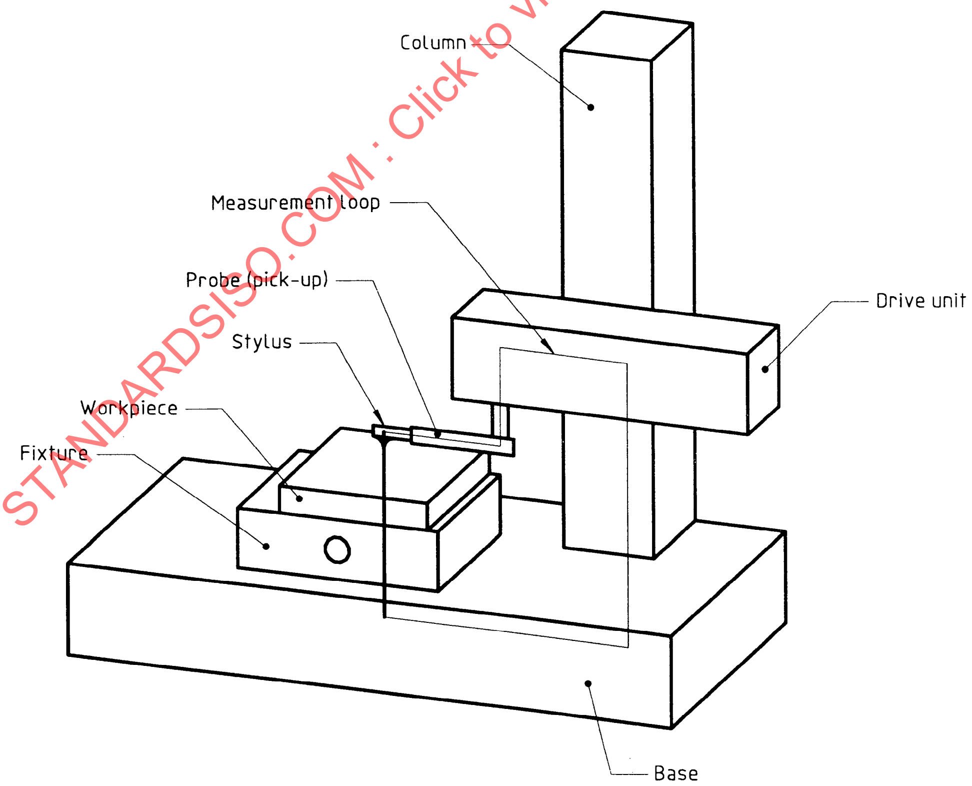


**Figure 2 — Example of measurement loop of a stylus instrument**

**3.3.4 probe (pick-up):** Component which contains the tracing element with the stylus tip and the transducer.

**3.3.5 tracing element:** Element which transmits the stylus tip displacement to the transducer.

**3.3.6 stylus tip:** Element which consists of a nominally right, circular cone of defined cone angle and of a nominally spherical tip of defined radius.

NOTE — It is a very important element in profile acquisition when employing stylus instruments.

**3.3.7 transducer:** Device which converts the vertical coordinates of the traced profile referred to the reference profile into the signal form used in the instrument.

NOTE — The transducer does not cause an intentional profile modification.

**3.3.8 amplifier:** Device which effects signal transformation in the instrument without causing any intentional profile modification.

**3.3.9 analog-to-digital converter (ADC):** Device which converts the signal form existing in the instrument into digital values.

NOTE — Together with the corresponding horizontal coordinates, these values form the total profile. The ADC does not cause any intentional profile modification.

**3.3.10 data input:** Data interface that the instrument may have which allows input of one or more types of profile from an external computer.

**3.3.11 data output:** Data interface that the instrument may have which allows output of one or more types of profile to an external computer.

**3.3.12 profile filtering and evaluation:** Operations carried out on the primary, roughness and waviness profiles by means of parameters and characteristic functions according to ISO 4287, ISO 11562, ISO 12085, ISO 13565-1, ISO 13565-2 and ISO 13565-3.

NOTE — The nominal value of the sampling length is equal to the wavelength cut-off $\lambda c$.

**3.3.13 profile recorder:** Recorder that the instrument may have which allows output of one or more types of profile and/or parameter value.

## 3.4 Metrological characteristics of the instrument

**3.4.1 static measuring force:** Force exerted by the stylus tip when in its mean position as it rests on the surface.

**3.4.2 change of static measuring force:** Change of measuring force which occurs when the stylus tip is displaced.

NOTE — Normally this change is proportional to the displacement.

**3.4.3 dynamic measuring force:** Force resulting from the acceleration of the stylus tip when continuously tracing the surface.

NOTE — These dynamic measuring forces are superimposed on the static measuring force.

**3.4.4 hysteresis:** Difference between the indicated stylus tip displacements for the same actual stylus tip displacement when the stylus tip moves inward and outward.

**3.4.5 transmission function for sine waves:** Function which, for a given tracing speed, depends both on the wavelength and on the amplitude of the profile to be measured.

NOTES

1 In order to denote the transmission behaviour, the smallest sine wavelength (groove interval) which can still be transmitted within given limits of permissible error may be stated for different traverse speeds and a given amplitude.

2 The transmission function of the probe is dependent on the probe configuration used and will change for a given instrument if the probe configuration is changed.

**3.4.6 measuring range of probe:** Vertical range over which the stylus tip and the transducer can acquire displacements within certain limits of permissible error and convert them to signals appropriate for digitization.

**3.7.4 measuring range of instrument:** Vertical range over which the instrument can acquire displacements within certain limits of permissible error, convert them to signals appropriate for digitization and digitize them.

**3.4.8 quantization step of the ADC:** Displacement corresponding to the least significant change in the ADC reading.

**3.4.9 instrument resolution:** Quantitative expression of the ability of the instrument to distinguish meaningfully between closely adjacent positions in the primary profile.

**3.4.10 range-to-resolution ratio:** Ratio of the measuring range to the instrument resolution.

NOTE — For instruments having several measuring ranges, the range-to-resolution ratio is calculated for each measuring range individually. Consequently, the range-to-resolution ratio is not the ratio of the largest measuring range to the instrument resolution of the smallest measuring range.



**3.4.11 probe linearity deviation:** Deviation of the actual characteristic curve from the straight line (or nominal characteristic curve) in the measuring range.

**3.4.12 short-wave transmission limitation:** Limitation formed by the low pass filter $\lambda s$ which separates out the short-wave signal components of the total profile which by definition do not belong to the primary, roughness or waviness profiles.

NOTE — It is defined in ISO 4287. The low pass filter can be engineered as a digital filter.

**3.4.13 vertical profile component transmission:** Transmission characteristic which indicates the amount by which the amplitude of a sinusoidal profile at the transducer is attenuated in the primary profile as a function of its wavelength.

NOTE — Nominally the wavelength transmission characteristic has the form of the low pass filter according to ISO 11562. It is realized by means of the transducer, amplifier, band limiter and ADC. They do not lead to a profile modification in the passband of wavelengths. The vertical profile transmission can contain other components correcting the primary profile, e.g. alignment corrections, corrections of systematic deviations of the guide, linearity compensation of characteristic curves, etc.

**3.4.14 horizontal profile position transmission:** Ratio of the difference between the horizontal coordinates of arbitrary position on the total profile to the difference between the corresponding horizontal coordinates of the stylus tip.

**3.4.15 deviations of the horizontal position transmission:** Difference between the real horizontal profile transmission and the nominal horizontal profile transmission.

**3.4.16 deviations of the profile transmission of the primary profile:** Deviation between the real profile transmission characteristic of the instrument and the theoretically exact profile transmission of the short-wave band limitation according to ISO 11562.

NOTES

1 In the pass band, the profile transmission is identical to the transmission of static stylus tip deflections.

2 The profile transmission limitations of the analog stage of the instrument (which usually consist of the frequency limitations of the mechanical parts of the instrument, the amplifier and the ADC) are included in this deviation. Because these limitations are frequency related, they will appear differently as the instrument is used at different tracing speeds, being most severe at high tracing speeds.

**3.4.17 zero point drift:** Change of indicated zero point of the instrument at constant ambient temperature and unchanged stylus position.

NOTE — A slow unidirectional rate of zero drift has negligible effect on the profile acquisition and none at all on the roughness filtered profile. A cyclical drift may be tolerated for the assessment of the roughness filtered profile, but the drift may have effects on the primary and subsequently obtained waviness filtered profile.

**3.4.18 vertical linearity deviation:** Overall linearity deviation (from the stylus to the primary profile) from the real vertical transmission characteristic curve from a linear regression line in the vertical direction.

**3.4.19 profile filter deviation:** Transmission deviation for all wavelengths of the component that are to be used.

**3.4.20 profile evaluation deviation:** Difference between the value obtained when applying the actual algorithm and the true value for a profile, e.g. the instrument derivation and the true value of the profile from a calibrated specimen such as type D according to ISO 5436.

NOTE — The true value for a parameter is the value which is obtained when the ideal algorithm for that parameter is applied to the same roughness standard profile.

**3.4.21 total deviation of the stylus instrument:** Difference, for a defined parameter, between the value determined when evaluating a surface using the given instrument and the true value.

NOTE — The true value is the value obtained using an ideal instrument as defined in this International Standard.

**3.4.22 deviation of the profile recording:** Deviation from the digital primary profiles for roughness or waviness and the corresponding output on graphic printers, plotters and monitors.

NOTE — The horizontal and vertical coordinates of the digital profiles are directly mapped into the pixel coordinates with respect to $V_v$ and $V_h$. The deviations in both coordinates should be smaller than the pixel spacing of the output device. Additional deviations such as linearity, hysteresis, amplitude and phase errors or overshoots do not occur. The transmission deviations of the recording are practically those of the primary, roughness and waviness profiles.



## 4 Nominal values for instrument characteristics

### 4.1 Stylus geometry

The ideal stylus shape is a cone with a spherical tip.

The nominal dimensions are as follows:

— Tip radius: $r_{tip}$ = 2 µm, 5 µm, 10 µm;

— Cone angle: 60°, 90°.

If not otherwise specified for the "ideal" instrument, cone angle 60° applies.

### 4.2 Static measuring force

The nominal value of the static measuring force at mean position of the stylus is 0,000 75 N.

The nominal rate of change of measuring force is 0 N/m.

## 4.3 Profile filter cut-off wavelength

A detailed description of the filter characteristic is given in ISO 11562. The nominal values of the cut-off wavelengths of the profile filter are obtained from the series:

... mm; 0,08 mm; 0,25 mm; 0,8 mm; 2,5 mm; 8,0 mm; ... mm

## 4.4 Relationship between the roughness cut-off wavelength $\lambda c$, tip radius and roughness cut-off ratio

If not otherwise specified, the relationship for standardized values of the stylus tip radius $r_{tip}$, and the roughness cut-off wavelength ratio $\lambda c/\lambda s$ for the standardized values of the $\lambda c$ cut-off according to table 1 apply.

**Table 1**

| $\lambda c$ mm | $\lambda s$ µm | $\lambda c/\lambda s$ | $r_{tip}$ max. µm | **Maximum sampling spacing** µm |
|---|---|---|---|---|
| 0,08 | 2,5 | 30 | 2 | 0,5 |
| 0,25 | 2,5 | 100 | 2 | 0,5 |
| 0,8 | 2,5 | 300 | 2*) | 0,5 |
| 2,5 | 8 | 300 | 5**) | 1,5 |
| 8 | 25 | 300 | 10**) | 5 |

*) For surfaces with $Ra > 0,5$ µm or $Rz > 3$ µm, $r_{tip} = 5$ µm can usually be used without significant differences in the measurement result.

**) For cut-off wavelengths $\lambda s$ of 2,5 µm and 8 µm, it is almost certain that the attenuation characteristic resulting from the mechanical filtering of a stylus with the recommended tip radius will lie outside the defined transmission band. Since this is the case, a small variation in stylus radius or shape will have negligible effect on the values of parameters calculated from the measured profile.

If another cut-off ratio is deemed necessary to satisfy the application, this ratio must be specified.

# Annex A
(informative)

# Instruments conforming to ISO 3274:1975

## A.1 Introduction

This International Standard has been significantly changed relative to ISO 3274:1975 in two respects:

— the transmission characteristic;

— the use of skids is no longer part of this International Standard.

## A.2 Analog instruments using 2RC filters

Differences between instruments using 2RC filters and the ideal (theoretically exact) instruments as defined in the main body of this International Standard when measuring $Ra$, $Rz$ and such parameters using the filter cut-off wavelength values specified in ISO 4288, are normally negligible. Observed differences obtained from industrially manufactured single-process surfaces are not greater than the natural scatter of the values distributed over the surface.

## A.3 Instruments using skids

Instruments using skids can be used for measuring roughness parameters only.

### A.3.1 Skid radius

If a skid is employed, its radius in the direction of the trace should be no less than 50 times the nominal cut-off wavelength used. If two simultaneously operative skids are used, their radii should be no less than eight times the nominal cut-off wavelength.

### A.3.2 Skid force

The force exerted by the skid on the surface to be measured should be no greater than 0,5 N.

# Annex B
(informative)

# Background for the improvements introduced in this International Standard

## B.1 Introduction

Formerly, instruments were perceived to have a well defined filter characteristic which was based on either an analog 2RC filter or a digital implementation of the same characteristic. However, it is not commonly understood that by necessity all instrumentation has limitations in its ability to replicate short wavelengths. These limitations are due to some or all of the following:

a) the finite stylus size (e.g. 2 µm, 5 µm, etc.) limits the extent to which valleys can be entered and hence perform a degree of filtration;

b) the stylus shape (e.g. pyramidal, conical, spherical) causes the fidelity of surface replication to be degraded particularly at short wavelengths (e.g. peak deformation);

c) the sampling interval will limit the actual minimum separation of detail present on a surface (e.g. 0,25 µm, 0,5 µm, etc.);

d) the sampling method (e.g. temporal or spatial, linear and non-linear) can effect the transmission characteristic.

There can be several factors which create a lower limit for the ability of an instrument to replicate short wavelength. These limits cannot be easily determined but are nevertheless present.

The effect of these factors can in some cases be determined (e.g. sampling interval) while others, such as those due to the stylus, cannot (see figure B.1). Furthermore, the relevance of each of these factors may be different for differing surfaces and/or filter cut-offs. This typically means that the cumulative effect of these factors is indeterminate and thus causes an uncertain region.

Since these limits cannot be well defined, this proposal suggests a methodology of providing a definable lower limit or short cut-off wavelength ($\lambda s$) with the uncertain region outside the measured region.



## B.2 The primary objectives for the introduction of transmission bands

By using the principles given in the rest of this International Standard, the following objectives have been achieved.

a) **To permit comparison of results both from "surface to surface" as well as "instrument to instrument"**

The primary purpose of this International Standard is to enable the comparison of similar surfaces (surface to surface) or the comparison of results from different measuring instruments (instrument to instrument) to be made. This requires that the methods and variables involved in the determination of the measured results be fully or adequately defined.

By specifying a short cut-off wavelength ($\lambda s$) and by paying attention to the recommended stylus size, it is possible to overcome the primary reasons for the lack of correlation either between instruments or between surfaces.

b) **To provide a means of defining "limits of instrument operation"**

As clear definition of the operational range of an instrument will allow users to make their choice of instrumentation with reference to the functionality required by the part under test.

As is typical in signal processing equipment (e.g. hi-fi systems, oscilloscopes, etc.), adoption of these proposals would allow a clear, unambiguous statement to be included in both an instrument's specification and on results of the limits applicable to the measurement made (subject to the correct stylus being used).

## B.3 Conclusion

The principles given within the body of this International Standard provide a suitable means of further standardizing surface characterization by the use of well defined mathematical principles (i.e the use of Gaussian type, phase-correct filters). Furthermore, by seeking to control both the upper and lower transmission characteristics of the instrumentation, the inter-comparison between instruments and between surfaces is more accurately achieved.



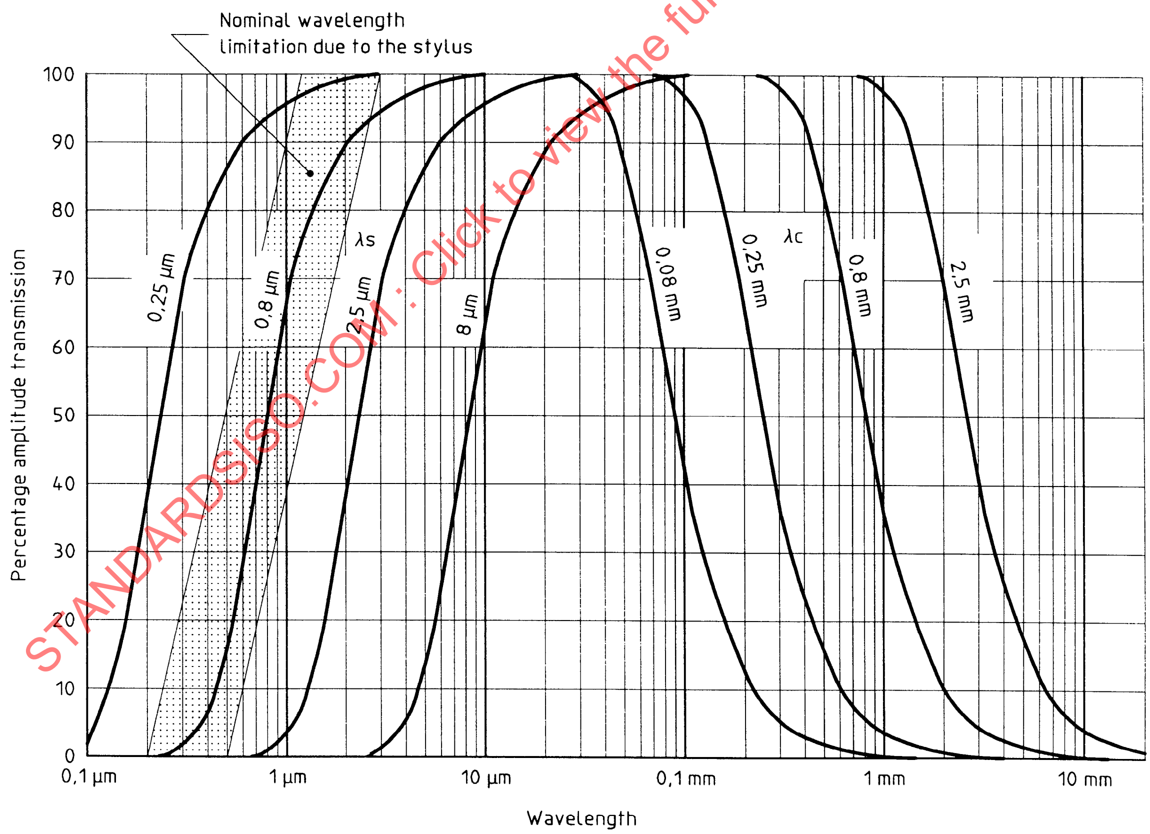


**Figure B.1 — Gaussian filter transmission characteristics together with the uncertain nominal transmission characteristics of a 2 µm stylus**

# Annex C
(informative)

# Relation to the GPS matrix model

For full details about the GPS matrix model, see ISO/TR 14638.

## C.1 Information about this International Standard and its use

This International Standard defines the reference surface texture measuring instrument using the profile method. It thus facilitates the application of other standards of the "surface texture" chains of standards for practical profile evaluation. It also specifies the properties of the reference instrument which influence profile evaluation and it provides the basis of the specification of contact (stylus) instruments (profile meter and profile recorder).

## C.2 Position in the GPS matrix model

This International Standard is a General GPS standard, which influences chain link 5 of the chains of standards for roughness profile, waviness profile and primary profile in the *General GPS matrix*, as graphically illustrated in figure C.1

**Fundamental GPS standards**

**Global GPS standards**

**General GPS matrix**

| **Chain link number** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| Size | | | | | | |
| Distance | | | | | | |
| Radius | | | | | | |
| Angle | | | | | | |
| Form of line independent of datum | | | | | | |
| Form of line dependent on datum | | | | | | |
| Form of surface independent of datum | | | | | | |
| Form of surface dependent on datum | | | | | | |
| Orientation | | | | | | |
| Location | | | | | | |
| Circular run-out | | | | | | |
| Total run-out | | | | | | |
| Datum planes | | | | | | |
| Roughness profile | | | | | | |
| Waviness profile | | | | | | |
| Primary profile | | | | | | |
| Surface defects | | | | | | |
| Edges | | | | | | |

**Figure C.1**

## C.3 Related International Standards

The related International Standards are those of the chains of standards indicated in figure C.1.